Rocky Intertidal Community Structure on Santa Barbara Island and the Effects of Wave Surge on Vertical Zonation

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Abstract - Rocky intertidal community structure was investigated at a site on the east shoreline of Santa Barbara Island, California by quarterly sampling over a 2-1/2 yr period. Zonational patterns of the macrobiota were determined by cluster analysis using percent cover data obtained from permanent quadrats established during the initial site visit. The resultant taxonomic and descriptive ecological data are discussed herein. Despite the fact that the study area was located on the leeward (sheltered) side of the island and did not receive direct wave shock, zonation of the biota was shifted dramatically upward. This elevated zonation is hypothesized to be the result of a persistent wave surge produced by refraction of the prevailing northwesterly swell around the northern and southern ends of the island. Vertical distributions of the dominant species of macrophytes and macroinvertebrates were compared between Santa Barbara Island and similar leeward sites on Santa Catalina Island (moderate surge impact) and San Clemente Island (low to negligible surge). For all species examined, vertical ranges were highest at Santa Barbara Island, intermediate at Santa Catalina Island and lowest at San Clemente Island.

Introduction

Santa Barbara Island is the smallest of the islands off southern California and, because of its size, is especially vulnerable to human perturbation. The island has been protected by National Monument status since 1938 and National Park status since 1980. It has a rugged terrain and is exposed to the prevailing northwesterly winds and swell. Also, it is isolated from the mainland and other islands; the nearest land mass is Santa Catalina Island, nearly 40 km away. Despite the unique character of the island, there are no published studies on the macrobiota of its rocky intertidal zone. The only related research (Nicholson & Cimberg 1971) is a survey of subtidal macrophytes from a site on the east side of the island.

The present paper is based on undisturbed, repetitively-sampled quadrat data collected over a 2-1/2 yr period at a site on the leeward side of the island. Details of this study are contained in chapters by Seapy & Littler (1977, 1978a and 1979) from the annual project reports to the Bureau of Land Management (now Minerals Management Services), Outer Continental Shelf Program, U.S. Department of the Interior. Biogeographical analyses of the rocky intertidal biota from the Southern California Bight (Seapy & Littler 1980, for macro-invertebrates; Murray *et al.* 1980, for macrophytes) also utilized this data base. These studies concluded that Santa Cruz Island had the strongest faunistic and floristic affinities with Santa Barbara Island. In turn, Santa Barbara and Santa Cruz Islands were intermediate between two southern islands (Santa Catalina and San Clemente Islands) with warm-water affinities and three northern and offshore islands (Santa Rosa, San Miguel and San Nicolas Islands, respectively) with cold-water affinites. The species records that served as the basis for the study by Seapy & Littler (1980) are included in this volume (Seapy & Littler 1993).

The study site on Santa Barbara Island was situated on the eastern side of the island, sheltered from the prevailing northwesterly winds and seas. In contrast with other sites investigated during the BLM Outer

Continental Shelf Program that also were located on the leeward sides of islands, zonation of the biota at Santa Barbara Island appeared to be shifted upward. This elevated zonation is hypothesized to result primarily from wetting of the shore by a persistent wave surge produced by refraction of the northwesterly swell around the northern and southern ends of the island. Further, vertical ranges of component species would appear to be expanded secondarily upshore by a reduction in desiccation stress, resulting from afternoon shading of the intertidal zone by steep cliffs located immediately behind the narrow shoreline.

Study Area

Santa Barbara Island is the smallest (2.6 km^2) of the islands off the southern California coast (Philbrick 1967) and is distant from the mainland (about 61 km) and the other islands in the Southern California Bight; Santa Catalina Island (39 km to the east), San Nicolas Island (44 km to the southwest) and Anacapa Island (65 km to the northwest) (Fig. 1). The island is a marine terrace, sloping west to east with high vertical cliffs on its northern and western sides.

Santa Barbara Island is part of the Channel Islands National Park, established in 1980 by the National Park Service. Although Indians

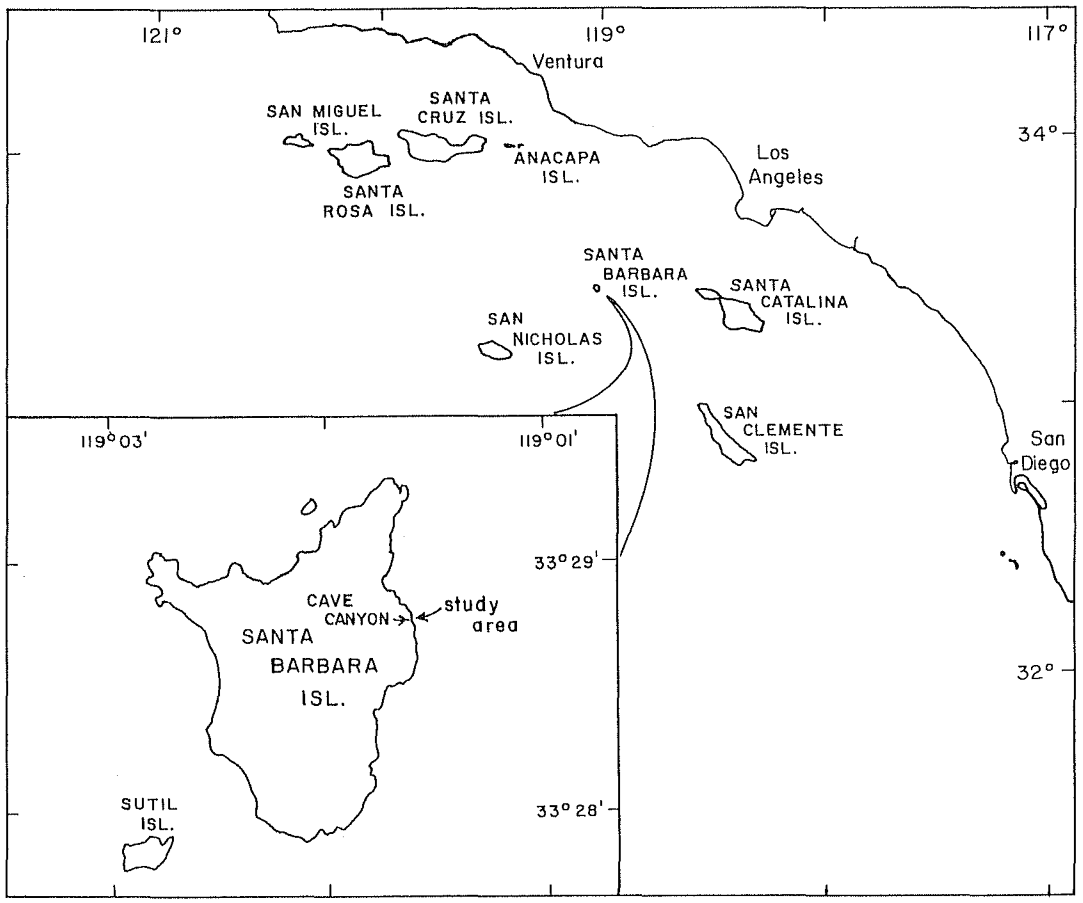

Figure 1. Location of Santa Barbara Island in the Southern California Bight and (inset) study area at Cave Canyon, Santa Barbara Island.

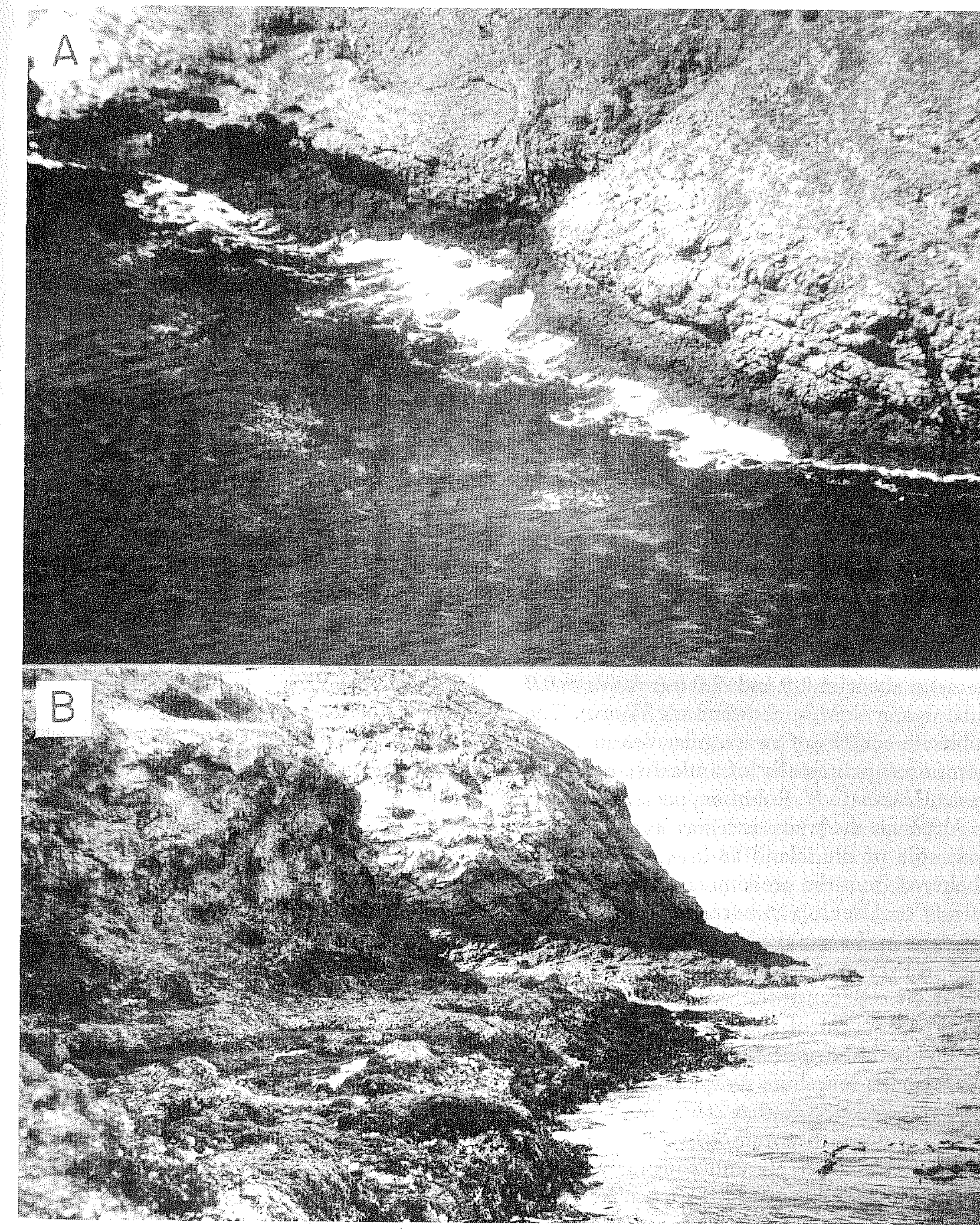

Figure 2. (A) Aerial photograph of study area on Santa Barbara Island. The diagonal indentation in the cliffs (upper center of photograph) marks Cave Canyon. (B) Northward view of shoreline at study site. Steep bluffs are located immediately shoreward of the narrow intertidal bench. The mouth of Cave Canyon is situated between the two bluffs.

used the island prior to the 1900's, they established no permanent settlements. Livestock were allowed to graze and forage crops were raised on the island during the first quarter of this century. However, human impact has been limited since the establishment of the Channel Islands National Monument in 1938. The island became an aircraft early-warning outpost for the U.S. Navy during World War II, and in the 1950's the Navy used the island as a missile photographic tracking station. The National Park Service presently maintains a quonset hut and a primitive camping area on the east side of the island. Park Rangers perform the important service of educating visitors about preservation of the fragile terrestrial ecosystem.

The study area is located on the east coast of the island (Fig. 1) at the mouth of Cave Canyon (33°28'43"N, 119°01'36"W). The rocky intertidal zone consists of a narrow, sloping bench 5-15 m in width that extends from the base of a 40-50 m high cliff to an abrupt dropoff into the subtidal zone (Fig. 2), at a tidal level between about +1.0 ft and -2.0 ft (relative to 0.0 tidal datum at Mean Lower Low Water). The substrate consists of an irregular volcanic rock composed principally of andesitic tachylite vesicular lava (C. V. Robinson, pers. comm.).

Although the study area was located on the east side of the island and, as a result, was sheltered from the predominant northwesterly winds and seas, a substantial wave surge (evident in the aerial photograph of the study area in Fig. 2A) was consistently present at the study site. Because the wave surge resulted from refraction of the northwesterly swell around both the northern and southern ends of the island, a longshore movement of the surge across the study site that came from both the north and south commonly was observed. Where the northerly and southerly surges converged, they reinforced each other, thus accentuating the height that the surge rose on the shore. These surge conditions made work on the lower portion of the intertidal bench either difficult or impossible. An extensive bed of kelp (*Macrocystis pyrifera*) was situated immediately offshore from the study area. The kelp bed appeared to dampen surface turbulence, but not to reduce the impact of the surge on the intertidal zone. Surge conditions prohibited access to the lower shore during winter (January) and spring (April) in 1976 when surge height averaged about 6 ft (2 m). During winter and spring in 1977, the surge averaged about 4 ft (1.3 m) and made sampling of the lower shore difficult. Surge was minimal during summer, averaging 2 ft (0.6 m) and 2.5 ft (0.8 m) for 1975 and 1976, respectively. The fall periods experienced intermediate surge conditions of 5 ft (1.5 m) and 2.5 ft (0.8 m) for 1975 and 1976, respectively.

Materials and Methods

Species abundances (percent cover for macrophytes; percent cover and density for macroinvertebrates) were assessed by means of a stratified quadrat sampling design. Because the study area consisted of a narrow sloping bench, it was necessary to select several locations where the slope was gradual enough to accomodate an adequate length of transect line oriented perpendicular to the shoreline. Four such locations were chosen, ranging in length from 7 m on the North transect line to 10 m on the South line. With reference to the mouth of Cave Canyon, the North transect line was situated 79 m to the north, the Middle North line was 7 m to the north within the small cove formed at the mouth of the canyon (Fig. 2B), and the Middle South and South lines were 19 m and 24 m, respectively, to the south along a relatively broad and uniformly sloping section of the shoreline (Fig. 2B). During the initial visit in August 1975, the North, Middle North and South transect lines were established. The Middle South line was added in November 1975.

The upper end (0 m) of each transect line was established by permanently affixing an eyebolt in the substratum at a level on the shore above which marine macroorganisms were absent. Each transect line was oriented at right angles to the shoreline and permanent quadrats were established at 1.0 m intervals along each line to the maximal distance down the beach where sampling could be accomplished. The precise location of each quadrat was marked by driving studs into the rock at the quadrat's center and one of the corners; usually the upper left. A plastic tie-wrap was attached to the center stud to assist in subsequent relocation of each quadrat and to distinguish the center from the corner studs.

The shore profile varied among the four transect lines. The North line had a relatively constant slope of 16° and extended downshore from +10.5 ft to a steep dropoff at about +1.0 ft into the subtidal zone. As a result the lowest permanent quadrat that could be sampled safely and consistently was at +2.0 ft. The Middle North line extended from +9.5 ft to +2.3 ft, below which the shoreline dropped off steeply. The upper half of the shore sloped evenly (about 20°), while the lower half consisted of a series of three platforms. The Middle South and South lines were located on an extended and relatively broad area. The Middle South line reached from +10.8 ft to +1.7 ft and sloped steeply (26°) along the upper one-fourth of its length, while the remainder of the line was at a 10° slope. The South line extended from +11.9 ft to +3.1 ft, with about a 16° slope along its length. Seaward of the last quadrats on both the Middle South and South lines, the substratum dropped off precipitously into the subtidal zone. Due to the surge encountered on the lower shore, the lowermost quadrats were usually difficult to work even during minus tide periods.

Table 1. Number of quadrat replicates in 1-ft tidal intervals at Cave Canyon, Santa Barbara Island during 1975 and 1976 (n = 39) and 1976 to 1978 (n = 42).

Tidal Interval (ft)	No. of Quadrat Replicates 1975-1976	1976-1978
+11.0 to +11.9	1	3
+10.0 to +10.9	3	3
+ 9.0 to + 9.9	2	2
+ 8.0 to + 8.9	4	4
+ 7.0 to + 7.9	4	4
+ 6.0 to + 6.9	3	3
+ 5.0 to + 5.9	4	4
+ 4.0 to + 4.9	5	5
+ 3.0 to + 3.9	7	7
+ 2.0 to + 2.9	3	4
+ 1.0 to + 1.9	3	3

Site visits were made at approximately quarterly intervals in early August, early November, late January and early April during 1975-1976 and 1976-1977. A single visit was made in early April 1978. During the first year of study the number of quadrats from which abundances of the macrobiota were censused increased from 30 during August 1975 to 39 in November 1975, but then decreased to 30 in both January and April 1976. The reduction in number of quadrats sampled in January and April was due to the presence of the extremely heavy surge conditions discussed above.

For the determination of species abundances as a function of tidal height (methods described below), the quadrats were grouped into 1.0 ft tidal intervals (Table 1). Due to the steep slope of the upper beach, the +11.0 to +11.9 ft interval was represented by only one quadrat. To increase the number of replicates in this tidal interval to three, two quadrats were added 1.0 m away from, and at right angles to, the second highest quadrat on the Middle South line during the initial visit of the second year of the study (August 1976). Similarly, a quadrat was positioned 1.0 m to the south of the second lowest quadrat on the Middle North line to increase the number of replicates in the +2.0 to +2.9 ft tidal interval from three to four. After these quadrat additions, a total of 43 permanent quadrats were available. During the 1976-1977 and April 1978 site visits, all 43 quadrats were sampled, except for August 1976 when 41 were utilized. Over the course of the study a grand total of 352 quadrats were assessed.

During each site visit the quadrats were censused for macrophyte cover and for macroinvertebrate cover and density by methods summarized below. Further details are given elsewhere (Seapy & Littler 1978b; Littler

1980). In the field, each quadrat was photographed with Kodachrome color transparency film (ASA 64) and Kodak infrared film. Field sketches were made of the distribution of each algal species in each quadrat as an aid to the subsequent determination of percent cover in the laboratory by a point-intercept method from the projected quadrat photographs. The infrared slides were particularly useful in determining the presence of blue-green algae (Cyanobacteria) and aided in discrimination of the different species of Rhodophyta which could not be separated in the color slides. Invertebrate densities were determined visually in the field and recorded directly on waterproof paper. Percent cover of invertebrate taxa was determined in the laboratory by the point-intercept method at the same time that algal cover was assessed.

Abundances of the various taxa were tabulated by quadrats and the quadrats were subsequently arranged into 1.0 ft tidal intervals. Mean abundances of each taxon were then computed for each tidal interval for use in plotting kite diagrams of taxon abundance as a function of tidal height. For each taxon, the mean abundance values for each tidal interval were summed and then divided by the total number of tidal intervals sampled to obtain grand mean abundance values for each taxon during each site visit. Patterns of zonation were determined objectively by cluster analysis of the quadrat samples during each site visit using the percent cover data for the macrophytes and macroinvertebrates. Dominant cover organisms in each cluster group were then selected to characterize each zone identified by the cluster analysis.

Difficulties were encountered in distinguishing certain closely related taxa in the field and abundance data were therefore combined. For the macrophytes two species of *Gelidium* (*G. coulteri* and *G. pusillum*) were combined. Among the invertebrates the small barnacles *Chthamalus fissus* and *C. dalli*, the chitons *Nuttallina fluxa* and *N. californica* and the bivalves *Septifer bifurcatus* and *Brachidontes adamsianus* were combined.

Results

Taxonomic Composition of the Macrobiota: Over the course of the study a total of 195 taxa were sampled, of which 91 were macrophytes (Table 2) and 104 were macroinvertebrates (Table 3). The majority of the macrophytes were Rhodophyta (59 taxa), followed by Phaeophyta (20) and Chlorophyta (8). The macroinvertebrates were dominated by the Mollusca (51 taxa), of which 35 were Gastropoda, 10 were Bivalvia and 6 were Polyplacophora. The Crustacea included 15 taxa, followed by the Porifera (11), Ascidiacea (8), Cnidaria (8) and Echinodermata (7).

Abundance of Taxa: Averaged over the tidal intervals sampled and as a grand mean for the 9 site visits, blue-green algae (Cyanobacteria) contributed the greatest areal coverage (49.0%) in the intertidal zone (Table 4); all other taxa averaged less than 8.0% cover. Blue-greens dominated cover because: 1) the component microscopic filaments form a mat of variable thickness over the rocky substratum as well as over the calcareous shells and plates of molluscs and barnacles and 2) the presence of even a thin layer of blue-greens was detectable by the infrared photographs. In the upper intertidal zone where macroscopic algal cover is low to absent, blue-greens commonly approached 100% cover over the available surfaces. Lower on the shore the presence of high macrophyte cover, combined with the grazing activities of gastropods and chitons, reduced blue-green cover to low levels.

Macrophyte cover was dominated by coralline algae, with a combined average of 19.3% (Table 4). The articulated corallines, *Corallina officinalis* var. *chilensis* (7.6%), *C. vancouveriensis* (4.2%) and *Bossiella orbigniana dichotoma* (1.0%), contributed a greater total cover (10.9%) than the crustose taxa (6.5%), which included *Lithophyllum proboscideum* (5.3%) and *Hydrolithon decipiens* (1.2%). Two species of large brown algae, *Halidrys dioica* and *Egregia menziesii*, were abundant on the lower shore, with average cover values of 5.7% and 2.4%, respectively. Cover by the latter species dropped dramatically between August 1975 (10.9%) and January 1976 (1.5%) and had not recovered by the end of the study (0.3% in April 1978). During both 1975-1976 and 1976-1977, the abundance of *E. menziesii* went from a high level in the fall to a low level in the spring. This pattern of seasonal decline undoubtedly is the result of a loss of stipe tissue during the physically-stressful winter periods and a subsequent recovery between spring and fall. Among fleshy red algae, *Gigartina canaliculata* (3.8%) and *Rhodoglossum affine* (2.0%) were the only taxa that averaged more than 0.7% cover. Like *E. menziesii*, *Iridaea cordata* var. *cordata* declined from an initial high cover (2.4% in August 1975) to low cover (0.9%) in January 1976, and never recovered after that. Ephemeral red algae, *Ceramium* spp., showed an interesting pattern of a high spring abundance during all three years of the study.

Only 13 taxa of macroinvertebrates averaged 0.1% cover or greater (Table 5). In terms of percent cover, sessile forms were dominant, with a combined total of 12.6% for 8 taxa. For the mobile invertebrates, the 6 top-ranked taxa contributed a total of only 1.3% cover. The most important sessile forms were barnacles, which totaled 6.4% cover, and consisted of *Chthamalus fissus* / *C. dalli* (3.3%), *Tetraclita rubescens* (2.1%) and *Pollicipes polymerus* (1.0%). Bivalves totaled 4.7% cover and included *Chama arcana* (2.8%) and *Mytilus californianus* (1.9%). Gastropods, anthozoans and polychaetes were represented by single sessile species; *Petaloconchus montereyensis* (0.7%), *Anthopleura elegantissima* (0.5%) and *Phragmatopoma californica* (0.3%), respectively. Among the mobile macroinvertebrates only the sea urchin *Strongylocentrotus purpuratus* (0.7%) and the small, but numerous, littorine snail *Littorina keenae* (0.3%) contributed cover that averaged greater than 0.1%.

The macroinvertebrate taxa occurring in highest densities (Table 6) were sessile barnacles, which totaled 2,109 individuals m^{-2} and included *Chthamalus fissus* / *C. dalli* (1,389 m^{-2}), *Tetraclita rubescens* (545 m^{-2}) and *Pollicipes polymerus* (175 m^{-2}). One gastropod, *Petaloconchus montereyensis* (324 m^{-2}) and four bivalves, *Mytilus californianus* (151 m^{-2}), *Chama arcana* (42 m^{-2}) and *Septifer bifurcatus* / *Brachidontes adamsianus* (22 m^{-2}) were also important numerically. The remaining taxa were mainly mobile gastropods that totaled 617 m^{-2} and included 10 species, the most abundant of which were *Littorina keenae* (324 m^{-2}), *Siphonaria brannani* (70 m^{-2}), *Macclintockia scabra* (62 m^{-2}), *Lottia pelta* (21 m^{-2}) and *Littorina scutulata* (21 m^{-2}). A long-term pattern of increase was shown by *Littorina keenae*, which increased steadily over the course of the study from 63 m^{-2} in August 1975 to 469 m^{-2} in April 1978. A pattern of general decline was shown for *Mytilus californianus*, from a high of 257 m^{-2} in November 1975 to a low of 75 m^{-2} in April 1977. By April 1978, however, *M. californianus* had recovered slightly (to 116 m^{-2}).

Community Structure and Vertical Zonation: The November 1975 site visit was selected for analysis of community structure because it provided the most complete set of quadrat samples (39) during the first year of study. The August visit was not used because of the low number of quadrats sampled; the Middle South transect line was not established until the November visit. The January and April visits represented incomplete data sets, since the lower shore quadrats were not accessible due to the heavy surge conditions. The dendrogram resulting from the cluster analysis for November indicates 6 major groups distinguished at a correlation coefficient level of 0.50 (Fig. 3). The locations of the quadrats comprising each group along the four transect lines are indicated in Figure 4A using the cluster group symbols from Figure 3. The quadrats have been repositioned in Figure 4B according to their tidal heights. Heavy dashed lines have been added to separate the quadrat groups and define vertical zones on the shore in Figure 4B. These zones occur at approximately the same tidal levels on each of the transect lines, although the zones are

Table 2. Macrophytes sampled at Cave Canyon, Santa Barbara Island between August 1975 and April 1978. Taxa present in transect samples (x) are distinguished from those collected in the vicinity of transect lines (c).

Taxon	1975-1976	1976-1977	1977-1978
Cyanobacteria			
Blue-green algae	x	x	x
Blue-green colony	x	x	x
Bacillariophyta			
Benthic diatoms	x	x	x
Chlorophyta			
Bryopsis corticulans Setch.	x	x	x
Cladophora spp.	x	x	x
Codium fragile (Sur.) Har.	x	x	x
C. hubbsii Daws.	c		c
C. setchellii Gardn.			c
Derbesia marina (Lyngb.) Sol.	c		
Enteromorpha spp.	x	x	
Ulva lobata (Kütz.) S. & G.	x		c
Phaeophyta			
Colpomenia sinuosa (Roth) Derb. & Sol. and *C. peregrina* (Sauv.) Ham.	x	x	x
Cylindrocarpus rugosus Okam.	x	x	x
Desmarestia ligulata var. *ligulata* (Lightf.) Lamour.	x	c	
Dictyopteris johnstonei Gardn.		c	
D. undulata Holmes	x	x	x
Dictyota flabellata (Coll.) S. & G.	x	x	x
Diplura simulans Hollenb.	x	x	x
Ectocarpaceae	x	x	x
Egregia menziesii (Turn.) Aresch.	x	x	x
Eisenia arborea Aresch.	x	x	x
Endarachne binghamiae J. Ag.	x	x	x
Halidrys dioica Gardn.	x	x	x
Hapterophycus canaliculatus S. & G.			x
Macrocystis pyrifera (L.) J. Ag.	x	x	x
Pachydictyon coriaceum (Holmes) Okam.	x	x	x
Petalonia fascia (Müll.) Kuntze	c		
Pseudolithoderma nigra Hollenb.	x	x	x
Ralfsiaceae	x	x	x
Sargassum agardhianum J. Ag.			c
Scytosiphon dotyi Wynne	x	c	c
Rhodophyta			
Acrosorium uncinatum (Turn.) Kyl.	x		
Amphiroa zonata Yendo		x	
Anisocladella pacifica Kyl.	x		
Bossiella orbigniana dichotoma (Manza) Johans.	x	x	x
B. orbigniana orbigniana (Dec.) Silva	x		
Calliarthron tuberculosum (Post. & Rupr.) Daws.	x	x	x
Callophyllis violacea J. Ag.	x		c
Callophyllis sp.	c		
Carpopeltis bushiae (Farl.) Kyl.		c	
Ceramium codicola J. Ag.	x	x	x

Taxon	1975-1976	1976-1977	1977-1978
Rhodophyta (cont.)			
C. eatonianum (Farl.) DeToni and *C. sinicola* S. & G.	x	x	x
C. viscainoense Daws.	x	x	x
Ceramium spp.	x	x	x
Corallina officinalis var. *chilensis* (Dec.) Kütz.	x	x	x
C. vancouveriensis Yendo	x	x	x
Cryptopleura corallinara (Nott.) Gardn.	c		
C. crispa Kyl.	x	x	x
C. violacea (J. Ag.) Kyl.		c	
Cumagloia andersonii (Farl.) S. & G.	c		x
Endocladia muricata (Post. & Rupr.) J. Ag.	x	x	x
Erythrocystis saccata (J. Ag.) Silva	x	x	x
Farlowia mollis (Harv. & Bail.) Farl. & Setch.		c	
Gastroclonium subarticulatum (Turn.) Kutz.	x	x	x
Gelidium coulteri Harv. and *G. pusillum* (Stackh.) Le Jol.	x	x	x
G. purpurascens Gardn.	x	x	x
G. robustum (Gardn.) Hollenb. & Abb.	x	x	x
Gigartina canaliculata Harv.	x	x	x
G. leptorhynchos J. Ag.	x	x	x
G. spinosa (Kütz.) Harv.	x	x	x
Grateloupia doryphora (Mont.) Howe	x	x	x
Haliptylon gracile (Lamour.) Johans.	x	x	x
Herposiphonia plumula (J. Ag.) Hollenb.	x	x	x
H. verticillata (Harv.) Kyl.		x	x
Iridaea cordata var. *cordata* (Turn.) Bory	x	x	x
Jania crassa Lamour.	x	x	x
Laurencia pacifica Kyl.	x	x	x
L. sinicola S. & G.	x	x	x
L. spectabilis Post. & Rupr.	x	x	
Lithothrix aspergillum Gray	x	x	x
Microcladia coulteri Harv.	x		
Nemalion helminthoides (Vell.) Batt.	x	x	x
Peyssonneliaceae/Hildenbrandiaceae	x	x	x
Plocamium cartilagineum (L.) Dix.	x	x	x
P. violaceum Farl.	x	x	x
Polysiphonia acuminata Gardn.		x	x
P. hendryi var. *hendryi* Gardn.	x	x	x
P. scopulorum var. *villum* (J. Ag.) Hollenb.			x
Polysiphonia spp.	x	x	x
Porphyra perforata J. ag.	x	x	x
Prionitis angusta (Harv.) Okam.	c		
P. lanceolata (Harv.) Harv.	x	x	x
Pterocladia capillacea (Gmel.) Born. & Thur.	x	x	x
Pterosiphonia baileyi (Harv.) Falk.	x	x	x
P. dendroidea (Mont.) Falk.	x	x	x
Rhodoglossum affine (Harv.) Kyl.	x	x	x
R. californicum (J. Ag.) Abb.	x	x	x
Rhodymenia pacifica Kyl.	x		
Sarcodiotheca gaudichaudii (Mont.) Gabr.		c	
Schizymenia pacifica (Kyl.) Kyl.	c		
Spermatophyta			
Phyllospadix scouleri Hook.	c	c	c

Table 3. Macroinvertebrates sampled at Cave Canyon, Santa Barbara Island between August 1975 and April 1978. Taxa present in quadrat samples (x) are distinguished from those collected in the vicinity of transect lines (c).

Taxon	1975-1976	1976-1977	1978
Porifera			
Calcarea			
Clathrina coriacea (Montagu, 1818)		c	
Leucandra heathi Urban, 1905	c	c	
Leucetta losangelensis (de Laubenfels, 1930)		c	
Leucosolenia nautilia de Laubenfels, 1930		c	
Scypha sp.		c	
Demospongiae			
Haliclona sp.		c	
Leptoclathria asodes (de Laubenfels, 1930)		c	
Penares cortius de Laubenfels, 1930		c	
Plocamia karykina (de Laubenfels, 1927)		c	
Pachastrella dilifera de Laubenfels, 1934		c	
Stelletta clarella de Laubenfels, 1930		c	
Cnidaria			
Hydrozoa			
Campanularia/Phialidium sp.			x
Eudendrium sp.	x		
Plumularia sp.			x
Sertularella spp.	x	c	
Sertularia spp.	x	c	
Syncoryne eximia (Allman, 1859)			x
Anthozoa			
Anthopleura elegantissima (Brandt, 1835)	x	x	x
Corynactis californica Carlgren, 1936		x	x
Mollusca			
Polyplacophora			
Callistochiton crassicostatus Pilsbry, 1893	x		
Chaetopleura gemma Dall, 1879		c	c
Cyanoplax hartwegii (Carpenter, 1855)	x	x	x
Mopalia muscosa (Gould, 1846)	x		c
Nuttallina californica (Reeve, 1847)			
and *N. fluxa* (Carpenter, 1864)	x	x	x
Gastropoda			
Aeolidia papillosa (Linnaeus, 1761)		c	
Aplysia californica Cooper, 1863		x	x
Ceratostoma nuttalli (Conrad, 1837)	x	x	x
Crepipatella lingulata Gould, 1846	x	x	c
Dendropoma lituella Morch, 1861			
and *D. rastrum* Morch, 1861		c	
Doriopsilla albopunctata Cooper, 1863		c	
Epitonium tinctum (Carpenter, 1864)	x	x	x
Fissurella volcano Reeve, 1849	x	x	x
Haliotis sp. (juvenile)	x	x	x
Hipponix cranioides Carpenter, 1864	x		x
Homalopoma baculum (Carpenter, 1864)	x		x
H. luridum (Dall, 1855)	x	x	x
Lacuna unifasciata Carpenter, 1857	x		
Littorina keenae Rosewater, 1978	x	x	x
[=*L. planaxis* Phillippi, 1847]			
L. scutulata Gould, 1849	x	x	x
Lottia conus (Test, 1945)	x	x	x
[=*Collisella conus*]			
L. digitalis (Rathke, 1833)	x	x	x
[=*Collisella digitalis*]			
L. gigantea Sowerby, 1834	x	x	x
L. limatula (Carpenter, 1864)	x	x	x
[=*Collisella limatula*]			
L. pelta (Rathke, 1833)	x	x	x
[*Collisella pelta*]			
L. strigatella (Carpenter, 1864)	x	x	x
[=*Collisella strigatella*]			
Macclintockia scabra (Gould, 1846)	x	x	x
[=*Collisella scabra*]			
Maxwellia gemma (Sowerby, 1879)			c

Taxon	1975-1976	1976-1977	1978
Mollusca (cont.)			
Mitra idae Melville, 1893		x	
Mitromorpha carpenteri Glibert, 1954	x		c
Norrisia norrisi (Sowerby, 1838)		c	
Ocenebra circumtexta Stearns, 1871	x	x	x
O. gracillima Stearns, 1871		c	x
Opalia funiculata (Carpenter, 1864)		c	c
Petaloconchus montereyensis Dall, 1919	x	x	x
Seila montereyensis (Bartsch, 1907)	x	c	
Serpulorbis squamigerus (Carpenter, 1857)	x	x	x
Siphonaria brannani (Stearns, 1873)	x	x	x
Triphora pedroana Bartsch, 1907		c	
Bivalvia			
Brachidontes adamsianus (Dunker, 1857)			
and *Septifer bifurcatus* (Conrad, 1837)	x	x	x
Chama arcana Bernard, 1976	x	x	x
Glans subquadrata (Carpenter, 1864)	x	x	
Hiatella arctica (Linnaeus, 1767)		c	x
Hinnites giganteus (Gray, 1825)		c	
Lasaea subviridis Dall, 1899		c	
Modiolus capax (Conrad, 1837)	x	c	
Mytilus californianus Conrad, 1837	x	x	x
M. edulis Linnaeus, 1758	x	x	c
Annelida			
Polychaeta			
Phragmatopoma californica (Fewkes, 1889)	x	x	x
Spirobranchus spinosus Moore, 1923	x	x	x
Spirorbis spp.	x	x	x
Vermiliopsis infundibulum (Philippi, 1844)		c	
Arthropoda			
Crustacea			
Balanus glandula Darwin, 1854	x	x	x
Cancer antennarius Stimpson, 1856	x	x	
Chthamalus dalli Pilsbry, 1916			
and *C. fissus* Darwin, 1854	x	x	x
Lophopanopeus leucomanus heathi Rathbun, 1900	x		x
Megabalanus californicus (Pilsbry, 1916)	x	x	x
Pachycheles rudis Stimpson, 1859	x		
Pachygrapsus crassipes Randall, 1839	x	x	x
Pagurus hirsutiusculus venturensis Coffin, 1957	c		
P. samuelis (Stimpson, 1859)	x		x
Paraxanthias taylori (Stimpson, 1860)	x	x	x
Pollicipes polymerus Sowerby, 1833	x	x	x
Pugettia producta (Randall, 1839)	x	x	
P. richii Dana, 1851		c	
Tetraclita rubescens Darwin, 1854	x	x	x
Echinodermata			
Asteroidea			
Astrometis sertulifera (Xantus, 1860)		c	
Henricia leviuscula (Stimpson, 1857)	x	x	x
Leptasterias hexactis (Stimpson, 1862)	x		
Pisaster giganteus (Stimpson, 1857)			x
P. ochraceus (Brandt, 1835)	x	x	c
Echinoidea			
Strongylocentrotus purpuratus (Stimpson, 1857)	x	x	x
Holothuroidea			
Pseudocnus californicus (Semper, 1868)	x	x	x
Chordata: Urochordata			
Ascidiacea			
Aplidium californicum (Ritter & Forsyth, 1917)		c	
Archidistoma psammion (Ritter & Forsyth, 1917)		c	x
A. ritteri Van Name, 1945	c	x	
Didemnum carnulentum (Ritter & Forsyth, 1917)		c	
Diplosoma macdonaldi Herdman, 1886		x	
Molgula verrucifera Ritter & Forsyth, 1917			x
Ritterella aequalisiphonis (Ritter & Forsyth, 1917)		c	
Synoicum parfustis (Ritter & Forsyth, 1917)		c	

Table 4. Mean cover (%) of macrophyte taxa (averaged over all tidal intervals) at Cave Canyon, Santa Barbara Island from August 1975 to April 1978. Only those taxa are included whose long term (or grand) mean cover was 0.3% or greater.

Taxon	1975-1976				1976-1977				1978	Grand
	Aug	Nov	Jan	Apr	Aug	Nov	Jan	Apr	Apr	Mean
Blue-green algae (Cyanobacteria)	28.6	23.0	54.0	42.3	60.1	59.9	57.4	53.0	63.0	49.0
Corallina officinalis var. *chilensis*	3.6	6.3	5.6	6.3	9.0	9.4	10.7	10.7	6.7	7.6
Halidrys dioica	9.2	6.6	5.0	1.8	3.9	6.2	6.8	7.4	4.5	5.7
Lithophyllum proboscidium	3.6	4.7	5.4	2.7	4.1	6.1	7.9	7.3	5.6	5.3
Corallina vancouveriensis	2.2	3.5	2.5	2.3	3.9	6.8	7.5	6.0	3.0	4.2
Gigartina canaliculata	4.9	5.5	5.0	4.7	4.0	2.1	2.8	2.9	2.1	3.8
Egregia menziesii	10.9	5.6	1.5	0.5	1.7	0.3	0.2	0.5	0.3	2.4
Rhodoglossum affine	1.3	1.3	1.0	2.2	2.4	2.0	2.8	3.2	2.0	2.0
Hydrolithon decipiens	1.6	1.9	1.5	3.7	0.2	0.3	0.4	1.1	0.4	1.2
Bossiella orbigniana dichotoma	1.4	2.6	0.3	0.3	0.7	1.1	0.5	0.6	1.4	1.0
Laurencia pacifica	0.9	0.6	0.4	0.2	0.8	1.3	0.7	0.9	0.7	0.7
Pterosiphonia baileyi	0.8	0.3	0.2	0.3	1.3	1.2	0.5	0.8	0.5	0.7
Diplura simulans	0.1	0.1	<0.1	<0.1	0.9	1.3	1.1	1.8	0.9	0.7
Gigartina spinosa	0.6	0.7	2.0	0.3	0.8	0.5	0.2	0.4	0.1	0.6
Ceramium spp.	0.1	0.1	0.1	1.3	<0.1	0	<0.1	2.2	1.2	0.6
Blue green colony	<0.1	<0.1	<0.1	<0.1	0.1	0.9	1.0	3.0	0.1	0.6
Iridaea cordata var. *cordata*	2.4	0.7	0.1	0.4	0.4	0.2	<0.1	0.1	0.1	0.5
Gelidium coulteri	0.6	1.2	0.1	0.5	0.8	0.1	0.4	0.3	0.3	0.5
Pseudolithoderma nigra	0.6	0.6	0.5	0.3	0.5	0.4	0.4	0.5	0.5	0.5
Cylindrocarpus rugosus	0.3	0.6	0.4	0.3	0.4	0.4	0.8	0.9	0.1	0.5
Endocladia muricata	0.6	0.7	0.4	0.9	0.4	<0.1	<0.1	<0.1	0.5	0.4
Cryptopleura crispa	0	0.3	0	0.8	0.3	0.5	1.0	0.5	0.1	0.4
Ralfsiacea	<0.1	<0.1	0.4	0.1	0.4	0.6	0.6	0.6	1.1	0.4
Plocamium violaceum	0.1	0.1	0.2	<0.1	0.3	0.3	0.4	0.4	0.6	0.3
Pachydictyon coriaceum	<0.1	<0.1	0.6	0.2	<0.1	0.3	0.4	0.4	0.7	0.3

shifted slightly higher on the South transect line, and the Zone I and II boundary on the Middle North line is extended somewhat downshore.

Zone I extended highest on the shore and ranged from about +8 to +12 ft (Fig. 4B) and was characterized by very low macroinvertebrate cover. Among the quadrats comprising the A cluster group, only the littorine snail *Littorina keenae* and, lower in the zone, the small acorn barnacle *Chthamalus fissus / C. dalli* were conspicuous, averaging 0.3% and 1.5% cover, respectively. The low cover value for *L. keenae* is misleading, however, since these small snails occurred in high density among the A quadrats, averaging 95 m^{-2}.

Zone II, between about +5 and +8 ft, was defined by the large cluster group B (Figs. 3 and 4B). The most conspicuous species in this zone were suspension-feeding macroinvertebrates, including the bivalve *Mytilus californianus* (7% mean cover among the quadrats in the B cluster group) and the barnacles *Chthamalus fissus / C. dalli* (12%) and *Tetraclita rubescens* (6%). The stalked barnacle *Pollicipes polymerus* (1%), which is associated with *M. californianus*, occurred in higher densities in the next zone. Among the macrophytes, only two, *Endocladia muricata* (3% mean cover) and *Corallina officinalis* var. *chilensis* (3%), were moderately conspicuous in this zone. *Chthamalus fissus / C. dalli*, *E. muricata* and *T. rubescens* were maximally abundant in the center of this zone, while *M. californianus* occurred in highest density lower in the zone (Fig. 5).

Zone III was represented by the C cluster group and extended from about +4 to +5 ft (Fig. 4B). Cover in this zone was dominated by *Corallina officinalis* var. *chilensis* (mean of 29%), *Chama arcana* (26%) and *Pollicipes polymerus* (4%). Several of the suspension-feeding

Table 5. Mean cover (%) of macroinvertebrate taxa (averaged over all tidal intervals) at Cave Canyon, Santa Barbara Island from August 1975 to April 1978. During initial visit in August 1975, percent cover was not enumerated (NE) for several species of tube-dwelling gastropods and polychaetes. Only those taxa are included whose long term (or grand) mean cover was 0.1% or greater.

Taxon	1975-1976				1976-1977				1978	Grand
	Aug	Nov	Jan	Apr	Aug	Nov	Jan	Apr	Apr	Mean
Chthamalus fissus/C. dalli	2.5	4.3	2.8	2.6	5.6	3.5	2.7	4.0	1.3	3.3
Chama arcana	1.3	3.5	3.8	3.6	1.7	2.5	3.9	4.6	0.3	2.8
Tetraclita rubescens	2.1	2.0	1.8	1.2	2.9	2.4	2.4	2.2	2.2	2.1
Mytilus californianus	4.0	2.8	2.2	2.8	2.0	1.3	0.9	0.9	0.8	1.9
Pollicipes polymerus	0.7	0.7	0.6	1.1	1.1	1.1	1.2	1.2	1.3	1.0
Petaloconchus montereyensis	NE	1.3	1.1	0.6	0.3	0.5	0.8	0.8	0.5	0.7
Strongylocentrotus purpuratus	1.2	0.6	1.0	0.5	0.3	0.3	0.6	0.8	0.7	0.7
Anthopleura elegantissima	0.3	0.3	0.6	0.5	0.4	0.4	0.8	0.6	0.7	0.5
Littorina keenae	0.2	0.2	0.1	0.2	0.4	0.3	0.6	0.5	0.2	0.3
Phragmatopoma californica	NE	0.3	0.1	0.1	<0.1	0.5	0.3	0.3	0.4	0.3
Siphonaria brannani	0.1	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1
Macclintockia scabra	0.1	0.2	0.2	0.2	0.1	0.1	0.2	0.1	<0.1	0.1
Nuttallina fluxa/N. californica	0.1	0.2	0.2	0.2	0.2	0.2	0.1	0.1	<0.1	0.1

invertebrates from Zone II ranged downward into Zone III, including *Mytilus californianus* (11%), *Tetraclita rubescens* (3%) and *P. polymerus*. Two macrophytes, *Gigartina canaliculata* (13%) and *Corallina vancouveriensis* (4%), contributed lower average cover than *C. officinalis* var. *chilensis* in this zone, but became important lower on the shore (Fig. 5).

Zone IV, characterized by the D cluster group, ranged from about +3 to +4 ft (Fig. 4B) and was dominated the macrophytes *Gigartina canaliculata* (43%), *Corallina officinalis* var. *chilensis* (16%), *C. vancouveriensis* (14%), *Egregia menziesii* (13%) and *Halidrys dioica* (13%) (Fig. 5).

Zone V was defined by cluster group E and extended downshore from about +3 ft (Fig. 4B). Like Zone IV, this zone was dominated by macrophyte cover, although the colonial sand-tube polychaete *Phragmatopoma californica* (7% mean cover) occurred in moderate density (Fig. 5). A number of algal species were abundant here and included *Halidrys dioica* (30%), *Egregia menziesii* (24%), *Bossiella orbigniana dichotoma* (13%), *Corallina vancouveriensis* (10%) and *C. officinalis* var. *chilensis* (8%).

In the cluster analysis (Fig. 3) the single quadrat at meter 7 on the North transect line defined a separate cluster group (F). The exclusion of this quadrat from the E cluster group was due to the high percent cover of *Egregia menziesii* (63%). Because the abundance of *E. menziesii* declined precipitously after this site visit, subsequent cluster analyses grouped this quadrat with the E group. For this reason the creation of a separate zone represented by this single quadrat was deemed unjustified.

Discussion

The most striking feature of the rocky intertidal zone on the east side of Santa Barbara Island was the apparent effect of the persistent wave surge on the species composition and vertical zonation of the biota. Suspension-feeding invertebrates (primarily barnacles, bivalves and tube-dwelling polychaetes) were abundant, despite the fact that the study area was located on the leeward side of the island and received no direct wave shock. Seapy & Littler (1978b) and others (*e.g.*, Lewis 1964; Stephenson & Stephenson 1972) have reported that suspension-feeding invertebrates become abundant on shorelines exposed to direct wave shock, while these species decline in density, exist lower on the shore, or simply do not occur in sheltered habitats.

The unusual nature of the study area on

Table 6. Mean density (number of individuals m^{-2}) of macroinvertebrate taxa, averaged over all tidal intervals, at Cave Canyon, Santa Barbara Island from August 1975 to April 1978. During initial visit in August 1975, tube-dwelling gastropods and polychaetes were not enumerated (NE). Only those taxa are included whose long-term (or grand) mean density was two or more individuals m^{-2}.

	1975-1976				1976-1977				1978	Grand
Taxon	Aug	Nov	Jan	Apr	Aug	Nov	Jan	Apr	Apr	Mean
Chthamalus fissus/C. dalli	708	1277	2376	1539	1539	974	856	1015	2219	1389
Tetraclita rubescens	207	352	439	404	764	574	546	961	661	545
Littorina keenae	63	270	317	312	381	344	377	382	469	324
Petaloconchus montereyensis	NE	239	206	278	116	258	322	328	213	272
Pollicipes polymerus	148	141	100	172	202	181	179	238	212	175
Mytilus californianus	216	257	199	183	128	104	78	75	116	151
Siphonaria brannani	20	80	134	90	82	41	57	63	60	70
Macclintockia scabra	39	103	91	75	81	63	46	52	51	67
Spirorbis spp.	NE	65	28	41	3	29	72	108	100	62
Spirobranchus spinosus	NE	37	36	54	34	45	66	92	78	61
Nuttallina fluxa/N. californica	16	56	44	56	38	40	31	44	59	43
Chama arcana	12	72	66	84	17	25	40	46	15	42
Lottia pelta	9	40	24	27	31	24	30	24	17	25
Septifer bifurcatus/Brachidontes adamsianus	7	45	36	37	8	12	14	20	18	22
Littorina scutulata	4	12	24	83	13	14	9	11	15	21
Strongylocentrotus purpuratus	14	23	41	13	8	15	17	18	23	19
Anthopleura elegantissima	10	12	14	16	6	16	14	18	21	14
Fissurella volcano	4	12	18	11	10	10	12	13	25	13
Ocenebra circumtexta	2	13	9	9	9	8	6	5	9	8
Lottia strigatella	6	3	6	12	1	5	4	6	<1	5
Megabalanus californicus	0	0	3	<1	2	3	5	20	23	5
Cyanoplax hartwegii	6	8	5	2	2	4	1	3	5	4
Pachygrapsus crassipes	4	4	2	3	5	6	<1	<1	1	3
Balanus glandula	2	2	1	1	8	0	0	0	1	2
Lottia digitalis	3	2	5	<1	2	4	<1	<1	2	2
Lottia limatula	3	4	3	3	<1	1	<1	2	1	2

Santa Barbara Island can be dramatized by comparing the vertical distributions of dominant cover organisms between Santa Barbara Island and sites from similar leeward locations on other islands investigated at the same time during the BLM's Outer Continental Shelf Program. The sites located on the northeast sides of Santa Catalina and San Clemente Islands were selected because they are comparable in exposure to the prevailing northwesterly swell. The intertidal zones at all three locations were narrow, with steep cliffs situated immediately shoreward of the intertidal benches. Thus, shading during late afternoon hours was approximately comparable at each locality. The Santa Catalina Island site was located on a headland at the east side of Big Fisherman's Cove and received a limited amount of wave surge from swells refracted around the north-west end of the island. The San Clemente Island site was located in Wilson Cove and largely was sheltered from wave surge. Thus, the three sites provided a gradient of wave surge exposure, ranging from high (Santa Barbara Island) to intermediate (Santa Catalina Island) to low (San Clemente Island).

Kite diagrams for the dominant cover organisms at Santa Barbara, Santa Catalina and San Clemente Islands are given in Figures 6 and 7. In all cases, vertical distributions were shifted downward on the shore, progressing from Santa Barbara to Santa Catalina to San Clemente Islands. The suspension-feeding bivalves *Mytilus californianus* and *Chama arcana* occurred lower on the shore and in very low abundance at Santa Catalina Island, whereas they were absent at San Clemente Island.

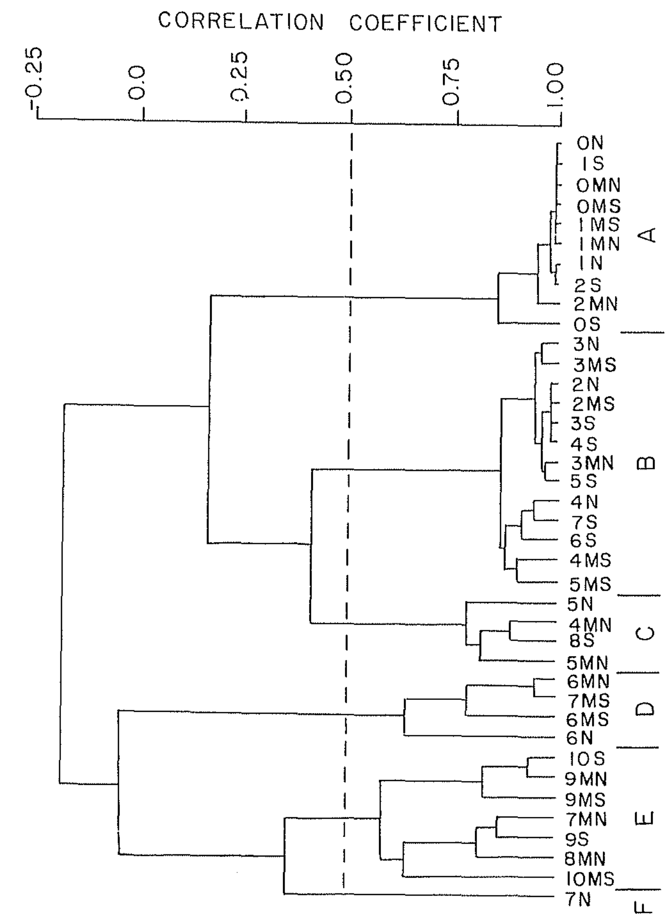

Figure 3. Cluster analysis dendrogram for all quadrats sampled in November 1975 at Cave Canyon, Santa Barbara Island. Quadrats are coded by number (meters downshore on each transect line, with 0 at top of line) and either N, MN, MS, or S (refering to North, Middle North, Middle South or South transect lines).

Although the vertical distributions of the barnacles *Chthamalus fissus / C. dalli* and *Tetraclita rubescens* were lower on the shore at Santa Catalina and San Clemente Islands than at Santa Barbara Island, their abundances did not decrease dramatically like the bivalves. This result could be related to higher nutritional requirements by the bivalves supported by the increased water movement provided by the surge.

The macrophytes *Gigartina canaliculata* and *Egregia menziesii* exhibited downward shifts in the vertical levels on the shore where their maximal abundances occurred (Fig. 7). Although the upper limits to the vertical distributions of *Corallina officinalis* var. *chilensis* (Fig. 6) and *Halidrys dioica* (Fig. 7) were at sequentially lower shore levels between the three sites, the abundance peaks for these two species were at the same vertical heights on both Santa Catalina and San Clemente Islands.

The occurrence of two species of invertebrates from Santa Barbara Island were particularly noteworthy. The pulmonate limpet, *Siphonaria brannani*, ranked seventh in overall abundance among the invertebrates, averaging 70 individuals m^{-2} (Table 6). Among the 23 sites investigated during the BLM's

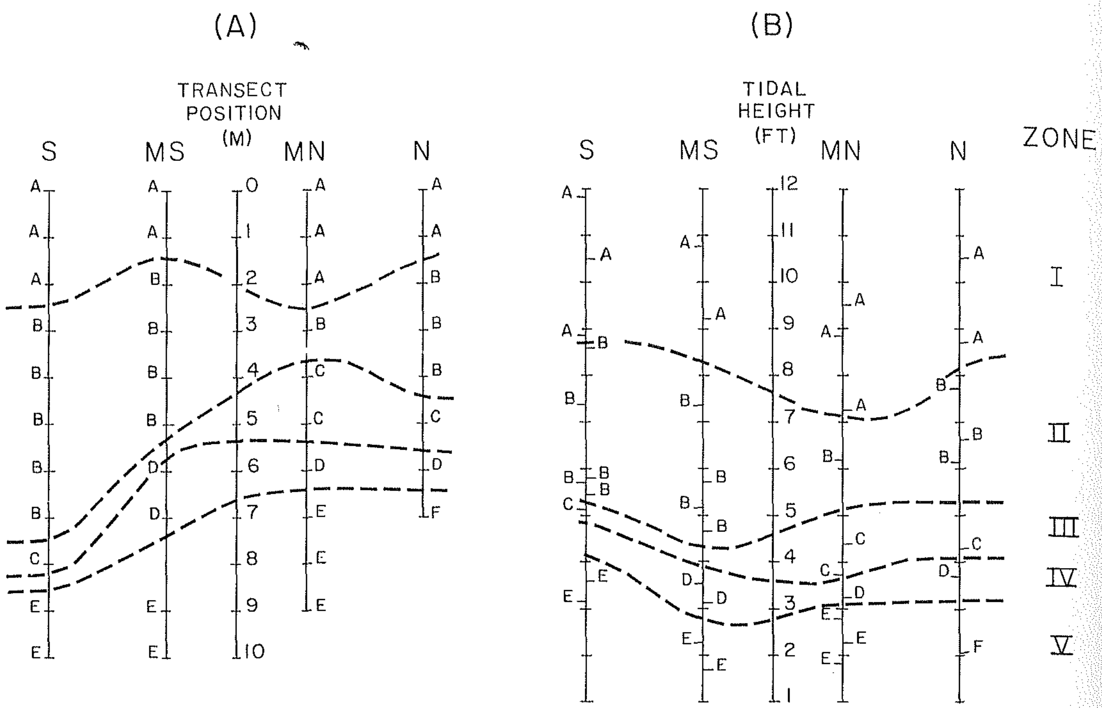

Figure 4. Location of quadrats comprising cluster groups identified in Figure 3: A) along transect lines as a function of distance downshore (in meters) and B) along transect lines repositioned according to tidal heights. Dashed lines have been added to separate cluster groups and to define vertical zones on the shore.

Outer Continental Shelf Program, we only recorded this species from the present study site and from Crook Point, San Miguel Island (Seapy & Littler 1992). During helicopter surveys of the northern Channel Islands, we observed low numbers of *S. brannani* at the west end of Santa Rosa Island. According to Keen (1971:852), *S. brannani* "is characteristically a southern Californian form, reported at Cape San Lucas, Baja California, but not found there in recent years." This species was not included in the intertidal fauna of the Gulf of California by Brusca (1980), and the record from Cabo San Lucas could have been erroneous. Thus, it appears plausible that *S. brannani* occurs only on the islands of the southern California Bight. The second species, the sea cucumber *Pseudocnus californicus*, was recorded from only two sites in the Southern California Bight; Cave Canyon, Santa Barbara Island and West Point, San Nicolas Island. This species has not been reported previously from north of Isla Santa Margarita in southern Baja California (M. Bergen, pers. comm.).

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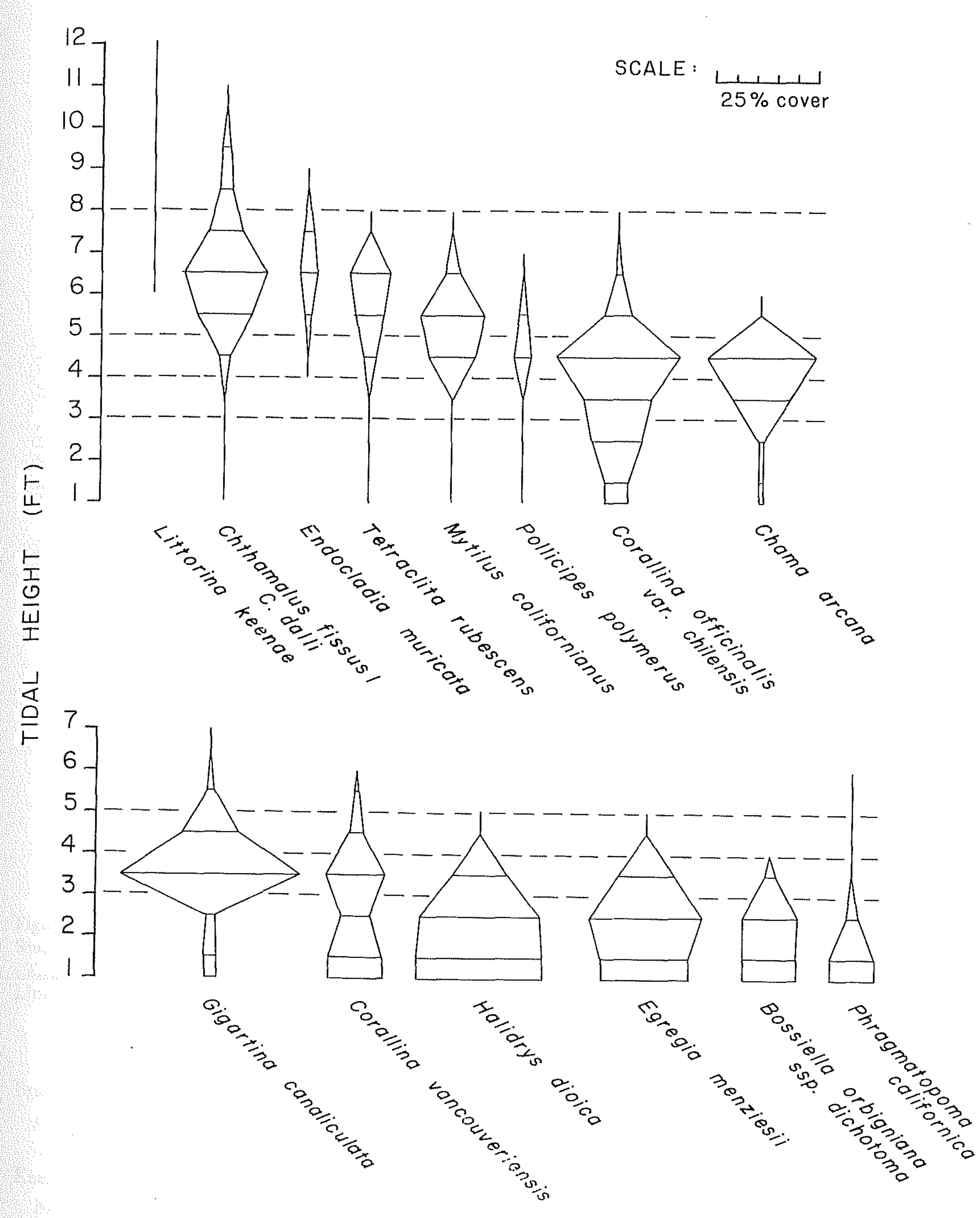

Figure 5. Vertical distributions of dominant cover organisms plotted as kite diagrams at Cave Canyon, Santa Barbara Island in November 1975. Widths of kites represent mean abundances in each 1-ft tidal interval. Dashed lines were added at the tidal levels identified in Figure 4 to separate the five zones on the shore.

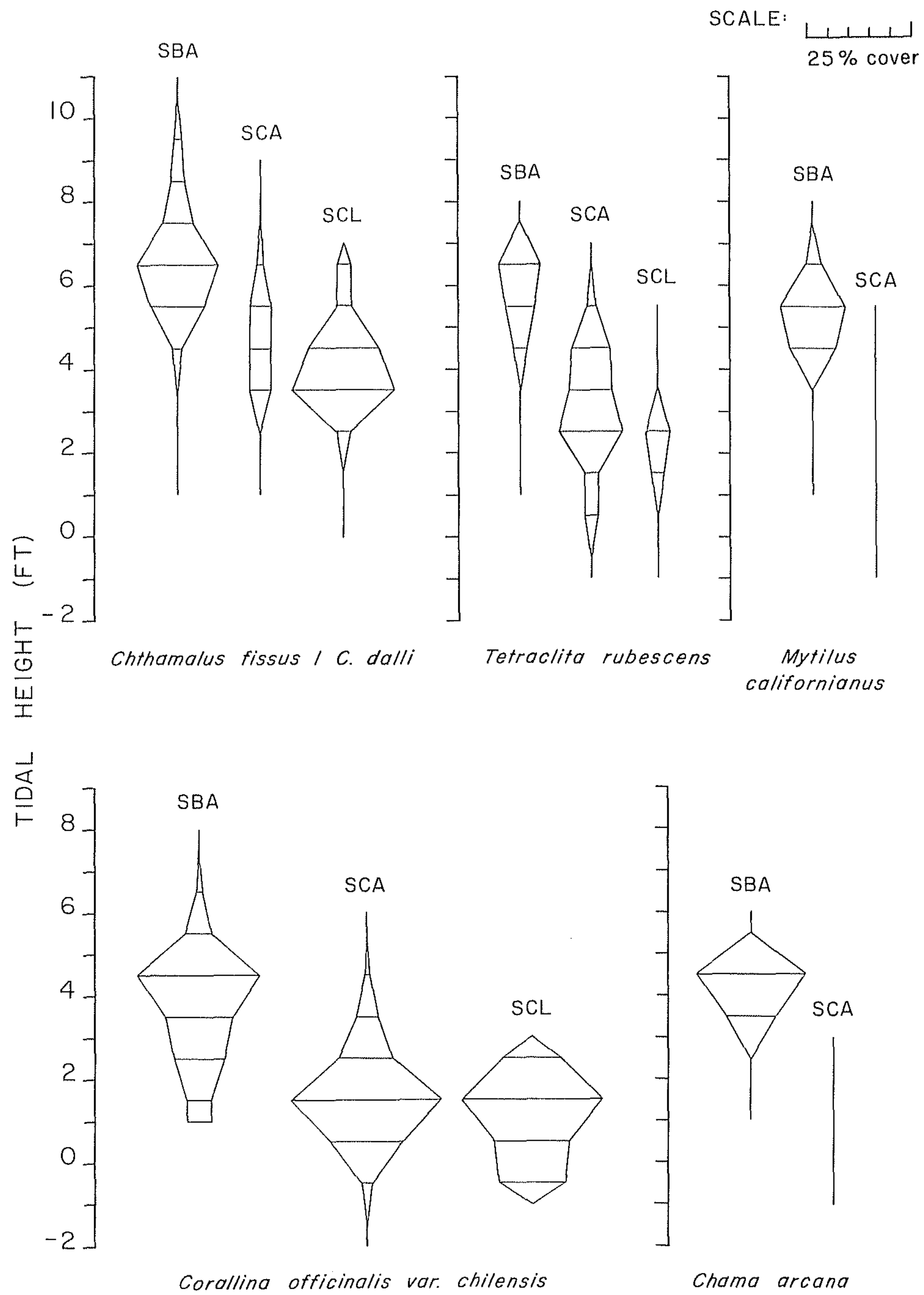

Figure 6. Comparisons of vertical distributions (as kite diagrams of percent cover) for four species of invertebrates and one species of macrophyte sampled at Cave Canyon, Santa Barbara Island (SBA) in November 1975, Big Fisherman's Cove, Santa Catalina Island (SCA) in November 1975 and Wilson Cove, San Clemente Island (SCL) in December 1975. Mean abundance data for each 1-ft tidal interval for Santa Catalina and San Clemente Islands from Littler (1977).

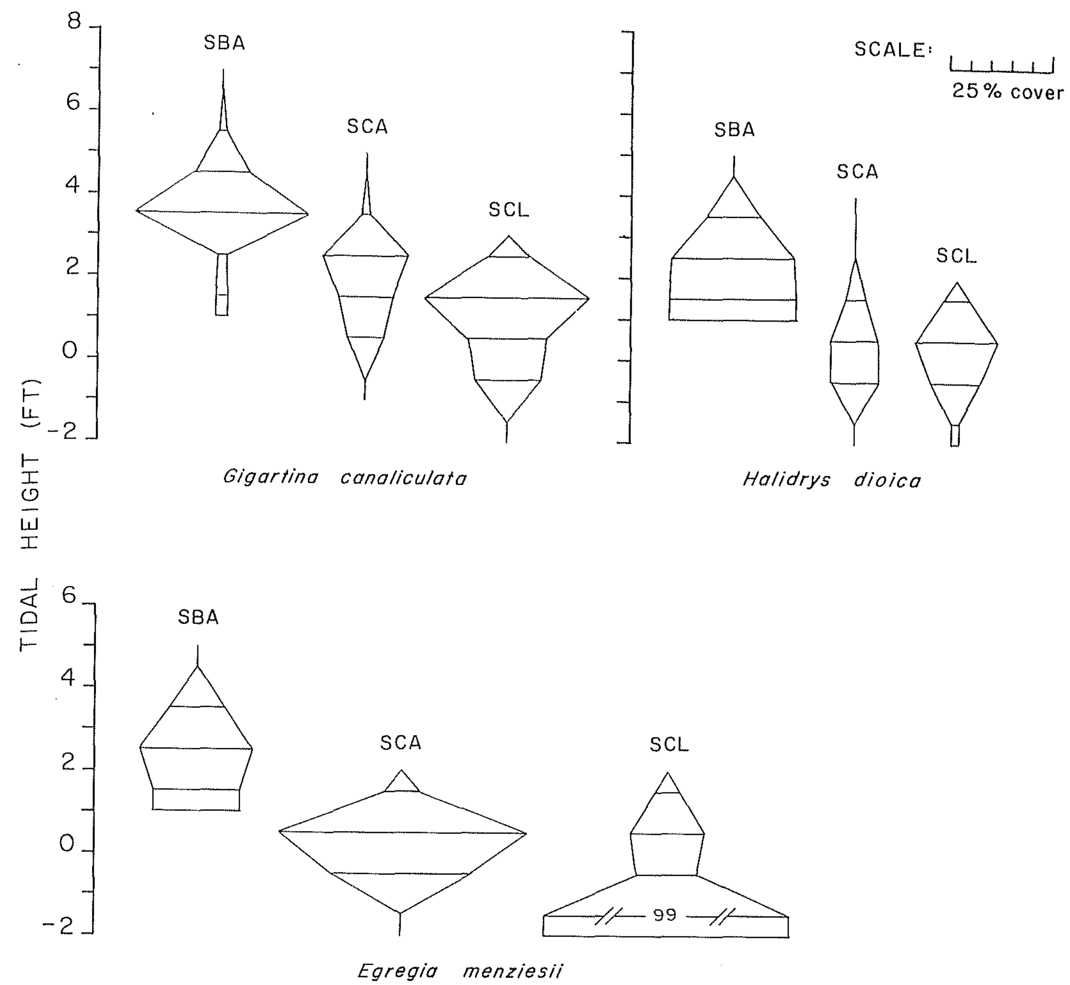

Figure 7. Comparisons of the vertical distributions (as kite diagrams of percent cover) for three species of macrophytes at Santa Barbara Island (SBA) in November 1975, Santa Catalina Island (SCA) in November 1975 and San Clemente Island (SCL) in December 1975. Mean abundance data for each 1-ft tidal interval for Santa Catalina and San Clemente Islands from Littler (1977).

Literature Cited

Brusca, R.R. 1980 Common intertidal invertebrates of the Gulf of California. (2nd edition). University of Arizona Press: Tucson, AZ. 513 pp.

Keen, M.A. 1971 Sea shells of tropical west America. Marine mollusks from Baja California to Peru. (2nd edition). Stanford University Press: Stanford, CA. 1064 pp.

Lewis, J.R. 1964. The ecology of rocky shores. English Universities Press: London, ENGLAND. 323 pp.

Littler, M.M. 1977 (ed.). Spatial and temporal variations in the distribution and abundance of rocky intertidal and tidepool biotas in the Southern California Bight. Year I-SCOSC Program. Tech. Rep. III-2.1. Bureau of Land Management, U.S. Government Printing Office: Washington, DC.

______. 1980. Overview of the rocky intertidal systems of southern California. Pp. 265-306. *In:* D.M. Power (ed.), The California Islands: proceedings of a multidisciplinary symposium. Santa Barbara Museum of Natural History: Santa Barbara, CA..

Murray, S.N., M.M. Littler and I.A. Abbott. 1980. Biogeography of the California marine algae with emphasis on the southern California Islands. Pp. 325-339. *In*: D. M. Power (ed.), The California Islands: Proceedings of a multidisciplinary symposium. Santa Barbara Museum of Natural History: Santa Barbara, CA.

Nicholson, N.L. and R.L. Cimberg. 1971. The Santa Barbara oil spills of 1969: a post-spill survey of the rocky intertidal. Pp. 325-399. *In*: D. Straughan (ed.), Biological and oceanographical survey of the Santa Barbara Channel oil spill, 1969-1970, Vol. I. Allan Hancock Foundation, University of Southern California: Los Angeles, CA.

Philbrick, R.N. 1967. Introduction. Pp. 3-8. *In*: R. N. Philbrick (ed.), Proceedings of the symposium on the biology of the California Islands. Santa Barbara Botanic Garden: Santa Barbara, CA.

Seapy, R.R. and M.M. Littler. 1977. Biological features of rocky intertidal communities near Cave Canyon, Santa Barbara Island, California. Pp. 209-316. *In*: M. M. Littler (ed.), Spatial and temporal variations in the distribution and abundance of rocky intertidal and tidepool biotas in the Southern California Bight. Year I-Southern California Outer Continental Shelf Program. Bureau of Land Management, Tech. Rep. III-2.1. U. S. Government Printing Office: Washington, DC.

_____ and _____. 1978a. Variations in the rocky intertidal biota near Cave Canyon, Santa Barbara Island, California. Chapter 1.1.4, 58 pp. *In*: M.M. Littler (ed.), The annual and seasonal ecology of Southern California rocky intertidal and tidepool biotas. Year II-Southern California Outer Continental Shelf Program. Bureau of Land Management, Tech. Rep. III-1.1. U.S. Government Printing Office: Washington, DC.

_____ and _____. 1978b. The distribution, abundance, community structure, and primary productivity of macroorganisms from two central California rocky intertidal habitats. Pac. Sci. 32:293-314.

_____ and _____. 1979. Assessments of the distribution, abundance, and community structure of rocky intertidal organisms at Cave Canyon, Santa Barbara Island, California. Chapter 1.15, 30 pp. *In*: M. M. Littler (ed.), The distribution, abundance, and community structure of rocky intertidal and tidepool biotas in the Southern California Bight. Year III-Southern California Outer Continental Shelf Program. Bureau of Land Management, Tech. Rep. II-1.0. U. S. Government Printing Office: Washington, DC.

_____ and _____. 1980. Biogeography of rocky intertidal macroinvertebrates of the Southern California islands. Pp. 307-323. *In*: D. M. Power (ed.), The California Islands: proceedings of a multidisciplinary symposium. Santa Barbara Museum of Natural History: Santa Barbara, CA.

_____ and _____. 1993. Rocky intertidal macroinvertebrates of the Southern California Bight: an overview and checklist. *In*: F. G. Hochberg (ed.), Third California Islands symposium: recent advances in research on the California Islands. Santa Barbara Museum of Natural History: Santa Barbara, CA.

Stephenson, T.A. and A. Stephenson. 1972. Life between tidemarks on rocky shores. Freeman and Company: San Francisco, CA. 425 pp.

Rocky Intertidal Macroinvertebrates of the Southern California Bight: An Overview and Checklist

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Abstract – A total of 349 epibenthic taxa of macroinvertebrates were recorded from 7 mainland and 15 island rocky intertidal sites in the Southern California Bight. The occurrence of these taxa among the 22 sites is presented as a checklist organized by phyla and classes. The majority of these were mollusks (188), followed by sponges (42) and crustaceans (30). Highest numbers of taxa were recorded from: Coal Oil Point (125); Big Fisherman's Cove, Santa Catalina Island (124); Santa Rosa Island (122); Willows Anchorage, Santa Cruz Island (122) and Government Point (120). Sites having the highest numbers of common taxa (*i.e.*, those whose average densities exceeded one individual per m^2) were located on islands, and included: Willows Anchorage, Santa Cruz Island (38 taxa); Catalina Harbor, Santa Catalina Island (36); Prisoners Harbor, Santa Cruz Island (34); Frenchy's Cove, Anacapa Island (33); Cave Canyon, Santa Barbara Island (33) and Big Fisherman's Cove, Santa Catalina Island (33). The most abundant taxa (based on density and averaged over all sites) were *Chthamalus fissus*/*C. dalli*, followed by *Littorina keenae*, *Phragmatopoma californica* and *Tetraclita rubescens*. Based on percent cover, the most abundant taxa were *C. fissus*/*C. dalli*, *P. californica*, *Mytilus californianus* and *Anthopleura elegantissima*. With the exception of sponges, the number of northerly and southerly range extensions along the Pacific Coast recorded by this study were few.

Introduction

Rocky intertidal community structure at a series of mainland and island sites in the Southern California Bight was studied intensively between 1975 and 1979 as a part of a broad investigation of the Bight by the Bureau of Land Management (now Minerals Management Services) Outer Continental Shelf Program. Site records for the taxa of epibenthic macroinvertebrates from this 3-yr study are contained in individual chapters of the unpublished annual reports for the project (Littler 1978a, b, 1979). The main objectives of this paper are to: 1) integrate these disparate records and make them available in a concise format and 2) provide the data base for a biogeographic study of the rocky shore macroinvertebrates of the Bight (Seapy & Littler 1980), which was published as a part of the proceedings of the previous symposium on the California Islands (Power 1980).

A review of the existing literature on the invertebrate taxa of the Southern California Bight was completed by Bright (1974) prior to the initiation of the Outer Continental Shelf Program in 1975. Bright compiled species lists, which were arranged by major taxonomic groups. A useful aspect of these lists was the inclusion of habitat type for each species. A more thorough and taxonomically-current listing of invertebrate species from the Bight was compiled by Straughan & Klink (1980). This paper consisted of chapters on the various taxonomic groups written by specialists actively working on the invertebrates of the Southern California Bight. Unfortunately, species habitats were not included. Data on species abundances obtained at island sites before the inception of the BLM's Outer Continental Shelf Program are limited to the studies of Caplan & Boolootian (1967) at San Nicolas Island and Littler & Murray (1975) at San Clemente Island.