A Nutritional Study of Seven Molluscan Species Recovered from CA-LAN-2630, Long Beach, California

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Abstract

This work estimates the protein and caloric contributions for each of seven molluscan species (four clam species, an oyster, a scallop, and a slipper limpet) recovered from Unit X-7 at CA-LAN-2630. The sum of 2,357 kcals and 395 g of protein indicates a substantial harvest and consumption of shellfish by the site's inhabitants. The total wet weight per m^3 of meat extrapolated from Unit X-7 (3,036 g/m^3) is comparable to estimates from San Clemente Island midden sites, yet exceeds that noted at CA-LAN-705. Although abundant, the slipper limpet (*Crepidula onyx*) represents a minor component of the estimated energy pool, contributing merely 5.3 percent of the total kilocalories and about 4.3 percent of the total protein in this collection; its percent protein content per individual (8.4 percent) is comparable to the oyster (9.6 percent), making it a reasonable choice as a food item. The present study provides a baseline assessment for this gastropod as a species harvested for human consumption; the inclusion of *Crepidula onyx* in nutritional analyses of shell middens in coastal southern California may prove beneficial.

Introduction

Archaeological site CA-LAN-2630 was discovered in May, 1993, during construction of Parking Lot 1 on the California State University, Long Beach (CSULB) campus (Figures 1 and 2). The CSULB Parking Structure site covers an area estimated at 15,700 m^2, and roughly 121.29 m^3 of midden was excavated from 49 test excavation units during the 1993 field season. Some of the site was destroyed by construction activities; however, a significant portion of the deposit remains intact. In all likelihood the CSULB Parking Structure Site represents either a temporary encampment where small groups of people gathered for perhaps not more than a few hours to process and consume food or a habitation camp where groups of related families lived for a period of days, weeks, or even months. LAN-2630 was utilized between AD 1150 and 1700 (Boxt and Dillon 2012). Prehistoric middens provide valuable data about the variety of molluscan species harvested as well as the nutritional and energetic values of meat consumed (e.g., Erlandson 1988:105-107; Jones 1991:434-436; Raab 1992:78).

The most common approach for gauging molluscan contribution to human diets has involved weighing a subsample of shells and then estimating energy/nutritional values using calculations usually based on tissue weight predicted from shell weight for extant, similar species. This technique has been expedient due to sampling time considerations and costs of doing nutritional analyses on specific species. However, there are problems associated with this method because some molluscan species have thicker, heavier shells than other species (e.g., Pismo clams vs. mussels), so that an analysis based on shell weight could falsely attribute greater significance to Pismo clams even though they are an order of magnitude less abundant than mussels (Mason et al. 1998:311-321). In our study we estimate by size class the numbers of molluscan individuals recovered from Unit X-7 (Figure 3). Size estimates of whole and fragmentary shell derive from the equations in Table 1. Then, with

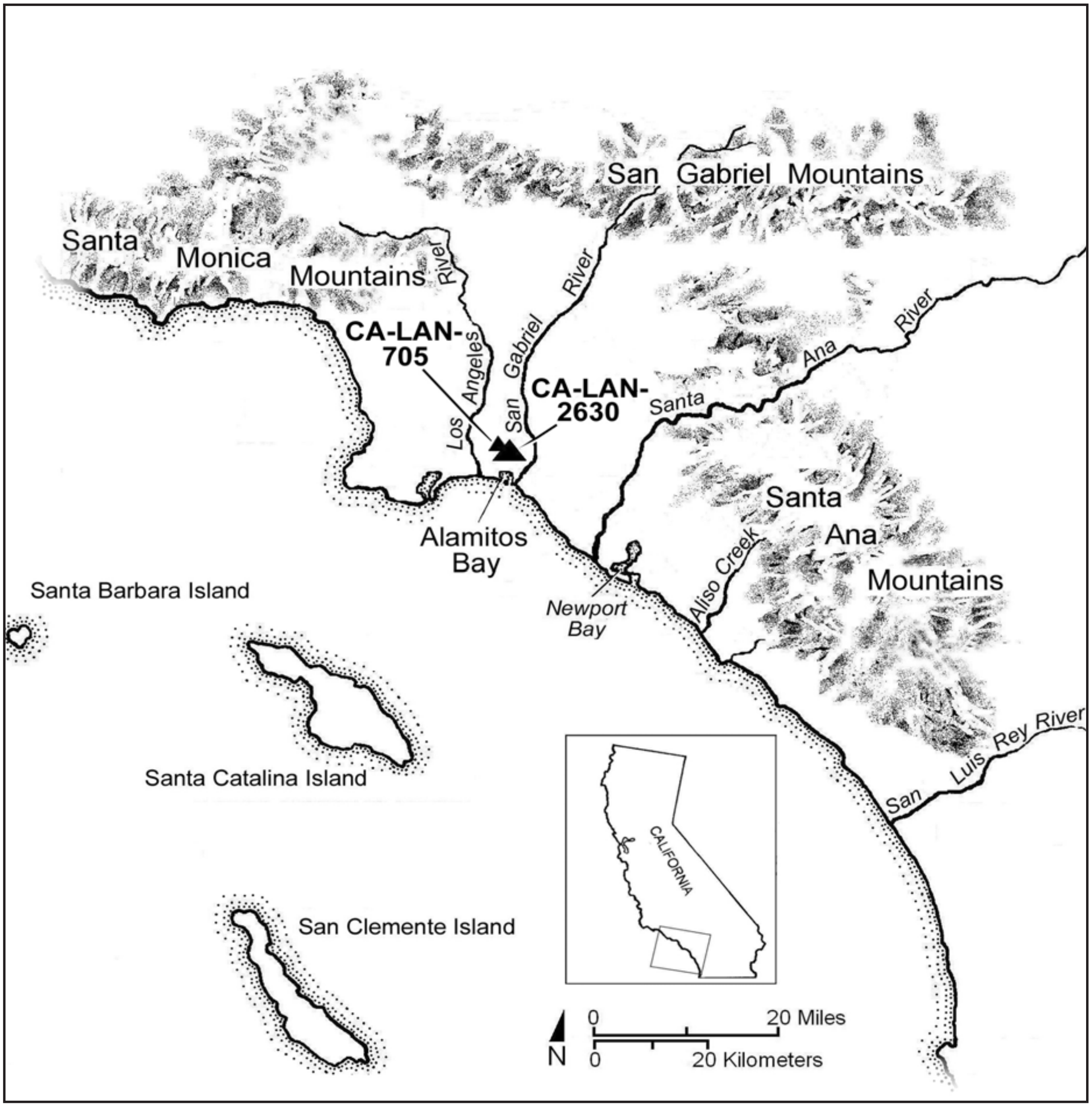

Figure 1. Location of CA-LAN-2630 and CA-LAN-705. Map by Rusty van Rossmann.

information on the amount of edible tissue versus individual size from living populations of these or related species, we estimate the amount of energy and protein that the excavated shells represent. Since large numbers of the slipper limpet (*Crepidula onyx*) occur in these excavations, we considered its potential benefit as a dietary constituent.[1]

Methods

Unit X-7, measuring 2-x-2 m, was chosen for this calorie and protein availability analysis because it produced abundant ecofactual shell[2] (Figure 4). Each 10-cm stratigraphic level was wet-screened using 1/8-in mesh. Our emphasis was on the recovery of all in

Figure 2. The study region, 1938. Image courtesy of the Fairchild Aerial Photography Collection, Whittier College.

Figure 3. Excavation of Unit X-7 at CA-LAN-2630, facing northeast. Shell concentrations just to the east and west of north arrow. Photo,1993.

Table 1. Molluscs Collected from Unit X-7 at CA-LAN-2630 and Regression Equations Used To Calculate the Whole Shell Size from Fragments.

Species	Regression Equations
Ostraea lurida (native oyster)	valve height = 3.09+3.46*hinge plate length (equation is for the lower valve only)
Aequipecten aequisulcatus (speckled scallop)	valve length = 0.293+13.22*resilium valve height = 1.226*valve length$^{0.938}$ (equations are for either valve)
Chione californiensis (banded cockle)	length = 1.54+4.5*hinge maximum (left valve) length = 1.27+4.9*hinge maximum (right valve)
Chione undatella (wavy cockle)	length = 1.16+5.9*hinge maximum (left valve) length = 0.93+6.3*hinge maximum (right valve)
Chione fluctifraga (smooth cockle)	length = 0.79+8.1*hinge maximum (left valve) length = 0.80+8.0*hinge maximum (right valve)
Protothaca staminea (littleneck clam)	length = 0.26+10.6*hinge maximum (left valve) length = 0.04+10.7*hinge maximum (right valve)
Crepidula onyx (slipper limpet)	shell length = 1.966*shelf length$^{0.789}$

Note: Measurement methods described in Miller and Boxt (2011:82-83). All measurements are in cm, and * indicates "multiply." [3]

Figure 4. Archaeological examples of the slipper limpet, *Crepidula onyx*. Photo by Ronald W. Jones.

situ cultural materials, including bone, stone, and shell (Figure 5). The regression equations used to estimate sizes of specimens were derived from measurements of the hinge and whole shell of individual oysters, scallops, and clams (Miller and Boxt 2011: 83). The regression equation to estimate slipper limpet shell length is based on the length of the shelf on its underside, which was measured from the distal end to the proximal attachment point of the shelf on the outer lip (Figure 6). Only the lower valves of the oyster were used to estimate individual numbers and sizes. For the clams and scallops, right and left valves were paired by size (±1 mm) when possible to give an estimate of the number of whole clams in the collection. Only the common, large molluscan species likely to have been harvested by humans were assessed (Table 1).

Since many individual slipper limpet shells were relatively large, we concluded that, in all likelihood, their meat was consumed by the site's inhabitants. We assume that the meat from smaller individuals was eaten and would not have been discarded, lost, or wasted. Energy (kcal) and the proportions of protein in the molluscan tissues were estimated based on previous studies (Dame 1972:1124; Sidwell 1981:128-133; Sandra E. Shumway, personal communication 1994) or, in the case of the slipper limpet, analysis of indivduals collected along the rocks at low tide from Alamitos Bay, Long Beach (Figures 2 and 7). The nutritional content of the slipper limpets was obtained from each of two samples analyzed; both samples contained meat from several individual limpets, satisfying the minimum tissue weight required for analysis (Associated Laboratories 1994).

Results

The results of the estimated counts and individual sizes of the molluscs from Unit X-7 appear in Figures 8-11.

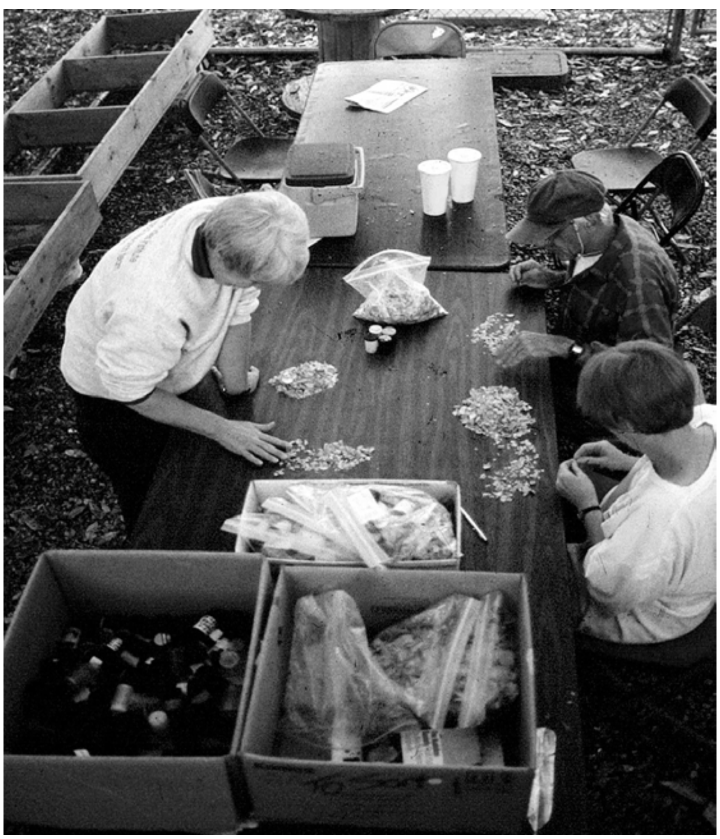

Figure 5. Alice Hale (left), Paul Porcasi, and Judith P. Clark sorting ecofactual shell from CA-LAN-2630, 1993.

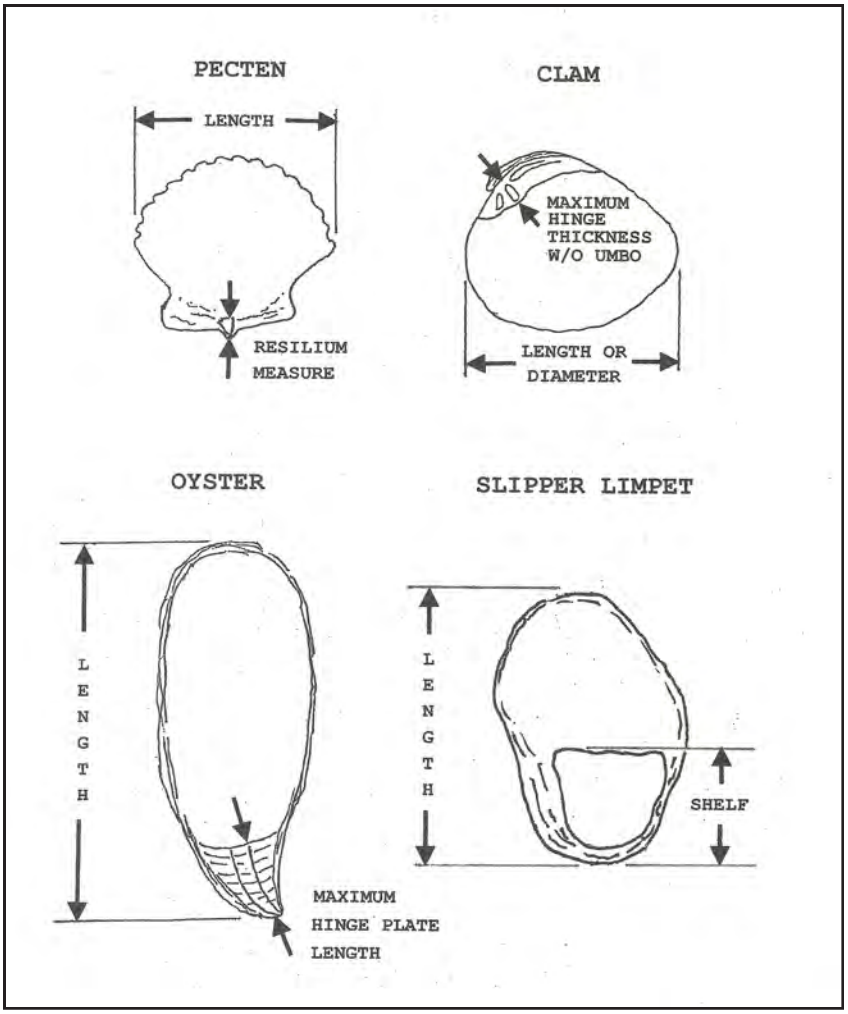

Figure 6. Internal views of scallop, clam, oyster, and slipper limpet shells showing the dimensions measured.

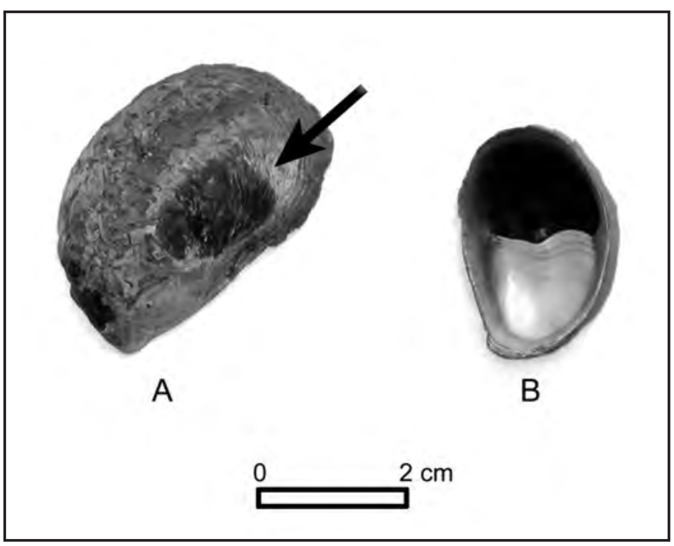

Figure 7. Modern slipper limpet shells collected along the rocks at low tide from Alamitos Bay, Long Beach, just north of the Second Street Bridge at the southern terminus of the Marine Stadium. Specimen at left exhibits a 2.6-cm scar outline, indicating where another individual attached itself to the outer shell surface.

Based on size distribution for each species, tissue dry weights were calculated using the regression equations in Table 2; these data derive from living clam and slipper limpet specimens and from published studies on similar species in the cases of the oyster and scallop. Table 3 presents nutritional values and wet to dry weight conversion factors used to calculate the nutritional estimates for the molluscs summarized in Table 4. Of the bivalves that comprise this sample, scallops (*Aequipecten aequisulcatus*) provide the highest quantity of nutrition (1,488 kcal/m^3 and 278 g/m^3 of protein), followed by oysters (*Ostraea lurida*) with 527 kcal/m^3 and 62 g/m^3 protein, and the clam species (all *Chione* spp. and *Protothaca staminea*) at 218 kcal/m^3 and 38 g/m^3 protein (Table 4). The 1,040 specimens of *Crepidula onyx* that comprise this study contributed 124 kcal/m^3 and 17 g/m^3 of protein to the total for all molluscs: 2,357 kcal/m^3 and 395 g/m^3 protein (Table 4). Although plentiful in our collection, the slipper limpets represent 5.3 percent of the total molluscan kilocalories and 4.3 percent of the total protein. Table 5 presents the results of the tissue

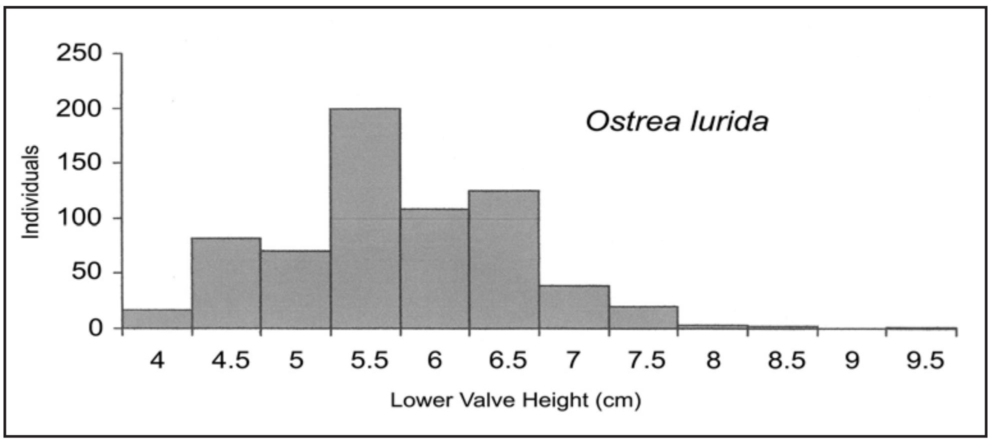

Figure 8. Size distributions for the oyster, *Ostrea lurida,* Unit X-7, CA-LAN-2630.

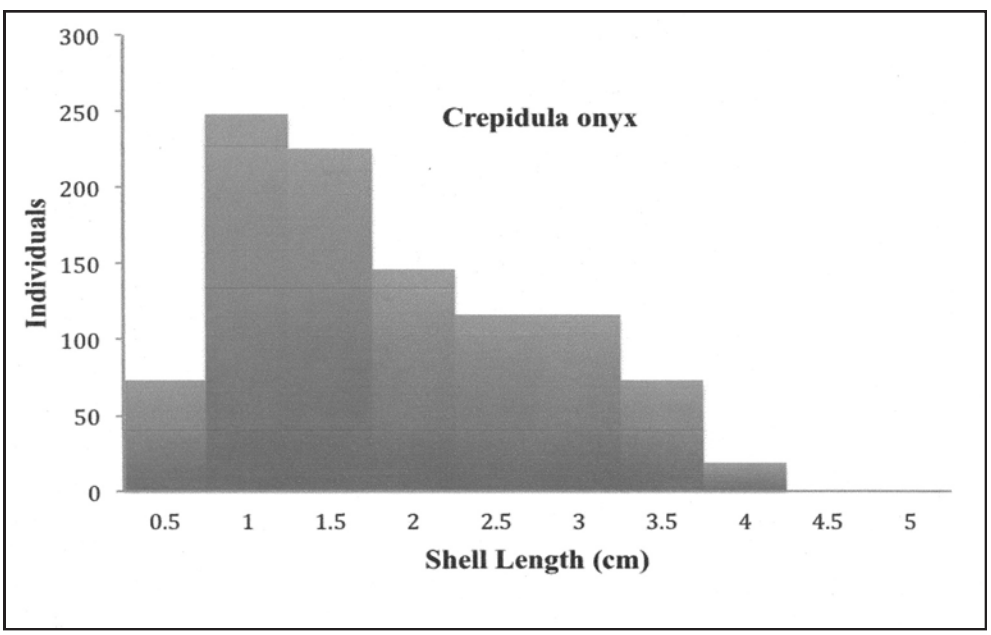

Figure 9. Size distributions for the slipper limpet, *Crepidula onyx*, Unit X-7, CA-LAN-2630.

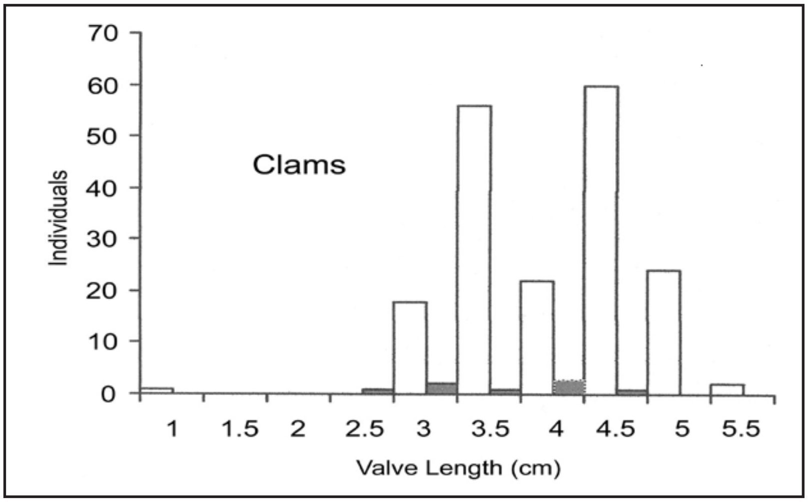

Figure 10. Size distributions for the clams, *Chione spp*. (open bars), and *Protothaca staminea* (solid bars), Unit X-7, CA-LAN-2630.

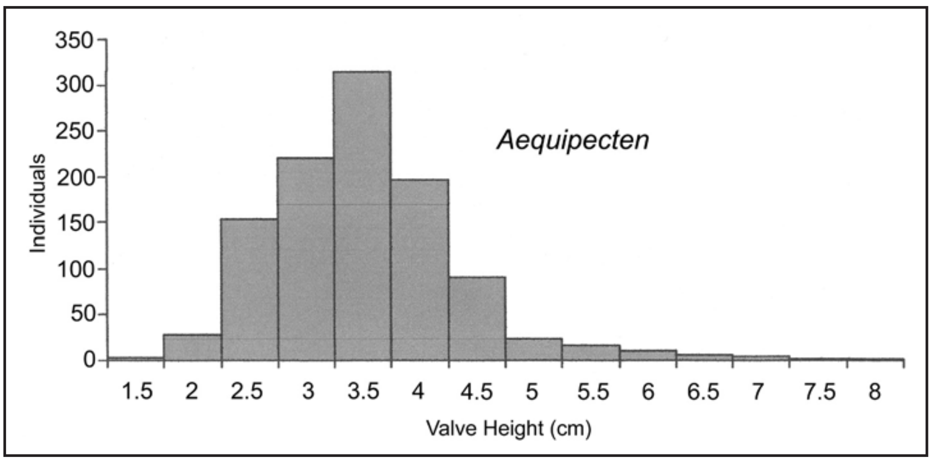

Figure 11. Size distributions for the scallop, *Aequipecten aequisulcatus,* Unit X-7, CA-LAN-2630.

Table 2. Equations Used To Estimate the Dry Tissue Weight of Individual Bivalves and Slipper Limpets.

Species	Equations To Estimate Dry Tissue Weight
Crassostrea ostrea (eastern U.S. oyster)	issue dry weight(g) = 0.0129*shell height(cm)$^{1.794}$ (Dame 1972:1124 used for *Ostrea lurida*)
Placopecten magellanicus (eastern U.S. scallop)	tissue dry wt.(g) = 0.00001*shell height(mm)$^{3.0}$ (used for *Aequipecten aequisulcatus*; note: mm, not cm)
Chione undatella (wavy cockle)	tissue dry weight(g) = 0.0085*shell length(cm)$^{2.8}$ (this study, used for the three species of *Chione*)
Protothaca staminea (littleneck clam)	tissue dry weight(g) = 0.0082*shell length(cm)$^{3.2}$ (this study)
Crepidula onyx (slipper limpet)	tissue dry weight(g) = 0.0067*shell length(cm)$^{2.64}$ (this study)

Note: * means “multiply.” All dry weights refer to tissue dried in an oven at 80^{o} C for at least 24 hours to a constant weight.

Table 3. Kilocalories, Percent Protein, and Wet to Dry Weight Conversion Values Used To Estimate the Kilocalories and Protein Results in Table 4.

Species	Dry Weight Conversion Values	Comments
oyster (*Ostrea lurida)*	82 kcal/100 g (wet weight) 9.6% protein (wet weight)	Source: Sidwell (1981:131); according to Dame (1972:1124), wet tissue of the oyster contains 83.5% water
scallop (unidentified)	78 kcal/100 g (wet weight) 14.6% protein (wet weight)	Source: Sidwell (1981:133); values are for muscle tissue only; wet tissue of the scallop, *Placopecten magellanicus*, contains 82.5% water (Sandra E. Shumway, personal communication 1994)
clam (*Protothaca staminea)*	77 kcal/100 g (wet weight) 13.5% protein (wet weight)	Source: Sidwell (1981:128); according to Sidwell (1981:128), wet clam tissue contains roughly 79.4% water
slipper shell (*Crepidula onyx)*	358 kcal/100 g (dry weight) 49.4% protein (dry weight)	Source: Associated Laboratories (1994); slipper limpet wet weights average about 83% water (s.d.=1.8%, n=12 [this study]); the dry weight values converted to wet weights are: 61 kcal/100 g (wet weight) and 8.4% protein (wet weight)

Note: All values are for whole tissues, unless noted.

Table 4. Calculations of Kilocalories and Grams of Protein per Molluscan Species from Unit X-7, CA-LAN-2630.

Total Tissue Weight (g/m^3)					
Species	**Dry**	**Percent Water**	**Wet**	**Kcals**	**Protein**
Ostrea lurida	106	83.5%	642	527	62
Aequipecten	334	82.5%	1,908	1,488	278
clams (all species)	58	79.4%	284	218	38
Crepidula	34	83%	202	124	17
Totals	533 g/m^3	–	3,036 g/m^3	2,357 kcal/m^3	395 g/m^3

Note: Conversion values appear in Table 2. Where wet weights are used in the literature, the dry weights from this study were converted to wet weights using correction factors in Table 2.

analyses done on two composite samples of meat from the slipper limpet. The values for these specimens (both on a wet and dry weight basis) are compared in Table 5 to nutritional analyses done on other gastropods and two bivalves. The protein content (in percent) of the slipper limpets (8.4 percent of wet tissue weight) is the smallest among these gastropods, but it is very similar to the oyster (9.6 percent of wet tissue weight), which is one of the two more common species of bivalves consumed by the site's occupants.

It should be noted that the size class distributions for the bivalves in this study lack small-sized individuals, which suggests that size preference was a factor in selecting shellfish for harvest. The volume of material excavated from Unit X-7 gave an estimated 6,075 g of consumable tissue (wet weight) for all edible species. This standardizes to 3,036 g/m^3 for the excavation unit, which is within the estimated range of the wet weight of black abalone (*Haliotis cracherodii*) and black turban snail (*Tegula funebralis*) tissue reported by Raab (1992:75) from San Clemente Island midden sites (Table 6). Based on these values, it appears that a substantial harvest of shellfish, including the slipper limpet, occurred at the CSULB Parking Structure Site, representing a reasonable amount of energy and protein to support groups of people for brief periods of time.

The data for Unit X-7 were also compared to archaeological site CA-LAN-705 (Table 7), lying 0.3 km to the northwest (Figures 1 and 2). Radiocarbon results demonstrated a temporal overlap for both sites (Boxt and Dillon 2012); thus, we calculated the weight of shell material from comparable stratigraphic levels. These shell weights were then converted to wet meat weights and wet protein weights using the same conversion factors used by Horner and Hudson (1995:17-20). The data in Table 7 show that Unit X-7 represents a much larger harvesting effort than found in any of the 12 units at LAN-705.

Discussion and Conclusions

This study addresses the role of shellfish in the ancient diet of LAN-2630. We have attempted to offer more refined estimates of the nutritional value of ecofactual shell than studies that merely consider the weights of shellfish, extrapolating tissue weights and nutritional values from such information. The development of size class frequencies for the different species provides greater precision because the tissue/nutritional

Table 5. Nutritional Data for *Crepidula Onyx* and Other Select Molluscs.

Species		H_2o (%)	Protein (%)	Fat (%)	Carbohydrate (%)	Ash (%)
Crepidula onyx (slipper limpet) (Associated Laboratories 1994)	wet	83.0	8.4	0.6	5.0	3.1
	dry	–	49.4±.71	3.3±.15	29.2±.85	18.1±.56
Acmaea spp. (limpets) (Gilliland 1985:61-62)	wet	75.7	17.3	1.9	4.2	0.9
	dry	–	71.2	7.8	17.3	3.7
Haliotis wallalensis (abalone) (Gilliland 1985:61-62)	wet	75.0	18.9	0.9	2.6	2.6
	dry	–	75.6	3.6	10.4	10.4
Homalopoma carpenteri (small turban snail) (Gilliland 1985:61-62)	wet	74.1	20.3	1.0	2.4	0.5
	dry	–	83.9	4.1	9.9	2.1
Ostrea lurida (California oyster) (Sidwell 1981:131)	wet	81.0	9.6	2.5	5.4	1.5
	dry	–	50.5	13.2	28.4	7.9
Protothaca staminea (littleneck clam) (Sidwell 1981:128)	wet	79.4	13.5	1.0	3.5	2.6
	dry	–	65.5	4.8	17.0	12.6

Note: The data are averages (± 1 std. dev.) for two composite samples of meat from several individual *Crepidula* and are presented in terms of wet and dry weights. The same type of nutritional content of other gastropods and bivalves are presented for comparative purposes.

Table 6. Comparison of Black Abalone and Black Turban Snail Tissue from San Clemente Island Sites (Raab 1992:75) and CA-LAN-2630, Unit X-7.

Site	Wet Weight per m^3	Age Range of the Material
San Clemente Island	2,222 g	Late Holocene
	22,469 g	
	15,645 g	
CA-LAN-2630 (Unit X-7)	3,036 g	AD 1440–1560

Table 7. Summarized Data for Wet Meat and Protein Weights for Oysters, Scallops, and Clams (*Chione* spp. and *Protothaca*) from CA-LAN-705 and CA-LAN-2630.

Site		Meat (g/m^3)	Protein (g/m^3)	Age
CA-LAN-705	average	392	56	AD 1200-1550
	standard deviation	±619	±89	
	range	11.2 - 1,751	1.4 - 261	
CA-LAN-2630 (Unit X-7)	total	2,834	378	AD 1440-1560

contribution of different sized molluscs is taken into account. As well, this study has examined the nutritional contribution of the slipper limpet, which is commonly found in southern California middens that are close to coastal wetlands, inlets, estuaries, bays and river mouths. Based on the tissue analyses (Table 5) and the fact that numerous small- to large-sized slipper limpets comprised the Unit X-7 shellfish assemblage, we suggest that ancient human populations considered this species to be a viable food source (the senior author's consumption of *Crepidula* was not a distasteful experience). However, due to its relatively small size and the availability of other edible molluscan species, *Crepidula* remained a minor dietary constituent, contributing about 5.3 percent of the total kilocalories and about 4.3 percent of the total protein in the LAN-2630 collection.

Most of the *Crepidula* would have been acquired when the oysters and scallops were harvested since this snail lives attached to submerged shells and rocks on the surface of the muddy substratum of bays. Thus, there would have been minimal additional effort to obtain limpets when they were attached to harvested oysters and scallops. In addition, collectors may have pried larger slipper limpets off the surface of intertidal and subtidal rocks. The numerous small *Crepidula* found in the collections resulted from the fact that larval slipper limpets initially develop in the water and then normally settle out of the plankton onto to the shell of a larger individual slipper limpet, often creating a pile of limpets attached to each other with the largest individual attached to a rock or bivalve shell. Some may settle onto other hard substrata or move off of another limpet onto a hard substratum. According to Perry (2004: 94), in some areas, coastal foragers of nearly any age or skill level could quickly gather a basket full of turban snails, enough to provision a household for one or several meals. We maintain that the same foraging behavior could apply to ancient inhabitants of LAN-2630. Either way, the abundance of *Crepidula* shells in the Parking Structure Site midden suggests that human populations made the most of their local resources, consuming every available edible invertebrate species.

End Notes

1. *Crepidula* is commonly reported at coastal southern California archaeological sites that range in age from the Millingstone Horizon (6500 BC to 1500 BC) to the Protohistoric (AD 1540 to 1769) (e.g., CA-LAN-138 [Autry Museum 2012]; CA-SBA-60 [Greenwood 1961]; 4-ORA-190 [Ross 1970]; CA-ORA-189 [Williams 1971]; CA-LAN-270 [Bates 1972]; CA-LAN-283 [Frey 1974]; CA-LAN-702 [Cottrell 1978]; CA-VEN-1 [Dallas 2000]). To the best of our knowledge, however, this is the first study to assess nutritional values for the slipper limpet among mainland Native populations.

2. Excavations at LAN-2630 produced 1.23 metric tons of ecofactual shell. Molluscan remains were recovered from every excavation unit. Weight per unit ranged from 1 to 60 kg. Unit X-7 produced roughly 50,000 kg of shell; the greatest concentration of shell was encountered between 20 cm and 70 cm below surface.

3. In Miller and Boxt (2011:96), the asterisk (*) in Table B was erroneously listed as "raise to the power" instead of "multiply."

Acknowledgments

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