

Ecological Considerations of Archaeological Shell Materials from CA-LAN-2630

Alan C. Miller and Matthew A. Bost

Abstract

Archaeological investigations at CA-LAN-2630 produced large quantities of shell material from clams, oysters, scallops, and, to a lesser extent, gastropods. Based on size analyses of the excavated clams and comparisons to sizes of clams found in random samples of existing clam beds, it is apparent that the majority of the specimens were collected for human consumption, since the smaller size classes are missing. The size ranges of the recovered oysters and scallops also represent primarily the middle and large size classes. Since these species of molluscs are associated with bays and estuaries, their discovery at CA-LAN-2630 suggests they were procured locally and their shells discarded by Native Americans after tissue consumption.

Introduction and Site Location

Archaeological site CA-LAN-2630 was discovered during construction for a new parking facility on the California State University, Long Beach (CSULB), campus. From May 7 to July 8, 1993, salvage excavations focused on two areas (Locus 2 and Locus 4) within the site (Figure 1). After gridding and site mapping were accomplished, 49 analytical test units of varied dimensions (2 m x 2 m, 1 m x 2 m, and 1 m x 1 m) were excavated, and roughly 121 m³ of midden were recovered, employing metrical stratigraphy. Excavation was carried out in 10 cm levels, and all sediments were wet screened through 5 mm (1/8 in) mesh. Artifactual and ecofactual remains were separated from the residual shell debris, which was then sorted by species or type of mollusc. Overall, 273 shell beads, hundreds of lithic flakes and tools, 642 Tizon brown ceramic sherds, 44,416 vertebrate faunal specimens, dozens of shell and bone artifacts,

and 2.8 metric tons of ecofactual shell were unearthed. Radiocarbon age determinations indicate that LAN-2630 was utilized between A.D. 1200 and 1700. One of the primary objectives was to ascertain whether the deposits of marine shell at this location were formed by cultural or natural processes.

LAN-2630 is located on the Downey Plain at the base of the Signal Hill Uplift and only a few kilometers from the Alamitos Gap. During its prehistoric occupation, LAN-2630 was situated along the banks of an incised channel of Bouton Creek. A topographic map prepared by the United States Geological Survey in 1893 and published in 1899 depicts a dendritic system of small streams in the area draining the interfluvial region between the Los Angeles and San Gabriel rivers (Figure 2). Alamitos Bay is less than 2 km south of LAN-2630. Today, Bouton Creek is channelized, bisecting the CSULB campus. Vestiges of the silted-in channel and estuaries can be seen on aerial photographs from the 1920s and 1940s (Figure 3 and Figure 4).

Since archaeological site LAN-2630 was adjacent to embayments and estuaries, the excavated molluscs could have died naturally and their shells concentrated by natural physical forces. As in any study of archaeological sites adjacent to the ocean environment where shell debris from marine molluscs is abundant, a central question is whether the shells at the site were deposited by natural physical forces (such as wave action) or by human activities, especially as the result of food gathering and processing. A collection of mollusc

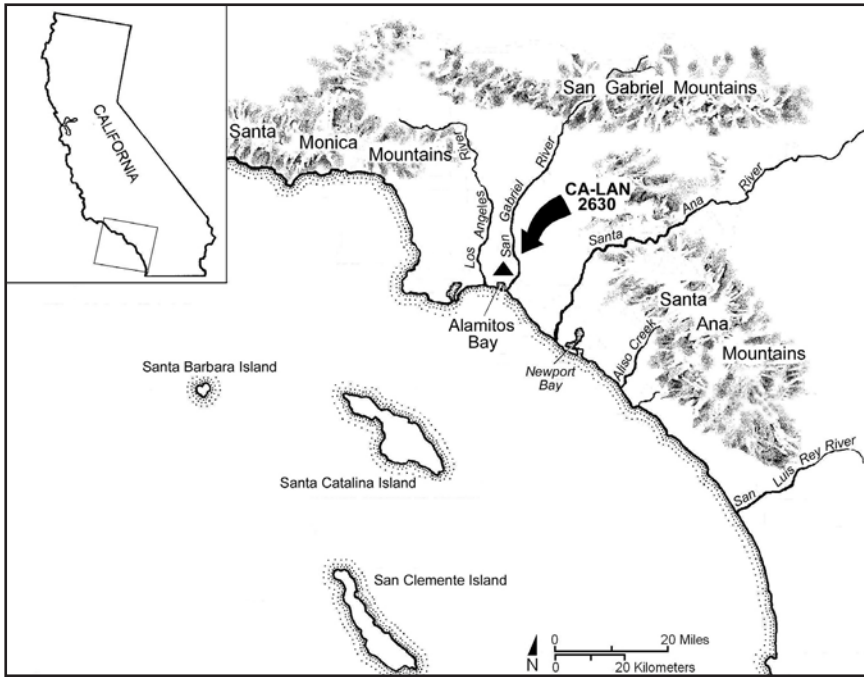


Figure 1. Location of CA-LAN-2630. Map by Rusty van Rossmann.

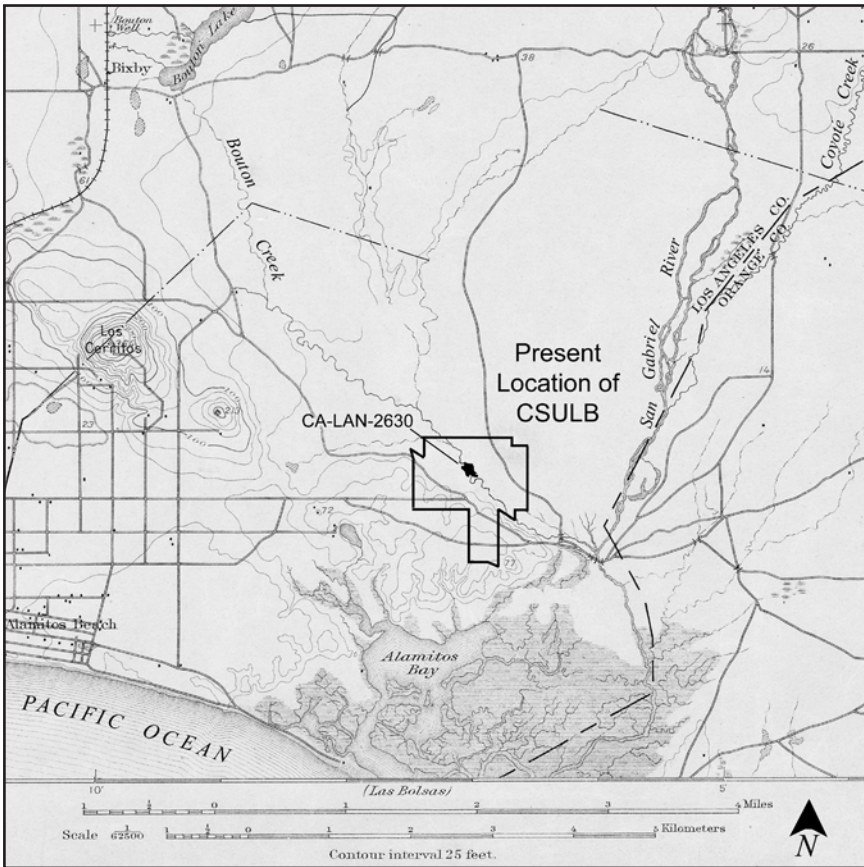


Figure 2. Portion of 1899 U.S. Geological Survey California Downey Sheet. CSULB campus indicated along with CA-LAN-2630.

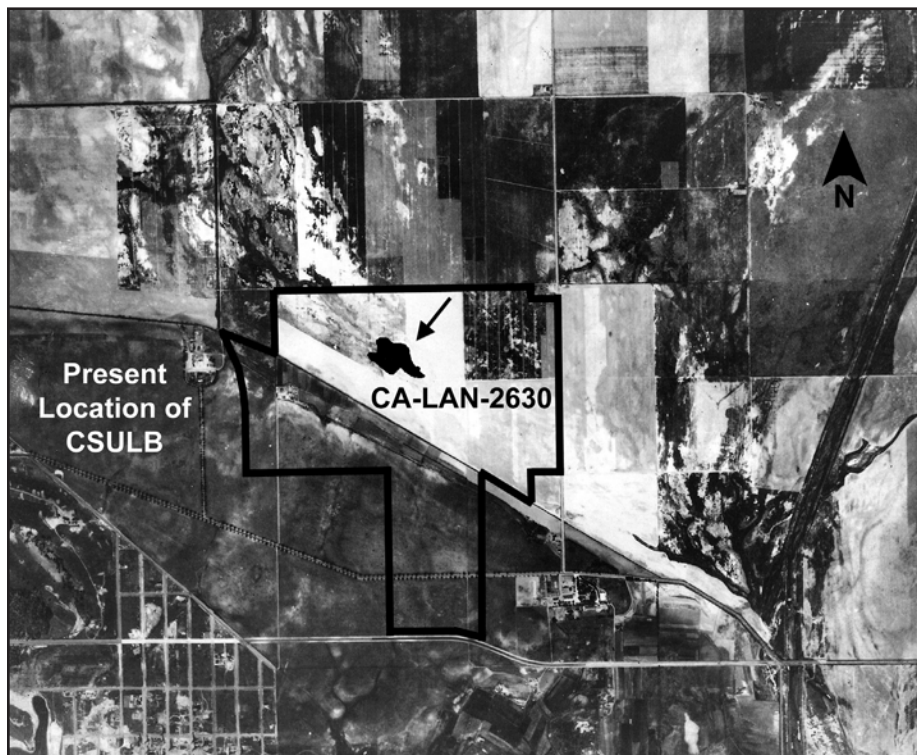


Figure 3. The study region, 1928. Image courtesy of the Fairchild Aerial Photograph Collection, Whittier College.

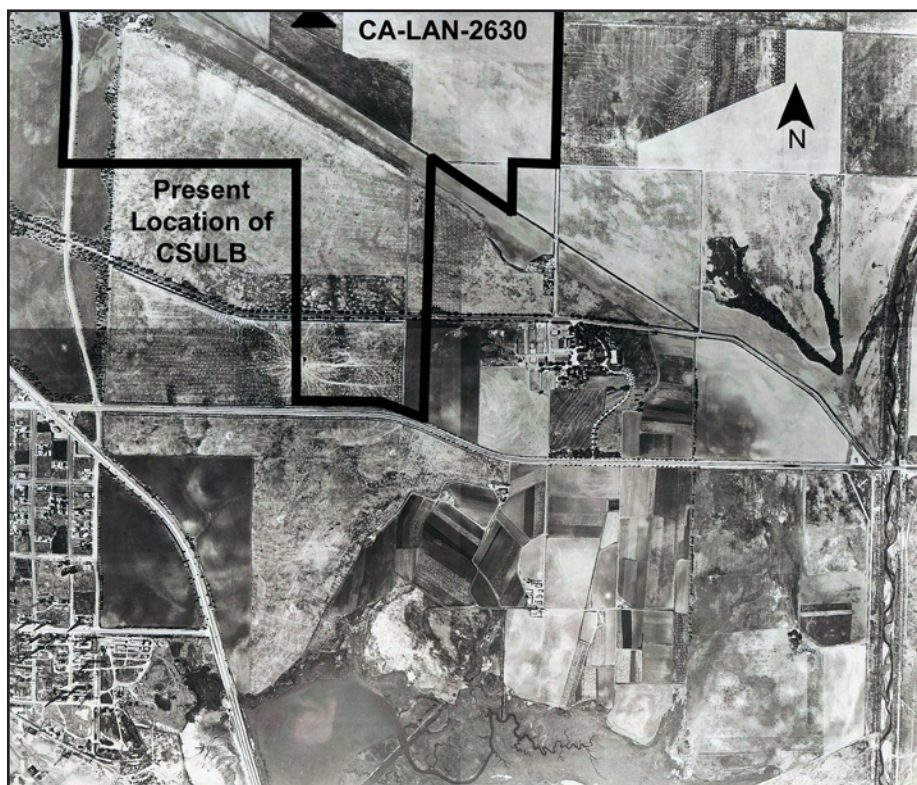


Figure 4. The study region, 1941. Indigenous peoples harvested molluscs and gastropods from Alamos Bay and local estuaries. This photograph reveals what appears to be a remnant estuary about 1 km southeast of CA-LAN-2630. Image courtesy of the Fairchild Aerial Photograph Collection, Whittier College.

shells that comprise a midden would be expected to consist of a restricted size class range since, based on optimal foraging theory, larger sized shells should predominate in human food remains. This study examines whether the deposition of recovered shells was the result of natural forces or human activity. In addition, the study elucidates the ecological context of the shell remains.

Methods

The large volume of shell recovered from LAN-2630 necessitated that a subsample be examined; a 15 percent sample was deemed sufficient. A stratified, systematic sample with a random start was employed. We identified two areas for sampling: Region 1, which produced the densest concentration of excavated shell, and Region 2, where fewer shells were recovered. Because the dimensions of test excavation pits varied across the site, our objective was to sample units of similar size within each region. Since the excavation units were numbered, the starting point for the systematic sample was selected via a random number generator (Table 1).

Sizes of the individual clams, pectens, and oysters were measured using whole shells (valves) or were estimated for the broken bivalves using regression analysis of hinge measurements (the greatest vertical measure across the hinge face) versus valve length (= diameter) or height (Figure 5). Since a whole clam might contribute two valves to the collection,

the number of individual bivalves in a collection was estimated by combining left valve lengths that matched in size to right valve lengths (± 1 mm) as one clam. Sampling of extant habitats for size distributions of bivalves was done using quadrats placed randomly on the muddy substratum exposed at low tides or, in the case of sampling the shell deposits above the drift line, located randomly parallel to the water's edge at the drift line and extending landward 0.5 m (Appendix 1).

Results: The Molluscan Species and Their Habitat

The molluscan shells at LAN-2630 represent species that were characteristic of a lagoon or bay and the adjacent terrestrial habitat (Appendix 2). Table 2 shows the number of individual species in each excavation unit. The most obvious clue to the general habitat type of the area is the large number of oysters, pectens, and clams in the midden. The oysters are commonly associated with quiet bays and lagoons. If *Ostrea lurida*, the native oyster on the West Coast, is influenced in its growth form by environmental forces in the same ways as the native East Coast oyster, *Crassostrea virginica*, the average shell height to length ratio of 1.7 (± 0.36 S.D.; n=27 whole lower valves randomly selected from Locus 4, Unit 7, at 70-80 cm depth [Figure 6]) suggests a mixed mud and sand habitat where the individuals are growing singly or in loose clusters (bed oysters) (Gunter 1938:547; Kent 1992:25). Only 44 of 122 (36%) lower valves or major lower valve fragments from these same randomly selected bags

Table 1. Excavation Units Selected for Analysis.

CA-LAN-2630: Region 1				CA-LAN-2630: Region 2			
2 m x 2 m		1 m x 2 m		2 m x 2 m		1 m x 2 m	
Locus	Unit	Locus	Unit	Locus	Unit	Locus	Unit
2	X-7	2	TT.5-5	2	A-28.73	2	B-6
–	–	2	X-4	–	–	2	F-3
–	–	4	7	–	–	4	1

showed evidence that these oysters were attached to other oysters, further supporting the bed oyster life-style, as opposed to reef or channel growth patterns where most individuals are crowded together and attached to each other.

The only pecten encountered in the excavated collection, *Agropecten aequisulcatus* (also called *Aequipecten circularis* and *Plagioctenium circularis*), occurs subtidally and is found on mixed sand and mud bottoms of bays and lagoons (McLean 1978:69). This pecten and the oyster were the more numerous bivalves recovered (Table 2). Less common, but still numerous, were four clam species: three species of

Chione and *Protothaca staminea*. These clams live in the intertidal and shallow subtidal portions of protected bays in mixed sand and mud, sometimes associated with gravel or cobblestones (McLean 1978:78).

Although not common, the bean clam, *Donax gouldii*, was found in five excavation units. It is associated with a more sandy substratum and one that receives a little wave action, but not necessarily a wave-exposed, open coast environment (McLean 1978:86). While significant quantities of bean clam have been reported at Late Holocene sites in northern San Diego County (Laylander and Iverson 2006:43),

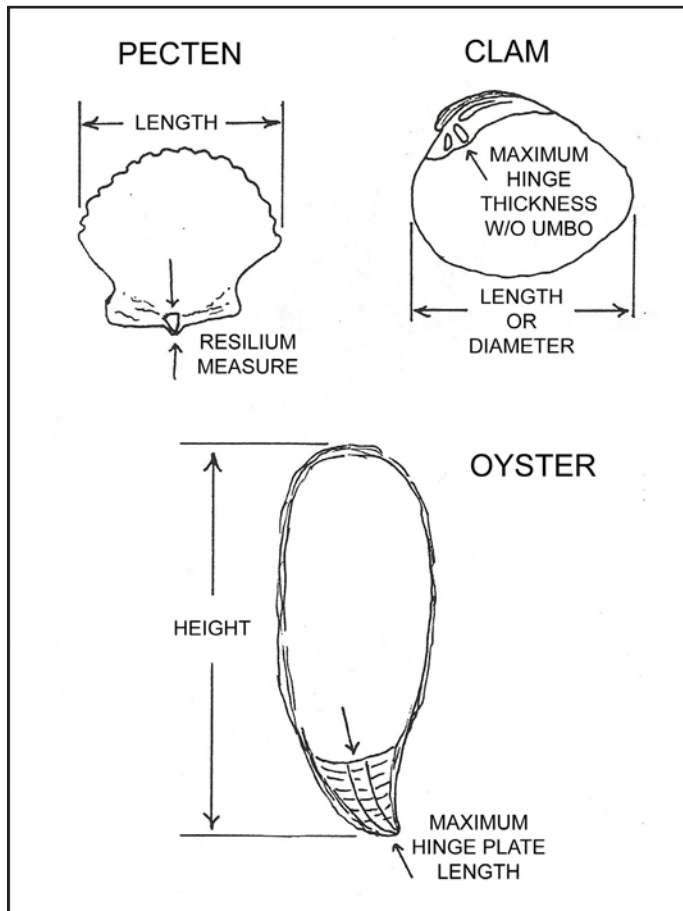


Figure 5. Internal views of scallop, clam, and oyster shells showing the dimensions recorded.

Table 2. Frequency of Shell Species by Unit.

Molluscan Remains	Locus-Unit								Total
	4-7	4-1	2- A28.73	2-B6	2-F3	2-X4	2-X7	2-TT.5-5	
Gastropod Species									
<i>Lucapinella callomarg.</i>	–	–	–	–	1	–	1	–	2
<i>Tegula eiseni</i>	1	–	–	–	–	1	–	–	2
<i>Lacuna unifasciata</i>	–	–	–	–	–	–	1	–	1
<i>Littorina scutulata</i>	–	–	–	–	1	–	–	–	1
<i>Cerithidea californica</i>	27	6	4	4	7	14	15	23	100
<i>Crepidula onyx</i>	4836	736	1125	672	662	708	1486	640	10865
<i>Crucibulum spinosum</i>	1001	150	171	85	19	78	210	48	1762
<i>Polinices reclusianus</i>	4	2	1	–	3	2	5	1	18
<i>Pteropurpura festiva</i>	–	–	–	–	–	–	1	–	1
<i>Ocenebra sp.</i>	2	–	1	–	–	–	–	1	4
<i>Acanthina spirata</i>	–	–	2	–	–	–	1	–	3
<i>Alia carinata</i>	7	2	–	1	1	5	1	–	17
<i>Nassarius tegula</i>	1	–	–	–	–	–	2	–	3
<i>Olivella baetica</i>	1	–	–	–	–	–	–	–	1
<i>Conus californicus</i>	2	1	–	–	1	–	1	–	5
<i>Melampus olivaceus</i>	–	1	–	1	1	–	–	1	4
<i>Planorbidae</i> (Pond Snail)*	–	–	8	9	–	–	–	–	17
<i>Physidae</i> (Pond Snail)*	–	–	6	3	–	1	5	1	16
<i>Lymnaeidae</i> (Pond Snail)*	3	3	7	1	2	–	1	–	17
<i>Patula</i> (Land Snail)	–	–	–	4	1	3	5	1	14
Bivalve Species									
<i>Ostrea lurida</i>	2801	772	437	579	629	589	943	611	7361
<i>Argopecten aequisul.</i>	1935	289	260	448	378	836	1592	1369	7107
<i>Laevicardium elatum</i>	–	–	–	–	–	1	1	–	2
<i>Laevicardium substri.</i>	1	–	–	–	–	1	1	1	4
<i>Tivela stultorum</i>	–	–	1	1	2	1	–	–	5
<i>Saxidomus nuttalli</i>	2	–	–	–	–	1	1	3	7
<i>Chione californiensis</i>	130	26	11	25	26	43	107	70	438
<i>Chione undatella</i>	257	248	16	54	51	76	140	91	933
<i>Chione fluctifraga</i>	66	19	9	25	11	68	97	102	398
<i>Protothaca staminea</i>	49	16	3	12	29	3	16	20	146
<i>Donax californicus</i>	1	–	–	–	1	–	–	–	2
<i>Donax gouldii</i>	15	–	–	1	1	4	–	1	22
<i>Chaceia ovoidea</i>	1	–	–	–	–	–	–	–	1
Unidentified Chiton plates	4	1	–	–	–	1	–	1	7

* Snails associated with freshwater habitats, such as Bouton Creek.

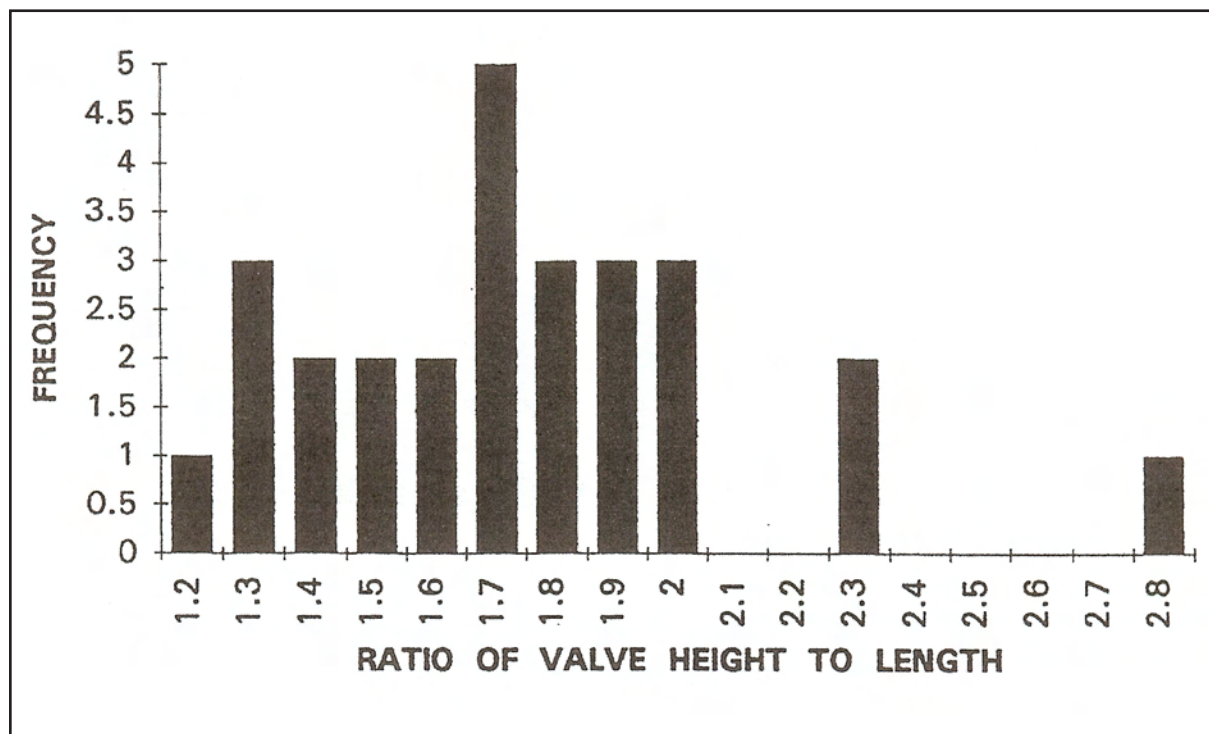


Figure 6. The distribution of height to length measurement ratios on 27 lower valves of oysters (*Ostrea lurida*) from CA-LAN-2630, Unit 7.

its low frequency at LAN-2630 indicates it was not a major constituent of the ancient diet. Also, a few pieces of the Pismo clam, *Tivela stultorum*, were recovered. It is normally found on wave-exposed sandy beaches, but the senior author has observed fresh shells from young individuals in the generally quiet waters inside the Los Angeles breakwater along Inner Cabrillo Beach and in Newport Bay. Even though it is possible that these species could have been washed into the area from more wave-exposed habitats during a particularly harsh storm or carried in by humans, they could be uncommon inhabitants of this bay habitat, especially where there is some water agitation.

The marine gastropods associated with mixed rock and soft bottom habitats within bays are limited in number in this collection: the herbivores, *Lucapinnella*, *Tegula*, *Lacuna*, and *Littorina*; the carnivores,

which feed primarily on barnacles and small bivalves, *Pteropurpura*, *Ocenebra*, and *Acanthina*; and a polychaete worm and small fish consumer, *Conus* (McLean 1978:51). More common are the marine gastropods associated with lagoon/bay soft bottom habitats, especially ones formed primarily of fine sediments: the herbivorous California horn or mud snail, *Cerithidae*, and the bivalve-eating moon snail, *Polinices reclusianus*.

The California horn or mud snail was the most frequently encountered free-living gastropod (100 individuals) and was found in every excavation unit (Table 2). This species is abundant in the higher intertidal zone on a muddy substratum in protected bays and estuaries (Keen and McLean 1971:419; McLean 1978:32). Of significance is the high proportion of beach-worn shells of this species in the study collection (74 percent of the 100 individuals had major portions of the shell missing

or broken). This suggests that archaeological site LAN-2630 was at the highest reaches of the tides, or above the water's edge. However, heavy rains and floods would have inundated LAN-2630, forcing its human inhabitants to seek higher ground.

Further evidence that this area was not generally covered by most tides is the presence of an unidentified terrestrial pulmonate gastropod species (*Patula*) (14 individuals in five excavation units) and the marine pulmonate gastropod, *Melampus olivaceus* (four individuals in four sampling units), which is found at the drift line of the high tides (McLean 1978:59). The presence of these species and the fresh water gastropods (unidentified species of the families Planorbidae, Physidae, and Lymnaeidae), which would be found in fresh water seeps and ponds on land, points to a habitat that was above or at the drift line of the bay or lagoon and indicates that fresh water runoff occurred during some periods. Whole shells of the terrestrial and fresh water snails were found in the samples, and these shells are extremely thin and fragile.

The Origin of the Shell Deposits

Since larval oysters settle and grow cemented to other shells and hard substrata, and pecten attach to the same types of substrata with their byssal threads, humans foraging for edible-sized bivalves will inadvertently capture attached, small individuals of these species when harvesting large bivalves. The small oysters and pecten could then be discarded along with consumed larger prey. For this reason, only the size class analyses for the clams should be used to examine the hypothesis that the shell deposits are composed of human harvested clams. Figure 7 compares the size distribution of the littleneck clam, *Protothaca staminea*, found in the LAN-2630 midden (pooled across all sampled units) to a collection made in a natural clam bed at Inner Cabrillo Beach, Los Angeles Harbor (San Pedro). Figure 8 compares the CSULB

assemblage to modern, smaller quadrat collections from Marina del Rey and Balboa Island intertidal zones.¹ It is obvious that the smaller size classes found in a natural collection are underrepresented in the archaeological samples from LAN-2630.

The size class distribution comparisons for the wavy cockle, *Chione undatella* (Figure 9 and Figure 10), the smooth cockle, *Chione fluctifraga* (Figure 11), and the banded cockle, *Chione californiensis* (Figure 12), show that the LAN-2630 size distributions are shifted to the larger size classes when compared to extant natural deposits.² Table 3 presents the percentages of bivalves found in the various collections that are in valve length size classes less than 3 cm. Notice the very low percentages associated with the LAN-2630 specimens, supporting the argument that these species were harvested by indigenous peoples.

Another observation supporting the argument for a primarily nonnatural deposition of the LAN-2630 material concerns the incidence of bivalve shells having a bore hole, indicating predation by a gastropod drill or an octopus. Human harvesters should not pick up empty drilled clam shells, so they should not be common in middens. Natural deposits would not be selecting for or against this trait. Only three clam shells of almost 2,000 examined in the CSULB collection had drill holes, compared to 10 out of 76 from the much smaller volume (about two liters [nine cups]) of clam shells collected from above the drift line in Newport Bay. Of course, molluscan drilled valves need to be distinguished from human drilled shells; the shape of the drill hole left by a snail or octopus is distinctive, having a slight bevel on the sides and terminating with a wide, flat-sided hole. Human drilled holes should be conical all the way through. This also assumes that some humans do not selectively retrieve shells with drill holes as curiosities.

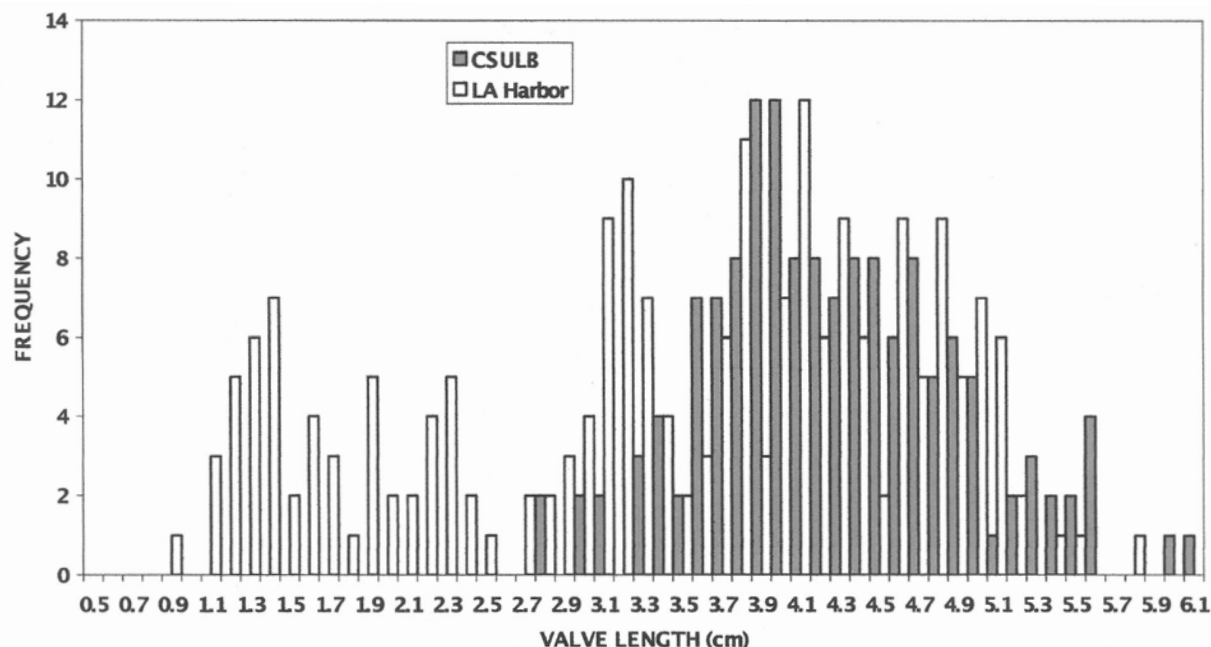


Figure 7. A comparison of the valve lengths of the littleneck clam, *Protothaca staminea*, from Inner Cabrillo Beach, Los Angeles Harbor, and CA-LAN-2630.

The size class distribution for the pecten (Figure 13) indicates that small individuals (< 3 cm) are more common (9 percent) than was found for the clams, but as with the clams, the size distribution favors the middle to larger sized individuals. The relatively larger number of small pecten individuals found is expected because the harvesting of larger pectens and oysters should bring up young pecten that are stuck to these shells by their byssal threads. With the oysters, the size estimations are extremely variable because the shells are so friable. It is difficult to find a whole valve from which to make hinge plate and valve height measurements. One cannot be sure that some of the shell has not broken away. Although the size distribution of lower oyster valves (Figure 14) suggests that, again, smaller sizes are rarer than might be expected from a natural deposit, we are hesitant to make as strong a statement about human harvesting based on size, compared to the clams, due to measurement conditions. Because the California horn snail, *Cerithidae*,

and other free-living gastropods were not very numerous and were small in size (except *Polinices*), these species were probably the result of natural deposition by storm waves. The moon snail, *Polinices*, may have been collected to eat. *Polinices reclusianus* shells at LAN-2630 were mostly intact, but after boiling a living moon snail, the foot is easily extracted from the shell by grabbing it and pulling, leaving the shell unbroken. The slipper shell, *Crepidula onyx*, and the cup and saucer shell, *Crucibulum spinosum*, live attached to rocks and other shells (especially oysters), and their high abundances probably reflect the high abundance of their hosts in the deposit. However, larger individuals of these gastropods may have been consumed by humans.

Discussion and Conclusion

The shells that comprise the LAN-2630 midden could have originated from either 1) a natural

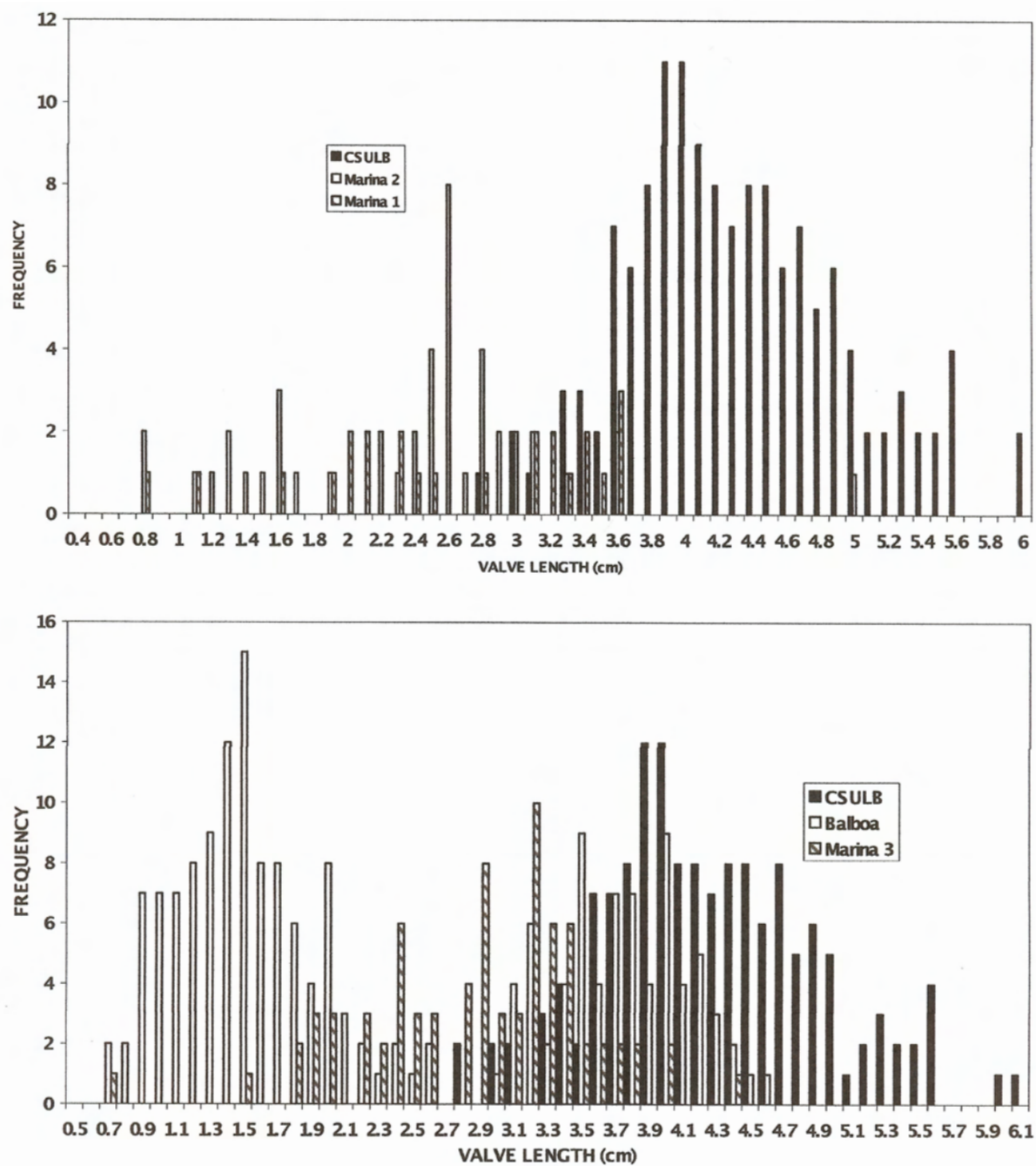


Figure 8. A comparison of the valve lengths of dead littleneck clams, *Protothaca staminea*, in intertidal (-0.3 m) collections from Marina del Rey, Balboa Island in Newport Bay, and CA-LAN-2630 (CSULB).

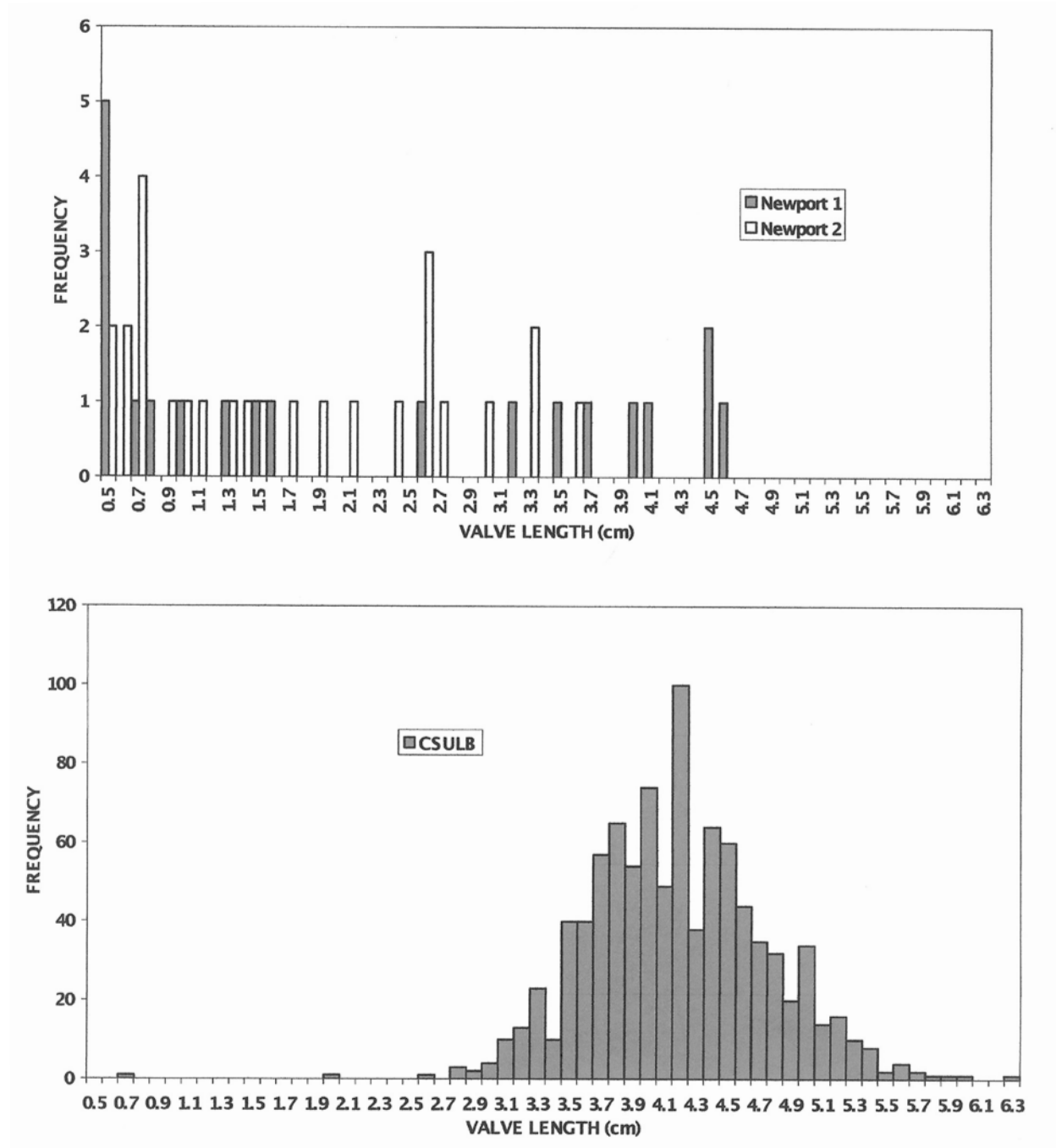


Figure 9. A comparison of the valve lengths of the wavy cockle, *Chione undatella*, from two 25 cm x 50 cm x 10 cm deep quadrats above the drift line in Newport Bay (upper graph) with specimens from CA-LAN-2630 (lower graph).

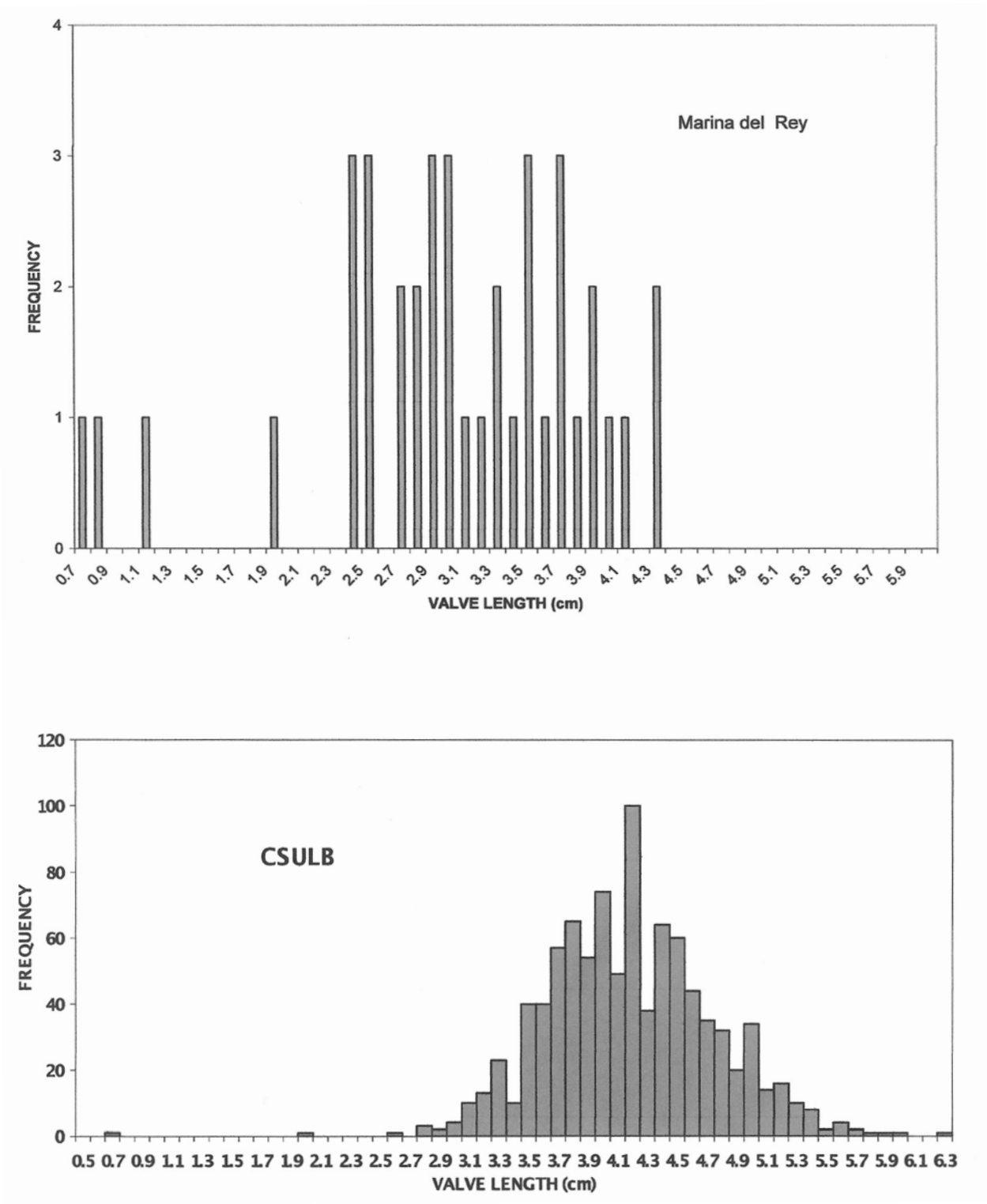


Figure 10. A comparison of the valve lengths of the wavy cockle, *Chione undatella*, collected alive from an intertidal (-0.2 m) quadrat (50 cm x 50 cm x 10 cm deep) at Marina del Rey (upper graph) with those found at CA-LAN-2630 (lower graph).

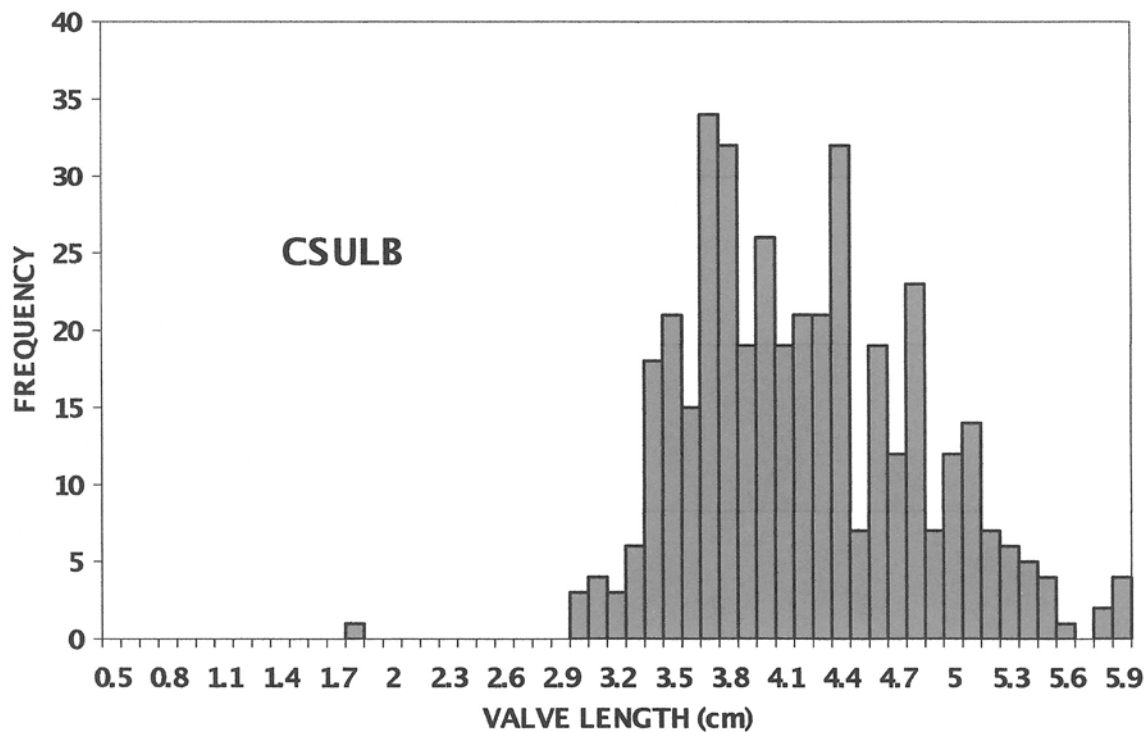


Figure 11. The distribution of valve lengths of the smooth cockle, *Chione fluctifraga*, found in the CA-LAN-2360 assemblage from the CSULB campus.

accumulation such as one might find in a channel or along a beach where waves and water currents have deposited shells and covered living and dead individuals with sediment and/or 2) a collection of molluscs harvested and consumed by humans, with the shells then discarded. Our evidence suggests the latter scenario. As mentioned above, the bivalve shell remnants are primarily from the middle and large size classes for a species, this based on comparisons to modern clam beds. It has been demonstrated that humans tend to select individual prey items from the larger end of the size class distribution of natural populations of molluscs (Moreno et al. 1986:363; Ortega 1987:254). The low number of small-sized individuals in the collection supports the case that the archaeological shells of LAN-2630 are the results of cultural activities since a natural collection should include individuals of most size classes.

An additional bit of circumstantial evidence supporting the hypothesis of human deposition of the bivalves is that the clam species, which are reasonably abundant in the LAN-2630 midden, co-occur with the oyster and pecten remains throughout the site (Table 2). Since pecten live subtidally and the clams are found principally in the lower intertidal to shallow subtidal depths (Keen and McClean 1971:185; McLean 1978:78; Miller), one should not expect such a high degree of overlap unless storms kept mixing naturally deposited shells or the accumulation was the result of human discards. The fact that the size classes are principally the larger ones supports the latter explanation.

Between 1900 and 1950, sprawling urban development and modern land-use patterns have been extensive enough to solidly cover, on a grand scale,

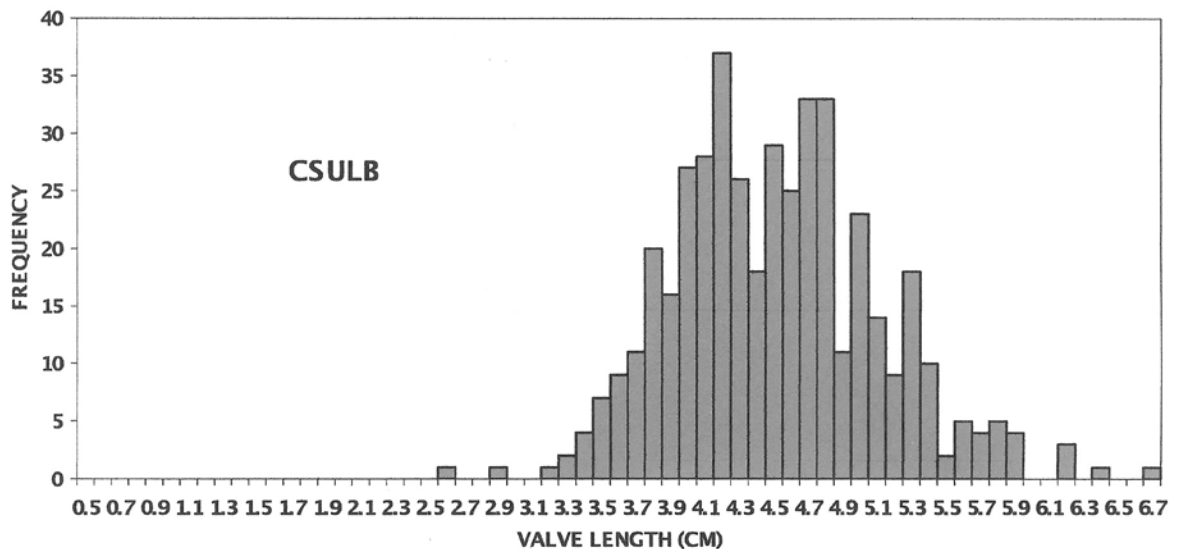
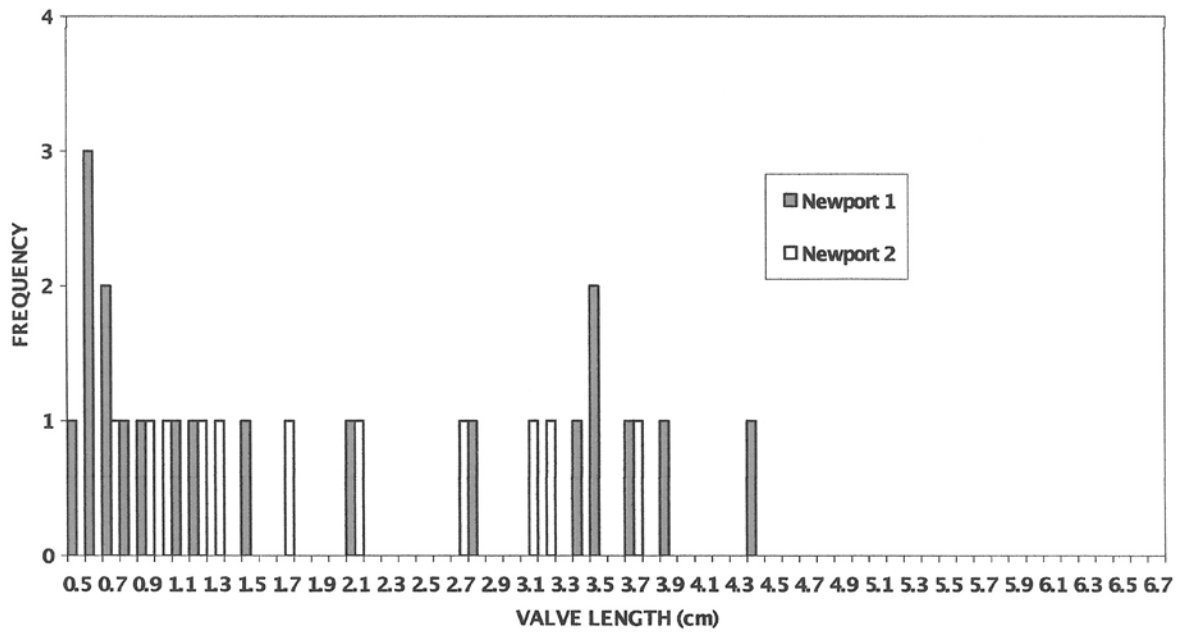


Figure 12. A comparison of the valve lengths of the banded cockle, *Chione californiensis*, from Newport Bay (upper graph) with *C. californiensis* from CA-LAN-2630 (lower graph).

Table 3. The Percentage of Clam (*Chione* and *Protothaca*) and Scallop (*Argopecten*) Individuals in the Study Collection.

	CSULB	Newport Bay		Marina Del Rey		Balboa Is.
		Above Drift Line		Dead	Living	Dead
		#1	#2			
Species						
<i>C. undatella</i>	0.7%	60% ¹	85% ¹	–	31%	–
<i>C. fluctifraga</i>	0.0%	–	–	–	–	–
<i>C. californiensis</i>	0.4%	68% ¹	73% ¹	–	–	–
<i>P. staminea</i>	1.4%	–	82% ¹	52% ¹	61%	50% ¹
<i>A. aequisulcatus</i>	9%	–	–	–	–	–

1. Only measurable whole valves used, no hinge remnants. These percentages would probably decrease slightly if hinge measurements were used to estimate valve lengths for fragmented valves.

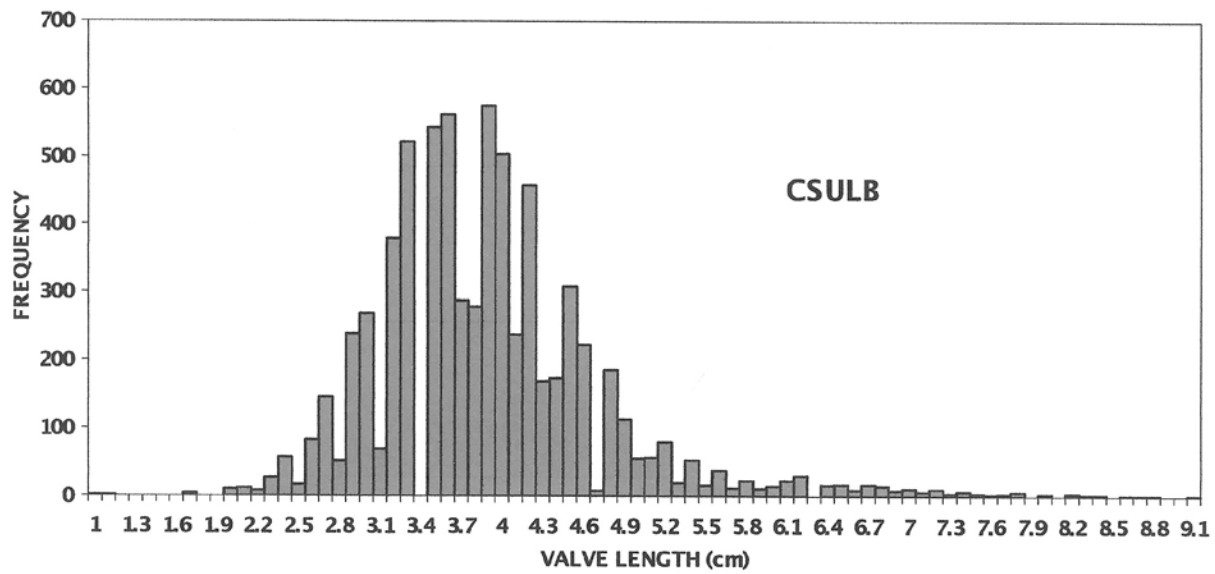


Figure 13. The distribution of valve lengths for the speckled pecten, *Argopecten aequisulcatus*, found among the CA-LAN-2630 specimens from CSULB.

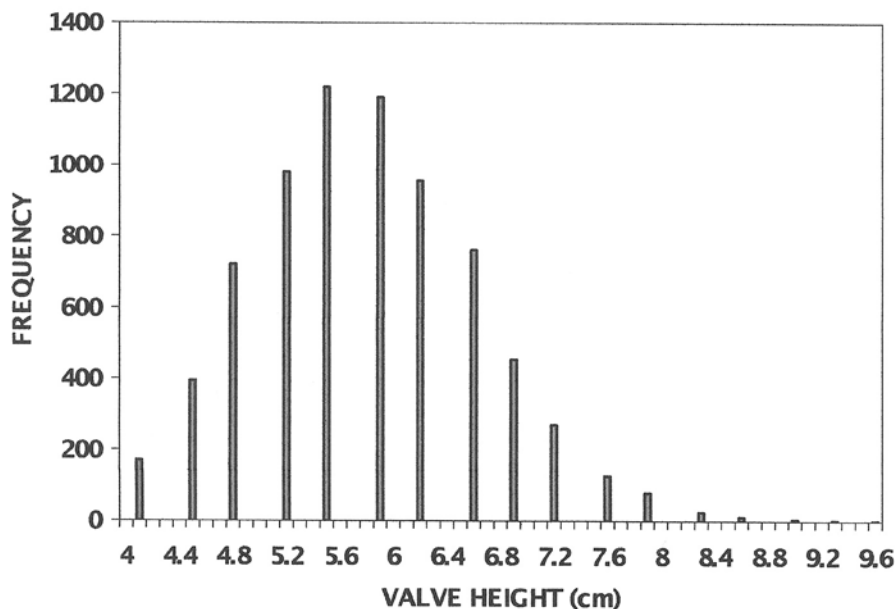


Figure 14. The size distribution of lower valves of oysters, *Ostrea lurida*, among the CA-LAN-2630 collection. Zero frequency size groups between bars are an artifact of the regression prediction process.

the dendritic system of small streams, estuaries, marine lagoons, and embayments that once proliferated in this region. The present study not only provides indisputable evidence of indigenous subsistence patterns, but it also serves to remind us how dramatically the region's coastal landscape has changed over the last 100 years.

Endnotes

1. The Marina del Rey (MDR) and Balboa Island (BI) quadrat sizes varied in size and depth: MDR 1, 25 cm x 25 cm x 10 cm deep; MDR 2, 20 cm x 20 cm x 10 cm deep; and MDR 3, 50 cm x 50 cm x 10 cm deep. The BI surface quadrat measured 1 m x 1 m.

2. The Newport Bay samples were collected from two quadrats above the drift line, measuring 25 cm x 50 cm x 10 cm deep.

Acknowledgments

We are grateful to the CSULB Department of Physical Planning and Facilities Management for funding this

research. We wish to thank Ivan Strudwick for reviewing this article along with an anonymous reviewer.

References Cited

- Gunter, Gordon
1938 Comments on the Shape, Growth, and Quality of the American Oyster. *Science* 88(2293):546-547.
- Keen, Angeline Myra, and James H. McClean
1971 *Sea Shells of Tropical West America: Marine Mollusks from Baja California to Peru*. Stanford University Press, Stanford, California.
- Kent, Bretton W.
1992 *Making Dead Oysters Talk: Techniques for Analyzing Oysters from Archaeological Sites*. Maryland Historical and Cultural Publications, Crownsville, Maryland.
- Laylander, Don, and Dave Iverson
2006 SDI-4533, Major Shellfish Genera and Prehistoric Change on the San Diego County

Coast. *Pacific Coast Archaeological Society Quarterly* 39(4):39-48.

McLean, James H.

1978 *Marine Shells of Southern California*. Natural History Museum of Los Angeles County, Science Series 24. Los Angeles.

Moreno, Carlos A., Karin M. Lunecke, and M. Irene L pez

1986 The Response of an Intertidal *Concholepas concholepas* (Gastropoda) Population to Protection from Man in Southern Chile and the Effects on Benthic Sessile Assemblages. *Oikos* 46(3):359-364.

Ortega, Sonia

1987 The Effect of Human Predation on the Size Distribution of *Siphonaria gigas* (Molluska: Pulmonata) on the Pacific Coast of Costa Rica. *Veliger* 29(3):251-255.

Appendix 1

A. Collections of non-CSULB survey bivalves. All sediment was shoveled and passed through a 2 mm x 2 mm mesh screen.

Site	Quadrat Size	Tidal Height
Inner Cabrillo Beach, Los Angeles Harbor	50 cm x 50 cm 10 cm depth. n=30	+0.3 m to -0.3 m
Via Marina St., Marina del Rey	#1: 25 cm x 25 cm #2: 20 cm x 20 cm #3: 50 cm x 50 cm Dug to 10 cm depth	-0.2 m to -0.3 m
Balboa Island, Newport Bay	1 m x 1 m surface	+1.0 m
Northstar Lane, Newport Bay	25 cm x 50 cm 10 cm depth 2-liter subsample	0.5 m above drift line

B. Regression equations used to estimate valve length (clams and pecten) or height (oysters) based on hinge measurements (also refer to Figures 7-14). Note: * = raise to the power.

Species	
<i>Ostrea lurida</i> native oyster	Height=4.31+1.7*Hinge plate length (upper) Height=3.09+3.46*Hinge plate length (lower)
<i>Argopecten aequisulcatus</i> speckled scallop	Length=0.293+13.22*Resilium (left valve) Length=0.123+14.54*Resilium (right valve)
<i>Chione californiensis</i> banded cockle	Length=1.54+4.5*Hinge maximum (left valve) Length=1.27+4.9*Hinge maximum (right valve)
<i>Chione undatella</i> wavy cockle	Length=1.16+5.9*Hinge maximum (left valve) Length=0.93+6.3*Hinge maximum (right valve)
<i>Chione fluctifraga</i> smooth cockle	Length=0.79+8.1*Hinge maximum (left valve) Length=0.8+8.0*Hinge maximum (right valve)
<i>Protothaca staminea</i> littleneck clam	Length=0.26+10.6*Hinge maximum (left valve) Length=0.04+10.7*Hinge maximum (right valve)

Appendix 2

CA-LAN-2630 Shell Species List

Class: Gastropoda

Subclass: Prosobranchia

- Family: Fissurellidae
Lucapinella callomarginata (Dall) ^{3,5}
 fleshy keyhole limpet
- Trochidae
Tegula eiseni Jordan ^{3,5}
 banded turban
- Lacunidae
Lacuna unifasciata Carpenter ^{2,5}
 one-banded lacuna
- Littorinidae
Littorina scutulata Gould ^{3,5}
 checkered periwinkle
- Potamididae
Cerithidae californica (Haldeman) ^{1,8}
 California horn or mud snail
- Calyptraeidae
Crepidula onyx Sowerby ^{3,8}
 onyx slipper shell
Crucibulum spinosum (Sowerby) ^{3,8}
 spiny cup and saucer shell
- Naticidae
Polinices reclusianus (Deshayes) ^{1,7}
 southern moon snail
- Muricidae
Pteropurpura festiva (Hinds) ^{3,5}
 festive murex
Ocenebra sp. ^{3,5}
 drill or rock shell
- Thaididae
Acanthina spirata (Blainville) ^{3,5}
 angular unicorn shell
- Columbellidae
Alia carinata (Hinds) ^{2,7}
 carinate dove shell
- Nassariidae
Nassarius tegula (Reeve) ^{1,5}
 basket shell

CA-LAN-2630 Shell Species List (continued)

Class: Gastropoda

Subclass: Prosobranchia

- Family Olividae
Olivella baetica Carpenter^{1,5}
 beatic olive
- Conidae
Conus californicus Reeve^{1,6}
 California cone snail

Subclass: Pulmonata

- Melampidae
Melampus olivaceus Carpenter^{1,5}
 salt marsh snail
- Planorbidae
 unidentified sp.^{4,7}
 pond snail
- Physidae
 unidentified sp.^{4,7}
 pond snail
- Lymnaeidae
 unidentified sp.^{4,7}
 pond snail
- Helicellidae
Patula? sp.^{4,7}
 terrestrial snail

Class: Polyplacophora

unidentified chiton plates

Class: Bivalvia

- Family: Ostreidae
Ostrea lurida Carpenter^{1,8}
 native oyster
- Pectinidae
Argopecten aequisulcatus (Carpenter)^{1,8}
 speckled scallop
- Cardiidae
Laevicardium elatum (Sowerby)^{1,5}
 giant cockle
- Laevicardium substriatum* (Conrad)^{1,5}
 egg-shell cockle

CA-LAN-2630 Shell Species List (continued)

Class: Bivalvia

Family

Veneridae

Tivela stultorum (Mawe) ^{1*,6}

Pismo clam

Saxidomus nuttalli Conrad ^{1,6}

Washington clam

Chione californiensis (Broderip) ^{1,8}

banded cockle

Chione undatella (Sowerby) ^{1,8}

wavy cockle

Chione fluctifraga (Sowerby) ^{1,8}

smooth cockle

Protothaca staminea (Conrad) ^{1,8}

littleneck clam

Donacidae

Donax californicus (Conrad) ^{1,5}

wedge clam

Donax gouldii (Conrad) ^{1*,7}

bean clam

Pholadidae

Chaceia ovoidea (Gould) ^{3,5}

wart-necked piddock

Superscript Codes:

- 1. mud and/or sand; shallow lagoons and bays
- 1*. wave-exposed and semi-protected sandy beaches
- 2. sea grass and algae; shallow lagoons and bays
- 3. rocks; shallow lagoons and bays
- 4. terrestrial or fresh water
- 5. <5 individuals in the collection
- 6. <10, ≥5 individuals in the collection
- 7. <25, ≥10 individuals in the collection
- 8. ≥25 individuals in the collection