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Coastal Foraging at Otter Cave: A 6600-Year-Old Shell Midden on San Miguel Island, California

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Test excavations at a small rock shelter near Otter Point on San Miguel Island produced an assemblage of well-preserved artifacts and faunal remains from buried midden deposits dated to approximately 6600 years ago. Along with an unusual assemblage of 40 Dentalium shell artifacts, faunal remains from Otter Cave (CA-SMI-605) provide valuable information on the nature of San Miguel Island environments and the adaptations of its maritime peoples during the early Middle Holocene. Here we summarize the context, chronology, nature, and implications of the Otter Cave materials. Shellfish from rocky intertidal habitats (turban snails, mussels, owl limpets, etc.) dominate the faunal assemblage, but fishing and marine mammal hunting also contributed to the subsistence of the cave occupants. We also discuss the Otter Cave data in the context of a long sequence of shell midden strata at Otter Point that span much of the past 7500 years, as well as general models for the evolution of maritime adaptations in the Santa Barbara Channel region.

The California Coast has produced some of the earliest and most extensive evidence for coastal settlement in the Americas. One of the most thoroughly studied portions of the California Coast is the Santa Barbara Channel area, including the Northern Channel Islands that contain an essentially continuous record of maritime cultural developments spanning the past 10,000 years. Much has been learned over the years about the earliest and latest segments of the Santa Barbara Channel cultural sequence, but much less is known about maritime peoples of the Middle Holocene, from about 7500 to 3500 cal BP (Glassow 1997; Vellanoweth 2001). Nonetheless, the Middle Holocene is generally regarded as a transitional period between Early Holocene economies where marine subsistence was focused on shellfish gathering, and the Late Holocene when the maritime Chumash people relied much more heavily on fishing and sea mammal hunting. These general patterns are supported by both faunal and technological data, the latter including a paucity of hunting equipment in early sites and the appearance

of circular shell fishhooks in the region around 2500 years ago (Rick et al. 2002). Superimposed on these general patterns, however, are substantial local variations that help elucidate the diversity of human adaptations and environments in the Santa Barbara Channel area through time (Erlandson and Rick 2002; Glassow 1980; Kennett 1998).

In this paper, we summarize the results of test excavations at Otter Cave (CA-SMI-605) on San Miguel Island in 2000. Because our excavations were limited, relatively few artifacts were collected, but a well-preserved assemblage of faunal remains was recovered. Our focus, therefore, is primarily on the analysis and interpretation of faunal remains and human subsistence at Otter Cave, as well as the implications for understanding changes in subsistence among the Island Chumash and their ancestors. We begin by summarizing the setting, structure, stratigraphy, and chronology of Otter Cave, and the methods we used in our analysis. We conclude by discussing some of the broader implications of the Otter Cave data, including a comparison to Middle

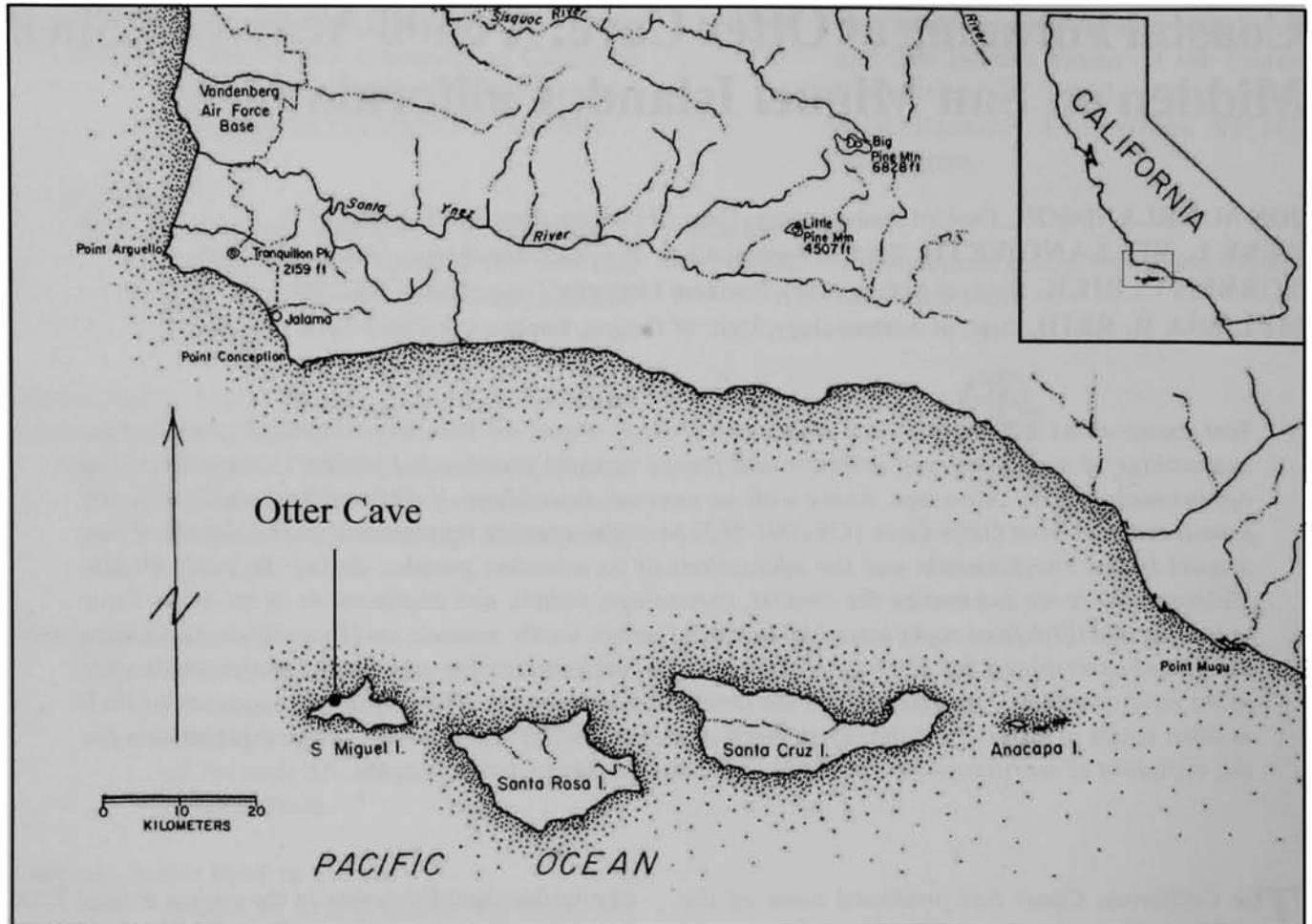


Figure 1. Location of Otter Cave (CA-SMI-605) on San Miguel Island.

and Late Holocene components at CA-SMI-481, a large midden complex located nearby. Although the Otter Cave assemblage is relatively small, the ability to place the recovered data within a broader comparative framework of subsistence change at Otter Point adds to its significance and interpretive potential.

ENVIRONMENTAL SETTING

San Miguel Island, the westernmost of the Channel Islands, is located about 42 km. from the mainland coast. With a total land area of about 37 km.², San Miguel is a maximum of about 13 km. long and 6.5 km. wide. The perimeter of the island consists of a mixture of rocky and sandy coastlines, with extensive near shore kelp forests and other

marine habitats. Often shrouded in fog, with strong winds blowing predominantly from the northwest, San Miguel's climate is cool and maritime. Extensive sand dunes and a series of uplifted marine terraces are the most prevalent terrestrial landforms, with a maximum elevation of 253 m. (Johnson 1972). The absence of large trees, an impoverished terrestrial fauna, and limited sources of fresh surface water resulted in a terrestrial landscape that offered few subsistence options, especially compared to the adjacent mainland coast.

In contrast, the waters around San Miguel Island are characterized by intensive marine upwelling and support an unusually diverse and productive suite of marine resources. Today, San Miguel is home to over 100,000 pinnipeds (seals and sea lions) of six different species, and its extensive kelp forest and rocky shore

habitats also support a variety of fish, shellfish (abalones, mussels, etc.), and seabirds. This highly productive marine ecosystem has attracted maritime peoples for at least 12,000 calendar years and more than 20 shell middens dated between about 10,000 and 7000 cal BP have been identified on the island.

Otter Cave is located on a ridge overlooking Otter Point on the northwest coast of San Miguel Island. The Otter Point area has extensive archaeological remains that include a nearly continuous record of human occupation from approximately 7250 years ago to historic times. Just below and east of Otter Cave, a large archaeological site complex known as CA-SMI-481 extends for over 500 m. along the shoreline, with multiple components stratified both vertically and horizontally. While most of these components are large open air middens occupied by larger groups of people, Otter Cave appears to have been the scene of

a limited number of occupations by very small groups of people over a relatively brief span of time. As such, the materials recovered in our investigation may provide insight into the nature of more individualized behavior than is often possible in larger middens occupied for relatively long periods of time.

Situated about 35 to 40 m. (115-131 feet) above sea level, Otter Cave is a relatively small rock shelter, with an interior floor area about 2.6 m. deep and 2.4 m. wide (Fig. 2). Today, the maximum ceiling height is about 120 cm., but nearly a meter of additional head room would have been available before the floor of the cave was covered with dune sand some time after about 6400 years ago. The mouth of Otter Cave faces northwest, opening just below a prominent ridge that forms the east side of Amphitheatre Cove. Although the mouth of the rock shelter faces the prevailing winds that blow from the northwest, it provides



Figure 2. Photograph of Otter Cave (CA-SMI-605).

substantial shelter when compared to open areas in the vicinity. Formed in coarse sandstone bedrock, the rock shelter has a relatively level sandy floor that is largely unvegetated except for tendrils of ice plant that encroach from the cave mouth. No archaeological materials are visible on the cave floor, but shell midden debris litters the talus slope below for a distance of 50 m. or more, suggesting that the site was once the scene of significant human occupation.

METHODS

We first recorded Otter Cave in 1999, after a large shell collected from the talus slope below the cave was radiocarbon (^{14}C) dated to about 6600 cal BP. In 2000, Erlandson and Vellanoweth returned to the site to determine if archaeological materials were present beneath the sandy floor of the cave and, if so, their extent, condition, and significance. Because of the logistical difficulties of working on San Miguel Island, where no wheeled vehicles are allowed and a long daily hike is required to access the Otter Point area, our excavation was limited to a single test pit that encompassed about 5 percent of the cave interior.

Once the ice plant was removed from the cave floor, we excavated a small 40 x 40 cm. wide test pit (Unit 1E) roughly in the center of the cave. This unit extended to a depth of 122 cm., with six discrete strata identified, including up to 27 cm. of finely stratified shell midden (see below). The next day, a 40 x 40 cm. wide extension of Unit 1 (1 West or 1W) was excavated towards the mouth of the cave, creating a small trench in which several substrata were defined.

All sediments from Units 1E and 1W (discussed together as Unit 1 below) were screened in the field, through 1/16-inch mesh. Residuals were bagged and returned to the University of Oregon for analysis. In the lab, these residuals were screened again over 1/8-inch mesh to facilitate sorting and sampling. The 1/8-inch fraction was completely sorted, with all artifacts and faunal remains identified to the most specific level possible. The 1/16-inch fraction, which made up a relatively small proportion of the well-preserved assemblage, was rough-sorted for artifacts and other diagnostic materials. Both shellfish and vertebrate remains were identified, then quantified by weight and minimum number of individuals (MNI). Vertebrate remains were also counted to determine

the number of individual specimens (NISP) present. To provide comparative data on the importance of various faunal classes to the diet of the site occupants, dry shell and bone weights were multiplied by meat weight conversions to estimate the edible meat represented by the recovered faunal remains. The length of whole mussel and abalone shells was also measured (in mm.) for comparison to other Channel Island assemblages.

SITE STRUCTURE, STRATIGRAPHY, AND CHRONOLOGY

Many caves on San Miguel Island were created by marine erosion, but this does not appear to be the case with Otter Cave. A small and possibly wave-cut notch on the ridge just above the cave may mark a former shoreline, but the cave appears to have formed primarily through weathering and wind abrasion of the sandstone bedrock. The limited size of the cave suggests that it never accommodated more than a small group of people, but the extensive midden deposits on the talus slope below suggest that it was occupied on multiple occasions or for a relatively sustained period. Soils on the slopes above the cave have been almost entirely lost to erosion. Dune sand blowing up the slope from the beach below the cave has provided some protection to the lower site deposits, but erosion has also been relatively severe on the steep slope outside the cave, where the head of a small gully appears to channel runoff during heavy rainstorms. A small linear dune flanking this gully just outside the cave mouth has several large red abalone shells embedded in its surface soil, midden materials that also appear to be associated with the occupation of Otter Cave.

Inside the cave, stratigraphic profiles in Unit 1 revealed sediments that range between about 100 and 122 cm. thick, with cultural deposits increasing in thickness towards the mouth of the cave (Fig. 3). Six major stratigraphic units were identified. The upper two (Strata 1 and 2) consisted of 70-95 cm. of sterile dune sand capped by a weakly developed soil. The lack of clear paleosols in this sand suggests that it accumulated during a single depositional event. The surface soil (Stratum 1) was more strongly developed towards the mouth of the cave, where thicker vegetation would have provided more organic matter

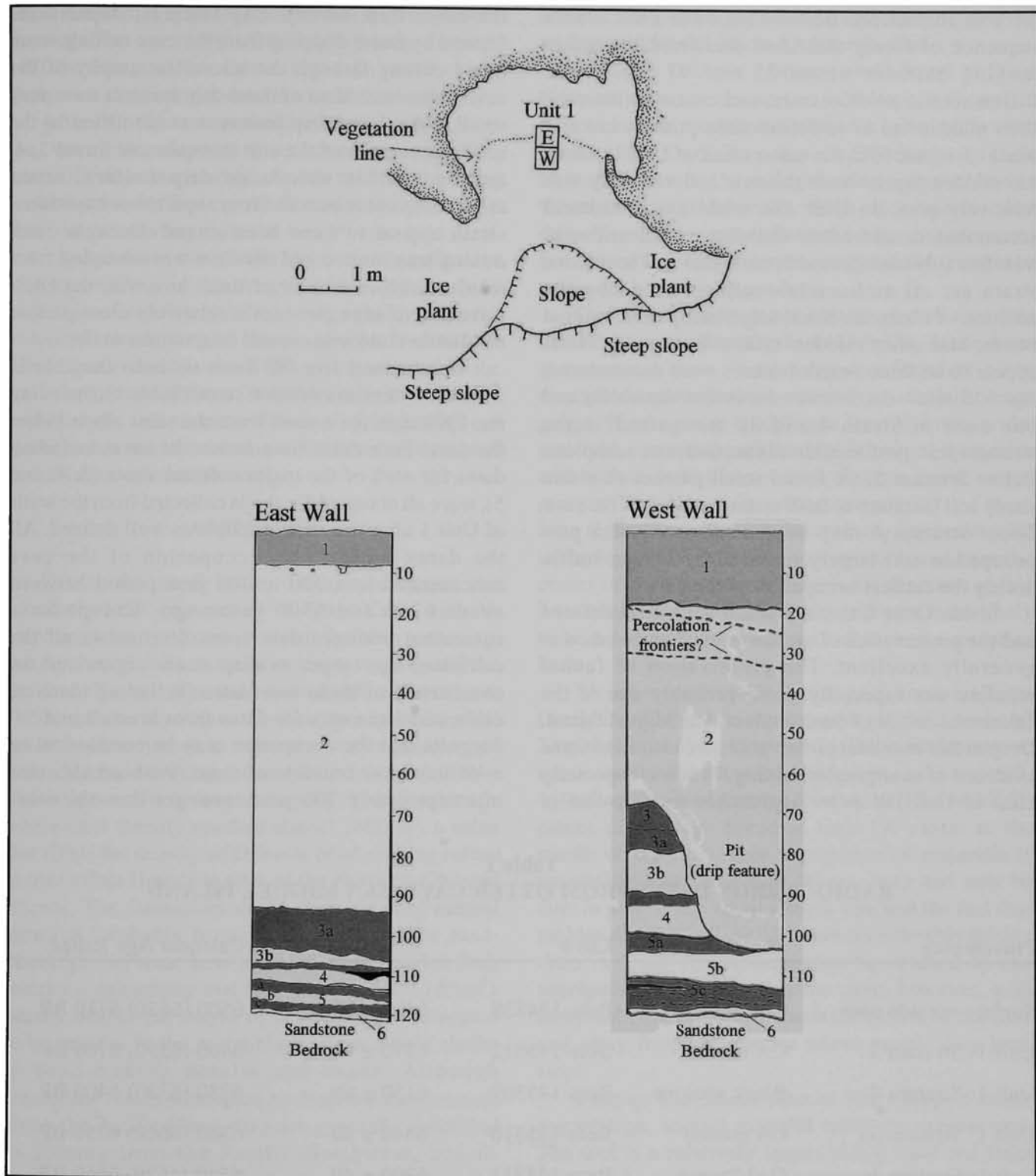


Figure 3. Plan View of Otter Cave (CA-SMI-605) and Stratigraphic Profiles of Unit 1.

for soil formation. Below this dune sand was a sequence of finely stratified shell midden layers ranging between about 25 and 47 cm. thick. Differences in color, texture, and content within the shell midden led us to define three primary cultural strata (3, 4, and 5) in the eastern half of Unit 1, where the midden layers were thinnest and visibility was relatively poor. In Unit 1W, with thicker cultural accumulations and better visibility, we identified at least five substrata (3a and b; 5a, b, and c). The midden strata are all anthrosols—soils enriched by the addition of charcoal, wood ash, marine shell, animal bones, and other midden refuse. Portions of what appear to be three hearth features were encountered, one in Stratum 3a that was excavated separately and one each in Strata 4 and 5c recognized in the stratigraphic profile after excavation was complete. Below Stratum 5, we found small patches of a thin sandy soil (Stratum 6) built on the bedrock of the cave floor. Stratum 6 may be the remnants of a pre-occupation soil largely removed by human traffic during the earliest occupation of the cave.

Inside Otter Cave, the strata were well defined and the preservation of archaeological materials was generally excellent. The preservation of faunal remains was especially good, probably due to the calcareous nature of dune sands on San Miguel Island. Despite this excellent preservation, we identified some evidence of stratigraphic mixing. This was especially clear in Unit 1W as we approached the drip-line of

the cave. Here several drip features, depressions formed by water dripping from the cave ceiling, were noted cutting through the microstratigraphy of the cave sediments. Most of these drip features were very small, but a large drip feature was identified in the northwest corner of the unit that crosscut Strata 3, 4, and 5a. Within this large drip feature, some archaeological materials from separate occupational strata appear to have been mixed. Because such mixing was limited and the cave was occupied for a relatively short amount of time, however, the Otter Cave assemblage provides a relatively clear picture of Middle Holocene coastal adaptations at the site.

We obtained five ^{14}C dates on individual shells from the Otter Cave midden strata (Table 1), including the 1999 date for a shell from the talus slope below the cave. Four dates from inside the cave, including dates for each of the major cultural strata (3, 4, and 5), were all obtained for shells collected from the walls of Unit 1 after the stratigraphy was well defined. All the dates indicate an occupation of the cave concentrated in a 300 to 400 year period between about 6700 and 6300 years ago. Except for a somewhat younger date from Stratum 4, all the calibrated age ranges overlap at one sigma and the consistency of these four dates (including identical calibrated intercepts for dates from Strata 3 and 5c) suggests that the occupation may be confined to an even narrower window of time. With a calibrated intercept nearly 300 years younger than the other

Table 1
RADIOCARBON DATES FROM OTTER CAVE, SAN MIGUEL ISLAND

Provenience	Material Dated	Lab #	^{14}C Date	Calendar Age Range
Surface outside cave	CA mussel	Beta-134838	6400 ± 80	6500 (6620) 6710 BP
Unit 1: Stratum 3	CA mussel	Beta-145812	6370 ± 90	6460 (6590) 6700 BP
Unit 1: Stratum 4	Black abalone	Beta-145309	6150 ± 60	6280 (6320) 6400 BP
Unit 1: Stratum 5a	CA mussel	Beta-145310	6440 ± 80	6560 (6660) 6750 BP
Unit 1: Stratum 5c	Owl limpet	Beta-145311	6390 ± 40	6540 (6620) 6660 BP

All dates on single shells, including adjustment for $^{13}\text{C}/^{12}\text{C}$ ratios. Beta-145311 dated via AMS, all others via conventional liquid scintillation counting. Calibrated age ranges (intercepts in parentheses, ranges at one sigma) calculated with CALIB program (Stuiver and Reimer 1993).

dates, Stratum 4 appears to represent a stratigraphic reversal. The age range of this date nearly overlaps with the others at two sigma, however, and it seems likely that the younger date is a statistical outlier.

After Otter Cave was abandoned about 6500 years ago, the midden deposits were buried under nearly a meter of calcareous sand blown into the cave by strong northwest winds. This event followed the accretion of a dune ramp extending from the beach to the cave itself, and may be related to a Middle Holocene intensification of dune building on San Miguel Island. After several millennia of relative stability, and probably after the historical introduction of sheep and other livestock to San Miguel Island in the 1800s, erosion became the dominant process at Otter Cave. Although it has heavily impacted the site vicinity, this erosion facilitated our identification and initial dating of the cave and stimulated our test excavation at the site.

ARTIFACTS

Due to the small scale of our excavations, the relatively brief occupation of Otter Cave, and the emphasis of the site occupants on shellfish gathering, the number and diversity of artifacts recovered from the site is limited. The most remarkable of these were 40 *Dentalium pretiosum* (Indian money tusk) shell artifacts that appear to represent a combination of beads and bead-making refuse (Erlandson et al. 2001). *Dentalium* artifacts came primarily from Stratum 5a where their density reached almost 2800/m³, a value that rivals the density of *Olivella* bead-making refuse in many Late Holocene sites of the Northern Channel Islands. The *Dentalium* shells show signs of natural abrasion (probably from water-rolling and/or sand-blasting), and some have a coarse shelly sand in their interiors, suggesting that they were collected from a nearby beach. All stages of bead production appear to be present in the assemblage, from whole shells, to bead-making debris, and beads. Although *Dentalium* beads were used by Native Americans all along the Pacific Coast, they are generally described as coming from the Pacific Northwest, and *D. pretiosum* beads are relatively rare in sites along the southern California Coast. The use of *D. pretiosum* at Otter Cave is consistent with King's (1990:228) hypothesis that only this species was used prior to

about 2500 years ago, with *D. neohexagonum* used exclusively by the Chumash later in time.

A single *Olivella biplicata* shell found at Otter Cave may also be an artifact, although it shows no sign of human modification. No *Olivella* beads were recovered at Otter Cave, but the Chumash and their ancestors used *Olivella* shells to make beads throughout the Holocene. With no evidence that *Olivella* shells were collected as food, specimens found in archaeological sites are generally thought to represent bead-making refuse.

One bone tool fragment was recovered from the hearth feature in Stratum 3a in Unit 1W. Made from sea mammal bone, this is a medial fragment of an elongated tool such as a bone awl, pin, barb, or large gorge. The fragment is 12.7 mm. long, 4.4 mm. wide, and 2.65 mm. thick, with a highly polished exterior and broken ends that reveal a flattened oval cross-section. The sides of the artifact are parallel and there is no sign of the intentional scratching (perpendicular to the long axis) or mastic sometimes found near the center of bone gorges. Although the function of this bone tool fragment is uncertain, it seems more likely to be a piece of an awl or pin rather than a gorge or barb.

We also recovered 24 chipped stone artifacts (weighing 43.8 g.), including a single flake tool and 23 pieces of tool-making debris. These artifacts were unevenly distributed in the two halves of the test unit, with the flake tool coming from Unit 1E and all 23 pieces of debitage found in Unit 1W closer to the mouth of the cave. This segregation of materials is unusual in a test unit only 80 cm. long and may be due, in part, to the small sample size and the fact that midden deposits in Unit 1W were considerably thicker than in Unit 1E. It may also be related to the segregation of activities in the cave, however, with sharp debris deposited towards the mouth of the cave and away from the interior where people may have slept.

Despite the small size of the chipped stone assemblage, several material types are represented. The tool is a relatively large (12.8 g.) utilized flake of Cico chert, the primary source of which is located on the northeast coast of San Miguel Island (Erlandson et al. 1997). Two small pieces of Cico chert debitage were also recovered. Most of the assemblage (12 pieces of angular debris, 7.3 g.) consists of

metavolcanic porphyry—cobbles of which are found on local beaches—a common constituent in San Miguel archaeological sites. Two fine-grained sandstone spalls (19.6 and 2.7 g) were also recovered, along with one piece of quartzite angular debris. Finally, six pieces of debitage of what appears to be siliceous shale were recovered. All six siliceous shale artifacts were found in Stratum 5a and appear to be from a single core. Several metavolcanic artifacts from 5a, and others from 3a and 3b, also appear to be from the same cobbles. Finally, a small spall-like flake detached from near the platform of the Cico flake tool was also found to refit onto a scar on the tool, although it is possible that this spall was detached during excavation.

Also recovered in Stratum 5c in Unit 1W was a 10-12 cm. wide “patty” of asphaltum up to 1.5 cm. thick and weighing 55.6 g. This tar probably originates from a large oil seep off the northwest coast of San Miguel Island. Asphaltum was widely used as a glue and sealant by the Chumash and their predecessors.

FAUNAL REMAINS

In the excavation of Unit 1 at Otter Cave, 3.4 kg. of marine shell and 38.3 g. of animal bone were recovered. Both shell and bone were extremely well preserved. Considering the small size of the sample, a relatively wide range of shellfish and vertebrate remains was recovered.

Shellfish

Among the 3.4 kg. of shellfish remains from Unit 1, 23 different taxa were identified (Table 2). Over 96 percent of the shell was identifiable to at least a general taxon, most of it to the species level. The assemblage is dominated by taxa from the intertidal zone of rocky shorelines, which makes up roughly half of the island perimeter today. Overall, black turban (*Tegula funebris*) shell comprises about 53 percent of the shell weight and 54 percent of the shellfish MNI. California mussel (*Mytilus californianus*) contributes about 28 percent of the shell weight and 16 percent of the MNI. Black abalone (*Haliotis cracherodii*), owl limpet (*Lottia gigantea*), chitons (*Cryptochiton*, etc.), and crabs are represented as well, but none of these make up more than 8.1

percent of the shell weight in any level. Several minor species (especially small barnacles, limpets, and gastropods, etc.) appear to be incidental midden constituents, probably carried to the site as “riders” attached to abalones, mussels, and other edible shellfish or seaweeds. The most abundant of these non-dietary shellfish types are tiny limpets (*Acmaea* sp.), with 124 specimens representing over 16 percent of the shellfish MNI. Although their MNI could not be calculated, the remains of small acorn barnacles (*Balanus* sp.) were also relatively abundant. The shells of land snail (*Helminthoglyptes ayresiana*) also appear to be incidental midden constituents that probably entered the site through natural means.

For the major food species represented in Strata 3, 4, and 5, significant variation in weight and MNI values is apparent between levels. Some of this variation may be due to the small nature of our samples, but some changes between strata probably are related to fluctuations in local intertidal habitats or human foraging behavior. While the small turban snail makes up a majority of the total assemblage and dominates the shellfish remains from Strata 3 and 5, for instance, it makes up just 14 percent of the shell weight and 39 percent of the MNI in Stratum 4. Although much less abundant, owl limpets show a similar pattern, being relatively well represented in Strata 3 and 5, but only minimally so in Stratum 4. In contrast, California mussels dominated Stratum 4, making up nearly 75 percent of the total weight and 40 percent of the MNI, but were clearly secondary species in Strata 3 and 5. Abalones and chitons, on the other hand, are relatively evenly distributed throughout the cultural strata.

Such changes in shellfish species through time are often attributed to the impacts of human predation, which are sometimes measured by fluctuations in the average size of individuals within a particular shellfish species. It is often assumed that coastal peoples preferentially harvest larger shellfish species first and that the intensive use of smaller taxa generally represents evidence for human impacts on shellfish populations. Changes in the average size of mussels in the three Otter Cave strata may provide some support for these ideas. The average length of whole (or nearly whole) California mussel shells differs significantly between the three strata, for instance: 35.2 mm. in Stratum 5, 42.8 mm. in Stratum 4, and

Table 2
SHELLFISH REMAINS FROM STRATA 3, 4, AND 5 IN TEST UNIT 1 AT OTTER CAVE

Taxon	Stratum 3			Stratum 4			Stratum 5			Totals			
	Wt.	Wt%	MNI	Wt.	Wt%	MNI	Wt.	Wt%	MNI	Wt.	Wt%	MNI	MNI%
<i>Acmaea</i> sp.	45.0	3.5	65	0.6	<0.1	4	6.1	0.4	55	51.7	1.5	124	16.1
<i>Balanus</i> sp.	3.4	0.3	-	3.1	0.5	-	11.2	0.7	-	17.7	0.5	-	-
<i>Chama</i> sp.	0.1	<0.1	1	-	-	-	-	-	-	0.1	<0.1	1	0.5
Crab, undiff.	19.9	1.6	4	14.5	2.5	1	6.4	0.4	1	40.8	1.2	6	0.8
<i>Crepidula</i> sp.	0.2	<0.1	3	0.1	<0.1	1	0.7	<0.1	6	1.0	<0.1	10	1.3
<i>Cryptochiton stelleri</i>	13.4	1.1	4	10.1	1.8	1	13.6	0.9	2	37.1	1.1	7	0.9
Chiton, undiff.	21.6	1.7	5	4.3	0.7	1	7.4	0.5	3	33.3	1.0	9	1.2
<i>Dentalium pretiosum</i>	0.1	<0.1	1	-	-	-	2.7	0.2	7	2.8	<0.1	8	1.0
<i>Haliotis cracherodii</i>	56.2	4.4	5	17.9	3.1	1	28.8	1.9	3	102.9	3.1	9	1.2
<i>Haliotis rufescens</i>	-	-	-	0.4	<0.1	1	8.4	0.6	1	8.8	0.3	2	0.3
<i>Haliotis</i> sp.	-	-	-	0.3	<0.1	-	4.7	0.3	-	5.0	0.1	-	-
<i>Hipponix</i> sp.	0.2	<0.1	1	-	-	-	-	-	-	0.2	<0.1	1	0.1
<i>Lepas anatifera</i>	0.1	<0.1	1	0.1	<0.1	-	-	-	-	0.2	<0.1	1	0.1
<i>Lottia gigantea</i>	103.1	8.1	9	3.1	0.5	1	55.6	3.6	11	161.8	4.8	21	2.7
<i>Mytilus californianus</i>	320.8	25.3	62	428.7	74.5	31	180.3	11.8	23	929.8	27.6	119	15.5
<i>Olivella biplicata</i>	1.0	<0.1	1	-	-	-	-	-	-	1.0	<0.1	1	0.1
<i>Pododesmus cepio</i>	-	-	-	3.0	0.5	1	-	-	-	3.0	<0.1	1	0.1
<i>Pollicipes polymerus</i>	5.4	0.4	1	1.2	0.2	1	42.5	2.8	1	49.1	1.5	3	0.5
<i>Septifer bifurcatus</i>	0.7	<0.1	2	0.2	<0.1	1	-	-	-	0.9	<0.1	3	0.4
<i>Serpulorbis squamigerus</i>	0.1	<0.1	1	0.1	<0.1	1	-	-	-	0.2	<0.1	2	0.3
<i>Strongylocentrotus</i> sp.	0.2	<0.1	2	0.2	<0.1	1	7.1	0.5	1	7.5	0.2	4	0.5
<i>Tegula funebris</i>	646.3	51.0	73	79.8	13.9	33	1065.1	69.9	312	1791.2	53.2	418	54.4
Gastropod, undiff.	1.5	<0.1	9	-	-	-	0.6	<0.1	3	2.1	<0.1	12	1.6
Shell, undiff.	25.3	2.0	-	6.7	1.2	-	79.3	5.2	-	111.3	3.3	-	-
Abraded shell, undiff.	3.2	0.3	-	1.2	0.2	-	2.9	0.2	-	7.3	0.2	-	-
Totals	1267.8	-	250	575.6	-	83	1523.4	-	429	3366.8	-	762	-

Notes: all weights in grams; also recovered were 1.3 g. (6 MNI) of land snail (*Helminthoglyptus ayresiana*) shell, which appears to be a natural site constituent.

32.0 mm. in Stratum 3. Thus, in the one Otter Cave stratum where the *Mytilus* shells recovered were relatively large, California mussels dominate the shellfish assemblage. In the two strata where mussels are considerably smaller, turban snails dominate. This pattern is consistent with some tenets of optimal foraging theory, suggesting human switching between shellfish species based on changes in their relative size or productivity (see Raab 1992). In other words, when

large mussels were locally available, the occupants of Otter Cave tended to focus on harvesting them, but when only smaller mussels were available they diversified their shellfish harvesting strategies to incorporate or focus on smaller species.

In coastal environments, however, shellfish harvesting choices are not governed solely by the size of the species targeted but on the total amount of meat, calories, or protein a person can gather and process

from various species during a given amount of time. In harvesting intertidal shellfish, efficiency is affected by the skill and pace of individual foragers, travel and search time, accessibility during tidal and daylight cycles, the density and aggregation of resources, their nutrient content, processing requirements, technological investments, and other factors. Because measuring all these variables is difficult, archaeologists and anthropologists often resort to simplified models, including the notion that larger resources are generally more productive than smaller ones. As a result, smaller shellfish such as turban snails, which rarely grow to more than about an inch in diameter, are often viewed as low-value or even "starvation" foods. Like California mussels, however, turbans are often found in large aggregations in the mid-to-upper intertidal zone, where a basket or bag of shellfish adequate to feed a family can sometimes be gathered in minutes (Perry 2004:94). Optimal foraging principles suggest that such resources may also be optimal choices where they are relatively abundant, readily available, and easily gathered (Raab 1992:77). This is particularly true in many coastal environments, where women often did the bulk of intertidal gathering to provide daily sustenance while men were engaged in riskier hunting or fishing activities that paid less regular dividends.

At Otter Cave, attributing the stratigraphic changes in the abundance of shellfish types or average mussel size to the impacts of human predation is problematic. First, the sample sizes are relatively small and the occupations relatively brief. There is also little reason to believe that these changes are due to human harvest pressure, because of the relatively low human population densities expected on San Miguel Island 6600 years ago, as well as the small number of people that could have occupied Otter Cave. Finally, a variety of natural processes also affect the abundance and size of shellfish populations, including such disparate variables as water temperature and nearshore productivity, storm cycles and wave energy, changes in intertidal substrates, the density of non-human predators (sea otters, starfish, fish, etc.), disease epidemics, and other ecological changes. These problems are exacerbated by any focus on a single site, particularly a relatively small site occupied for brief intervals of time, rather than a regional perspective that examines multiple sites and

variables across longer periods of time. As a result, we interpret stratigraphic variation in shellfish distributions at Otter Cave as a reflection of optimal choices made by intertidal foragers to local environmental variability during the early Middle Holocene.

Vertebrate Remains

We recovered a total of 935 animal bone fragments weighing 38.3 g. in Unit 1 (Table 3). Unlike several of the mollusks, the vast majority of the vertebrate remains appear to represent food refuse. Most of the bone was recovered from Stratum 3 (51%), but variation in the types of animals identified in each of the strata was minimal. Of 935 bones, 890 (95%) were identifiable to general animal categories, including mammal, fish, bird, rodent, and lizard. The small and fragmentary assemblage of mammal and bird bones was not identifiable to family, genus, or species distinctions, but many of the fish bones were diagnostic. Rodent bones, lizard bones, and other small vertebrate remains are found in substantial numbers in some early Channel Island sites, but they are rare at Otter Cave where only four rodent bones and one lizard bone were found near the very base of the midden. The low proportion of rodents and lizards in the assemblage attests to a relatively well preserved context where most of the bones represent the activities of the people who occupied the cave rather than natural agents.

Most of the bones are from teleost (bony) fishes, which contribute about 68 percent of the bone weight and 85 percent of the count and MNI. Most of the fish bones were undiagnostic fragments, but roughly 9 percent of the bones were identified to family, genus, or species. At least seven teleost taxa and one elasmobranch were identified. Similar to most Channel Islands sites, rocky nearshore or kelp forest taxa—including cabezon, surfperches, rockfish, and lingcod—dominate the assemblage (see Bowser 1993; Rick et al. 2001; Salls 1988). The fish remains from Otter Cave could have been obtained using hook and line, spears, or nets. A few bones of small fishes, including sculpin and prickleback, were also identified. These may have been captured by people in the intertidal zone, but they may also have been deposited as the stomach contents of larger prey.

Table 3
VERTEBRATE REMAINS FROM STRATA 3, 4, AND 5 IN TEST UNIT 1 AT OTTER CAVE

Taxon	Stratum 3		Stratum 4		Stratum 5		Unit Totals					
	NISP	Wt.	NISP	Wt.	NISP	Wt.	NISP	NISP%	Wt.	Wt. %	MNI	MNI%
Cottidae (sculpin)	4	0.12	—	—	—	—	4	0.43	0.12	0.31	1	4.8
<i>Scorpaenichthys marmoratus</i> (cabezon)	5	1.04	4	0.64	2	0.26	11	1.18	1.94	5.07	3	14.3
Embiotocidae (surfperch)	1	0.16	2	0.09	13	0.48	16	1.71	0.73	1.91	3	14.3
Labridae (señorita or wrasse)	1	0.02	1	0.01	—	—	2	0.21	0.03	0.08	2	9.6
<i>Ophiodon lingatus</i> (lingcod)	1	0.17	—	—	—	—	1	0.11	0.17	0.44	1	14.3
<i>Sebastes</i> spp. (rockfish)	15	0.94	6	0.47	2	0.10	23	2.46	1.51	3.94	3	14.3
Stichaeidae (prickleback)	1	0.01	2	0.07	5	0.46	8	0.86	0.54	1.41	3	14.3
<i>Galeorhinus galeus?</i> (soupfin shark)	2	0.04	—	—	—	—	2	0.21	0.04	0.10	1	4.8
Teleost undiff.	350	11.10	218	5.60	146	4.32	714	76.36	21.02	54.88	—	—
Fish subtotal	380	13.60	233	6.88	168	5.62	781	83.53	26.10	68.15	17	81.0
Bird	18	1.50	6	0.30	8	0.99	32	3.42	2.79	7.28	1	4.8
Lizard	—	—	—	—	1	0.01	1	0.11	0.01	0.03	1	4.8
Mammal, undiff.	53	7.29	14	0.42	10	0.49	77	8.24	8.20	21.41	1	4.8
Rodent undiff.	—	—	—	—	4	0.06	4	0.43	0.06	0.16	1	4.8
Bone, undiff.	22	0.73	7	0.10	11	0.31	40	4.28	1.14	2.98	—	—
Total	473	23.12	260	7.70	202	7.48	935	—	38.30	—	21	—

All weights in grams; undifferentiated bone = non-fish bone.

Although mammal bone is the second most abundant category in the Otter Cave vertebrate assemblage, mammal remains make up just 8 percent of the total NISP and 21 percent of the total weight. Most of the mammal bones were small fragments of cancellous bone with a thin cortical layer. Because the Channel Islands contain no large land mammals other than humans, these bones likely are the remains of sea mammals. Because none of these fragmentary

bones were diagnostic to higher taxonomic categories, we classified them as undifferentiated mammal.

Compared to fish and mammal bones, the remains of birds are relatively limited in Channel Islands archaeological sites. At Otter Cave, only 32 undifferentiated bird bone fragments weighing 2.79 g. were recovered. Most of the bird bones were small shaft fragments from long bones. Such bones were often used by people to make bone gorges and

other tools, but no clear artifacts or bone tool-making debris were identified among the avian remains.

Dietary Reconstruction

To understand the importance of various food resources to ancient peoples, we need to know not just the weight of the faunal refuse (bone, shell, etc.) they left behind, but the nutritional value represented. Because different types of shellfish and other animals can have dramatically different ratios of edible meat to skeletal weights, numerous studies have shown that the dietary importance of various types of animals can differ significantly from their contribution to the shell and bone weights represented at a site. To estimate the dietary significance of various species or faunal classes to the cave occupants, we used the weight method to transform dry shell and bone weights to edible meat values. This method, which uses experimentally derived shell and bone-to-meat ratios for various taxa (Table 4), has numerous problems (see Erlandson 1994; Grayson 1984; Reitz and Wing 1999; Vellanoweth and Erlandson 1999). Many of these are minimized, however, when analyzing well-preserved faunal assemblages (collected in relatively fine screens) such as those

from Otter Cave, and when comparisons are restricted to sites subject to similar taphonomic histories. The weight method provides rough approximations of the animal diet that can be compared to other subsistence studies for Santa Barbara Channel shell middens. Numerous dietary reconstructions from the Santa Barbara Channel area have revealed general patterns in human subsistence across the Holocene, patterns consistent with technological evidence from archaeological sites, environmental variation within the region, and ethnographic descriptions of Chumash subsistence.

Our dietary reconstruction for the faunal remains recovered from Otter Cave is presented in Table 5, including estimates of the faunal yields for each of the major cultural strata and the assemblage as a whole. Transforming the data from raw shell and bone weights to estimated meat weights illustrates the potential of such conversions in reconstructing the nutritional significance of various faunal types. Most dramatic is the reduced dietary importance of shellfish, which comprised about 98.5 percent of the total faunal assemblage by weight (and 97% of MNI), but only about 58 percent of the estimated yield of edible meat. In contrast, fish contributed just 0.9 percent of the total faunal weight (2% of the MNI),

Table 4
MEAT YIELD MULTIPLIERS USED IN DIETARY RECONSTRUCTION FOR OTTER CAVE

Faunal Taxon	Meat	Primary Reference and Notes
Chiton (<i>Nuttalina</i> sp.)	1.15	Vellanoweth and Erlandson 1999:265
Black abalone (<i>Haliotis cracherodii</i>)	0.944	Vellanoweth and Erlandson 1999:265
Red abalone (<i>Haliotis rufescens</i>)	1.36	Koloseike 1969
<i>Haliotis</i> sp.	1.15	Average of red and black abalone
Owl limpet (<i>Lottia gigantea</i>)	1.36	Tartaglia 1976
California mussel (<i>Mytilus californianus</i>)	0.298	Erlandson 1994:59
Turban (<i>Tegula funebris</i>)	0.365	Erlandson 1994:59
Other shell	0.674	Average of mussel, turban, and <i>Lottia</i>
Fish	27.7	Tartaglia 1976
Bird	15.0	Ziegler 1975
Marine mammal and other bone	24.2	Glassow and Wilcoxon 1988

Table 5

ESTIMATED MEAT YIELDS FOR FAUNAL REMAINS FROM STRATA 3, 4, AND 5, OTTER CAVE

Faunal Taxon	Stratum 3			Stratum 4			Stratum 5			Total	
	Gross	Meat	%	Gross	Meat	%	Gross	Meat	%	Meat	%
Chitons	35.0	39.9	6.9	14.4	16.6	8.3	20.9	24.0	4.0	80.5	5.6
Abalone (<i>H. cracherodii</i>)	56.2	53.1	9.1	17.9	16.9	8.5	28.5	26.9	4.5	96.9	7.0
<i>H. rufescens</i>	-	-	-	0.4	0.5	0.3	7.9	10.7	1.8	11.2	0.8
<i>Haliotis</i> sp.	-	-	-	0.3	0.3	0.2	4.6	5.3	0.9	5.6	0.4
Limpet (<i>Lottia gigantea</i>)	103.1	140.2	24.1	3.1	4.2	2.1	41.6	56.6	9.5	201.0	14.6
Mussel (<i>M. californianus</i>)	320.8	95.6	16.4	428.7	127.8	63.9	165.6	49.3	8.3	272.7	19.8
Turban (<i>T. funebris</i>)	646.3	235.9	40.5	79.8	29.1	14.6	1009.4	368.4	62.1	633.4	46.1
Shell, undiff.	25.3	17.1	2.9	6.7	4.5	2.3	77.8	52.4	8.8	74.0	5.4
Shellfish Total		581.8	49.5		199.9	49.0		593.6	77.6	1375.3	58.6
Fish bone	13.60	376.7	32.1	6.88	190.6	46.8	0.49	13.6	1.8	580.9	24.7
Mammal bone	8.02	194.1	16.5	0.52	12.6	3.1	5.89	142.5	18.7	349.2	14.9
Bird bone	1.50	22.5	1.9	0.30	4.5	1.1	0.99	14.9	1.9	41.9	1.8
Vertebrate subtotal		593.3	50.5		207.7	51.0		171.0	22.4	972.0	41.4
Total		1175.1			407.6			764.6		2347.3	

All weights in grams; gross weight = dry bone or shell weight, meat weight = estimated meat yield. Incidental shellfish, rodent, and other non-dietary remains are omitted. Crab was also omitted due to a lack of data on shell-to-meat ratio.

but roughly one quarter of the meat represented in our reconstruction. Mammal remains show a similar increase, from 0.5 percent of total faunal weight to almost 15 percent of the estimated meat yield.

Such transformations are less dramatic for the major types of edible shellfish, but still have important implications for evaluating the nature of shellfish harvesting. Although turban snails remain the single most important type, their estimated contribution to the total shellfish meat yield declines to about 46 percent, from highs of 54.4 percent of the total MNI for shellfish and 53.2 percent of the shell weight. Due to their relatively high shell-to-meat ratio, California mussels also decline in importance to 19.8 percent of

the estimated edible meat yield for shellfish. The apparent dietary significance of chitons, abalones, and owl limpets increases, however, from 2.1, 3.5, and 4.8 percent of total shell weight (2.1, 1.5, and 2.7 % of MNI) to 5.6, 8.2, and 14.6 percent of the edible meat yield, respectively. The generally larger abalones, limpets, and *Cryptochiton stelleri*, therefore, are transformed from minor faunal contributors to significant (if secondary) sources of shellfish meat.

Variations in the relative importance of different shellfish and vertebrate taxa in the three major strata may reflect somewhat different economic strategies or environmental conditions between different occupations. Given the narrow window of time

represented by the occupations—as well as the small samples from individual strata—it would be dangerous to over-interpret the evidence for adaptive variation between the components. It is worth noting that shellfish represent the single greatest dietary contributor in the nutritional reconstructions for each of the three strata, however, and that smaller shellfish taxa (turban snails or California mussels) dominate the nutritional yields for every stratum.

Combining data for Strata 3, 4, and 5, the largest estimated provider of meat was shellfish at almost 59 percent, with fish providing approximately 25 percent, mammals roughly 15 percent, and birds about 2 percent. Given the dearth of land mammals on San Miguel Island, the mammal remains almost certainly come primarily from marine species. The combined dietary reconstruction for the 6600 year old occupations of Otter Cave is consistent with general models of subsistence change identified elsewhere on the Northern Channel Islands and the Santa Barbara Channel area. As expected on an island with a relatively impoverished terrestrial flora and fauna, the Otter Cave data suggest that the economy of the site occupants was dominated by marine resources. The relative emphasis on shellfish, fish, and sea mammals also fits well into the transition from Early Holocene economies dominated by shellfish gathering and Late Holocene economies dominated by marine fishing.

DISCUSSION

Our data from Otter Cave illustrate the complexities of understanding ancient human foraging in coastal environments. The faunal remains illustrate the unique nature of some coastal or other aquatic environments, where small animals (shellfish, schooling fish, etc.) can often be obtained efficiently in large quantities using relatively simple technologies. In coastal settings, an economic emphasis on small shellfish does not necessarily constitute evidence for an intensification of coastal subsistence or human impacts on larger (i.e., vertebrate) resources. The faunal data from Otter Cave are consistent with evidence for heavy use of shellfish at numerous more substantial island and mainland sites in the Santa Barbara Channel area dated to the Early and Middle Holocene (see Erlandson 1994; Erlandson et al. 1999; Vellanoweth and Erlandson

1999). Population pressure, human depletion of resources, and economic intensification do not explain this pattern, since there is no evidence that human populations were particularly large during the Early and Middle Holocene.

For the Otter Cave residents and many early maritime peoples of the Santa Barbara Channel area, shellfish appear to have been optimal resources that were widely used because they were: (1) abundant and accessible during daily tidal cycles; (2) found in highly predictable and aggregated concentrations that could be harvested quickly with minimal technological investment; (3) often available to virtually all members of society, including children and the elderly; (4) a valuable source of complete animal protein and calories when incorporated into a broader diet that provided adequate amounts of carbohydrates and fats; and (5) productive enough in many rocky coast and estuarine habitats to represent a sustainable resource under conditions of low or moderate human population densities.

At the same time, the data from Otter Cave are consistent with evidence from other San Miguel Island sites, which suggest that fishing and sea mammal hunting were of increasing importance during the Middle and Late Holocene. At Otter Cave, our dietary reconstructions suggest that vertebrates contributed roughly 40 percent of the edible meat represented in the faunal samples. At two Early Holocene middens located west of Otter Point, shellfish contributed more than 90 percent of the edible meat represented by midden samples, with fish and sea mammals making minor contributions (Erlandson, Rick et al. 2004, 2005). Faunal samples from two 6000 year old midden components at nearby CA-SMI-481 on Otter Point are more similar to Otter Cave, however, with shellfish providing approximately 67 percent of the estimated meat yields, sea mammals about 25 percent, and fish about 7 percent (unpublished data in possession of the authors). In contrast, a large and very dense Late Holocene midden at CA-SMI-481 contains vast quantities of sea mammal, fish, and shellfish—including cetaceans, swordfish, and other pelagic species. A dietary reconstruction for this 1100-1200 year old component, suggests that sea mammals contributed roughly 72 percent of the edible meat represented, fish about 21 percent, and shellfish only about 7 percent (Rick 2004). These comparisons

suggest that the subsistence data from Otter Cave fit relatively comfortably with general patterns of trans-Holocene subsistence change identified on San Miguel Island and in the broader Santa Barbara Channel region (see Glassow 1993; Kennett 2005).

SUMMARY AND CONCLUSIONS

Between about 6700 and 6400 years ago, Otter Cave served as a temporary camp used by small groups of people who foraged, fished, and hunted along the northwest shore of San Miguel Island. The presence of three major cultural strata, along with the varying combinations of constituents found in Strata 3, 4, and 5, suggest that the cave was occupied on at least three to four separate occasions. Other than an unusual concentration of *Dentalium* shells in Stratum 5, relatively few artifacts were recovered. This was due in part to the limited nature of our excavations and the short duration of the site occupations, but the low density of artifacts is probably also related to the heavy reliance on shellfish collecting by the site occupants—a pursuit that requires little in the way of durable technology. Dietary reconstructions for the site suggest that the maritime peoples of Otter Cave relied primarily on rocky shore shellfish, fish, and sea mammals for subsistence, with an emphasis on small shellfish species that are often found in intertidal aggregations where meals can be collected relatively quickly and efficiently.

Even with the limited nature of our excavations, the information gathered from Otter Cave tells an important story about the history of the island and its human occupants. Despite the relatively brief nature of the occupations, the subsistence data are consistent with the broader transitions proposed for the Santa Barbara Channel region during the Early, Middle, and Late Holocene. Although the relative emphasis on various shellfish and vertebrate species varies through space and time on San Miguel Island, the Island Chumash and their predecessors appear to have relied on the same basic suite of resources for roughly 10,000 years, despite significant changes in technology and human population densities.

Finally, the data from Otter Cave also illustrate the remarkable variability in human subsistence along the southern California Coast during the Middle

Holocene. At Otter Cave and many other Channel Island sites, people appear to have been engaged primarily in shellfish gathering and nearshore fishing in rocky shore habitats. At roughly the same time, however, some Channel Islanders appear to have been intensively fishing (Vellanoweth and Erlandson 1999) or hunting dolphins and pinnipeds (Porcasi and Fujita 1999), while people along the mainland coast practiced a Milling Stone adaptation focused on the gathering of small seeds and estuarine shellfish. Such adaptive diversity reflects the natural variation in the marine and terrestrial environments of the southern California Coast and the range of foraging strategies devised to cope with such variability.

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