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Analysis of Mussel (*Mytilus californianus*) Communities in Areas Chronically Exposed to Natural Oil Seepage

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Analysis of Mussel (*Mytilus californianus*) Communities in Areas Chronically Exposed to Natural Oil Seepage

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EXECUTIVE SUMMARY

The mussel, *Mytilus californianus*, community dominates most of the lower rocky intertidal areas along the west coast of North America. The available data indicate that this is the most diverse of the intertidal communities in the region. It could also be impacted by stranded, floating, dissolved, and dispersed petroleum because of the intertidal location.

In areas of natural oil seepage, the mussel community is exposed to petroleum either continually or intermittently depending on the rate of natural oil seepage in the area. Coal Oil Point in the Santa Barbara Channel is an area with a high rate of natural oil seepage. Data are available which indicate increases in tolerance to Santa Barbara crude oil among *M. californianus* at Coal Oil Point and an apparent reduction in brooding rate among the associated stalked barnacles, *Pollicipes polymerus*, when covered with tar.

However, comparative data are lacking on mussel (*M. californianus*) communities from oil seep and non-oil seep areas. This study was designed to determine whether community structure changes with exposure to seep oil using communities selected to eliminate as many differences in other variables as possible. Sample locations were selected so that the greatest differences between localities would be the relative exposure to petroleum.

Three sites were selected on the basis of available knowledge of oil seep activity and distribution. Exposure of communities to petroleum was measured both by the amount of tar in each sample and by analysis of tissues for petroleum hydrocarbons. Goleta Point, adjacent to Coal Oil Point, was the area of low natural chronic exposure to petroleum, and Reef Point was the area of no natural chronic exposure to petroleum. Some tar (0.2g) was collected in the Reef Point samples. This was not considered to indicate that the Reef Point mussel communities were chronically exposed to petroleum. The intermediate exposure site was Carpinteria.

Five replicate samples were collected at upper and lower intertidal sites at each of the three collecting areas. The data were first analyzed to ensure that the number of replicates accounted for the variability at each of the sampling sites. The data indicate that three replicates would have been sufficient. Therefore, the differences recorded between sites can be assumed to be actual differences between the sites and not differences due to sampling errors.

Abiotic parameters such as intertidal height, depth and space in mussel community, and parameters of the sediment trapped in the mussel community were measured in addition to the measures of petroleum exposure mentioned earlier.

The biotic data were analyzed by cluster analysis techniques so that the samples would be clustered into groups on the basis of similar species composition and relative abundance of species. These groups were then related to the abiotic parameters measured at these sites using discriminant analysis and principal coordinate analyses. The former method allows all abiotic variables to be considered simultaneously while the latter technique provides information on each abiotic parameter separately.

A total of 160 invertebrate species and 78 algal species were recorded in this survey. Only 25 invertebrate species were recorded at all 6 sampling sites. These 25 species comprised over 90% of the organisms collected. In a more extensive survey of mussel communities in the Southern California Bight, 481 invertebrate species were collected. The number of invertebrate species in 5 replicate samples ranged from a low of 45 at Government Point at the northern end of the Santa Barbara Channel to a high of 131 in 5 replicate samples from a site on San Clemente Island. In the present survey, the number of invertebrate species in 5 replicate samples ranged from 42 to 72. Fifty-six and 67 invertebrate species were recorded at the two sampling sites at Goleta Point.

Analysis of the biotic data indicates that there is a group of organisms found at each of the six sampling sites. In addition, each sampling site except the lower intertidal site at Reef Point has a group of species which are characteristic of that particular sampling site. Analysis of the abiotic data indicates the parameters associated with trapped sediment are the most important differences between these sites, petroleum is the second most important, and intertidal height appears to be the third most important. When data from each intertidal level are analyzed separately, petroleum shows a high correlation with changes in community composition at both intertidal levels. However, the quantity of trapped sediment and detritus is more important than petroleum at the upper intertidal level, and the composition of trapped sediment in terms of size is more important than petroleum at the lower intertidal level.

Therefore the survey revealed a difference in communities and that exposure to petroleum was an important factor. However, the actual impact is difficult to define. Two species, the barnacle, *Chthamalus dalli*, and the nematode, *Oncholaimina*, increased in abundance with increasing abundance of tar. No reverse trends were observed. Individual species distributions were more readily related to the type and amount of sediment trapped in the mussel community and intertidal height rather than exposure to petroleum as measured in this study.

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INTRODUCTION

Studies to determine the influence of either acute or chronic exposure to petroleum on marine organisms have usually been confined to the socalled 'dominant' species. These species are generally the most obvious species in the area either due to their abundance or size. For example, the documented population changes after the Bunker C oil spill in San Francisco Bay in 1971 were mainly confined to the dominant molluscs and crustaceans in the area [1,2,3]. This same type of data was recorded following the Santa Barbara oil spill [4].

Few studies have been conducted at the community level. Currently, a study of a shallow water benthic infaunal community is in progress in the natural oil seep areas at Coal Oil Point [5]. However, in an effort to reduce the between-site variability, this latter study lacks a control site which is not chronically exposed to petroleum.

The dominant species approach has resulted in the neglect of large numbers of organisms which comprise an important portion of the ecosystem. As a result there is a paucity of data on which to scientifically base the selection of marine indicator species. For example, a survey of the dominant species would record the fate of the barnacle populations but neglect the algal film on the barnacles which provides the food source for grazing species living between the barnacles. Records of this algal film, or possible lack of it when petroleum was present, could provide the basis for prediction of a possible delayed mortality among these grazing species.

The three-dimensional mussel communities found along the western coast of North America provide a much more complex situation than that observed in the less structurally complex barnacle community used in the hypothetical example discussed above. These mussel communities may support on the order of 150 to 200 species [6]. While studies on barnacle communities in the western United States of America place the number of species at 93, only 28 of these species were recorded more than 98% of the time [7]. Biomass, as well as number and abundance of species, is greater in the mussel community than in other intertidal communities described from the western coast of North America [7,8]. In other words, these mussel communities appear to be the most ecologically important communities, both in terms of species composition and productivity, in rocky intertidal areas.

These open coastal mussel communities, which are dominated by *Mytilus californianus* Conrad, are most abundant in lower intertidal areas although *M. californianus* has been recorded in both mid-intertidal and subtidal areas [9]. This extensive vertical range on the shore indicates that the *M. californianus* community has a wide tolerance to different physiological stresses such as temperature and exposure to air. This would suggest that there could be variations in the community composition associated with differences in vertical distribution, as well as variations in the physiology of *M. californianus* itself, associated with vertical distribution. For example, some differences in the breeding cycle have been recorded in *M. californianus* from different intertidal levels at a locality [10].

Studies on the influence of oil pollution in intertidal areas on the western coast of North America have dealt extensively with the influence of oil spills on *M. californianus* both in terms of lethal [1,2,3] and sublethal effects [11]. The influence of natural chronic exposure to petroleum on *M. californianus* has also been studied in terms of tolerance to petroleum [12,13,14] and sublethal changes such as changes in reproduction [15]. Other authors have studied the relative amounts of petroleum hydrocarbons in the tissues although as yet this has not been related to either lethal or sublethal changes [14,16, 17].

This volume of research suggests that *M. californianus* is a good socalled indicator organism. In fact, a "mussel watch" was proposed to monitor pollution levels in the ocean [18]. However, the question remains, indicator of what? *Mytilus californianus* can survive and breed without the large community generally associated with *M. californianus* beds. However, the associated community does not survive *in toto* in these areas without the habitat formed by *M. californianus*. In other words, by the time *M. californianus* registers a response to exposure to petroleum, the other associated species could all be dead. This could be due to different tolerance levels of the organisms to petroleum or, to a difference in exposure. For example, while the mussels on the outside of the mussel bed may be covered by petroleum, they are also washed by well circulated seawater at high tide. The worm living in the sediment deep in the mussel bed may also be exposed to petroleum as it seeps down between the mussels. The mussels could survive due to adequate water circulation while the worm, in a much more restricted area of water circulation, may not survive.

This study was designed to detect and analyze changes in natural field communities that could be related to natural chronic exposure to petroleum. This will provide information on the tolerance of the community as a whole to generally low levels of petroleum. Further studies need to be conducted following a major oil spill. Both types of information are needed to determine if *M. californianus*, as the dominant organism in the community, is indicative of the state of the community as a whole.

The study was designed to measure the biotic and abiotic variables of the mussel community at locations on a gradient from high to no natural chronic exposure to petroleum. The biotic parameters measured were the identity and number of organisms. Abiotic parameters known to, or suspected to influence the distribution and abundance of species (e.g., intertidal height, sediment parameters) were measured. The exposure to petroleum was measured in two ways - the weight of tar present in the community sample and the presence of tar in *M. californianus* tissues.

Three sites along the southern California coastline were selected: Goleta Point (high chronic exposure to natural oil seepage); Carpinteria (low chronic exposure to natural oil seepage); and Reef Point (not chronically exposed to natural oil seepage) (Figure 1). Mussel communities at these sites were sampled at two intertidal levels. This was to account for natural variations in species distribution and abundance due to differences in intertidal height. It is also possible that because of physiological differences between individuals of the same species at different intertidal heights, a species may respond differently to exposure to petroleum when it is found near low tide than when it is found higher in the intertidal area. In addition, the exposure to petroleum will be different at different intertidal heights. Figure 2 is a simple diagram that illustrates some of these differences. The mussel community at level A could be exposed to seawater containing no petroleum for a third of the tidal cycle, seawater containing dissolved and dispersed petroleum for a third of the tidal cycle and a layer of petroleum for the third of the tidal cycle it is out of water. The mussel community at level B, in contrast, could be exposed to seawater lacking petroleum for half of the tidal cycle, seawater containing dissolved and dispersed petroleum for a third of the tidal cycle and a layer of petroleum for a sixth of the tidal cycle when it is out of water.

Temperatures of intertidal oiled substrates show greater fluctuations than temperatures of intertidal unoiled substrates at low tide [19]. Likewise, the internal body temperature of the stalked barnacle *Pollicipes polymerus*, which is frequently associated with mussel communities, is higher in oiled than unoiled animals at low tide in intertidal areas [14].

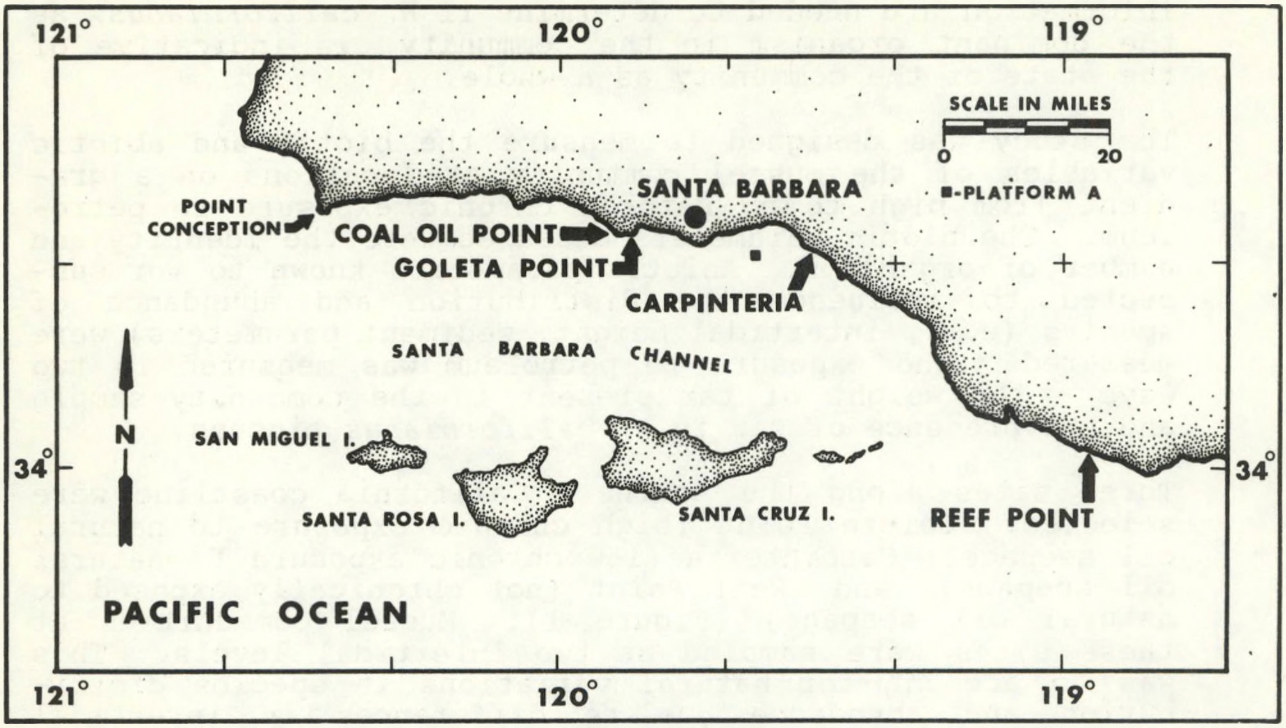

Figure 1. Map of southern California showing location of study sites.

Differences in mussel communities at different intertidal heights could be due to natural biological and/or ecological factors as well as differences in exposure to petroleum in terms of dosage and physical form. It is also difficult to equate different intertidal heights between localities. The intertidal range varies between sites dependent on the slope of the area. The relative exposure to water and air will also vary depending on slope and exposure to wave action. Therefore, rather than attempt to equate a single intertidal height from each location, high and low intertidal samples were collected at each site.

One other important aspect of this study is the attempt to ensure that the sample size was adequate to describe the community at each of the six sampling points. To this end, a series of replicate samples was collected and the data analyzed using cumulative species and diversity index curves as well as information loss curves. This is to ensure that the community differences or lack of differences recorded between the six sampling points were not due to inadequate sampling. Five replicates were initially used on the basis of information obtained from previous studies in mussel communities in southern California which indicated that in most instances the communities were adequately sampled when this sampling strategy was used [6,52].

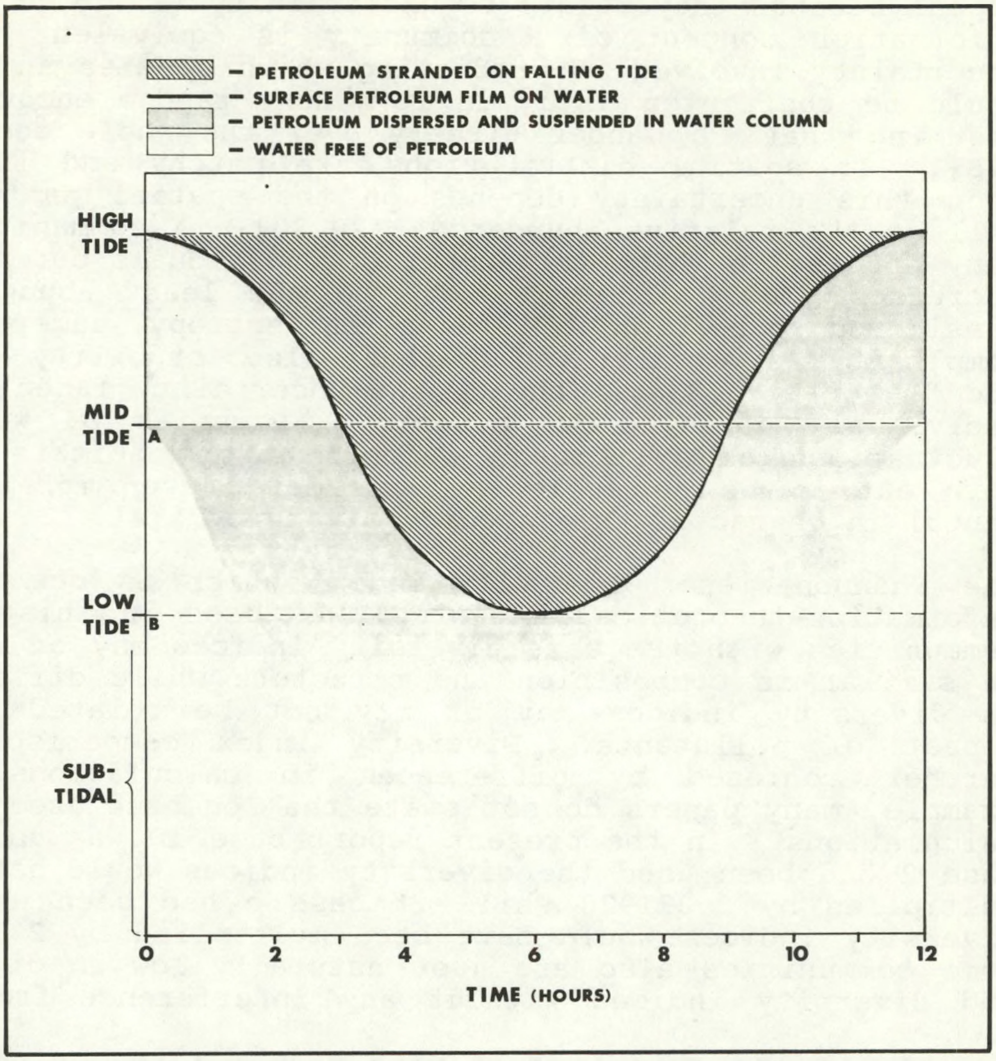

Figure 2. Diagram to show relative differences in petroleum exposure at different intertidal heights during the tidal cycle.

Species diversity (number of species) and species diversity indices are provided in the text. However, it should be noted that their use in a study of this type is limited. For example, these values do not indicate if the same species are present in different samples. Species diversity or number of species indicates if there are more or fewer species at each site. Species diversity indices, which are frequently used to compare different communities and as an arbitrary measure of the impact of pollutants, provide a measure of community complexity.

Of the many types of species diversity indices available, information-theoretical measures have a great theoretical appeal because they relate to uncertainity [25,26,27]. The information content of a community is equivalent to the uncertainty involved in predicting which species an animal would be confronted with, in it's next random encounter - assuming that it wanders freely over the whole community [28]. If spatial distributions are patchy and limited, then this uncertainty depends on the spatial pattern as well as the relative abundances [29,30]. A community with many species in which the number of individuals per species decreases slowly from the most to the least abundant is considered to be high in information, entropy, uncertainty, complexity, diversity, and, perhaps also, stability [31,32] and "maturity" [33]. Indeed, the uncertainty faced by the individual, in all its aspects - vagaries of weather, fluctuations of resources, patchiness of habitats - may turn out to be an ecological parameter even more fundamental in character than species diversity [34].

The Shannon-Wiener diversity index, which is one of the information-theoretical measures, was used in this study. Communities with the same diversity indices may or may not be similar in composition and structure while differences in diversity indices may or may not be related to the impact of pollutants. Diversity index comparisons are further confused by differences in calculations. For example, many papers do not state the log base used in the calculations. In the present report base 10 was used. If base 2 had been used the diversity indices would have been multiplied by 3.321928 while if base e had been used the diversity indices would have been multiplied by 2.302585. Some communities also are just naturally low in diversity and diversity indices without any interference from man.

The biotic and abiotic data were then related using techniques of classification, discrimination, and ordination in order to determine correlations between the two sets of parameters. This, of course, does not consider biological interactions between species. However, such interactions are outside the scope of the present study. It is assumed that the initial definition of community in fluctuating environments such as the intertidal zone is a result of response to abiotic parameters. In this instance those abiotic parameters related to intertidal height would appear important. Within this framework, further delineation of species distribution would be in response to biotic interactions. The importance of such biotic interactions was recently demonstrated by records of the raising of the upper limit of *Laminaria digitata* and *Himanthalia elongata* by as much as 2 meters in the absence of limpets during recolonization after the Torrey Canyon oil spill [20]. Kikkawa [21] also points out that there is not a single cause, abiotic or biotic, which can be used in an overall hypothesis to explain patterns in species distribution. However, if a species cannot survive within the confines of the abiotic parameters in an area, there will be no biotic interaction.

Correlations between the distribution and abundance of intertidal species in the intertidal zone and abiotic parameters have been demonstrated on both rocky shores and sandy beaches [6,22]. The greatest correlations between species distributions and abiotic parameters after the Santa Barbara oil spill were reported to be between species distribution and presence of sand [23]. This was interpreted to indicate that sand movement had a greater impact on these organisms than oil from the spill had.

This study is designed to consider changes in community structure in relation to chronic exposure to petroleum. Since community structure changes in response to these other abiotic parameters, it is important to consider correlations with other abiotic parameters operating in the area. This will provide information on the relative ecological importance of the response of the mussel community to natural chronic exposure to petroleum in comparison to the response to other abiotic variables [24]. This surely is the basis for determining the significance of an environmental impact.

PHYSIOGRAPHY

The three areas sampled once during July-August 1976 were Goleta Point, Carpinteria, and Reef Point, California (Figure 1). All three locations were typical *M. californianus* habitats, located in intertidal areas exposed to direct wave and surge action. These sites were selected using information gained through seven years of field work in the area, to optimize the differences in chronic natural exposure to petroleum and to minimize the difference between other abiotic parameters. The two collections at each area represented the accessible extremes in intertidal height occupied by the mussel beds at each area. These are not the stressed extremes of the intertidal range of *M. californianus* because this species extends both higher intertidally and lower subtidally in southern California.

The collection areas at Goleta Point are located on a large rock outcrop (Figure 3). The substrate was very smooth, and appeared to be composed of claystone. The upper intertidal collection (A) was removed from a mussel bed (approximately 5.0 m x 2.0 m) on the horizontal top of the rock outcrop. The mussels located on the surface of the mussel

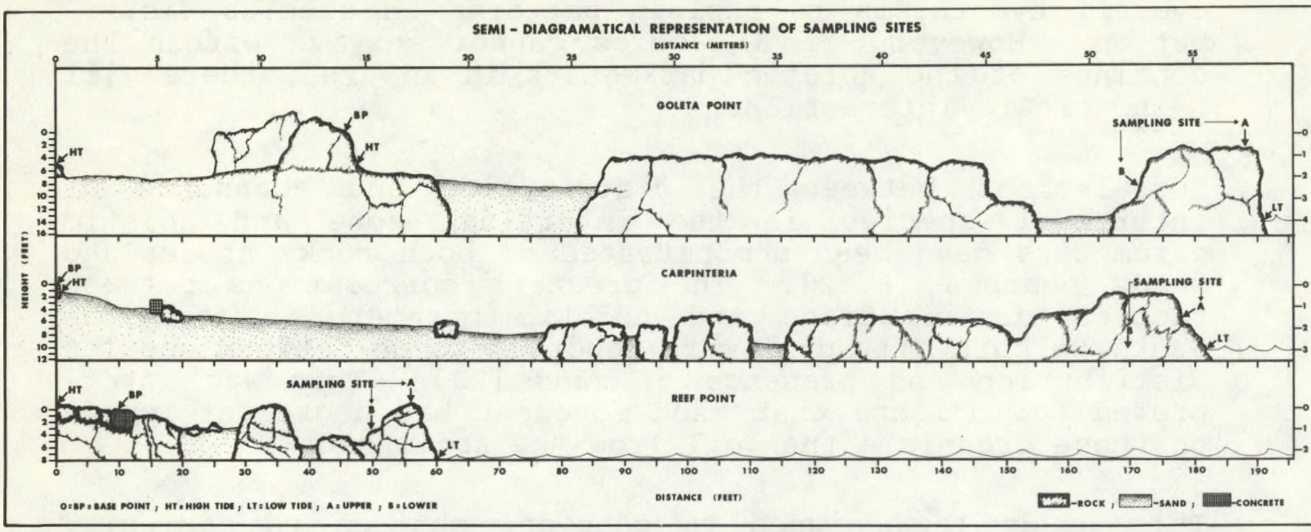

Figure 3. Diagram to show position of sampling sites (A,B) at Goleta Point, Carpinteria and Reef Point.

bed bore algae of various species (e.g., *Ulva* sp., *Enteromorpha* sp.). The lower intertidal collection (B) was removed from a near vertical face of the rock outcrop, in the middle of a surge channel. The mussel bed was small (approximately 2.0 m x 0.5 m). Many gooseneck barnacles (*P. polymerus*) were visible on the surface of this mussel bed along with some atttached algae (e.g., *Ulva* sp.).

The collection areas at Carpinteria were very similar to those at Goleta Point. The mussel beds were located on a large metamorphic rock outcrop at Carpinteria State Beach. The upper samples (A) were collected from a small mussel bed (approximately 1.0 m x 0.5 m) near the top of the rock outcrop (Figure 3). The mussel bed covered the irregular surface, extending over both horizontal and near vertical surfaces. Small amounts of algae were noted on the surfaces of the mussels. The lower collection (B) was removed from a mussel bed on the vertical side of the rock outcrop. This mussel bed was small (approximately 1.0 m x 0.5 m) and contained many conspicuous gooseneck barnacles (*P. polymerus*) on the surface. Both mussel beds at this locality displayed evidence of human perturbation. Numerous pieces of fishing line were found tangled within the mussel beds.

The Reef Point collection locality was a metamorphic rock outcrop similar in composition to the rock at Carpinteria. The rock outcrop was somewhat smaller than those at the other two collection localities. The upper collection (A) was removed from a small mussel bed (approximately 1.0 m x 0.5 m) located on a relatively horizontal surface of the rock outcrop (Figure 3). The lower collection (B) was removed from an irregular area on the side of the rock outcrop. Some of the samples were collected from patchy mussel beds located on horizontal surfaces, while others were removed from nearby vertical patches of mussel bed on adjacent portions of the rock. The surfaces of the mussels from both collections were smooth and lacked obvious accumulations of attached algae.

MATERIALS AND METHODS

Goleta Point, Carpinteria, and Reef Point were sampled on July 16, July 30, and August 28, 1976, respectively. Each sampling site was marked with a labelled metal disc attached to the substrate by a metal stud (Plate 1a). The profile of the intertidal area was measured using Emery sticks [35] and related to surveyed basepoints (Plates 1b, 2a, 2b).

Ocean temperature, air temperature, surface mussel bed temperature, and internal mussel bed temperature were recorded using a Yellow Springs Instrument Telethermometer. Triplicate measurements of the thickness of the mussel bed were obtained by pushing a calibrated stainless steel rod through the mussel bed until it touched the underlying substrate. These triplicate measurements were averaged.

An area of 1500 sq cm was sampled by removing five cores (300 sq cm each) from both the upper (A) and lower (B) extremes of the intertidal mussel bed at each locality. Each sample was collected by pushing a stainless steel corer (Figure 4) with a sharp cutting edge through the mussel bed. The corer containing the mussel sample was pried from the substrate by sliding a broad "crow bar" between the mussels and the rock. The mussel core was removed intact, where possible, and included organisms, sediment, and detritus. Any remaining sediment and organisms were collected with a stainless steel spoon and combined with the mussel core. Each core sample was preserved separately in 15% formalin (Total 30 cores in entire survey).

Mytilus californianus were collected for hydrocarbon analysis adjacent to the core samples but far enough away (approximately 0.5 m) to avoid contamination by the coring procedure. Twenty animals were collected at each sampling site. Samples were wrapped in acetone washed foil and transported to the laboratory on dry ice. Samples were held at -70°C in the laboratory.

Plate 1a. Metal disc locating the upper intertidal (A) sampling area at Goleta Point.

Plate 1b. Base point (↓) at Goleta Point. Note the large amount of black tar stranded in the upper intertidal area.

Plate 2a. Base point (↓) at Carpinteria. R. Kanter is standing on small amount of tar stranded in upper intertidal area.

Plate 2b. Base point (↓) at Reef Point. There is no visible stranded tar in the upper intertidal area.

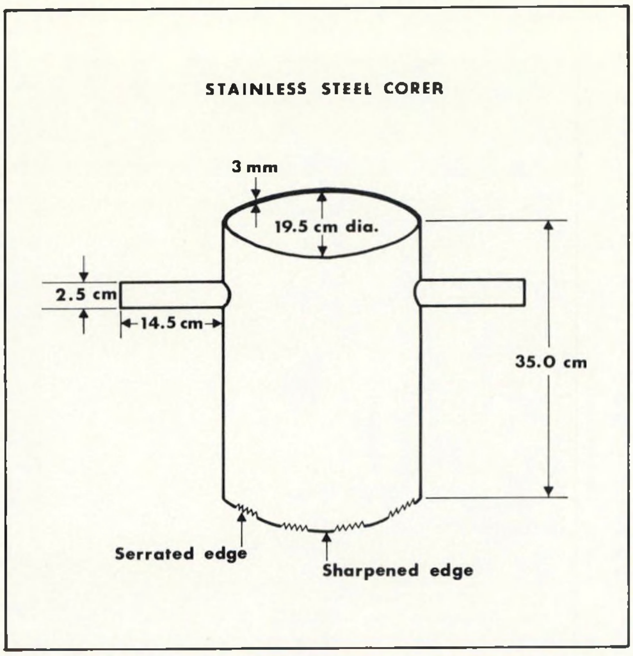

Figure 4. Diagram of stainless steel corer used to sample mussel beds.

The mussels for hydrocarbon analyses were shucked using acetone washed equipment and shipped in chemically cleaned glassware on dry ice to Dr. J. Scott Warner at Battelle Laboratories. The hydrocarbon analyses of these tissues involved aqueous caustic digestion, ether extraction, high-pressure liquid chromatography and silica gel chromatography [36].

A sequential series of procedures was performed on the mussel core samples in the laboratory. The mussel samples were first washed with fresh water for 24 hours under extremely low water pressure with the container opening covered by a fine mesh screen to prevent loss of any material. After washing, the mussels were separated from the rest of the sample. Each mussel was individually inspected, and all adhering animals (except permanently attached barnacles and bryozoans) were removed and combined with the rest of the unsorted sample. Both the mussels and the unsorted sample were preserved in 100% ethanol.

The samples were handsorted into major phyla. All macroscopic organisms (>0.5 mm) were removed from the sediment and debris. The specimens were identified to species and counted. The animals attached to the exterior of the mussels as well as the mussels themselves were also identified and counted.

Residual volume is the intermussel space which can be filled by associated fauna, sediment, and detritus. Residual volume was calculated for each sample by subtracting the volume occupied by the mussels from the total volume of the sample. The volume of the mussels was determined by recording water displacement in a calibrated cylinder. The total volume of the sample was calculated using the standard formula for the volume of a cylinder $V = \pi r^2 h$ where h = thickness of mussel bed.

Sediment and detritus remained after the organisms were separated out of each core sample. These two components were separated and analyzed in a series of sequential operations. The sand and finer sediment (<2 mm) were separated from the coarse sediment (>2 mm, e.g., rock and shell debris) and detritus by washing through a 2 mm screen.

The sand and finer sediment was washed free of preservatives. This process involved triple warm distilled water washings with intermediate centrifugation to prevent loss of silts and clays. This process was repeated three times with cold distilled water [37]. A wet sample (~2 g) was split for pipette size analysis (fraction <0.063 mm) [38, 39] and automatic settling tube size analysis (0.063 mm < fraction <1 mm) [40,41]. The remaining sample was oven dried at 100°C, and then weighed.

The dried sample was ground into a fine powder using a mortar and pestle. The powdered sample was analyzed for organic carbon (total carbon minus carbonate carbon) using the L.E.C.O. technique [42,43]. The coarse sediment (>2 mm, mostly rock and shell debris) was separated from the detritus by differential floatation. The detritus was floated off under low water pressure. Constant swirling of the mixture aided this separation. After separation, both coarse fraction and detritus were microscopically examined and their composition recorded. Tar was separated out. They were then oven dried at 100°C for 24 hours and dry weighed. Tar separated from the coarse sediment fraction and from any organisms was weighed.

Quantitative techniques of data analyses were applied in five major areas of this study:

1. Physical characterization of mussel bed sediment based on data from pipette and settling tube analysis.

2. Determination of species diversity for the mussel samples for each locality.

3. Determination of optimal sample size (cummulative species diversity curves, information loss curves).
4. Comparison of the *M. californianus* communities from different localities (community classification analysis).
5. Examination of the relationship between abiotic characteristics (particularly tar and hydrocarbons) and the biotic characteristics of the mussel bed (multiple discriminant analysis, principal coordinate analysis).

1. Physical Characterization of Sediment

Sediment particle size and particle size distribution characteristics were computed from data generated by pipette and automatic settling tube analyses. The parameters measured were based on sediment size in terms of phi (ø) intervals [44]. The calculations (performed by the computer) included ø mean size, ø kurtosis, and ø skewness [45]. The mean ø size provides a measure of mean diameter of the sediment particles, kurtosis provides a measure of how well the sediments are sorted, and skewness is a measure of the position of the sediment curve peak.

2. Species Diversity

Species diversity can be considered simply in terms of numbers of different species or in terms of a species diversity index which includes a weighting for the relative abundance of each species. Both types of comparison are included herein.

Species diversity was calculated using the formula of Shannon-Wiener [29].

$$H' = \sum_{i=1}^{S} P_i \log P_i$$

H' = diversity index
P = proportion of the $i^{\underline{th}}$ species in the sample
S = number of species.

The diversity index (H') is a component measure which incorporates both species richness and evenness of abundance into one term. It is often more informative to consider each component separately in order to understand the variability of the diversity figures. The Gleason index [46] of richness was calculated using the formula:

$$R = S/\log N$$

R = richness
S = number of species
N = number of individuals.

Species evenness [29] was calculated from the formula:

$$J' = H'/H_{max}$$

J' = evenness of species representation in the association
H' = diversity index (Shannon-Wiener)
Hmax = maximum diversity with all species equally represented.

3. Optimal Sample Size

In all assemblages of organisms there are a large number of very rare species. It would frequently require removal of the entire community to record every one of these rare species. On the other hand, if the area of community sampled is too small, apparent differences or lack of differences between communities could be due to inadequate sampling. Hence, it is desirable to optimize the sampling program to reflect the characteristics of the community but yet not destroy the community in the process.

A replicate sampling technique was used at each of the six sampling sites (Figure 3) in order to retain a measure of variability within each sampling site. The aim is to determine the minimum sample size which includes biological variability and thus minimizes sampling error.

This analysis has been approached in two ways. One method involves the construction of species area curves [47]. The cumulative number of species (diversity) was plotted against the number of cores from each sampling position (5 cores each). The asymptote of the curve indicated the optimal sample size. Likewise, the cumulative diversity index was plotted against the number of cores. While the cumulative species curve either rises or remains flat, the cumulative diversity index curve can fluctuate either up or down in response to the relative abundance component. Hence, the asymptote may not be as clearly defined.

The second method involved the use of the deferred or information loss statistic ($1-r^2$) to determine the information loss when progressively 1 to 5 samples were considered at each sampling area. r is the product - moment correlation coefficient between 1) the elements of the inter-sample distance matrix with all replicate samples included, and 2) the elements of a distance matrix with fewer replicate samples included [48].

4. Comparison of Mussel Communities

Mussel bed communities from the six different sampling localities were compared by two forms of classification [39]. (a) The samples (entities) were classified by their species composition (attributes). This was the normal analysis. (b) The species (entities) were classified in terms of their distribution among samples (attributes). This was the inverse analysis. Classification involved three basic steps:

- The calculation of similarities between entities based on attributes.
- The sorting and clustering into hierarchical dendrograms of the classified entities.
- The construction of a two-way coincidence table based on the normal and inverse analyses.

The "Bray-Curtis" index [49] was used to compute an inter-entity distance matrix. This provides a measure of how similar/dissimilar the species composition at each collection site is to the species composition at each of the other collection sites. Classification was performed on all identified species that occurred in more than one sample. The species counts were transformed prior to normal analysis by square root and weighted species mean, and by square root and species maximum prior to inverse analysis [24]. The sorting strategy selected for construction of hierarchical dendrograms was "flexible" [49, 50]. A symbolic two-way coincidence table was constructed from the resulting normal and inverse classification [24].

The weights used in the mean standardization prior to classification of sampling sites are proportional to the biotic and presumably the environmental "uniqueness" of the sampling sites. These weights are applied to overcome the effect of uneven habitat type sampling on the mean standardization [24]. When these data were used in the inter-species distance calculations, the sampling sites were weighted by the same "uniqueness" weights used in the site analyses. These weightings were used to overcome the adverse effects of uneven habitat-type sampling in the calculation of inter-species overlaps [24,51]. Data were classified both with (Figure 13) and without (Figure 11) weighting.

5. Relation between Community Composition and Abiotic Features of the Mussel Bed.

The mussel community appears to partition resources, particularly habitat resources, within the mussel bed [41]. That is, the species composition of the community can be related to the abiotic characteristics of the mussel bed. In order to determine differences in the mussel community in response to petroleum it was necessary to consider its response to all relevant abiotic variables. The following abiotic variables were measured:

- Mussel bed thickness
- Quantity of sediment
- Quantity of detritus
- Residual volume of entire sample
- Quantity of coarse fraction sediment
- Pore base of coarse fraction sediment
- Mean sediment size
- Skewness of the sediment
- Kurtosis of the sediment
- Organic carbon content of the sediment
- Quantity of tar in the mussel bed
- Quantity of petroleum hydrocarbons in mussel tissues

The above variables, except for the last listed, were considered in the multiple discriminant analyses. The quantity of petroleum hydrocarbons in mussel tissues was not determined for each subsample but only for the different sampling sites. Therefore this information was used in interpretation of the discriminant analyses.

Discriminant analysis is used in this study to describe and test between-group differences. In this case, define the abiotic differences between the site groupings formed by the cluster analysis. Let us consider two variables, e.g., intertidal height and grain size, operating at the upper and lower sites at Goleta Point. If all of the samples from these two sites were plotted on two axes according to their intertidal height and grain size values, the two site groups would separate on the basis of intertidal height even though there is overlap in the grain size values between the two groups. If the samples had overlapping intertidal heights, they could still form distinct groups on these two axes. In this latter case both variables, intertidal height and grain size, are probably related to the group separation. If all points in this plot were perpendicularly projected onto a third line, the point projections for the two groups would be completely separated. In effect, a new variable which separates the groups has been defined. The values of this variable are the values of the projections onto the diagonal line. Projections onto the line will be correlated with the values of both intertidal height and grain size. The new variable could be thought of as a "intertidal height-grain size considered simultaneously" - type parameter. In contrast, the new variable defined using actual data would be parallel, or nearly parallel, with the intertidal height axis and have little grain size influence. This is the new axis defined in space by the actual data.

Discriminant analysis attempts to find these "new variables" which will best separate the predefined groups as follows:

A hypothetical, multidimensional "space" is set up. The dimensions of this space represent the measured environmental variables. The position of a site (sample) will depend on the level of each variable measured at the site.

A new variable, which best separates the groups, is defined. The variable is represented in space by a line called a discriminant axis. The value of this new variable at a site is the perpendicular projection of the site point onto the discriminant analysis. The value of the projection is called a discriminant score.

The position of the discriminant axis in this space will depend on which combination of variables best separates the groups. When more than two groups have been defined, more than one discriminant axis may be required to separate the groups. These axes are not necessarily at right angles to each other. The axes are visually ordered according to the amount of group separation accounted for, i.e., the first axis will show the most group separation, the second axis, the second most, and so on.

Discriminant coefficients are used to indicate which original variables are related to each axis. Each axis has a separate set of coefficients, with one coefficient for each original variable. The magnitude of the absolute value of a coefficient is relative to the importance of the corresponding variable on the axis in question. In this report, coefficients of separate determination are calculated to provide this information.

The need to use a multivariate technique in which all variables are considered simultaneously is demonstrated in the analyses in this report. Consideration of one or two variables (abiotic parameters) at a time would suggest a greater importance for intertidal height than is revealed by the multivariate analysis which shows the combined effects of other parameters to be more important on the first two axes (Tables 7,8. See [55] for more detailed explanations).

Discriminant analysis [24,53,54] defined axes, in abiotic space described by linear combinations of variables, which best separated the sample groups obtained by the classification analysis. The groups were plotted in two dimensional space (two axes). The correlations between the biotic patterns shown by the classification and the environmental variables are studied using non-weighted and weighted discriminant analysis [24,55].

In weighted discriminant analysis the usual discriminant analysis calculations [53,56] are modified by giving each sampling site a weight proportional to how typical (in a biological sense) the site is of the group in question. The weights are the mean of the biotic similarities between the site and group in question [55].

This is an improvement over regular discriminant analysis because the biotic relationships within and between the groups are considered in the calculations.

For each discriminant axis, the method produced coefficients of separate determination [55] for each environmental variable, and mean scores for these variables at each sampling site. The coefficients of separate determination indicate which environmental variables are correlated with the group separation along the various axes and are proportional to the measurements of the important variables. This allowed the most important of the measured variables to be singled out. Those variables that showed a correlation with the major community differences were interpreted in relation to the ecology and composition of the associated mussel community inhabitants.

In four samples there was not enough sediment to complete chemical and physical measurements. Total organic carbon measurements were not made on these samples and data were estimated using predictive regressions based on the relationships of all other variables. This procedure should not change the results of the weighted discriminant analysis because the estimates are based on the covariances between the variables. The covariances are also used in discriminant analysis. Since the same covariances are used in both procedures, the estimations will not change the covariance structure of the data.

Correlations with the environmental parameters for each site (pooled data for five replicates) were examined by 1) ordination of the biological data, followed by 2) plotting the trends of the environmental variables in the ordination space. Principal coordinates analysis [58] was used to ordinate the biotic data.

RESULTS

1. Abiotic Parameters

Temperatures recorded at both intertidal levels at each locality at the time of collection, are presented in Table 1.

Table 1.
Temperatures (°C) Recorded at Mussel Beds

Locality	Goleta Point		Carpinteria		Reef Point	
Intertidal Level	Upper	Lower	Upper	Lower	Upper	Lower
Air	16.0	16.5	17.5	17.0	19.8	19.5
Water	17.5	17.5	18.0	18.0	18.5	18.5
Mussel Bed Surface	16.0	17.0	17.5	17.5	18.3	20.2
	16.2	17.0	17.5	17.0	18.1	20.1
	16.2	16.8	17.0	17.0	18.5	19.6
Mussel Bed Internal	16.2	17.0	17.5	18.0	19.1	20.9
	16.5	17.1	18.0	18.5	19.5	20.5
	16.4	17.0	18.0	18.0	19.0	20.6

All temperatures had increased between the collections at Goleta Point and Carpinteria in July 1976 and the collections at Reef Point in August 1976. This is probably related to seasonal warming rather than intersite differences. The difference between upper and lower intertidal mussel bed temperatures at Goleta Point and Carpinteria was never more than 1°C while at Reef Point, the lower intertidal mussel bed temperatures were 1 to 2°C higher than the upper intertidal mussel bed temperatures. Upper intertidal mussel bed temperatures at Reef Point (18.1 to 19.5°C) were more similar to those recorded at mussel beds at Goleta Point and Carpinteria (16.0 to 18.5°C) than were the lower intertidal mussel bed temperatures at Reef Point (19.6 to 20.6°C).

Other abiotic parameters measured in each sample (5 replicate samples per intertidal height at each locality) are presented in Tables 2,3,4. These data illustrate the difficulty in matching experimental and control sites in the field and point to the necessity of using multivariate

Table 2
Abiotic Characteristics of Goleta Point Samples
July 1976

ABIOTIC PARAMETERS	Upper Intertidal 1A	2A	3A	4A	5A
Intertidal Height* (m)	0.63	0.63	0.63	0.63	0.63
Dry Weight Detritus (g)	7.70	10.90	9.60	8.90	12.60
Dry Weight of Coarse Sediment (g)	22.10	42.20	135.10	91.80	71.70
Dry Weight Sediment (g)	37.64	48.01	162.56	119.76	195.76
Mean Sediment Size (ϕ)	1.83	1.69	2.41	2.47	1.44
Skewness (ϕ)	1.15	2.68	4.58	2.64	1.41
Kurtosis (ϕ)	5.79	17.08	29.03	19.71	6.99
Pore Base of Coarse Sediment (cc)	13.00	32.00	44.00	152.00	105.00
Total Organic Carbon (%)	7.20	5.70	2.49	2.18	1.32
Tar Weight (g)	0.10	0.80	0.80	1.40	0.70
Mussel Bed Thickness (cm)	5.66	4.33	5.66	5.33	3.83
Total Residual Volume (cc)	852.35	124.15	782.35	952.80	729.83

ABIOTIC PARAMETERS	Lower Intertidal 1B	2B	3B	4B	5B
Intertidal Height* (m)	-0.10	-0.10	-0.10	-0.10	-0.10
Dry Weight Detritus (g)	8.60	13.30	8.40	2.20	6.10
Dry Weight of Coarse Sediment (g)	208.60	175.90	137.20	86.60	91.70
Dry Weight Sediment (g)	210.70	314.63	225.06	117.55	92.90
Mean Sediment Size (ϕ)	1.52	1.36	1.76	1.60	2.25
Skewness (ϕ)	1.89	2.22	1.85	1.77	2.88
Kurtosis (ϕ)	13.01	13.82	13.17	11.81	27.02
Pore Base of Coarse Sediment (cc)	248.00	189.00	366.00	50.00	49.00
Total Organic Carbon (%)	2.81	2.49	2.38	3.57	5.40
Tar Weight (g)	1.70	6.60	5.20	1.60	0.80
Mussel Bed Thickness (cm)	7.33	7.66	10.00	8.00	10.00
Total Residual Volume (cc)	1110.10	1364.65	2236.50	1754.20	1996.50

* = Vertical distance above (+) and below (-) the 0.0 level as determined by a geological survey of the base point.
Values are totals for each subsample (1-5)

Table 3

Abiotic Characteristics of Carpinteria Samples
July 1976

ABIOTIC PARAMETERS	Upper Intertidal 1A	2A	3A	4A	5A
Intertidal Height* (m)	0.50	0.50	0.50	0.50	0.50
Dry Weight Detritus (g)	1.20	2.90	3.40	4.30	4.70
Dry Weight of Coarse Sediment (g)	24.90	181.10	70.00	51.60	91.40
Dry Weight Sediment (g)	16.84	11.96	23.28	102.06	169.91
Mean Sediment Size (ϕ)	2.13	1.86	2.08	2.34	2.46
Skewness (ϕ)	2.72	2.48	3.08	3.20	3.31
Kurtosis (ϕ)	13.33	11.41	17.09	21.55	28.20
Pore Base of Coarse Sediment (cc)	22.00	198.00	55.00	42.00	72.00
Total Organic Carbon (%)	3.32**	2.86**	3.18**	2.51	2.18
Tar Weight (g)	0.00	0.00	0.10	0.10	0.20
Mussel Bed Thickness (cm)	3.16	5.83	4.33	5.00	4.00
Total Residual Volume (cc)	615.73	1122.13	834.15	1153.25	779.60

ABIOTIC PARAMETERS	Lower Intertidal 1B	2B	3B	4B	5B
Intertidal Height* (m)	-0.009	-0.009	-0.009	-0.009	-0.009
Dry Weight Detritus (g)	31.50	20.80	15.00	13.20	9.50
Dry Weight of Coarse Sediment (g)	159.00	105.70	58.50	16.00	27.50
Dry Weight Sediment (g)	469.00	309.14	210.49	249.91	125.99
Mean Sediment Size (ϕ)	2.53	2.52	2.53	2.47	2.29
Skewness (ϕ)	2.67	4.49	3.37	3.84	2.68
Kurtosis (ϕ)	23.90	42.77	30.50	36.16	18.62
Pore Base of Coarse Sediment (cc)	251.00	164.00	113.00	8.00	18.00
Total Organic Carbon (%)	1.71	1.70	1.92	1.66	2.60
Tar Weight (g)	1.20	2.00	0.30	0.60	0.50
Mussel Bed Thickness (cm)	11.16	12.83	6.00	7.66	7.66
Total Residual Volume (cc)	2234.93	2787.67	1181.90	1839.65	1729.65

* = Vertical distance above (+) and below (-) the 0-0 level as determined by a geological survey of the base point. ** = Values estimated statistically. Values are totals for each subsample (1-5).

Table 4.

Abiotic Characteristics of Reef Point Samples
August 1976

ABIOTIC PARAMETERS	Upper Intertidal 1A	2A	3A	4A	5A
Intertidal Height* (m)	0.61	0.58	0.58	0.58	0.57
Dry Weight Detritus (g)	3.30	2.20	4.30	3.10	3.80
Dry Weight of Coarse Sediment (g)	133.00	385.50	241.10	197.50	429.80
Dry Weight Sediment (g)	119.72	717.48	224.48	86.86	390.26
Mean Sediment Size (ϕ)	1.64	1.90	1.91	1.57	1.64
Skewness (ϕ)	1.12	1.74	1.04	2.02	2.60
Kurtosis (ϕ)	8.89	19.14	10.72	13.47	23.07
Pore Base of Coarse Sediment (cc)	68.00	189.00	185.00	186.00	436.00
Total Organic Carbon (%)	1.52	0.75	1.34	2.64	1.06
Tar Weight (g)	0.10	0.10	0.00	0.00	0.00
Mussel Bed Thickness (cm)	4.50	7.33	6.00	6.00	8.83
Total Residual Volume (cc)	833.93	1130.10	36.90	871.90	1488.08

ABIOTIC PARAMETERS	Lower Intertidal 1B	2B	3B	4B	5B
Intertidal Height* (m)	0.22	0.22	0.23	0.24	0.27
Dry Weight Detritus (g)	1.40	0.40	2.10	1.70	3.50
Dry Weight of Coarse Sediment (g)	119.00	325.80	268.30	118.90	54.50
Mean Sediment Size (ϕ)	0.87	1.16	1.21	1.09	1.24
Skewness (ϕ)	1.23	0.85	0.05	0.68	0.03
Dry Weight Sediment (g)	93.01	287.72	79.53	57.03	71.60
Kurtosis (ϕ)	7.69	8.06	2.74	5.37	3.00
Pore Base of Coarse Sediment (cc)	48.00	122.00	209.00	57.00	24.00
Total Organic Carbon (%)	0.72	0.62	0.90	1.12	**2.66
Tar Weight (g)	0.00	0.00	0.00	0.00	0.00
Mussel Bed Thickness (cm)	2.66	5.16	3.83	4.83	4.66
Total Residual Volume (cc)	306.40	793.03	214.83	758.45	793.70

* = Vertical distance above (+) and below (-) the 0.0 level as determined by a geological survey of the base point. ** = Value estimated statistically. Values are totals for each subsample (1-5).

techniques (e.g. discriminant analysis) to consider all variables. For example, more detritus had collected in the mussel beds at Goleta Point (88.3 g) and Carpinteria (106.5 g) than at Reef Point (25.8 g), while more coarse sediment had collected at Reef Point (2273 g) than at the other two sites (1063 g; 785 g). It should also be noted that there was variability between replicate samples at each intertidal height at each locality so that there was frequently overlap of these parameters between each collecting site. Comparison of the finer sediment components (less than 1 mm in diameter) indicates that these components were generally coarser in the samples at Reef Point (mean ø 0.87 to 1.91) than at the other sites (Carpinteria mean ø 1.86 to 2.53; Goleta Point mean ø 1.36 to 2.47). Further examination of the phi (ø) distribution of the sediment in the samples indicates that the lower intertidal samples at Reef Point contained coarser sediments than samples from the other sites and also were lacking a component of fine sediments as shown by the extended tail of the curves from the other sites (Figure 5).

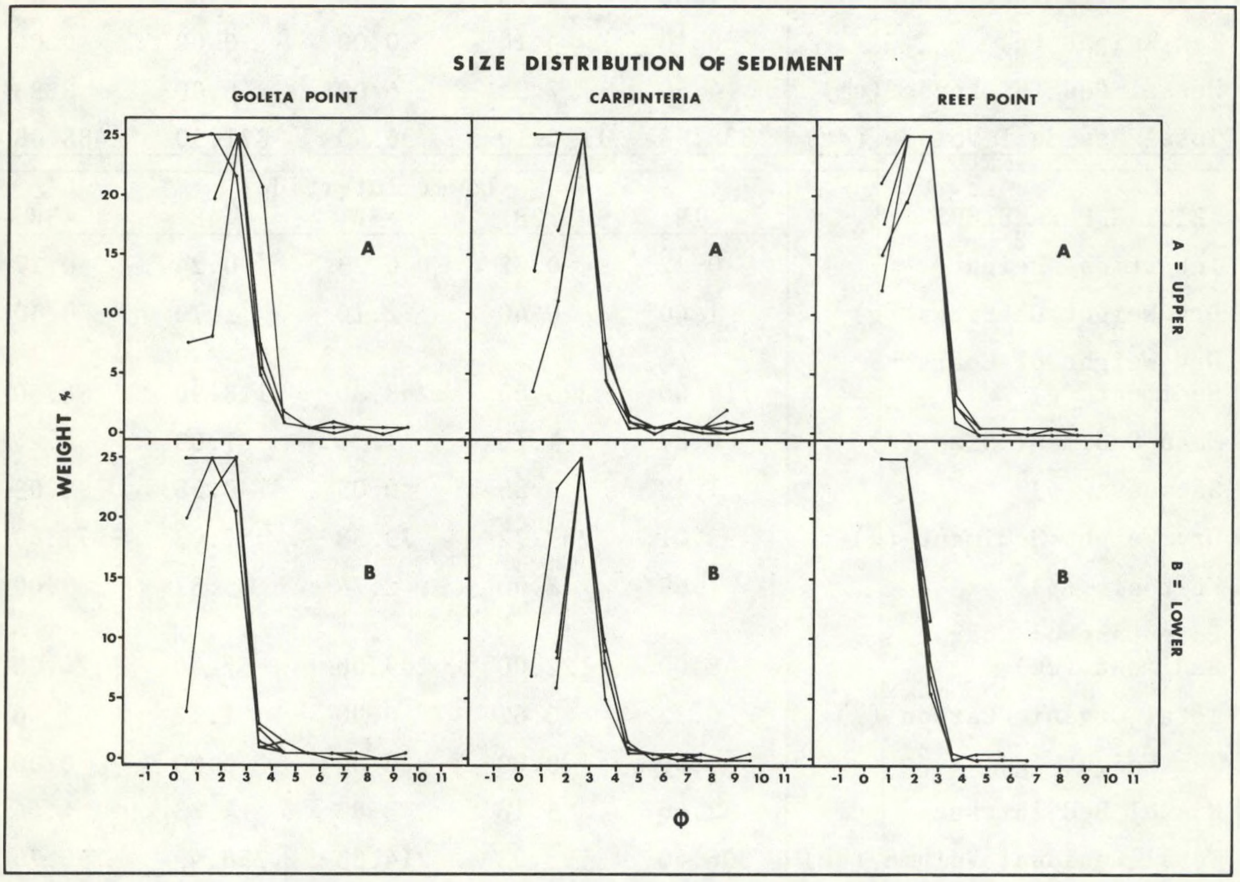

Figure 5. Size distribution of sediments in all samples at upper (A) and lower (B) intertidal sites at each locality.

It was difficult to locate mussel beds with a large enough area at comparable intertidal heights, suitable for sampling in this program. The upper intertidal samples were well matched (0.50 to 0.63 m above 0.0) and the lower intertidal samples at Goleta Point and Carpinteria were also relatively well matched (0.10 to 0.009 m below 0.0). However, the lower intertidal site at Reef Point was close to midway between these other upper and lower intertidal sites (0.22 to 0.27m above 0.0). No other extensive mussel beds were found in the lower intertidal area at this site.

Mussel bed thickness and total residual volume between the mussels was greater in the lower intertidal samples than the upper intertidal samples at Goleta Point and Carpinteria while the reverse was true at Reef Point. Total organic carbon values varied between samples at each locality, particularly at Goleta Point.

Tar was present in all samples at Goleta Point (3.8 g, 16.9 g) and the lower intertidal samples at Carpinteria (4.6 g) (Tables 2,3,4). Tar was recorded in three samples from the upper intertidal site at Carpinteria (0.4 g) and two samples from the upper intertidal site at Reef Point (0.2 g). Tar was not recorded in any of the lower intertidal samples at Reef Point.

Samples of *M. californianus* tissues were analyzed by Dr. J. Scott Warner to provide an indication of exposure of the community to lighter hydrocarbons (Table 5). The main indication of possible contamination by petroleum hydrocarbons is the values obtained for unresolved components. On this basis, the two samples from Goleta Point and the upper intertidal sample from Carpinteria contain petroleum hydrocarbons while the other samples do not.

The individual resolved hydrocarbons cannot be used as petroleum indicators for these samples because the very low level of C_{16} in all samples and the high values for pristane and phytane in the Goleta Point lower intertidal sample, are indicative of biogenic origins.

High pressure liquid chromatography was used to separate compounds larger than C_{12} n-alkane from those smaller than C_{12} n-alkane. The fraction lower than C_{12} should contain most of the naphthenes and aromatic hydrocarbons but none of the biogenic olefins. Each of these two fractions was further fractionated by silica gel chromatography to a saturated fraction and an aromatic fraction. The appreciable amounts of $>C_{12}$ unresolved saturates in some cases is indicative of many different branched chain components and alkyl naphthenes such as alkyl cyclohexanes. All of the unresolved aromatics reported are from the $<C_{12}$ fraction and thus do not contain biogenic olefins as interferences.

Table 5.
Hydrocarbon Content (μg/g) of *M. californianus**

Locality	Goleta Point		Carpinteria		Reef Point
Intertidal Level	Upper	Lower	Upper	Lower	Upper
<u>Hydrocarbons</u>					
Unresolved Saturates					
$<C_{12}$	3	5	5	<2	<2
$>C_{12}$	5	35	5	<2	<2
Unresolved Aromatics					
$<C_{12}$	12	10	5	<2	<2
Total	20	50	15	<5	<5
Resolved Saturates					
$<C_{12}$	0.1	0.4	0.4	0.5	0.02
$>C_{12}$	0.5	2.5	0.2	0.1	0.2
Resolved Aromatics					
$<C_{12}$	0.2	0.4	0.2	0.2	<0.02
Resolved Saturates					
C_{15}	0.02	0.05	0.02	0.02	0.02
C_{16}	<0.02	<0.02	<0.02	<0.02	<0.02
C_{17}	0.03	0.03	0.03	0.02	0.03
Pristane	0.05	0.17	0.04	0.02	0.02
C_{18}	0.05	0.06	0.04	0.03	0.04
Phytane	0.05	0.20	0.03	0.02	<0.02
C_{19}	<0.02	0.06	0.02	<0.02	<0.02
C_{20}	0.02	0.07	0.02	<0.02	<0.02
C_{21}	<0.02	0.03	<0.02	<0.02	<0.02
C_{22}	<0.02	0.05	<0.02	<0.02	<0.02
C_{23}	<0.02	0.07	<0.02	<0.02	<0.02
C_{24}	0.02	0.08	<0.02	<0.02	<0.02
C_{25}	<0.02	0.07	<0.02	<0.02	<0.02
C_{26}	<0.02	0.05	<0.02	<0.02	<0.02
C_{27}	<0.02	0.02	<0.02	<0.02	<0.02
C_{28}	<0.02	<0.02	<0.02	<0.02	<0.02

* = wet weight basis.

2. Biotic Parameters

Several methods were used to determine if sufficient replicate samples were taken at each site to account for the variability in the community at each site. The information loss curve for all data (Figure 6) shows that less than 10% of the information is lost if only 3 replicate samples rather than 5 replicate samples are considered at each site.

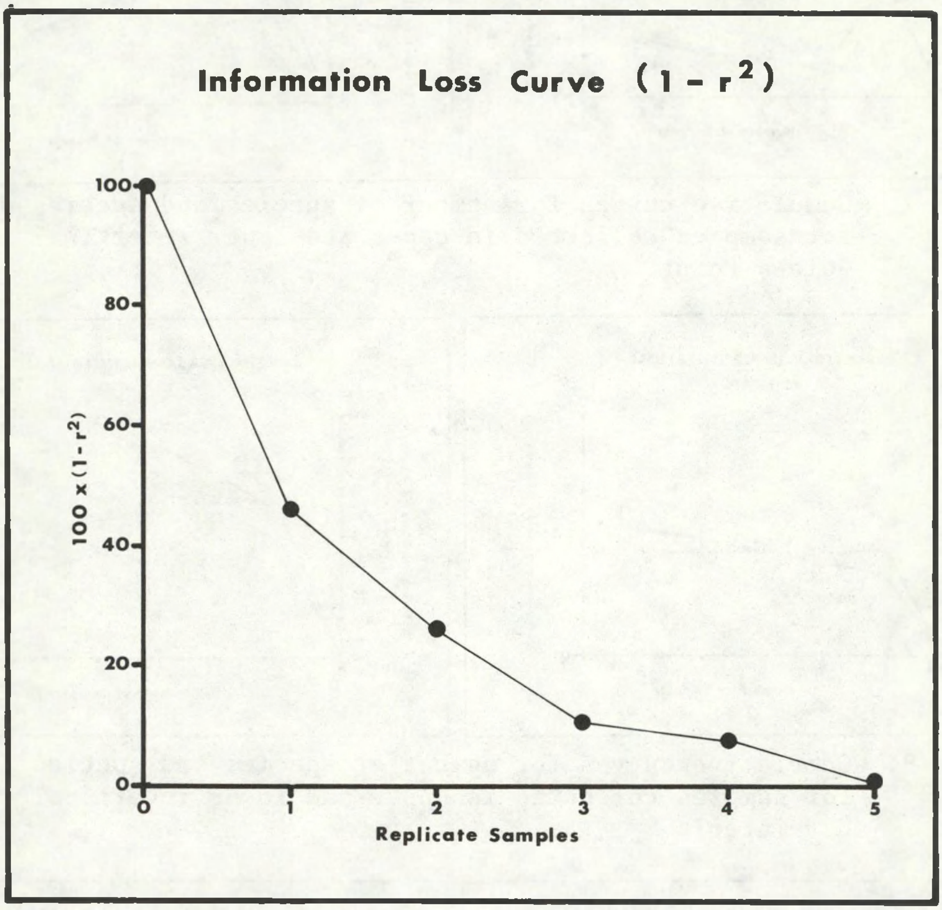

Figure 6. Information loss curve ($1-r^2$) using data from all (30) samples. Note that relatively little information is lost by using 3 replicates at each site instead of all 5 replicates at each site.

Cummulative curves of number of species and species diversity were constructed using the data for the five replicate samples taken at each collecting site (Figures 7,8,9). In all instances, the number of species reached a relatively constant level when 3 samples were considered. This is also true for the species diversity index (H') for the upper intertidal site at Carpinteria and the lower intertidal site at Reef Point. However, the measure has more variability at the other sites.

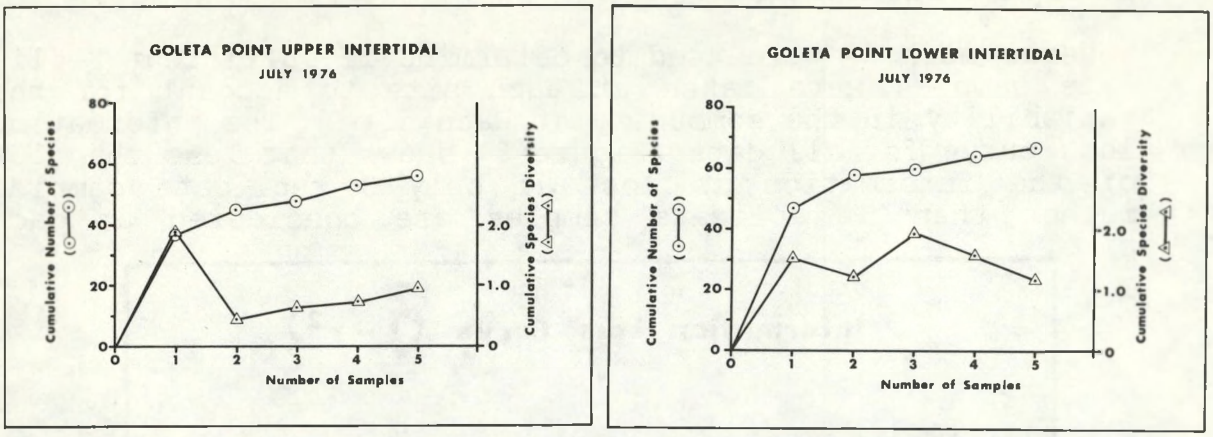

Figure 7. Cumulative curves for number of species and species diversity for samples collected in upper and lower intertidal areas at Goleta Point.

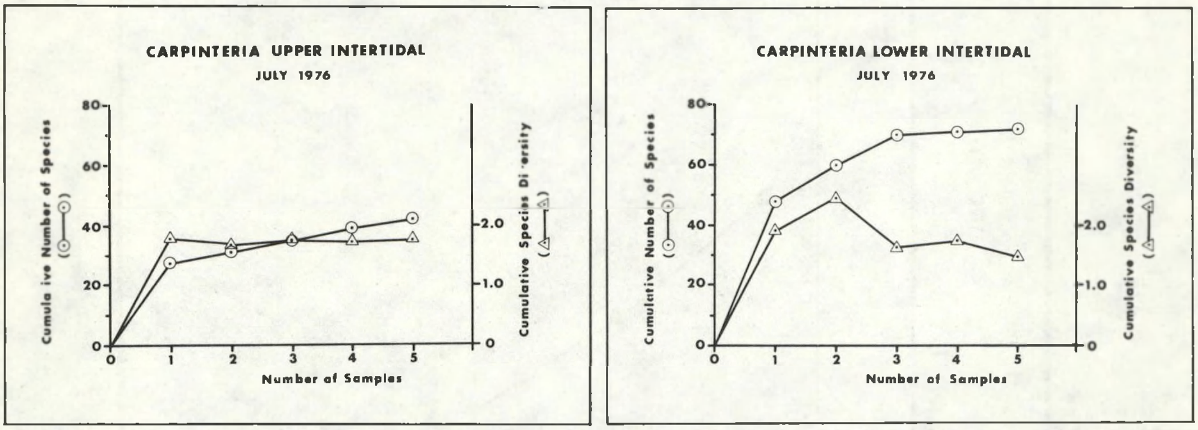

Figure 8. Cumulative curves for number of species and species diversity for samples collected in upper and lower intertidal areas at Carpinteria.

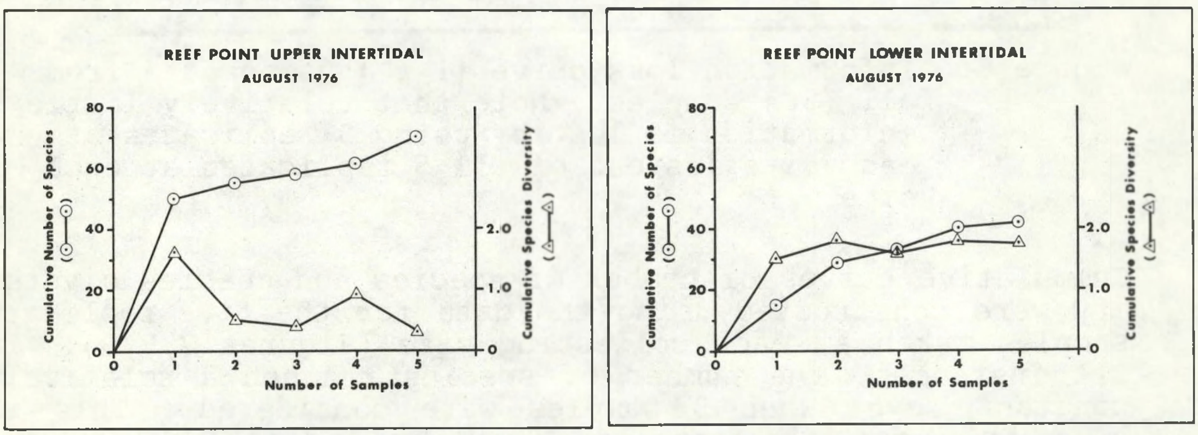

Figure 9. Cumulative curves for number of species and species diversity for samples collected in upper and lower intertidal areas at Reef Point.

Species diversity values were calculated for each of the six sampling sites (Table 6). Only invertebrate data were used in these calculations because it is difficult to determine if some of the algal and plant material was stranded or attached to the mussel community. The number of species was not consistently higher or lower at any locality or intertidal level. Values for the most heavily oiled site, Goleta Point (56,67), fell between those recorded at the other two sites. Fewer animals were recorded at lower intertidal than at upper intertidal sites although the difference was very low (7-8%) at both Goleta Point and Carpinteria. Again, the values at Goleta Point (42,343 and 39,712) fell between those recorded at the other collecting sites (53,212 and 1,846). This trend also occurs for the Shannon-Weiner Diversity Index (H'), the richness value (R), and the evenness value (J').

Table 6.

Species Diversity* Values for each Sampling Area

Locality	Goleta Point		Carpinteria		Reef Point	
Intertidal Level	Upper	Lower	Upper	Lower	Upper	Lower
Number Species	56	67	42	72	70	42
Number Animals	42,343	39,712	12,559	11,884	53,212	1,846
Diversity Index (H')	0.952	1.174	1.770	1.497	0.311	1.767
Richness (R)	3.671	4.194	3.959	3.706	4.632	2.853
Evenness (J')	0.268	0.320	0.511	0.440	0.082	0.611

* = Animals with incomplete species identifications are not included.

Site (normal) dendrograms were constructed using data for 1 to 5 replicate samples (Figure 10). These dendrograms remain virtually unchanged if 2,3, 4, or 5 replicates are used but differ if only 1 replicate is used. Therefore, it is concluded that 5 samples more than adequately account for the variability in the community at each site and also are adequate to show differences between each site. In fact, based on these data, 3 samples would have been sufficient.

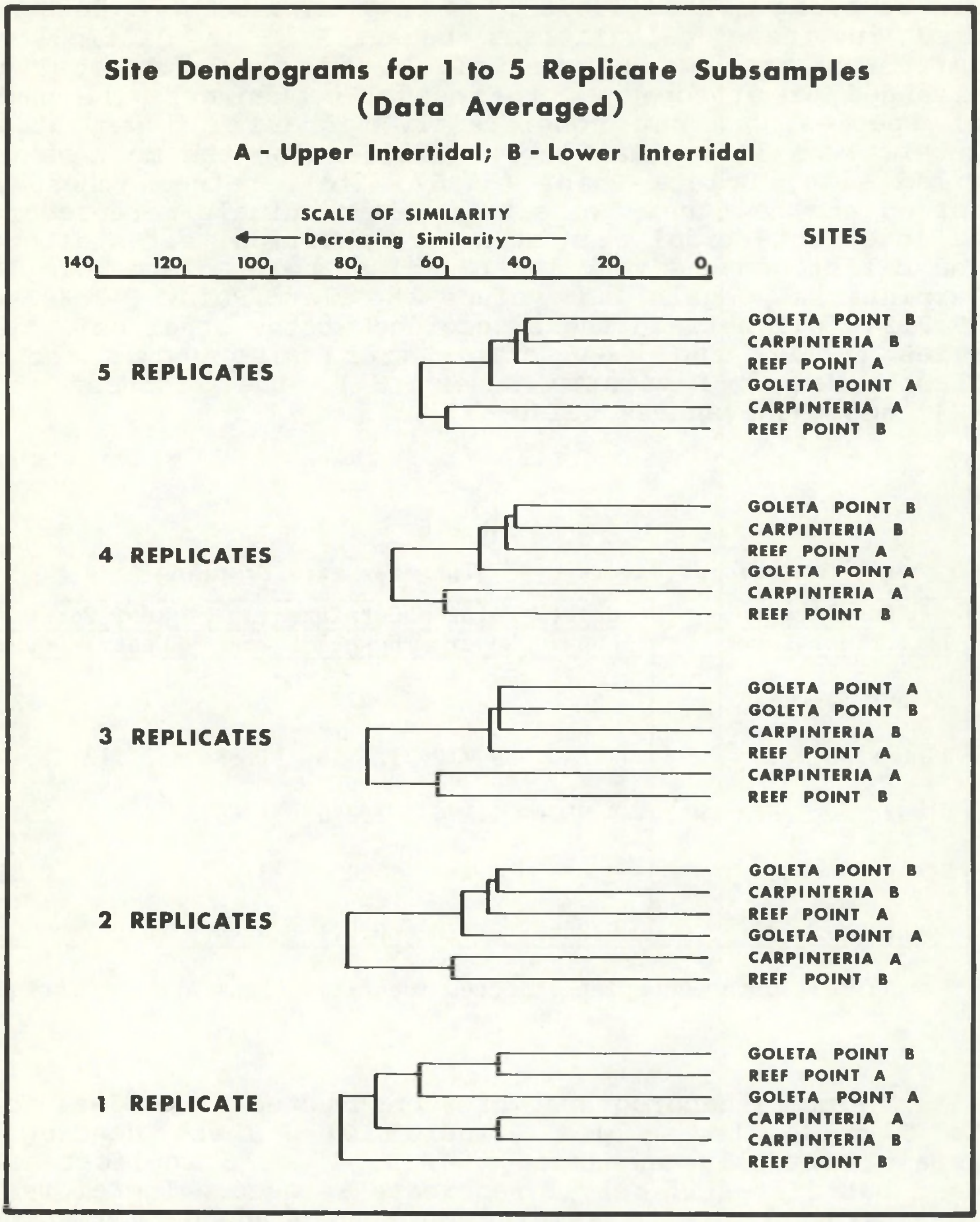

Figure 10. Site dendrograms to show groupings if data for 5,4,3,2, or 1 replicates are averaged. Note relative stability of the larger groupings with 5-2 replicates.

A total of 160 invertebrate species (Table 7, Appendices 1,2,3) and a total of 78 algal species (Appendices 4,5,6) were recorded in the survey. Some identifications are incomplete because the characteristics necessary to make positive identifications were lacking. This may be due to damage to a specimen, the specimen being a juvenile, lack of reproductive parts etc. In some instances, e.g., the polychaete genus *Typosyllis*, the genus is currently being revised and tentative names have been applied to animals currently recognized as separate species.

On the basis of the species listed in the appendices, more algal species were recorded from Goleta Point (47) and Carpinteria (49) than from Reef Point (38). Only six species, *Ahnfeltia plicata*, *Amplisiphonia pacifica*, Bossiella orbigniana ssp. *orbigniana*, *Gracilaria verrucosa*, *Phyllospadix* sp., *Plocamium cartilagineum* and *Pterochondria woodii* var. *woodii* were found at all six collecting sites. The *Phyllospadix* sp. was almost certainly stranded between the mussels and not growing there. Only *Phyllospadix* sp. and *P. cartilagineum* were found in all 30 samples.

Similar trends were also recorded in the invertebrates. Only 25 invertebrate species were recorded at all 6 sampling sites (Appendix 7). Note that the rare species eliminated from the classificatory data analyses by site were not included in this appendix. Even including these rare species, the 25 species found at all sites would comprise over 90% of the organisms collected. This is partly because of the large numbers of the barnacles, *Balanus glandula* and *Chthamalus dalli*, the bivalves, *Lasaea subviridis* and *M. californianus*, and the stalked barnacle, *P. polymerus*. Four of these species were found in all 30 samples (Appendix 8). The fifth species, *L. subviridis* was only found in 27 samples. However, it was the most abundant species collected (117,647 animals). One sample alone contained 14,960 *L. subviridis*. It also comprised almost 65% of the animals collected. Eleven species made up over 90% of the animals collected. Therefore, only a small percentage (23%) of the large number of organisms found in these communities were found in all samples.

3. <u>Analysis of Data from Upper and Lower Sampling Sites Together</u>.

The faunal distribution data were analyzed by classificatory methods in three ways (Figures 11,13,15). The data for species abundance were analyzed for all thirty samples (Figure 11). This resulted in two major site groupings: all Goleta Point and upper intertidal Reef Point samples in one group and all Carpinteria and all lower intertidal Reef

Table 7.
List of Species

DIVISION CHLOROPHYTA
Class Chlorophyceae (Order Ulotrichales)

Enteromorpha intestinalis (Linnaeus) Link, 1820
Enteromorpha sp.
Enteromorpha flexuosa (Roth) J. Agardh, 1883

Ulva californica Wille, 1895-1919
Ulva lactuca Linnaeus, 1753
Ulva sp.

Class Chlorophyceae (Order Caulerpales)

Derbesia marina (Lyngbye) Solier, 1846

Class Chlorophyceae (Order Cladophorales)

Chaetomorpha spiralis Okamura, 1903
Cladophora microcladioides Collins, 1909

DIVISION PHAEOPHYTA

Phaeophyta, unid.

Class Phaeophyceae (Order Dictyosiphonales)

Punctaria hesperia Setchell & Gardner, 1924

Class Phaeophyceae (Order Dictyotales)

Dictyotales unid.
Dictyopteris undulata Holmes, 1896
Zonaria farlowii Setchell & Gardner, 1924

Class Phaeophyceae (Order Laminariales)

Macrocystis sp.

Class Phaeophyceae (Order Scytosiphonales)

Scytosiphon lomentaria (Lyngbye) J. Agardh, 1848

DIVISION RHODOPHYTA

Rhodophyta, unid

Class Rhodophyceae (Order Bangiales)

Porphyra cf. *perforata* J. Agardh, 1883
Porphyra sp.

Table 7.
List of Species

DIVISION RHODOPHYTA
Class Rhodophyceae (Order Nemaliales)

Gelidium purpurascens Gardner, 1927
Gelidium robustum (Gardner) Hollenberg & Abbott, 1965
Gelidium sp.
Pterocladia capillacea (Gmelin) Bornet & Thuret, 1876

Class Rhodophyceae (Order Gigartinales)

Ahnfeltia gigartinoides J. Agardh, 1847
Ahnfeltia plicata (Hudson) Papenfuss, 1950

Gigartina agardhii Setchell & Gardner, 1933
Gigartina canaliculata Harvey, 1841
Gigartina cf. *leptorhynchos* J. Agardh, 1885
Gigartina sp.
Gracilaria sp.
Gracilaria verrucosa (Hudson) Papenfuss, 1950
Gymnogongrus leptophyllus J. Agardh, 1876

Plocamium cartilagineum (Linnaeus) Dixon, 1967
Plocamium sp.

Rhodoglossum affine (Harvey) Kylin, 1928

Stenogramme interrupta (C. Agardh) Montagne, 1846

Class Rhodophycea (Order Cryptonemiales)

Bossiella orbigniana (Decaisne) Silva, 1957
Bossiella orbigniana spp. *orbigniana* (Decaisne) Silva, 1957
Calliarthron sp.
Corallina officinalis var. *chilensis* (Decaisne) Kutzing, 1858
Corallina sp.
Corallina vancouveriensis Yendo, 1902
Cryptosiphonia sp.

Endocladia muricata (Postels & Ruprecht) J. Agardh, 1847

Haliptylon gracilis (Lamouroux) Johansen, 1971

Lithothrix aspergillum Gray, 1867
Prionitis sp.

Class Rhodophyceae (Order Rhodymeniales)

Rhodymenia californica Kylin, 1931
Rhodymenia sp.

Table 7.
List of Species

DIVISION RHODOPHYTA
Class Rhodophyceae (Order Ceramiales)

Acrosorium uncinatum (Turner) Kylin, 1924
Amplisiphonia pacifica Hollenberg, 1939
Antithamnion sp.

Botryoglossum ruprechtianum (J. Agardh) DeToni, 1900

Centroceras clavulatum (C. Agardh) Montagne, 1846
Cryptopleura lobulifera (J. Agardh) Kylin, 1924
Cryptopleura sp.

PHYLUM CNIDARIA
Class Anthozoa

Actiniaria, unid.
Anthopleura sp.
Anthopleura xanthogrammica (Brandt, 1835)

PHYLUM PLATYHELMINTHES

Leptoplanidae

Notoplana acticola (Boone, 1929)

PHYLUM NEMERTEA
Class Anopla

Lineus sp.

Class Enopla

Amphiporus sp.

Emplectonema gracile (Johnston, 1837)

Nemertopsis gracilis Coe, 1904

Paranemertes peregrina Coe, 1901

PHYLUM SIPUNCULA

Phascolosoma agassizii Keferstein, 1867

PHYLUM NEMATODA

Deontostoma sp.

Enoplus sp.

Oncholaimina sp.

Paraeurystomina sp.

Table 7.
List of Species

PHYLUM ANNELIDA
Class Oligochaeta

Oligochaeta, unid.

Class Polychaeta

Arabella semimaculata (Moore, 1911)
Arabella sp.
Arabellidae
Armandia bioculata Hartman, 1938

Boccardia sp.
Boccardia proboscidea Hartman, 1940
Branchiomaldane vincenti Langerhans, 1881
Brania sp.

Chaetozone sp.
Chone minuta Hartman, 1944
Chrysopetalum occidentale Johnson, 1897
Chrysopetalum sp.
Cirriformia sp.

Eulalia bilineata (Johnston, 1840)
Eulalia quadrioculata Moore, 1906

Halosydna brevisetosa Kinberg, 1855
Hemipodus borealis Johnson, 1901
Hydroides gracilis (Bush, 1904)

Lumbrineridae
Lumbrineris sp.
Lumbrineris zonata (Johnson, 1901)

Naineris dendritica (Kinberg, 1867)
Nereidae
Nereis grubei (Kinberg, 1866)
Nereis latescens Chamberlin, 1919
Nereis sp.
Nereis vexillosa Grube, 1851
Notomastus tenuis Moore, 1909

Orbiniidae

Paraonella platybranchia (Hartman, 1961)
Perinereis monterea (Chamberlin, 1918)
Phragmatopoma californica (Fewkes, 1889)
Phyllodocidae
Polydora limicola Annenkova, 1934
Polydora websteri Hartman, 1943
Polydora cf. *websteri* Hartman, 1943
Polynoidae
Potamilla sp.

Table 7.
List of Species

PHYLUM ANNELIDA
Class Polychaeta

Rhynchospio glutaea (Ehlers, 1897)

Sabellidae
Spionidae
Spirobranchus spinosus Moore, 1923
Syllidae
Syllis gracilis Grube, 1840

Tharyx sp.
Typosyllis aciculata Treadwell, 1945
Typosyllis adamantea (Treadwell, 1914)
Typosyllis alternata (Moore, 1908)
Typosyllis armillaris (Muller, 1771)
Typosyllis hyalina (Grube, 1863)
Typosyllis pulchra (Berkeley & Berkeley, 1938)
Typosyllis cf. *pulchra* (Berkeley & Berkeley, 1938)
Typosyllis sp.
Typosyllis sp. A (New species)
Typosyllis variegata (Grube, 1860)

PHYLUM MOLLUSCA
Class Gastropoda

Acanthina spirata (Blainville, 1832)

Barleeia californica Bartsch, 1920

Collisella conus (Test, 1945)
Collisella digitalis (Rathke, 1833)
Collisella limatula (Carpenter, 1864)
Collisella pelta (Rathke, 1833)
Collisella scabra (Gould, 1846)
Collisella sp.
Collisella strigatella (Carpenter, 1864)
Crepidula sp.

Epitonium tinctum (Carpenter, 1864)

Iselica ovoidea (Gould, 1853)

Littorina planaxis Philippi, 1847
Littorina scutulata Gould, 1849
Littorina sp.
Lottia gigantea Sowerby, 1834

Mitrella aurantiaca (Dall, 1871)

Nucella emarginata (Deshayes, 1839)

Ocenebra circumtexta Stearns, 1871
Odostomia nota Dall & Bartsch, 1909

Tegula funebralis (A. Adams, 1855)

Table 7.
List of Species

PHYLUM MOLLUSCA
Class Bivalvia

Adula diegensis (Dall, 1911)

Branchidontes adamsianus (Dunker, 1857)

Glans carpenteri (Lamy, 1922)

Hiatella arctica (Linnaeus, 1767)

Kellia laperousii (Deshayes, 1839)

Lasaea subviridis Dall, 1899

Modiolus capax (Conrad, 1837)
Mytilus californianus Conrad, 1837
Mytilus edulis Linnaeus, 1758

Protothaca staminea (Conrad, 1837)

Septifer bifurcatus (Conrad, 1837)

Veneridae

Class Polyplacophora

Cyanoplax hartwegii (Carpenter, 1855)

Mopalia muscosa (Gould, 1846)
Mopalia porifera Pilsbry, 1893
Mopalia sp.

Nuttalina fluxa (Carpenter, 1864)

PHYLUM ARTHROPODA
Class Crustacea (Order Cirripedia)

Balanus glandula Darwin, 1854
Balanus tintinnabulum californicus Pilsbry, 1916

Chthamalus dalli Pilsbry, 1916
Chthamalus fissus Darwin, 1854

Pollicipes polymerus Sowerby, 1833

Tetraclita squamosa rubescens Darwin, 1854

Class Crustacea (Order Isopoda)

Cirolana harfordi (Lockington, 1877)

Dynamenella dianae (Menzies, 1962)

Excorallana kathyae Menzies, 1962

Gnorimosphaeroma sp. No. 1

Jaeropsis dubia Menzies, 1951

Sphaeromatidae sp. No. 1

Table 7.
List of Species

PHYLUM ARTHROPODA
Class Crustacea (Order Amphipoda)

Ampithoe sp.
Aoroides columbiae Walker, 1898

Elasmopus rapax Costa, 1853
Elasmopus sp.

Hyale anceps (J.L. Barnard, 1969)
Hyale frequens (Stout, 1913)
Hyale californica J.L. Barnard, 1969
Hyale plumulosa (Stimpson, 1857)

Synchelidium sp.

Class Crustacea (Order Tanaidacea)

Anatanais sp.

Synapseudes intumescens Menzies, 1953

Tanaidacea

Class Crustacea (Order Decapoda)

Pachycheles rudis Stimpson, 1859
Pachygrapsus crassipes Randall, 1839
Petrolisthes cabrilloi Glassell, 1945
Pugettia producta (Randall, 1839)

Class Pycnogonida

Ammothella tuberculata Cole, 1904

Halosoma viridintestinale Cole, 1904

Pycnogonum stearnsi Ives, 1892

Class Insecta

Diptera, unid.

PHYLUM ECHINODERMATA
Class Asteroidea

Pisaster ochraceus (Brandt, 1835)
Pisaster sp.

Class Echinoidea

Strongylocentrotus purpuratus (Stimpson, 1857)

Table 7.
List of Species

PHYLUM ECTOPROCTA

Cellaria mandibulata Hinks, 1882
Crisia serrulata Osburn, 1953
Crisulipora occidentalis Robertson, 1910
Cryptosula pallasiana (Moll, 1803)

Filicrisia franciscana (Robertson, 1910)

Hippothoa hyalina (Linnaeus, 1758)

Membranipora membranacea (Linnaeus, 1767)
Membranipora tuberculata (Bosc, 1802)
Microporella californica (Busk, 1856)
Microporella ciliata (Pallas, 1766)

Rhynchozoon rostratum Busk, 1856

Scrupocellaria californica Trask, 1857
Scrupocellaria diegensis Robertson, 1905
Synnotum aegyptiacum (Audouin, 1826)

Thalamoporella californica (Levinson, 1909)
Tricellaria occidentalis (Trask, 1857)

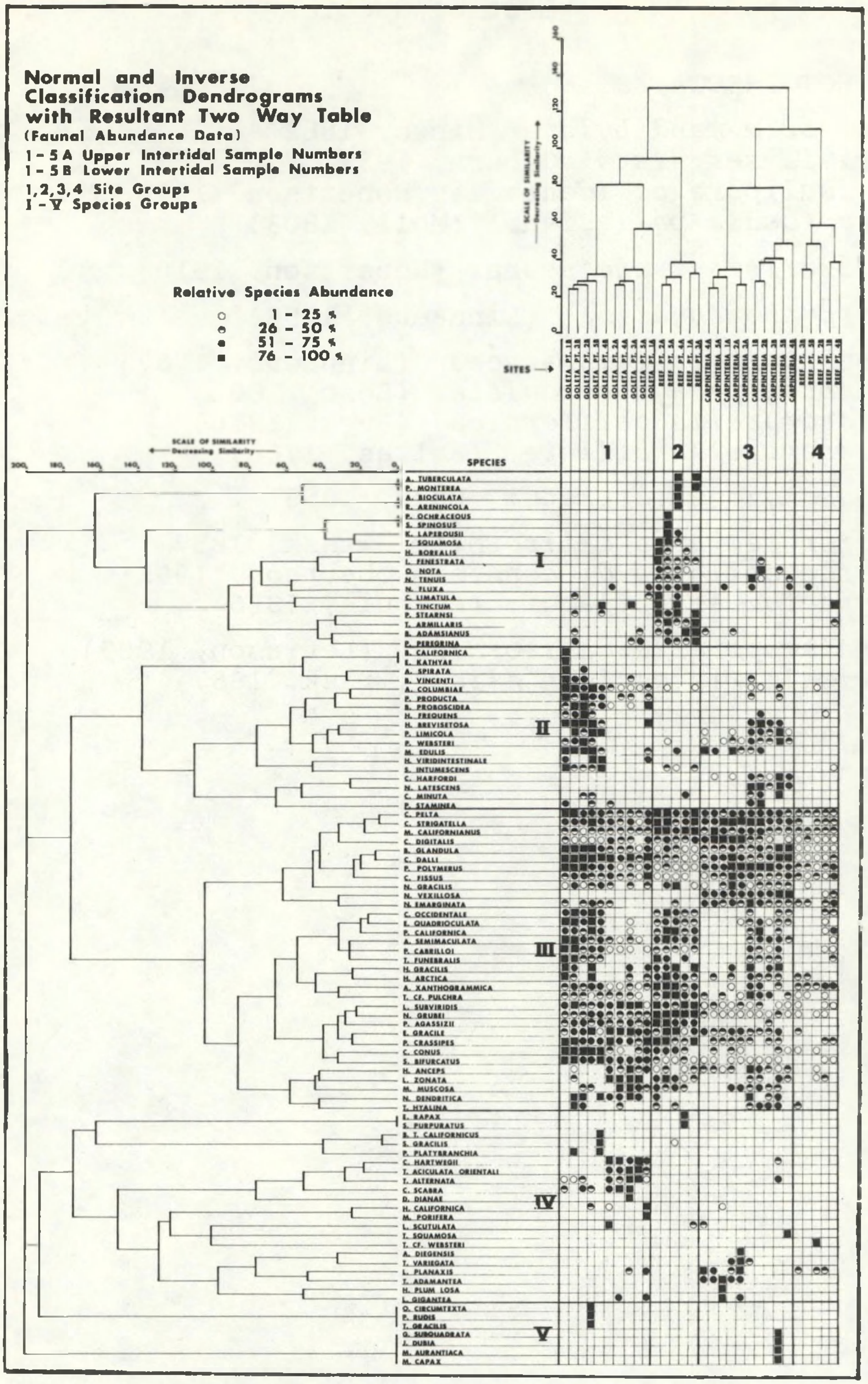

Figure 11. Classification of faunal data for each of the thirty samples collected based on species abundance data. Presence/absence data are not included.

Point samples in the other group. The Reef Point samples were then separated out from the samples at the other site within each of these groups. Note that the five replicate samples from each of the six collecting sites were grouped together indicating distinct differences between the collecting sites which were greater than any differences between subsamples.

All sites were characterized by the presence of species group III. This was basically composed of the 25 species recorded at all six sites with the addition of six species which occurred at most of the six sites. Species in group I were generally characteristic of the upper intertidal site at Reef Point. Species in group II were characteristic of the lower intertidal site at Goleta Point and the upper intertidal site at Carpinteria although some of the species were only found at one of these sites. Species group IV contained species characteristic of the upper intertidal site at Goleta Point and species characteristic of the lower intertidal site at Carpinteria. Species group V contained animals found in single samples.

The results of the discriminant analysis were plotted on axis 1 and axis 2 to show the relative position of the subsample in space. All replicate samples from Goleta Point were grouped together (Figure 12, site group 1) and all replicate samples from Carpinteria were grouped together (Figure 12, site group 3). The upper intertidal replicate samples from Reef Point (Figure 12, site group

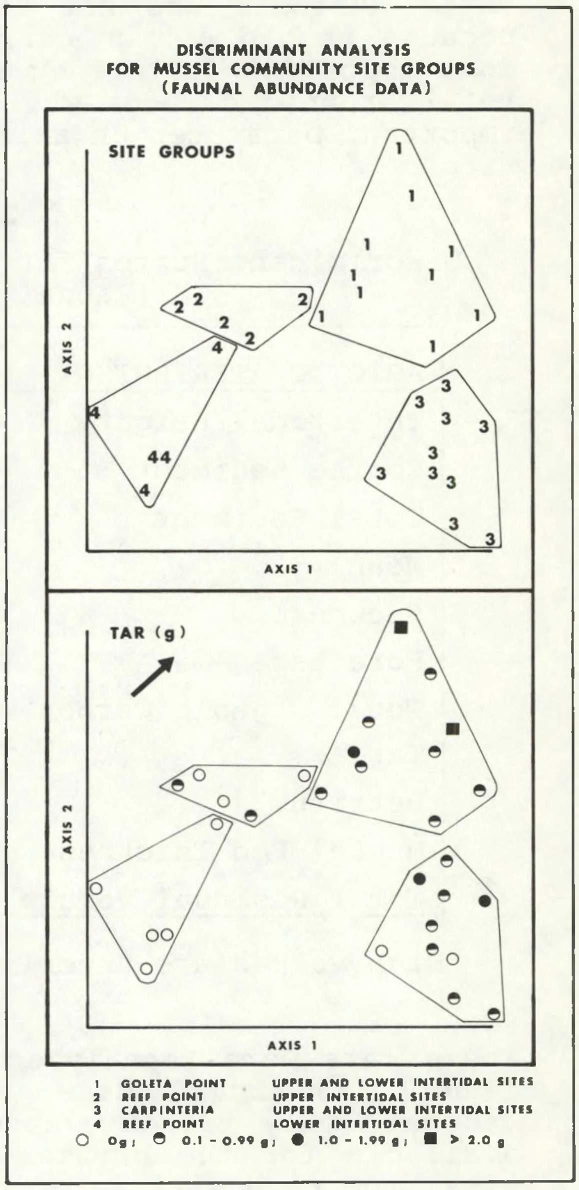

Figure 12. Distribution of site groups 1,2,3,4 on axes 1 and 2 and weight of tar in each sample.

2) were generally grouped separately from the lower intertidal replicate samples from Reef Point (Figure 12, site group 4). There were increasing values of tar in each of the subsamples indicated by the direction of the arrow arrow (Figure 12). This suggests that tar may be an important factor on one of these axes. 63% of the variation is accounted for on axis 1 and 27% of the variation is accounted for on axis 2. The coefficients of separate determination for axis 1 indicate the sediment parameters such as grain size (mean ø), skewness, and volume of coarse sediment were the most important parameters (Table 8). (Note kurtosis was not included as a separate attribute because it had a high correlation with skewness). The two most important factors on axis 2 were the weight of tar and total organic carbon, while intertidal height was the most important parameter on axis 3.

Table 8.
Discriminant Scores for All Mussel Community Site Groups
(Faunal Abundance Data)

	Axis		
ABIOTIC ATTRIBUTE	1	2	3
Intertidal Height	0.8	9.0	<u>20.0</u>
Coarse Sediment	14.3	6.8	11.7
Total Sediment	0.4	12.3	12.0
Mean Φ	<u>19.6</u>	6.4	2.5
Skewness	15.8	1.9	3.9
Pore Base	5.3	4.6	17.0
Total Organic Carbon	13.6	<u>23.9</u>	3.1
Tar	7.5	<u>27.8</u>	17.1
Detritus	2.1	2.3	10.8
Mussel Bed Thickness	10.2	3.5	10.8
Total Residual Volume	10.2	1.5	0.7

High values are underlined.

These data were reanalyzed by classificatory methods using faunal abundance data and presence/absence data. In general, only presence/absence and not abundance data are available for the bryozoa. Again the five replicate samples from each site were grouped together (Figure 13). The major division in the site groupings separates the upper intertidal samples from Carpinteria and the lower intertidal samples from Reef Point (site group 2) from the other samples (site group 1).

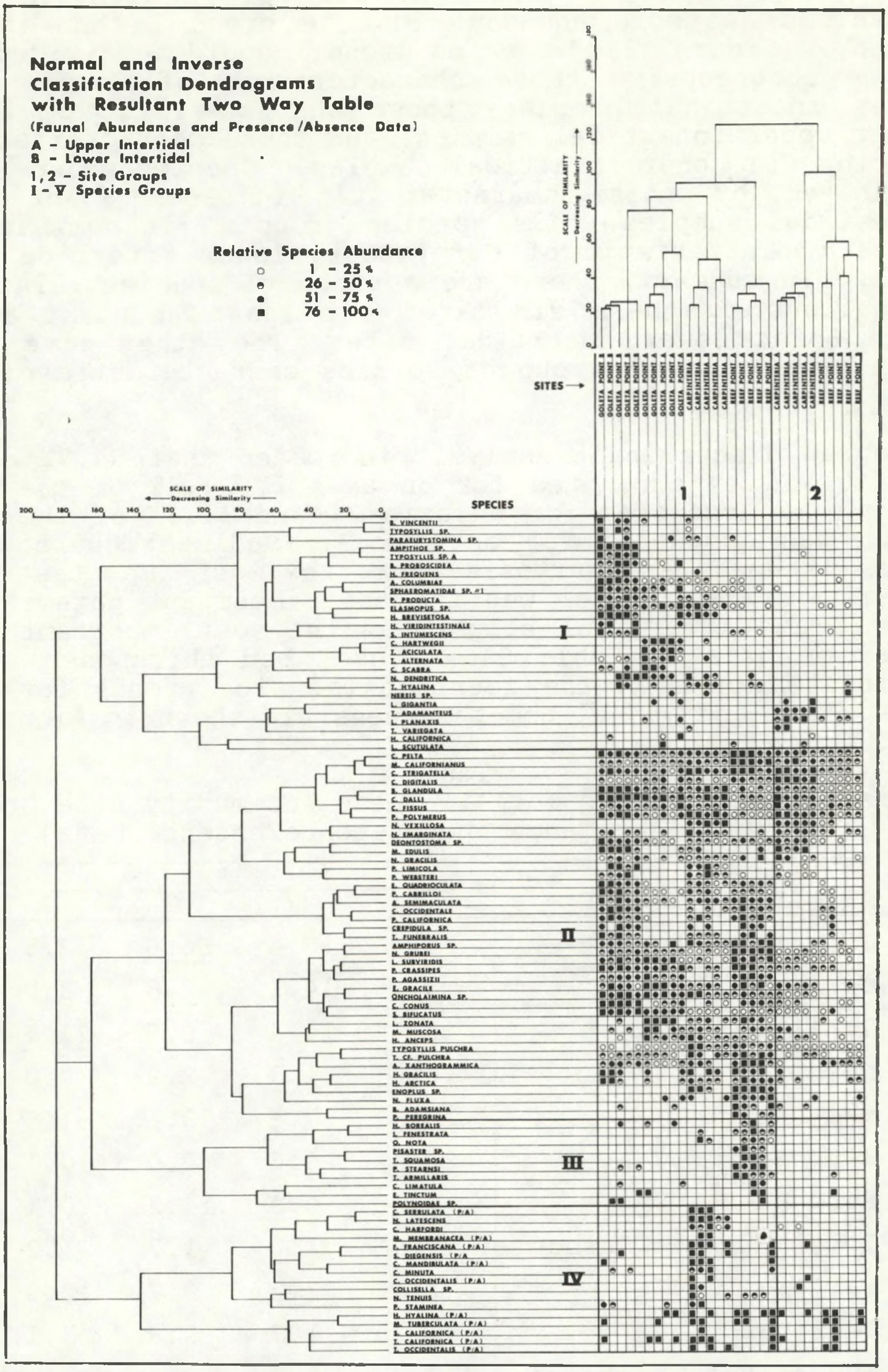

Figure 13. Classification of faunal data for each of the thirty samples collected. Species abundance and presence/absence data are included.

Species group II is found at all sites, although these organisms are more abundant in site group 1 than in site group 2 (Figure 13). Species group I could be divided into three subgroups: those characteristic of Goleta Point lower intertidal samples, those characteristic of Goleta Point upper intertidal samples, and those characteristic of Carpinteria upper intertidal samples. Species group III is dominated by those characteristic of Reef Point upper intertidal samples while species group IV is dominated by those characteristic of Carpinteria lower intertidal samples. In summary, there are a group of species relatively ubiquitous to these six sites but least abundant at the Reef Point lower intertidal site. The other five sites each have a small group of species characteristic of that site.

Weighted discriminant analysis indicated that 54.7% of the variation was accounted for on axis 1, 21.4% of the variation was accounted for on axis 2, and 11.3% of the variation was accounted for on axis 3. Sediment characteristics (skewness and kurtosis) were the most important parameters on axis 1, tar was the most important parameter on axis 2 and intertidal height was the most important parameter on axis 3 (Table 9). Mussel bed thickness was the dominant factor on the fourth axis. The trends for skewness, tar, and mussel bed thickness are shown in Figure 14.

Table 9.
Discriminant Scores for All Mussel Community Site Groups
(Faunal Abundance and Presence/Absence Data)

ABIOTIC ATTRIBUTE	Axis 1	Axis 2	Axis 3	Axis 4
Intertidal Height	4.7	10.4	<u>56.0</u>	2.5
Coarse Sediment	3.4	14.1	0.8	3.0
Total Sediment	2.9	15.4	6.5	<u>21.4</u>
Mean Φ	10.4	1.3	2.9	7.0
Skewness	<u>28.5</u>	7.8	3.1	1.5
Kurtosis	<u>21.4</u>	0.6	0.0	0.1
Pore Base	2.0	0.0	14.2	0.1
Total Organic Carbon	0.4	1.0	1.7	1.2
Tar	7.1	<u>47.2</u>	9.7	10.0
Detritus	1.2	1.7	3.8	3.1
Mussel Bed Thickness	12.3	0.2	0.1	<u>36.7</u>
Total Residual Volume	5.7	0.3	1.0	13.4

High values are underlined.

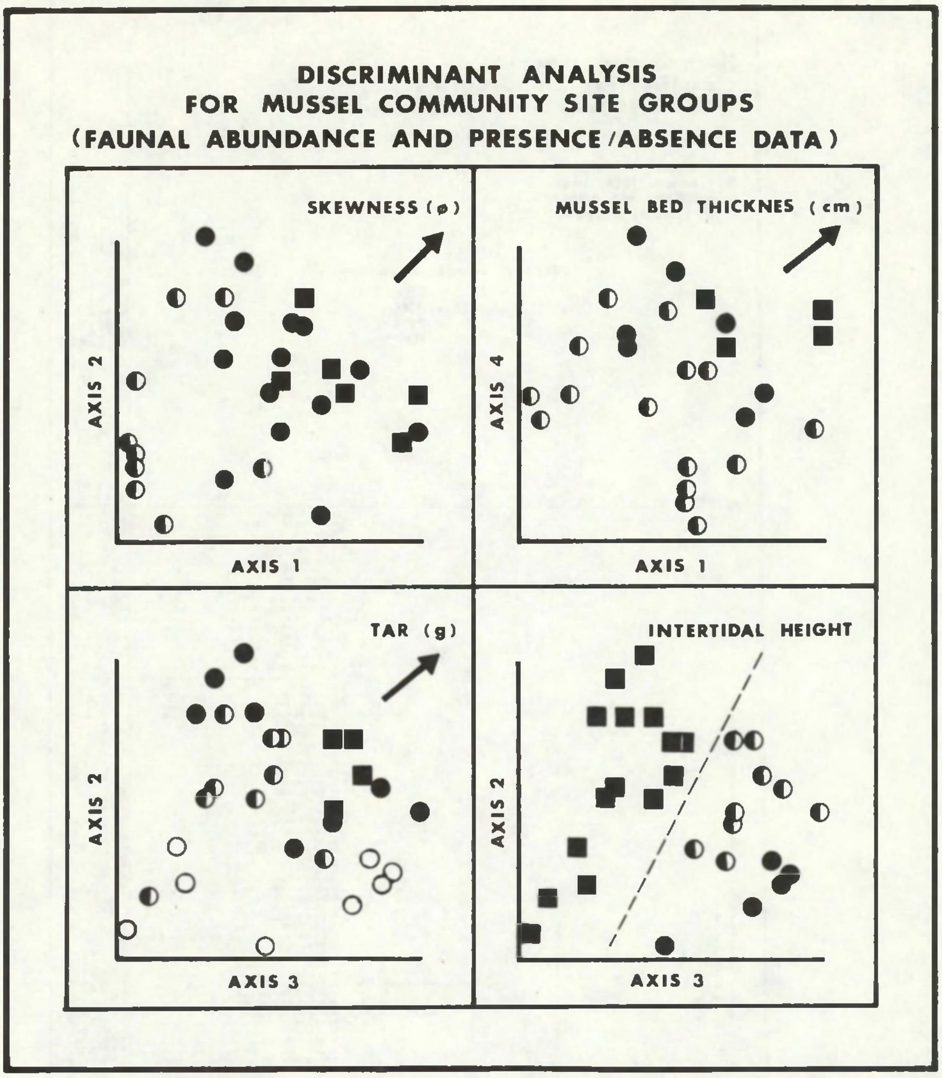

Figure 14. Dominant abiotic trends revealed by discriminant analysis using faunal abundance and presence/ absence data for 30 samples. Symbols refer to a data rating on a scale from 0 to 9 for each abiotic characteristic ○ = 0; ◐ = 1,2,3; ● = 4,5,6; ■ = 7,8,9. --- divides upper intertidal from lower intertidal sites.

(Figure 18 shows the source of the samples on axes 1,2, and 3). There is also a definite separation between upper intertidal samples and the lower intertidal samples. Note the lower intertidal samples from Reef Point are shown as a black circle to indicate that this site was not as low in the intertidal zone as the lower intertidal sites at Goleta Point and Carpinteria (◐).

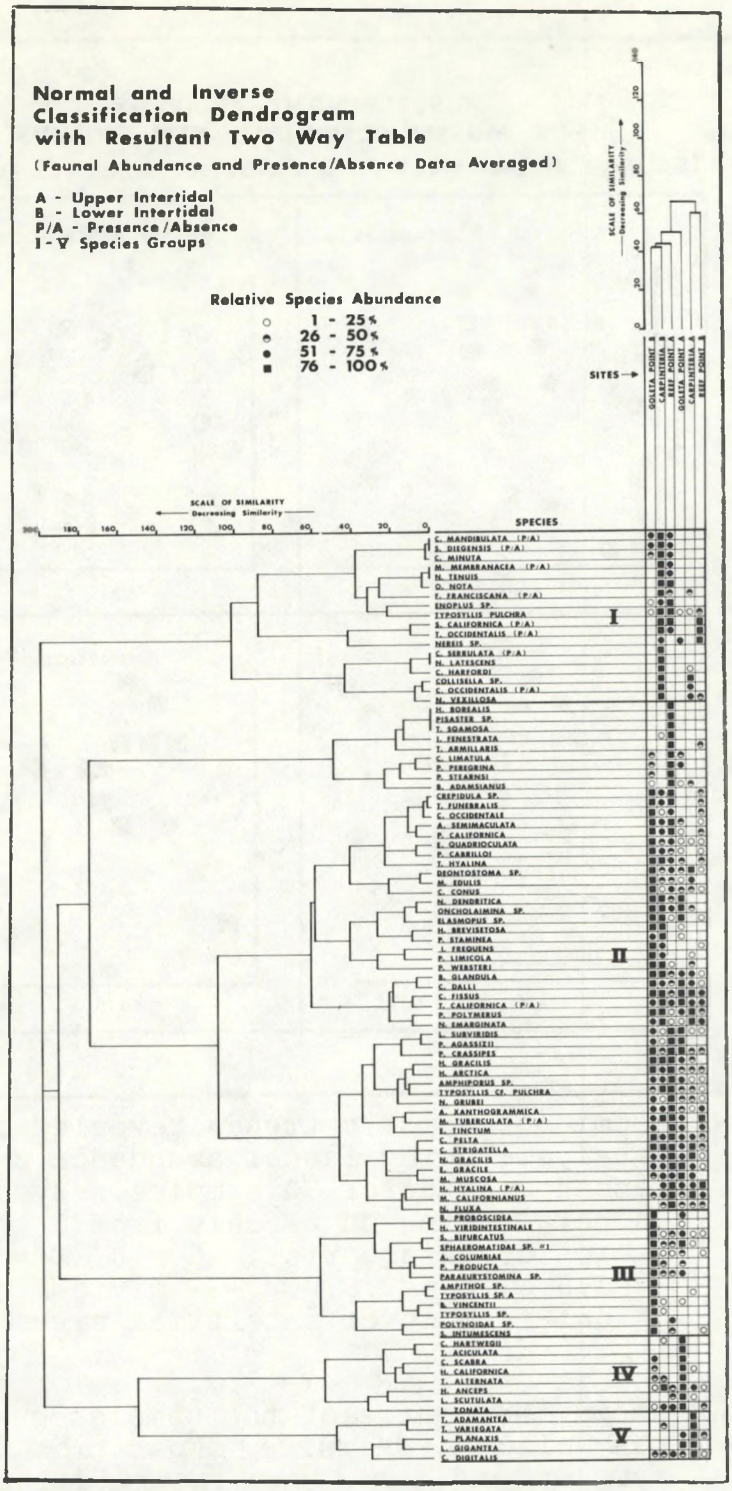

Figure 15. Classification of faunal data for each of the six sites sampled. Data from the five replicate samples at each site are averaged (Appendix 7). Species abundance and presence/absence data are included.

The biotic data, both faunal abundance and presence/absence data, were analyzed on a site basis. The data for the five samples at each site were averaged prior to analysis. While there is no really clearcut division between the sites, as in the 30 sample analyses, the upper intertidal sample from Carpinteria and the lower intertidal sample from Reef Point are grouped together (Figure 15). There is also a large group of species found at most, if not all, sites (species group II) and a group of species characteristic of each site but, in most instances, with some overlap in distribution to other sites. These data were not analyzed by discriminant analysis because the number of environmental variables exceeded the number of sites. This causes computational problems [59].

The site data were analyzed using principal coordinate analysis with the biotic data only. This technique may reveal the biotic relationships between sites better than the classificatory technique. To examine correlations between the environmental variables and the biotic patterns, the values of the variables were then plotted symbolically in place of the site positions. Note that the hydrocarbon data as well as the weight of tar are included in these analyses (Figures 16, 17). In both

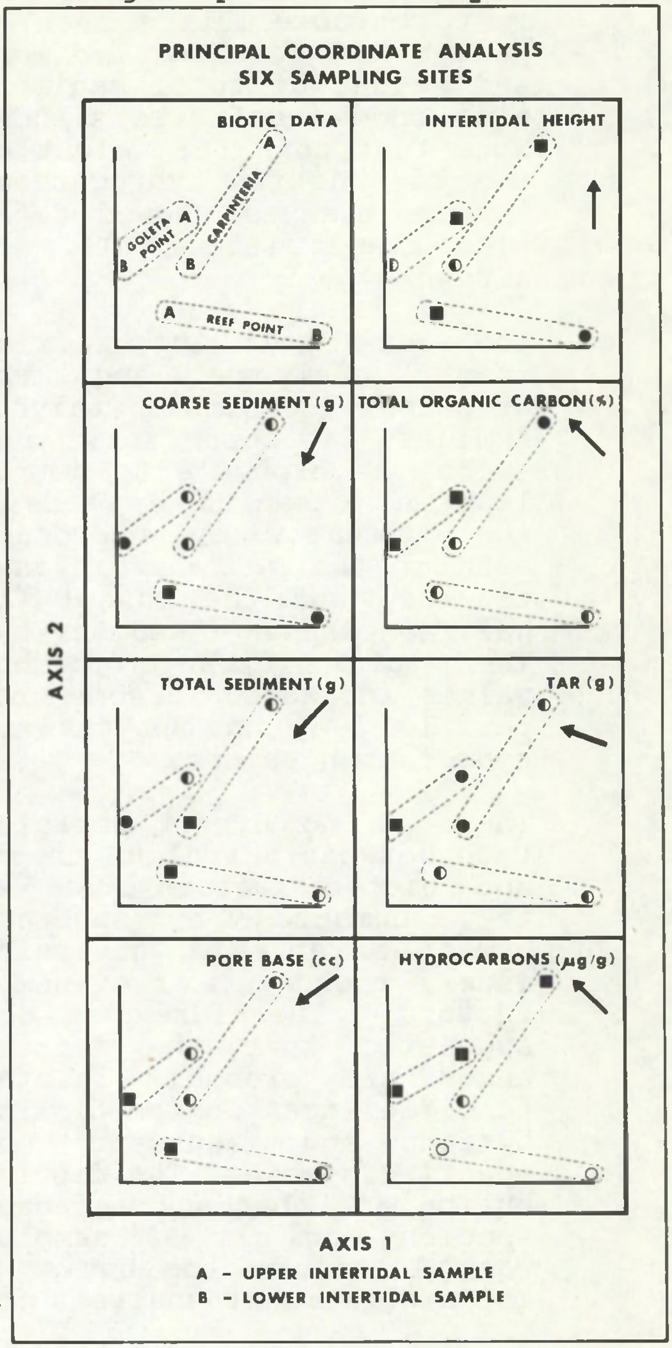

Figure 16. Principal coordinate analysis showing the distribution of abiotic parameters with distinct trends along axis 1 and 2. Abiotic parameters are rated along a scale from 0 to 9 and plotted as follows: ○ = 0; ◐ = 1,2,3; ● = 4,5,6; ■ = 7,8,9. Arrows indicate approximate direction of increasing trend.

Figure 16 and and Figure 17, the replicates form separate site groups. At all sites, the upper intertidal site is higher along axis 2 than the lower intertidal sites. Sediment characteristics such as weight of coarse sediment and weight of total sediment also showed definite trends. Note that both the weight of the tar and the hydrocarbons in the tissues showed definite trends (Figure 16, see arrows).

Therefore, both the discriminant analysis and the principal coordinate analysis indicate a correlation between the exposure to petroleum as measured by tar in the community and hydrocarbons in the *M. californianus* tissues, and the mussel (*M. californianus*) community. The total organic carbon values increased in some-what parallel way to the tar and hydrocarbon values.

There is no direct correlation between petroleum trends and biotic factors such as the number of species, number of animals, diversity index, richness, or evenness factors. Therefore it is suggested that the differences are probably related to differences in the distribution and abundance of specific species. The distribution and abundance of each species for all 30 samples was plotted on the basis of the discriminant analyses for

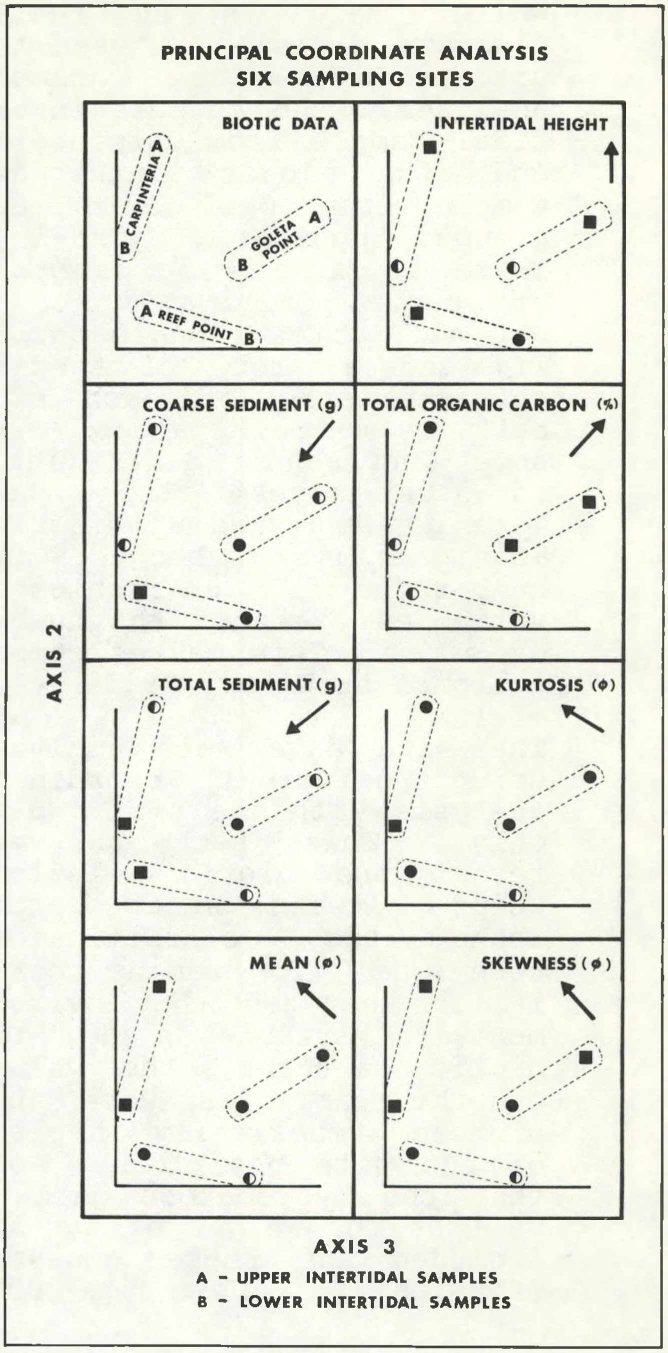

Figure 17. Principal coordinate analysis showing the distribution of biotic and abiotic parameters with distinct trends along axes 2 and 3. Abiotic parameters are rated along a scale from 0 to 9 and plotted as follows: ○ = 0; ◐ = 1, 2, 3; ● = 4, 5, 6; ■ = 7, 8, 9. Arrows indicate approximate direction of increasing trend.

30 samples. This was compared to the site groupings based on the same analyses (Figure 18).

Distributional trends differed with different species. This can perhaps best be illustrated by considering the distribution of four of the species of the polychaete genus *Typosyllis* which occurred in the survey (Figure 19). *T. adamantea* was recorded in all upper intertidal samples at Carpinteria only; *T. armillaris* was found in Reef Point samples only; *T. alternata* was found in Goleta Point and Carpinteria samples only, while *Typosyllis* sp. was found only in lower intertidal samples at Goleta Point and Carpinteria. The polychaete worm, *Boccardia proboscidea*, was only collected from Goleta Point, while the crustacean, *Ampithoe* sp. was further restricted to the lower intertidal samples at Goleta Point (Figure 20). The crab, *Pugettia producta* was recorded most abundantly at Goleta Point and in only two lower intertidal samples from Carpinteria. The isopod Sphaeromatidae sp, was more abundant at the oiled sites than the unoiled sites, but it was also recorded in several samples from Reef Point. The anemone, *Anthopleura xanthogrammica* was most abundant at Reef Point and least abundant at Carpinteria.

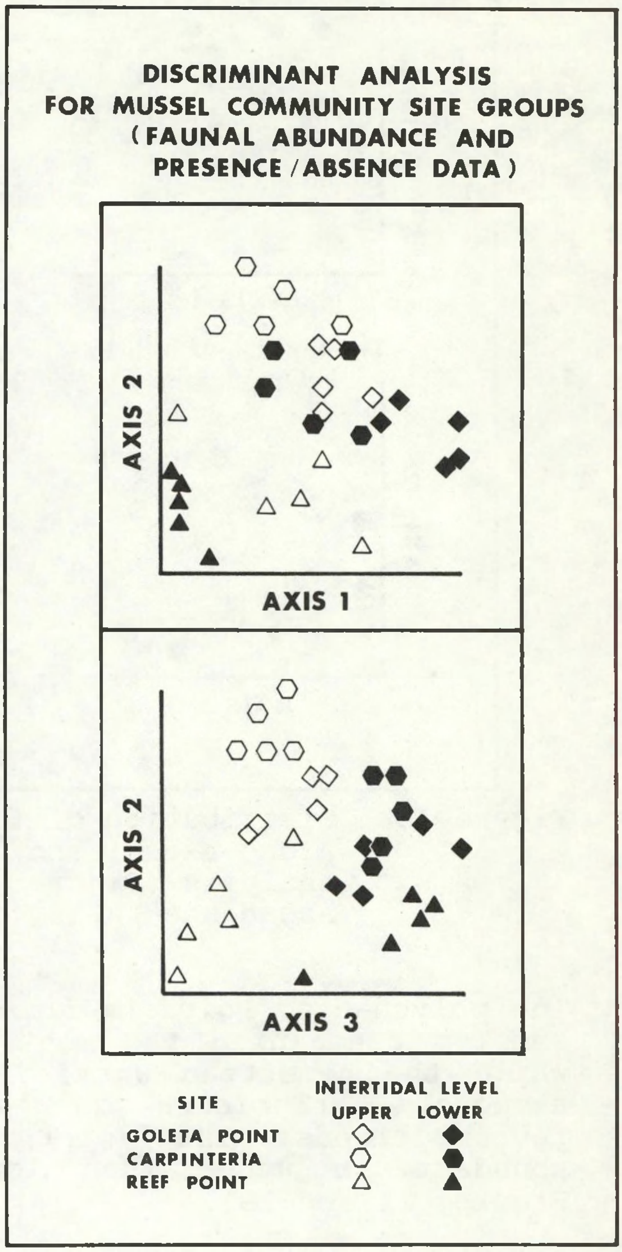

Figure 18. Discriminant analysis of mussel community samples (30) to show relationships of different site groups using abundance and presence/absence data.

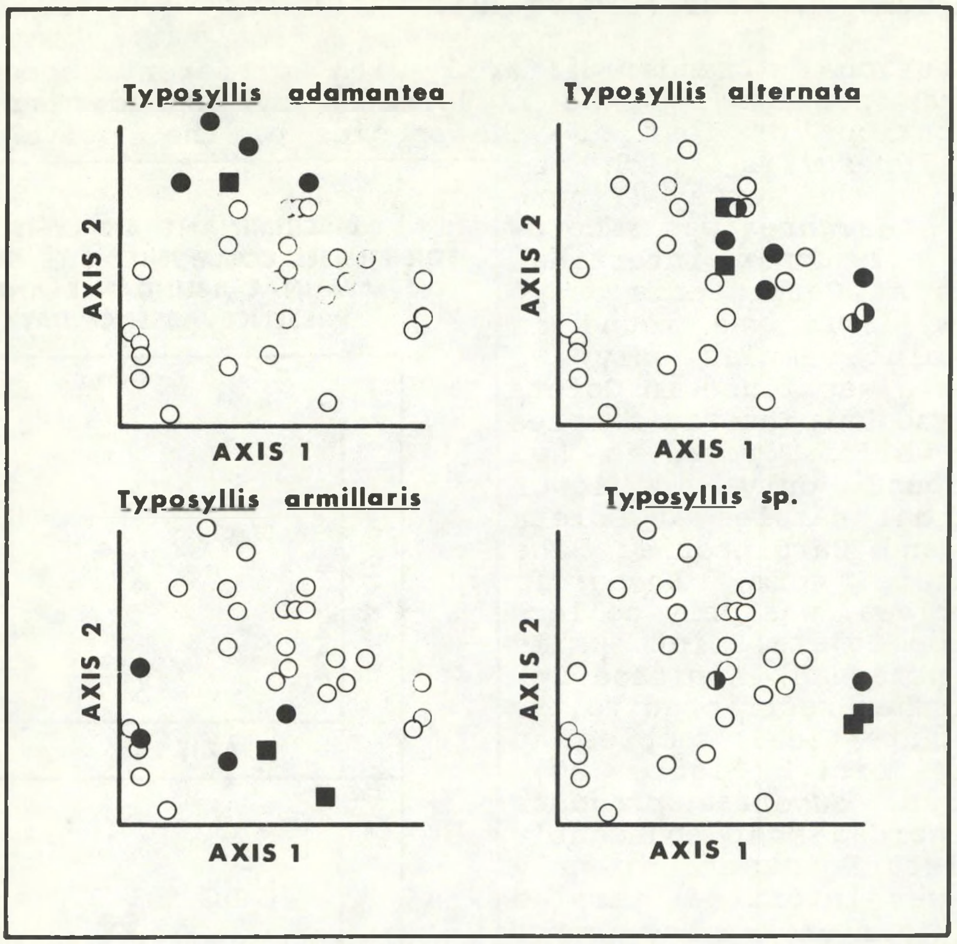

Figure 19. Distribution of four species of *Typosyllis* along axes 1 and 2 formed by discriminant analysis (Figure 18). (See Figure 16 for abundance rating code).

The polychaete, *Polydora limicola* was almost exclusively in samples containing the most tar (cf. Figures 21 and 14) while the nemertean worm, *Paranemertes peregina*, and the anemone, *Anthopleura xanthogrammica* showed almost the reverse trends. The limpet, *Collisella digitalis* was more abundant in upper than lower intertidal samples (cf. Figures 21 and 18).

Similar plots were also prepared on the basis of the principal coordinates analysis presented in Figures 16 and 17. The species showing distributional patterns that can be related to abiotic trends are listed in Tables 10 (axis 1: axis 2) and 11 (axis 2: axis 3). Fourteen species showed increasing abundance paralleling sediment parameters (e.g., amount of coarse sediment and amount of total sediment),

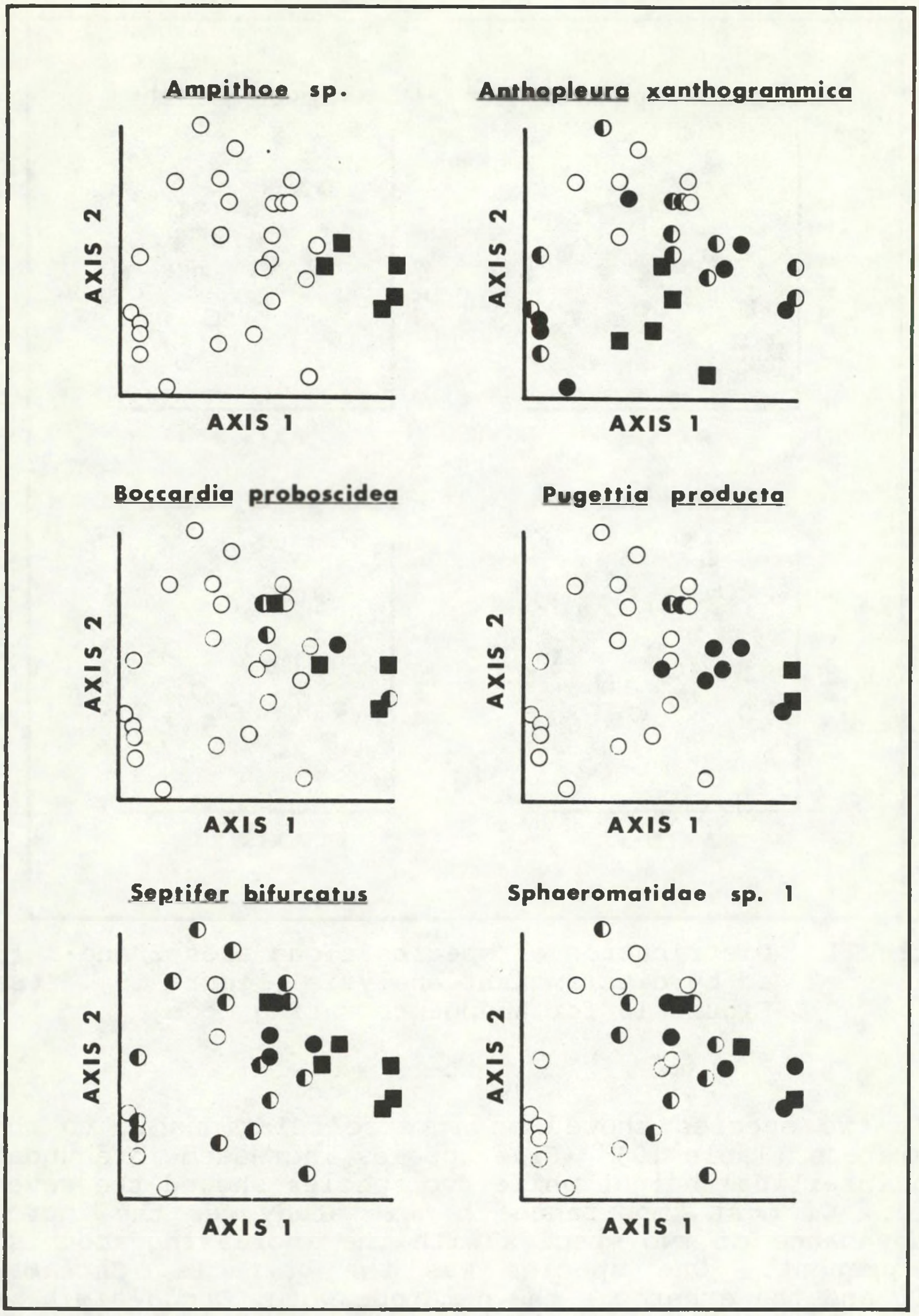

Figure 20. Distribution of species along axes 1 and 2 formed by discriminant analysis (Figure 18). (See Figure 16 for abundance rating code).

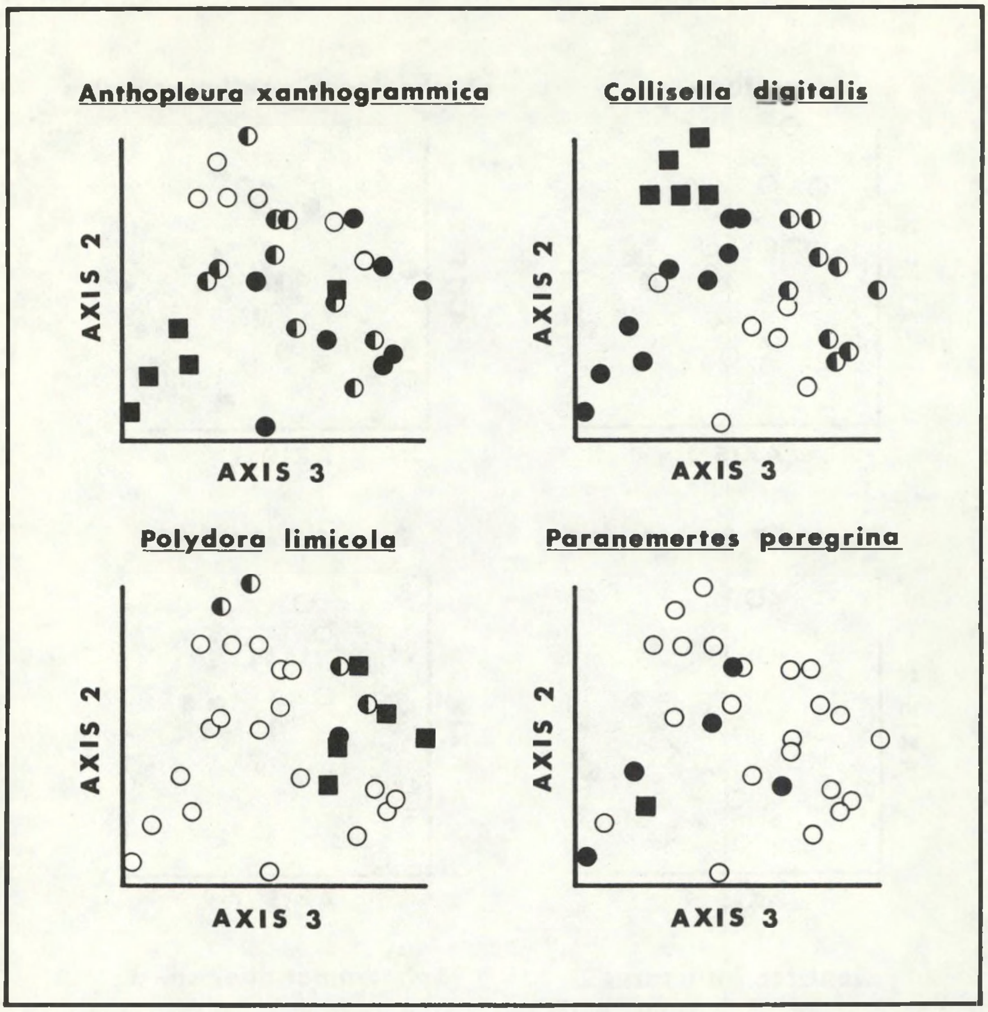

Figure 21. Distribution of species along axes 2 and 3 formed by discriminant analysis (Figure 18). (See Figure 16 for abundance rating code).

while two species showed an inverse relationship to these parameters (Table 10). Five species increased in abundance with intertidal height while two species showed the reverse trend. Of most importance in this study was the increase in abundance of two species with the increasing amounts of tar present. One species was the barnacle, *Chthamalus dalli* and the other was the nematode worm, *Oncholaimina* sp. The plots on axis 2 and axis 3 showed no additional distributional relationships to petroleum (Table 11).

Table 10
Parallel Trends Between Species Distribution and Abiotic Parameters
Shown by Principal Coordinate Analysis Axis 1: Axis 2

Species	Coarse Sediment	Total Sediment	Pore Base	Intertidal Height	Total Organic Carbon	Hydro-carbons
Amphiporus sp.	+	+	+			
Anthopleura xanthogrammica	+	+	+			
Arabella semimaculata	+	+	+			
Chrysopetalum occidentale	+	+	+			
Chthamalus dalli					+	+
Collisella digitalis				+		
Crepidula sp.	+	+	+			
Eulalia quadrioculata	+	+	+			
Hiatella arctica	+	+	+			
Hyale frequens				-		
Lasaea subviridis				+		
Littorina planaxis		-				
Littorina scutulata				+		
Lottia gigantea	-					
Membranipora tuberculata (P/A)	+					
Mytilus californianus				+		
Nereis grubei			+			
Oncholaimina sp.						+
Petrolisthes cabrilloi		+				
Phragmatopoma californica	+	+				
Pollicipes polymerus				-		
Polynoidae sp.			+			
Scrupocellaria californica (P/A)					-	
Tegula funebralis	+	+	+			
Typosyllis cf. *pulchra*		+				

(P/A) = Presence/absence data only. + = both increasing in the same direction;
- = increasing in opposite directions.

Table 11.
Parallel Trends Between Species Distribution and Abiotic Parameters Shown by Principal Coordinate Analysis
Axis 3: Axis 2

Species	Coarse Sediment	Total Sediment	Inter-tidal Height	Total Organic Carbon
Anthopleura xanthogrammica	+	+		
Chone minuta		+		
Collisella digitalis			+	
Emplectonema gracile			+	
Enoplus sp.		+		
Hyale frequens			-	
Hyale californica				+
Lasaea subvirides			+	
Littorina scutulata			+	
Mytilus californianus			+	
Pollicipes polymerus			-	
Scrupocellaria diegensis (P/A)		+		

(P/A) = Presence/absence data only.
\+ = Both increasing in the same direction;
\- = increasing in opposite directions.

The distribution of the stalked barnacle, *p. polymerus*, was also plotted to determine any relationship to tar because previous research has indicated that tar may have sublethal effects on the species [14,15] (Figure 22). *P. polymerus* was most abundant at Goleta Point where most tar was recorded and least abundant at Reef Point where the least tar was recorded.

4. <u>Analysis of Data from Upper and Lower Sampling Sites Separately</u>.

The sampling program was designed on the premise that there would be some difference between the two intertidal levels. Therefore, it was decided to reanalyze the data for the upper and lower sampling sites separately.

Classificatory analyses of the upper intertidal data using square root transformations and species maxima, indicated that the five replicates for each location clustered together (Figure 23). The biota from the Goleta Point and Carpinteria locations were more similar to each other than to the Reef Point location. While there was a large group

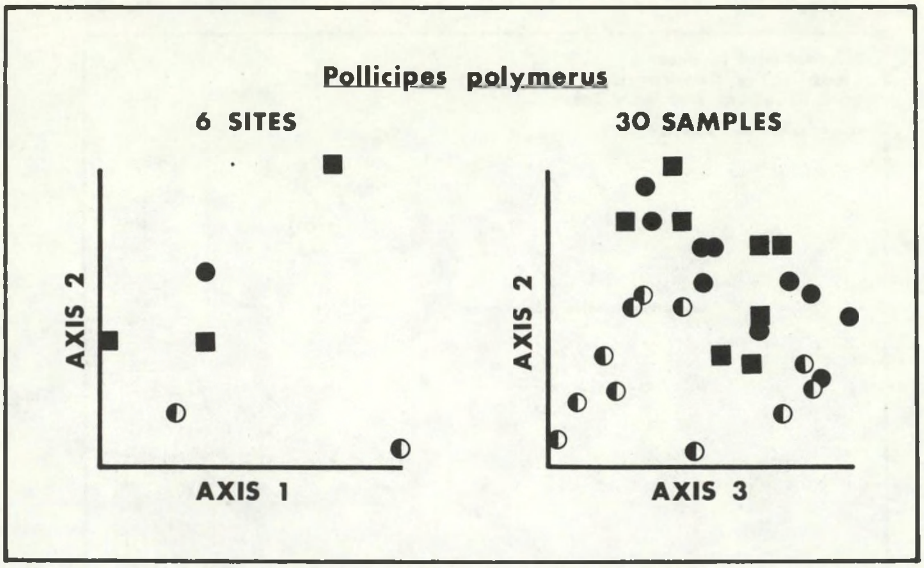

Figure 22. Distribution of the stalked barnacle, *P. polymerus* plotted as a result of principal coordinate analysis for 6 sites and discriminant analysis for 30 samples (Figure 18). (See Figure 16 for abundance rating code).

of species that tended to be recorded at all three sites (species group D), there were also groups of species characteristic of each site. Nine species composing species group B can be regarded as characteristic of the upper intertidal mussel community at Carpinteria while 16 species shown in species group C are generally characteristic of the upper intertidal community at Goleta Point. A group of 19 species (species group F) were generally characteristic of the upper intertidal mussel community at Reef Point, while the species in species group E were found at all three sites but were most abundant in the upper intertidal community at Reef Point.

These data were then analyzed by weighted discriminant analysis, assuming that the samples at each site were collected at the same effective intertidal height. Therefore, intertidal height was not included in the analysis. In this analysis, 69% of the variation was accounted for on axis 1,19.2% of the variation was accounted for on axis 2, and 5.4% of the variation was accounted for on axis 3 (Table 12). The most important parameters operating on axis 1 were dry weight of coarse sediment and tar weight (coefficient of separate determination = 32.2,18.0 respectively), the most important parameter operating on axis 2 was dry weight of sediment (coefficient of separate determination = 34.8), and the most important parameter operating on axis 3

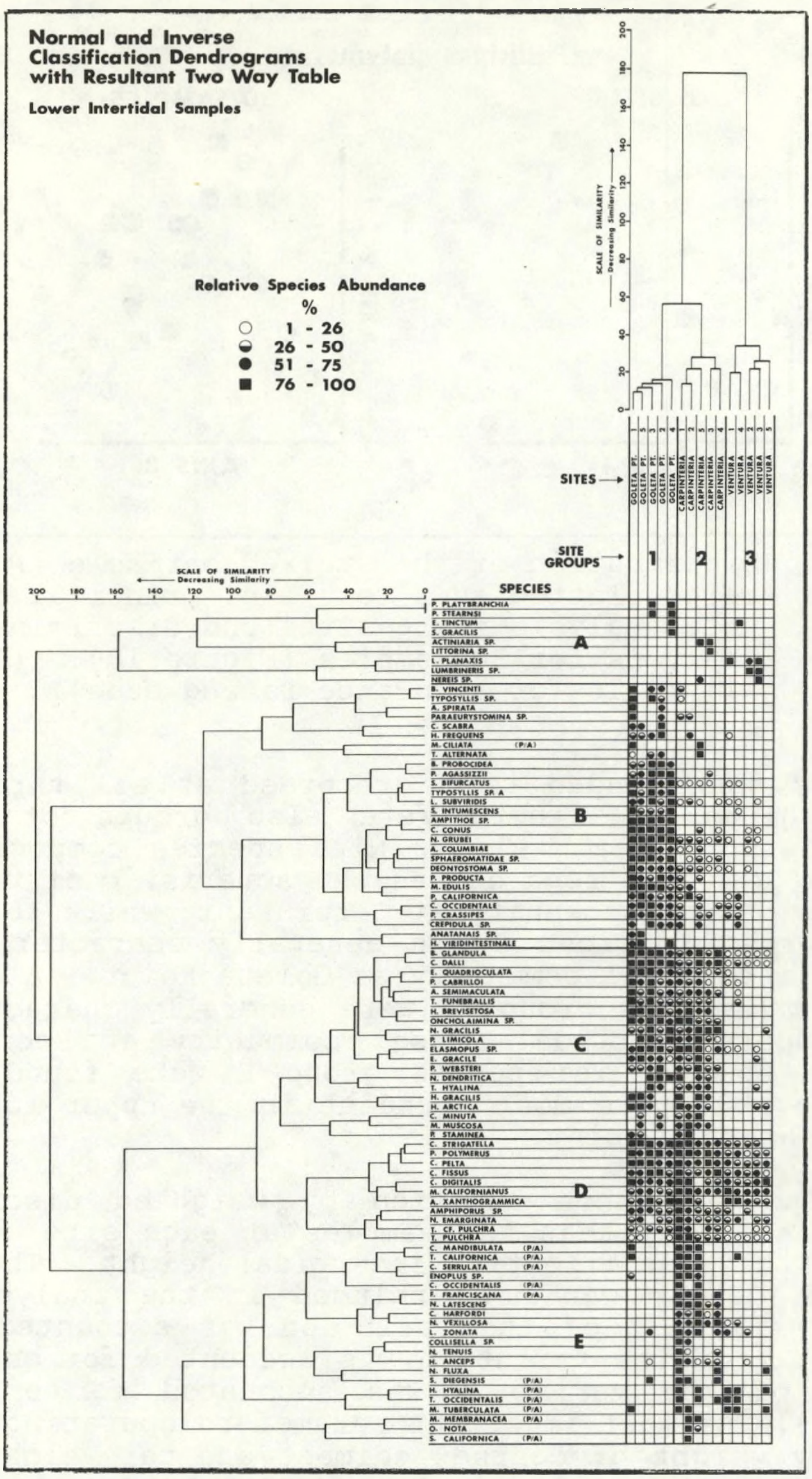

Figure 23. Classification of faunal data from upper intertidal replicate samples (15) Ventura = Reef Point).

Table 12.
Discriminant Scores for Upper Intertidal
Mussel Community Site Groups

Abiotic Attribute	Axis 1	Axis 2	Axis 4
Detritus	2.4	8.9	27.0
Coarse Sediment	32.2	7.6	5.3
Total Sediment	3.8	34.8	7.1
Kurtosis	2.6	8.4	8.2
Skewness	13.4	13.5	2.6
Mean Φ	0.5	1.9	14.3
Total Organic Carbon	5.2	10.0	1.3
Pore Base	9.5	3.2	2.6
Mussel Bed Thickness	11.0	2.1	11.2
Tar	18.0	9.1	7.2
Total Residual Volume	1.4	0.4	9.2

High values are underlined.

was dry weight of detritus (coefficient of separate determination = 27.0). In other words, the differences in biota in the upper intertidal mussel communities were correlated with the amounts of trapped and/or stranded material which included sediment, tar, and detritus.

Classificatory analysis of samples from lower intertidal areas revealed that the five replicates from each site clustered together and that the Goleta Point and Carpinteria sites had much greater biotic similarity than either of these sites had with the Reef Point site (Figure 24). The two way table showed a group of species that occurred at all three sites (species group D); a group of species almost confined to Carpinteria and Reef Point (species group C); a group of species almost exclusively found at Carpinteria (species group E), and a group of species characteristically found at Goleta Point, with some occurrences at Carpinteria and a few occurrences at Reef Point (species group B). The remaining species were relatively isolated occurrances (species group A). There was no species group that could be considered characteristic of the Reef Point site.

Analyses of the data for the lower intertidal samples by weighted discriminant analyses and again assuming that all samples approximated to the same effective intertidal

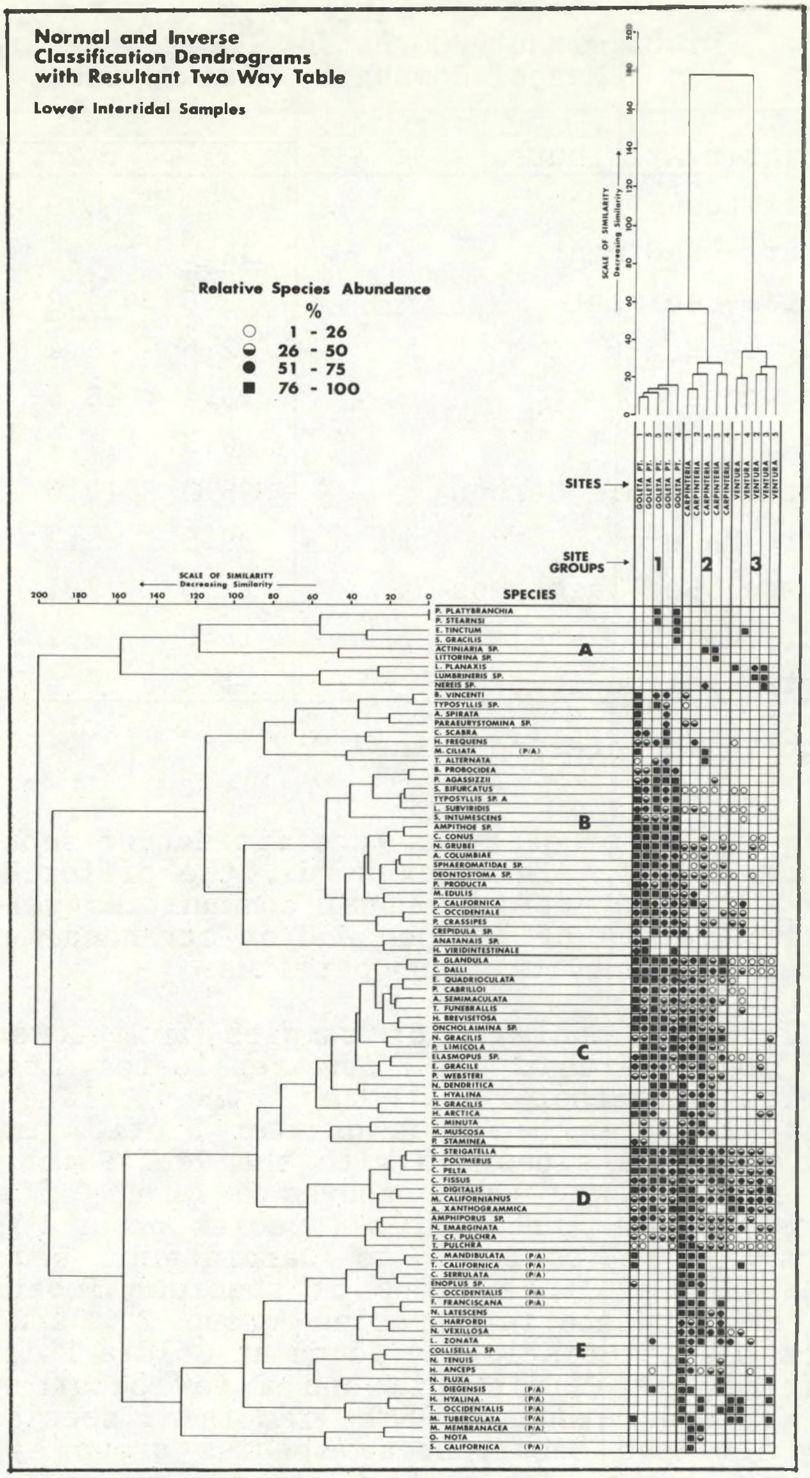

Figure 24. Classification of faunal data from lower intertidal replicate samples (15) Ventura = Reef Point.

level, were conducted. Axis 1 accounted for 95.9% of the variability, axis 2 accounted for 1.8% of the variability, and axis 3 accounted for 0.9% of the variability (Table 13). The most important parameters on axis 1 are the combined measures of sediment (size, skewness, kurtosis) and tar; on axis 2, organic carbon, sediment size, and tar are most important, while on axis 3, the weights of detritus and sediment are most important. Therefore, at the lower intertidal level, the composition of the trapped materials were the most important parameters. This is in contrast to the upper intertidal level where the weight of the trapped material appeared most important.

Table 13.
Discriminant Scores for Lower Intertidal
Mussel Community Site Groups

Abiotic Attribute	Axis 1	Axis 2	Axis 3
Detritus	4.0	3.3	39.4
Coarse Sediment	5.2	7.8	1.6
Total Sediment	5.4	1.7	24.2
Kurtosis	16.9	5.9	4.5
Skewness	23.3	12.8	5.2
Mean Φ	18.8	22.0	5.1
Total Organic Carbon	2.9	26.2	3.3
Pore Base	0.3	0.7	2.9
Mussel Bed Thickness	1.0	0.7	6.3
Tar	13.2	17.4	2.3
Total Residual Volume	9.1	1.4	5.2

High values are underlined.

Two conclusions can be drawn from this that are relevant to this study. The first is that there are differences in the mussel community and its response to abiotic parameters at different intertidal levels and the second is that tar is an important abiotic parameter at both intertidal levels.

DISCUSSION

These sampling and data analysis programs were designed to detect changes in mussel community structure which could be related to natural chronic exposure to petroleum. Three sites were chosen on the basis of location in relation to known natural oil seeps and visual inspection of the sites for recent tar deposits, to obtain a gradation in exposure. In this context, recent tar deposits are those that have not permanently hardened. This distinction is important because there are old hard deposits in the intertidal area at Goleta Point and Carpinteria. These deposits are in higher intertidal areas than the mussel communities.

Natural oil seepage has been recorded in the Santa Barbara Channel for several hundred years [60]. Studies in more recent years have plotted the location of many of the oil seep areas [61,62,63] as well as the volume of oil seeping into the ocean [64,65]. The data available indicate the natural oil seepage areas and which provide some indication of the continuity of natural oil seepage. For example, oil seepage was recorded offshore at Carpinteria in 1969 but at that time indications suggested that this was one of the few records of active oil seepage in the area [66]. However, oil seepage was observed in the high intertidal zone behind the sampling area on visits at the site in 1973 and 1974.

The problem in southern California, is not so much one of finding an oil seep area but of defining the size of area actually exposed to the seepage and of finding an area not exposed to the seepage. Data are available on the tolerance of *M. californianus* to Santa Barbara crude oil when the animals have been collected from oil seep and non-oil seep localities [12,14,67]. Data from the Coal Oil Point area show a higher tolerance of *M. californianus* to the crude oil at that site than at other sites including East Cabrillo which is less than 20 miles away from the oil seep areas at Coal Oil Point - Goleta Point. This suggests that chronic exposure impacts on mussel communities may only be measured at sites in close proximity to oil seepage.

The Goleta Point site has the largest volume of soft tar covering the rock platforms of the three areas studied. It is also the site closest and just to the east of the area of the Santa Barbara Channel with the greatest natural seep activity - Coal Oil Point. Coal Oil Point itself was not sampled because the mussel beds are not extensive and have already been, and are being very heavily sampled in other surveys. The mussel beds at Coal Oil Point are also not distributed over a wide enough intertidal range, probably due to substrate limitations, to collect samples from two different intertidal heights.

The Carpinteria site is in an area with some soft tar on rock platforms and an area where intermittent seepage occurs. Old tar mounds exist in some intertidal and subtidal areas indicating a higher level of oil seepage in recent geological times. However seepage is only actually reported intermittently at Carpinteria while it is visible in nearshore waters in the Coal Oil Point - Goleta Point area most of the time.

There are no adjacent areas of natural oil seepage to the Reef Point site and only small isolated pieces of tar have been observed in the area.

In the actual sampling program, all tar collected in the samples was weighed. Four criteria have been discussed which were used to measure the graded exposure to natural oil seepage at these sites: presence of soft tar in the intertidal area; relationship to known areas of active oil seepage; relative activity of these natural oil seep areas; weight of tar in the samples (Table 14).

Table 14.
Relative Natural Exposure to Petroleum

Locality	Proximity to Active Natural Seepage	Amount Active Natural Seepage	Visible Sticky Tar Intertidally	Tar in Sample	Tar in Tissues
Goleta Point	+++	+++	+++	+++	+++
Carpinteria	++	++	++	++	++
Reef Point	+	+	+	+	+

+++ = greatest; + = least.

However, the community will also be exposed to the less visible components of petroleum which are dissolved or dispersed in the water column. Since these values doubtlessly vary, a single water sample analysis may not truly reflect the exposure. Therefore, chemical analyses of mussel tissues were conducted bearing in mind that the mussels may selectively accumulate and depurate different petroleum components.

All of these five measures now provide an indication of exposure to petroleum over a short period of time. The actual length of time is not known accurately but I would suggest several weeks. This is on the basis that the tar recorded intertidally was stranded on the substrate and would only be removed by an increase in wave energy. Such an increase was not been recorded at these sites for several weeks prior to sampling.

The tissue concentrations, which are the result of accumulation and depuration of these compounds over the life of the mussels, are probably indicative of exposure levels for the period for several weeks before sampling. This estimate is based on reports that the half-life for the aromatic compounds to be released from naturally contaminated mussels when the mussels are transferred to clean water is four to five weeks [18]. Faster release rates have been recorded in mussels in laboratory experiments after short term high level exposure [68]. In summary, the data show the relative rate of natural exposure to petroleum currently found at these sites and provide more accurate data on the actual exposure rates for the month preceeding sampling.

Data analyses have indicated a change in the distribution and abundance of species in the mussel community which can be correlated with natural exposure to petroleum. Correlations do not prove a cause and effect relationship. However these intense data analyses suggest that this is not a chance occurrence and should be subject to closer scrutiny.

One factor that must be remembered is that the animals in the community are responding to all the biotic and abiotic parameters to which they are subjected. This response in many instances may simply be 'no response' because the parameter is not limiting or stressing the animal. However, it is extremely unlikely that the community differences between sites are in response to any one factor. This is well demonstrated by examination of the discriminant and principal coordinate analyses.

Let us consider this further. Examination of the grain size characteristics indicates that the lower intertidal Reef Point site has coarser sediment in the mussel bed than the other five sites (Figure 5). In addition, both Goleta Point and Carpinteria mussel beds and the upper intertidal mussel bed at Reef Point contain a small precentage of fine sediments not found at the lower intertidal mussel bed site at Reef Point. In general, numbers of species increase with increasing fineness of sediments in unstable substrate infaunal situations (e.g., sandy beaches and marshes). This generalization certainly does not apply to the invertebrate biota of the mussel community as a whole. This is not so surprising because many species in the mussel community are epifaunal species and not sediment infaunal species.

Polychaete species also usually increase numerically in finer sediments and it has been suggested that the fine sediments as shown by the tail on the sediment curves may provide a habitat for more polychaetes. However, while this trend may apply to individual species it does not appear to apply to polychaetes as a whole in this case.

However, the size of the sediment was important in only the lower intertidal samples and not the upper intertidal samples as determined by discriminant analysis. Analysis of total number of faunal species indicates that 85,50 and 48 species were recorded at Goleta Point, Carpinteria, and Reef Point respectively and that 27,27 and 18 polychaete species were recorded respectively at these three lower intertidal locations. This closely parallels the prediction that more species will occur at Goleta Point and Carpinteria where there is a larger component of fine sediments than at Reef Point. Examination of these species lists reveals that most of the polychaetes are indeed infaunal species as are some of the other species found at the lower intertidal level.

The analyses indicated consistent intertidal height relationships at each site. This was also reflected in the analyses of individual species distributions, while overall community composition and response correlations were suggested by separate analysis of data from upper and lower intertidal levels.

If chronic exposure to petroleum was having a significant negative impact on the *M. californianus* community, one would predict either decreasing numbers of species or decreasing numbers of animals with increasing chronic exposure to petroleum. Other possible impacts would include a change in relative species composition. For example, experiments on larval settlement in *C. fissus* have shown increased larval settlement on areas covered with dry black tar [19]. In fact, there was a parallel increase in abundance in the closely related barnacle *C. dalli*, with increasing chronic exposure to petroleum in the present survey. There was a similar parallel increase in the nematode species identified as *Oncholaimina* with increasing chronic exposure to petroleum.

No reverse trends were observed. That is, while some species were confined to specific sampling sites, the data analyses did not indicate that absence from Goleta Point was due to chronic exposure to petroleum. The overall pattern is a group of species found at all sites but least abundant at the lower intertidal site at Reef Point and additional groups of site characteristic species at each site except the lower intertidal site at Reef Point.

Just over 100 invertebrate species were recorded at each location (106,102,104) (Appendices 1,2,3). In contrast about 20% fewer algal species were recorded at Reef Point than at Goleta Point and Carpinteria. The trend of more algal species at the oil seep than the non-oil seep sites parallels that recorded in surveys of the entire intertidal area of a number of sites after the Santa Barbara oil spill [69].

Other similar studies have been and are being conducted on mussel communities in southern California [6,52,70,71]. Three of these studies involve sites chronically exposed to natural oil seepage. In 1975-1976, Coal Oil Point and San Miguel Island were studied as part of the Bureau of Land Management (B.L.M) Baseline Study [52]. Presence of tar in the samples was an important parameter in two of the four discriminant analyses but it was difficult to interpret. The sites in the BLM survey were generally at one intertidal height and were not specifically chosen to reduce variation in parameters other than exposure to petroleum, as were the sites in the present study.

Goleta Point was surveyed during the 1976-1977 phase of the BLM baseline study [70]. These data from Goleta Point are generally comparable to those recorded in the present study. The between-site analyses again indicates that tar is an important parameter but the relationship tends to be to a lower species diversity than that recorded at the other sites. The suggestion is made that some invertebrate species are unable to live at Goleta Point and possibly Government Point, another oil seep area, because of the presence of petroleum [70]. However, neither Carpinteria nor Reef Point were included in the 1976-1977 baseline surveys and these have similar or even lower species diversities than Coal Oil Point depending how the data are analyzed. In other words, in all surveys tar is an important parameter but in some instances it appears related to a low diversity and in other instances it does not. While there is a small group of species recorded only at Reef Point and not at the oil seep sites, an even larger number of species are recorded at the oil seep sites and not at the Reef Point site.

Data from the present survey and the BLM surveys were examined for so-called indicator or opportunistic species in relation to chronic exposure to petroleum. No invertebrate species could be classified in either of these categories.

In summary, all analyses indicate that natural chronic exposure to petroleum does influence this community. However, in the light of this present study it does not appear that this can be interpreted in terms of loss of large numbers of species from areas of chronic exposure, nor in terms of differential impact on numerous individual species in the form of decreased or increased abundances paralleling exposure to petroleum. Such a change was recorded in only two species.

Distributional changes that were related to chronic exposure to petroleum were not recorded in the stalked barnacle, *P. polymerus*. Particular attention was given this species because of sublethal effects of exposure to petroleum on the brooding rate.

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Appendix 1

Fauna Collected in Mussel Community Samples Goleta Point 1976

	Upper Intertidal Samples					Lower Intertidal Samples				
	1A	2A	3A	4A	5A	1B	2B	3B	4B	5B
PHYLUM CNIDARIA										
Class Anthozoa										
Actiniaria, unid.										
Anthopleura sp.										
Anthopleura xanthogrammica	7	2	7	2	1	8	5	33	25	20
PHYLUM PLATYHELMINTHES										
Leptoplanidae	8	3	7	1	3	18	9	50	5	39
Notoplana acticola						1				
PHYLUM NEMERTEA										
Class Anopla										
Lineus sp.						3				1
Class Enopla										
Amphiporus sp.			7	3	12	4	2	4	2	5
Emplectonema gracile	34	50	61	35	30	12	18	23	1	46
Nemertopsis gracilis	3	4	5			1	1	8	8	2
Paranemertes peregrina			1		3			2		
PHYLUM SIPUNCULA										
Phascolosoma agassizii	5	1	11	1	2	1	5	4	3	2
PHYLUM NEMATODA										
Deontostoma sp.		10	32	10	5	344	96	129	127	138
Enoplus sp.						1				
Oncholaimina sp.	179	315	277	100	158	207	267	306	146	167
Paraeurystomina sp.					4	10	4			

Appendix 1

Fauna Collected in Mussel Community Samples Goleta Point 1976

	Upper Intertidal Samples					Lower Intertidal Samples				
PHYLUM ANNELIDA	1A	2A	3A	4A	5A	1B	2B	3B	4B	5B
Class Oligochaeta										
Oligochaeta, unid.		7	42	21	129	132	17	43	138	24
PHYLUM ANNELIDA										
Class Polychaeta										
Arabella semimaculata		3	2	1	1	20	8	15	11	2
Arabella sp.										
Arabellidae	1									
Armandia bioculata										
Boccardia sp.		2	2							
Boccardia proboscidea	35	2	3			5	50	42	27	11
Branchiomaldane vincenti			1			13	6	5		
Brania sp.									1	
Chaetozone sp.								1		
Chone minuta							1			1
Chrysopetalum occidentale						4	3	8	4	5
Chrysopetalum sp.		1								
Cirriformia sp.		1								
Eulalia bilineata										
Eulalia quadrioculata			1			38	15	40	17	36
Halosydna brevisetosa	3					4	3	3	1	3
Hemipodus borealis										
Hydroides gracilis	1		1			2		1		2
Lumbrineridae	1			1		1				
Lumbrineris sp.		1								
Lumbrineris zonata		11	19	12	15			2		

Appendix 1

Fauna Collected in Mussel Community Samples Goleta Point 1976

PHYLUM ANNELIDA	Upper Intertidal Samples					Lower Intertidal Samples				
	1A	2A	3A	4A	5A	1B	2B	3B	4B	5B
Class Polychaeta										
Naineris dendritica		3	4	2	3		5	4	6	
Nereidae	1									
Nereis grubei	6	5	8	6	6	14	14	15	19	19
Nereis latescens										
Nereis sp.					1					
Nereis vexillosa										
Notomastus tenuis										
Orbiniidae						1				
Paraonella platybranchia								2	2	
Perinereis monterea										
Phragmatopoma californica			1			11	2	14	7	23
Phyllodocidae				1						
Polydora limicola							4	30	33	35
Polydora websteri						5	30	10		6
Polydora cf. *websteri*										
Polynoidae sp.								1		1
Potamilla sp.										
Rhynchospio glutaea										
Sabellidae										
Spionidae										
Spirobranchus spinosus										
Syllidae										
Syllis gracilis									25	6
Tharyx sp.										
Typosyllis aciculata	5	19	39	27	56					
Typosyllis adamanteus										
Typosyllis alternata	2	15	53	12	45	1	9	2		

Appendix 1

Fauna Collected in Mussel Community Samples Goleta Point 1976

	Upper Intertidal Samples					Lower Intertidal Samples				
	1A	2A	3A	4A	5A	1B	2B	3B	4B	5B
PHYLUM ANNELIDA										
Class Polychaeta (Cont'd.)										
Typosyllis armillaris										
Typosyllis sp. A						44	30	62	51	14
Typosyllis hyalina				1			2	4		
Typosyllis pulchra	6	8	6	5	10	23			11	16
Typosyllis cf. *pulchra*		3	3	3	1	4	4	8	3	1
Typosyllis sp.						22	3	16		
Typosyllis variegata										
PHYLUM MOLLUSCA										
Class Gastropoda										
Acanthina spirata						2	1			
Barleeia californica						1				
Collisella conus	9	3	1		2	14	16	16	12	19
Collisella digitalis	19	16	11	11		6	2	3	2	2
Collisella limatula	1					3		1		
Collisella pelta	24	10	12	12	5	42	22	40	21	28
Collisella scabra		2	7	6		1	3			1
Collisella sp.										
Collisella strigatella	12	9	16	6	2	15	12	18	16	22
Crepidula sp.						1	1	3	1	
Epitonium tinctum								1	1	
Iselica ovoidea										
Littorina planaxis	7		3							
Littorina scutulata		8								
Littorina sp.										
Lottia gigantea	1			1						

Appendix 1

Fauna Collected in Mussel Community Samples Goleta Point 1976

	Upper Intertidal Samples					Lower Intertidal Samples				
	1A	2A	3A	4A	5A	1B	2B	3B	4B	5B
PHYLUM MOLLUSCA										
Class Gastropoda (Cont'd.)										
Mitrella aurantiaca										
Nucella emarginata						5	4		6	11
Ocenebra circumtexta										1
Odostomia nota										
Tegula funebralis						3	1	5	1	1
Class Bivalvia										
Adula diegensis										
Branchidontes adamsianus					1			1		
Glans carpenteri										
Hiatella arctica	2		1			7		2		5
Kellia laperousii										
Lasaea subviridis	830	7952	12736	9168	10832	4400	1349	8608	6000	3143
Modiolus capax										
Mytilus californianus	75	119	98	80	123	58	41	68	43	68
Mytilus edulis	1					5	4	5	1	7
Protothaca staminea		1				2				1
Septifer bifurcatus	115	165	189	132	163	332	191	375	351	207
Veneridae										
Class Polyplacophora										
Cyanoplax hartwegii	2	4	2	6	6					

Appendix 1

Fauna Collected in Mussel Community Samples Goleta Point 1976

	Upper Intertidal Samples					Lower Intertidal Samples				
	1A	2A	3A	4A	5A	1B	2B	3B	4B	5B
PHYLUM MOLLUSCA										
Class Polyplacophora (Cont'd.)										
Mopalia muscosa	1		4	6	2		1			1
Mopalia porifera	1									
Mopalia sp.		3								
Nuttalina fluxa	1	1								
PHYLUM ARTHROPODA										
Class Crustacea (Order Cirripedia)										
Balanus glandula	279	149	114	73	30	534	408	587	239	380
Balanus tintinnabulum californicus									1	
Chthamalus dalli	1661	1569	1515	895	345	1926	1291	1584	1350	1704
Chthamalus fissus	164	91	40	27	4	33	81	51	20	28
Pollicipes polymerus	305	200	94	29	11	493	672	474	222	212
Tetraclita squamosa rubescens										
Class Crustacea (Order Isopoda)										
Cirolana harfordi										
Dynamenella dianae			1							
Excorallana kathaye						1				
Gnorimosphaeroma sp. No. 1										
Jaeropsis dubia										
Sphaeromatidae sp. No. 1	42	11	11	3		29	10	17	17	20
Class Crustacea (Order Amphipoda)										
Ampithoe sp.						14	15	14	11	14
Aoroides columbiae	19	9	3	2	1	60	30	53	34	84

Appendix 1

Fauna Collected in Mussel Community Samples Goleta Point 1976

	Upper Intertidal Samples					Lower Intertidal Samples				
	1A	2A	3A	4A	5A	1B	2B	3B	4B	5B
PHYLUM ARTHROPODA										
Class Crustacea (Order Amphipoda)										
Elasmopus rapax										3
Elasmopus sp.	225	141	66	23	17	52	95	115	18	162
Hyale anceps	130	84	157	55	33			1		
Hyale frequens						4	18	8		4
Hyale californica	26	1								2
Hyale plumulosa										
Synchelidium sp.										1
Class Crustacea (Order Tanaidacea)										
Anatanais sp.						2				2
Synapseudes intumescens						48	3	8	30	6
Tanaidacea juvenile	1								3	
Class Crustacea (Order Decapoda)										
Pachycheles rudis										1
Pachygrapsus crassipes	8	11	4	6	2	10	4	12	6	6
Petrolisthes cabrilloi	3	2	1	2		80	24	106	54	40
Pugettia producta	2		1	3		11	13	2	4	4
Class Pycnogonida										
Ammothella tuberculata										
Halosoma viridintestinale	1					1			2	2
Pycnogonum stearnsi								1	1	
Class Insecta										
Diptera, unid.										

Appendix 1

Fauna Collected in Mussel Community Samples Goleta Point 1976

	Upper Intertidal Samples					Lower Intertidal Samples				
	1A	2A	3A	4A	5A	1B	2B	3B	4B	5B
PHYLUM ECHINODERMATA										
Class Asteroidea										
Pisaster ochraceus										
Pisaster sp.										
Class Echinoidea										
Strongylocentrotus purpuratus										
PHYLUM ECTOPROCTA										
Cellaria mandibulata						+				
Crisia serrulata										
Crisulipora occidentalis										
Cryptosula pallasiana										
Filicrisia franciscana										
Hippothoa hyalina		+			+					
Membranipora membranacea										
Membranipora tuberculata				+		+				
Microporella californica										
Microporella ciliata						+				
Rhynchozoon rostratum										
Scrupocellaria californica										
Scrupocellaria diegensis								+		
Synnotum aegyptiacum										
Thalamoporella californica			+	+	+	+				
Tricellaria occidentalis										

+ = present

Appendix 2

Fauna Collected in Mussel Community Samples Carpinteria July 1976

	Upper Intertidal Samples					Lower Intertidal Samples				
	1A	2A	3A	4A	5A	1B	2B	3B	4B	5B
PHYLUM CNIDARIA										
Class Anthozoa										
Actiniaria, unid.								2		2
Anthopleura sp.									5	
Anthopleura xanthogrammica		1				39	23			8
PHYLUM PLATYHELMINTHES										
Leptoplanidae		2	1	3		22	21		1	7
Notoplana acticola		1								
PHYLUM NEMERTEA										
Class Anopla										
Lineus sp.										
Class Enopla										
Amphiporus sp.	1					12	5	3	1	1
Emplectonema gracile	12	20	25	20	13	13	10	7		34
Nemertopsis gracilis	2	29	9	1		1	3	5	5	5
Paranemertes peregrina										
PHYLUM SIPUNCULA										
Phascolosoma agassizii								1		
PHYLUM NEMATODA										
Deontostoma sp.	4	119	50	173	147	48	29	3	5	28
Enoplus sp.						7	6			
Oncholaimina sp.	10	39	10	43	14	323	271	41	63	72
Paraeurystomina sp.						1	2			

Appendix 2

Fauna Collected in Mussel Community Samples Carpinteria July 1976

	Upper Intertidal Samples					Lower Intertidal Samples				
	1A	2A	3A	4A	5A	1B	2B	3B	4B	5B
PHYLUM ANNELIDA										
Class Oligochaeta										
Oligochaeta, unid.		9		97	4	868	305	4	20	14
PHYLUM ANNELIDA										
Class Polychaeta										
Arabella semimaculata						2	6	6	4	6
Arabella sp.										
Arabellidae					1			1		
Armandia bioculata										
Boccardia sp.										
Boccardia proboscidea										
Branchiomaldane vincenti						1				
Brania sp.										
Chaetozone sp.										
Chone minuta						1	2			6
Chrysopetalum occidentale						2			2	1
Chrysopetalum sp.										
Cirriformia sp.										
Eulalia bilineata							1			
Eulalia quadrioculata			1			10	11	1	3	7
Halosydna brevisetosa						2	4	2		2
Hemipodus borealis										
Hydroides gracilis		1				3		1		3
Lumbrineridae										
Lumbrineris sp.										
Lumbrineris zonata						4	2		3	6

Appendix 2

Fauna Collected in Mussel Community Samples Carpinteria July 1976

	Upper Intertidal Samples					Lower Intertidal Samples				
	1A	2A	3A	4A	5A	1B	2B	3B	4B	5B
PHYLUM ANNELIDA										
Class Polychaeta (Cont'd.)										
Naineris dendritica						5		1		3
Nereidae							1	1		
Nereis grubei	3	2	2	7	2	2	2	1	3	4
Nereis latescens						15	17	2	6	11
Nereis sp.										1
Nereis vexillosa	7	6	7	7	6	12	8	6	13	23
Notomastus tenuis						31	1		2	
Orbiniidae										
Paraonella platybranchia										
Perinereis monterea										
Phragmatopoma californica						2	13			4
Phyllodocidae										
Polydora limicola		2		1		9	16	3	2	21
Polydora websteri	1	9	2	1		17	6	7	6	39
Polydora cf. *websteri*										
Polynoidae										
Potamilla sp.										
Rhynchospio glutaea										
Sabellidae										
Spionidae				1						
Spirobranchus spinosus										
Syllidae	2									
Syllis gracilis										
Tharyx sp.										8
Typosyllis aciculata										
Typosyllis adamantea	6	2	2	2						
Typosyllis alternata										19
Typosyllis armillaris										

Appendix 2

Fauna Collected in Mussel Community Samples Carpinteria July 1976

	Upper Intertidal Samples					Lower Intertidal Samples				
	1A	2A	3A	4A	5A	1B	2B	3B	4B	5B
PHYLUM ANNELIDA										
Class Polychaeta (Cont'd.)										
Typosyllis sp. A			2							
Typosyllis hyalina						1	2	2		2
Typosyllis pulchra	2	24	8	15	9	584	395	57	103	109
Typosyllis cf. *pulchra*	4		1	3		38	13	15	6	
Typosyllis sp.						1				
Typosyllis variegata		2	6			1				
PHYLUM MOLLUSCA										
Class Gastropoda										
Acanthina spirata										
Barleeia californica										
Collisella conus		2	1		2				1	3
Collisella digitalis	46	49	63	31	46	7	7	1	1	
Collisella limatula										
Collisella pelta	12	26	23	20	17	25	22	26	13	23
Collisella scabra										
Collisella sp.					15	15	5			
Collisella strigatella	23	35	23	14	13	21	27	12	13	11
Crepidula sp.						1				1
Epitonium tinctum										
Iselica ovoidea								3		
Littorina planaxis		3	14	12	5					
Littorina scutulata				1						
Littorina sp.								2		
Lottia gigantea	2		1							

Appendix 2

Fauna Collected in Mussel Community Samples Carpinteria July 1976

	Upper Intertidal Samples					Lower Intertidal Samples				
	1A	2A	3A	4A	5A	1B	2B	3B	4B	5B
PHYLUM MOLLUSCA										
Class Gastropoda (Cont'd.)										
Mitrella aurantiaca										2
Nucella emarginata	6	12	4	11	11	28	10	3	5	2
Ocenebra circumtexta										
Odostomia nota							19			2
Tegula funebralis						1	1	1		1
Class Bivalvia										
Adula diegensis			2							
Brachidontes adamsianus		1		1						
Glans carpenteri										1
Hiatella arctica		1			1	4	2	1		2
Kellia laperousii										
Lasaea subviridis	596	40	1087	761	1131	42	1421		1	9
Modiolus capax										1
Mytilus californianus	216	148	195	142	591	205	235	96	120	62
Mytilus edulis		4	1	4	2	1	2			
Protothaca staminea						2	4			
Septifer bifurcatus		1	3	1	2	6	13	8		3
Veneridae										8
Class Polyplacophora										
Cyanoplax hartwegii										1
Mopalia muscosa		2	3			1	3	1		1

Appendix 2

Fauna Collected in Mussel Community Samples Carpinteria July 1976

	Upper Intertidal Samples					Lower Intertidal Samples				
	1A	2A	3A	4A	5A	1B	2B	3B	4B	5B
PHYLUM MOLLUSCA										
Class Polyplacophora (Cont'd.)										
Mopalia porifera										
Mopalia sp.										
Nuttalina fluxa	1					1			1	
PHYLUM ARTHROPODA										
Class Crustacea (Order Cirripedia)										
Balanus glandula	142	287	155	95	132	128	181	139	622	557
Balanus tintinnabulum californicus										
Chthamalus dalli	826	1229	969	395	666	413	457	562	1295	1607
Chthamalus fissus	17	131	47	10	17	51	19	24	88	17
Pollicipes polymerus	280	423	382	197	325	438	596	388	225	234
Tetraclita squamosa rubescens									1	
Class Crustacea (Order Isopoda)										
Cirolana harfordi		2			1	11	6	1	17	37
Dynamenella dianae										
Excorallana kathyae										
Gnorimosphaeroma sp. No. 1										
Jaeropsis dubia										1
Sphaeromatidae sp. No. 1		1					1	1	2	2
Class Crustacea (Order Amphipoda)										
Ampithoe sp.										
Aoroides columbiae						1	1			10

Appendix 2

Fauna Collected in Mussel Community Samples Carpinteria July 1976

	Upper Intertidal Samples					Lower Intertidal Samples				
	1A	2A	3A	4A	5A	1B	2B	3B	4B	5B
PHYLUM ARTHROPODA										
Class Crustacea (Order Amphipoda)										
Elasmopus rapax										
Elasmopus sp.						97	125	7	80	104
Hyale anceps	13	44		43	17	243	64	20	44	7
Hyale frequens							9			
Hyale californica	1									
Hyale plumulosa	10									
Synchelidium sp.										
Class Crustacea (Order Tanaidacea)										
Anatanais sp.										
Synapseudes intumescens										
Tanaidacea juvenile										
Class Crustacea (Order Decapoda)										
Pachycheles rudis										
Pachygrapsus crassipes	1	1	2		1	1		1		1
Petrolisthes cabrilloi						45	25	6		50
Pugettia producta						3				2
Class Pycnogonida										
Ammothella tuberculata										
Halosoma viridintestinale										
Pycnogonum stearnsi										
Class Insecta										
Diptera, unid.									1	

Appendix 2

Fauna Collected in Mussel Community Samples Carpinteria July 1976

	Upper Intertidal Samples					Lower Intertidal Samples				
	1A	2A	3A	4A	5A	1B	2B	3B	4B	5B
PHYLUM ECHINODERMATA										
Class Asteroidea										
Pisaster ochraceus										
Pisaster sp.										
Class Echinoidea										
Strongylocentrotus purpuratus										
PHYLUM ECTOPROCTA										
Cellaria mandibulata						+	+			+
Crisia serrulata						+	+			+
Crisulipora occidentalis				+		+				+
Cryptosula pallasiana						+				
Filicrisia franciscana				+		+	+		+	+
Hippothoa hyalina		+		+		+				+
Membranipora membranacea							+			+
Membranipora tuberculata						+	+			
Microporella californica										
Microporella ciliata										+
Rhynchozoon rostratum										+
Scrupocellaria californica							+			
Scrupocellaria diegensis						+	+		+	
Synnotum aegyptiacum						+				
Thalamoporella californica		+				+	+			+
Tricellaria occidentalis						+			+	+

+ = Present

Appendix 3

Fauna Collected in Mussel Community Samples Reef Point August 1976

	Upper Intertidal Samples					Lower Intertidal Samples				
	1A	2A	3A	4A	5A	1B	2B	3B	4B	5B
PHYLUM CNIDARIA										
Class Anthozoa										
Actiniaria, unid.										
Anthopleura sp.										
Anthopleura xanthogrammica	15	66	41	61	76	30	10	8	33	6
PHYLUM PLATYHELMINTHES										
Leptoplanidae	10	18	25	11	22					
Notoplana acticola										
PHYLUM NEMERTEA										
Class Anopla										
Lineus sp.			1	4						
Class Enopla										
Amphiporus sp.	13	3	15	12	13	1	1			
Emplectonema gracile	3	7	33	40	61			6		
Nemertopsis gracilis			1	18	16					1
Paranemertes peregrina			6	1	2					
PHYLUM SIPUNCULA										
Phascolosoma agassizii	4	10	3	3	11					
PHYLUM NEMATODA										
Deontostoma sp.	60	27	58	19	87	3	1			
Enoplus sp.	4	6	8	5	5					
Oncholaimina sp.	51	43	57	64	95					
Paraeurystomina sp.			1							

Appendix 3

Fauna Collected in Mussel Community Samples Reef Point August 1976

	Upper Intertidal Samples					Lower Intertidal Samples				
	1A	2A	3A	4A	5A	1B	2B	3B	4B	5B
PHYLUM ANNELIDA										
Class Oligochaeta										
Oligochaeta, unid.	15		44	7	53					
PHYLUM ANNELIDA										
Class Polychaeta										
Arabella semimaculata	8	8	7	7	12				1	
Arabella sp.					1					
Arabellidae						1				
Armandia bioculata				3						
Boccardia sp.										
Boccardia proboscidea										
Branchiomaldane vincenti										
Brania sp.										
Chaetozone sp.										
Chone minuta	3									
Chrysopetalum occidentale	1	1	1	3	7	1			1	
Chrysopetalum sp.										
Cirriformia sp.		1								
Eulalia bilineata										
Eulalia quadrioculata	4	3	8	11	12	1				
Halosydna brevisetosa										
Hemipodus borealis	1	4			1					
Hydroides gracilis		1	3	2	1					
Lumbrineridae		1			1					1
Lumbrineris sp.							2	2		
Lumbrineris zonata	1	6	3	7	11	3	1			

Appendix 3

Fauna Collected in Mussel Community Samples Reef Point August 1976

	Upper Intertidal Samples					Lower Intertidal Samples				
	1A	2A	3A	4A	5A	1B	2B	3B	4B	5B
PHYLUM ANNELIDA										
Class Polychaeta (Cont'd.)										
Naineris dendritica		3								
Nereidae										
Nereis grubei	52	44	50	37	60	1	2	1		
Nereis latescens										
Nereis sp.								1		
Nereis vexillosa						1			3	
Notomastus tenuis		7		6	2					
Orbiniidae				1						
Paraonella platybranchia										
Perinereis monterea			1	1						
Phragmatopoma californica	3	2	9	13	18	1			6	
Phyllodocidae									1	
Polydora limicola										
Polydora websteri					1					
Polydora cf. *websteri*							1			
Polynoidae sp.				1						
Potamilla sp.					1					
Rhynchospio glutaea				1						
Sabellidae								1		
Spionidae										
Spirobranchus spinosus					1					
Syllidae			1		1					
Syllis gracilis				1						
Tharyx sp.					1					
Typosyllis aciculata										
Typosyllis adamantea										
Typosyllis alternata										
Typosyllis armillaris	1	1	6	1	4				1	

Appendix 3

Fauna Collected in Mussel Community Samples Reef Point August 1976

	Upper Intertidal Samples					Lower Intertidal Samples				
	1A	2A	3A	4A	5A	1B	2B	3B	4B	5B
PHYLUM ANNELIDA										
Class Polychaeta (Cont'd.)										
Typosyllis sp. A										
Typosyllis hyalina		1		1				1		
Typosyllis pulchra	226	133	254	141	219	33	12	20	20	5
Typosyllis cf. *pulchra*	13	9	11	38	23	1		1		1
Typosyllis sp.										
Typosyllis variegata										
PHYLUM MOLLUSCA										
Class Gastropoda										
Acanthina spirata										
Barleeia californica										
Collisella conus	3	5		9	5		1	1		
Collisella digitalis	8	15	18	8	17	3	1	3	1	5
Collisella limatula		5		2						
Collisella pelta	31	44	67	29	61	16	5	10	6	11
Collisella scabra										
Collisella sp.										
Collisella strigatella	19	25	28	7	26	3	4	3	6	
Crepidula sp.		1		1	2				1	
Epitonium tinctum		1		1					1	
Iselica ovoidea	4	31	5	3	5					
Littorina planaxis						2	1	2		
Littorina scutulata			1							
Littorina sp.										
Lottia gigantea										

Appendix 3

Fauna Collected in Mussel Community Samples Reef Point August 1976

	Upper Intertidal Samples					Lower Intertidal Samples				
	1A	2A	3A	4A	5A	1B	2B	3B	4B	5B
PHYLUM MOLLUSCA										
Class Gastropoda (Cont'd.)										
Mitrella aurantiaca										
Nucella emarginata				2		4		2	8	2
Ocenebra circumtexta										
Odostomia nota	1	9		2	2					
Tegula funebralis	2	3			2				1	
Class Bivalvia										
Adula diegensis										
Branchidontes adamsianus	7	1	7		2					
Glans carpenteri										
Hiatella arctica	3	3	2	4	8			1		1
Kellia laperousii				1	3					
Lasaea subviridis	12640	11328	14960	1580	7026	1		1	5	
Modiolus capax										
Mytilus californianus	393	584	674	251	381	149	109	126	83	124
Mytilus edulis				2						
Protothaca staminea										
Septifer bifurcatus	25	29	21	4	20	6			1	
Veneridae										
Class Polyplacophora										
Cyanoplax hartwegii										
Mopalia muscosa	1	3		2	1					

Appendix 3

Fauna Collected in Mussel Community Samples Reef Point August 1976

	Upper Intertidal Samples					Lower Intertidal Samples				
	1A	2A	3A	4A	5A	1B	2B	3B	4B	5B
PHYLUM MOLLUSCA										
Class Polyplacophora (Cont'd.)										
Mopalia porifera										
Mopalia sp.										
Nuttalina fluxa	3	1	2	1	1					1
PHYLUM ARTHROPODA										
Class Crustacea (Order Cirripedia)										
Balanus glandula	10	24	28	77	157	1	1	4	2	1
Balanus tintinnabulum californicus										
Chthamalus dalli	55	164	101	316	445	107	30	113	177	53
Chthamalus fissus	2	3		10	10	7	11	41	42	5
Pollicipes polymerus	2	6	16	16	46	71	32	63	178	54
Tetraclita squamosa rubescens		4		1	6					
PHYLUM ARTHROPODA										
Class Crustacea (Order Isopoda)										
Cirolana harfordi										
Dynamenella dianae										
Excorallana kathyae										
Gnorimosphaeroma sp. No. 1									1	
Jaeropsis dubia										
Sphaeromatidae sp. No. 1			2	2	2					
Class Crustacea (Order Amphipoda)										
Ampithoe sp.	3									
Aoroides columbiae			4	9	1		1			

Appendix 3

Fauna Collected in Mussel Community Samples Reef Point August 1976

	Upper Intertidal Samples					Lower Intertidal Samples				
	1A	2A	3A	4A	5A	1B	2B	3B	4B	5B
PHYLUM ARTHROPODA										
Class Crustacea (Order Amphipoda)										
Elasmopus rapax										
Elasmopus sp.	1		3	10	1	1		1	1	
Hyale anceps	10	13	19	19	18		1			
Hyale frequens						1				
Hyale californica										
Hyale plumulosa										
Synchelidium sp.										
Class Crustacea (Order Tanaidacea)										
Anatanais sp.										
Synapseudes intumescens			5	3	4				2	
Tanaidacea juvenile				1						
Class Crustacea (Order Decapoda)										
Pachycheles rudis										
Pachygrapsus crassipes	2	9	10	3	10	1			2	
Petrolisthes cabrilloi	1	13	11	19	7	1			1	
Pugettia producta										
Class Pycnogonida										
Ammothella tuberculata			1	1						
Halosoma viridintestinale										
Pycnogonum stearnsi		3	5	4	2					
Class Insecta										
Diptera, unid.										

Appendix 3

Fauna Collected in Mussel Community Samples Reef Point August 1976

	Upper Intertidal Samples					Lower Intertidal Samples				
	1A	2A	3A	4A	5A	1B	2B	3B	4B	5B
PHYLUM ECHINODERMATA										
Class Asteroidea										
Pisaster ochraceus					1					
Pisaster sp.		2	3	2	10					
Class Echinoidea										
Strongylocentrotus purpuratus	1									
PHYLUM ECTOPROCTA										
Cellaria mandibulata	+									
Crisia serrulata										
Crisulipora occidentalis										
Cryptosula pallasiana										
Filicrisia franciscana	+									
Hippothoa hyalina	+		+	+	+	+			+	+
Membranipora membranacea				+						
Membranipora tuberculata	+		+		+	+			+	+
Microporella californica				+						
Microporella ciliata										
Rhynchozoon rostratum										
Scrupocellaria californica	+								+	
Scrupocellaria diegensis	+									
Synnotum aegyptiacum										
Thalamoporella californica	+								+	
Tricellaria occidentalis	+					+			+	

+ = Present

Appendix 4

Flora Collected in Mussel Community Samples Goleta Point July 1976

SPECIES	Upper Intertidal Samples					Lower Intertidal Samples				
	1A	2A	3A	4A	5A	1B	2B	3B	4B	5B
Acrosorium uncinatum								+		
Ahnfeltia gigartinoides										
Ahnfeltia plicata		+		+	+	+	+		+	
Amplisiphonia pacifica		+		+	+			+	+	+
Antithamnion sp.										
Bossiella orbigniana										
Bossiella orbigniana ssp. *orbigniana*	+					+	+	+	+	
Botryoglossum ruprechtianum										
Calliarthron sp.							+			
Centroceras calvultum								+	+	
Chaetomorpha spiralis										
Cladophora microcladioides								+		
Corallina officinalis var. *chilensis*						+	+	+		
Corallina sp.						+				+
Corallina vancouveriensis										
Cryptopleura lobulifera						+	+	+		
Cryptopleura sp.										+
Cryptosiphonia sp.										
Derbesia marina				+						
Dictyopteris undulata										
Dictyotales, unid.										
Endocladia muricata										
Enteromorpha intestinalis	+			+	+		+	+	+	+
Enteromorpha sp.					+					
Enteromorpha flexuosa	+	+	+			+				
Erythroglossum sp.										

Appendix 4

Flora Collected in Mussel Community Samples Goleta Point July 1976

SPECIES	Upper Intertidal Samples 1A	2A	3A	4A	5A	Lower Intertidal Samples 1B	2B	3B	4B	5B
Gelidium purpurascens	+	+	+			+	+			
Gelidium robustum										
Gelidium sp.					+					+
Gigartina agardhii										
Gigartina canaliculata		+				+				
Gigartina cf. *leptorhynchos*								+		
Gigartina sp.										+
Gracilaria sp.										+
Gracilaria verrucosa				+	+			+		
Gymnogongrus leptophyllus						+	+			
Haliptylon gracile		+	+	+			+		+	
Hymenena sp.										
Laurencia sinicola										
Laurencia splendens				+		+	+			+
Lithothrix aspergillum							+			
Macrocystis sp.										
Nienburgia andersoniana		+								
Odonthalia sp.				+		+		+	+	
Phaeophyta, unid.									+	
Phyllospadix sp.	+	+	+	+	+	+	+	+	+	+
Plocamium cartilagineum										+
Plocamium sp.					+					
Polysiphonia hendryi var. *gardneri*					+	+				
Polysiphonia nathanielii										
Polysiphonia pacifica var. *delicatula*										
Polysiphonia sp.										

Appendix 4

Flora Collected in Mussel Community Samples Goleta Point July 1976

SPECIES	Upper Intertidal Samples					Lower Intertidal Samples				
	1A	2A	3A	4A	5A	1B	2B	3B	4B	5B
Porphyra cf. *perforata*						+				
Porphyra sp.										
Prionitis sp.	+			+				+		
Pterochondria woodii var. *pygmaea*									+	
Pterochondria woodii var. *woodii*	+	+	+	+	+	+	+	+	+	+
Pterocladia capillacea										
Pterosiphonia baileyi	+	+		+						
Pterosiphonia dendroidea										
Pterosiphonia pennata										
Pterosiphonia sp.				+						
Punctaria hesperia		+								
Rhodoglossum affine										
Rhodomela sp.									+	
Rhodymenia californica										
Rhodymenia sp.							+			
Rhodophyta, unid.										+
Scytosiphon lomentaria										
Stenogramme interrupta										
Ulva californica					+	+				+
Ulva lactuca	+	+	+	+			+		+	
Ulva sp.										+
Zonaria farlowii										

Appendix 5

Flora Collected in Mussel Community Samples Carpinteria July 1976

SPECIES	Upper Intertidal Samples					Lower Intertidal Samples				
	1A	2A	3A	4A	5A	1B	2B	3B	4B	5B
Acrosorium uncinatum										
Ahnfeltia gigartinoides						+				
Ahnfeltia plicata				+	+		+		+	
Amplisiphonia pacifica			+	+					+	
Antithamnion sp.										
Bossiella orbigniana				+						
Bossiella orbigniana ssp. *orbigniana*					+	+				+
Botryoglossum ruprechtianum						+				
Calliarthron sp.										
Centroceras calvultum							+			
Chaetomorpha spiralis										
Cladophora microcladioides					+	+			+	
Corallina officinalis var. *chilensis*										
Corallina sp.									+	
Corallina vancouveriensis			+						+	
Cryptopleura lobulifera										
Cryptopleura sp.				+	+				+	
Cryptosiphonia sp.	+									
Derbesia marina										
Dictyopteris undulata				+		+				
Dictyotales, unid.	+									
Endocladia muricata		+				+				
Enteromorpha intestinalis										
Enteromorpha sp.										
Enteromorpha flexuosa										
Erythroglossum sp.										

Appendix 5

Flora Collected in Mussel Community Samples Carpinteria July 1976

SPECIES	Upper Intertidal Samples 1A	2A	3A	4A	5A	Lower Intertidal Samples 1B	2B	3B	4B	5B
Gelidium purpurascens		+	+	+			+	+	+	
Gelidium robustum	+					+				
Gelidium sp.						+				
Gigartina agardhii										
Gigartina canaliculata			+			+	+		+	+
Gigartina cf. *leptorhynchos*				+			+		+	+
Gigartina sp.		+		+	+					
Gracilaria sp.										
Gracilaria verrucosa		+	+	+	+	+	+	+	+	+
Gymnogongrus leptophyllus		+	+				+	+		+
Haliptylon gracile				+	+	+		+	+	+
Hymenena sp.										
Laurencia sinicola			+				+			
Laurencia splendens								+	+	+
Lithothrix aspergillum										
Macrocystis sp.							+			
Nienburgia andersoniana										
Odonthalia sp.	+				+					
Phaeophyta, unid.										
Phyllospadix sp.	+	+	+	+	+	+	+	+	+	+
Plocamium cartilagineum							+		+	
Plocamium sp.										
Polysiphonia hendryi var. *gardneri*	+				+	+		+		+
Polysiphonia nathanielii			+							
Polysiphonia pacifica var. *delicatula*				+						
Polysiphonia sp.										

Appendix 5

Flora Collected in Mussel Community Samples Carpinteria July 1976

SPECIES	Upper Intertidal Samples					Lower Intertidal Samples				
	1A	2A	3A	4A	5A	1B	2B	3B	4B	5B
Porphyra cf. *perforata*			+	+			+	+	+	
Porphyra sp.		+								
Prionitis sp.							+	+	+	+
Pterochondria woodii var. *pygmaea*										
Pterochondria woodii var. *woodii*	+	+	+	+	+	+	+	+	+	+
Pterocladia capillacea										
Pterosiphonia baileyi	+	+	+			+	+	+	+	+
Pterosiphonia dendroidea					+					
Pterosiphonia pennata	+			+						
Pterosiphonia sp.										
Punctaria hesperia										
Rhodoglossum affine			+							
Rhodomela sp.								+	+	
Rhodymenia californica						+				
Rhodymenia sp.					+				+	
Rhodophyta, unid.										
Scytosiphon lomentaria		+		+						
Stenogramme interrupta										
Ulva californica					+					+
Ulva lactuca										
Ulva sp.										
Zonaria farlowii				+						

Appendix 6

Flora Collected in Mussel Community Samples Reef Point July 1976

SPECIES	Upper Intertidal Samples					Lower Intertidal Samples				
	1A	2A	3A	4A	5A	1B	2B	3B	4B	5B
Acrosorium uncinatum	+									
Ahnfeltia gigartinoides										
Ahnfeltia plicata	+	+	+	+		+	+	+		+
Amplisiphonia pacifica	+	+	+	+	+		+		+	+
Antithamnion sp.			+							
Bossiella orbigniana										
Bossiella orbigniana ssp. *orbigniana*		+				+				
Botryoglossum ruprechtianum										
Calliarthron sp.										
Centroceras calvultum					+					
Chaetomorpha spiralis	+			+						
Cladophora microcladioides										
Corallina officinalis var. *chilensis*										
Corallina sp.										
Corallina vancouveriensis										
Cryptopleura lobulifera										
Cryptopleura sp.			+	+	+	+	+			+
Cryptosiphonia sp.										
Derbesia marina										
Dictyopteris undulata										
Dictyotales, unid.										
Endocladia muricata										
Enteromorpha intestinalis										
Enteromorpha sp.										
Enteromorpha flexuosa	+		+							
Erythroglossum sp.	+	+								

Appendix 6

Flora Collected in Mussel Community Samples Reef Point July 1976

SPECIES	Upper Intertidal Samples					Lower Intertidal Samples				
	1A	2A	3A	4A	5A	1B	2B	3B	4B	5B
Gelidium purpurascens		+	+	+	+			+	+	+
Gelidium robustum										
Gelidium sp.	+	+								
Gigartina agardhii		+								
Gigartina canaliculata										
Gigartina cf. *leptorhynchos*	+		+	+	+					+
Gigartina sp.										
Gracilaria sp.					+					
Gracilaria verrucosa	+	+	+	+	+	+	+	+	+	+
Gymnogongrus leptophyllus		+	+	+	+		+	+	+	+
Haliptylon gracile						+				
Hymenena sp.	+	+								
Laurencia sinicola										
Laurencia splendens	+	+	+	+	+					
Lithothrix aspergillum										
Macrocystis sp.	+									
Nienburgia andersoniana				+	+				+	
Odonthalia sp.				+						
Phaeophyta, unid.										
Phyllospadix sp.	+	+	+	+	+	+	+	+	+	+
Plocamium cartilagineum	+	+	+	+	+		+	+	+	+
Plocamium sp.										
Polysiphonia hendryi var. *gardneri*	+	+	+	+	+					
Polysiphonia nathanielii										
Polysiphonia pacifica var. *delicatula*										
Polysiphonia sp.							+			

Appendix 6

Flora Collected in Mussel Community Samples Reef Point July 1976

SPECIES	Upper Intertidal Samples					Lower Intertidal Samples				
	1A	2A	3A	4A	5A	1B	2B	3B	4B	5B
Porphyra cf. *perforata*										
Porphyra sp.			+	+						
Prionitis sp.				+	+	+		+	+	
Pterochondria woodii var. *pygmaea*										
Pterochondria woodii var. *woodii*	+	+	+	+	+	+	+	+	+	+
Pterocladia capillacea						+				
Pterosiphonia baileyi		+			+	+				+
Pterosiphonia dendroidea										
Pterosiphonia pennata										
Pterosiphonia sp.										
Punctaria hesperia										
Rhodoglossum affine										
Rhodomela sp.				+						
Rhodymenia californica					+					+
Rhodymenia sp.		+		+				+	+	
Rhodophyta, unid.					+				+	
Scytosiphon lomentaria										
Stenogramme interrupta					+					
Ulva californica										
Ulva lactuca										
Ulva sp.										
Zonaria farlowii										

Appendix 7
Relative Abundance of Species at the Six Sampling Sites
(Data Averaged/Subsample)

Species	Number Sampling Sites	Total Number Organisms	Maximum Number/Site	Cumulative % of Total Number Organisms
Amphiporus sp.	6	24.00	11.20	0.07
Anthopleura xanthogrammica	6	105.40	51.80	0.36
Balanus glandula	6	1107.20	429.60	3.42
Chthamalus dalli	6	4764.00	1571.00	16.61
Chthamalus fissus	6	218.20	65.20	17.22
Collisella conus	6	25.00	15.40	17.29
Collisella digitalis	6	80.40	47.00	17.51
Collisella pelta	6	140.60	46.40	17.90
Collisella strigatella	6	88.20	21.60	18.14
Deontostoma sp.	6	350.40	166.80	19.11
Emplectonema gracile	6	122.80	42.00	19.45
Eulalia quadrioculata	6	43.80	29.20	19.57
Hiatella arctica	6	10.00	4.00	19.60
Hyale anceps	6	200.40	90.80	20.16
Lasaea subviridis	6	23529.39	9506.80	85.30
Mytilus californianus	6	1131.40	456.60	88.43
Nemertopsis gracilis	6	25.60	8.20	88.50
Nereis grubei	6	77.40	48.60	88.72
Nucella emarginata	6	27.60	9.60	93.86
Pachygrapsus crassipes	6	22.80	7.60	88.78
Pollicipes polymerus	6	1336.80	414.60	92.48
Septifer bifurcatus	6	472.60	291.20	93.79
Thalamoporella californica (P/A)	6	2.00	0.60	93.87
Typosyllis pulchra	6	490.80	249.60	95.23
Typosyllis cf. *pulchra*	6	41.40	18.80	95.34

(P/A) = Presence/Absence Data only.

Appendix 7
Relative Abundance of Species at the Six Sampling Sites
(Data Averaged/Subsample)

Species	Number Sampling Sites	Total Number Organisms	Maximum Number/Site	Cumulative % of Total Number Organisms
Aoroides columbiae	5	57.80	47.60	95.50
Arabella semimaculata	5	26.00	11.20	95.58
Elasmopus sp.	5	261.60	91.80	96.30
Hippothoa hyalina (P/A)	5	2.60	0.80	96.32
Hydroides gracilis	5	4.40	1.40	96.31
Lumbrineris zonata	5	21.20	11.40	96.38
Membranipora tuberculata (P/A)	5	2.00	0.60	96.38
Mopalia muscosa	5	6.60	2.60	96.40
Mytilus edulis	5	7.80	4.40	96.42
Nuttalina fluxa	5	2.80	1.60	96.43
Oncholaimina sp.	5	663.60	218.60	98.27
Petrolisthes cabrilloi	5	98.20	60.80	98.54
Phragmatopoma californica	5	25.00	10.60	98.61
Sphaeromatidae sp. #1	5	34.60	18.60	98.71
Typosyllis hyalina	5	3.40	1.40	98.71
Branchidontes adamsianus	4	4.20	3.40	98.73
Chrysopetalum occidentale	4	8.80	4.80	98.75
Crepidula sp.	4	2.60	1.20	98.76
Epitonium tinctum	4	1.00	0.40	98.76
Naineris dendritica	4	7.80	3.00	98.78
Paraeurystomina sp.	4	4.40	2.80	98.79
Phascolosoma agassizii	4	13.40	6.20	98.83
Polydora websteri	4	28.00	15.00	98.91
Tegula funebralis	4	4.60	2.20	98.92

(P/A) = Presence/Absence Data Only.

Appendix 7
Relative Abundance of Species at the Six Sampling Sites
(Data Averaged/Subsample)

Species	Number Sampling Sites	Total Number Organisms	Maximum Number/Site	Cumulative % of Total Number Organisms
Branchiomaldane vincentii	3	5.60	5.20	98.94
Cellaria mandibulata (P/A)	3	1.00	0.60	98.94
Chone minuta	3	2.80	1.80	98.95
Collisella limatula	3	1.80	1.40	98.95
Enoplus sp.	3	8.80	5.60	98.98
Filicrisia franciscana (P/A)	3	1.20	0.80	98.98
Halosydna brevisetosa	3	5.40	2.80	99.00
Hayle frequens	3	8.60	6.60	99.02
Hyale californica	3	6.00	5.40	99.04
Littorina planaxis	3	9.80	6.80	99.06
Littorina scutulata	3	2.00	1.60	99.07
Nereis sp.	3	0.80	0.40	99.07
Nereis vexillosa	3	19.80	12.40	99.13
Paranemertes peregrina	3	3.20	2.00	99.13
Polydora limicola	3	31.20	20.40	99.22
Protothaca staminea	3	2.00	1.20	99.23
Pugettia producta	3	9.00	6.80	99.25
Scrupocellaria diegenis (P/A)	3	1.00	0.60	99.25
Scrupocellaria californica (P/A)	3	0.60	0.20	99.25
Synapseudes intumescens	3	20.80	18.40	99.31
Tricellaria occidentalis (P/A)	3	1.20	0.60	99.32
Typosyllis alternata	3	31.60	25.40	99.40
Boccardia proboscidea	2	35.00	27.00	99.50
Cirolana harfordi	2	15.00	14.40	99.54
Collisella scabra	2	4.00	3.00	99.55

(P/A) = Presence/Absence Data Only.

Appendix 7
Relative Abundance of Species at the Six Sampling Sites
(Data Averaged/Subsample)

Species	Number Sampling Sites	Total Number Organisms	Maximum Number/Site	Cumulative % of Total Number Organisms
Collisella sp.	2	7.00	4.00	99.57
Crisulipora occidentalis (P/A)	2	0.60	0.40	99.57
Cyanoplax hartwegii	2	4.20	4.00	99.59
Halosoma viridintestinale	2	1.20	1.00	99.59
Iselica ovoidea	2	10.20	9.60	99.62
Lottia gigantea	2	1.00	0.60	99.62
Membranipora membranacea (P/A)	2	0.60	0.40	99.62
Notomastus tenuis	2	9.80	6.80	99.65
Odostomia nota	2	7.00	4.20	99.67
Polynoidae	2	0.60	0.40	99.67
Pycnogonum stearnsi	2	3.20	2.80	99.68
Typosyllis sp. A	2	40.60	40.20	99.79
Typosyllis armillaris	2	2.80	2.60	99.80
Typosyllis sp.	2	8.40	8.20	99.82
Typosyllis variegata	2	1.80	1.60	99.83
Ampithoe sp.	1	12.80	12.80	99.86
Crisia serrulata (P/A)	1	0.60	0.60	99.86
Hemipodus borealis	1	1.20	1.20	99.87
Nereis latescens	1	10.20	10.20	99.90
Pisaster sp.	1	3.40	3.40	99.91
Tetraclita squamosa rubescens	1	2.20	2.20	99.91
Typosyllis aciculata	1	29.20	29.20	99.99
Typosyllis adamanteus	1	2.80	2.80	100.00

(P/A) = Presence/Absence Data Only.

Appendix 8
Abundance of Species in Thirty Sampling Cores

Species	Number Cores	Total Number Organisms	Maximum Number/Core	Cumulative % of Total Number Organisms
Balanus glandula	30	5536	622	3.02
Chthamalus dalli	30	23820	1926	16.04
Collisella pelta	30	703	67	16.42
Mytilus californianus	30	5657	674	19.51
Pollicipes polymerus	30	6684	672	23.16
Chthamalus fissus	29	1091	164	23.76
Collisella strigatella	29	441	35	24.00
Collisella digitalis	28	402	63	24.22
Nereis grubei	28	387	60	24.43
Typosyllis pulchra	28	2454	584	25.77
Lasaea subviridis	27	117647	14960	90.04
Deontostoma sp.	26	1752	344	91.00
Emplectonema gracile	25	614	61	91.34
Oncholaimina sp.	25	3318	323	93.15
Septifer bifurcatus	25	2363	375	94.44
Anthopleura xanthogrammica	24	527	76	94.73
Pachygrapsus crassipes	24	114	12	94.79
Typosyllis cf. *pulchra*	24	207	38	94.90
Leptoplanidae	22	286	50	95.06
Amphiporus sp.	21	120	15	95.12
Elasmopus sp.	21	1308	219	95.84
Nemertopsis gracilis	21	128	29	95.91
Oligochaeta, unid.	21	1993	868	97.00
Arabella semimaculata	20	130	20	97.07
Collisella conus	20	125	19	97.14
Hyale anceps	20	1002	242	97.68
Nucella emarginata	20	138	28	98.03
Petrolisthes cabrilloi	20	491	106	97.95

Appendix 8
Abundance of Species in Thirty Sampling Cores

Species	Number Cores	Total Number Organisms	Maximum Number/Core	Cumulative % of Total Number Organisms
Eulalia aviculiseta	18	219	40	98.15
Hiatella arctica	18	50	8	98.17
Sphaeromatidae sp. #1	17	173	42	98.27
Aoroides columbiae	16	289	78	98.43
Lumbrineris zonata	16	106	19	98.49
Mopalia muscosa	16	33	6	98.50
Phascolosoma agassizii	16	67	11	98.54
Phragmatopoma californica	16	125	23	98.61
Chrysopetalum occidentale	15	44	8	98.63
Polydora websteri	14	140	39	98.71
Hippothoa hyalina (P/A)	13	13	1	98.73
Hydroides gracilis	13	22	3	98.72
Mytilus edulis	13	39	7	98.75
Tegula funebralis	13	23	5	98.76
Nereis vexillosa	12	99	23	98.82
Naineris dendritica	11	39	6	98.84
Nuttalina fluxa	11	14	3	98.84
Polydora limicola	11	156	35	98.93
Crepidula sp.	10	13	3	98.94
Halosydna brevisetosa	10	27	4	98.95
Membranipora tuberculata (P/A)	10	10	1	98.96
Pugettia producta	10	45	13	98.98
Thalamoporella californica (P/A)	10	10	1	98.99
Typosyllis hyalina	10	17	4	99.00

(P/A) = Presence/Absence Data Only.

Appendix 8
Abundance of Species in Thirty Sampling Cores

Species	Number Cores	Total Number Organisms	Maximum Number/Core	Cumulative % of Total Number Organisms
Enoplus sp.	9	44	8	99.02
Littorina planaxis	9	49	14	99.05
Synapseudes intumescens	9	104	47	99.10
Typosyllis alternata	9	158	53	99.19
Boccardia proboscidea	8	175	50	99.29
Brachidontes adamsianus	8	21	7	99.30
Cirolana harfordi	7	75	37	99.34
Paranemertes peregrina	7	16	6	99.35
Chone minuta	6	14	6	99.35
Collisella scabra	6	20	7	99.37
Cyanoplax hartwegii	6	21	6	99.38
Filicrisia franciscana (P/A)	6	6	1	99.38
Hyale frequens	6	43	18	99.40
Iselica ovoidea	6	51	31	99.43
Lumbrineridae sp.	6	6	1	99.44
Notomastus tenuis	6	49	31	99.46
Odostomia nota	6	35	19	99.48
Paraeurystomina sp.	6	22	10	99.49
Pycnogonum stearnsi	6	16	5	99.50
Tricellaria occidentalis (P/A)	6	6	1	99.51
Typosyllis sp. A	6	203	62	99.62
Typosyllis armillaris	6	14	6	99.62

(P/A) = Presence/Absence Data Only.

Appendix 8
Abundance of Species in Thirty Sampling Cores

Species	Number Cores	Total Number Organisms	Maximum Number/Core	Cumulative % of Total Number Organisms
Ampithoe sp.	5	64	14	99.66
Branchiomaldane vincentii	5	28	13	99.67
Cellaria mandibulata (P/A)	5	5	1	99.68
Epitonium tinctum	5	5	1	99.68
Nereis latescens	5	51	17	99.71
Protothaca staminea	5	10	4	99.71
Scrupocellaria diegensis (P/A)	5	5	1	99.72
Typosyllis aciculata	5	146	56	99.80
Typosyllis adamanteus	5	14	6	99.80
Arabellidae sp.	4	4	1	99.80
Collisella limatula	4	9	5	99.81
Halosoma viridintestinale	4	6	2	99.81
Hyale californica	4	30	26	99.83
Lottia gigantea	4	5	2	99.83
Pisaster sp.	4	17	10	99.84
Typosyllis sp.	4	42	22	99.86
Collisella sp.	3	35	15	99.88
Crisia serrulata (P/A)	3	3	1	99.89
Crisulipora occidentalis (P/A)	3	3	1	99.89
Hemipodus borealis	3	6	4	99.89
Littorina scutulata	3	10	8	99.90
Lumbrineris sp.	3	5	2	99.90
Membranipora membranacea (P/A)	3	3	1	99.90
Nereidae sp.	3	3	1	99.90
Nereis sp.	3	4	2	99.90
Polynoidae	3	3	1	99.91
Scrupocellaria californica (P/A)	3	3	1	99.91
Tetraclita squamosa rubescens	3	12	6	99.91
Typosyllis variegata	3	9	6	99.92

(P/A) = Presence/Absence Data Only.

Appendix 8
Abundance of Species in Thirty Sampling Cores

Species	Number Cores	Total Number Organisms	Maximum Number/Core	Cumulative % of Total Number Organisms
Acanthina spirata	2	3	2	99.92
Actiniaria sp.	2	4	2	99.92
Ammothella tuberculata	2	2	1	99.92
Anatanais sp.	2	3	2	99.92
Boccardia sp.	2	4	2	99.93
Cirriformia sp.	2	2	1	99.93
Kellia laperousii	2	4	3	99.93
Lineus sp.	2	2	1	99.93
Littorina sp.	2	3	2	99.93
Microporella ciliata (P/A)	2	2	1	99.93
Orbiniidae sp.	2	2	1	99.93
Paraonides platybranchia	2	4	2	99.94
Perinereis monterea	2	2	1	99.94
Phyllodocidae	2	2	1	99.94
Syllidae	2	3	2	99.94
Syllis gracilis	2	26	25	99.96
Tharyx sp.	2	9	8	99.96
Adula diegensis	1	2	2	99.96
Anthopleura sp.	1	5	5	99.96
Arabella sp.	1	1	1	99.96
Armandia bioculata	1	3	3	99.97
Balanus t. *californicus*	1	1	1	99.97
Barleeia californica	1	1	1	99.97
Brania sp.	1	1	1	99.97
Chaetozone sp.	1	1	1	99.97
Chrysopetalum sp.	1	1	1	99.97
Cryptosula pallasiana (P/A)	1	1	1	99.97
Diptera, unid.	1	1	1	99.97
Dynamenopsis dianae	1	1	1	99.97

(P/A) = Presence/Absence Data Only.

Appendix 8
Abundance of Species in Thirty Sampling Cores

Species	Number Cores	Total Number Organisms	Maximum Number/Core	Cumulative % of Total Number Organisms
Elasmopus rapax	1	3	3	99.97
Excorallana kathyae	1	1	1	99.97
Glans carpenteri	1	1	1	99.97
Gnorimosphaeroma sp. 1	1	1	1	99.97
Hyale plumulosa	1	10	10	99.98
Jaeropsis dubia	1	1	1	99.98
Microporella californica (P/A)	1	1	1	99.98
Mitrella aurantiaca	1	2	2	99.98
Modiolus capax	1	1	1	99.98
Mopalia porifera	1	1	1	99.98
Mopalia sp.	1	3	3	99.98
Ocenebra circumtexta	1	1	1	99.98
Pachycheles rudis	1	1	1	99.99
Pisaster ochraceus	1	1	1	99.99
Potamilla sp.	1	1	1	99.99
Rhynchospio glutaea	1	1	1	99.99
Rhynchozoon rostratum (P/A)	1	1	1	99.99
Sabellariidae	1	1	1	99.99
Spionidae	1	1	1	99.99
Spirobranchus spinosus	1	1	1	99.99
Strongylocentrotus purpuratus	1	1	1	99.99
Syllides	1	1	1	99.99
Synchelidium sp.	1	1	1	99.99
Synnotum aegyptiacum (P/A)	1	1	1	99.99
Typosyllis cf. *websteri*	1	1	1	99.99
Typosyllis gracilis	1	6	6	100.00
Veneridae	1	8	8	100.00

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