HUMAN IMPACTS ON NEARSHORE SHELLFISH TAXA: A 7,000 YEAR RECORD FROM SANTA ROSA ISLAND, CALIFORNIA

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Within the broad framework of historical and behavioral ecology, we analyzed faunal remains from a large habitation site (CA-SRI-147) on Santa Rosa Island to explore a 7,000 year record of coastal subsistence, nearshore ecological dynamics, and human impacts on shellfish populations. This long, stratified sequence provides a rare opportunity to study the effects of prolonged human predation on local intertidal and nearshore habitats. During the past 7,000 years, the Island Chumash and their predecessors had significant impacts on nearshore ecosystems, caused by growing human populations and depletion of marine and terrestrial ecosystems. At CA-SRI-147, local depletion of higher ranked shellfish species stimulated dietary expansion and a heavier reliance on lower-ranked shellfish taxa and more intensive exploitation of nearshore and pelagic fishes. In the Late Holocene, as local ecosystems were increasingly depleted, the Island Chumash relied increasingly on craft specialization and trade to meet their subsistence needs. Native peoples clearly impacted Channel Island ecosystems, but data from CA-SRI-147 suggest that they adjusted their subsistence strategies toward productive fisheries that sustained the high population densities and sociopolitical complexity recorded by early Spanish chroniclers at European contact.

Dentro de los marcos amplios de la ecología histórica y la ecología del comportamiento, analizamos los restos faunísticos de un sitio habitacional grande (CA-SRI-147) en la Isla Santa Rosa para investigar el historial de 7000 años de subsistencia costera, la dinámica ecológica cercana a la costa, y los impactos humanos sobre poblaciones de mariscos. Esta secuencia larga y estratificada nos provee de la rara oportunidad de estudiar las consecuencias de degradación humana prolongada en hábitats locales intermareales y cercanos a la costa. En los últimos 7000 años, la Isla Chumash y sus predecesores tenían un gran impacto sobre los ecosistemas cercanos a la costa, causado por las poblaciones humanas cada vez mayor y el agotamiento de ecosistemas marinos y terrestres. En CA-SRI-147, el agotamiento local de especies de mariscos de alto rango promovió la expansión dietética, más dependencia de los mariscos de bajo rango, y la explotación más intensiva de los peces pelágicos y cercanos a la costa. En el Holoceno tardío, cuando los ecosistemas locales fueron agotados cada vez más, la Isla Chumash se basó cada vez más en la especialización artesanal y el comercio para satisfacer sus necesidades de subsistencia. Aunque la población indígena tenía un impacto claro sobre los ecosistemas de las Islas Channel, los datos arqueológicos de CA-SRI-147 dan a entender que ajustaron las estrategias de subsistencias a pesquerías productivas que habían sostenido las altas densidades demográficas y la complejidad sociopolítica anotado por los cronistas españoles del contacto europeo.

The systematic investigation of how humans impacted ancient ecosystems has emerged as an important area of archaeological inquiry (see Crumley 1994a; Redman 1999; Redman et al. 2004). Archaeological sequences provide a long-term record of human interaction with their environment and patterned variability in faunal and floral records often suggests that people altered the ecosystems they inhabited. Recent studies have explored these impacts on different societal scales, from hunter-gatherer to state-level societies (see Grayson 2001; Kirch et al. 1992; Redman 1999; Redman et al. 2004). Historical ecological studies of this type are of great value to resource managers and policymakers because they can provide deeper historical frameworks in which to evaluate modern environmental impacts, along with a better understanding of the causes and consequences of human decision-making (see Jackson et al. 2001).

In this paper, we evaluate evidence for ancient human impacts on shellfish communities along the
south coast of California’s Santa Rosa Island, using one of the longest archaeological sequences yet reported for the Channel Islands (ca. 7300 to 350 cal. B.P.). Archaeological evidence from CA-SRI-147, and elsewhere on these islands (Kennett 2005; Rick et al. 2005), indicates that marine mollusks ranging from large abalones to small snails played a central dietary role through much of the Holocene and that people focused on the harvest of different species at different times. Commercial shellfishing in the last 150 years has been an important economic industry in this region and over-harvesting has had a significant impact on the availability of targeted species (e.g., abalones, lobsters, sea urchins). This parallels a global trend of fish and shellfish decline in the late twentieth century and what is now considered a worldwide fisheries crisis (Jackson et al. 2001; Pauly et al. 1998; Pew Oceans Commission 2003; Rick and Erlandson 2007). The data we present in this paper help put these modern ecological impacts into a deeper historical context.

We explore and evaluate the potential effects of human predation on shellfish communities—visible in the faunal record at CA-SRI-147—within a historical ecological framework that considers changes in human demography, technology, subsistence, and sociopolitical organization. We also consider independent environmental changes evident in proxy climate records for the region (Fridleifsson et al. 2003; Kennett and Kennett 2000; Kennett et al. 2007). One of the underlying assumptions of human ecology is that people use subsistence resources selectively, not randomly, and make informed and economically rational decisions based on long-term interactions with their natural and social environments (see Crumley 1994b:5–8; Winterhalder 1994). To formalize this assumption, we employ the prey choice model from behavioral ecology to create a set of expectations to compare against the archaeological record. To this end, we assume a tendency toward optimization in human foraging behavior (see Winterhalder and Smith 2000), recognizing the complexity of measuring such tendencies under a variety of demographic, social, and ecological contexts, and with archaeological data (Grayson and Delpech 1998; Grayson et al. 2001). Given the varied suite of resources available in local intertidal habitats, we also assume that foragers generally exploit a mix of prey that provide the greatest return of calories, protein, or other economic benefits per energy expended (see Foley 1985; Kelly 1995). This is a fundamental tenet of optimal foraging theory (see Jochim 1976, 1981) and human behavioral ecology (HBE) (Winterhalder and Smith 1992, 2000). Assuming a tendency toward optimal foraging behavior, we can predict which marine resources people exploited through the Holocene given changing demographics, settlement patterns, and climatic conditions and compare these predictions to the results from CA-SRI-147.

Santa Rosa and the other Channel Islands are excellent laboratories for exploring the effects human foragers have on marine ecosystems (see Braje et al. 2006; Erlandson et al. 2004b, 2005a; Kennett 2005; Raab 1992). Santa Rosa is located 55 km from the California mainland and is the second largest of the Northern Channel Islands (Figure 1). The island’s 217 km² feature a varied topography of rolling hills, raised marine terraces, and canyon lands. Isolation from the mainland during the Pleistocene and Holocene has led to a low diversity of terrestrial flora and fauna. Less than half the plant species found on the adjacent California mainland occur on these islands and, after the extinction of pygmy mammoths (Mammuthus exilis) about 13,000 years ago (see Agenbroad et al. 2005), the largest animal was a small, cat-sized fox (Urocyon littoralis) that may have been introduced to the islands by humans sometime during the Holocene (Collins 1991a, 1991b; Schoenherr et al. 1999; Vellanoth 1998). In contrast, the islands have highly productive marine ecosystems that include a diverse range of potential subsistence resources from rocky intertidal, beach, kelp forest, and other nearshore habitats.

The Northern Channel Islands have been occupied by humans since at least 13,000 cal B.P. (Johnson et al. 2002), and numerous well-preserved shell middens provide evidence for human interaction with terrestrial and marine ecosystems from about 11,500 years ago to historic times (Erlandson et al. 1996, 2005b). Combined with detailed paleoecological records from the Santa Barbara Basin (Kennett and Ingram 1995a, 1995b; Kennett and Kennett 2000; Kennett et al. 2007), these continuous archaeological sequences provide a wealth of historical data on the adaptations of the Island Chumash and their predecessors along with their
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Figure 1. The Santa Barbara Channel Islands, the Southern California Coast, and the location of CA-SRI-147 and the ODP Site 893 A/B (base map drafted by R. van Rossman).

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man 1999; van der Leeuw and Redman 2002), but
human alteration of the local abundance of select
prey affects subsequent foraging decisions.

Prey Choice Model

Several California archaeologists have developed
prey choice models that provide a starting point for
evaluating the potential impacts of human preda-
tion on marine ecosystems on Santa Rosa Island
(see Beaton 1991; Botkin 1980; Broughton 1997,
1999; Hildebrandt and Jones 1992; Jones and
Hildebrandt 1995; Kennett 2005). On a daily basis,
prehistoric islanders were presented with a variety
of potential subsistence alternatives to provision
their households. Ethnographic research in other
parts of the world suggests that human foragers
generally make economically effective dietary deci-
sions, mediated by changing environmental,
demographic, and social conditions (constrained
Studies also show that interactions between human
foragers and their prey are dynamic, creating com-
plex ecological effects on target prey species. A
number of archaeological studies indicate that
human foragers substantially alter the abundance
and availability of selected prey and the local ecol-
ogy in the long term (Broughton 1997; Butler 2000;
Erlandson et al. 2005b; Grayson 2001). Under cer-
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prey affects subsequent foraging decisions.

Prey choice models, borrowed from behavioral
ecology (MacArthur and Pianka 1966), capture
aspects of forager-prey relationships and provide a
framework for exploring temporal changes at CA-
SRI-147 and other Channel Island archaeological
sites. Such models assume that a human forager will
take the highest-ranked prey items when encoun-
tered and add lower-ranked resources until reach-
ing an optimal diet breadth where the opportunity
cost of the next item exceeds the value of adding it
to those already selected when encountered (see
Broughton 1999; Kelly 1995; Kennett 2005; Win-
terhalder 1986; Winterhalder and Smith 2000). Net
acquisition rates (i.e., calories per hour) often serve
as a proxy to establish resource rankings. The inclu-
sion of lower-ranked resources is contingent on
encounter rates with higher-ranked prey, so such decisions are sensitive to the depletion of high-ranked resources due to predation or other environmental or social pressures (Madsen and Schmitt 1998; Ugan 2005). Persistent or increased predation of high-ranked prey may lower their local or regional abundance, stimulating dietary expansion or more intensive use of low-ranked resources. Prey choice models are ideal for exploring resource depression and prehistoric human impacts on ecological systems because they establish a clear set of expectations about foraging behavior that can be compared against the archaeological record.

A significant problem in investigating anthropogenic alterations to ecosystems is distinguishing them from natural (noncultural) ecological changes, including long-term climatically driven environmental changes. Changes in shellfish harvesting strategies evident in Channel Island archaeological assemblages were probably the result of ecological relationships involving both overharvesting of highly ranked species, climatically driven environmental change, and complex cultural interactions. Fortunately, the Santa Barbara Channel area has a relatively high-resolution record of environmental change preserved in a long sequence of varved sediments from the Santa Barbara Basin (Friddell et al. 2003; Kennett and Ingram 1995a, 1995b; Kennett 2005; Kennett and Kennett 2000), as well as other paleoecological records for marine and terrestrial ecosystems (e.g., Heusser 1978; Kinnan et al. 2005). These proxy records of changes in sea-surface temperature and marine productivity help us differentiate some of the effects of natural environmental changes from those potentially caused by humans.

Building a Prey Choice Model

A number of archaeologists have questioned aspects of optimal foraging theory, HBE, and prey choice models in explaining the complexities of human behavior and regionally specific historical trajectories of human evolution (see Dwyer 1985; Erlandson 1991, 2001; Jochim 1981; Madsen and Schmitt 1998). Here, we employ HBE to create a model against which to explore site-specific archaeological data. Building these models can be challenging, especially in coastal environments where resources are unevenly distributed and patchy. Fortunately, a number of anthropologists have studied indigenous shellfish foragers (e.g., Bird 1997; Bird and Bliege Bird 1997; de Boer 2000; Meehan 1982; Thomas 2001), collecting data that can help create prey choice models that consider the costs and returns associated with collecting shellfish from coastal ecosystems.

For California's Channel Islands, ethnographic or experimental data are not available on the economic productivity of collecting various shellfish species. Representative data can no longer be collected, moreover, because intertidal and nearshore shellfish communities have been heavily altered by historic impacts to marine ecosystems—the local extinction of sea otters, historic overfishing, and the collapse of abalone populations due to disease. While many archaeological prey choice models have assumed that animal size is a reasonable proxy for prey rank (e.g., Broughton 1994), ethnographic studies suggest that abundance, aggregation, accessibility, and reproductive rate, as well as search and processing times, are also important in influencing the return rates and ranking of resources that human foragers harvest.

For our Santa Rosa Island case study, we ranked major shellfish species according to a number of factors including size, meat yield, habitat location, abundance, and aggregation. Body size is an important variable, for instance, but smaller animals with higher reproductive rates and occurring in predictably large clusters may also be highly ranked (Erlandson et al. 2005c; Madsen and Schmitt 1998; Winterhalder and Lu 1997). This is particularly true in coastal ecosystems where some shellfish species occur in large clusters and can be acquired by nearly all members of society with little technological investment (Erlandson 2001; Jones and Richman 1995; Meehan 1982; Moss 1993). Acquisition rates also depend on available technologies (e.g., boats, pry bars, etc.), which can affect travel, capture, processing, and other time or energy investments. Finally, the location of shellfish within the nearshore environment can affect collection costs. Shellfish found in the middle intertidal (uncovered by many, but not all, low tides), for example, are more accessible than lower intertidal (exposed by only the lowest of tides) or subtidal (beyond the influence of tides) resources (Schoenherr et al. 1999:87–101), and require less energy to procure.
Two of our starting assumptions are that people living at CA-SRI-147 foraged for shellfish within a relatively circumscribed area and transported all shellfish to this central location for processing. Figure 2 shows the distribution of rocky headlands, rocky intertidal, and sandy beach habitats within a 2 km foraging radius from the mouth of Jolla Vieja Canyon. The rocky headlands to the east are relatively inaccessible and provided little in the way of subsistence resources. Rocky intertidal habitats and pocket beaches west of the canyon mouth were more accessible and productive, with rocky intertidal habitats and associated subtidal zones providing some of the highest ranked shellfish taxa. Sea level rise of 5–10 meters during the past 7,500 years (Berger 1983; Inman 1983) would have affected the location and structure of nearby shoreline habitats, but the local bathymetry suggests that intertidal habitats were only about 250-500 meters further from CA-SRI-147 than today. Experimental processing studies of California mussels (Bettinger et al. 1997; Jones and Richman 1995), and our own study of abalone, suggest that the assumption that people transported shellfish to the site (located ca. 2-2.5 km from the coast) without first removing the shells is reasonable (see discussion).

Table 1 provides the predicted ranking of the ten major shellfish species represented at CA-SRI-147, all of which come from rocky intertidal or subtidal habitats. Despite their intermediate size, we ranked California mussels (Mytilus californianus) the highest because they live in extensive, dense, and highly predictable aggregations in the middle intertidal zone; are available almost daily during relatively moderate low tides; and can often be harvested en masse (Jones and Richman 1995).
Table 1. Shellfish Rankings and Taxa Characteristics Considered in Our Analysis of CA-SRI-147.

<table>
<thead>
<tr>
<th>Rank</th>
<th>Taxa</th>
<th>Average Size (mm)</th>
<th>Meat Multiplier</th>
<th>Habitat Location</th>
<th>Occurrence</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>California Mussel (Mytilus californianus)</td>
<td>140</td>
<td>.298</td>
<td>Middle Intertidal</td>
<td>Extensive distribution and Dense Clusters</td>
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<tr>
<td>2</td>
<td>Black Abalone (Haliotis cracherodii)</td>
<td>115</td>
<td>.944</td>
<td>Lower Intertidal</td>
<td>Small Groups/ Individuals</td>
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<tr>
<td>3</td>
<td>Red Abalone (Haliotis rufescens)</td>
<td>220</td>
<td>1.36</td>
<td>Low Intertidal to Subtidal</td>
<td>Small Groups/ Individuals</td>
</tr>
<tr>
<td>4</td>
<td>Owl Limpet (Lottia gigantea)</td>
<td>85</td>
<td>1.36</td>
<td>Middle Intertidal</td>
<td>Individuals/Territorial</td>
</tr>
<tr>
<td>5</td>
<td>Turban Snail (Tegula spp.)</td>
<td>20</td>
<td>.365</td>
<td>Upper Intertidal</td>
<td>Moderately Dense Clusters</td>
</tr>
<tr>
<td>6</td>
<td>Sea Urchin (Strongylocentrotus spp.)</td>
<td>45</td>
<td>.383</td>
<td>Lower Intertidal</td>
<td>Individuals</td>
</tr>
<tr>
<td>7</td>
<td>Platform mussel (Septifer bifurcatus)</td>
<td>20</td>
<td>.364</td>
<td>Middle Intertidal</td>
<td>Dense Clusters</td>
</tr>
<tr>
<td>8</td>
<td>Crab</td>
<td>Variable</td>
<td>N/A</td>
<td>Upper Intertidal</td>
<td>Individuals</td>
</tr>
<tr>
<td>9</td>
<td>Rock Scallop (Hinnites multilineatus)</td>
<td>140</td>
<td>N/A</td>
<td>Subtidal</td>
<td>Individuals</td>
</tr>
<tr>
<td>10</td>
<td>Wavy Turban (Astrea undosa)</td>
<td>110</td>
<td>N/A</td>
<td>Subtidal</td>
<td>Individuals</td>
</tr>
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</table>

Note: Shellfish size and habitat data compiled from Schoenherr et al. (1999) and Cox (1962).

Although not as abundant or gregarious as California mussels, we ranked abalones next due to their large size and relatively high meat and protein yields. Red abalone (Haliotis rufescens), the larger of the two species, prefers cooler subtidal conditions and is less accessible than black abalone (H. cracherodii) or California mussel. However, red abalones can be found in the intertidal where sea surface temperatures (SSTs) are cooler (see Ault 1985), which may have made them more accessible at various times through the Holocene. The large owl limpet (Lottia gigantea) can also be fairly abundant in the mid-to-upper intertidal zone—where it would have been highly vulnerable to human predation—and is ranked relatively high. Compared to these top-ranked shellfish species, other taxa offered lower returns due to their small size (turban snails, Tegula spp., platform mussels, Septifer bifurcatus), low densities or meat yields (e.g., sea urchins, Strongylocentrotus spp.), increased processing time (e.g., turban snails and crab), harvesting difficulty (rock scallop, Hinnites multilineatus), or limited accessibility or distribution in subtidal locations (wavy turban, Astrea undosa). We predicted that these lower-ranked species would increase in middens as populations grew and predation pressure reduced the productivity of high-ranked taxa in the vicinity of CA-SRI-147.

While our sample size is not large enough to effectively investigate sea mammal use (see below), fish bone tends to be more widely and evenly distributed in Channel Island shell middens. Due to a limited number of identifiable elements, however, we approach fish bone as a general analytical category to compare against general trends visible in shellfish availability. We assumed that most fish were lower ranked than shellfish on the Northern Channel Islands due to increased technological requirements (e.g., boats, weirs, nets, fishhooks) and the generally longer search and capture times that fishing requires. This is generally supported by archaeological research on the islands, where reliance on marine fish increased through the Holocene, with a dramatic increase in fish bone densities in many Late Holocene middens (see below).

Trans-Holocene Demographic, Technological, and Social Changes

Substantial changes in subsistence, demography, economy, and sociopolitical organization occurred on the Northern Channel Islands during the Holocene—changes that affected the subsistence decisions of island peoples. Early Holocene sites (>7500 cal B.P.) are relatively rare on the Channel Islands compared to Middle and Late Holocene sites. Most early sites are located on Santa Rosa and San Miguel islands and tend to be small or low-density middens with artifact assemblages consisting primarily of expedient flakes and cores, along with occasional bifaces, bone gorges, and beads (e.g., Braje et al. 2004; Erlandson 1994; Erlandson et al. 1999, 2004a, 2005a). Most of these sites probably were occupied seasonally or intermittently by small groups of people (Kennett 2005; Rick et al. 2005). Most of the known early sites are
located near springs or in caves that were some distance from the contemporary coast. Sites closer to the coast have probably been lost to sea-level rise and coastal erosion. Faunal data suggest that early populations relied heavily on intertidal foraging: focusing on California mussels, black abalones, and other rocky shore taxa (e.g., owl limpets and turban snails). Fishing appears to have been largely restricted to near-shore species taken from kelp-forest habitats and seems to have played a secondary, dietary role to shellfishing. Evidence for early sea mammal hunting is also limited on the Channel Islands (Colten and Arnold 1998, 2000; Kennett 2005; Walker et al. 2000), but a dearth of sea mammal remains in early sites may result from disruption of breeding populations (Jones and Hildebrandt 1995) or the loss of early coastal sites to sea-level rise and erosion (Kennett 2005). Erlandson et al. (2005a) reported technological evidence for early sea mammal hunting, but we suspect that human impacts were relatively limited during the Early Holocene when human population densities were relatively low.

By the Middle Holocene (~7500–3500 cal B.P.), the number of Channel Island sites increased significantly, with growing populations establishing more permanent villages along productive rocky shorelines (Kennett 2005; Rick et al. 2005). Small interior settlements located on ridges and low-lying hills suggest that marine resources were supplemented with terrestrial plants (Kennett and Clifford 2004), Hubbs (1955) and Glassow (1993) first recognized that numerous middens dating to the Middle Holocene contain large numbers of red abalone shells. Since red abalone is a cold-water species, they suggested that these sites were evidence for cooler SSTs during the Middle Holocene, when red abalones were available in the intertidal zone. A trans-Holocene record of SST developed from varved sediments in Santa Barbara Basin (Kennett 2005; Kennett and Kennett 2000) suggests that some red abalone middens formed when SSTs were cooler between 6200 and 5800 cal B.P. Much of the Middle Holocene, however, was dominated by warm water conditions, and the abundance of red abalone in middens during this period may be more related to the reduction in El Niño/Southern Oscillation (ENSO) activity (Kennett et al. 2007). Sharp (2000) and others have proposed that red abalones were harvested through subtidal diving and Erlandson et al. (2005b) argued that the abundance and size of red abalone shells found in Middle Holocene middens could only be attained if local sea otter populations were limited—probably by Native hunting.

After about 3500 cal B.P., the Late Holocene is marked by extensive changes in subsistence, settlement, and technology that occurred within the context of expanding island populations (Arnold 1992, 2004; Kennett 2005; Rick et al. 2005). Late Holocene sites are almost exclusively located along the coastlines of San Miguel, Santa Rosa, and Santa Cruz, and include the emergence of fully sedentary villages. Few interior sites date after 3000 cal B.P., suggesting that people were aggregating in coastal locations (Kennett 2005), though short-term logistical forays to collect and process terrestrial resources may have occurred (see Glassow 1996). Kennett (2005) suggested that people were more tethered to highly productive marine habitats as primary settlements expanded around the coasts of the three larger islands. The increased importance of fishing in the Late Holocene is signaled by middens with much higher quantities of fish bone and by advancements in regional fishing technology such as the j-shaped fishhook (after ~2500 cal B.P.; Glassow 1996; Kennett and Kennett 2000; Rick et al. 2002) and the plank canoe (after 1500 cal B.P.; Arnold 1995; Gamble 2002). The Late Holocene also saw increased production of artifacts associated with craft specialization and trade (beads, microblades, ground stone tools, etc.), suggesting that exchange between island and mainland peoples became more important. Tools made from exotic stone and other materials such as deer bone increased in the Late Holocene (Kennett 2005:198–209). Arnold (1992, 2000) traced the origins of the historic Chumash chiefdoms and the complex bead currency exchange system (King 1990) to similar evidence in Late Holocene sites. This explosion in exchange may represent economic diversification, as islanders traded Olivella beads and other goods for resources found exclusively or more abundantly on the mainland such as obsidian, plant foods, and land mammals (Kennett 2005; Rick 2004).

Considering the likely resources available near CA-SRI-147, our proposed relative shellfish ranking scheme, and historical patterns identified during the Holocene, the prey choice model generates
several testable predictions. First, expanding populations during the Holocene on Santa Rosa Island increased human predation on the highest-ranked shellfish taxa (California mussels and abalone) and caused overall declines in their abundance. Second, this increased predation pressure measurably reduced the size of the highest-ranked shellfish taxa through time. Third, the diversity of lower-ranked shellfish taxa should increase through time in response to decreases in the abundance and size of the highest-ranked taxa. Fourth, decreases in the abundance and size of the highest-ranked shellfish taxa and dietary expansion to lower-ranked taxa ultimately stimulated an increased reliance on fishing and the development of new economic strategies to expand dietary breadth (e.g., trade).

CA-SRI-147 provides a detailed archaeological record against which to test these predictions. Due to the absence of gophers, ground squirrels, and most other burrowing animals, many Channel Islands archaeological sites remain highly stratified and relatively undisturbed. Long archaeological sequences such as those found at CA-SRI-147—with well-preserved stratigraphy, faunal remains, and artifacts—are still intact at many island sites. Through careful sampling, dating, and detailed analysis, we constructed a record of human interaction with marine environments spanning much of the Holocene.

CA-SRI-147: Testing the Model

Site Setting and Background

CA-SRI-147 is located at the confluence of two drainages in Jolla Vieja Canyon about two kilometers from the south coast of Santa Rosa Island. The site contains several substantial shell middens, a series of caves and rock shelters containing rock art and other archaeological materials, and numerous human burials. The first archaeological excavations at CA-SRI-147 were conducted by Jones (1956) in the early 1900s, who described the site as “a large rancheria of great interest” (Orr 1968:233). In three days excavating the site, Jones collected a variety of artifacts and exhumed numerous burials. In the mid-1900s, Orr (1968:229–233) also worked extensively at CA-SRI-147, reporting habitation debris and human remains in every cave, one of which contained the only petroglyphs (incised dots and lines) on Santa Rosa Island. In 1995, Dames and Moore, Inc. archaeologists surveyed Jolla Vieja Canyon, recording 45 archaeological sites and describing a deeply stratified series of shell midden strata exposed along the creek bank at CA-SRI-147 (York 1996:32). A single 14C date on a red abalone shell collected from a depth of 230 cm in one gully wall exposure suggested that the site was occupied for at least 5,600 years.

Current Investigation:
Site Chronology and Analytical Methods

The size and density of midden deposits, the presence of numerous human burials, and the diversity of artifacts recovered by earlier investigators, all suggest that CA-SRI-147 was a seasonal or long-term residential base, either permanently occupied or (more likely) regularly visited. In 1996, Kennett and Don Morris (NPS) visited CA-SRI-147 and found that—despite damage from early excavations and heavy erosion—well-preserved and deeply stratified shell midden deposits were still exposed in the canyon walls. To develop a detailed chronology for the site and collect quantitative data on the midden constituents, they sampled a deep stratigraphic profile exposed in the eastern branch of the canyon. The face of the exposure was cleaned and squared, revealing a densely packed shell midden deposit over three meters thick. A 25-x-25-cm column sample was excavated in arbitrary 10 cm levels, with 1/8-inch screen residuals collected for 31 levels. The excavated sample had a total volume of about 194 liters (.194 m³) and appears representative of the midden constituents exposed in the larger (~7 m wide) creek bank section. However, some site constituents—especially those rarer objects (sea mammal bones, finished artifacts, etc.) that tend to be scattered widely in shell middens—are clearly underrepresented in our sample. Shellfish and fish remains are abundant in the section, in contrast, and are more likely to be representative of long-term changes in human foraging patterns as well as ecological changes in local intertidal and nearshore habitats.

To better define the chronology of human occupation at CA-SRI-147, we obtained five 14C dates on single, well-preserved marine shells (Table 2). These include three conventional dates on individual California mussel shells, one at 60-70 cm (2600 ± 60, Beta-195746), one at 100-110 cm (3880 ±
Rosa Island. In the archaeological stratigraphic sequence, single 14C dates suggest a depth of 230 cm to the base of the deposit at 290–300 cm (6570 ± 80, Beta-92060). Two additional shells were submitted to the NOSAMS facility at Woods Hole for AMS dating, one from 190–200 cm (5270 ± 30, OS-46832) and one from the top of the deposit (950 ± 45, OS-43077). After correction and calibration, the six dates from CA-SRI-147 suggest that the site was occupied on multiple occasions between about 7300 and 350 cal B.P. Following Jerardino (1995), we estimated accumulation rates between dated levels and interpolated dates for each level using the midpoint of the calibrated age range. Since rates of deposition are not constant through time, and CA-SRI-147 may not have been continuously occupied, our interpolated dates should be regarded as estimates.

To develop a trans-Holocene record of human subsistence and impacts on nearshore ecosystems on Santa Rosa Island’s south coast, we analyzed the materials recovered from this long occupational sequence. Lab work was conducted by trained undergraduate students at the University of California, Santa Barbara and the University of Oregon. The middle 29 levels were analyzed, as the top and bottom levels were either disturbed or incomplete. All residues measuring 1/2-inch and larger were sorted into faunal classes and weighed. Samples of shellfish remains from the 1/4-inch (100 g) and 1/8-inch (15 g) residues were identified, and their constituent weights were used to estimate the composition of the larger shellfish assemblage (see Moss 1989). The remaining 1/4-inch and 1/8-inch material was sorted for diagnostic materials such as vertebrate remains and artifacts. The results of the faunal analysis were tabulated (see Table 3) and dietary reconstructions were calculated to approximate the amount of edible meat represented by major taxa (see Colten 1993; Erlandson 1994; Glassow and Wilcoxon 1988).

Our dietary reconstructions consider a number of quantitative measures (NISP, MNI, weight), but here we rely primarily on meat weight conversions (see Table 1) that use shell and bone weights to estimate dietary yields. Like other archaeological measures, the “weight method” is subject to a variety of problems (see Erlandson 1994:57–58; Klein and Cruz-UrIBE 1984:26–29; Lyman 1982: 359–363). CA-SRI-147’s excellent preservation and the minimal loss of material due to the use of a small screen size (1/8-inch) suggest a reasonably accurate reconstruction of dietary yields for shellfish and fish—data that can be used to compare various strata within the sequence. Our reconstructions can also be compared to other studies of subsistence variation along the southern California Coast through time (e.g. Colten 1993; Erlandson 1994; Glassow 1993; Glassow and Wilcoxon 1988; Kennett 2005; Rick 2004).

Changes in taxonomic diversity were estimated using the Shannon-Weaver function (1949) as described by Reitz and Wing (1999:235):

\[ H' = -\sum (p_i) \log (p_i) \]

where \( p_i \) is the relative abundance of each taxon per level in terms of meat weight contribution.

We also used an index of shellfish rank to calculate the relative importance of the higher ranked resources (California mussel and abalone) to all other shellfish taxa per level (see Butler 2000:654):

\[ \frac{\sum Mytilus + Haliothis \text{ Meat Weight}}{\sum \text{ Total Shellfish Meat Weight}} \]

Following Jones and Richman (1995), a mus-
<table>
<thead>
<tr>
<th>Level</th>
<th>California Mussel wt (g)</th>
<th>Red Abalone wt (g)</th>
<th>Black Abalone wt (g)</th>
<th>Turban Snail wt (g)</th>
<th>Sea Urchin wt (g)</th>
<th>Platform Mussel wt (g)</th>
<th>Other Shellfish wt (g)</th>
<th>Fish wt (g)</th>
<th>Other Bone wt (g)</th>
<th>Total wt (g)</th>
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<td>2.0</td>
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<td>-</td>
<td>-</td>
<td>86.4</td>
<td>3.9</td>
<td>164.2</td>
<td>7.4</td>
<td>4.1</td>
<td>193.3</td>
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</table>
essel size template was used to measure the relative sizes of all California mussel hinges in our sample. One person measured the hinges from all 29 levels (a total of 4,910 hinges) and mussel size class was averaged for each level (Table 4). While this method is not a precise measure of specific mussel size, it accurately estimates shell length within 1-cm increments. Averaging the size class by level (along with a standard deviation) provides a measure of the changing size of mussels harvested through time and a proxy for investigating human impacts on mussel beds. Although mussel size changes may also result from other environmental factors (e.g., kelp forest coverage changes, storms and wave action, changes in substrate, etc.), the long, continuous record at CA-SRI-147 helps to mediate episodic and relatively short-lived fluctuations. Longer-term environmental effects on mussel size can be identified by comparing SST and productivity data from the Santa Barbara Channel (e.g., Kennett and Kennett 2000; Kennett 2005; Kinlan et al. 2005). Correlations between the datasets were examined using a two-tailed Pearson’s r test (SPSS v. 11.0.1).

Results:

**Diachronic Changes in Faunal Constituents**

In our sample from the 3-m-deep sequence at CA-SRI-147, shellfish densities generally decrease over time. Accumulation rates vary throughout the sequence with the highest in the Middle Holocene between ca. 5640–4115 cal B.P. (7.1–15.7 cm/C), the lowest after ca. 4115 cal B.P. (2.3–2.6 cm/C), and an overall average rate of 4.0 cm per century. Very little cultural material was collected from level 9 (80–90 cm), marking a possible occupational hiatus from ca. 3400–3300 cal B.P. Changes in the abundance of material after this hiatus suggest a reduction in site use that is consistent with the development of more sedentary communities on the coast and a general shift away from the residential use of interior locations and resources (Kennett 2005).

Although mean mussel size fluctuates throughout the sequence, there is an overall decline from mean size class 3.5 to 2.0 between ca. 6100 cal B.P. and 350 cal B.P., a mean decrease of 42 percent (Figure 3A). We identified three cycles of rebound and decline in mean California mussel size in the record. The earliest of these cycles is found between about 7300 and 5100 cal B.P. (300–170 cm), where mean mussel size declines from a maximum of about 3.6 to 2.0 size class. At the same time, the estimated meat yields of mussel shell decline from about 140 kg/m² to 35 kg/m², red abalone declines from 75–80 kg/m² to almost nothing, and the contributions of turban snail and fish peak near the end of this cycle.

A second cycle occurs between about 5100 and 3350 cal B.P. (170 and 80 cm), when mean California mussel size class rebounds to over 3.0 and then declines to 2.7. At the same time, California mussel meat yields decline from over 80 kg/m² to nearly zero, with red abalone showing a recovery before virtually disappearing from the record. Meat yields of small platform mussels reach a maximum of 70–80 kg/m² before collapsing, and sea urchins make a small but relatively consistent contribution. Meat yields for fish bone climb steadily as shellfish yields decline, then drop by roughly 75 percent.

A final cycle may be represented between about 3350 and 350 cal B.P. (80–10 cm), where mean California mussel size declines from 2.6 to 1.7 before increasing slightly. California mussel meat yields decline by almost 80 percent then rebound, other shellfish make only minimal contributions, and fish fluctuate while generally increasing through time. In the Late Holocene levels, our dietary reconstruction suggests that marine fish are important meat-weight contributors relative to shellfish. Two separate peaks are also evident in the density of Olivella shell—both higher than earlier levels.

Each of these three cycles of rebound and decline are of similar magnitude, but each rebound episode returns to a slightly lower mean mussel size than the previous peak. Size classes 1 and 2 (0–3 cm) are steadily represented throughout the column and the rebound/decline trends primarily represent shifts between proportions of small (0–2 cm) and medium (2–5 cm) mussel size classes (Table 4). The overall trans-Holocene decline is accentuated by the near absence of California mussels larger than 5 cm after ca. 4115 cal B.P. (100–110 cm level). Larger standard deviations earlier in the sequence also reflect the greater frequency of larger mussels.

Figure 3B shows changes in the abundance of high- and low-ranked shellfish taxa through time. Among the shellfish remains, California mussels are the largest meat-weight contributor in most lev-
Figure 3. Trans-Holocene changes in CA-SRI-147 midden composition. A. Mean Mytilus californianus size class (solid line), ±1σ (dashed lines). Vertical lines define three cycles of rebound and decline discussed in the text. B. Reconstructed meat weight for 7 shellfish groups and marine fish. C. Olivella shell weight, indicating intensity of bead production (note different scale than for meat weight constructions). Curves were fit to a uniform time scale by interpolating between midpoints of 1σ range on 5 ^14C dates (top).
Table 4. California Mussel Size Class Frequency by Level at CA-SRI-147.

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<th>Size Class</th>
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<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>Total</th>
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</thead>
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<td>Level</td>
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<td>(2-3 cm)</td>
<td>(3-4 cm)</td>
<td>(4-5 cm)</td>
<td>(5-6 cm)</td>
<td>(6-7 cm)</td>
<td>(7-8 cm)</td>
<td>(8-9 cm)</td>
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<td>-</td>
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<td>142</td>
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<td>200-210 cm</td>
<td>42</td>
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<td>210-220 cm</td>
<td>13</td>
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<td>220-230 cm</td>
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<td>30</td>
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<td>240-250 cm</td>
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<td>44</td>
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<td>47</td>
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<td>71</td>
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<td>270-280 cm</td>
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<td>93</td>
<td>41</td>
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<td>18</td>
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<td>5</td>
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<td>280-290 cm</td>
<td>29</td>
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<td>27</td>
<td>31</td>
<td>16</td>
<td>3</td>
<td>6</td>
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<td>34</td>
<td>18</td>
<td>6</td>
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els through the sequence, but red and black abalones contribute significantly to many levels prior to about 4400 cal B.P. (120–130 cm). Turban snails are also common in many levels prior to about 4500 cal B.P. (130–140 cm), and sea urchins are also regular—if ancillary—shellfish contributors between about 5500 and 3500 cal B.P. (210–90 cm). Small and low-ranked platform mussels are present in small quantities through most of the sequence, except for a pronounced peak between about 5000 and 4400 cal B.P. (170–120 cm) corresponding to a period when other shellfish species are all poorly represented. The dietary contribution of fish also varies significantly through the sequence, but is generally low prior to about 4700 (150–160 cm) cal B.P. except for two pronounced peaks at about 6700 (270–280 cm) and 5100 (170–180 cm) cal B.P. The dietary importance of fish increases again about 4700 cal B.P. (140–150 cm) then stays at intermediate levels through the Late Holocene, a period when shellfish meat yields decline substantially.

Fragmented shells of the purple olive snail (*Olivella biplicata*), a small gastropod commonly used by the Island Chumash to make shell beads, are present in relatively low densities through most of the sequence when compared with other Late Holocene island sites (Kennett 2005:198–209). At CA-SRI-147 the densities of *Olivella* increase after ca. 4700 to 4300 cal B.P. (150–110 cm) and ca. 2200 cal B.P. (50–60 cm), however, then rise steadily from about 800–350 cal B.P. (40–10 cm).

**Discussion**

Several lines of evidence suggest that the occupants of CA-SRI-147 had significant impacts on local intertidal habitats. Consistent with our predictions, these include a general decline in the size and abundance of California mussels during the past 7,300 years, a pattern superimposed on several cycles of recovery and decline that may rep-
resent serial resource depression during multiple episodes of site occupation and abandonment. Another trend in the data is a sharp reduction of high-ranked black and red abalone after about 4500 cal B.P. As predicted, abalones were relatively abundant early in the CA-SRI-147 sequence, then decline as increased human predation limited their size and availability. As these high-ranked shellfish species declined in size and density, people diversified their foraging strategies to incorporate greater numbers of lower-ranked species.

Cyclical patterns of decline and rebound in mean California mussel size class and the decline of red and black abalone use can be further explained in relation to other important prey species. If human predation was responsible for these changes, we would expect foragers to switch to lower-ranked resources, and increases in sea urchin, turban snail, and fish are evident near the end of the first mussel decline. A dramatic increase in small platform mussels follows this, a spike comparable in dietary importance to earlier red abalone peaks (i.e., on the scale of 80 kg/m²), showing that people harvested this low-ranked mussel species as a major meat source.

The third cycle of rebound and decline in California mussel shell size is unique in several ways and suggests a range of alternative behavioral responses to predation pressure on intertidal habitats. Declines in the highest-ranked shellfish taxa are accompanied by a reduction in the overall abundance of shellfish, an increased diversification of low-ranked shellfish (platform mussel, turban snail, and sea urchin), the persistent use of fish, and an increase in broken *Olivella biplicata* (purple olive snail) shells. *Olivella*-shell bead production is one of several trade-related activities linked to increased cross-channel exchange networks after 1300 cal B.P. (see Arnold 1987, 1991, 1992, 2001, 2004; Arnold and Munns 1994; Kennett 2005), and increases in *Olivella* bead-making detritus have been interpreted in other Channel Island sites as a type of economic diversification (Kennett 2005). A system of chiefly exchange of plant foods across the channel from the mainland—for island fish, beads, otter pelts, and other craft items—is documented in ethnohistoric accounts (King 1990). Our CA-SRI-147 data suggest that intensified *Olivella* bead production began around 2200 cal B.P., possible evidence that islanders were engaged in smaller scale trade networks to replace depleted local resources earlier than previously documented.

Our dietary reconstructions suggest that shellfishing and fishing were inversely related at CA-SRI-147. Generally, when the mean size, density, and meat yields of high-ranked shellfish are low, fish remains are more abundant. This pattern is evident not only when abalone is nearly absent after about 4500 cal B.P., but also early in the sequence after 7315 cal B.P. for a brief period when abalone is absent or minimal. While shellfish were the dominant dietary contributor through the sequence, inhabitants of CA-SRI-147 seem to have switched to fishing to replace depleted shellfish resources. Middle Holocene fishing at CA-SRI-147 may not compare to the intensive fishing of the Late Holocene, but it may be a local precursor to later regional patterns of demographic expansion, increased territorial circumscription, and resource intensification identified elsewhere in southern California (Kennett 2005; Kennett and Kennett 2000; Rick 2004).

To explore the relationship between resource depression and diversification we used the Shannon-Weaver diversity function and a shellfish index that compares the abundance of the highest- and lowest-ranked taxa. According to the diversity function there were two major periods of shellfish taxa diversification during the occupational sequence at the site—one increase before the hiatus (80–90 cm, ca. 3400–3300 cal B.P.) and one after the hiatus until the end of the sequence (Figure 4). The shellfish rank index also shows increased reliance on lower-ranked resources starting at the base of the sequence until the hiatus between 3400 and 3300 cal B.P., with a sharp decline in the importance of California mussel and abalone after ca. 5000 cal B.P. During the Late Holocene there is an increased reliance on fish as a dietary staple, but small California mussels continue to provide a high proportion of shellfish meat yields as other edible shellfish taxa are nearly absent (Figure 3).

Before we can confidently attribute these changes to human impacts and resource depression, we must explore other potential explanations. To evaluate the potential influence of climatically driven environmental change on assemblage composition, we compared our CA-SRI-147 data to high-resolution SST and marine productivity
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Figure 4. Subsistence diversification through the Holocene. Changes in shellfish diversity and overall rank, described by the Shannon-Weaver Diversity Function (H') and a prey rank index (Reitz and Wing 1999; Butler 2000), are compared to fish meat weight and Olivella shell, which reflect increased labor investment to broaden the subsistence base.

curves developed by Kennett and Kennett (2000; also see Kennett 2005; Kennett et al. 2007). Figure 5 shows the relationship between SST, marine productivity, and changes in the abundance and size of the highest-ranked shellfish taxa. Over the entire record mussel size shows a significant but weak inverse correlation with SST at the p < .05 level (Pearson's r = -.368; p = .049), but not with productivity (r = -.021; p = .275). Aside from this, there is no significant correlation between SST or productivity and any measure except for weak correlations with urchin meat weight (vs. SST: r = -.420; p = .023; vs. productivity: r = -.399; p = .032).

Examining shorter-term patterns, mean mussel size peaks between 6300-5800 cal B.P. when SSTs are cool and regional marine productivity is high. This is followed by the first decline (250-260 cm to 170-180 cm) in mean California mussel size that parallels a SST warming trend that co-occurs with a dramatic shift toward low productivity at 5800 cal B.P. We cannot rule out changing marine conditions as a contributing factor to mussel size changes through this interval. The subsequent rebound, however, occurs during an interval when SSTs continue to increase and productivity is low, an unexpected pattern if climate change was the driving force impacting nearshore habitats. A similar pattern is evident in the second period of mussel size decline after 4000 cal B.P., which occurs during a shift to cooler, more productive, marine conditions. The following rebound centered on 2500 cal B.P. occurs during a period of cool, but variable, SST and slightly declining productivity. The final decline generally corresponds with decreasing productivity, but cooler SST. Although changing environmental conditions may have played a role in some of these changes, we believe human predation was the dominant force shaping the size
and availability of California mussels through time.

The role of climatically induced environmental change can also be evaluated by comparing the relative abundances of red (cooler water species) and black (warmer water species) abalone with the SST and marine productivity proxies from Santa Barbara Basin site ODP 893 A/B. Peaks in red abalone do not appear to correlate with cooler SST episodes (Pearson’s \( r = .034; p = .863 \)), nor does black abalone abundance correlate with warmer SST (Pearson’s \( r = .003; p = .987 \)). Temperature-related alternations between red and black abalone abundances are not readily apparent. This suggests that the appearance of red abalone middens is not directly tied to millennial-scale changes in SST (see Glassow 1993) and might be better explained by a combination of infrequent ENSO activity through the Middle Holocene (Kennett et al. 2007), changing collection strategies (i.e., shallow subtidal diving or wading: Sharp 2000), and ecological reorganization due to human predation (i.e., sea otter hunting: Erlandson et al. 2005b). The fact that red abalone harvesting increases as California mussel shell size declines also suggests a response to changes in their availability caused by overharvesting of the highest-ranked shellfish taxa.

These data suggest that Middle Holocene “red abalone middens” are more likely the result of resource diversification than climatic change (see discussion above; Glassow 1993). Local foragers may have expanded their diet to include subtidal red abalone only after higher-ranked intertidal shellfish species (California mussel and black abalone) were locally reduced in size and productivity. Red abalone probably required greater energy expenditure and technology (i.e., diving, pry bars, and possibly boats) to capture, but their high meat yield and ease of processing would have made them an attractive resource. Peaks in red abalone between ca. 6750-5450 cal B.P. (280 to 200
cm) when mussel size was declining and black abalone is rare or absent support this conclusion.

Independent of the ecological impacts of overharvesting or environmental change, the composition of archaeological faunal assemblages can also result from changes in site use. At CA-SRI-147, the overall character of the faunal assemblage differs between the Middle and Late Holocene, a change marked by a substantial hiatus in settlement between about 3400 and 3300 cal B.P. Middle Holocene deposits contain larger quantities of shell and the assemblage is dominated by relatively large California mussels and abalones, with reductions in the size and abundance of these high-ranked taxa, and associated dietary expansion occurring between 4500 and 4000 cal B.P., just prior to the hiatus in site occupation. The Late Holocene deposits are characterized by a lower-density shell midden and low, but increasing shellfish diversity that is also suggestive of dietary expansion. Fish bone and small California mussel shells dominate the faunal assemblage and fragmented *Olivella* shells suggest that bead manufacturing increased in frequency through the Late Holocene. These data suggest a shift in how the site was used over time, from a relatively permanent base camp in the Middle Holocene to a more seasonally occupied settlement in the Late Holocene.

This is consistent with an overall reduction in the use of interior locations on the Northern Channel Islands after 3000 cal B.P. as people became more tethered to strategic coastal locations (Kennett 2005:154–180). One of these villages (CA-SRI-130) was established at the mouth of Jolla Vieja Canyon after 1500 cal B.P., where house depressions are visible on the surface and dense midden deposits contain concentrations of fish bone and *Olivella* bead-making debris (Kennett 2005). By this time CA-SRI-147 was no longer the primary settlement in the area and its use may have been more specialized and less frequent.

The interior or peri-coastal location of CA-SRI-147, along with the hypothesized change of site use after 3000 cal B.P., further complicates our interpretations of faunal changes due to the potential for differential processing and transport of mollusks collected prehistorically along the coast (Bird and Bliege Bird 1997). Ethnographic work in several settings indicates that people tend to make economical decisions regarding the transportation and processing of resources (Binford 1978; Bird and Bliege Bird 1997; O’Connell and Hawkes 1988; Yellen 1977). These decisions are sensitive to the size and utility of a resource, the weight or size ratio of edible or high-utility parts to inedible or low-utility components, time required for processing, and transport distance from kill sites or collection locations to centralized communities (Bird 1997; Bird and Bliege Bird 1997; Gremillion 2006; Kennett et al. 2006). Mollusks have inedible shells and the decision to remove them prior to transport depends on overall size, shell to meat ratio, variation in processing time (e.g., gastropods vs. bivalves), the length of time a species will survive (and remain fresh) out of the water, and the distance from collection location to base camp. Larger mollusk species, like the highest-ranked taxa found in the assemblage at CA-SRI-147, generally have heavier shells and are easier to process than smaller species (e.g., *Tegula* sp.). Given the location of CA-SRI-147 (2 km from the modern coast), changes in the abundance of California mussels and the virtual disappearance of abalone from the record could be related to resource depression near the mouth of Jolla Vieja Canyon that resulted in longer travel and transport distances to productive shellfish beds, with processing at more distant locations. This seems unlikely with California mussels, for which experimental work suggests that people should remove shells for transport only at distances between 4.5 and 11 km (Bettinger et al. 1997:896). Our experiments with red abalone found that this larger species should be processed when transport distances approach 2.5 km (15 kg load). This suggests that the decline of red abalone at CA-SRI-147 during the Late Holocene could result from increased transport costs and localized resource depression. Ultimately, such increased travel and transport times may also have contributed to the relocation of the community to the coast (CA-SRI-130).

Finally, the patterns of shifting resource use identified at CA-SRI-147 should be evaluated cautiously given the relatively small sample. Additional high-resolution studies are needed to replicate these trends and to explore spatial variability in the impact of human predation on intertidal habitats. Some confidence, however, can be taken from the excellent preservation of the stratigraphy and faunal remains at CA-SRI-147, the reliance on relatively fine-mesh screens (1/8-inch)
for recovery and analysis, and similarities in the general patterns identified in the sequence with those found in other sites on the Northern Channel Islands and the Santa Barbara Channel region. Concordance with regional records include the dietary importance of shellfish during the Early and Middle Holocene, the relatively large size of mussels earlier in the sequence, the abundance of red abalone shell during the Middle Holocene, a general increase in the density and dietary importance of marine fishing through time, and increasing densities of *Olivella* shell through time.

Conclusions

Analysis of a long occupational sequence at CA-SRI-147 spanning the period from approximately 7300 to 350 cal B.P. allowed us to explore long-term changes in human subsistence and nearshore habitats along the south coast of Santa Rosa Island. We used a prey choice model to rank shellfish taxa and develop predictions against which to compare faunal data. As predicted, the overall abundance of highly ranked California mussel and abalones declined though time. A general decline in California mussel size through the sequence was superimposed on three cycles of rebound and decline. Declines in mean California mussel size co-occurred with increases in the harvest of lower-ranked species, including fish. While shellfish remained an important meat source at CA-SRI-147, periodic increases of fish and lower-ranked shellfish species (turban snail, sea urchin, and platform mussel) suggest that coastal peoples diversified their foraging efforts in response to anthropogenic depletion of high-ranked resources. Finally, despite a likely shift in site use, the Late Holocene is marked by increased reliance on fish and production of *Olivella* beads for trade. Both of these activities are relatively labor intensive and interpreted as forms of dietary expansion consistent with the predictions of the prey choice model.

Climatically driven environmental changes in faunal assemblages from archaeological middens also influenced changes in the shellfish composition at CA-SRI-147. In one instance, declines in California mussel size are partially attributed to increases in SST or decreases in marine productivity, but we argue that the overall size reduction trends in California mussel populations resulted primarily from intensified human predation through the Holocene. The dietary importance of shellfish decreased during the Holocene while the consumption of fish increased. This pattern follows our expectations as human populations grew and increasingly sophisticated technologies were developed to exploit marine vertebrates. Our data also suggest that island populations exploited a variety of intertidal shellfish species through the Holocene and impacted local populations. Depletion of local abalone and California mussel populations may have spurred local residents to use alternative species of shellfish and fish, and to relocate settlements periodically. Subsistence changes at CA-SRI-147, then, are shown to result from a complex mix of climate change, human impacts, and subsequent ecological and economic reorganization.

The current crisis of the oceans, including the accelerating degradation of fisheries and marine ecosystems around the world, has rallied scientists, conservationists, and resource managers to reconsider existing management strategies. It is increasingly apparent that the degraded state of modern marine ecosystems is the result of complex and continuous interactions between humans, other organisms, and their environments spanning millennia. Through the interdisciplinary work of ecologists, biologists, historians, archaeologists, and other scientists, the emerging field of historical ecology strives to better understand the past, present, and future of marine environments. The prey choice model from behavioral ecology is an effective tool for exploring the ecological effects of human predation and environmental fluctuations in the archaeological record, providing the deep historical perspective necessary to develop more effective protocols for present day conservation efforts.

Acknowledgments. Our research was supported by the National Science Foundation (SBR-9521974, Kennett), Channel Islands National Park (1443CA8120-96-003, Kennett), a Mia Tegner Memorial Grant (Erlandsen and Brage) from the Marine Conservation Biology Institute, an NSF Graduate Research Fellowship (Culleton), and the University of Oregon. We are indebted to Don Morris, Kelly Minas, Ann Huston, and Channel Islands National Park for supporting our research, Jacob Barnett for help with Figure 2, Autumn Brown for help in the lab, Frances White for statistical guidance, Josh Fisher for translating our abstract into Spanish, Bruce Winterhalder and anonymous reviewers for their constructive comments, and Michael Jochim, Steve Plog, and the editorial staff of *American Antiquity* for assistance in the revision and production of this paper.
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Received May 22, 2006; Revised December 27, 2006; Accepted February 15, 2007.