

AN OPTIMAL FORAGING ANALYSIS OF PREHISTORIC SHELLFISH COLLECTING ON SAN CLEMENTE ISLAND, CALIFORNIA

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ABSTRACT.—The subsistence yield of black abalones (*Haliotis cracherodii*) and black turban snails (*Tegula funebris*) was estimated within prehistoric aboriginal shell middens dated 250–2830 B.P. on San Clemente Island, California. Abalones were the key element of the aboriginal shellfish economy, but consumption of the smaller turban snails increased with depletion of abalones in a pattern that conforms to an optimal foraging model of predation.

RESUMEN.—El rendimiento de abalón negro (*Haliotis cracherodii*) y caracol de turbante negro (*Tegula funebris*) para la subsistencia de las poblaciones indígenas fue estimado en concheros prehistóricos (250 a 2830 años antes del presente, datados con carbono radioactivo) en la Isla de San Clemente, California. Los abalones fueron el elemento clave en la economía aborigen de mariscos, pero el consumo de los caracoles de turbante, más pequeños, aumentó con el agotamiento de los abalones en un patrón que concuerda con un modelo de depredación como forrajeo óptimo.

RESUME.—Des traces de présence d'haliotides noires (*Haliotis cracherodii*) et d'escargots noirs à turban (*Tegula funebris*) ont été découvertes au sein de vestiges résiduels préhistoriques de coquillages aborigènes (250 à 2830 années radio-carbones avant le temps présent) sur l'île de San Clemente, en California. Les haliotides constituaient l'élément principal de l'économie de coquillages aborigènes, mais la consommation des escargots à turban, bien plus petits, s'est accrue au fur et à mesure de la disparition des haliotides selon une progression conforme à un modèle optimal de ravages causés par des prédateurs.

Marine gastropod species were important subsistence resources among the aboriginal peoples of the southern California Channel Islands. Two species, the black abalone (*Haliotis cracherodii* Leach, 1814) and the black turban snail (*Tegula funebris* A. Adams, 1855), are the focus of the present discussion. Abalone shells are a conspicuous component of prehistoric middens (domestic refuse deposits) on the Channel Islands. Beads, ornaments, fishhooks, containers, and other artifacts were manufactured from abalone shells. Despite this presence, reconstruction of the subsistence role of abalones and other shellfish species remains a relatively poorly developed area of investigation. Reconstructions usually estimate food yields based upon shell weight or MNI (minimum number of individuals) figures. Frequently, such estimates do not reflect the possibility that several species may have been utilized in shifting patterns of exploitation over

the time interval represented by a midden. This situation is surprising when one considers that the role of shellfishing by maritime hunter-gatherers is currently undergoing reexamination in many quarters. Recent archaeological and ethnographic studies have demonstrated the important role that shellfishing may play within a variety of economic adaptations. Consideration of biological characteristics of shellfish species, combined with appropriate analytical methods, reveal dynamic patterns of aboriginal shellfish collecting on San Clemente Island, southern California.¹

ABALONE AND TEGULA BIOLOGY

Abalones are large, herbivorous marine snails that inhabit many regions of the world. They require rock surfaces, where they attach themselves with a large, muscular "foot." Thus attached, they are protected by a thick univalve shell from predators and other hazards while grazing on floating kelp fragments. Species are readily differentiated based upon shell morphology. Water drawn through the gills is expelled through a series of prominent respiratory pores arrayed along the shell, the number and characteristics of which also vary by species (Howorth 1988:38-44). Abalone species occupy much of the Pacific Coast of North America, including California (Morris 1966:52), as well as Australia, New Zealand, and elsewhere.

Four species occur in significant frequencies within archaeological deposits of southern California. The three largest of these species generally occupy the subtidal zone; i.e., rocky substrates that remain submerged even during the lowest tides. Although these species vary in size and specific habitat requirements, they all inhabit substantially similar environments. Among the subtidal forms is the largest species in the world, the red abalone (*Haliotis rufescens*) with a shell length approaching 300 mm and a soft-tissue weight of as much as 3 lbs (1.36 kg; Morris et al. 1980:232; Ault 1985:4). The green (*H. fulgens*) and pink (*H. corrugata*) abalones reach a maximum length of about 250 mm (Ault 1985:4; Morris et al. 1980:234-235). All the subtidal species inhabit a depth gradient from the intertidal zone to at least 165 m for the red abalone, 18 m for the green abalone, and 50 m for the pink abalone. In cooler waters, such as found north of Point Conception in California, red abalone and other species may be found in the intertidal zone. The majority of individuals of subtidal species tend, however, to occur most frequently between about 6 m and 24 m (Cox 1960:386-390; Ault 1985:15-16). A number of factors appear to affect preferred depth, including algal production, habitat that offers protection to juvenile abalones, the presence of predators such as the sea otter, and water temperature (Ault 1985:15-16; Morris et al. 1980:232).

Generally, subtidal species can only be obtained by diving. Where these species exist in comparatively shallow water, diving can produce large harvests. The relatively large size of the subtidal forms may compensate for the effort involved in diving. It has also been suggested that red abalone may have been intertidal during the early and mid-Holocene (i.e., around 5000-7000 B.P.; Glassow et al. 1988:70), when periods of sea temperature cooler than at present may

have existed in the California Bight (southeastward bend of the California coast below Point Conception). A spatulate prying device (aboriginal forms were made of bone or wood) is generally required to break the animal's extremely powerful grip on its rocky perch.

Water temperature has a major impact on the life-cycle of subtidal abalones, with each species exhibiting a particular tolerance range. The red abalone, for example, feeds between 7° and 20°C, but the thermal optimum for the species is between 14° and 18°C (Ault 1985:15). Water temperature requirements are probably more important in relation to paleoenvironmental reconstruction than assessment of dietary yield. Use of abalone species as indicators of past marine environmental regimes is a topic important to archaeological research in southern California, but beyond the scope of this paper (Walker and Snethkamp 1984:7; Glassow 1977:19; Glassow et al. 1988:70; Raab and Yatsko 1990a, 1990b).

During abalone reproduction, eggs and sperm are released into the water, where fertilization occurs. After fertilization, larvae begin grazing within a few days. Initial growth of all species is relatively rapid, reaching about 20–30 mm within the first year (Morris et al. 1980:232–237; Ault 1985:5–6). After reaching the juvenile stage, abalone grow more slowly, adding a few millimeters length each year. Abalone appear to reach sexual maturity within 3–5 years, and it is thought that few individuals live longer than 20 years (Morris et al. 1980:232–237). All abalone species are slow growing organisms with few defenses against human predators. Consequently, their numbers are rapidly reduced under sustained collecting, and considerable time is required for a population to recover.

The black abalone (*Haliotis cracherodii*), the species of interest in the present discussion, is largely an intertidal form. These organisms frequently are exposed during low tides on rocks, where they can exist in large numbers. These abalone may be particularly at risk from human predators because they are easily harvested without diving. Individuals of this species reach a maximum size of about 200 mm, but few individuals exceed 150 mm. Black abalone have temperature requirements similar to red abalone (Ault 1985:15). Black abalone, as in the case of other abalones, requires several years to reach maximum size; about 2 years to reach 55 mm, then growing about 4 mm a year after reaching 90 mm in length (Ricketts et al. 1985:245). During early phases of growth, abalones seek the protection of rock crevices to avoid predators. Individuals become *emergent* upon reaching a length of 75–100 mm; i.e., they venture onto exposed rock surfaces in search of food (Ault 1985:6).

The black turban snail (*Tegula funebris*) is common to abundant on open rocky surfaces of the intertidal habitats that support the black abalone (Morris et al. 1980:253). The smooth, rounded to conical shell may reach a diameter of 30 mm, though many individuals are much smaller. At low tide *T. funebris* is sedentary, and hundreds of individuals often aggregate in rock crevices. Locomotion is achieved with a muscular foot in the same fashion as other marine gastropods. Tegula are herbivores that eat many species of algae, including microscopic films and kelp fragments (Morris et al. 1980:253). They may reach 20–30 years of age, and thus may have a lifespan longer than any other gastropod (Morris et al. 1980:254). Like black abalone, black turban snails are readily exploited by terrestrial predators during low tide.

RETHINKING THE LOWLY SHELLFISH

As compared to terrestrial resources, shellfish often have been characterized as "emergency" or low-yield foods of comparatively minor importance. Osborn (1977) argues, for example, that marine environments are generally less productive per unit area than terrestrial environments. He suggests that human populations tend to relegate marine resources to a lower order of importance if terrestrial resources are available. The open ocean is less productive than many terrestrial ecosystems (Pianka 1974:48), but Yesner (1980) and Erlandson (1988, 1991) point out that this fact is misleading in view of the comparatively high productivity of certain coastal habitats.

Shellfish collecting has long been regarded as unimpressive as a gauge of cultural "advancement." Uhle (1907:31), for example, dismissed the prehistoric inhabitants of the Emoryville shell mounds in California as representative of the "lower classes of society" owing to their dependence on shellfish:

The manner of procuring the essentials of life by collecting shells in itself indicates a low form of human existence. In all parts of the world, even today, people may be seen by the shore at low water collecting for food the shells uncovered by the retreating tide; and although under changed conditions of life they raise shellmounds, these people always belong to the lower classes of society, and lead in this manner a primitive as well as simple life.

Meehan (1982), in her excellent ethnographic study of shellfishing in Australia, points out the many misconceptions and biases that have worked against an informed understanding of shellfish economies. Fortunately, the significance of shellfish in maritime adaptations recently has received more objective attention. Sanger (1988:91), for instance, notes the important role of shellfish in settlement patterning and subsistence in the northeastern United States:

Shellfishing, obviously an important aspect of the Gulf of Maine maritime adaptation, required only the use of hands to pluck mussels from rocks, or "pick" clams through their siphon holes... Briefly, shellfish, although frequently belittled in the literature as gross contributors to the overall caloric component of shell midden sites, may have constituted the primary motivation for site selection and abandonment. They constituted a reliable, if not spectacular, food source, and it would have been possible to over-exploit resources in the kinds of intertidal flats commonly found associated with habitation sites. A pattern of brief occupation, followed by movement to another site, may help to explain the presence of nearly 2,000 known shell midden sites on the coast of Maine that have survived erosion due to a submerging shoreline.

Erlandson (1988:107), in evaluating the role of shellfish in the prehistoric maritime economy of southern California, makes a similar point:

... I have tried to counter previous assertions that shellfish exploitation is universally inefficient subsistence strategy by demonstrating that, under

a variety of conditions, shellfish can serve as an efficient and sustained protein yield. This hypothesis has been supported with experimental data on protein yields for shellfish collecting, an archaeological example from coastal California, and a reexamination of two previous models of shellfish exploitation.

Recent evidence suggests that coastal populations of early Holocene (7000–10,000 B.P.) southern California subsisted on a diet in which calories were supplied to a large extent by hard seeds, and substantial protein was provided by shellfish (Erlandson 1991).

Relying on both ethnographic and archaeological data, Davidson (1984) demonstrates the important role played by shellfishing in the aboriginal settlement-subsistence systems around Palliser Bay, New Zealand. Virtually in a class by itself, the study by Meehan (1982) of aboriginal shellfishing in Australia provides detailed data on the ecology, social organization, nutritional yield, and integration with larger economic systems of shellfish economics.

The result of these investigations is increasing recognition of the distinctive and important roles of shellfishing. This recognition should prompt archaeologists to go beyond the cursory treatment of shellfish remains that have been characteristic of many research efforts of the past:

... the economics of shellfish exploitation should be evaluated in relation to the productivity and reliability of other resource alternatives, including factors such as the nutritional role played by various resources, the technological investment in resource acquisition, non-food payoffs, the availability of various foods to different age and gender groups within a society, seasonal limitations on the availability of different resources, and differential storability (Erlandson 1989:15).

SAN CLEMENTE ISLAND

San Clemente Island, 58 sq mi (148 sq km) in extent, is the southern-most of the eight Channel Islands found off the southern California coast (Fig. 1), and lies 48 mi from the nearest landfall on the mainland. In historical times the island was occupied by the island Gabrielino Indians (Johnson 1988; Bean and Smith 1978). Although the island's culture history is poorly understood at present, recent archaeological studies indicate a human occupation of nearly 10,000 years (Salls 1988:353–362). The island contains evidence of some of the oldest maritime cultural adaptations on the Pacific coast of North America (Raab and Yatsko 1990a, 1990b).

During the Miocene, the island was thrust above the ocean by block faulting. This process, combined with rising and lowering ocean levels during the Pleistocene, has formed at least 18 wave-cut terraces on the island's west shore (Olmsted 1958). Active terrace-cutting produces a broad, rocky shelf of the type that characterizes most of the island's west shore today. Rocky intertidal, shallow reef, and kelped habitats support a rich marine ecosystem characteristic of rocky substrates. A number of gastropod species, including abalones, inhabit this zone.

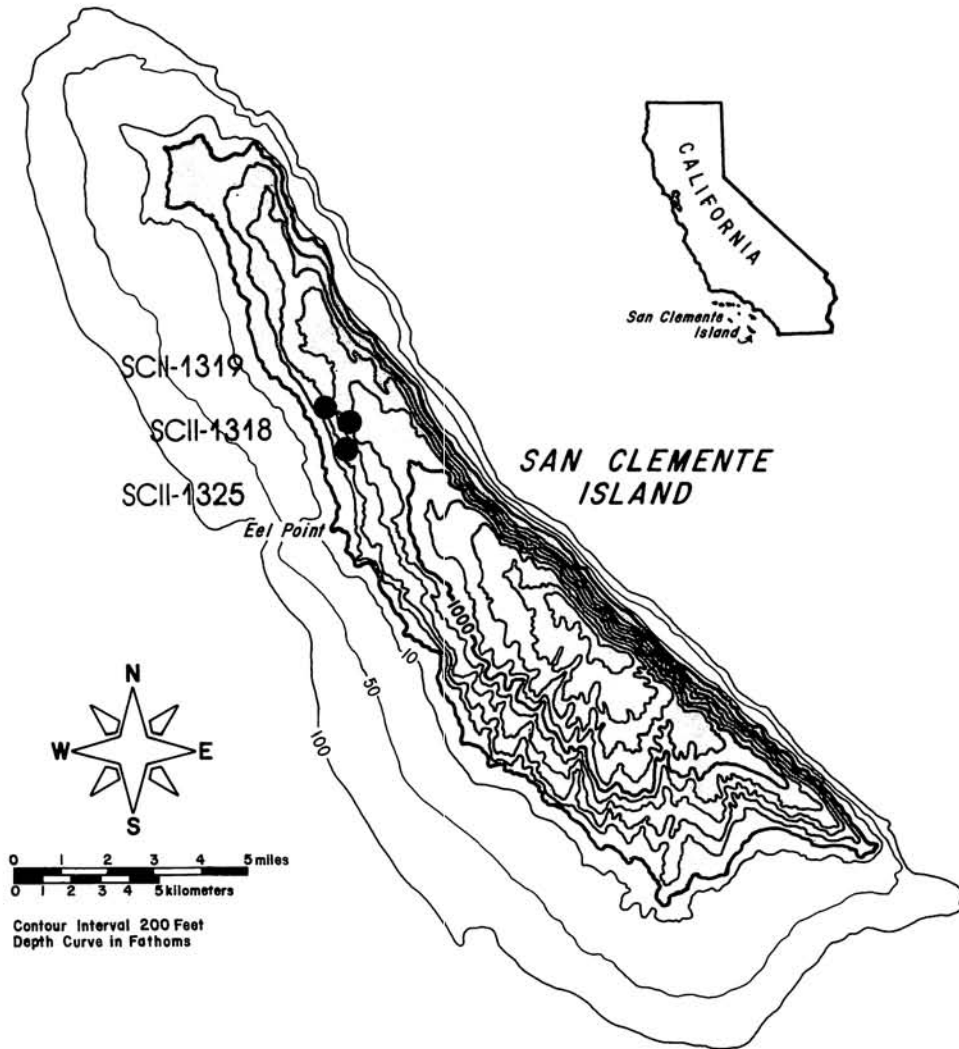


FIG. 1.—San Clemente Island, California. Archaeological sites SCII-1318, SCII-1319, SCII-1325, and the Eel Point site (SCII-43) are indicated.

Significantly, marine terraces have the greatest number of archaeological sites per sq km of any physiographic zone on the island; frequently 200–300 per sq km (Yatsko 1987a, 1987b). Most sites are relatively small, discrete shell midden sites, some of which have apparent house floor depressions. The site in Fig. 2 is characteristic of the small, shallow shell middens found on the coastal terraces of San Clemente Island. The Eel Point site complex (SCII-43), covering many acres and producing the oldest dated cultural component on the island (9700 B.P.; Salls 1988:353–369), is found within this zone.

Three coastal midden sites, SCII-1318, SCII-1319, and SCII-1325, were partially excavated. These sites are located on a high marine terrace, approximately 300 m above sea level, on the central west side of the island (Fig. 1). Sites SCII-1318

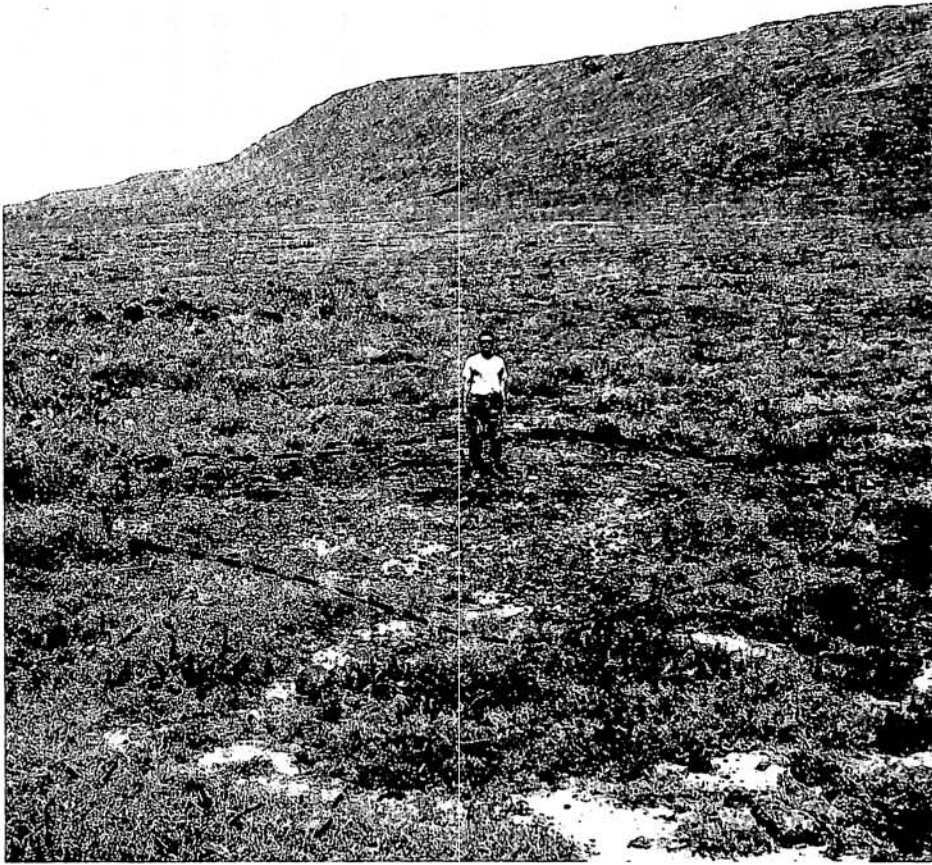


FIG. 2.—Midden sites on the west shore of San Clemente Island are characteristically small, spatially discrete shell middens. The broken line indicates limits of midden (site SA-61; photo by Andrew Yatsko).

and SCII-1319 were selected for excavation because they appeared typical of hundreds of others in the area, and were comparatively easy to reach from an existing road. Both sites are black, ashy midden deposits containing abundant marine shell and burned rock deposits. All three sites were systematically tested with a soil auger, 10 cm in diameter, in order to estimate their subsurface character and extent. Based on the auger data, excavation units were placed to obtain samples of midden from the deepest to the shallowest portions of the deposits at a site.

Site SCII-1318 is approximately 24 m (north-south) by 16 m (east-west), with a total volume of approximately 41 m³. Four 1 m by 1 m excavation units were placed within this site; one near the periphery, two in the deepest midden deposits, and one between the periphery and the two deep pits. All excavation units were dug to a depth of 30 cm below surface, for a total of 1.20 m³ of excavated midden matrix.

Site SCII-1319 proved to be nearly circular in outline, 21 m in diameter, with a volume of approximately 76 m³. Four 1 m by 1 m excavation units were excavated within the site; two near the center and deepest portion of the deposits, one at the periphery, and one between the center and periphery. Three excavation units were dug to a depth of 40 cm, and one unit reached a depth of 30 cm before encountering culturally sterile sediments, for a total of 1.5 m³ of excavated midden matrix.

Site SCII-1325 was selected to salvage information from a midden damaged by past military activities. A military "foxhole" had been dug into the center of the midden, exposing a 60-cm-deep midden stratum. The depth of this site is unusual for coastal midden sites in this area. We examined this stratum in the area of the site damaged by the foxhole. A portion of the wall of the foxhole was cleaned and a vertical profile established. A 1 m by 1 m unit was excavated into the midden deposit from the cleaned profile. This site was approximately 30 m in diameter, with the excavation unit located near the center of the site. The site contains about 212 m³ of midden. The excavation unit was dug to a depth of 60 cm, yielding a total volume of 0.6 m³ of excavated midden matrix. Despite efforts to clear away midden deposits disturbed by the excavation of the foxhole, variability in compaction of the midden matrix and other factors suggest a reversed stratigraphic sequence.

Two of these sites have been radiocarbon dated. However, these dates present difficulties that cannot be resolved within the scope of this paper. Paired samples of charcoal and shell were taken from each excavation level of the two sites ("arbitrary" 10-cm levels). Unfortunately, the dates of charcoal and shell samples from the same midden proveniences vary greatly; far beyond differences one might expect to result from the ¹⁴C "reservoir effect" (Stuiver et al. 1986). In radiocarbon years before present these dates are:

Site SCII-1318:

	Charcoal Dates	Shell Dates
0-10 cm	250 +/-50 (Beta-39148)	1560 +/-60 (Beta-39143)
10-20 cm	350 +/-50 (Beta-39146)	1777 +/-50 (Beta-39145)

Site SCII-1319:

	Charcoal Dates	Shell Dates
10-20 cm	240 +/-50 (Beta-39148)	2160 +/-50 (Beta-39147)
20-30 cm	300 +/-70 (Beta-39150)	2830 +/-50 (Beta-34149)

No time-diagnostic artifacts were found in the middens. Studies are in progress by the author to identify possible sources of errors in radiocarbon dating on San Clemente Island, but at present one can only safely conclude that the sites are of late Holocene age.

As noted above, excavation units were dug in 10-cm levels to culturally sterile sediments. All excavated midden was passed through 1/8" (5 mm) mesh screen. Material collected in the screen was sent to the lab where *all* recovered midden constituents were identified and weighed. The resulting data were entered into a computer data base. The sheer volume of shell and other materials to be

identified and recorded imposed a substantial analytical burden. Nearly 480 person-hours were required to analyze and record the 3.3 m³ of midden matrix recovered by our excavations.

Analysis identified a broad spectrum of subsistence remains. For purposes of analysis, however, emphasis was placed upon five classes of faunal remains which are useful indicators of a number of ecological and subsistence variables: abalone (*Haliotis*) shell, *Tegula* shell, sea urchin tests (hard body parts) and spines, sea mammal bone, and fish bone (Table 1). Most of the abalone shell from the middens was fragmentary. All specimens are black abalone (*H. cracherodii*), common to the island's rocky west shore. *Tegula funebris*, the small black turban snail inhabiting the intertidal zone of the west shore (Hedgpeth and Hinton

TABLE 1.—Tabulation by weight (gm) of midden constituents, by stratigraphic levels, for sites SCII-1318, SCII-1319, and SCII-1325.

	<i>Haliotis</i>	<i>Tegula</i>	Sea Urchin	Mammal Bone	Fish Bone	<i>Tegula/Haliotis</i> Ratio
SCII-1318:						
0-10 cm	151.29	1,409.70	0.07	1.04	4.0	9.3:1
10-20 cm	415.67	2,656.8	0.05	5.53	5.86	6.4:1
20-30 cm	411.83	1,579.04	0.13	12.77	3.13	3.8:1
Totals:	978.89	5,654.61	0.25	19.34	12.99	
Site Percentage: ¹	8.10	65.83	0.0029	0.23	0.15	
SCII-1319:						
0-10 cm	136.00	2,859.44	6.55	6.31	6.27	20.9:1
10-20 cm	1,457.92	17,333.07	17.12	15.87	19.28	11.9:1
20-30 cm	5,051.38	26,837.13	83.42	90.49	95.84	5.3:1
30-40 cm	7,036.14	12,882.62	79.25	207.44	69.35	1.8:1
Totals:	13,682.04	59,912.26	186.35	320.11	190.74	1.8:1
Site Percentage: ¹	16.63	72.82	0.23	0.39	0.23	
SCII-1325:						
0-10 cm	157.55	1,864.11	1.92	6.65	22.93	11.8:1
10-20 cm	689.65	6,533.00	6.09	10.28	62.01	9.5:1
20-30 cm	965.94	6,675.00	3.10	75.10	37.96	6.9:1
30-40 cm	590.79	5,085.00	11.35	17.87	17.07	8.6:1
40-50 cm	572.64	2,885.00	10.87	34.35	7.83	5.0:1
50-60 cm	68.04	289.58	0.83	00.00	0.85	4.3:1
Totals:	3,044.61	23,331.69	34.16	144.25	148.65	
Site Percentage: ¹	8.78	67.31	0.10	0.42	0.43	

¹Percentages do not sum to 100% because these figures are not based on the total weight of all dietary elements and other midden constituents.

