USC Sea grant program

INTERTIDAL MACROBIOLOGY OF SELECTED SANDY BEACHES IN SOUTHERN CALIFORNIA

BY

MARY M. PATTERSON*

*ALLEN HANCOCK FOUNDATION
UNIVERSITY OF SOUTHERN CALIFORNIA
LOS ANGELES, CALIFORNIA 90007

USC-SG-9-74

UNIVERSITY OF SOUTHERN CALIFORNIA • SEA GRANT PROGRAM • LOS ANGELES, CALIFORNIA 90007

INTERTIDAL MACROBIOLOGY OF SELECTED SANDY BEACHES IN SOUTHERN CALIFORNIA

By

Mary M. Patterson*

*Allan Hancock Foundation
University of Southern California
Los Angeles, Ca. 90007

Present Address:

Cat Cove Marine Laboratory
92 Fort Avenue
Salem, Mass. 01970

This work is the result of research sponsored by NOAA Office of Sea Grant, Department of Commerce under Grant #2-35227 to the University of Southern California. The U.S. Government is authorized to produce and distribute reprints for governmental purposes notwithstanding any copyright notation that may appear hereon.

USC-SG-9-74

INTRODUCTION

Ecological studies dealing with sandy beach macrofauna have not been common in the past; some early papers are cited by Hedgpeth (1957). More recent investigations include the work of Dexter (1969, 1972) on North Carolina and Panamanian beaches, Brown (1971) in South Africa, McIntyre (1968) in south-east India, and Ansell et al (1972) in south-west India. The extensive sandy beaches of southern California have been neglected except for a study of San Diego beaches (Clark, 1969 unpublished) and several autecological studies. The present study is designed to provide information about the intertidal macrofauna of representative sandy beaches in southern California, along with the factors affecting their distribution. This basic data is an essential portion of a longer term study of the effects of people on sandy beaches. Nine beaches between Coal Oil Point in the north and Doheny State Park in the south (Figure 1) were sampled to provide a wide range in physical attributes.

Biologists familiar with sandy beach biota agree on several general characteristics. Sandy beaches are low diversity environments, whether species diversity or dominance diversity is considered. The phenomenon of intertidal zonation is important in species distribution; Dahl (1952) proposed a scheme of three vertical zones for beaches worldwide. There is considerable variability between surveys in beach faunal studies (see Clark, 1969, and Ansell et al, 1972). Thus to describe the situation at one beach adequately, it is necessary to consider seasonal fluctuations in the fauna. The distribution of sandy beach species is dependent on the abiotic factors of beach substratum, intertidal slope and amount of wave exposure. In this paper, numerical classificatory analysis techniques are employed to elucidate the effects of zonation, seasonality and site physiography on the beach macrofauna.

SITE DESCRIPTIONS

The nine study beaches extend from Santa Barbara County to Orange County in southern California (Figure 1). Appendix 1 describes the locations of the study basepoints. Beaches are referred to by roman numerals ordered from north to south in some figures and tables.

Coal Oil Point beach (I) is the northernmost study area, approximately 10.5 miles north of Santa Barbara Yacht Harbor. The site is narrow and flat, and composed of fine, well-sorted sand. A cliff limits the highest tides while low tides expose algae-covered shale. There are kelp beds parallel to the shoreline. Hope Ranch beach (II) is a more deserted length of coastline 5.75 miles north of Santa Barbara Yacht Harbor. A grass edge and cliff are behind the flat, wide beach. Carpinteria State Beach (III), the third study site in Santa Barbara County, is approximately 9.75 miles south of Santa Barbara Yacht Harbor. Small dunes lie backshore of the high tide line. Again the intertidal zone exhibits a gentle slope and fine-grained sand. All three northern sites face towards the south. Only Coal Oil Point is interrupted lengthwise by a headland barrier. This headland is approximately 0.5 miles from the sampling site.

Zuma Beach (IV) and Little Dume (V) in Ventura County have steep foreshores without much fine-grained material. The two beaches are separated by Point Dume, which shelters Little Dume from the high wave energy that arrives at Zuma Beach. Little Dume is directed towards the southeast, while Zuma Beach faces the southwest.

Huntington (VI) and Doheny State (VII) Beaches in Orange County are similar to Zuma Beach in terms of their extended length and width. Their exposure to wave action is also unobstructed. The remaining two study sites, Horse Pastures (VIII) and Dana Point (IX), are more sheltered than the two state beaches; they are located approximately 12.5 and 22.5 miles respectively south of Huntington State Beach. These two beaches most resemble those surveyed in Santa Barbara County: foreshores are flat with boulders and kelp offshore, and terrestrial plants and boulders border the hills backshore. There are large rocky outcrops positioned at comparable distances from the basepoints as the headland cited at Coal Oil Point. Huntington State Beach, Horse Pastures and Doheny State Beach face a southern direction; Dana Point faces more to the southwest.

SAMPLING METHODS

Each site was sampled during low tide at approximately two month intervals for a year commencing November-December 1970. (Zuma Beach and Little Dume were not sampled in 1970). Seaward of the designated basepoint a stratified random sampling procedure began at the previous high tide line. From there a tape was extended to the middle of the low tide wash line. Another tape (40 ft) was laid perpendicular to the first tape along the high tide line. Both tapes had divisions every ten feet so that four contiguous ten-foot square quadrats were formed in every ten-foot row from high tide to low tide. Three cores of sediment were taken near one point that was chosen randomly within every square quadrat. The coring device measured three inches (7.7 cm) in diameter and was driven eight inches (20.6 cm) into the sand, unless rocks made this depth impossible to reach. Sampling was discontinued if boulders were exposed by the outgoing tide. Each set of three cores was combined and sieved using sea water in the field. Screens of 1.0 mm mesh were used for sieving, except when coarse gravel dominated the sample and a 2.0 mm mesh screen conserved time. Animals were placed in 10% formalin and returned to the laboratory for sorting and identification. Middle fragments of polychaetes were disregarded unless they represented the single occurrence of a species at a particular survey. Essentially all macroscopic invertebrates present in the cores, except for quick juvenile amphipods of the genus Orchestoidea, were recovered by these methods.

Beach intertidal profiles for slope comparisons were calculated by measuring the change in elevation every twenty feet from the previous high tide along the transect using the horizon as a reference point. Sand samples were obtained as normal cores taken at the same twenty-foot intervals and split lengthwise. Back in the laboratory these samples were washed of debris and dried. Weight percents of sediment greater than 2 mm (= -1.0 phi) were determined by shaking through sieves of 2 mm mesh. The remaining fraction of 2 mm or less was run down an Emery settling tube. A computer program calculated sediment parameters of phi diameter and degree of sorting (generally equal to the standard deviation of the mean diameter). Shaded surf water and air temperatures were recorded at low tide.

Table 1 lists all species recovered during the study. The raw data on beach fauna is included in the Appendix. The total number of rows in a survey, with the corresponding organisms from the four quadrats per row, is divided by 3 into intertidal areas, termed upper, middle and lower beach areas. Beach profiles and sediment data are presented in the Appendix. Using the methods of analysis which are discussed next; information based on the raw data is presented in more convenient forms.

DATA ANALYSIS

Intertidal faunal distributions have been analyzed in different ways by previous authors. Kite diagrams are presented (e.g. Ansell et al, 1972, Dexter, 1972) to show intertidal zonation in terms of biomass or numbers per square meter for each species. Although these diagrams are convenient for comparisons between studies, the extrapolations usually employed can give misleading results, since many infaunal species have patchy patterns of distribution. Treatment of communities, instead of separate species, was achieved with the calculation of diversity indices by Dexter (1972). However in the present case physical discontinuities between beaches are considered too large, and number of individuals per sample too small, for these indices, including the Shannon-Wiener index, to be meaningful.

Temporal changes in faunal abundances have rarely been incorporated into methods of analysis. Beach fauna is usually related to seasonal factors, as well as to the abiotic environment, by subjective evaluation alone. One exception is the work by Clark (1969), who uses multiple regression to determine associations between physical conditions and the individual distributions of common species.

Numerical classificatory techniques have been employed in recent marine ecological studies to reveal faunal similarities between spatially distinct groups (normal analysis). There is a review of relevant literature in Stephenson (manuscript, 1973). Faunal similarities between temporally distinct groups are analyzed by similar methods in one study by Williams and Stephenson (manuscript in press, 1973). The approach taken in the present paper is derived mainly from the procedures of analysis in the latter manuscript. In essence, site-groups are formed by the species in common after all the surveys at one site have been fused. Likewise, time-groups are differentiated by seasonal changes in the fauna, and each time entry is composed of the surveys from all sites that were taken during the same time period.

It is of interest also to determine what species can be expected to co-occur, in other words, to construct species-groups (inverse analysis). At the study sites, for example, species restricted to one intertidal area, or one beach type, should be clustered together. Species-groups are then juxtaposed against site-groups and time-groups in two-way tables. When a species-group characterizes only one site-group or time-group, the species-group is considered to represent a distinct faunal assemblage. Physical parameters of substrate and slope are used to evaluate the ecological bases for the main groups.

The steps taken to form site and time-groups, species-groups, and two-way tables are enumerated below. Occasionally the literature and the data suggested various alternatives in terms of which method of data reduction, transformation, standardization and so on should be employed. As often as possible, the merits of different methods were compared using the beach data. Whereas the use of numerical classification methods is still relatively new in marine studies, common sense and subjective judgments are sometimes relied upon in this report.

1. Site-groups.

Site-group entries considering the total intertidal zone are formed by pooling the raw data (Table 1-9 in Appendix) within each of the three intertidal areas for all surveys from a site to compose one entry. The data matrix is therefore 9 (sites) x 34 (species). Deletion of thirteen intertidal areas that contained no specimens leaves a total of 170 areas contributing to the analyses. In addition, taxonomic difficulties led to the omission of three groups (nemerteans, beetles and insect larvae) from further consideration. Species represented by only one individual are retained. The reason for this is that the data matrix is very sparse, and such rare species may be characteristic of an area. Consequently a final data matrix contains 31 species.

The similarity between the nine sites is measured by calculating coefficients of similarity. Czekanowski's coefficient as expanded by Bray and Curtis (1957), is used as it considers relative abundance of a species, instead of only presence and absence. The equation for this coefficient is:

$$C_X = 2W/(A+B)$$

with W the sum of the lower values of each species for two sites being compared, A the sum of the abundance values at the first site, and B a similar sum at the second site. The abundance value for a species used in this equation is the number of specimens found at the site, divided by total number of rows sampled at the site, and transformed to log (X+1). The transformation minimizes the effect of very abundant species which would otherwise overshadow all the other species in the analysis.

The 9 x 9 coefficient matrix obtained is reduced and clustered by a group-average sorting method (Lance and Williams, 1967) that is recommended for ecological work by Field and McFarlane (1968), Day et al (1971) and Field (1971). The groups are graphically displayed in a dendrogram.

The same sequence of steps is followed to group the nine sites according to their upper beach, middle beach and lower beach fauna. Upper, middle, and lower distributions are based on intertidal sampling areas of variable distance. Hence, fauna are compared in three sections of the intertidal slope and not necessarily in comparable intertidal zones based on profile elevation or species composition. This type of division is important in terms of public activity on beaches which will be discussed in a subsequent paper. The abundance values used to calculate the Bray-Curtis coefficient are simply limited to the abundances at the respective intertidal areas.

2. Time-groups.

The generalized procedure above produces time-groups instead of site-groups when all the sites are fused from one sampling period to make one entry, i.e. seven times are considered. Due to the fusion of dissimilar sites, only gross seasonal trends are expected. Time-group dendrograms of all three intertidal areas combined and for each of the areas alone are obtained.

3. Species-groups.

In order to characterize species-groups, pooled data from all the surveys are included. A 31 x 170 data matrix becomes a coefficient matrix of 31 x 31. Data matrices of unstandardized and standardized values are constructed. Again group-average sorting is used to form the two dendrograms. If the artifical division of the fauna into three vertical areas is a reliable estimate of intertidal zonation, the species-groups should be assembled by areas. There is probably some unavoidable overlap as a result of sparse records, and because each of the tripartite areas does not correspond to identical tidal heights throughout the year.

4. Two-way tables.

In this presentation, two-way tables of site-groups versus species-groups, and time-groups versus species-groups, are filled by using the log-transformed data values that determine group construction. The means and standard deviations of phi diameter and slope ratio values for the members in a group are calculated for all main groups.

RESULTS

A brief descriptive assessment of the physical environments at the beach sites is valuable to preface the results of the faunal analyses. Overall, the air and surf temperatures (Table 8) did not provide insight into species distribution. Anomalies encountered in the weather included a heavy rainfall the day before the Hope Ranch survey in December 1970 and showers during surveys at Hope Ranch and Little Dume in December 1971.

The sediment and slope data (Table 2) divide the sites into two broad categories: fine-grained, flat beaches (Coal Oil Point, Hope Ranch, Carpinteria, Horse Pastures, Dana Point) versus steeper beaches with coarser, more heterogeneous deposits (Zuma Beach, Little Dume, Huntington Beach, Doheny Beach). Reference to Table 2, which gives the mean phi diameter and slope ratio values for each vertical area, summarizes this dichotomy.

In the first category of fine-grained, gently sloping beaches, the substrate tends to stay constant or become more fine in a seaward direction. Phi diameters are generally greater than 2. Also profiles become less steeply inclined towards low tide. There are exceptions to these two trends only in the spring and early summer, notably at Horse Pastures and Dana Point. Conversely at the remaining beaches, phi diameters are usually less than 2 and sorting is poor. Mean diameters vary considerably from one area to the next (Table 2). Finer samples in the lower intertidal area are almost limited to surveys from Little Dume and Huntington Beach.

In general, degree of exposure is correlated to the substrate and intertidal profile, and may be the most important criteria in the beach environment. While exposure was not measured directly in this study, personal observation and other sources (as Littoral Environmental Observation Program data) distinguish three levels of exposure: semi-sheltered (Coal Oil Point, Dana Point), moderately exposed (Hope Ranch, Carpinteria, Little Dume, Horse Pastures), and exposed (Zuma Beach, Huntington Beach, Doheny Beach).

Site-Groups.

The four site-group dendrograms (Figure 2) show percent of similarity along the side axis. Those groups that appear important are designated by the dashed lines; it is the physical parameters of these groups that are contrasted later. Detailed inspection of the site-groups is postponed to the section dealing with two-way tables.

The site-group dendrogram derived from the fauna of all three vertical areas is presented in Figure 2. There are two main groups that divide the exposed sites from the other six sites. The less exposed beaches are distinguished by a richer fauna.

Only the upper beach is considered in the dendrogram of Figure 3. It is clear that Zuma Beach (IV) has no association with the other sites. The split between Doheny Beach (IX) and Little Dume (V), Huntington Beach (VI), and the five other beaches is based on the abundance of *Euzonus mucronata* (the numerically most abundant species at the study sites), and species of the genus *Orchestoidea*.

In the dendrogram limited to abundance records from the middle areas (Figure 4), Doheny Beach (IX), and Huntington Beach (VI) and Zuma Beach (IV), are separated from the other sites again. Also Hope Ranch (II) is isolated from the other clusters. Dana Point (VIII) is associated with Little Dume (V) and Horse Pastures (VII), instead of Carpinteria (III) and Coal Oil Point (I) as in Figure 3.

Coal Oil Point (I) is unrelated to the other sites in terms of lower beach fauna (Figure 5), reflecting the influence of eight rare polychaetes. The remaining sites join up with each other in a stepwise progression, so that no strong lower beach clusters are apparent.

A few points about the site-groups should be emphasized. Level of similarity between two sites is never complete, about 75 percent is the maximum similarity that is achieved. Therefore the beaches are segregated by their biota, and any combinations made are relative. On the basis of these site-group dendrograms, beaches may have similar fauna in one vertical area while dissimilar in others; for instance, Little Dume (V) is clustered with Doheny Beach (IX) in Figure 3 (upper beach), with Horse Pastures (VII) and Dana Point (VIII) in Figure 4 (middle beach), and with Dana Point (VIII) and Carpinteria (III) in Figure 5 (lower beach). Phi and slope measurements, as well as degree of exposure, hardly vary enough to account for these changing associations.

Time-Groups.

Only the time-group dendrogram with total intertidal fauna is presented, because the other time dendrograms yielded little new information. Figure 6 demonstrates that the seven time entries are all very similar. Such results indicate that seasonality among the beach populations is not strong, at least not when the data from the nine sites are fused. Nevertheless the groups that are formed separate spring-summer months (February, April, June, August) from the winter months.

Species-Groups.

The dendrograms from unstandardized and standardized data (Figure 7 and Figure 8 respectively) both produce three large species-groups. These groups contain identical member species except for three polychaetes: Capitellid n.g.n.sp., *Pygospio californica* and *Nephtys californiensis*. The species-groups from standardized values are organized more clearly and make better ecological sense. Standardization accounts for the fact that some species occur in restricted aggregations, whereas others are evenly distributed. Henceforth the standardized version alone will be considered.

Predominantly upper beach species are included in the first species-group, referred to as Group A. *Euzonus mucronata*, *Orchestoidea corniculata*, *Cirolana chiltoni*, and then *O. benedicti* can be expected to co-inhabit an area. While *Nerinides acuta*, *Hemipodus borealis* and *Emerita analoga* form another group, they are not confined to the upper beach. There is a third cluster joining *Tylos punctatus*, *O. californiana* and *O. columbiana*.

Group B associates *Tivela stultorum* and *Olivella biplicata* with *Paranoides platybranchia*, *Onuphis eremita* and *Donax gouldii*, and also the Capitellid n.g.n.sp. and *Pygospio californica* with *Nephtys californiensis* and *Lepidopa californica*. These species are most predictable in the lower intertidal, although the Capitellid n.g.n.sp. and *N. californiensis* extend to the middle beach areas. Low tide species form Group C as well; these are found at less exposed sites with finer sediments, particularly at Coal Oil Point.

Two-way Tables.

In the five two-way tables obtained from the site-group and time-group dendrograms the species-group sequence is taken from Figure 8. As a result of the log transformation applied to the data, the values that fill in the tables are scaled down considerably. There are statistics of the physical parameters presented for different groups at the bottom of each table.

Pooled data values from all three vertical areas are contained in Table 3. The first site-group, from Dana Point (VIII) through Little Dume (V), includes most of the species recovered during the study, while several common ones are nearly lacking from Huntington Beach (VI), Zuma Beach (IV) and Doheny Beach (IX). These common species are Euzonus mucronata, Orchestoidea corniculata, O. benedicti, Nephtys californiensis and Lumbrineris zonata. The five latter species are typical of beaches with fine sand (phi= 2.19 ± 0.46) and gentle slopes (ratio= 1:21.1 ± 1:12.9).

Other numerically significant species are not confined to one of the main site-groups. Emerita analoga is ubiquitous at the study beaches, but distributional patterns are distinguished when relative abundances and the time-groups are investigated. Cirolana chiltoni is absent only from the most southern sites, Dana Point and Doheny Beach, suggesting some geographical component to its distribution. Upon close inspection of the relative data values in Table 3, a north-south split is evident that the site groups do not emphasize: Nerinides acuta is most abundant (i.e. values near 2.5 or above) at southern beaches, whereas it seems to be replaced by Nephtys californiensis at Carpinteria (III), Hope Ranch (II), and Coal Oil Point (I).

Table 4 illustrates that the upper intertidal fauna of the study sites is limited to Group A in general, so this species-group represents a fairly close assemblage. Yet most of these species, except for the species of Orchestoidea, continue into the other intertidal areas. Euzonus mucronata, O. corniculata, and Nerinides acuta are characteristic of the first six sites that have fine sand on flat shores (phi= 2.25 ± 0.25 and ratio= 1:15.6 ± 1:6.7). At Carpinteria (III), Coal Oil Point (I), and Dana Point (VIII), E. mucronata and O. corniculata are more abundant than at Horse Pastures (VII) or Hope Ranch (II). In contrast O. benedicti inhabits these last two sites and Dana Point (VIII). The upper intertidal area at Huntington Beach (VI) is coarser and steeper (phi=1.82 ± 0.27 and ratio= 1:7.3 ± 1:4.2) relative to the other five sites, and no E. mucronata or Orchestoidea species occur there. Doheny Beach (IX) and Little Dume (V) have less biota in their upper beach areas. Zuma Beach (IV) has essentially no upper beach fauna.

When only the middle intertidal fauna is considered (Table 5,), Doheny Beach (IX) is isolated from the other sites since it contains only Emerita analoga and Donax gouldii. The substrate at Doheny Beach (IX) is coarse and variable (phi= 0.82 ± 1.45).

The Capitellid n.g.n.sp. sets Hope Ranch (II) apart from the other sites, but no causative factor is obvious. E. analoga are less plentiful at Hope Ranch (II) than elsewhere. Horse Pastures (VII), Little Dume (V), Dana Point (VIII), Carpinteria (III) and Coal Oil Point (I) are clustered together in Table 5 on account of Euzonus mucronata, which extends to the middle intertidal area from the upper beach. The middle intertidal areas of the study sites are not inhabited by a particular species-group.

Nerinides acuta, Emerita analoga, and Groups B and C determine the site-groups in Table 6. The near absence of any E. analoga contributes to the uniqueness of Coal Oil Point (I). Also Group C species are almost limited to Coal Oil Point (I), where phi averages (2.53 ± 0.27) are preceptually more fine than elsewhere. Group B species follow different patterns of distribution in the lower beach intertidal areas; molluscs are recorded from Carpinteria (III), Huntington Beach (VI), Doheny Beach (IX), and Hope Ranch (II).

The two-way table with time-group data is presented in Table 7. Several of the species are infrequent or absent from the two December surveys, and usually these are upper beach species, such as Orchestoidea californiana and O. columbiana. O. benedicti is not collected during the December 1971 surveys. A reduction in the E. mucronata population also is evident. The spring-summer increase in Emerita analoga reflects the arrival of immature megalopae at the site beaches. Other species, especially those in Groups B and C, are most numerous in the winter months.

DISCUSSION

The Sandy Beach Physical Environment

The importance of substrate, slope and exposure to beach infaunal distribution is stressed throughout this paper. A review of how these factors operate is given now, although more detailed discussions are available in Brown (1971), Newell (1970), and Clark (1969).

Since fine sediments have a greater water-holding capacity than coarse sediments, the water table is closer to the sand surface at low tide on fine-grained beaches. Thus the corresponding infauna is kept permanently moist at low tide, though it is also more apt to suffer from low oxygen tensions while exposed (Clark, 1969). There is an increase in adsorbed organics, which comprise the diet of several species (e.g. probably Euzonus mucronata), correlated to decreasing grain sizes (Newell 1970). Another result of fine deposits is reduced substrate mobility. The subsequent stability allows polychaetes to build permanent burrows in the sand. In contrast, larger grains are rolled about by the surf and often have sharp edges injurious to delicate species. Also sorting is usually very poor at coarser-grained sites.

At steep beaches with their short intertidal zones, wave energy is dissipated over a narrow space, whereas at flatter beaches the wave is spent before it reaches most of the foreshore. Occasional large waves are more likely to scour and erode away a more inclined foreshore, with a flat beach left essentially unchanged. The water table is influenced by the steepness of a beach as well: it can extend higher up flat sites during a given tidal period.

Wave exposure, along with local wind and current conditions, determines the beach slope. As Brown (1971) points out, moderately exposed beaches may have gentler, lower sloping intertidal zones than sheltered beaches. In this investigation the sheltered sites (Coal Oil Point, Dana Point; Table 2) do not vary in slope ratio in different intertidal areas as much as do the moderately exposed sites. Among the exposed beaches, flat low terraces are typical of Huntington Beach and Doheny Beach, but not of Zuma Beach; this difference identified Zuma Beach as the most exposed beach among the study sites.

Additional factors that contribute to littoral faunal distributions include the backshore and offshore environments, and the length of a beach. The availability of a backshore escape is important in the distributions of talitrid amphipods (genus Orchestoidea), Tylos punctatus, and possibly other upper beach species. According to Bowers (1963), cliffs or boulders that prevent retreat are indicative of O. corniculata habitats. Indeed this species is predominant at Coal Oil Point and Dana Point, where high tides usually reach terrestrial blockades. The situation is involved, of course, as O. corniculata also inhabits Carpinteria, a beach with drifted sand backshore. O. benedicti, O. californiana, and T. punctatus, on the other hand, are more common at sites with wide berms or dunes backshore, especially Hope Ranch, Little Dume and Horse Pastures. O. corniculata, and O. californiana are also associated with more protected and more exposed locations respectively (Bowers, ibid), conditions that further separate Coal Oil Point and Dana Point from Hope Ranch, Little Dume and Horse Pastures.

Directly offshore from a sandy beach there may lie shallow algae-covered rocks, extensive kelp beds, or both. Such rich habitats provide protection from wave action for the infauna, as well as sources of food. These functions may likewise be performed by jetties or natural outcrops that interrupt a stretch of beach lengthwise, such as at Coal Oil Point, Little Dume, Horse Pastures and Dana Point. Colonization of a beach by pelagic larvae may be prevented by large barriers perpendicular to a shoreline, although a particular instance would be difficult to substantiate.

Intertidal Distribution.

The classification analyses used in this study isolate distinct upper and lower beach faunas. There are no species, however, restricted to the middle beach. This may be due to the arbitrary method used in dividing the beach into 3 areas based on slope and not considering intertidal height. The middle area is more of a transition zone, or part of a continuum, between the higher beach, where desiccation may be a limiting factor, and the lower beach, which is only exposed for short periods of time.

A sheltered, gently sloping beach of fine sand, such as Coal Oil Point or Dana Point, has this type of distribution developed most markedly. *Orchestoidea corniculata*, *Euzonus mucronata*, and *Cirolana chiltoni* inhabit the upper area predominantly. *Eohaustorius washingtonianus*, *Emerita analoga*, *Nephtys californiensis*, *Nerinides acuta* and *Lumbrineris zonata* are found in the middle beach and elsewhere in the intertidal. The lower area is occupied by several polychaete species (Group C).

The scheme above is modified at the other site beaches. At the moderately exposed sites, lower area polychaetes are replaced by molluscs like *Tivela stultorum* and *Donax gouldii*, which are able to tolerate surf action. *Euzonus mucronata* are present but less plentiful. The *E. mucronata* and *Cirolana chiltoni* at Little Dume hardly reach into the upper intertidal area, probably because the moisture content is too low (Hong, 1971). Without barriers at high tide, the debris-associated fauna includes *Orchestoidea benedicti*, *O. californiana* and *O. columbiana*. *Tylos punctatus* is also present at Horse Pastures, Hope Ranch and Little Dume.

A permanent upper intertidal fauna is lacking at the more exposed sites. In some instances the reason could be removal by beach crews. Little wrack accumulates to attract species of *Orchestoidea*; Doheny Beach has a few *O. columbiana*, but none occur at Huntington Beach or Zuma Beach. Euzonus mucronata are essentially absent and polychaetes infrequent overall. Still there are some polychaetes, especially Hemipodus borealis and Nerinides acuta, in the upper and middle intertidal area at Huntington Beach. This demonstrates the importance of substrate for these species, since Huntington Beach has considerable fine material even though in an exposed location. In the lower beach, Doheny Beach and Huntington Beach are both populated by Donax gouldii. At Zuma Beach, intertidal profiles are especially steep and short, which makes the intertidal a single homogeneous unit.

The results indicate that Dahl's (1952) hypothesis of three intertidal zones on sandy beaches cannot be used as a broad generalization. The intertidal distribution of sandy beach fauna is dependent on the physical parameters (particularly grain size and beach slope) and the presence and number of defined intertidal zones is also dependent on such factors.

Seasonality.

The observed seasonal changes in the fauna come from two sources, climatic and tidal. The general winter decrease in numbers of Orchestoidea is probably caused by climatic conditions. Heavy rains at this time of the year (as noted at Hope Ranch) may wash the amphipods away or cause them to burrow above the high tide mark. Clark (1967) also reported that Orchestoidea sp. were more abundant in warmer months. It should be remembered that activity cycles, daily fluctuations in amounts of high tide litter and in weather conditions, and time of the day when sampled, probably contribute to a large sampling variability with Orchestoidea in estimating seasonal peaks.

Emerita analoga, the common sand crab, is most abundant in April, May and June, when immature aggregations are encountered. Some juveniles are recorded at all of the beaches, from December 1970 to August 1971, in agreement with fall, winter and spring arrival of megalopae recorded by Barnes and Wenner (1968).

The winter increase in species of polychaetes (Group C) and molluscs (Group B) is not clearly due to climatic aberrations. The lowest minus tides sampled were during the winter, so the landward stragglers of subtidal populations are exposed on these surveys. Several of the low beach polychaetes at Coal Oil Point, Nerinides sp., Dispio sp., Sthenelais tertiaglabra, Arabella iricolor, Scoloplos armiger, Cirriformia spirabrancha, Notomastus tenuis, and Hesionella mccullochae, certainly continue into deeper water, as do the three mollusc species. The reason for their appearance in winter transects may be tidal conditions alone.

CONCLUSIONS

Southern California beaches between Coal Oil Point and Doheny State Beach range in type from sheltered, fine-grained sites to less stable beaches of coarser material. At the nine study beaches, there were more species and individuals associated with fine, homogeneous sand than with coarse, heterogeneous sand. Intertidal zonation is well-developed at the sheltered beach type, where gently inclined profiles are typical. Except for ubiquitous *Emerita analoga*, beaches at the other extreme may be devoid of all macrofauna.

The physical environment is thus most important in determining the beach infauna. Geographical and seasonal factors must also be considered. Colonization of a site may be prevented by local current conditions, or local storms may deplete a resident population. A few species may have clear seasonal peaks to their population densities. The interaction of these variables is very complex, even within one beach.

ACKNOWLEDGMENTS

Field assistance during this study was given by numerous people and I am grateful to them all; to Mrs. Tena Martella and Dr. Ron Harris I am particularly indebted in this respect. Polychaete identifications were made with the assistance of Dr. Olga Hartman and Dr. Kristian Fauchald of the Allan Hancock Foundation. *Eohaustorius washingtonianus* was identified by Mr. Sung Yon Hong. Mr. Robert Smith is responsible for the classification analysis programs, as well as for valuable criticism of the entire report. I wish to thank Tom Licari for final preparation of the figures. Dr. Dale Straughan gave continuous support and advice throughout the study and manuscript preparation; these contributions were invaluable. Partial requirements for a masters degree were fulfilled with this work.

LITERATURE CITED

Ansell, A.D., P. Sivadas, B. Narayanan, V.N. Sankaranarayanan and A. Trevallion. 1972. The Ecology of Two Sandy Beaches in South West India. I. Seasonal Changes in Physical and Chemical Factors, and in the Macrofauna. Marine Biology, 17: 38-62.

Barnes, N.B., and A.M. Wenner. 1968. Seasonal Variation in the Sand Crab Emerita analoga (Decapoda, Hippidae) in the Santa Barbara area of California. Limmol. and Oceanography, 13(3): 465-475.

Bowers, D.E. 1963. Field Identification of Five Species of Californian Beach Hoppers (Crustacea: Amphipoda). Pacific Science, 17: 315-320.

Bray, J.R. and J.T. Curtis. 1957. An Ordination of the upland forest communities of southern Wisconsin. Ecol. Monogr., 27: 325-349.

Brown, A.C. 1971. The ecology of Sandy Beaches of the Cape Peninsula, South Africa. Part I: Introduction. Trans. Roy. Soc. S. Afr., 39 (Part III): 247-249.

Clark, M.B. 1969. Distribution and Seasonal Dynamics of Animal Populations in San Diego Beaches. Unpubl. Masters Thesis: 177 pp.

Dahl, E. 1952. Ecology and zonation of fauna of sand beaches. Oikos, 4: 1-23.

Day, J.H., J.G. Field, and M.P. Montgomery. 1971. The Use of Numerical Methods to Determine the Distribution of the Benthic Fauna Across the Continental Shelf of North Carolina. J. of Anim. Ecol., 40(1): 93-125.

Dexter, D.M. 1969. Structure of and Intertidal Sandy Beach Community in North Carolina. Chesapeake Science, 10(2): 93-98.

________ 1972. Comparison of the Community Structures in a Pacific and an Atlantic Panamanian Sandy Beach. Bull. of Mar. Science, 22(2): 449-462.

Efford, I.E. 1970. Recruitment to sedentary marine populations as exemplified by the sand crab Emerita analoga (Decapoda, Hippidae). Crustaceana, 18: 293-308.

Field, J.G. 1971. A numerical analysis in the soft bottom fauna along a transect across False Bay, South Africa. *J. exp. Mar. Biol. Ecol.*, 7: 215-253.

________ and G. McFarlane. 1968. Numerical Methods in Marine Ecology. 1. A quantitative "similarity" analysis of rocky shore samples in False Bay, South Africa. *Zool. Afr.*, 3: 119-137.

Hedgpeth, J.W. 1957. Sandy beaches. In Treatise on Marine Ecology and Paleoecology. Vol. 1. Ecology. Mem. geol. Soc. Am.

Hong, S.Y. 1971. Studies on the Distribution of *Euzonus mucronata* (Treadwell) on the Scripps Beach. Unpublished, 13 pp.

Lance, G.N. and M.T. Williams. 1967. A general theory of classificatory sorting strategies. I. Hierarchal systems. *Comput.* J., 9: 373-380.

McIntyre, A.D. 1968. The meiofauna and macrofauna of some tropical beaches. *J. Zool.*, 156: 377-392.

Newell, R.C. 1970. *Biology of Intertidal Animals*.

Stephenson, W. 1973. Introduction. Recognition of Communities. Manuscript.

Williams, W.T. and W. Stephenson. 1973. The Analysis of three-dimensional data (Sites x Species x Times) in Marine Ecology. Manuscript in press.

Table 1. Species list of all animals recovered during study period.

Amphipoda
- *Orchestoidea benedicti* Shoemaker
- *O. californiana* (Brandt)
- *O. columbiana* Bousfield
- *O. corniculata* Stout
- *Eohaustorius washingtonianus* (Thorsteinson)

Isopoda
- *Cirolana chiltoni* Richardson
- *Tylos punctatus* Holmes and Gay

Decapoda
- *Blepharipoda occidentalis* Randall
- *Emerita analoga* (Stimpson)
- *Lepidopa californica* Efford

Polychaeta
- *Arabella iricolor* (Montagu)
- *Capitellid*, n.g., n.sp.
- *Cirriformia spirabrancha* (Moore)
- *Dispio* sp.
- *Eteone dilatae* (Hartman)
- *Euzonus mucronata* (Treadwell)
- *Hemipodus borealis* Johnson
- *Hesionella mccullochae* Hartman
- *Lumbrineris zonata* (Johnson)
- *Nephtys californiensis* Hartman
- *Nerinides acuta* (Treadwell)
- *Nerinides* sp.
- *Notomastus tenuis* Moore
- *Onuphis eremita* Audoin and M. Edwards
- *Paranoides platybranchia* (Hartman)
- *Pygospio californica* Hartman
- *Scoloplos armiger* (Muller)
- *Sthenelais tertiaglabra* Moore

Nemerteans

Mollusca
- *Donax gouldii* Dall
- *Olivella biplicata* (Sowerby)
- *Tivela stultorum* (Mawe)

Insecta
- *Coleoptera* spp.
- larvae

Table 2. Mean phi, sorting, and slope ratio values for upper, middle, and lower intertidal areas.

Date	11-12/70			2-3/71			4/71			5-6/71			7-8/71			10/71			11-12/71		
	Phi	Sorting	Gradient	Phi	Sorting	Gradient	Phi	Sorting	Gradient	Phi	Sorting	Gradient	Phi	Sorting	Gradient	Phi	Sorting	Gradient	Phi	Sorting	Gradient
Coal Oil Point																					
Upper	2.58	0.385	1:20.8	2.31	0.46	1:11.2	2.29	0.455	1:11.4	2.20	0.415	1:9.2	2.36	0.50	1:10.4	2.47	0.435	1:15.4	2.21	0.393	1:25.1
Middle	2.69	0.41	1:30.4	2.71	0.436	1:26.7	2.00	0.81	1:13.0	2.22	0.645	1:15.0	2.39	0.655	1:11.4	2.58	0.515	1:17.7	2.34	0.4575	1:36.2
Lower	2.66	0.503	1:41.7	2.74	0.446	1:50.0	2.21	1.21	1:19.7	2.14	2.14	1:24.0	2.41	0.79	1:14.1	2.78	1.03	1:19.5	2.76	0.4475	1:23.6
Hope Ranch																					
Upper	2.62	0.383	1:20.7	2.28	0.426	1:37.8	2.55	0.423	1:18.0	2.32	0.453	1:21.2	2.24	0.525	1:20.0	2.26	0.445	1:13.3	2.09	0.433	1:11.7
Middle	2.57	0.49	1:28.7	2.09	0.593	1:14.5	2.41	0.52	1:42.4	2.22	0.58	1:25.5	2.33	0.605	1:17.0	2.44	0.473	1:18.3	2.31	0.433	1:24.0
Lower	2.56	0.363	1:28.6	2.42	0.626	1:27.0	2.38	0.543	1:120.0	1.47	0.96	1:45.6	2.42	0.60	1:27.2	2.51	0.646	1:25.7	2.32	0.466	1:30.0
Carpinteria																					
Upper	2.48	0.35	1:18.0	2.45	0.486		2.37	0.356	1:22.4	2.21	0.43	1:10.7	2.46	0.413	1:13.9	2.44	0.383	1:16.1	2.25	0.4325	1:12.6
Middle	2.60	0.366	1:20.0	2.69	0.506		2.03	1.18	1:27.3	2.19	0.485	1:13.9	2.50	0.516	1:35.6	2.40	0.5575	1:24.0	2.11	0.5675	1:20.9
Lower	2.75	0.335	1:24.0	2.61	0.506		1.85	1.22	1:41.8	2.08	1.085	1:23.9	2.44	0.666	1:34.1	2.19	0.92	1:32.7	2.42	0.535	1:32.5
Zuma Beach																					
Upper				1.42	0.645	1:10.0	1.39	0.72	1:6.1	1.36	0.52	1:8.6	1.40	0.545	1:16.0	1.38	0.83	1:5.5	1.31	0.56	1:8.3
Middle				1.24	1.05	1:9.6	1.52	0.65	1:8.1	1.23	0.77	1:8.6	1.37	0.595	1:7.4	1.41	0.01	1:8.6	1.30	0.603	1:16.6
Lower				0.99	1.20	1:8.5	1.62	0.68	1:14.0	1.09	0.95	1:8.6	1.38	0.615	1:9.5	1.99	0.555	1:15.0	0.94	1.16	1:22.9
Little Dume																					
Upper				1.40	0.615	1:6.5	1.68	0.585	1:8.2	1.53	0.59	1:8.2	1.14	0.75	1:6.2	1.29	0.625	1:3.7	1.27	0.69	1:4.5
Middle				1.50	0.80	1:8.2	1.70	0.905	1:11.8	1.11	0.735	1:7.1	1.37	0.73	1:6.5	1.63	0.68	1:6.6	1.58	0.843	1:9.1
Lower				2.30	0.51	1:10.6	2.25	0.66	1:24.1	1.04	1.06	1:8.9	1.94	0.44	1:10.4	2.27	0.50	1:11.2	2.45	0.725	1:24.0
Huntington Beach																					
Upper	2.10	0.50	1:9.5	1.48	0.825	1:7.8	1.52	0.63	1:6.2	2.08	0.57	1:12.2	1.67	0.645	1:12.4	1.65	0.615	1:6.5	1.77		1:9.0
Middle	2.17	0.51	1:27.7	1:91	1.11	1:30.6	1.68	0.665	1:8.6	1.17	0.94	1:24.0	1.50	0.93	1:9.6	2.05	0.703	1:22.7	1.02		1:62.7
Lower	2.35	0.75	1:65.4	1:93	1.14	1:95.3	1.90	0.94	1:12.0	0.73	1.41	1:46.2	1.61	0.98	1:8.8	1.93	1.15	1:37.4	2.41		1:80.1
Horse Pastures																					
Upper	2.40		1:27.4	2.32	0.41	1:15.5	1.90		1:12.0	1.94	0.635	1:13.7	2.49	0.275	1:18.3	2.29	0.38	1:14.0	2.42	0.315	1:17.1
Middle	2.44		1:18.1	2.30	0.583	1:17.1	0.97		1:16.2	2.37	0.353	1:18.5	2.52	0.35	1:20.2	2.40	0.54	1:20.7	2.55	0.353	1:22.6
Lower	2.74		1:21.3	2.46	0.705	1:17.1	-.23		1:14.1	2.39	0.375	1:24.0	2.50	0.357	1:37.7	2.17	0.826	1:23.1	2.59	0.536	1:26.9
Dana Point																					
Upper	2.35	0.34	1:14.7	2.24	0.37	1:9.8	1.88	1.04	1:7.5	2.26	0.38	1:12.0	2.27	0.34	1:24.7	2.20	0.37	1:20.0	2.34	0.366	1:20.5
Middle	2.36	0.413	1:24.0	2.35	0.52	1:17.8	0.94	1.62	1:21.8	2.04	0.40	1:12.9	2.38	0.35	1:15.8	2.19	0.214	1:27.2	2.29	0.673	1:25.2
Lower	2.06	0.713	1:37.9	2.35	0.495	1:28.2	1.89	1.225	1:28.2	1.40	2.00	1:17.9	2.48	0.385	1:15.0	2.31	0.376	1:24.0	2.34	0.56	1:28.5
Doheny Beach																					
Upper	1.39	0.89	1:7.3	1.54	0.70	1:8.6	1.45	0.78	1:4.9	1.35	0.615	1:8.7	0.78	1.11	1:7.4	1.07	0.845	1:6.1	1.26	0.81	1:5.9
Middle	2.47	0.67	1:30.0	1.34	0.84	1:6.4	0.92	1.09	1:63.3	0.88	1.46	1:8.7	0.47	1.705	1:9.3	-.25	1.746	1:8.1	0.23	1.816	1:10.2
Lower	2.24	0.906	1:46.6	1.69	1.23	1:7.2	0.60	1.51	1:8.1	-.29	1.94	1:9.0	0.35	2.00	1:8.1	1.41	1.39	1:34.3	2.37	1.345	1:28.2

Table 3. Two-way table considering all three intertidal areas.

	Station / Species	VIII	III	I	VII	II	V	VI	IV	IX
Group A	E. mucronata	5.91	4.50	6.54	4.05	3.77	2.97		0.62	
	O. corniculata	2.10	3.59	2.57	0.49	0.30				
	C. chiltoni		0.27	2.61	1.99	1.55	2.67	0.83	0.89	
	O. benedicti	1.87			3.08	2.43	0.81			
	N. acuta	2.44	1.57	1.98	3.73	1.14		2.74	0.41	
	H. borealis		0.17	0.55	0.81	0.97	0.62	1.62	0.70	
	E. analoga	3.77	3.95	3.11	3.33	1.84	4.12	3.19	5.32	2.91
	E. dilatae		0.89	0.70		0.30				
	T. punctatus				1.01	2.13	1.56			
	O. californiana			0.36	0.22	0.36	0.92			
	O. columbiana					0.64	1.79			1.11
Group B	L. californica	0.55	0.60		0.18	0.62		0.40		0.47
	N. californiensis	1.55	2.71	3.11	0.73	2.70	1.34	1.43		
	P. californica		0.17	0.46		0.50				
	C. (n.g.n.sp.)		0.53			3.56				
	D. gouldii					0.19		1.20		0.72
	O. eremita							0.11		
	P. platybranchia	0.62	0.30		1.09			0.84		0.22
	O. biplicata		0.15							
	T. stultorum		0.15			0.30		0.11		
Group C	E. washingtonianus	1.29	0.13	0.88	0.73		0.32	0.11		
	L. zonata	0.59	0.16	3.52	2.01	0.17	0.92	0.32		
	H. mccullochae			0.90						
	N. tenuis			0.62						
	C. spirabrancha			2.10						
	S. armiger		0.13	0.79						
	A. iricolor			0.47						
	S. tertiaglabra			0.14						
	D. sp.			0.26						
	N. sp.			0.14						
	B. occidentalis						0.56			
		ø	2.309 ± 0.305		2.070 ± 0.556			1.760 ± 0.440	1.341 ± 0.265	1.182 ± 0.917
		S_i	1:21.941 ± 9.027		1:20.142 ± 16.040			1:29.884 ± 27.683	1:10.843 ± 4.625	1:15.195 ± 13.640
		ø	2.193 ± 0.460					1.582 ± 0.426		
		S_i	1:21.063 ± 12.909					1:21.806 ± 23.046		

Table 4. Two-way table considering only upper intertidal areas.

	Locality / Species	VII	II	III	I	VIII	VI	IX	V	IV
Group A	E. mucronata	3.95	3.69	4.47	6.52	5.64				
	O. corniculata	0.49	0.30	3.59	2.57	2.10				
	C. chiltoni	1.31	1.51	0.27	2.57				1.03	0.52
	O. benedicti	3.06	2.41			1.87			0.81	
	N. acuta	2.57	0.34	0.90	1.80	1.41	2.00			
	H. borealis	0.70	0.82	0.17	0.36		0.91		0.42	0.70
	E. analoga	1.03	0.81	2.36	2.24	2.86	2.08	1.19	1.73	
	E. dilatae			0.83	0.70					
	T. punctatus	0.81	2.13						1.56	
	O. californiana	0.22	0.36		0.36				0.92	
	O. columbiana		0.64					1.19	1.73	
Group B	L. californica									
	N. californiensis		0.16	0.53	1.76				0.24	
	P. californica		0.15	0.17	0.14					
	C. (n.g.n.sp.)		0.47							
	D. gouldii									
	O. eremita									
	P. platybranchia									
	O. biplicata									
	T. stultorum									
Group C	E. washingtonianus	0.47				0.43				
	L. zonata									
	H. mccullochae									
	N. tenuis									
	C. spirabrancha									
	S. armiger									
	A. iricolor									
	S. tertiaglabra									
	D. sp.									
	N. sp.									
	B. occidentalis									
	Ø	2.294 ± 0.209		2.315 ± 0.148			1.816 ± 0.271	1.432 ± 0.083	1.385 ± 0.195	1.350 ± 0.057
	S_i	1:18.621 ± 6.994		1:15.552 ± 5.342			1:7.340 ± 4.215	1:5.732 ± 3.775	1:6.217 ± 1.856	1:7.200 ± 1.556
	Ø	2.245 ± 0.246						1.404 ± 0.155		
	S_i	1:15.600 ± 6.693						1:6.023 ± 2.594		

Table 5. Two-way table considering only middle intertidal areas.

	Locality / Species	VII	V	VIII	III	II	VI	IV	II	IX
Group A	E. mucronata	1.84	2.96	4.49	1.18	2.71		0.62	1.41	
	O. corniculata									
	C. chiltoni	1.53	2.54			0.46	0.83	0.36	0.18	
	O. benedicti	0.17								
	N. acuta	2.30		2.06	1.12		1.84	0.22	1.00	
	H. borealis	0.22	0.29				1.08	0.70	0.31	
	E. analoga	2.96	3.52	2.36	3.05	2.61	2.13	3.82	0.65	1.53
	E. dilatae				0.13				0.30	
	T. punctatus	0.22								
	O. californiana									
	O. columbiana									
Group B	L. californica				0.28		0.18		0.51	
	N. californiensis	0.19	0.24	0.82	2.03	2.35	0.19		2.20	
	P. californica					0.36			0.40	
	C. (n.g.n.sp.)								3.35	
	D. gouldii						0.67			0.43
	O. eremita									
	P. platybranchia	0.73			0.17					
	O. biplicata									
	T. stultorum									
Group C	E. washingtonianus	0.38		0.95		0.47	0.11			
	L. zonata	0.18	0.49	0.29		1.10				
	H. mccullochae									
	N. tenuis									
	C. spirabrancha					0.47				
	S. armiger					0.14				
	A. iricolor									
	S. tertiaglabra									
	D. sp.									
	N. sp.									
	B. occidentalis									
	ø	2.131 ± 0.494					1.505 ± 0.353		2.339 ± 0.156	0.817 ± 1.452
	S_i	1:18.947 ± 7.704					1:18.831 ± 15.595		1:24.329 ± 9.425	1:16.100 ± 12.083
	ø	1.958 ± 0.536								
	S_i	1:18.915 ± 10.297								

Table 6. Two-way table considering only lower intertidal areas.

	Locality / Species	VIII	V	III	VI	IX	IV	VII	II	I
Group A	E. mucronata	0.29	0.22							0.26
	O. corniculata									
	C. chiltoni						0.29			
	O. benedicti							0.22	0.17	
	N. acuta	0.40		0.26	1.32		0.22	3.02		0.79
	H. borealis				0.50					0.26
	E. analoga	2.85	3.18	3.10	2.29	2.51	5.08	2.04	1.42	0.36
	E. dilatae									
	T. punctatus							0.22		
	O. californiana									
	O. columbiana									
	L. californica	0.55		0.41	0.25	0.47		0.18	0.17	
	N. californiensis	1.23	1.19	2.05	1.38			0.62	1.90	2.09
	P. californica									
	C. (n.g.n.sp.)			0.53					1.98	
	D. gouldii				0.87	0.43			0.19	
	O. eremita				0.11					
	P. platybranchia	0.62		0.15	0.84	0.22		0.64		
	O. biplicata			0.15						
	T. stultorum			0.15	0.11				0.30	
	E. washingtonianus	0.41	0.32	0.13						0.59
	L. zonata	0.38	0.63	0.16	0.32			1.98	0.17	3.46
	H. mccullochae									0.90
	N. tenuis									0.62
	C. spirabrancha									2.02
	S. armiger			0.13						0.72
	A. iricolor									0.47
	S. tertiaglabra									0.14
	D. sp.									0.26
	N. sp.									0.14
	B. occidentalis		0.56							
		ø	1.901 ± 0.696				1.335 ± 0.412	2.089 ± 1.037	2.297 ± 0.373	2.529 ± 0.272
		S_i	1:28.750 ± 20.332				1:13.083 ± 5.565	1:23.457 ± 7.613	1:43.443 ± 34.438	1:27.514 ± 13.164
		ø	1.857 ± 0.742							
		S_i	1:25.962 ± 18.326							

Table 7. Two-way table from time groups, considering all three intertidal areas.

	Month / Species	AUG	FEB	JUNE	APRIL	OCT	DEC 1970	DEC 1971
Group A	E. mucronata	5.75	5.13	5.91	4.86	4.28	5.25	3.46
	O. corniculata	2.07	1.48	2.39	2.10	1.50	2.98	1.95
	C. chiltoni	2.86	1.99	0.17	2.19	1.09	1.51	1.34
	O. benedicti	2.04	2.71	1.40	0.72	1.33	2.41	
	N. acuta	1.89	1.68	2.57	1.91	2.77	2.54	3.20
	H. borealis	0.89	0.81	0.81	1.21	0.36	1.00	0.84
	E. analoga	3.84	4.28	5.02	4.82	2.85	3.53	2.60
	E. dilatae	1.09	0.43					0.25
	T. punctatus	1.56	0.88	1.01		1.95		
	O. californiana	0.94	0.22	0.32		0.36		
	O. columbiana	1.27	1.16	0.29	0.83	0.94		
Group B	L. californica	0.58	0.47	0.45	0.17	0.37	0.42	0.46
	N. californiensis	2.24	2.42	1.56	2.18	2.71	1.83	2.46
	P. californica	0.65			0.15			0.29
	C. (n.g.n.sp.)	2.39	0.88	1.83	2.27	1.39		2.05
	D. gouldii		0.45			0.50	0.94	0.61
	O. eremita							0.11
	P. platybranchia	0.35		0.22		0.91		1.28
	O. biplicata					0.15		
	T. stultorum				0.15	0.15		0.27
Group C	E. washingtonianus	0.47	0.88	0.22		1.25	0.15	0.61
	L. zonata	1.28	2.10	1.32	1.52	1.47	3.06	1.28
	H. mccullochae		0.47				0.62	
	N. tenuis						0.62	
	C. spirabrancha		0.34				1.27	1.65
	S. armiger							0.85
	A. iricolor							0.47
	S. tertiaglabra							0.14
	D. sp.							0.26
	N. sp.							0.14
	B. occidentalis							0.56
	Ø	2.066 ± 0.537		1.714 ± 0.640		2.040 ± 0.615	2.409 ± 0.307	2.000 ± 0.626
	S_i	1:19.262 ± 15.225		1:19.024 ± 17.771		1:18.624 ± 8.868	1:26.516 ± 13.585	1:24.035 ± 16.652
	Ø	1.918 ± 0.615						
	S_i	1:19.036 ± 15.220						

Table 8. Air and surf water temperatures at nine study beaches (°C)

	Coal Oil Point						
	11/27/70	2/8/71	4/4/71	5/19/71	7/26/71	10/3/71	12/1/71
Air	17.1	14.7	21.5	24.0		23.0	17.4
Surf	19.5	14.2	14.5	18.0		20.0	13.6
	Hope Ranch						
	12/1/70	2/9/71	4/5/71	5/18/71	7/27/71	10/7/71	12/3/71
Air	16.8	17.2	20.3	23.8	17.5	20.0	10.1
Surf	15.7	14.5	18.7	17.5	18.0	19.0	12.0
	Carpinteria						
	11/24/70	2/7/71	4/6/71	5/17/71	7/25/71	10/6/71	11/30/71
Air	16.2	15.5	16.6	22.0	16.0	22.0	17.6
Surf	16.1	14.0	14.4	16.0	16.0	19.0	14.2
	Zuma Beach						
		3/8/71	4/7/71	5/21/71	8/9/71	10/5/71	12/4/71
Air			16.8	15.0	19.0	27.0	14.8
Surf			14.0	13.5	21.0	19.0	12.9
	Little Dume						
		3/7/71	4/19/71	5/20/71	8/10/71	10/4/71	12/2/71
Air		17.5	15.7	20.0	24.0	29.0	13.8
Surf		12.5	11.4	14.5	20.0	19.0	13.4
	Huntington Beach						
	12/10/70	2/10/71	4/23/71	6/14/71	8/11/71	10/19/71	12/16/71
Air	17.0	17.5	17.0	16.4	25.0	18.5	19.0
Surf	16.8	14.5	15.5	14.9	24.0	18.8	12.5
	Horse Pastures						
	12/13/70	2/12/71	4/20/71	6/16/71	8/10/71	10/20/71	12/17/71
Air	17.0	20.5	16.6	20.4	24.5	21.4	14.4
Surf	16.0	15.5	14.8	18.8	24.8	18.0	12.3
	Dana Point						
	12/12/70	2/11/71	4/21/71	6/1/71	8/12/71	10/17/71	12/19/71
Air	18.0	18.4	13.5	19.9	24.0	21.0	14.0
Surf	15.7	14.4	15.0	15.8	24.0	18.0	12.5
	Doheny Beach						
	12/11/70	2/13/71	4/22/71	6/15/71	8/9/71	10/18/71	12/18/71
Air	19.0	23.0	16.0	19.0	24.0	18.6	12.0
Surf	15.7	15.0	14.0	17.8	24.5	18.4	12.0

Figure 1. Locations of Study Sites

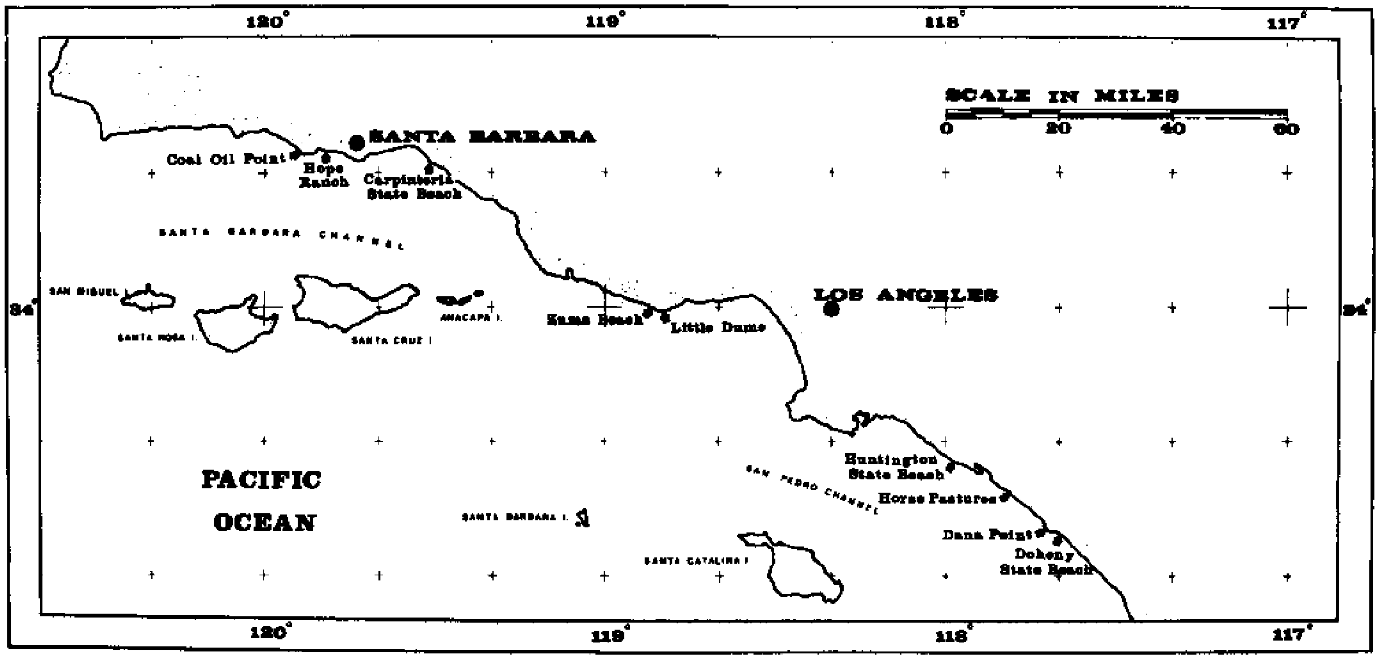


Figure 2. Site-group dendrogram considering all three intertidal areas.

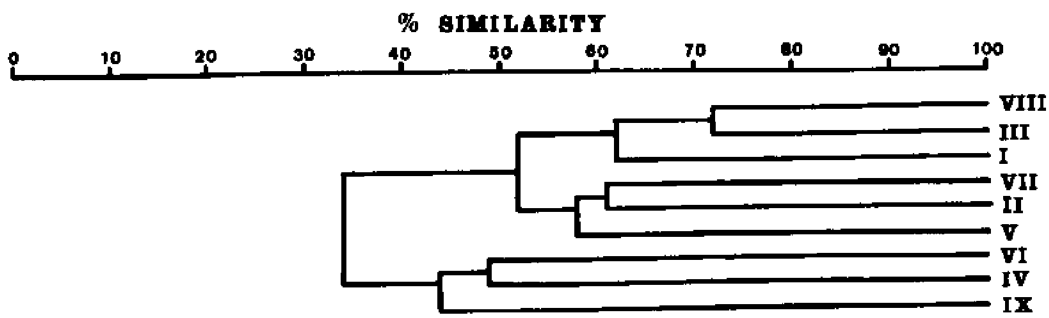


Figure 3. Site-group dendrogram considering upper intertidal areas only.

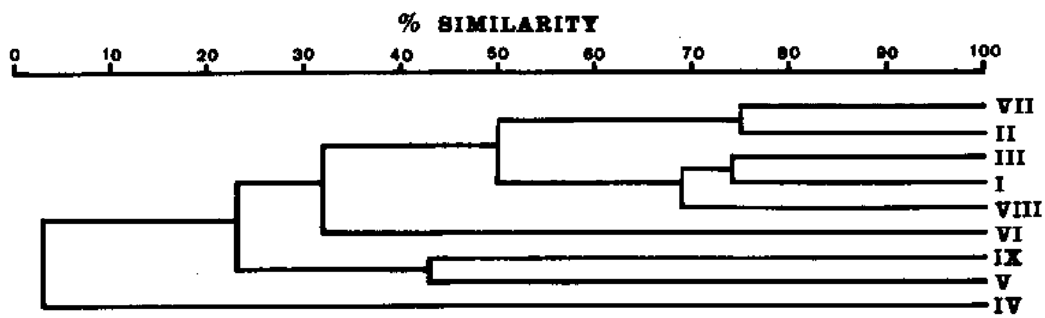


Figure 4. Site-group dendrogram considering middle intertidal areas only.

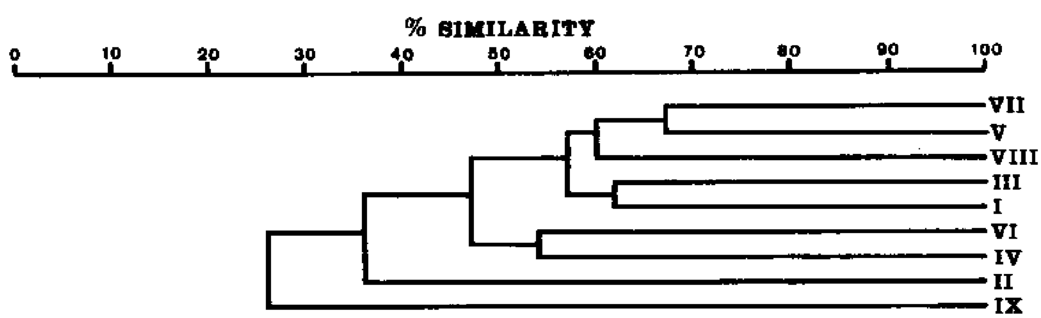


Figure 5. Site-group dendrogram considering lower intertidal areas only.

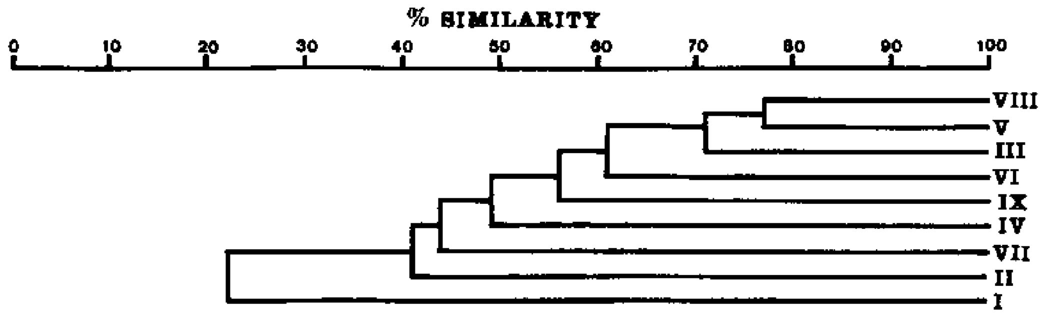


Figure 6. Time-group dendrogram considering all three intertidal areas.

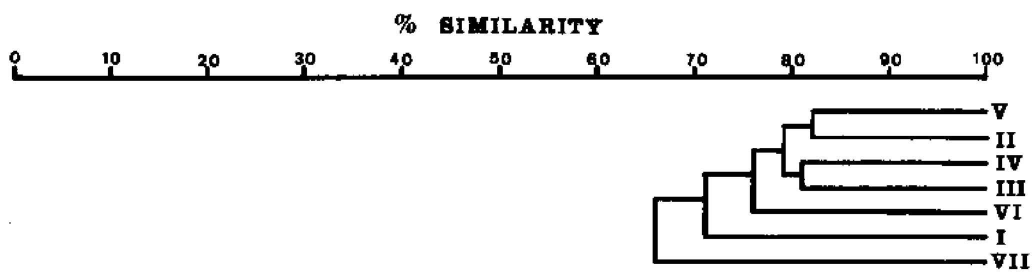


Figure 7. Species-group dendrogram considering 31 species, unstandardized data.

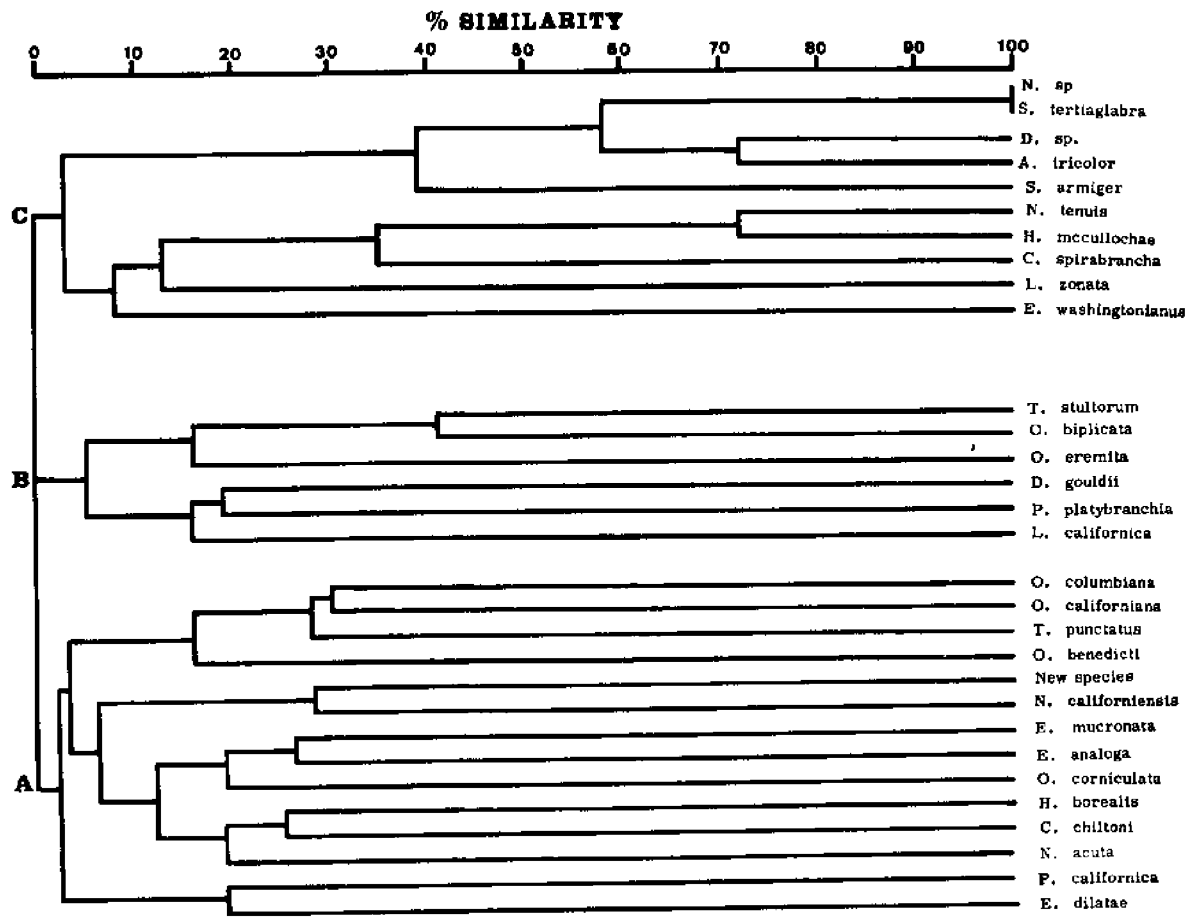
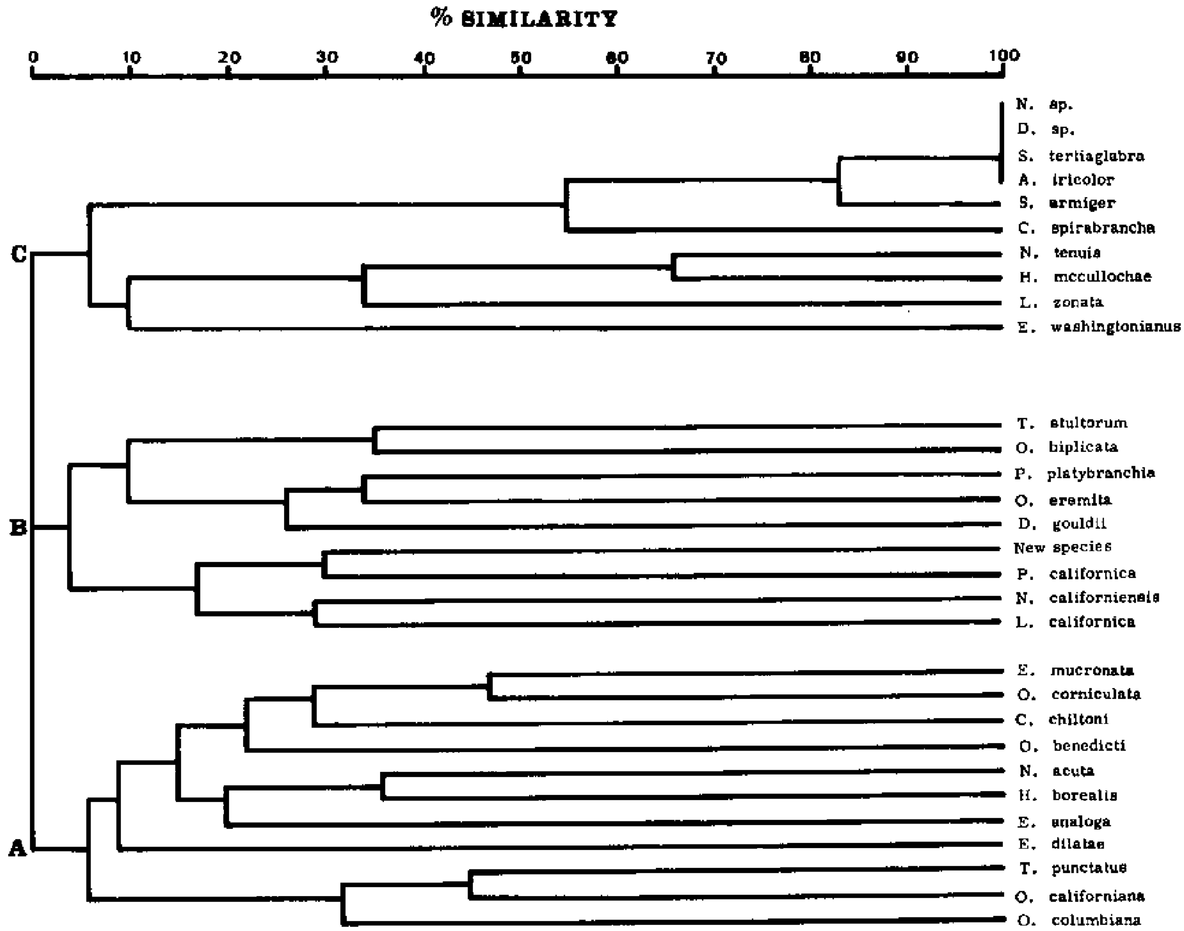


Figure 8. Species-group dendrogram considering 31 species, standardized data.



Appendix 1.

Basepoint Descriptions

Coal Oil Point.	Basepoint was located at the rock outcrop 60 feet east of the cement steps which are seaward of Camino Majorca road.
Hope Ranch.	Basepoint was marked by the drainage pipe projecting from the cliff backshore; pipe is about 200 yards north of the controlled access beach entrance.
Carpinteria State Beach.	Beach was sampled seaward of a permanent wood post between the ocean and the main entrance.
Zuma Beach.	First lifeguard stand downshore from Zuma Creek was basepoint for the surveys.
Little Dume.	The beach was sampled below a cyclone fence on the surrounding cliff, about 450 yards north of the private path entrance.
Huntington State Beach.	The basepoint was in front of the first lifeguard stand near the park entrance from Beach Blvd.
Horse Pastures.	A deep gully 150 yards east of the cliff road at Irvine Equestrian Center served as the basepoint.
Dana Point.	Sampling began in front of concrete steps 180 yards downshore from the broken jetty at Laguna Nigel Beach Club.
Doheny State Beach.	At the campground section, a permanent LEO (Littoral Environmental Observation Program) marker served as the basepoint for transects.

Appendix 2.

Beach Fauna Data.

Organisms recovered at each date are given in Tables 1-9. The animals from the four quadrats per vertical row have been combined into one sample, i.e. each sample contains the specimens from 3x4 cores of sediment. Then the total number of rows in a survey, with the corresponding fauna, has been divided into three intertidal areas. This creates equal upper, middle and lower intertidal areas in each survey. When computations were conducted for the Bray-Curtis coefficients, the number of animals in a given intertidal area were divided by the number of samples (or rows) taken to make up that intertidal area, so that abundances can be compared. U,M,L, refer to upper, middle, and lower intertidal areas respectively.

TABLE 1.

Organisms recovered from Coal Oil Point study area 11/27/70 through 12/1/71.
Sampled intertidal is divided into upper, middle and lower intertidal areas

	11/27/70*			2/8/71			4/4/71			5/19/71			7/26/71			10/3/71			12/1/71		
	U	M	L	U	M	L	U	M	L	U	M	L	U	M	L	U	M	L	U	M	L
O. benedicti																					
O. californiana													1								
O. columbiana																					
O. corniculata	2						14			8			11								
E. washingtonianus					3	4															
C. chiltoni	4			13			12						5	1		2			14	1	
T. punctatus																					
B. occidentalis	1																				
E. analoga	2	2	2										14	42		4			3	1	
L. californica																					
A. iricolor																				1	2
C. spirabrancha			12			2														7	25
D. sp.																					2
E. dilatae													2						1		
E. mucronata	698			76			280	1	1	720			352	47		111			10		
H. borealis	2																			1	1
H. mccullochae			4			3															
L. zonata			86		1	30		1	12		1	4		2	72		52	2		5	10
N. californiensis	2	10	2	2	5			3	1		1	1		3	45	11	6	4	11	13	11
N. sp.																					1
N. acuta	10			13						1									3		6
N. tenuis			4																		
O. eremita																					
P. platybranchia																					
P. californica														1					1	5	
S. armiger																				7	8
S. tertiaglabra																					1
New species																					
Nemerteans	1	4	8	1		5		1	2	1				1	2					8	24
D. gouldii																					
O. biplicata																					
T. stultorum																					
Coleoptera spp.							1												1		
Insect larvae																					
Distance sampled (feet)	140			150			100			90			70			80			200		

* Only 2 quadrats were sampled every 10 feet; animals recovered have been multiplied x 2.

TABLE 2.

Organisms recovered from Hope Ranch study area 12/1/70 through 12/3/71.
Sampled intertidal is divided into upper, middle and lower intertidal areas

	12/1/70*			2/9/71			4/5/71			5/18/71			7/27/71			10/7/71			12/3/71		
	U	M	L	U	M	L	U	M	L	U	M	L	U	M	L	U	M	L	U	M	L
O. benedicti				20			3			3		1	11			12					
O. californiana																3					
O. columbiana							1						1			2					
O. corniculata				1																	
E. washingtonianus																					
C. chiltoni	4	1		1			2			1			4			3			1		
T. punctatus				8												28					
B. occidentalis																					
E. analoga			5	1	1		3					3		1	4		2		3		7
L. californica					1						1	1		1							
A. iricolor																					
C. spirabrancha																					
D. sp.																					
E. dilatae					4																
E. mucronata	27	4					2			11			101	2		20					1
H. borealis	3	6		2	1					1			1								1
H. mccullochae																					
L. zonata												1									
N. californiensis		4	6	1	2	4		9	12		7	5		5	7		13	2		4	2
N. sp.																					
N. acuta		3														1			2	5	
N. tenuis																					
O. eremita																					
P. platybranchia																					
P. californica							1							1						3	
S. armiger																					
S. tertiaglabra																					
New species						5		56	22		49		1	63	14		21				59
Nemerteans						1		2				1					1	3			2
D. gouldii																		1			
P. biplicata																					
T. stultorum									1												1
Coeleoptera spp.				1			4			2			1			1					
Insect larvae							2						2						1		
Distance sampled (feet)	150			170			180			160			100			140			160		

* Every alternate row x 2 because only half of these rows were sampled.

TABLE 3.

Organisms recovered from Carpinteria study area 11/24/70 through 11/30/71.
Sampled foreshore is divided into upper, middle and lower intertidal areas

	11/24/70			2/7/71			4/6/71			5/17/71			7/25/71			10/6/71			11/30/71		
	U	M	L	U	M	L	U	M	L	U	M	L	U	M	L	U	M	L	U	M	L
O. benedicti																					
O. californiana																					
O. columbiana																					
O. corniculata	64			3			9			14			10			21			44		
E. washingtonianus																					1
C. chiltoni				1															1		
T. punctatus																					
B. occidentalis																					
E. analoga	19	6		2					4	2	61	55	16	11	7	6			1	1	1
L. californica						1			1					1						1	1
A. iricolor																					
C. spirabrancha																					
D. sp.																					
E. dilatae				1									7							1	
E. mucronata	16			23			210			302	5		129			68			4		
H. borealis													2								
H. mccullochae																					
L. zonata						1															
N. californiensis		1	1	1	20	17		10	6		2			3		2	7	6		8	7
N. sp.																					
N. acuta				1							2	1				19	3		2	10	
N. tenuis																					
O. eremita																					
P. platybranchia														2				1			
P. californica													1	2							
S. armiger																					4
S. tertiaglabra																					
New species						4															
Nemerteans									1						1		2				
D. gouldii																					
O. biplicata																		1			
T. stultorum																		1			
Coleoptera spp.																5					
Insect larvae										29						1					
Distance sampled (feet)	110			170			160			100			160			180			220		

TABLE 4.

Organisms recovered from Zuma Beach study area 3/8/71 through 12/4/71
Sampled intertidal is divided into upper, middle and lower intertidal areas

	3/8/71			4/7/71			5/21/71			8/9/71			10/5/71			12/4/71		
	U	M	L	U	M	L	U	M	L	U	M	L	U	M	L	U	M	L
O. benedicti																		
O. californiana																		
O. columbiana																		
O. corniculata																		
E. washingtonianus																		
C. chiltoni					2						1					1		
T. punctatus																		
B. occidentalis																		
E. analoga		43	60		74	138		9	74		4	6		14	3		4	3
L. californica																		
A. iricolor																		
C. spirabrancha																		
D. sp.																		
E. dilatae																		
E. mucronata					2													
H. borealis					1						1						2	
H. mccullochae																		
L. zonata																		
N. californiensis																		
N. sp.																		
N. acuta																	1	1
N. tenuis																		
O. eremita																		
P. platybranchia																		
P. californica																		
S. armiger																		
S. tertiaglabra																		
New species																		
Nemerteans																		
D. gouldii																		
O. biplicata																		
T. stultorum																		
Coleoptera spp.																		
Insect larvae																		
Distance sampled (feet)		80			70			40			90			90			120	

TABLE 5.

Organisms recovered from Little Dume study area 3/7/71 through 12/2/71.
Sampled intertidal is divided into upper, middle and lower intertidal areas

	3/7/71			4/19/71			5/20/71			8/10/71			10/4/71			12/2/71		
	U	M	L	U	M	L	U	M	L	U	M	L	U	M	L	U	M	L
O. benedicti	1			2			1											
O. californiana							1			3								
O. columbiana	4			1						6			3					
O. corniculata																		
E. washingtonianus															1			
C. chiltoni	1			4							31		1					
T. punctatus										10								
B. occidentalis																		3
E. analoga		45	9	27	10	5		66	5		1	1		3			11	
L. californica																		
A. iricolor																		
C. spirabrancha																		
D. sp.																		
E. dilatae																		
E. mucronata	47				5												12	1
H. borealis		1	4	1												1		
H. mccullochae																		
L. zonata									1		1	1					1	2
N. californiensis			3	1	1	1			2						1			1
N. sp.																		
N. acuta																		
N. tenuis																		
O. eremita																		
P. platybranchia																		
P. californica																		
S. armiger																		
S. tertiaglabra																		
New species																		
Nemerteans																		
D. gouldii																		
O. biplicata																		
T. stultorum																		
Coleoptera spp.										1								
Insect larvae				1			2							1				
Distance sampled (feet)		90			110			80			80			80			120	

TABLE 6.

Organisms recovered from Huntington Beach study area 12/10/70 through 12/16/71.
Sampled intertidal is divided into upper, middle and lower intertidal areas.

	12/10/70			2/10/71			4/23/71			6/14/71			8/11/71			10/19/71			12/16/71*		
	U	M	L	U	M	L	U	M	L	U	M	L	U	M	L	U	M	L	U	M	L
O. benedicti																					
O. californiana																					
O. columbiana																					
O. corniculata																					
E. washingtonianus																				1	
C. chiltoni								3													
T. punctatus																					
B. occidentalis																					
E. analoga	32	1	2		7			3	5			7		24	3	5	1	2	10		
L. californica			1								1										1
A. iricolor																					
C. spirabrancha																					
D. sp.																					
E. dilatae																					
E. mucronata																					
H. borealis		4		3				2	1	4				1			2	1	2		
H. mccullochae																					
L. zonata			1															1			
N. californiensis		1	1			1											1	1			21
N. sp.																					
N. acuta	22	14	1	3				9	3	17	2						3		5		
N. tenuis																					
O. eremita																					2
P. platybranchia																					15
P. californica																					
S. armiger																					
S. tertiaglabra																					
New species																					
Nemerteans			2																		3
D. gouldii		2	1		1	2											2				7
O. biplicata																					
T. stultorum																					1
Coleoptera spp.																					
Insect larvae																					
Distance sampled (feet)	180			160			70			150			80			140			250		

* Transect between 100 and 180 feet was not sampled due to immersion.

TABLE 7.

Organisms recovered from Horse Pastures study area 12/13/70 through 12/17/71. Sampled intertidal is divided into upper, middle and lower intertidal areas

	12/13/70			2/12/71			4/20/71 -(Alternate)-			6/16/71			8/10/71			10/4/71			12/17/71		
	U	M	L	U	M	L	U	M	L	U	M	L	U	M	L	U	M	L	U	M	L
O. benedicti	44	1		34						3		1	12								
O. californiana				1																	
O. columbiana																					
O. corniculata	2			1																	
E. washingtonianus											2					3			1		
C. chiltoni	3	6		2	10			1		5	1	1	3			1					
T. punctatus										5	1										
B. occidentalis																					
E. analoga	1	39	11		13	14	2	12	1		9	2			5	4	6	1	2	4	1
L. californica																					
A. iricolor																					
C. spirabrancha																					
D. sp.																					
E. dilatae																					
E. mucronata		1		30			20			2	4		176	2		15	10		2		
H. borealis	1						1			2	1		1	1		2			1		
H. mccullochae																					
L. zonata			15			5						4			5		7	11		2	7
N. californiensis			1			1												1		1	1
N. sp.																					
N. acuta	6		17		1	5		1		2	10	32	8	15	15	20	8	11	39	17	30
N. tenuis																					
O. eremita																					
P. platybranchia												1		1			2			5	1
P. californica																					
S. armiger																					
S. tertiaglabra																					
New species																					
Nemerteans																		2			
D. gouldii																					
O. biplicata																					
T. stultorum																					
Coleoptera spp.							2			2			1					1			
Insect larvae	252						1			3											
Distance sampled (feet)	160			120			80			120			130			150			140		

TABLE 8.

Organisms recovered from Dana Point study area 12/12/70 through 12/19/71.
Sampled intertidal is divided into upper, middle, and lower intertidal areas

	12/12/70			2/11/71			4/21/71			6/1/71			8/12/71			10/20/71			12/19/71		
	U	M	L	U	M	L	U	M	L	U	M	L	U	M	L	U	M	L	U	M	L
O. benedicti	10			9						2			2			1					
O. californiana																					
O. columbiana																					
O. corniculata	2			9			5			8			1								
E. washingtonianus	1													1	1		6	1	2		
C. chiltoni																					
T. punctatus																					
B. occidentalis																					
E. analoga	32	7	3	4	2	1	32	5	5	2	40	3			8	1	4	4	4		2
L. californica															1						1
A. iricolor																					
C. spirabrancha																					
D. sp.																					
E. dilatae																					
E. mucronata	179		2	537				1		318	89			200		20	32			141	
H. borealis																					
H. mccullochae																					
L. zonata		3							1									1			
N. californiensis		3	1		3	1					1				6	6				1	
N. sp.																					
N. acuta	3				1	2			1					1		4	26		9	5	
N. tenuis																					
O. eremita																					
P. platybranchia																		5			
P. californica																					
S. armiger																					
S. tertiaglabra																					
New species																					
Nemerteans																					
D. gouldii																					
O. biplicata																					
T. stultorum																					
Coleoptera spp.													3								
Insect larvae	1												1								
Distance sampled (feet)	180			120			120			80			100			140			160		

TABLE 9.

Organisms recovered from Doheny Beach study area 12/11/70 through 12/18/71.
Sampled intertidal is divided into upper, middle and lower intertidal areas

	12/11/70*			2/13/71			4/22/71			6/15/71			8/9/71			10/18/71			12/18/71		
	U	M	L	U	M	L	U	M	L	U	M	L	U	M	L	U	M	L	U	M	L
O. benedicti																					
O. californiana																					
O. columbiana				2			2			1											
O. corniculata																					
B. washingtonianus																					
C. chiltoni																					
T. punctatus																					
B. occidentalis																					
E. analoga	8	10				10			1			12			6		5			6	2
L. californica			2															1			
A. iricolor																					
C. spirabrancha																					
D. sp.																					
E. dilatae																					
E. mucronata																					
H. borealis																					
H. mccullochae																					
L. zonata																					
N. californiensis																					
N. sp.																					
N. acuta																					
N. tenuis																					
O. eremita																					
P. platybranchia																		2			
P. californica																					
S. armiger																					
S. tertiaglabra																					
New species																					
Nemerteans																					
D. gouldii			6																		2
O. biplicata																					
T. stultorum																					
Coleoptera spp.																					
Insect larvae																					
Distance sampled (feet)		170			70			70			90			70			120			120	

* Only two quadrats were sampled every 10 feet; organisms recovered have been multiplied X2.