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The Ecology of *Parvilucina tenuisculpta* (Carpenter, 1864) (Bivalvia: Lucinidae) on the Southern California Borderland

by

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Abstract. The pelecypod *Parvilucina tenuisculpta* (Carpenter, 1864) is a widely distributed member of the benthos of the southern California borderland where it is a prominent faunal element of every major habitat except the deep basins. In this fairly wide range of environments it lives with a large number of other taxa which may differ markedly from one location to another. The population densities of *Parvilucina* were highest in two very dissimilar environments—the insular shelf of the northern Channel Islands and the central part of the mainland shelf (Santa Monica Bay and San Pedro Bay). The insular shelf is primarily a non-depositional environment where relatively strong currents result in the development of coarse sediments rich in biogenic calcium carbonate components. The area is influenced by persistent upwelling. By contrast, the parts of the mainland shelf where population densities of *Parvilucina* were highest are in equilibrium environments highly influenced by the release of sewage wastewaters. Organic enrichment, in one case upwelling and the other sewage wastewaters, may be the factor responsible for the areas of high population densities.

INTRODUCTION

THE SEA FLOOR OF southern California and northern Baja California is much more complex than continental shelves in most other areas of the world. The region is complex and different enough to have been designated by a special term, "the continental borderland" (SHEPARD & EMERY, 1941; UCHUPI & EMERY, 1963). The part of the borderland that forms the Southern California Bight includes islands, banks, ridges, basins, and troughs. The bathymetry spans the range from the sublittoral zone to the bathyal depths (EMERY, 1960). Numerous submarine canyons transect the mainland and island shelves, descending toward and into the basins. Imposed upon this structural variety is a highly diverse substrate pattern. Consequently, the sea floor of the Bight consists of a very complex set of benthic habitats, and the diversity of the benthic macrofauna reflects this complex habitat (EMERY, 1960; FAUCHALD & JONES, 1978, 1979a, b; HARTMAN, 1955, 1956, 1963, 1966; HARTMAN & BARNARD, 1958, 1960; JONES, 1969).

The pelecypod *Parvilucina tenuisculpta* (Carpenter, 1864) (=*Lucina tenuisculpta*) (Figure 1) is an important member of the benthos of the southern California continental borderland. It has been collected in most of the major quantitative studies of the benthic macrofauna of the borderland. The purpose of this paper is to review these findings and to document the distribution, abundance, spatial and temporal variation, feeding and faunal associates of *P. tenuisculpta* in the region.

In an extensive survey of the benthos of the San Pedro Basin, HARTMAN (1955, 1966) recorded the biological components of 267 samples. WILSON (1956) reported *Parvilucina* in 18 of Hartman's samples. The population densities varied from 4 to 72 per m^2 (mean = 24.4/m^2) in depths ranging from 14.6 to 702.5 m (mean = 178.7 m). In a paper on the dominant benthic molluscan faunas of the San Pedro Basin based on Wilson's data, BANDY (1958) included *Parvilucina tenuisculpta* as one of the elements of his Fauna 2 (dominant pelecypod faunas; the other members of this faunal group are *Nuculana taphria, Solamen columbianum, Solemya panamensis, Solen rosaceus* and *Thyasira barbarensis*). *Parvilucina* was reported only once (Sta-

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tion 3492, 3 specimens in 47.3 m) by HARTMAN (1956) in her study of the benthic macrofauna of Santa Monica Bay, but most of the molluscan specimens collected in this survey were not identified to species.

From 1956 to 1961, the California Water Quality Control Board supported an extensive investigation of the oceanography, geology, and marine biology of the mainland shelf of southern California. During the study the benthic macrofauna was sampled at 456 locations (AHF: USC, 1965). *Parvilucina tenuisculpta* was collected at 78 (17%) of the sampling locations of this study with population densities ranging from 4 to 68 per m^2 (mean = $12.0/m^2$) in water depths ranging from 13 to 253 m (mean = 66.5 m). It was absent from the 121 Van Veen grab samples collected from the shallower portion (2.4 to 10.1 m) of the shelf.

In her study of the benthic macrofauna of the submarine canyons of the borderland HARTMAN (1963) reported *Parvilucina* from Hueneme and Redondo submarine canyons. In their study of the benthos of the basins of the borderland HARTMAN & BARNARD (1958, 1960) did not record *Parvilucina* as a faunal element of any basin.

Working with a group of Allan Hancock Foundation scientists, FAUCHALD (1971) studied the impact of the Santa Barbara oil spill (1969) on the biota of the Santa Barbara shelf. *Parvilucina tenuisculpta* (reported as *Phacoides tenuisculpta*) was collected in more than 10% of the 85 samples in this study.

In a survey of the mainland shelf conducted by the Southern California Coastal Water Research Project (SCCWRP) in 1977, benthic samples were collected at intervals of approximately 10 km at a depth of 60 m along the entire length of the mainland shelf from Point Conception to the US-Mexican border. Very high densities of *Parvilucina,* approaching $10{,}000/m^2$, were encountered off the Palos Verdes Peninsula and in Santa Monica Bay; densities along the 60-m transect north and south of these two areas were very much lower by comparison (WORD & MEARNS, 1978, fig. 4).

The present paper is based on data gathered during two major studies of the benthos of southern California funded by the Bureau of Land Management, the Baseline Study (1975–1976) and the Benchmark Study (1976–1977). These two studies, together, are the largest investigations of this kind ever made in this marine region (FAUCHALD & JONES, 1978, 1979a, b).

The benthic macrofauna was sampled at over 700 locations during the Baseline Study; 546 of these sampling locations were grouped in 11 regular grids termed High Density Sampling Areas (HDSAs); within these grids sampling stations were arranged on 1.7-km (1-mile) centers. These grids varied in size from 16 to over 100 sampling locations. Four of these HDSAs were on the mainland shelf and its slopes; one was on the Santa Catalina Ridge; two were on the insular shelf of the Channel Islands; and four were on the Santa Rosa-Cortes Ridge.

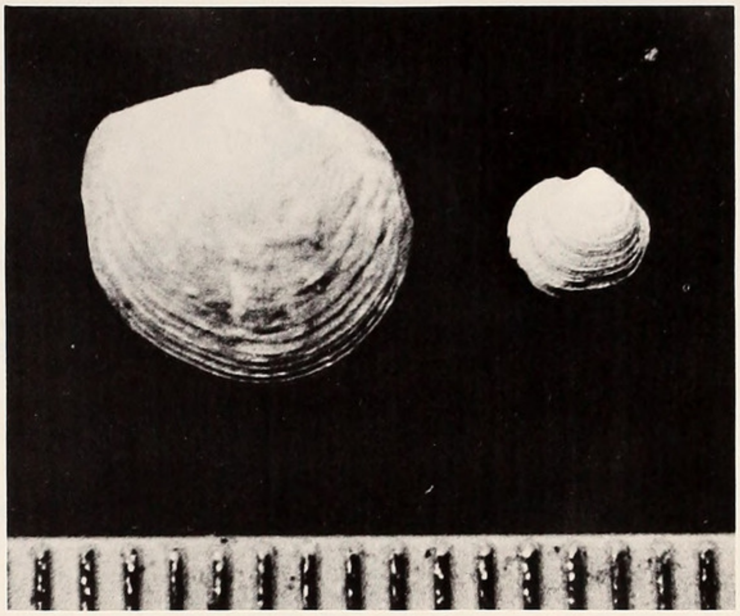

Figure 1

Parvilucina tenuisculpta (Carpenter, 1864). Larger specimens are from an outfall area; smaller specimens from near Point Conception. Scale in millimeters.

Another 227 sampling stations were located outside the HDSAs.

During the Benchmark Study, replicate sampling was conducted at 21 sampling stations in six areas of the borderland: off Coal Oil Point and the slope of the Santa Barbara Basin (3 stations); off San Pedro, on the slope of San Pedro Basin and within the basin (6 stations); south of San Miguel Island (2 stations); south of Santa Rosa Island (1 station); on the northern portion of the Santa Rosa-Cortes Ridge south of Santa Rosa Island, the slope of Santa Cruz Basin and within the basin (3 stations); and on the southern portion of the Santa Rosa-Cortes Ridge, including Tanner Bank, the slope of San Nicolas Basin and within the basin (6 stations). Sampling was conducted twice during the year, once in the period of low water temperature (early spring) and once in the period of high water temperature (early fall). Eight replicate samples were collected at each station during each sampling period.

METHODS

In both the Baseline and Benchmark studies, a navigational system was used that could guarantee an accuracy of ±30.5 m.

Samples were collected by a modified 1/16 m^2 USNEL-Reineck spade (or box) corer (HESSLER & JUMARS, 1974). A subsample of each core was collected for sedimentary analysis. Benthic samples were screened through 1.0 mm and 0.5 mm stainless steel screens using the overflow-barrel method. The benthic macrofaunal invertebrates were narcotized for 20 min in 6% magnesium chloride in sea-

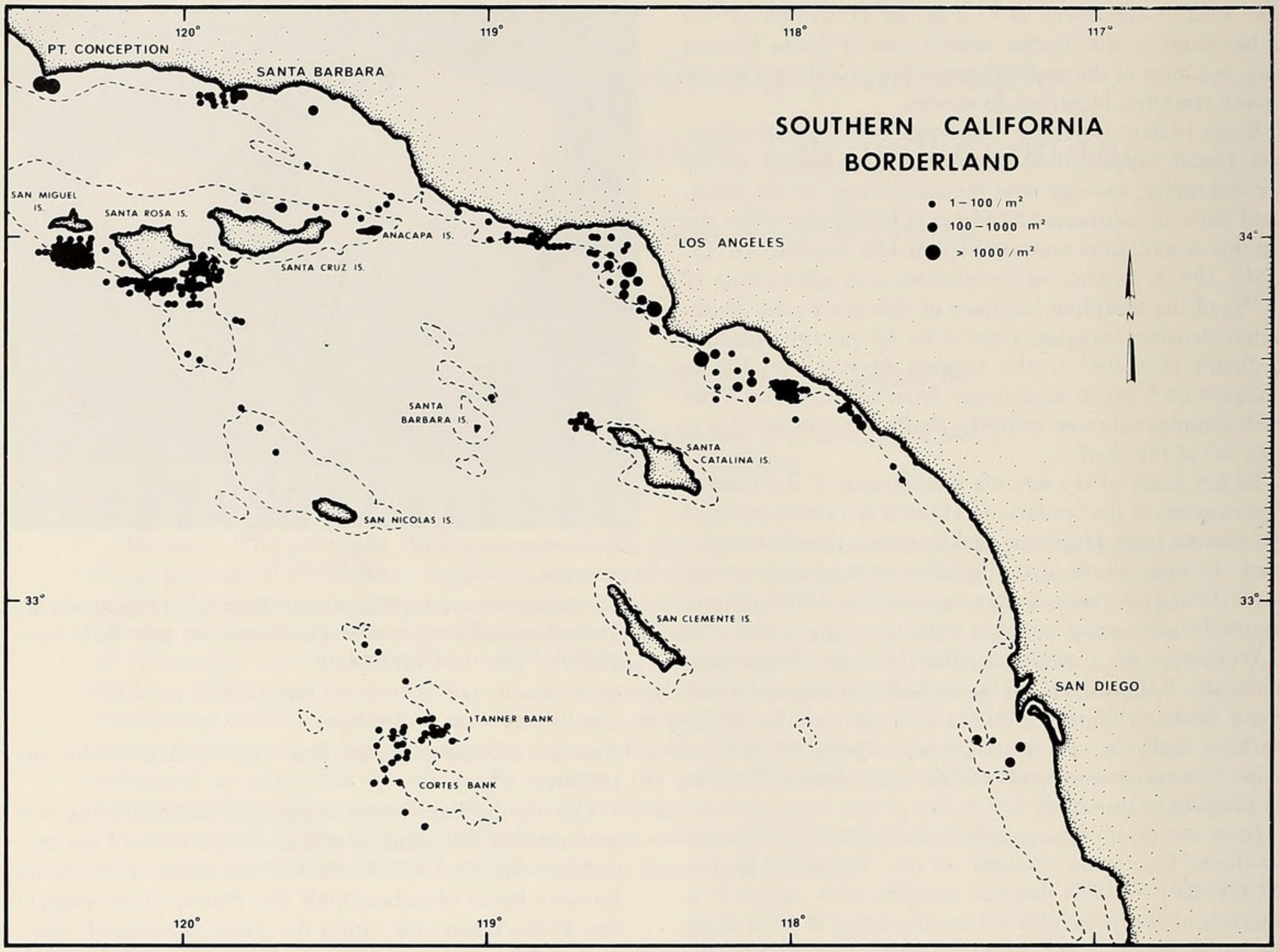

Figure 2

Chart of southern California borderland showing locations where *Parvilucina tenuisculpta* was collected. Circle-size reflects population density; see legend.

water prior to killing and fixation; specimens were killed and fixed in 10% buffered seawater formalin; after 36 h samples were transferred to 70% ethanol for preservation.

The *rapid identification procedure* was used to analyze the benthic samples (FAUCHALD & JONES, 1978). Some taxa were identified to the specific level, whereas others were identified only to the familial or generic level under the limitations of this method. All taxa were identified to species (where possible) for 165 of the 712 samples collected during the Baseline Study and for all of the 318 samples collected during the Benchmark study.

The diet and mineral particle-size range used by *Parvilucina tenuisculpta* in the major benthic habitats of the southern California borderland were analyzed (THOMPSON, 1982). The gut contents of 20 specimens from all habitats, offshore and mainland shelves, near and away from sewage outfalls, winter and summer, were examined microscopically (10–100×) and the material categorized into five food groups: (1) detrital aggregates, (2) single mineral particles, (3) particulate organic material, (4) animal remains, and (5) Foraminifera. The proportion of each of the food groups in total sample volume was estimated visually to the nearest 10%. The sizes of mineral particles ingested were measured to the nearest 10 μm using a light microscope (1000×). Because of the small sample size obtained from each specimen, the gut contents of five specimens from Stations 805 and 806 were pooled. A total of 150 particles from 15 random fields were measured.

The spatial dispersion of *P. tenuisculpta* at two different sampling scales was determined using an Index of Dispersion (MORISITA, 1959).

Determination of the organisms associated with *Parvilucina* was based on the faunal composition of representative sample-sets each consisting of 10 samples.

Sedimentary analyses were made by geologists at Cal-

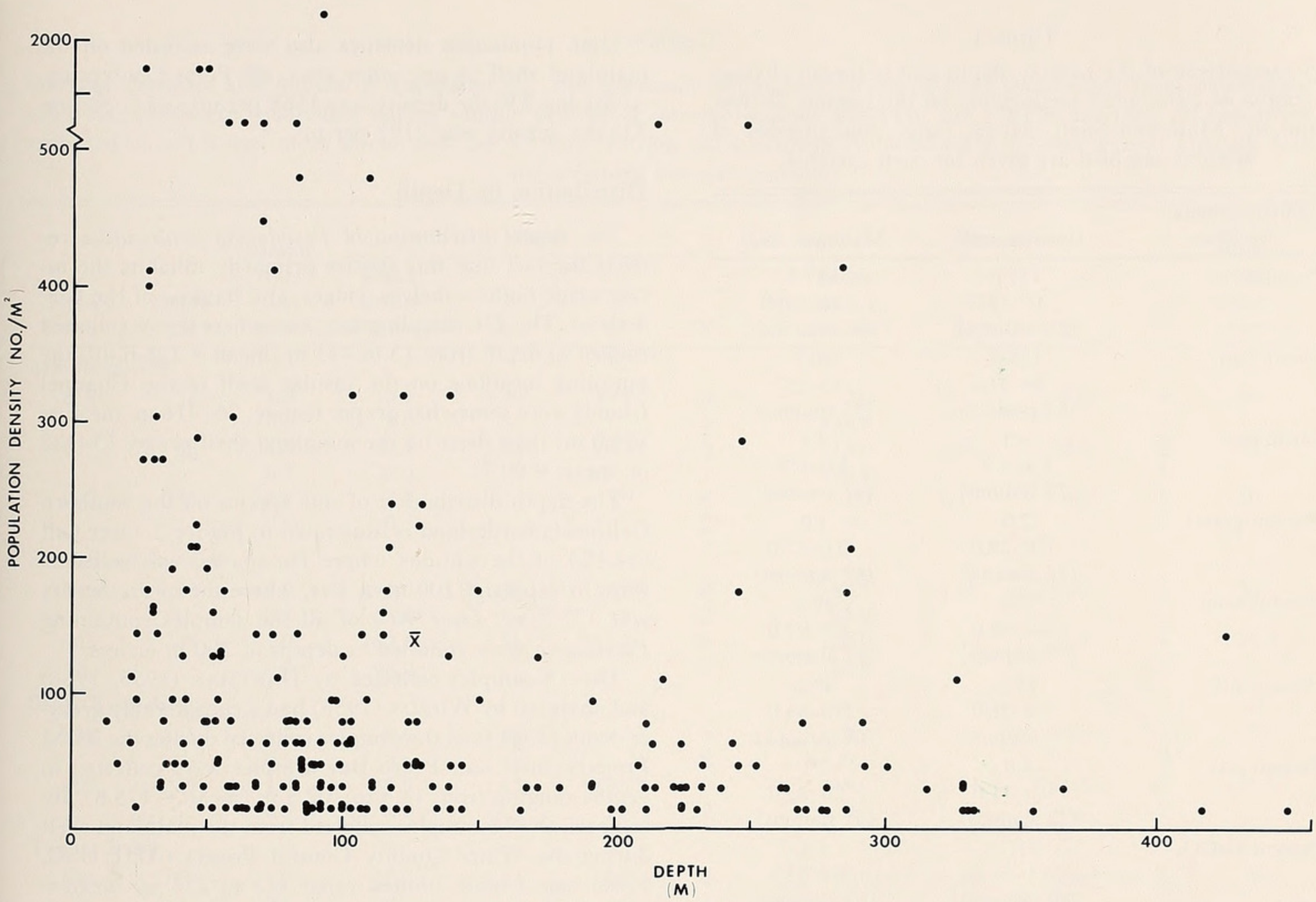

Figure 3

Depth distribution of *Parvilucina tenuisculpta* on the southern California borderland. The symbol x̄ indicates the position of the mean depth and the mean density.

ifornia State University, Northridge (Baseline Study) and University of California, Los Angeles (Benchmark Study).

RESULTS

Geographic Distribution

Parvilucina tenuisculpta is widely distributed throughout the southern California borderland (Figure 2). KEEN (1937) records the distribution of *Parvilucina tenuisculpta* as from 32°N to 60°N latitude (midpoint of range, 46°N) along the west North American coast, or approximately from Ensenada, Baja California to Cook Inlet, Alaska. It is a prominent faunal element of every major habitat type in the borderland except the deep basins. On the mainland shelf it occurs from Point Conception to the US-Mexican Border. It is an important element of the biota of the insular shelf of the Channel Islands and occurs on the Santa Rosa-Cortes Ridge including Tanner and Cortes Banks. It also occurs on the Santa Catalina Ridge north of Santa Catalina Island.

Parvilucina was collected at 226 (31.7%) of the 712 stations during the Baseline Study. Population densities ranged from 16 to 2560 individuals per m² (mean = 139.1/m²). Densities were highest in two very dissimilar environments—the insular shelf of the Channel Islands (the San Miguel Island HDSA and the Santa Rosa HDSA) and the central part of the mainland shelf in Santa Monica Bay and San Pedro Bay (including the Huntington Beach HDSA).

The insular shelf of the Channel Islands is primarily a nondepositional environment. Relatively strong currents result in winnowing of finer detrital sediments and the development of ripple marks. Sediments are frequently coarse and relatively high in calcium carbonate content, and the sediment patterns of the region tend to be complex. Evidence of bioturbation is minimal. The area may be influenced by the persistent upwelling centers of the Point Conception area (R. C. Dugdale, personal communication) and the upwelling resulting from the entrainment of deeper, subsurface water by the California Current across the Santa Rosa-Cortes Ridge (EMERY, 1960).

Table 1

A comparison of the habitat, depth and sediment characteristics of *Parvilucina tenuisculpta* on the Insular Shelves and the Mainland Shelf. Mean, range, and number of stations sampled are given for each variable.

Environmental variable	Insular shelf	Mainland shelf
Number/m^2	157.0 16–1872 (85 stations)	187.5 16–2560 (85 stations)
Depth (m)	124.0 26–416 (85 stations)	90.7 13–332 (85 stations)
Mean *phi*	3.3 1.4–4.4 (72 stations)	4.4 1.0–6.2 (67 stations)
Percent gravel	2.0 0.0–28.0 (72 stations)	1.0 0.0–57.0 (67 stations)
Percent sand	79.1 54.0–98.0 (72 stations)	49.8 3.0–99.0 (67 stations)
Percent silt	14.5 1.0–38.0 (72 stations)	42.1 0.0–84.0 (67 stations)
Percent clay	4.0 0.0–11.0 (72 stations)	7.1 2.0–23.0 (67 stations)
Percent $CaCO_3$	21.7 3.1–54.8 (70 stations)	4.5 0.2–53.5 (53 stations)

Parvilucina was collected at 34 (72%) of the 47 stations comprising the San Miguel Island HDSA; population densities ranged from 16 to 544 individuals per m^2 (mean = 124.9/m^2). It was present in 52 (51%) of the 102 stations forming the Santa Rosa Island HDSA; in this sampling grid, population densities ranged from 16 to 1872 individuals per m^2 (mean = 161.8/m^2).

By contrast, the areas on the mainland shelf where densities of *Parvilucina* are high are equilibrium environments modified by man's activities, particularly the release of domestic and industrial wastewater into the marine environment. The combined discharge levels are in excess of one billion gallons of effluent per day (SCHAFER, 1980). Except for areas of rock and relic sediments, sediments in this area are finer, much lower in calcium carbonate and higher in total organic content than on the insular shelf. Neither strong currents nor major upwelling are major factors in the area.

On the mainland shelf at 34 stations in Santa Monica Bay and San Pedro Bay, population densities ranged from 16 to 2560 individuals per m^2 (mean = 247.8/m^2). Further south, in the Huntington Beach HDSA, *Parvilucina* occurred at 19 (73.1%) of the 26 stations comprising the grid, with population densities ranging from 32 to 380 individuals per m^2 (mean = 199.0/m^2).

High population densities also were recorded on the mainland shelf in one other area, off Point Conception. At Station 830 the density was 1568 per m^2 and at Station 835 the density was 2192 per m^2.

Distribution by Depth

The depth distribution of *Parvilucina tenuisculpta* reflects the fact that this species primarily inhabits the topographic highs—shelves, ridges, and banks—of the borderland. The 226 sampling locations where it was collected ranged in depth from 13 to 433 m (mean = 126.6 m); the sampling locations on the insular shelf of the Channel Islands were somewhat deeper (range, 26–416 m; mean = 124.0 m) than those on the mainland shelf range, 13–322 m; mean = 90.7).

The depth distribution of this species on the southern California borderland is illustrated in Figure 3. Over half (54.4%) of the stations where *Parvilucina* was collected were in depths of 100 m or less, where the mean density was 177.7/m^2. Over 90% of all the samples containing *Parvilucina* were collected at depths of 300 m or less.

The 18 samples collected by HARTMAN (1955, 1966) and analyzed by WILSON (1956) had a considerably greater depth range than the samples collected during the BLM Projects; their San Pedro Bay samples were collected in depths ranging from 14.6 to 702.5 m (mean = 178.8). By contrast, the 78 samples collected from the mainland shelf during the Water Quality Control Project (AHF:USC, 1956) had a more limited range (13 to 253 m; mean = 66.5 m). Combining the data from these two surveys with that of the BLM study the overall range of this species in the borderland is from 13 to 702 m (mean = 114.7).

Distribution in Relation to Sediments

Data are available on the sedimentary characteristics of the substrate at most of the sampling locations (186 and 226) where *Parvilucina tenuisculpta* was collected. A comparison of the habitat of *Parvilucina* on the Channel Island shelf and the mainland shelf is presented in Table 1. Sediments, in general, are coarser on the insular shelf than on the mainland shelf (average mean *phi* of 3.3 compared to 4.4). An important difference between these two environments is that the calcium carbonate content of the sediments is much higher on the island shelf than on the mainland shelf (mean of 21.7% compared to 4.5%). This illustrates the fact that in the non-depositional environment of the insular shelves, biogenic contributions of calcium carbonate materials are a much more important sedimentological component than in the equilibrium environment of the mainland shelf.

Spatial and Temporal Variation

Limited information was available on the temporal variation of *Parvilucina tenuisculpta* populations. Only a single-year sequence (winter–summer) was analyzed and

Table 2

Average densities and indices of dispersion (I_δ) and seasonal comparisons for *Parvilucina tenuisculpta* from benchmark sites. Samples were subdivided during sample processing into two sample fractions: the 1.0-mm fraction, all specimens collected on a 1.0-mm mesh screen and the 0.5-mm fraction, all specimens collected on a 0.5-mm screen. Density data are presented for each fraction.

			Winter				Summer				Mann-Whitney
Station	Depth (m)	Sample fraction (mm)	Mean density (No./m²)	I_δ	χ^2	N	Mean density (No./m²)	I_δ	χ^2	N	U_s winter *vs* summer
Mainland shelf											
819	32	1.0	10.1	3.20	15.8	8	2.0	0	7.0	8	50
		0.5	8.0			2	136.0			2	
801	68	1.0	22.1	2.33	20.3*	8	12.0	1.60	10.0	8	29
		0.5	32.0			2	48.8			2	
802	336	1.0	2.0	0	7.0	8	4.0	0	6.0	8	50
		0.5	0			2	0			2	
San Miguel Is. shelf											
806	99	1.0	148.0	1.38	35.0*	8	142.1	1.06	10.9	8	26
		0.5	56.0			2	64.0			2	
805	239	1.0	162.1	1.11	15.7	8	120.0	1.13	14.9	8	21.5
		0.5	48.0			2	48.0			2	
Santa Rosa Ridge											
808	105	1.0	9.6	1.67	5.3	5	0			8	12
		0.5	8			2	0			2	
809	225	1.0	49.9	1.95	29.7*	8	44.0	1.21	11.5	8	31.5
		0.5	8.0			2	0			2	
Tanner Bank											
815	100	1.0	12.0	2.13	12.7	8	12.0	3.20	18.0*	8	30
		0.5	0			2	0			2	
818	188	1.0	0	—	—	1	2.0	0	7.0	8	—
		0.5	0			1	8.0			2	
817	519	1.0	2.0	0	7.0	8	0	—	—	8	31.5
		0.5	0			2	0			2	

* = Significant value ($\chi^2 \geq 19.0$), $\alpha = 0.05$.

is interpreted cautiously. Seasonal differences in population density were not significantly different (Mann-Whitney U_s, $\alpha = 0.05$) at any of the sites sampled, even though at Stations 808, 817, and 818, specimens were collected at one season but not the other (Table 2).

At the mainland shelf sites (Stations 801, 819), most often the densities in the 0.5-mm fraction were greater than in the 1.0-mm fraction; in the Station 819 summer sample nearly 99% of the specimens were in the 0.5-mm fraction. These small specimens, mostly juveniles, may be evidence of recruitment, but none of the other summer samples contained such densities of juveniles.

To understand the spatial variation of *P. tenuisculpta*, three separate sample sets, each collected at a different spatial scale, were analyzed. Populations collected during the Benchmark Study (scale = 1 km) (Table 2) generally showed a tendency towards randomness; 13 samples were randomly dispersed and only 4 were aggregated among the replicates. There were no apparent effects of density or presence of juveniles on aggregation.

Using SCCWRP data (Table 3), 10 samples were selected to represent each of three zones along sewage outfall gradients: "control," "transition," and "contaminated." Samples collected on a large scale (>1 km) indicated that the populations of *P. tenuisculpta* from all zones were highly aggregated. However, when sets of 10 replicates (scale ≈ 20 m) were analyzed, the populations were randomly dispersed except in the "transition" zone where they exhibited aggregated dispersions and were most dense.

To summarize the results from these three sample sets, it appears that patches of *P. tenuisculpta* may exist at several scales. In "control" or "normal" areas, patches were detected at the kilometer scale, but near sewage outfalls, in the "transition" zone, patches apparently were more densely packed. The cause of this change in population structure in the "transition" zone is not clear.

Table 3

Average densities and indices of dispersion for two different sets of data on *Parvilucina tenuisculpta* from mainland shelf areas. N = 10.

Station	Mean density (No./m²)	I_δ	χ^2
Between zones, km scale			
Normal	84	3.49	215.3*
Transition	1304	1.64	877.0*
Contaminated	243	2.60	400.4*
Within zones, m scale			
Normal			
3-3	15	1.05	9.7
4-3	56	0.99	8.6
22-2	25	0.90	6.6
24-2	59	0.95	13.4
Transition			
5-4	3568	1.03	115.6*
59	1844	1.03	56.5*
8-3	424	1.16	74.3*
Contaminated			
7-3	25	1.23	14.6

* = Significant value ($\chi^2 \geq 19$; $\alpha = 0.05$).

Diet

Parvilucina has been collected to a depth of 6 cm below the surface (Balcom, 1980) indicating that it may feed at or below the sediment surface. This species has a short incurrent siphon and a muscular pharynx. In some of the specimens examined, the mantle cavity and ctenidia contained many large (>50 μm) single mineral particles. In three specimens examined from the offshore insular shelf (Stations 805, 806), the pharynx contained 2–5 of these particles (59–216 μm). The digestive tracts contained mostly detrital aggregates (aggregations of clay mineral particles, organic material, and microbes). By volume, mineral particles up to 100 μm occurred in the gut contents (Figure 4). No spatial or temporal variation in gut contents was observed in the 20 specimens examined.

It is believed that *P. tenuisculpta* ingests primarily organic rich detrital aggregates from fine sediment on the mainland shelf, but in areas where coarser sediments predominate (offshore shelves, ridges and banks) it may ingest larger single mineral particles, either to remove organic encrustations and microbes or to use as "mill stones" in the pharynx to crush other food items.

Preliminary analysis of the tissues of *Parvilucina* has revealed the presence of endosymbiotic bacteria that can oxidize sulfide to obtain metabolic energy (Felbeck *et al.*, 1981). Populations of *P. tenuisculpta* living near outfalls may utilize this alternative energy source in addition to normal food resources, which could explain the reported increase in size of the clams living near the outfalls (Word *et al.*, 1977).

Macrofaunal Associates

Determination of the organisms associated with *Parvilucina tenuisculpta* has been made for the two dissimilar

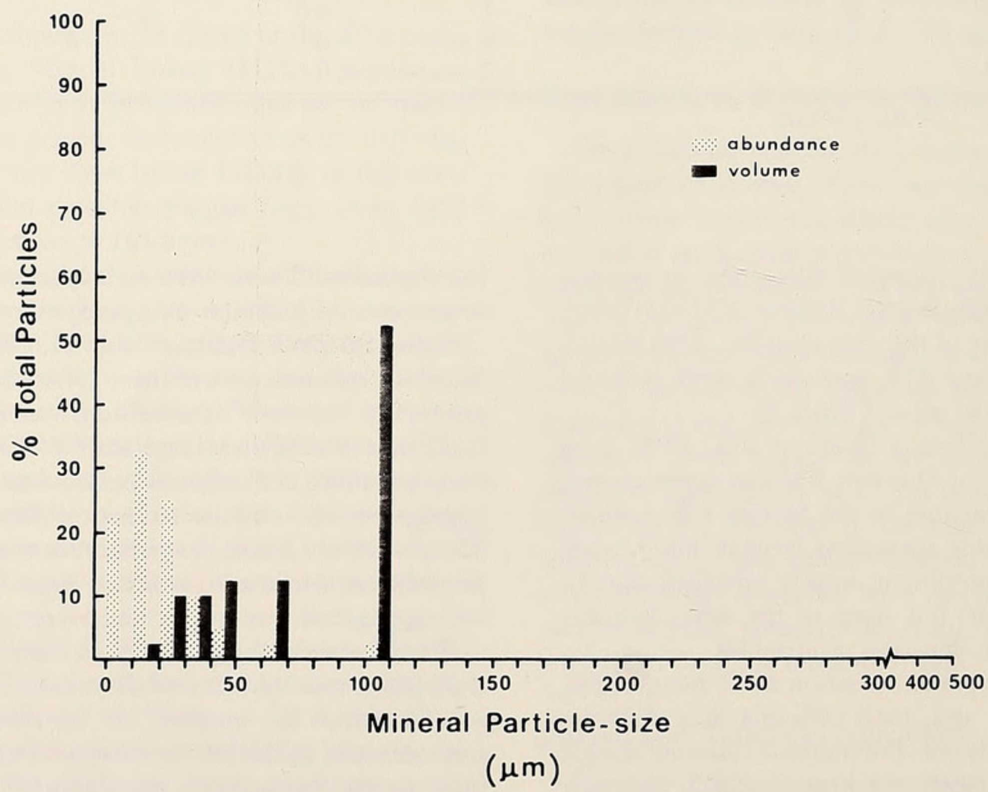

Figure 4

Average mineral particle-size distribution from guts of *Parvilucina tenuisculpta* collected from the insular shelves.

Table 4a

The numerically dominant faunal associates of *Parvilucina tenuisculpta* in 10 representative samples from the Huntington-Laguna High Density Sampling Area. Abbreviations: crust. = crustacean; gastro. = gastropod; pelecy. = pelecypod; poly. = polychaete; and oph. = ophiuroid.

Rank	Name of species	Major taxon	Density (No./m^2) (mean ± SD)	Frequency
1	*Euphilomedes producta*	crust.	1212 (±2076.1)	0.5
2	*Euphilomedes carcharodonta*	crust.	630 (±698.9)	0.9
3	*Parvilucina tenuisculpta*	pelecy.	279 (±126.9)	1.0
4	*Lumbrineris* spp. (6 species)	poly.	134 (±144.0)	0.9
5	*Mediomastus californiensis*	poly.	130 (±115.9)	1.0
6	*Amphiodia urtica*	oph.	122 (±90.8)	1.0
7	*Prionospio cf. malmgreni*	poly.	114 (±99.0)	0.9
8	*Axinopsida serricata*	pelecy.	94 (±61.7)	1.0
9	*Glycera* spp. (4 species)	poly.	91 (±44.7)	0.9
10	*Heterophoxus oculatus*	crust.	75 (±81.6)	0.7
11	*Pectinaria californiensis*	poly.	72 (±114.8)	0.7
12	*Macoma yoldiformis; Macoma* sp.	pelecy.	62 (±52.8)	0.9
13	*Mysella tumida*	pelecy.	48 (±44.9)	0.9
14	*Compsomyax subdiaphana*	pelecy.	30 (±37.5)	0.6
15	*Tellina carpenteri*	pelecy.	18 (±19.5)	0.6
15	*Westwoodilla caecula*	crust.	18 (±19.5)	0.6
15	*Rictaxis punctocoelata*	gastro.	18 (±20.8)	0.5

Table 4b

The numerically dominant faunal associates of *Parvilucina tenuisculpta* in 10 representative samples from the mainland shelf of Santa Monica Bay and San Pedro Bay. Abbreviations as in Table 4a.

Rank	Name of species	Major taxon	Density (No./m^2) (mean ± SD)	Frequency
1	*Parvilucina tenuisculpta*	pelecy.	789 (±734.1)	1.0
2	*Axinopsida serricata*	pelecy.	378 (±460.4)	0.9
3	*Euphilomedes carcharodonta*	crust.	158 (±174.3)	0.7
4	*Lumbrineris* spp. (2 species)	poly.	93 (±92.8)	0.9
5	*Pectinaria californiensis*	poly.	78 (±88.4)	0.7
6	*Heterophoxus oculatus*	crust.	69 (±89.5)	0.5
7	*Glycera* sp.	poly.	50 (±49.6)	0.9
8	*Prionospio cf. malmgreni*	poly.	46 (±47.7)	0.6
9	*Tellina carpenteri*	pelecy.	22 (±23.9)	0.7
9	*Mysella tumida*	pelecy.	22 (±43.7)	0.5
11	*Goniada* sp.	poly.	19 (±22.4)	0.5

borderland environments where it is most frequent and abundant, the mainland shelf and the Channel Islands shelf. The faunal composition of four representative sample sets, one from each of the areas, has been examined: on the mainland shelf, the Huntington Beach HDSA (Table 4a) and the Santa Monica Bay and San Pedro Bay shelves (Table 4b) and on the insular shelf, the San Miguel HDSA (Table 4c) and the Santa Rosa HDSA (Table 4d). The 10 samples selected to represent each area were those in which *Parvilucina* was most abundant.

The numerically dominant taxa varied considerably and only a few were dominant in all four areas; these included the polychaetes *Prionospio cf. malmgreni, Lumbrineris* spp. and *Glycera* spp., and the mollusk *Tellina carpenteri.* Several other species were numerically dominant in three of the four areas, including the polychaete *Pectinaria californiensis,* the crustaceans *Euphilomedes carcharodonta* and *Heterophoxus oculatus,* and the echinoderm *Amphiodia urtica.*

Species richness was somewhat greater at the insular shelf locations (Santa Rosa Island sample set, 250 taxa; San Miguel Island sample set, 198 taxa) than at the mainland shelf locations (Santa Monica Bay-San Pedro Bay sample set, 184 taxa; Huntington Beach sample set, 166

Table 4c

The numerically dominant faunal associates of *Parvilucina tenuisculpta* in 10 representative samples from the San Miguel Island High Density Sampling Area. Abbreviations as in Table 4a.

Rank	Name of species	Major taxon	Density (No./m^2) (mean ± SD)	Frequency
1	*Parvilucina tenuisculpta*	pelecy.	256 (±109.7)	1.0
2	*Amphiodia urtica*	oph.	237 (±158.0)	1.0
3	*Paraphoxus bicuspidatus*	crust.	51 (±32.6)	0.9
4	*Lumbrineris* spp. (7 species)	poly.	50 (±56.1)	0.7
5	*Prionospio cf. malmgreni*	poly.	48 (±29.5)	0.9
6	*Onuphis* spp. (2 species)	poly.	40 (±66.1)	0.6
7	*Ampelisca pacifica*	crust.	37 (±22.9)	1.0
8	*Heterophoxus oculatus*	crust.	35 (±31.8)	0.7
9	*Pista* sp. B; *Pista* sp.	poly.	34 (±25.2)	0.9
10	*Mediomastus californiensis*	poly.	32 (±37.2)	0.5
11	*Tellina carpenteri*	pelecy.	30 (±36.8)	0.7
11	*Tomburchus redondoensis*	pelecy.	30 (±28.1)	0.6
13	*Amphissa undata*	gastro.	29 (±29.0)	0.7
13	*Dougalopus amphicantha*	oph.	29 (±27.5)	0.6
13	*Glycera* spp. (2 species)	poly.	29 (±36.5)	0.6
16	*Aricidea cf. longicirrata*; *Aricidea* sp.	poly.	24 (±27.0)	0.8
16	*Nephtys ferruginea*	poly.	24 (±22.9)	0.6
18	*Notomastus* spp. (2 species)	poly.	22 (±23.9)	0.7
18	*Aoroides columbiae*	crust.	22 (±29.7)	0.5
20	*Polycirrus* sp.	poly.	21 (±25.8)	0.5
21	*Leptochelia* sp.	crust.	19 (±21.2)	0.5
22	*Pholoe glabra*	poly.	18 (±13.3)	0.7
22	*Byblis veleronis*	crust.	18 (±20.8)	0.5
24	*Pectinaria californiensis*	poly.	16 (±14.3)	0.6

Table 4d

The numerically dominant faunal associates of *Parvilucina tenuisculpta* in 10 representative samples from the Santa Rosa Island High Density Sampling Area. Abbreviations as in Table 4a.

Rank	Name of species	Major taxon	Density (No./m^2) (mean ± SD)	Frequency
1	*Parvilucina tenuisculpta*	pelecy.	602 (±488.9)	1.0
2	*Lumbrineris* spp. (4 species)	poly.	101 (±81.6)	1.0
3	*Euphilomedes carcharodonta*	crust.	91 (±211.7)	0.5
4	*Tellina carpenteri*	pelecy.	78 (±78.2)	0.9
5	*Nephtys* spp. (3 species)	poly.	54 (±69.5)	0.7
6	*Pholoe glabra*	poly.	51 (±60.6)	0.6
7	*Glycera oxycephalis*; *Glycera* sp.	poly.	45 (±63.5)	0.7
7	*Ampelisca pugetica*	crust.	45 (±75.3)	0.6
9	*Amphiodia urtica*	oph.	38 (±35.2)	0.6
10	*Aricidea wassi*; *Aricidea* sp.	poly.	35 (±34.9)	0.7
11	*Driloneris falcata*	poly.	26 (±32.2)	0.5
11	*Prionospio cf. malmgreni*	poly.	26 (±35.2)	0.5
13	*Pista* sp. B; *Pista* sp.	poly.	22 (±24.9)	0.6
14	*Byblis veleronis*	crust.	21 (±21.5)	0.5
15	*Artacamella hancocki*	poly.	18 (±16.6)	0.6

taxa). In all four areas, over half of the taxa were recorded only once in the respective sample sets, indicating a relatively high level of diversity in all of these areas.

SUMMARY AND DISCUSSION

The pelecypod *Parvilucina tenuisculpta* is an important, widely distributed member of the benthos of the southern

California borderland, where it is a prominent faunal element of every major habitat type except the deep basins. The population densities of this species were highest in two very dissimilar environments—the insular shelf of the northern Channel Islands and the central part of the mainland shelf (Santa Monica Bay and San Pedro Bay). The insular shelf is primarily a non-depositional environment. Relatively strong currents result in the winnowing of finer detrital sediments, and the development of coarse sediments rich in biogenic calcium carbonate components. The area is influenced by persistent upwelling. By contrast, the parts of the mainland shelf where densities are highest are in environments highly influenced by man's activities, particularly the release of sewage wastewaters into the marine environment.

Parvilucina appears to exhibit little temporal variation, but the data are indequate to make firm conclusions. Populations of *Parvilucina* are patchy on a large scale (km), but within patches they are usually randomly dispersed, except in the areas near sewage outfalls, where the scale of heterogeneity is approximately 20 m and densities are the highest measured in the region. The reasons for this change in population structure are not clear.

A diverse array of macrofaunal taxa is associated with *Parvilucina*. The numerically dominant taxa varied considerably from location to location, and only a few were dominant in the four representative sample sets examined in this study.

Parvilucina has been identified as a co-dominant element in a faunal assemblage on the Santa Rosa-Cortes Ridge. Combining the results derived from classification and recurrent group analysis, FAUCHALD & JONES (1979b) identified 13 species groups from the continental borderland. Four of these groups were on the Santa Rosa-Cortes Ridge and Tanner Bank (Stations 805, 806, 809, 815, 816, and 818). Three of the groups were ophiuroid-dominated assemblages: the *Amphiodia urtica* assemblage; the *Amphipholis squamata-Golfingia minuta* assemblage and the *Amphiura acrystata-Ampelisca cristata* assemblage. The fourth assemblage, the *Lumbrineris cruzensis-Parvilucina tenuisculpta* assemblage, is a loosely aggregated species group that occurred at most of the offshore stations. The principal faunal components of this assemblage are: the polychaetes *Chloeia pinnata, Decamastus gracilis, Acesta caterinae, Acestra cf. assimilis, Glycera tesselata, Travisia brevis,* and *Euchone hancocki*; the mollusks *Amphissa undata* and *Tomburchus redondoensis*; the crustaceans *Byblis veleronis, Ampelisca pugetica, Diastylis* sp. A., *Maera simile,* and *Photis lacia*; and the echinoderm *Amphiodia urtica*. Only half of these species occurred in the two mainland shelf sample-sets, all at a frequency of 4 or less out of 10 samples, whereas 75% of them were present in the two insular shelf sample sets at frequencies up to 7 samples out of 10 (Tables 4a–d).

Ecologically *Parvilucina* appears to be able to live in a fairly wide range of environments populated by a large number of other taxa which may differ markedly from one location to another.

The two most interesting questions concerning the ecology of *Parvilucina* on the borderland are: (1) why have the frequency and abundance of this species on the mainland shelf increased so dramatically (from a mean of 12.0/m^2 to 186.5/m^2) in approximately 20 years? and (2) what factor or factors lead to a high density of this species in two areas that are quite dissimilar in most respects?

The load of wastewaters contributed to the marine environment has increased markedly over the last 20 years, and this change could easily explain the elevated population densities of *Parvilucina* on the affected parts of the mainland shelf.

The insular shelf, an area of clean water, also is an area of high organic enrichment, although the source of this enrichment, upwelling, is very different from that on the central portion of the mainland shelf. In another upwelling area, at Point Conception on the mainland shelf, population densities also are high.

Parvilucina ingests fine detrital aggregates. It may feed at the sediment surface, or below the surface, and may process large mineral particles to obtain food. This species also may use endosymbiotic bacteria to oxidize sulfide near outfalls, thereby deriving additional energy, which may allow it to grow larger than in other areas.

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