Southern California Bight 1994 Pilot Project:

IV. Benthic Infauna

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FOREWORD

More than ten million dollars is spent annually monitoring southern California's coastal waters, yet some basic questions about the ocean's condition, such as how many acres of ocean bottom are impaired, can't be answered. The principal limitation is that less than 5% of the area on the mainland shelf of the Southern California Bight (SCB) is routinely monitored. Moreover, the constituents measured, as well as the frequency and methodology by which they are measured, typically differ among monitoring programs in the SCB. These limitations reflect the predominant association of monitoring in southern California with discharge permit requirements that are focused on site-specific, single-source issues. While these programs generally collect high quality data, they are not designed to describe changes which occur on regional scales or to assess cumulative impacts from multiple sources whose fates commingle.

Recognizing the need for integrated assessment of the southern California coastal ocean, 12 governmental organizations, including the four largest municipal dischargers and the five regulators of discharge in southern California, collaborated to conduct a comprehensive regional monitoring survey in the summer of 1994. Referred to as the Southern California Bight Pilot Project (SCBPP), the monitoring survey included measures of the water quality, sediment chemistry, sediment toxicity, benthic infauna, and demersal fishes. This report summarizes the benthic portion of the study. Other reports are available on the web (www.sccwrp.org) or from the Southern California Coastal Water Research Project.

Participating Agencies In The SCBPP

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United States Environmental Protection Agency, Region IX
City of Los Angeles, Environmental Monitoring Division
County Sanitation Districts of Los Angeles County
County Sanitation Districts of Orange County
City of San Diego, Metropolitan Wastewater Department
State Water Resources Control Board
Regional Water Quality Control Board, Los Angeles Region
Regional Water Quality Control Board, Santa Ana Region
Regional Water Quality Control Board, San Diego Region
Santa Monica Bay Restoration Project
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The Steering Committee, particularly Drs. Jeff Cross and Steve Weisberg, provided the impetus and vision that guided this effort.

The field teams collected the samples with great efficiency and care. The captains and crew of the *La Mer* and *Marine Surveyor*, City of Los Angeles; the *Ocean Sentinel*, County Sanitation Districts of Los Angeles County; the *Crusader*, MEC Analytical Systems, Inc.; and the *Monitor III* and *Metro*, City of San Diego, were responsible for navigation and overall safety of the field operations.

It would not have been possible to produce this report without the in-depth knowledge of the taxonomists. The taxonomists produced the primary data and provided the essential information for the analysis of assemblages and for the development of the Benthic Response Index (BRI). We especially wish to thank Dave Montagne, who spearheaded the effort to develop and implement laboratory protocols, including QA/QC of identification and enumeration of specimens.

The Benthic Infauna Working Group worked cooperatively on all aspects of data analysis and report preparation. Their discussions were open, thoughtful and created new and interesting ideas. Dr. Don Stevens and Mike McDowell, ManTech, Inc., provided essential help with the sampling design and statistics. Dr. Mary Bergen took primary responsibility for writing the assessment report. Drs. Bob Smith, Mary Bergen and Steve Weisberg took primary responsibility for writing the description of the BRI. Liesl Tiefenthaler and David Tsukada analyzed most of the data, prepared figures and tables and produced multiple versions of this report.

To all those who contributed part of themselves to this project, we thank you.

EXECUTIVE SUMMARY

Bottom (benthic) organisms have many characteristics that make them useful as indicators of environmental stress. For this reason, they have been used worldwide to assess the effects of municipal wastewater outfalls, disposal of dredged materials, and other anthropogenic activities. Monitoring programs in southern California have provided useful information for evaluating local impacts. However, there is also a need for regional data that can be used to scale the severity of individual impacts and make regional assessments. Recognizing this need, 12 agencies joined in the Southern California Bight Pilot Project (SCBPP) to assess the environmental status of soft-bottom habitats on the mainland shelf of southern California.

In July-August 1994, benthic infauna were collected from 251 stations at depths of 10-200 m between Point Conception and the U.S.-Mexico international border. Stations were chosen using a stratified random design with geography (Santa Monica Bay), and proximity to input sources (wastewater outfalls and river mouths) as the primary strata. Samples were taken with a modified 0.1m^2 Van Veen grab and sieved through a 0.1 mm mesh screen. Samples were then sorted and identified according to protocols established in a laboratory manual developed for the project.

A primary objective of the survey was to characterize benthic communities. This objective was accomplished by calculating community characteristics, such as the number of taxa and individuals, and determining the effects of latitude and depth on community characteristics and species distributions. An average of 85 taxa/sample, 3850 individuals and 58 grams wet-weight biomass/m^2 were collected on the mainland shelf of the Bight. Individuals were relatively evenly distributed among the taxa; no one taxon was dominant. Approximately 50% of the organisms were annelids; 19, 13, and 10% were arthropods, ophiuroids, and mollusks, respectively.

Most community characteristics were not correlated with latitude. Even where statistically significant relationships were found, correlations were relatively weak. Most community characteristics were correlated with depth, but, with one exception, the regressions did not explain more than 7% of the variance.

Sixteen taxa averaged 40 or more individuals/m^2 and occurred in at least 30% of the samples. All but five of these taxa were annelids. No indication of a latitudinal gradient was found for most taxa; however, distributions did vary with depth. The majority of taxa were most abundant in 40-80 m of water.

A second objective of the survey was to identify groups of stations with similar species composition. Cluster analysis defined four groups of stations. Each group occupied a different habitat, characterized by differences in depth and sediment grain size. Groups 1 and 2 were found in greater than 115 m of water in coarse and fine sediment, respectively. Group 4 was found in less than 30 m of water or in 30-45 m in coarse sediment. Group 3 was found in intermediate depths.

A third objective of the survey was to estimate the areal extent of alterations to benthic communities in the Bight and to compare the amount of altered area in Santa Monica Bay, in the vicinity of discharges from municipal wastewater outfalls (POTW's) and near rivers and stormdrains. The assessment of infaunal condition was based on analysis of: 1) species composition, 2) community parameters (e.g., number of species) and 3) the Benthic Response Index (BRI). The BRI is the abundance-weighted average pollution tolerance of species in a sample. Pollution tolerance was measured by determining the position of a species on a gradient between the most and least affected stations in an ordination space. If most of the species in a sample are reference species, the index score for the station is low. If most of the species are pollution tolerant, the index value for the station is high. For this assessment, the percent of area exceeding the reference threshold of the BRI was determined for four levels of biological response: I) marginal deviation, a change in relative abundance of species; II) loss of biodiversity, the exclusion of sensitive species that often causes a change in species composition of the assemblage; III) loss of community function, the exclusion of groups of species, particularly arthropods and ophiuroids; and IV) defaunation, the exclusion of most species.

While the BRI measures changes in benthic communities caused by a disturbance, the BRI cannot be used to determine the source of the disturbance. Species respond in a similar manner to both natural and anthropogenic disturbances. For example, pollution tolerant species may colonize an area near the head of a submarine canyon as well as an area that is affected by a discharge from an outfall. For this reason, benthic communities that are determined to be altered should not be assumed to be anthropogenically impacted.

Most of the Bight had healthy benthic communities. Over 90% of the Bight was classified as reference by the BRI. Alterations, where found, were limited in magnitude. Eight percent of the mainland shelf of the Bight was classified in Response Level I, marginal deviation from reference. Less than two percent was classified in Response Level II, loss in biodiversity. None of the mainland shelf was classified in Response Level III or IV. Most stations classified in Response Levels I and II were located in the Santa Barbara Channel, near the mouth of the Santa Clara and Ventura Rivers, in central and northern Santa Monica Bay or on the Palos Verdes shelf

The condition of benthic assemblages was marginally poorer in Santa Monica Bay than in other areas of the Bight. Benthic assemblages were classified as reference by the BRI in 87% of Santa Monica Bay, compared to 92% of areas outside of Santa Monica Bay. The number of taxa/sample and total abundance of organisms were lower in Santa Monica Bay. Proportionally more mollusks and fewer annelids were found in Santa Monica Bay than in other areas of the Bight.

The condition of benthic communities in POTW areas was similar to other areas of the Bight. Benthic assemblages were classified as reference by the BRI in 89% of POTW areas, compared to 92% of non-POTW areas. While the number of taxa was similar, dominance was higher and diversity lower in mid-depth POTW than in non-POTW areas. Proportionately more annelids and fewer arthropods were found in POTW than in non-POTW areas.

More area was altered in stormwater areas than in the Bight as a whole; however, changes in benthic assemblages were limited in magnitude. Benthic assemblages in 60% of stormwater discharge areas were classified as reference by the BRI, compared to 87% of shallow non-stormwater areas; 23 and 17% of the area was categorized in Response Levels I and II, respectively. Diversity, abundance, and other characteristics of the populations in stormwater and non-stormwater areas were similar. The proportion of biomass contributed by mollusks was lower in stormwater discharge areas; however, the difference was small. The causes of alterations in stormwater discharge areas are not known, but could include natural and/or anthropogenic disturbances such as seasonal changes in salinity or sediment movement caused by waves.

Even though altered benthic communities were found in areas within the influence of municipal wastewater outfalls and stormwater runoff, little relationship was found between the level of biological response as measured by the BRI and concentration of chemicals (e.g., chlorinated hydrocarbons and trace metals) in the sediment. The reasons for the lack of correspondence between sediment chemistry and alterations in benthic communities are not known. The fact that normal benthic communities were found in areas with high concentrations of chemicals could be related to the sequestering effect of binding factors, such as organic carbon, in the sediment. It is also possible that organisms in southern California have become adapted to high concentrations of chemicals in the sediment. In areas with altered benthic communities and low concentrations of chemicals in the sediment, it is possible that whatever is causing the disturbance occurs intermittently and/or is not captured in the measured sediment chemistry. The alterations may be caused by natural events.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

INTRODUCTION

Bottom (benthic) organisms possess many characteristics that make them useful indicators of environmental stress in the marine environment. Benthic organisms are very diverse. They have a wide range of physiological tolerances and feeding and reproductive modes, and therefore have the potential to respond to a wide array of environmental stressors. Because benthic organisms are relatively sedentary, they cannot escape sediment contamination. For these reasons, benthic organisms often show measurable responses to environmental stress.

Benthic organisms have been used worldwide for environmental assessment (Pearson and Rosenberg 1978, Word and Mearns 1979, Gray *et al*. 1990, Anderlini and Wear 1992, Weisberg *et al*. 1997). In southern California, benthic organisms have been used to assess the effects of municipal wastewater outfalls (e.g., Bascom 1978, Stull *et al*. 1986, Zmarzly *et al*. 1994, Diener *et al*. 1995, Dorsey *et al*. 1995, Stull 1995); thermal and industrial discharges (e.g., Southern California Edison Company 1997); and disposal of dredged material and drilling muds (U.S. EPA 1987) and stormwater runoff (Bay and Schiff 1997).

In southern California, monitoring programs have provided useful information that has allowed evaluation of local impacts. However, these programs are not designed to provide information that can be used to evaluate the environmental health of the region. In order to make effective decisions, environmental managers need to be able to compare sites, determine the relative importance of pollutant sources and evaluate cumulative impacts (NRC 1990). In other word, environmental managers need regional data.

Between 1956 and 1959, scientists at the University of Southern California collected 862 benthic infaunal in the area between Point Arguello and 4 km south of the border between the United States and Mexico. To date, this is the only truly Bight-wide survey that has been done. The results of the sampling provided the foundation of our knowledge of benthic assemblages in the Bight (Allan Hancock Foundation 1959, 1965; Stevenson 1961; Barnard and Hartman 1959, Barnard and Ziesenhenne 1960; Jones 1969), but were never used for regional environmental assessment. In 1977, scientists at SCCWRP collected benthic samples at intervals of approximately 10 km between Point Conception and the United States/Mexico border (Word and Mearns 1979). These data were used for environmental assessment; however, the assessment was limited to the 60 m depth contour. A survey with fewer sites and more depths was conducted in 1985 (Thompson *et al*. 1987) and 1990 (Thompson *et al*. 1993); the objective of the sampling was to provide information on reference conditions, not environmental assessment.

The Southern California Bight Pilot Project (SCBPP) was a cooperative regional sampling effort designed to assess the ecological health of soft-bottom habitats on the mainland shelf of southern California. The sampling was intended to provide the information needed to compare the effects of point and non-point discharges as well as to determine reference conditions. In addition, the program was designed to test the feasibility of cooperative regional monitoring. It was a test of the ability of several organizations to jointly plan and implement a large-scale survey and produce high quality data.

This report includes: 1) a description of sampling design and methods, 2) a review of program quality, 3) a summary description of characteristics of benthic communities, and 4) an assessment of the areal extent of alterations in benthic infaunal communities in southern California.

METHODS

Two hundred and fifty-one sites were sampled on the continental shelf (defined as 10-200 m deep) from Point Conception, California, to the United States-Mexico border between July 13 and August 22, 1994 (Figure 1). Sites were selected using a stratified random design, with the primary strata being depth zone (the inner shelf from 10-25 m, the middle shelf from 26-100 m, and the outer shelf from 101-200 m); geography (Santa Monica Bay); and proximity to input sources (wastewater outfalls and river mouths) (Figure 2a). Details of site selection are provided in Bergen (1996) and Stevens (1997).

Sediment samples were collected with a modified 0.1 m^2 Van Veen grab. Only samples with penetration depth of at least 5 cm and no evidence of disturbance (i.e., by washout) were accepted for processing. Sediment for infaunal analysis was sieved though a 1 mm mesh screen. The material retained on the screen was placed in a relaxant solution of 1 kg of $MgSO_4$ per 20 L of seawater for 30 minutes and then preserved in 10% sodium borate buffered formalin.

Sediment samples for total organic carbon (TOC), sediment grain size, trace metals, DDTs, PCBs, and PAHs were taken from a second grab sample. Sediment chemistry samples were taken from the top 2 cm of the grab (Schiff and Gossett 1997).

Samples for infaunal analysis were distributed to four laboratories for sorting and identification. After 3-14 days, samples were rinsed and transferred from formalin to 70% ethanol. Samples were then sorted into six major taxonomic categories (annelids, arthropods, mollusks, ophiuroids, other echinoderms, and other phyla), and the wet weight of each group was measured. One of two methods was used to remove excess preservative prior to weighing the sample: 1) the organisms were drained on a fine sieve and then air dried for five minutes on absorbent paper, or 2) the organisms were poured into a funnel with a fenestrated plate and a gentle vacuum was applied until no liquid was visible in the stem of the funnel. Balances capable of reading to 0.01 gram were used to weigh the samples. Weights were reported to the nearest 0.1 gram. Specimens were then identified to the lowest practicable taxon and enumerated.

An evaluation of quality assurance and control procedures, including methodology for sample collection and processing, are presented in Appendices A and B.

DATA ANALYSIS

The following types of data analysis were conducted: 1) mean parameter response (e.g., mean infaunal abundance) was calculated for the SCB and various subpopulations (such as Santa Monica Bay), 2) parameters were regressed against latitude and depth, 3) the abundance of individual species was plotted against latitude and depth, 4) the fractional area within each subpopulation that had altered benthic assemblages was assessed, 5) cluster analysis was conducted to identify clusters of stations with similar species composition, and 6) the physical habitat factors associated with the site clusters were identified. The areas around wastewater outfalls are labeled Publically Owned Treatment Work (POTW) areas in this report. This name is a technical term applied to municipal wastewater treatment plants.

Community characteristics used in the analysis included number of species, Shannon-Wiener Diversity, evenness, dominance and the percent of abundance and biomass comprised by major phyletic groups. Shannon-Wiener Diversity (H') is $\sum_{i=1}^{s}(p_i)(\log_2 p_i)$ where s is the number of species and p_i is the proportion of the total sample belonging to the ith species. Eveness (J') is H'/$\log_2$s. Dominance is $\sum_{i=1}^{s} p_i^2$. Mean community characteristics and lists of the most commonly-occurring species for the depth and latitudinal zones are in Appendices C and D, respectively.

Mean parameter values were calculated using a ratio estimator (Thompson 1992):

$$m = \frac{\sum_{i=1}^{n}(p_i * w_i)}{\sum_{i=1}^{n} w_i}$$

where:

m = Mean concentration for population j
p_i = Parameter value (e.g. concentration) at station i
w_i = Weighting for station i, equal to the inverse of the inclusion probability for the site
n = Number of stations sampled in population j

The ratio estimator was used in lieu of a stratified mean because an unknown fraction of each stratum was unsampleable (e.g., hard bottom). Thus, the estimated area, a random variable, was used as a divisor in place of the unknown true area. Standard error of the mean response was calculated as:

$$\text{Standard Error} = \sqrt{\frac{\sum_{i=1}^{n}\left((p_i - m)\bullet w_i\right)^2}{\left(\sum_{i=1}^{n} w_i\right)^2}}$$

Confidence intervals were calculated as 1.96 times the standard error. Statistical differences between populations of interest were defined on the basis of non-overlapping confidence intervals. Use of the ratio estimator for the standard error approximates joint inclusion probabilities among samples and assumes a negligible spatial covariance, an assumption that appears warranted based on preliminary examination of the data. The assumption, though, is conservative in that its violation would lead to an overestimate of the confidence interval (Stevens and Kincaid 1997).

The percent of area exceeding a selected threshold was estimated in the same fashion after converting the data to a binomial form. For any sample observation, p_i was 1 if it exceeded the threshold value and was 0 otherwise. The proportion of area that exceeded the selected threshold was taken as the mean of the indicator variable y_i.

The benthic data for a site were converted to binomial form using the Benthic Response Index (BRI). The BRI is a new index developed during the SCBPP (See Appendix E for details about development of the index and thresholds and index validation). The BRI is the abundance-weighted average pollution tolerance of species in a sample. Pollution tolerance was measured by determining the position of the species on a gradient between the most and least affected stations in an ordination space. If most of the species in a sample are those typically found at reference sites, the index score for the station is low. If most of the species are pollution tolerant, the index value for the station is high. For this assessment, the fractional area exceeding the reference threshold was determined for four biological response levels defined as: I) marginal deviation, a change in relative abundance of species; II) loss of biodiversity, the exclusion of sensitive species that often causes a change in species composition of the assemblage; III) loss of community function, where taxonomic groups, particularly arthropods and ophiuroids are, for the most part, excluded; and IV) defaunation, the exclusion of 90% of the species.

The BRI is designed to be a screening tool that discriminates disturbed and undisturbed communities and measures the magnitude of the disturbance. However, since benthic species respond in a similar manner to both natural and anthropogenic disturbances, it cannot be used to determine the source of the disturbance. For this reason, benthic communities that have index values above the reference threshold are called altered rather than impacted.

Hierarchical cluster analysis was used to group stations with similar species composition. Prior to cluster analysis, species occurring at fewer than 15 stations or with total abundance less than 50 individuals in the data set were eliminated (Smith 1976). In addition, potentially contaminated sites were eliminated from the data set so that only natural assemblages were identified. Potentially contaminated sites were identified as those with: 1) three or more chemicals exceeding Long *et al.* (1995) Effects Range Low (ER-L) values, 2) one or more chemicals exceeding Long *et al.* (1995) Effects Range Median (ER-M) values, 3) TOC greater than 2%, or 4) the sample was collected from the wastewater outfall, river discharge or Santa Monica Bay stratum.

Clusters were calculated using the flexible clustering method (Lance and Williams 1967, Clifford and Stephenson 1975), based on the Bray-Curtis dissimilarity index values (Bray and Curtis, 1957, Clifford and Stephenson 1975), with the variable clustering coefficient $b=-.25$. To produce more accurate dissimilarity values, the stepacross distance re-estimation procedure (Williamson 1978, Bradfield and Kenkel 1987) was applied to all dissimilarity values greater than 0.80. Data were transformed by a square root and standardized by the species mean of abundance values greater than zero (Smith 1976, Smith *et al*. 1988). Station groups were defined by inspection of the two-way table showing the coincidence between species abundances and the location of the station in the cluster group. Stations were identified as a group if most of the dominant species were limited to the station group. The two-way table will be available on SCCWRP's Web Site (www.sccwrp.org).

CHARACTERISTICS OF BENTHIC COMMUNITIES

COMMUNITY CHARACTERISTICS

An average of 85 taxa/sample, and 3850 individuals and 58 grams wet-weight biomass/m^2 was collected on the mainland shelf of the Bight (Table 1). Individuals were relatively evenly distributed among taxa; no one taxon was dominant. Average evenness for the Bight was 0.46. About half of the organisms in the Bight were annelids; 19, 13 and 10% were arthropods, ophiuroids and mollusks, respectively. Annelids and ophiuroids comprised 33% and 31% of the biomass; 15, 7 and 9% were mollusks, other phyla and arthropods.

Most community characteristics were not correlated with latitude (Table 2). Even where statistically significant relationships were found, correlations were relatively weak. The highest coefficient of determination (R^2) was 0.06, indicating that, at best, latitude explained 6% of the variance in the data. Evenness decreased and total biomass increased with latitude; however, the trends were not linear (Appendix F1). Evenness was generally lower north of the Palos Verdes Peninsula, ranging from 0.25-0.5, compared to 0.35-0.65 in the southern area. South of Dana Point biomass ranged from 10-100 gms wet weight/m^2. North of Dana Point there were samples with more than 150 gms wet weight/m^2. The proportion of annelids decreased and the proportion of ophiuroids and other echinoderms increased with increasing latitude (Appendix F2).

Although regressions between depth and community characteristics were significant for 13 out of 18 parameters, the relationships were relatively weak (Table 2). The number of taxa/sample, diversity, evenness and number of individuals/m^2 all significantly decreased with depth; dominance increased with depth (Appendix F4). For most of these measures, the range of values was lower in depths greater than 140 m than in shallower water. For example, the range in number of taxa/sample was 20-160 in less than 140 m and 20-80 in deeper water.

The proportion of the abundance comprised by annelids and ophiuroids increased and the proportion of arthropods and other phyla decreased with depth (Appendix F5). Ophiuroids always comprised less than 10% of the abundance in less than 25 m of water. Changes in biomass with depth were similar to changes in abundance; however, the trend for mollusks was statistically significant for biomass but not for abundance (Appendix F6).

The highest and lowest values for community characteristics were to some degree associated with particular geographic areas. The area between Point Conception and Santa Barbara had high species richness and low dominance (Appendix G1 and G3). Areas with low species richness and high dominance were found off of the Santa Clara and Ventura Rivers, in the central Santa Barbara Channel, and in central Santa Monica

Bay. The Palos Verdes Shelf had high species richness, as well as high abundance and biomass of organisms.

DOMINANT FAUNA

Sixteen taxa averaged 40 or more individuals/m^2 and occurred in at least 30% of the samples (Table 3). All but six of these taxa were polychaetes. The most common taxon was the polychaete *Spiophanes missionensis*, which was found in 94% of the samples. The polychaetes *Paraprionospio pinnata*, *Lumbrineris* spp., *Pectinaria californiensis,* and maldanid polychaetes occurred in more than 70% of the samples. The most abundant species were the polychaete *Spiophanes missionensis* and the ophiuroid *Amphiodia urtica,* which averaged 240-360 individuals/m^2. All other taxa averaged less than 100 individuals/m^2. A complete listing of taxa collected in the Bight is provided in Appendix H.

No indication of a latitudinal gradient was found in the distribution of most of these species (Table 4, Appendix I1). All taxa occurred throughout the Bight. However, the range in the abundance of some taxa, including the polychaetes *Paraprionospio pinnata*, *Lumbrineris* spp., *Sthenelanella uniformis,* and the amphipod *Amphideutopus oculatus,* was lower south of Solana Beach than further north.

The distribution of taxa did, however, vary with depth (Table 5, Appendix I2). The majority of the taxa, including the polychaetes *Spiophanes missionensis, Prionospio* sp. A, *Chloeia pinnata,* and *Sthenelanella uniformis,* the ophiuroid *Amphiodia urtica,* and phoronids in the genus *Phoronis*, were most abundant in 40-80 m of water. Several taxa were found mostly in shallow water. The amphipod *Amphideutopus oculatus,* the brachiopod *Glottidia albida* and the polychaete *Melinna oculata* were most abundant in 25-35 m and were rarely found in more than 50 m of water. The polychaete *Paraprionospio pinnata* was most abundant in 30 m of water, but was broadly distributed in deeper water as well. No taxa were restricted to deep water, although the highest abundances of the ostracod *Euphilomedes producta,* the polychaete *Pectinaria californiensis,* and the bivalve mollusk *Parvilucina tenuisculpta,* were found in more than 75 m of water.

Some species were not widespread, but were locally abundant; i.e., there were 1000 or more individuals/m^2 at an individual site (Table 6). The bivalve mollusks *Axinopsida serricata* and *Parvilucina tenuisculpta* were abundant in central Santa Monica Bay (Appendix J4 and J22). The polychaetes *Cossura* spp. and *Mediomastus* spp. were abundant off the Santa Clara and Ventura Rivers and in the northern Santa Barbara Channel, along with maldanid polychaetes (Appendix J7 and J15). The polychaetes *Myriochele* sp. M and *Myriochele gracilis* were common off Point Loma and in central Santa Monica Bay (Appendix J19 and J18). The polychaetes *Euchone incolor* and *Chone* sp. B were most abundant off Newport Beach near the County Sanitation Districts of Orange County outfall (Appendix J8 and J6). The polychaetes *Monticellina* *tesselata*, *Aphelochaeta marioni* and *Sthenelanella uniformis,* and the bivalve mollusk *Parvilucina tenuisculpta* were most abundant on the Palos Verdes Shelf near the County Sanitation Districts of Los Angeles County outfall (Appendix J17, J3, J28, and J22).

CHARACTERISTICS OF STATION GROUPS

Cluster analysis was used to define groups of stations with similar species composition. Since the objective was to define natural groupings, only stations geographically distant from anthropogenic activity were included in the analysis. The dendrogram produced by cluster analysis was divided into four major station groups. Each group was found in a different habitat, characterized by differences in depth and sediment grain size. Group 4 was the shallowest group, ranging in depth from 10-43 m. Group 3 occurred in mid-depth water, ranging in depth from 27-112 m. The depths of stations in groups 1 and 2 overlapped, ranging from 120-200 m and 87-200 m, respectively (Figure 3a).

While groups 1 and 2 overlapped in terms of depth, group 1 occurred in sediment with less than 40% fines and group 2 occurred in sediment with more than 40% fines. Sediment grain size of samples in groups 3 and 4 ranged from coarse to fine (Figure 3b). Groups 2, 3 and 4 were distributed throughout the Bight; however, group 1 was restricted to the northern Bight (Figure 3c).

Using a combination of depth and sediment grain size, distinct habitats were defined for each group (Figure 4, Table 7). Groups 1 and 2 were found in greater than 115 m of water in coarse and fine sediment, respectively. Group 4 was found in less than 30 m of water or in 30-45 m in coarse sediment. Group 3 was found in intermediate depths.

Stations in the deep coarse sediment group supported an assemblage characterized by the presence of the brittlestar *Amphiodia digitata,* the ostracod *Euphilomedes producta,* the polychaete *Decamastus gracilis,* the amphipod *Photis lacia,* and the cumacean *Eudorella pacifica* (Table 8). Within this group, there were an average of 87 taxa/sample, and 4000 individuals and 41 gms wet weight biomass/m^2 (Table 9). Annelids, arthropods and ophiuroids respectively comprised 42, 33 and 17% of the abundance, respectively. Annelids and arthropods comprised 29 and 43% of the biomass, respectively.

Stations in the deep fine sediment group supported an assemblage characterized by presence of the polychaetes *Levinsenia* spp., *Maldane sarsi, Cossura* spp. and *Laonice appelloefi* (Table 8). There was an average of 62 taxa/sample, and 2330 individuals and 44 gms wet weight biomass/m^2 (Table 9). Annelids comprised 64% and ophiuroids and arthropods 16 and 10% of the abundance, respectively.

Stations in the mid-depth group supported an assemblage characterized by the presence of the polychaetes *Sthenelanella uniformis, Paramage scutata, Glycera nana, Prionospio* sp. A and *Pholoe glabra,* the ostracod *Euphilomedes carcharodonta,* the bivalve mollusks *Parvilucina tenuisculpta* and *Tellina carpenteri,* the amphipods *Heterophoxus oculatus* and *Ampelisca pugetica,* the tanaid *Leptochelia dubia,* the isopod *Gnathia crenulatifrons,* the nemertean *Tubulanus polymorphus* and phoronids in the genus *Phoronis* (Table 8). There was an average of 101 taxa/sample, and 4910 individuals and 79 gms wet weight biomass/m^2 in this station group (Table 9). Annelids comprised 50% and arthropods and ophiuroids 17-18% of the abundance, respectively. Ophiuroids and annelids respectively comprised 41 and 31% of the biomass, respectively.

Stations in the shallow group supported an assemblage characterized by the presence of the amphipods *Amphideutopus oculatus, Ampelisca cristata,* and *Rhepoxynius menziesi,* the polychaetes *Spiophanes bombyx, Owenia collaris, Apoprionospio pygmaea, Ampharete labrops,* and *Amphicteis scaphobranchiata,* the brachiopod *Glottidia albida,* the bivalve mollusks *Tellina modesta* and *Macoma yoldiformis,* and the nemertean *Carinoma mutabilis* (Table 8). In this station group, there was an average of 76 taxa/sample, and 3120 individuals and 36 grams wet weight biomass/m^2 (Table 9). Annelids comprised 51% of the abundance. Arthropods, mollusks and other phyla comprised 21, 15 and 11% of the abundance, respectively. Annelids and mollusks comprised 35 and 31% of the biomass, respectively.

While the stations clustered into distinguishable groups that occupied distinct habitats, species were not restricted to a single group (Table 10). Over 60% of the species were found at least occasionally in all four groups. Some species, such as the polychaetes *Spiophanes missionensis* and *Paraprionospio pinnata*, were common and abundant (i.e., occurred in more than 60% of the samples with average abundance greater than 20/m^2) in all groups. The ophiuroid *Amphiodia urtica* and the polychaete *Pectinaria californiensis* were common and abundant in the middle and deep groups, but were found in less than 40% of the stations in the shallow group. Some species were more common in deeper water. The polychaete *Spiophanes fimbriata*, for example, occurred in approximately 90% of the deep stations, but only in 40 and 2% of the mid-depth and shallow stations, respectively. Other species were more common in shallow water. The amphipod *Amphideutopus oculatus*, for example, occurred in 55-68% of the mid-depth and shallow stations and in 0-12% of the deep stations.

ASSESSMENT OF BENTHIC INFAUNAL CONDITION

The assessment of infaunal condition was based on analysis of: 1) species composition, 2) community parameters (e.g., number of species) and 3) the Benthic Response Index (BRI). The BRI is the abundance-weighted average pollution tolerance of species in a sample. Pollution tolerance was measured by determining the position of a species on a gradient between the most and least affected stations in an ordination space. If most of the species in a sample are reference species, the index score for the station is low. If most of the species are pollution tolerant, the index value for the station is high. For this assessment, the percent of area exceeding the reference threshold of the BRI was determined for four levels of biological response: I) marginal deviation, a change in relative abundance of species; II) loss of biodiversity, the exclusion of sensitive species that often causes a change in species composition of the assemblage; III) loss of community function, the exclusion of groups of species, particularly arthropods and ophiuroids; and IV) defaunation, the exclusion of most species.

While the BRI measures changes in benthic communities caused by a disturbance, the BRI cannot be used to determine the source of the disturbance. Species respond in a similar manner to both natural and anthropogenic disturbances. For example, pollution tolerant species may colonize an area near a whale carcass as well as an area that is affected by a discharge from an outfall. For this reason, benthic communities that are determined to be altered or changed should not be assumed to be anthropogenically impacted.

THE BIGHT

Benthic communities in 91% of the mainland shelf of the Bight were classified as reference by the BRI (Figure 5). Eight percent of the area was within Response Level I; less than 2% of the area was categorized in Response Level II. No areas were found with index values in Response Levels III and IV.

Most stations classified in Response Levels I and II were located in the Santa Barbara Channel, near the mouth of the Santa Clara and Ventura Rivers, in central and northern Santa Monica Bay or on the Palos Verdes shelf (Figure 6). One station was located near the mouth of the Los Angeles River, one was near the Santa Ana River and one was at the head of the La Jolla Canyon.

SANTA MONICA BAY

Benthic communities were classified as reference by the BRI in 87% of Santa Monica Bay, compared to 92% of areas outside of Santa Monica Bay (Figure 5). Ten percent of Santa Monica Bay was classified in Response Level I and 2% in Response Level II.

The number of taxa, diversity and total abundance of organisms were lower in Santa Monica Bay than in other areas of the Bight; however, the differences were not large (Table 11). Annelids comprised less and mollusks more of the abundance in Santa Monica Bay than in other areas of the Bight.

Species composition of communities in Santa Monica Bay was generally similar to communities in other areas of the Bight (Table 12). However, the bivalve mollusk *Axinopsida serricata* was more abundant and the polychaete *Mediomastus* spp. was less abundant in Santa Monica Bay than elsewhere in the Bight.

POTW AREAS

Benthic communities were classified as reference by the BRI in 89% of POTW areas, compared to 92% of non-POTW areas (Figure 5). Eight percent of POTW areas were classified in Response Level I and 3% in Response Level II.

While the number of taxa was similar, dominance was higher and diversity lower in mid-depth POTW than in non-POTW areas; again, the difference was not large (Table 13). The proportion of the abundance comprised by annelids was higher and the proportion comprised by arthropods lower in POTW than in non-POTW areas.

Species composition of communities in mid-depth POTW and non-POTW areas was, for the most part, similar (Table 14). However, except for the polychaete *Mediomastus* spp., maldanid polychaetes, and the tanaid *Leptochelia dubia*, most species were more abundant in POTW than in non-POTW areas.

STORMWATER AREAS

Benthic communities in 60% of stormwater discharge areas were classified as reference by the BRI, compared to 87% of non-stormwater areas; 23 and 17% of the area were categorized in Response Levels I and II, respectively (Figure 5).

Diversity, abundance, and other characteristics of communities were similar in stormwater and non-stormwater areas (Table 15) The proportion of biomass contributed by mollusks was lower in stormwater discharge areas; however, the difference was small.

The species composition of communities in stormwater discharge areas was similar to the species composition in other shallow areas, in terms of frequency of occurrence. The average abundance most species was lower in stormwater discharge areas than in other shallow areas of the Bight (Table 16).

DISCUSSION

The results of the survey indicate that, on the whole, benthic communities on the mainland shelf of the Bight were healthy. Over 90% of the Bight was classified as reference.

In the areas that differed from reference, alterations to benthic communities were limited in magnitude. Eight percent of the mainland shelf of the Bight was classified in Response Level I, a marginal deviation from reference. Less than two percent of the mainland shelf of the Bight was classified in Response Level II and none of the mainland shelf was classified in Response Level III or IV.

While alterations to benthic communities were limited in 1994, both in extent and magnitude, this has not always been the case. Data from the NPDES monitoring program for the Joint Water Pollution Control Plant (JWPCP) show that in 1973, areas within 2 km of outfall were in Response Level IV. Only the most tolerant, specialized species could survive in the vicinity of the outfall (Figure 7). Other regions of the shelf were in Response Level III. Whole groups of organisms, particularly echinoderms and arthropods, were excluded from the area. Since arthropods are a primary prey item of many species of fish (Allen 1982), this level of impact may be associated with changes in fish populations. Monitoring data from 1973 showed that fish populations on the Palos Verdes Shelf were impacted (Allen 1977, Mearns *et al.* 1976, Stull 1995). By 1985, the area around the outfall was classified in Response Level III; marginal areas of the shelf were primarily in Response Level II. By 1990, most of the shelf was in Response Level II and, by 1994, most of the shelf was in Response Level I.

In the 1994 survey, there was more area with altered benthic communities stormwater areas (30%) than in Santa Monica Bay (13%), POTW areas (11%) or in the Bight as a whole (10%). The magnitude of alterations was limited as only 17% of the area was in Response Level II. Altered communities were found off the Santa Clara and Ventura Rivers, near Malibu Creek, the San Gabriel River, and the Santa Ana River. Given the location of the stations, it is probable that the stations were within the area of influence of the rivers. In the northern area, the stations with altered benthic communities were in an area known to be subject to sediment transport from the Santa Clara and Ventura Rivers (Drake *et al.* 1972, Kolpack and Drake 1985). After floods in the winter of 1969, a significant sand delta formed within 2 km of the mouths of the Ventura and Santa Clara Rivers. Sand and clay sized particles were also deposited in a wedge-shaped deposit, extending 2 km offshore, between Ventura and Santa Barbara. The deposit was gradually moved by wave action northward and offshore and in three years was removed from the shelf. Since the areas that were determined to be altered in 1994 were within the area of the initial wedge-shaped deposit, it is reasonable to assume they were within the area of influence of outflow from the rivers. The patterns of deposition of sediment from the Santa Ana and San Gabriel Rivers and Malibu Creek are not known, but since the stations were nearby, it is reasonable to expect that the affected stations were also within the area of influence of the outflow. However, it is not possible to conclude with the information in hand that the changes in benthic communities were caused by the rivers.

Another group of stations with altered benthic communities was located in Santa Monica Bay, between 60-200 m, near the City of Los Angeles' Hyperion Treatment Plant outfall, and on the Palos Verdes Shelf, near the Joint Water Pollution Control Plant outfall (Figure 6). The stations on the Palos Verdes Shelf are in an area known to be within the influence of the outfall (County Sanitation Districts of Los Angeles County 1996). The station in Santa Monica Bay that was immediately south of the five-mile outfall is known to be influenced by the outfall (City of Los Angeles 1995). The three stations to the west of the 7-mile outfall were not in an area that has been identified as influenced by either the 5-mile outfall or by historical discharge of sludge from the 7-mile outfall. However, two of the three stations were not within the City of Los Angeles' sampling grid (City of Los Angeles 1995).

Even though altered benthic communities were found in areas within the influence of municipal wastewater outfalls and stormwater runoff, little relationship was found between the level of biological response as measured by the BRI and concentration of chemicals in the sediment. If there were a strong relationship, then most stations with altered benthic communities should have sediment with elevated concentrations of at least one chemical; and most stations classified as reference should have sediment with background levels of contaminants in sediments. However, benthic communities are classified as reference by the BRI at many stations with one, two or three chemicals exceeding the Long *et al.* (1995) ER-M values, the concentrations which are expected to cause biological effects. The BRI value is above reference only when there are four chemicals above the ER-M (Figure 8).

The fact that normal benthic communities were found in sediment with high concentrations of chemicals may be attributed to any of several factors. First, the BRI may not be measuring biological response appropriately. Because the BRI is a new index that has not been used extensively, it is possible that effects are underestimated. We feel this is an unlikely explanation, though, because the index was validated with independent data and consistently reproduced gradients of effect that had been documented in other published reports about southern California benthos (Appendix E). In addition, samples with BRI values below the reference threshold had species that are usually found in undisturbed assemblages (Jones 1969, Thompson *et al.* 1987, 1993). Samples with BRI values in Response Level I and II had species that are not normally found in similar reference habitats. For example, the polychaetes *Cossura* sp. and *Mediomastus* sp. were dominant in disturbed shallow areas off the Santa Clara and Ventura Rivers. These polychaetes are uncommon in undistured shallow water areas.

Second, the Long et al. (1995) thresholds used to identify elevated concentrations may be inaccurate and/or imprecise. The three chemicals that constituted the greatest percentage of ER-M threshold exceedances in our survey (DDT, PCB and nickel) were chemicals for which Long *et al.'s* database for threshold development was the smallest. This explanation, though, also appears unlikely because Long *et al.* (in press) conducted a recent study evaluating the predictability of the thresholds using independent data from throughout the country and found that 84-100% of tests using more than one species showed toxicity when DDT, PCB, or nickel was higher than the ER-M.

Bulk sediment thresholds, such as the ER-L and ER-M values, can be confounded by binding factors in the sediment that sequester high concentrations and render the chemicals biologically unavailable. Some authors have suggested that equilibrium partitioning, in which chemical concentrations are normalized to potentially binding compounds, such as organic carbon (DiToro *et al.* 1991), is a more appropriate threshold development approach. The U.S. Environmental Protection Agency (U.S. EPA) has endorsed equilibrium partitioning in their development of national sediment quality criteria (U.S. EPA 1993a, b, c). Although EPA criteria are not yet available for DDT or PCB, MacDonald *et al.* (1994), Swartz *et al.* (1994), and Chapman (1996) have developed TOC-normalized DDT thresholds. When these criteria are applied, the frequency of threshold exceedances is similar to that using the ER-L thresholds (Schiff and Gossett 1997).

A fourth possible explanation for the lack of correlation is that organisms in the Bight have become adapted to high concentrations of chemicals in the sediment. The DDT concentrations in the Palos Verdes Shelf sediments are as high as any found in the United States (NOAA 1990) and the exposure period has exceeded three decades. Adaptation to local environmental stresses, with increased tolerance to individual pollutants, has been found in other areas where high concentrations of individual pollutants persist (Weis and Weis 1989). Adaptation does not explain all of the discrepancies between SCB pollutant exposure and biological response, as we found high survival in amphipod toxicity tests conducted with non-native test organisms at some of SCB high DDT sites (Bay 1996); however, it is a testable hypothesis that deserves further investigation.

In areas with altered benthic communities and low concentrations of chemicals in the sediment, it is possible that whatever is causing the disturbance occurs intermittently and/or is not captured in the measured sediment chemistry. These disturbances could be natural or anthropogenic. For example, disturbances to benthic communities near the mouths of rivers and stormdrains may occur during the winter. Sediment contaminated with pesticides, petroleum products and/or other contaminants may be deposited near the mouths of rivers and stormdrains during runoff events. The deposit would likely be transient, since wave action suspends and resuspends smaller particles and removes them to deeper depositional sites. The disturbance may, in fact, be natural. Freshwater runoff carrying a heavy load of fine particulate matter may reduce the salinity of the water, smother benthic infauna or change the texture of sediments in the vicinity of the river mouth. Away from river mouths, there are many factors, both anthropogenic and natural, that may disturb benthic communities. For instance, bottoms may be disturbed by storms, trawls or boat anchors, or by the feeding activities of whales and fish (VanBlaricom 1982; Oliver *et al.* 1983). All these disturbances will not be reflected in the measured sediment chemistry.

While it is not possible to pinpoint causes, the geographic distribution of altered sites suggests that stormwater runoff may have had an effect on benthic communities near the mouths of Malibu Creek, the San Gabriel and Santa Ana Rivers and in the inshore area between Ventura and Santa Barbara. The Palos Verdes Shelf and a small area of Santa Monica Bay are affected by discharges from POTWs. Ninety percent of the mainland shelf of the Bight is undisturbed.

CONCLUSIONS

1) Most of the mainland shelf of the Southern California Bight had healthy benthic communities.

- Benthic communities in 91% of the Bight were classified as reference by the Benthic Response Index (BRI).

2) When found, alterations to benthic communities were limited in magnitude.

- Less than 2% of the Bight was classified by the BRI in Response Level II. No areas were found with BRI values in Response Levels III or IV.

3) The condition of benthic communities in Santa Monica Bay was similar to other areas of the Bight.

- Benthic communities were classified by the BRI as reference in 87% of Santa Monica Bay, compared to 92% of areas outside of Santa Monica Bay; 2% of Santa Monica Bay was classified in Response Level II.

- The number of taxa and total abundance of organisms was lower in Santa Monica Bay than in other areas of the Bight, but the difference was small.

- Species composition in Santa Monica Bay was similar to other areas of the Bight.

4) The condition of benthic communities in POTW areas was similar to other areas of the Bight.

- Eighty-nine percent of POTW areas were classified by the BRI as reference compared to 92% of non-POTW areas; 3% of POTW areas were classified in Response Level II.

- While the number of taxa were similar, dominance was higher and diversity lower in POTW than in non-POTW areas. The difference was small.

- Species composition in POTW areas was similar to other areas of the Bight; however, most species were more abundant in POTW areas.

5) More area was altered in stormwater areas than in the Bight as a whole; however, changes in benthic communities were small. The changes may be caused by natural and/or anthropogenic factors.

- Sixty percent of stormwater areas were classified by the BRI as reference, compared to 87% of non-stormwater areas; 17% of stormwater areas were classified in Response Level II.

- The number of taxa, total abundance of organisms and other community characteristics were similar in stormwater and non-stormwater areas.

- Species composition was similar in stormwater and non-stormwater areas; however, the abundance of many species was lower in stormwater areas than in other areas of the Bight.

RECOMMENDATIONS

The SCBPP successfully achieved its objective to measure the magnitude and extent of alterations in benthic infaunal communities on the mainland shelf of the Bight. The BRI was used to differentiate disturbed and undisturbed communities and to quantitatively measure the magnitude of the disturbances. The survey also provided detailed descriptions of infaunal communities, including species composition and community statistics such as diversity and abundance. This information can be used to evaluate the condition of infaunal communities in the Bight and in site-specific programs.

While the SCBPP provided useful information on the current conditions of the Bight, these conditions are not static. Regional climatic events, such as El Niños, can affect benthic communities. Inputs from anthropogenic sources may increase or decrease over time. Since benthic communities will change in response to regional climatic events and changes in anthropogenic inputs, we recommend that future surveys should be conducted to assess the health of benthic communities in the Bight. These surveys will provide up-to-date baseline information that can be used in site-specific monitoring programs to evaluate the magnitude of local changes in benthic communities. The surveys will also provide information that can be used by environmental managers to evaluate the efficacy of regulations and best management practices in reducing impacts on benthic communities, both in local areas and in the Bight as a whole.

In order to improve upon the success of the SCBPP, we recommend that the following measures be implemented prior to future surveys:

1. **Include measurement of temporal trends in the design of future regional surveys.** For reasons stated above, we recommend that conditions in the Bight be measured over time to determine whether conditions are improving or declining. Repeated surveys will provide the opportunity to measure temporal change by revisiting a selected subset of stations sampled in 1994 and/or by revisiting stations sampled by SCCWRP 1977, 1985 and 1990.

2. **Eliminate biomass as an indicator.** In the SCBPP, biomass was estimated for groups of species. Given the number of taxa and small size of most individuals in each sample, it was not practical to weigh individual taxa. Since these taxonomic groups include a wide range of species, the taxonomic composition and weight of the group is inherently variable. In addition, the grouping provides information about biological processes and impacts only inasmuch as the processes and impacts are manifested at higher taxonomic levels. Measuring biomass takes time and effort and adds a step to sample processing that can contribute to damage and loss of specimens. Since the infaunal working group did not find that the data for biomass materially added to the understanding of communitiess or impacts, the expenditure of resources

to measure biomass does not seem warranted.

3. **Continue to develop the Benthic Response Index.** The Benthic Response Index (BRI) was developed as a assessment tool for the SCBPP. It was applied to the data and successfully used to assess the condition of benthic communites in the Bight. While the BRI can, at present, be used for other data and other programs, it can be improved. The infaunal working group would like to see additional work done to improve the application of the BRI to shallow water communities. While sufficient, the amount of data for impacted areas in shallow water was less than optimal for index development. In order to ensure the robustness of the index, more data should be collected and the index recalibrated. In addition, the BRI should be extended so that it can be applied in bays and harbors.

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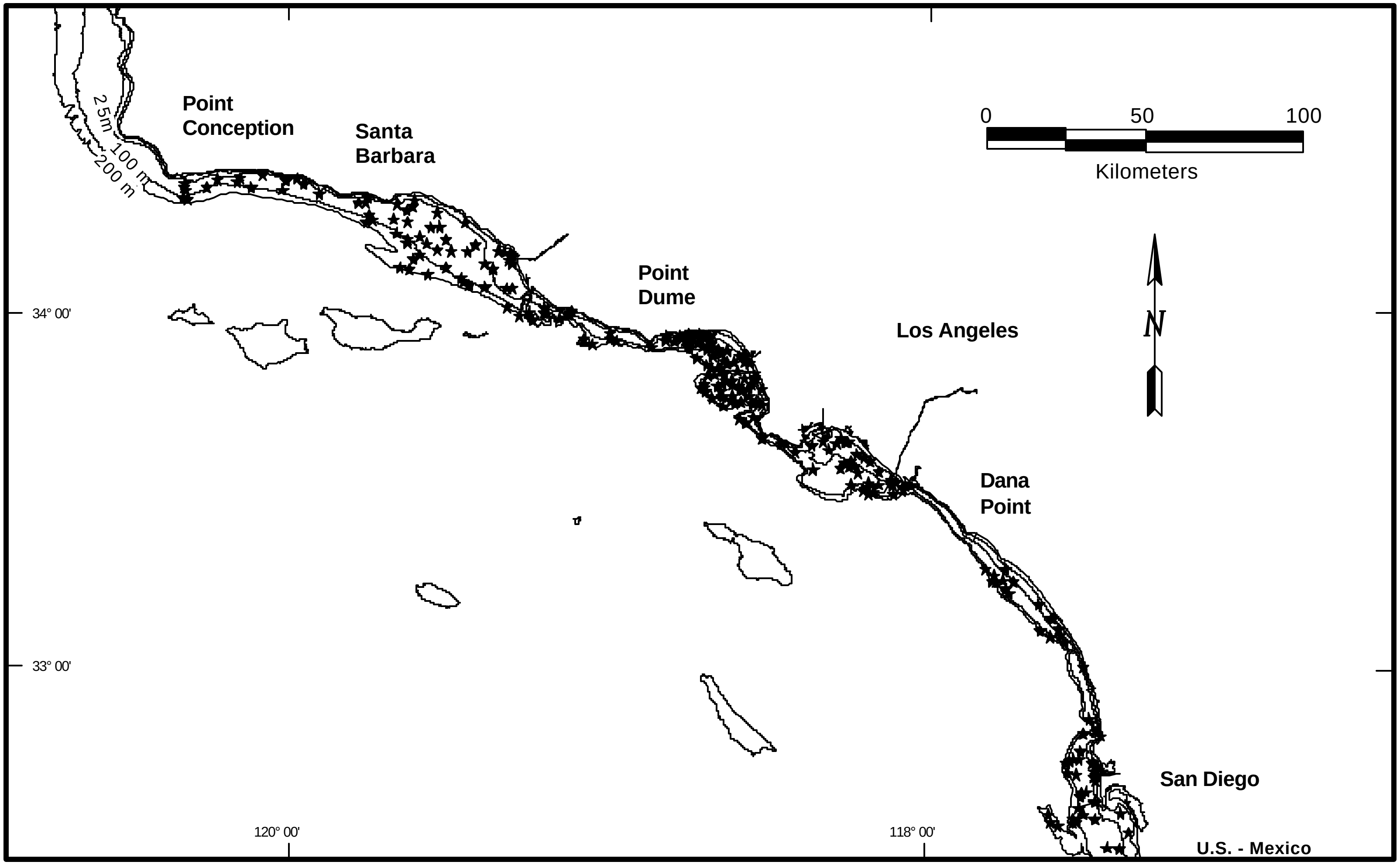

Figure 1. Location of benthic infaunal stations sampled on the mainland shelf of southern California (N=251).

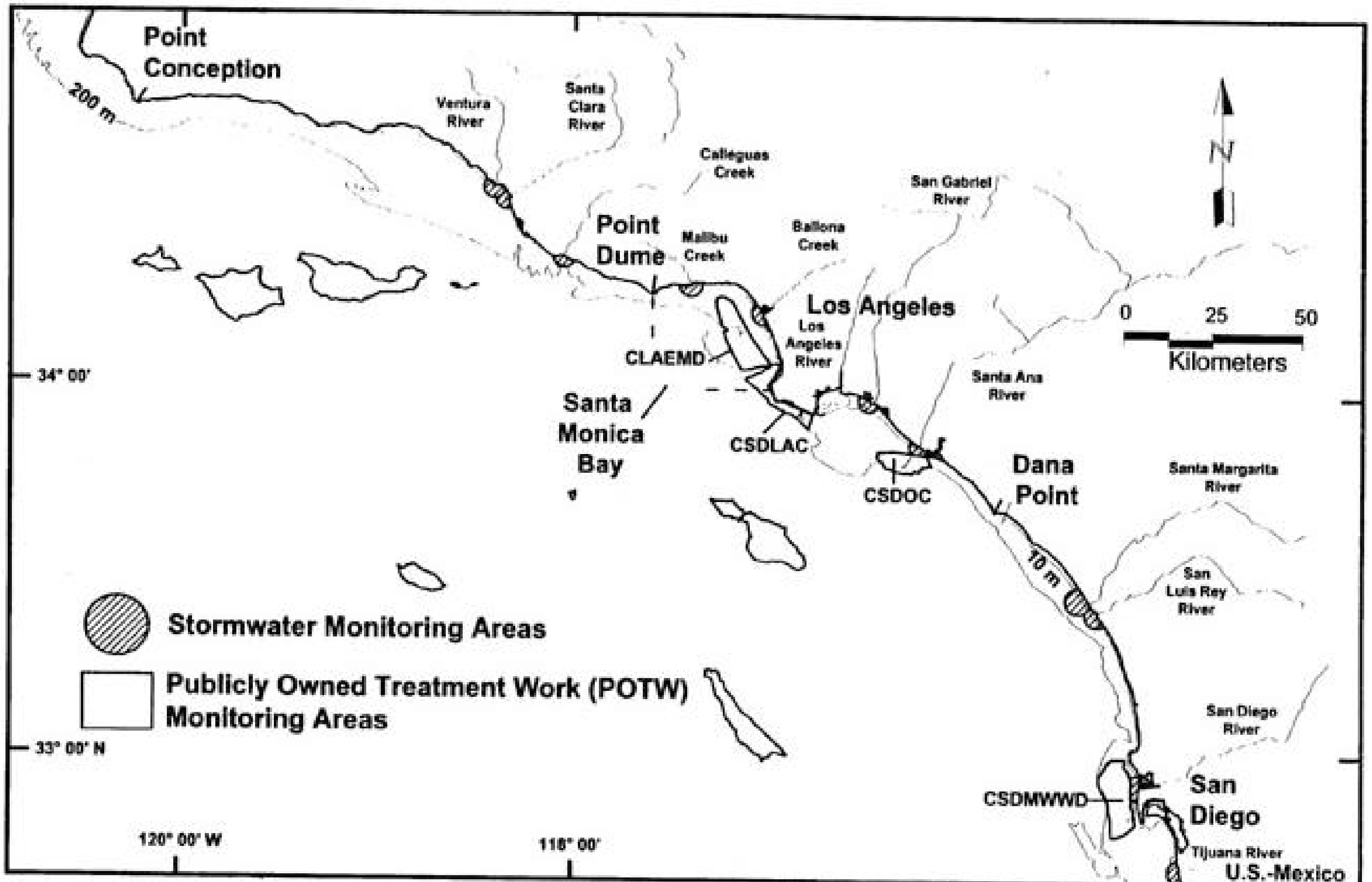

Figure 2a. Location of strata for input sources sampled in the Southern California Bight Pilot Project. Publicly owned treatment works include City of Los Angeles (CLAEMD), County Sanitation Districts of Los Angeles County (CSDLAC), County Sanitation Districts of Orange County (CSDOC), and the City of San Diego (CSDMWWD).

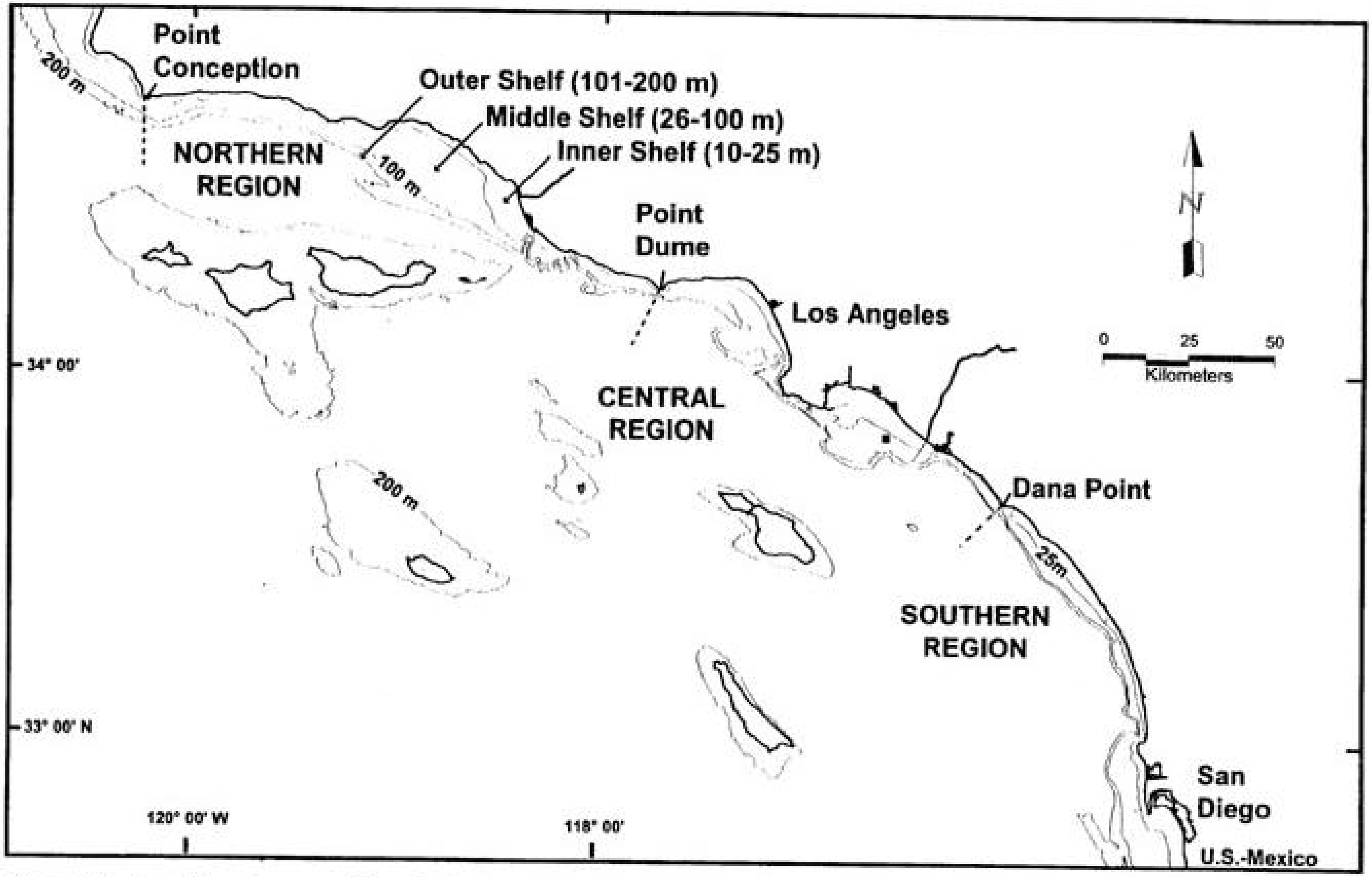

Figure 2b. Location of geographic and depth zones sampled in the Southern California Bight Pilot Project.

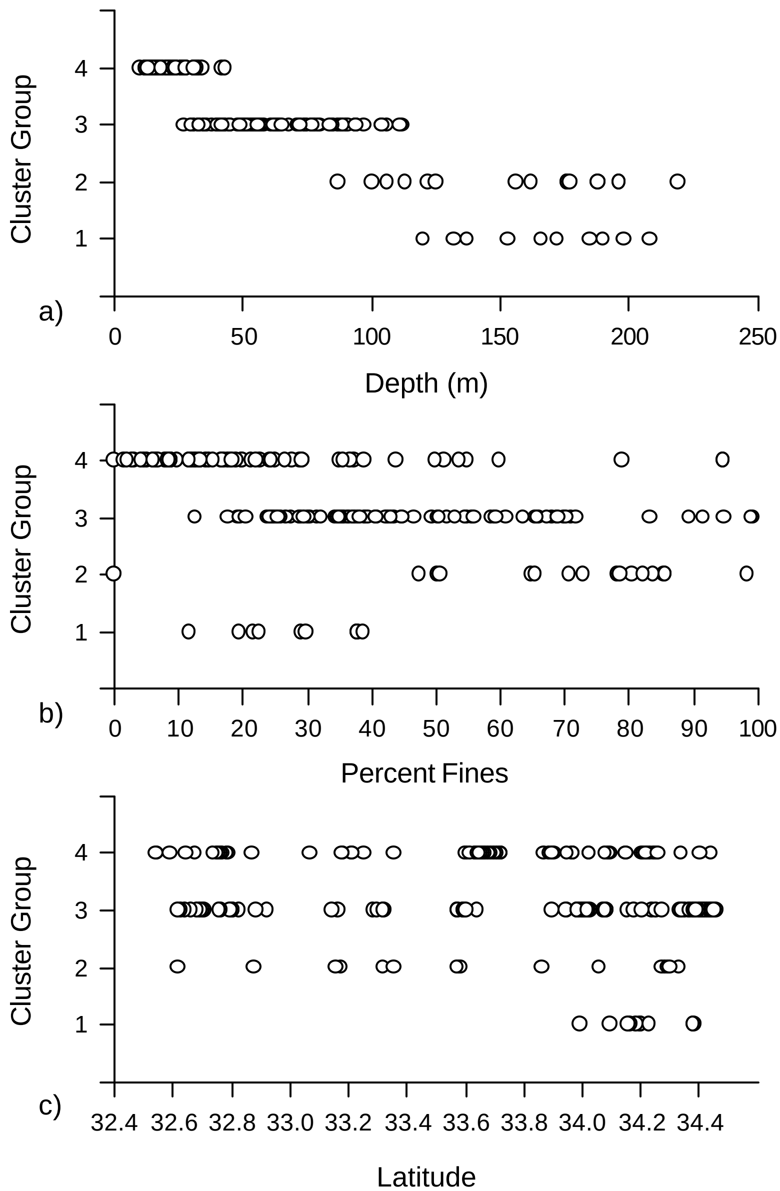

Figure 3. Distribution of samples in each cluster group versus: a) depth, b) percent fines and c) latitude.

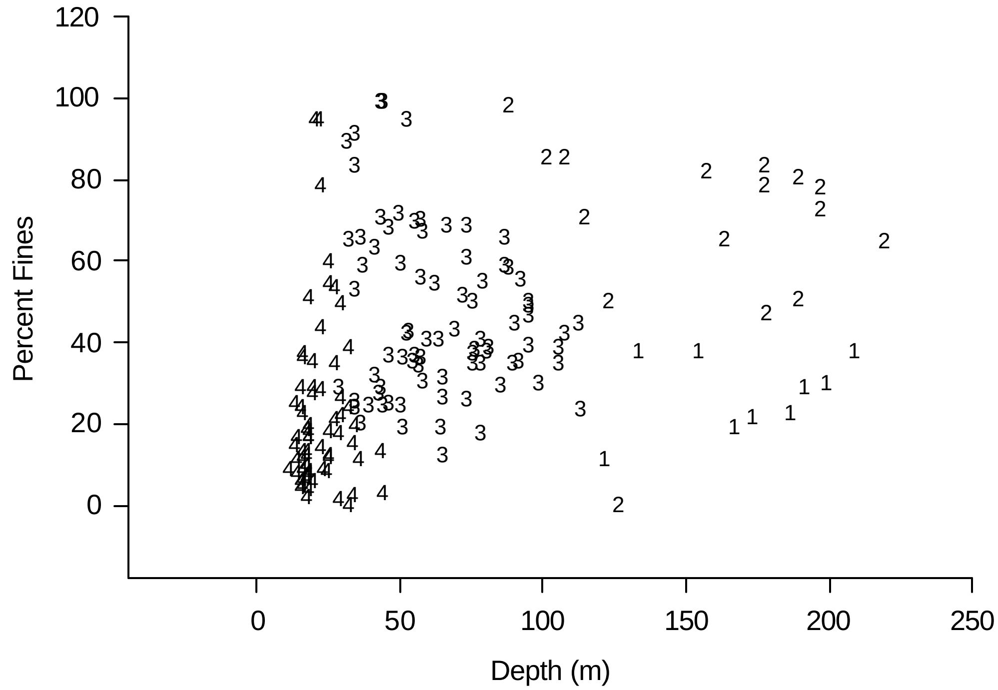

Figure 4. Distribution of cluster groups (1-4) relative to depth and sediment grain size.

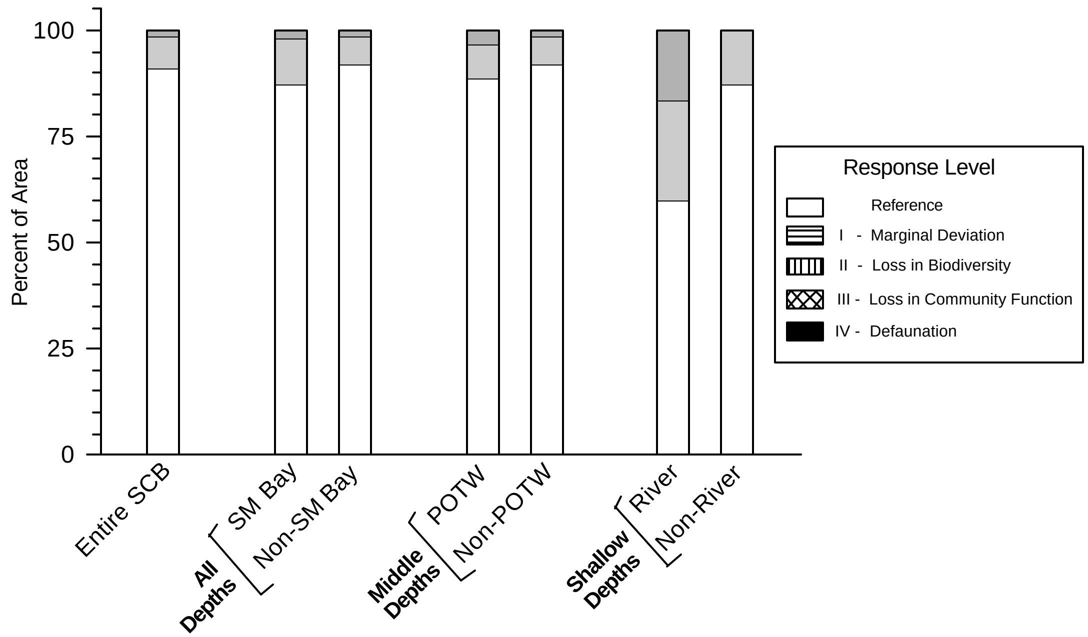

Figure 5. Percent of area that is reference or altered in subpopulations of interest in the Southern California Bight.

32

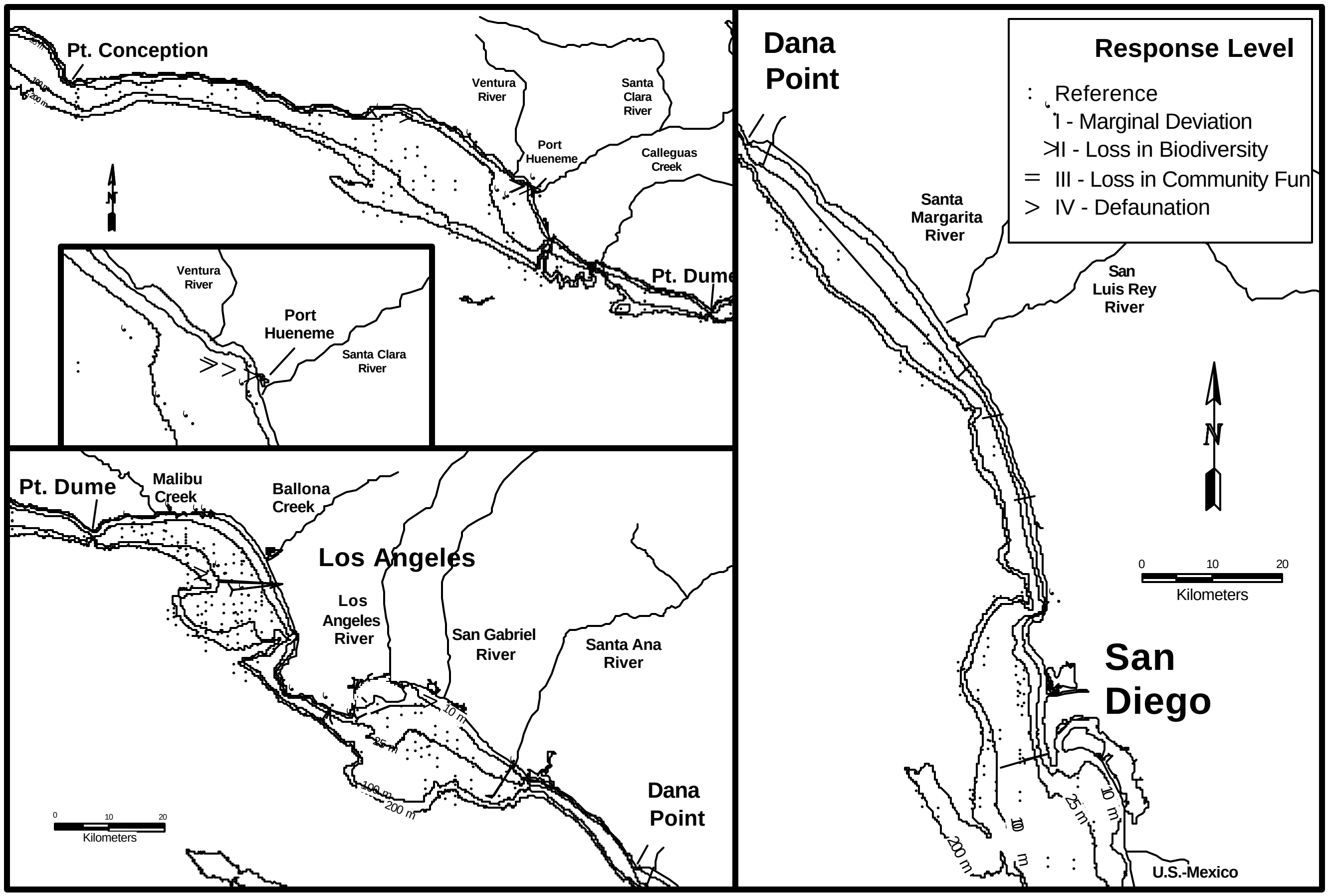

Figure 6. Stations measured as reference or altered on the mainland shelf of southern California.

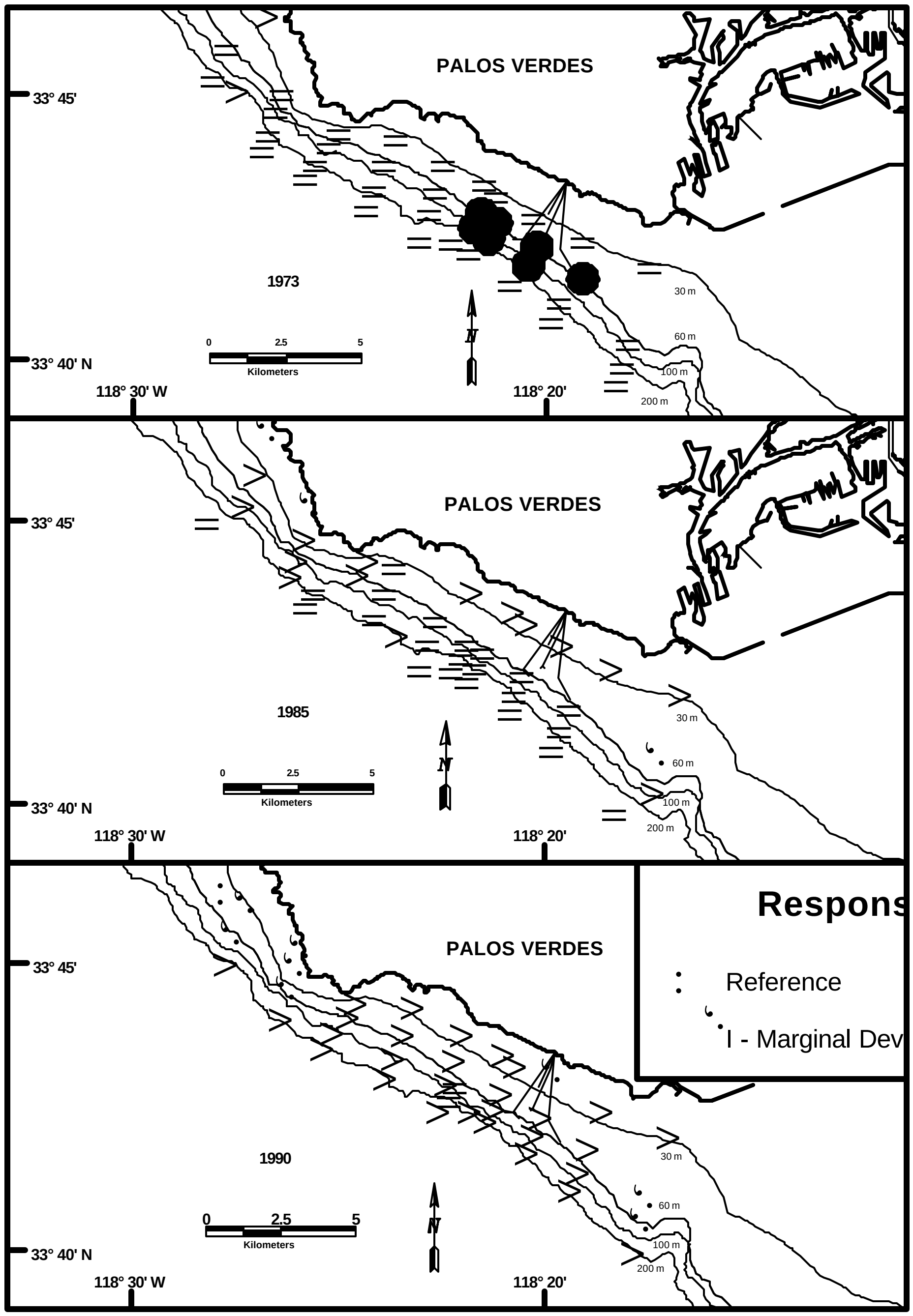

Figure 7. Response levels measured by the Benthic Response Index on the Palos Verdes Shelf for the years 1973, 1985, and 1990.

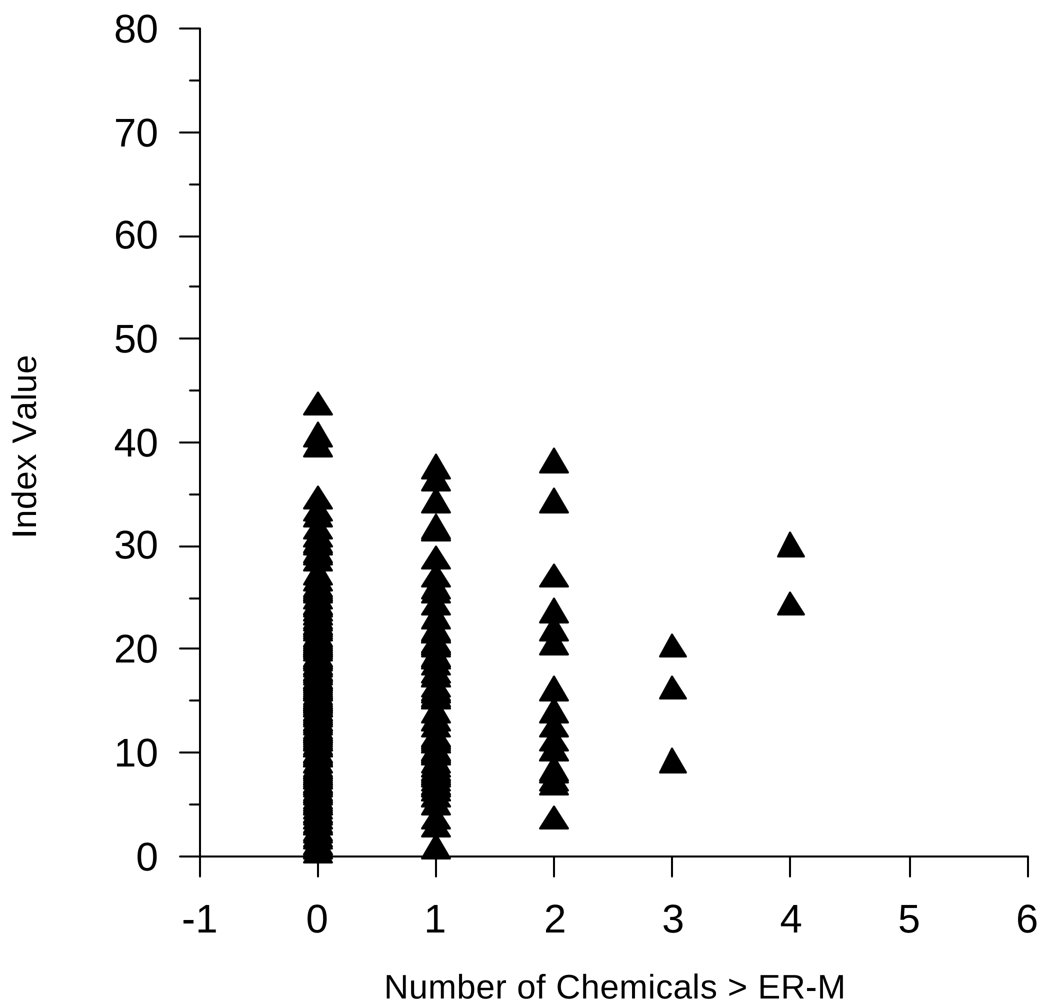

Figure 8. Benthic Response Index values at Southern California Bight Pilot Project stations compared to number of chemicals that exceed Long *et al.* (1995) Effects Range Median values.

Table 1. Community characteristics in the Southern California Bight . All values are area weighted.

Characteristic	Area Weighted Mean	95%CL	StdDev	Minimum	25% ile	Median	75% ile	Maximum
Number of Taxa / sample	84.5	4.7	31.1	18.0	60.1	79.9	104.8	162.0
Shannon-Wiener Diversity Index (H')	3.6	0.1	0.4	2.0	3.4	3.6	3.9	4.4
Dominance	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.3
Evenness	0.5	0.0	0.1	0.2	0.4	0.4	0.5	0.9
Total Abundance / m^2	3851.9	325.2	2285.3	350.0	2158.8	3492.6	4850.8	16960.0
Percent Abundance as:								
Annelida	50.5	2.0	13.7	11.2	41.6	51.4	59.4	87.4
Arthropoda	19.4	1.6	10.5	1.1	11.8	17.5	24.4	52.3
Ophiuroidea	12.6	1.8	12.4	0.0	2.1	8.6	21.0	71.3
Misc. Echinodermata	0.7	0.2	1.1	0.0	0.0	0.4	0.8	10.4
Mollusca	9.6	1.1	8.8	1.2	3.7	7.3	11.9	71.3
Other Phyla	7.0	0.9	6.2	0.0	2.5	5.7	9.3	47.2
Total Biomass (gms wet weight / m^2)	57.9	6.5	44.4	6.0	27.8	47.5	76.6	350.0
Percent Biomass as:								
Annelida	33.1	2.3	16.7	3.3	20.4	29.7	42.7	95.4
Arthropoda	6.5	1.0	7.2	0.3	2.7	4.3	7.6	60.6
Ophiuroidea	31.1	3.4	23.6	0.0	7.3	29.0	48.5	89.1
Misc. Echinodermata	5.0	1.1	8.4	0.0	0.0	1.8	5.0	83.3
Mollusca	15.1	2.3	15.8	0.9	3.4	8.2	22.2	88.9
Other Phyla	9.2	1.7	11.0	0.0	2.9	5.1	11.0	88.3

Table 2. Coefficients of determination (r^2) for regressions between community characteristics and latitude and depth. Coefficients that are statistically significant ($p < 0.05$) are bolded.

Characteristic	Correlation with latitude	Correlation with depth
Number of Taxa / sample	0.01	**0.03**
Shannon-Wiener Diversity Index (H')	0.00	**0.04**
Dominance	0.00	**0.02**
Evenness	**0.02**	**0.02**
Total Abundance / m^2	0.00	**0.02**
Percent of Abundance as:		
Annelida	**0.04**	**0.03**
Arthropoda	0.00	**0.02**
Ophiuroidea	**0.02**	**0.03**
Misc. Echinodermata	**0.03**	0.00
Mollusca	0.00	0.00
Other Phyla	0.01	**0.26**
Total Biomass (gms wet weight) / m^2	**0.06**	0.00
Percent of Biomass as:		
Annelida	0.00	**0.02**
Arthropoda	0.01	**0.07**
Ophiuroidea	0.00	**0.06**
Misc. Echinodermata	**0.03**	0.00
Mollusca	0.00	**0.03**
Other Phyla	**0.02**	**0.07**

Table 3. Species with frequency of occurrence greater than 30% and average abundance greater than 40 / m^2 in the Southern California Bight.

Species	Taxonomic Group	Frequenc Percent	Average Abundance (Number /
Spiophanes missionensis	Annelida	94.0	361
Paraprionospio pinnata	Annelida	85.2	61
***Lumbrineris* spp.**	Annelida	79.7	55
Maldanidae*	Annelida	76.1	91
Pectinaria californiensis	Annelida	72.5	62
***Mediomastus* spp.**	Annelida	68.5	88
Amphiodia urtica	Ophiuroidea	65.7	239
***Prionospio* sp. A**	Annelida	64.1	46
Parvilucina tenuisculpta	Mollusca	61.8	41
***Phoronis* sp.**	Phoronida	61.4	47
Sthenelanella uniformis	Annelida	51.4	44
Amphideutopus oculatus	Arthropoda	47.8	56
Glottidia albida	Brachiopoda	45.4	44
Chloeia pinnata	Annelida	40.2	41
Euphilomedes producta	Arthropoda	31.9	51
Melinna oculata	Annelida	31.5	42

*** all Maldanids except 11 identified species (See Appendix H)**

Table 4. Distribution of species relative to latitude. The latitude at 10, 50, and 90 percentiles of the abundance for each species are shown. Latitude is expressed as decimal degrees.

Species	Taxonomic Group	Percentile Abundance Latitude at 10%	50%	90%
Glottidia albida	Brachiopoda	33.59	33.67	34.07
Melinna oculata	Annelida	33.33	33.68	33.96
***Lumbrineris* spp.**	Annelida	33.25	33.83	34.33
***Phoronis* sp.**	Phoronida	32.87	33.85	34.42
Paraprionospio pinnata	Annelida	33.40	33.85	34.23
Pectinaria californiensis	Annelida	32.77	33.87	34.34
Spiophanes missionensis	Annelida	32.80	33.87	34.38
Sthenelanella uniformis	Annelida	33.58	33.87	34.42
Chloeia pinnata	Annelida	32.76	33.88	34.18
***Prionospio* sp. A**	Annelida	33.25	33.89	34.41
Parvilucina tenuisculpta	Mollusca	33.59	33.92	34.42
Maldanidae*	Annelida	33.28	33.95	34.40
Amphideutopus oculatus	Arthropoda	33.59	33.95	34.26
Amphiodia urtica	Ophiuroidea	32.76	33.99	34.34
Euphilomedes producta	Arthropoda	32.79	33.99	34.21
***Mediomastus* spp.**	Annelida	33.21	34.07	34.41

*** all Maldanids except 11 identified species (See Appendix H)**

Table 5. Distribution of species relative to depth (m). The depth at 10, 50 and 90 percentiles of the abundance for each species are shown.

Species	Taxonomic Group	Percentile Abundance Depth (m) at 10%	50%	90%
Amphideutopus oculatus	Arthropoda	17	27	47
Glottidia albida	Brachiopoda	16	31	45
Paraprionospio pinnata	Annelida	15	33	127
Melinna oculata	Annelida	22	34	64
Maldanidae*	Annelida	18	42	110
***Phoronis* sp.**	Phoronida	22	49	75
Sthenelanella uniformis	Annelida	31	50	81
***Mediomastus* spp.**	Annelida	21	57	136
***Lumbrineris* spp.**	Annelida	16	60	156
***Prionospio* sp. A**	Annelida	28	60	111
Amphiodia urtica	Ophiuroidea	42	69	100
Spiophanes missionensis	Annelida	34	70	120
Chloeia pinnata	Annelida	53	75	152
Euphilomedes producta	Arthropoda	71	94	171
Pectinaria californiensis	Annelida	45	99	197
Parvilucina tenuisculpta	Mollusca	31	104	152

*** all Maldanids except 11 identified species (See Appendix H)**

Table 6. Species with frequency of occurrence less than 30% or average abundance less than 40 / m^2 that occurred at least once with abundance greater than 1000 / m^2.

Species	Taxonomic Group	Number of Samples	Maximum Abundance (Number /
Euphilomedes carcharodonta	Arthropoda	121	1030
Axinopsida serricata	Mollusca	112	1950
***Cossura* spp.**	Annelida	108	2470
Spiophanes bombyx	Annelida	77	1700
***Myriochele* sp. M**	Annelida	68	5690
Myriochele gracilis	Annelida	67	1080
Euchone incolor	Annelida	66	1580
Monticellina tesselata	Annelida	56	2230
***Chone* sp. B**	Annelida	33	1400
Nephasoma diaphanes	Other Phyla	13	2310
Gammaropsis ociosa	Arthropoda	13	1050
Aphelochaeta marioni	Annelida	9	3290

Table 7. Definitions of habitat based on depth and sediment grain size for cluster groups 1-4.

Cluster Group	Habitat Definition	Percent Stations Included in Definition
1	>115 m and fines <40%	100.0
2	>115 m and fines >40% or 80-115 m and fines >70%	93.8
3	30-45 m and fines >20% or 45-80 m or 80-115 and fines <70%	98.8
4	<30 m or 30-45 m and fines <20%	97.0

Table 8. Average abundance of species with frequency of occurrence greater than 60% and average abundance of at least 20 / m^2 in each cluster group. All values are area weighted.

Species	Taxonomic Group	Average Abundance (Number / m^2) Cluster Group 1 Deep	2 Deep	3 Mid-	4 Shallow
Spiophanes missionensis	Annelida	386.0	195.0	563.2	132.2
Amphiodia digitata	Ophiuroidea	236.0			
Euphilomedes producta	Arthropoda	215.0			
***Mediomastus* spp.**	Annelida	168.0	71.6	117.8	76.2
Chloeia pinnata	Annelida	100.0			
Amphiodia urtica	Ophiuroidea	83.0	263.2	422.0	
Spiophanes fimbriata	Annelida	82.0	149.7		
Ampelisca careyi	Arthropoda	69.0	21.0		
Photis lacia	Arthropoda	69.0			
Rhepoxynius bicuspidatus	Arthropoda	59.0		43.0	
Maldanidae*	Annelida	51.0	91.5	105.0	127.9
Pectinaria californiensis	Annelida	50.0	91.1	85.3	
Eudorella pacifica	Arthropoda	35.0			
***Lumbrineris* spp.**	Annelida	35.0	94.0	50.8	57.5
Paraprionospio pinnata	Annelida	33.0	47.8	45.4	108.9
***Euclymeninae* sp. A**	Annelida	31.0		28.2	
Decamastus gracilis	Annelida	21.0			
Terebellides californica	Annelida		23.0	20.2	
***Levinsenia* spp.**	Annelida		30.3		
***Cossura* spp.**	Annelida		26.9		
Maldane sarsi	Annelida		34.0		
Laonice appelloefi	Annelida		21.8		
Sthenelanella uniformis	Annelida			84.2	
***Phoronis* sp.**	Phoronida			77.9	
***Prionospio* sp. A**	Annelida			76.4	
Ampelisca brevisimulata	Arthropoda			50.2	31.6
Euphilomedes carcharodonta	Arthropoda			47.5	
Paramage scutata	Annelida			46.4	
Parvilucina tenuisculpta	Mollusca			44.0	
Leptochelia dubia	Arthropoda			42.3	
Heterophoxus oculatus	Arthropoda			37.6	
Pholoe glabra	Annelida			28.0	
Glycera nana	Annelida			26.7	
Tellina carpenteri	Mollusca			24.4	
Gnathia crenulatifrons	Arthropoda			24.2	
Tubulanus polymorphus	Nemertea			23.2	
Ampelisca pugetica	Arthropoda			22.2	
Spiophanes bombyx	Annelida				82.6
Tellina modesta	Mollusca				50.8
Glottidia albida	Brachiopoda				90.3
Ampelisca cristata	Arthropoda				65.1
Apoprionospio pygmaea	Annelida				50.0

*** all Maldanids except 11 identified species (See Appendix H)**

Table 8 continued.

Species	Taxonomic Group	Average Abundance (Number / m²) Cluster Group 1 Deep	2 Deep	3 Mid-	4 Shallow
Owenia collaris	Annelida				44.7
Ampharete labrops	Annelida				23.4
Amphideutopus oculatus	Arthropoda				132.9
Lineidae	Nemertea				20.3
Macoma yoldiformis	Mollusca				54.8
Carinoma mutabilis	Nemertea				24.3
Rhepoxynius menziesi	Arthropoda				22.2
Amphicteis	Annelida				24.8

Table 9. Community characteristics of the four cluster groups. All values are area weighted. CI = Confidence interval.

Characteristic	Cluster Group 1 Deep Coarse n = 10 Mean	(95% CI)	2 Deep Fine n = 16 Mean	(95% CI)	3 Mid-depth n = 81 Mean	(95% CI)	4 Shallow n = 66 Mean	(95% CI)
Number of Taxa / sample	86.6	24.0	61.6	7.0	101.0	6.6	75.9	7.9
Shannon-Wiener Diversity Index (H')	3.6	0.2	3.4	0.2	3.7	0.1	3.6	0.1
Dominance	0.1	0.0	0.1	0.0	0.1	0.0	0.1	0.0
Evenness	0.4	0.0	0.4	0.0	0.5	0.0	0.5	0.0
Total Abundance / m^2	4005.0	1727.4	2329.8	539.2	4908.2	464.0	3121.5	597.8
Percent Abundance as:								
Annelida	41.8	6.6	63.6	8.2	50.0	2.9	51.0	3.5
Arthropoda	33.3	6.3	10.4	3.1	18.1	1.8	20.9	3.4
Ophiuroidea	16.8	4.1	15.7	15.7	17.1	2.6	1.9	0.7
Misc. Echinodermata	1.0	0.4	1.1	1.2	0.5	0.1	0.9	0.3
Mollusca	4.1	1.5	5.7	1.9	6.9	1.0	14.6	2.7
Other Phyla	2.2	1.0	3.2	2.0	7.2	1.2	10.6	1.5
Total Biomass (gms wet weight / m^2)	41.0	15.3	44.3	10.6	79.4	12.2	35.9	8.6
Percent Biomass as:								
Annelida	28.5	7.3	44.6	9.7	30.9	3.8	34.8	4.4
Arthropoda	8.1	4.7	3.0	0.8	3.9	0.5	10.6	1.8
Ophiuroidea	43.2	8.2	34.0	0.8	41.1	5.2	8.0	2.6
Misc. Echinodermata	9.1	6.0	1.4	1.1	4.3	1.8	5.3	1.8
Mollusca	7.8	3.7	12.8	6.8	6.9	1.5	31.5	5.0
Other Phyla	3.4	1.6	3.6	1.2	12.9	3.6	9.8	2.5

Table 10. Frequency of occurrence and range of abundance (number / m², excluding 0's) of all species in Table 8.

Species	Group 1		Group 2		Group 3		Group 4	
	Frequency (Percent)	Range (Number/m²)	Frequency (Percent)	Range (Number/m²)	Frequency (Percent)	Range (Number/m²)	Frequency (Percent)	Range (Number/m²)
Spiophanes missionensis	100.0	20 - 2210	87.5	10 - 790	100.0	20 - 2470	87.9	10 - 910
Amphiodia digitata	100.0	70 - 470	25.0	20 - 70	50.6	10 - 480	21.2	10 - 140
Euphilomedes producta	90.0	20 - 950	43.8	10 - 20	39.5	10 - 1070	1.5	30
Mediomastus sp.	100.0	10 - 670	68.8	10 - 330	76.5	10 - 1680	62.1	10 - 1110
Chloeia pinnata	90.0	10 - 290	62.5	10 - 60	48.1	10 - 650	6.1	10 - 270
Amphiodia urtica	70.0	20 - 350	81.3	20 - 820	96.3	10 - 1420	16.7	10 - 500
Spiophanes fimbriata	90.0	10 - 280	87.5	10 - 420	40.7	10 - 280	1.5	10
Ampelisca careyi	100.0	10 - 310	87.5	10 - 60	67.9	10 - 140	4.5	10
Photis lacia	70.0	10 - 310		-	19.8	10 - 180	1.5	10
Rhepoxynius bicuspidatus	80.0	20 - 200	12.5	10 - 30	65.4	10 - 230	4.5	10 - 30
Maldanidae*	80.0	20 - 180	93.8	10 - 270	86.4	10 - 570	69.7	10 - 680
Pectinaria californiensis	80.0	10 - 160	100.0	10 - 490	92.6	10 - 490	37.9	10 - 170
Eudorella pacifica	100.0	10 - 60	56.3	10 - 50	37.0	10 - 90		-
Lumbrineris sp.	90.0	20 - 60	93.8	20 - 190	79.0	10 - 260	71.2	10 - 210
Paraprionospio pinnata	80.0	10 - 100	100.0	10 - 260	85.2	10 - 270	86.4	10 - 410
Euclymeninae sp. A	70.0	10 - 100	37.5	10 - 50	67.9	10 - 180	31.8	10 - 120
Decamastus gracilis	100.0	10 - 50	25.0	10 - 170	13.6	10 - 20		-
Terebellides californica	30.0	10 - 30	75.0	10 - 160	71.6	10 - 80	12.1	10 - 20
Levinsenia sp.	40.0	10	68.8	10 - 110	48.1	10 - 170	6.1	10 - 60
Cossura sp.	20.0	10	68.8	10 - 90	56.8	10 - 570	22.7	10 - 2470
Maldane sarsi	20.0	10	62.5	10 - 130	33.3	10 - 80		-
Laonice appelloefi	50.0	10 - 40	62.5	10 - 130	22.2	10 - 60		-
Sthenelanella uniformis	10.0	10		-	77.8	10 - 790	33.3	10 - 130
Phoronis sp.		-	12.5	10	85.2	10 - 550	59.1	10 - 240
Prionospio sp. A	40.0	30 - 140	68.8	10 - 100	90.1	10 - 340	31.8	10 - 260
Ampelisca brevisimulata	20.0	20 - 60	12.5	10 - 50	88.9	10 - 240	65.2	10 - 110
Euphilomedes carcharodonta	30.0	10 - 590	6.2	10	60.5	10 - 610	50.0	10 - 140
Paramage scutata	10.0	10	18.8	10 - 20	66.7	10 - 260	1.5	10
Parvilucina tenuisculpta	60.0	10 - 130	62.5	10 - 70	69.1	10 - 680	37.9	10 - 170
Leptochelia dubia	30.0	40 - 80		-	64.2	10 - 200	50.0	10 - 330
Heterophoxus oculatus	20.0	10	25.0	10 - 90	66.7	10 - 180	3.0	30 - 50

* All Maldanids except 11 identified species (See Appendix H)

Table 10 continued.

Species	Group 1		Group 2		Group 3		Group 4	
	Frequency (Percent)	Range (Number/m²)	Frequency (Percent)	Range (Number/m²)	Frequency (Percent)	Range (Number/m²)	Frequency (Percent)	Range (Number/m²)
Pholoe glabra	60.0	10 - 40	50.0	10 - 70	65.4	10 - 130		-
Glycera nana	70.0	10 - 30	75.0	10 - 60	74.1	10 - 160	7.6	10 - 40
Tellina carpenteri	10.0	10	43.8	10 - 100	60.5	10 - 160	16.7	10 - 100
Gnathia crenulatifrons	50.0	10 - 140	50.0	10 - 60	71.6	10 - 130	22.7	10 - 190
Tubulanus polymorphus		-	43.8	10 - 40	65.4	10 - 120	56.1	10 - 260
Ampelisca pugetica	20.0	10 - 30	12.5	10	72.8	10 - 130	22.7	10 - 50
Spiophanes bombyx	10.0	20		-	11.1	10 - 60	78.8	10 - 1700
Tellina modesta	10.0	10	12.5	10	2.5	20 - 30	75.8	10 - 350
Glottidia albida	10.0	10		-	46.9	10 - 620	74.2	10 - 390
Ampelisca cristata		-		-	17.3	10 - 60	69.7	10 - 300
Apoprionospio pygmaea		-	6.2	10	4.9	10 - 50	69.7	10 - 430
Owenia collaris	10.0	10		-	22.2	10 - 100	69.7	10 - 460
Ampharete labrops	10.0	10		-	2.5	10 - 40	69.7	10 - 200
Amphideutopus oculatus		-	12.5	10 - 20	55.6	10 - 280	68.2	10 - 630
Lineidae	40.0	10 - 20	43.8	10 - 30	66.7	10 - 120	66.7	10 - 70
Macoma yoldiformis		-	6.3	10	13.6	10 - 140	63.6	10 - 510
Carinoma mutabilis	20.0	10 - 40	18.8	10	44.4	10 - 70	62.1	10 - 170
Rhepoxynius menziesi		-		-	19.8	10 - 90	62.1	10 - 110
Amphicteis scaphobranchiata	10.0	10	12.5	20	19.8	10 - 40	60.6	10 - 110

Table 11. Community characteristics in Santa Monica Bay compared to the rest of the Southern California Bight. Values are area weighted. Values that are significantly different ($p < 0.05$) are indicated by a box. CI = Confidence interval.

	Santa Monica Bay n = 79		Rest of SCB n = 172	
	Mean	(95% CI)	Mean	(95% CI)
Number of Taxa / sample	72.85	5.15	86.18	5.28
Shannon-Wiener Diversity Index (H')	3.42	0.10	3.59	0.07
Dominance	0.07	0.01	0.06	0.01
Evenness	0.49	0.03	0.46	0.01
Total Abundance / m^2	3128.7	305.66	3957.9	369.25
Percent Abundance as:				
Annelida	45.7	3.2	51.2	2.2
Arthropoda	19.8	2.0	19.3	1.8
Ophiuroidea	14.0	3.8	12.4	2.0
Misc. Echinodermata	0.8	0.4	0.7	0.2
Mollusca	14.6	2.9	8.9	1.2
Other Phyla	5.0	1.1	7.2	1.1
Total Biomass (gm wet weight / m^2)	57.55	7.85	57.96	7.40
Percent Biomass as:				
Annelida	30.5	4.1	33.4	2.6
Arthropoda	7.2	2.0	6.4	1.2
Ophiuroidea	36.0	6.1	30.4	3.8
Misc. Echinodermata	6.0	2.1	4.8	1.2
Mollusca	13.7	3.6	15.3	2.6
Other Phyla	6.6	1.8	9.6	1.9

Table 12. Frequency of occurrence and average abundance of species in Santa Monica Bay and in the rest of the Southern California Bight. Species with frequency of at least 60% and average abundance greater than 20 / m^2 are shown.

Species	Taxonomic Group	Frequency (Percent) SMB	Frequency (Percent) Non-SMB	Average Abundance (Number / m^2) SMB	Average Abundance (Number / m^2) Non-SMB
Spiophanes	Annelida	93.7	94.2	323.7	367.0
Paraprionospio pinnata	Annelida	89.9	83.1	63.3	60.6
Parvilucina tenuisculpta	Mollusca	81.0	52.9	57.2	38.4
***Lumbrineris* spp.**	Annelida	79.7	79.7	40.2	57.0
Pectinaria californiensis	Annelida	75.9	70.9	55.5	62.4
Axinopsida serricata	Mollusca	70.9	32.6	102.5	14.0
Ampelisca brevisimulata	Arthropoda	70.9	61.0	52.0	30.0
Maldanidae*	Annelida	70.9	78.5	35.2	99.7
Amphiodia urtica	Ophiuroidea	69.6	64.0	260.9	235.8
***Prionospio* sp. A**	Annelida	67.1	62.8	27.6	48.7
***Phoronis* sp.**	Phoronida	65.8	59.3	30.5	48.9
Tellina carpenteri	Mollusca	64.6	36.6	36.9	15.0
Leptochelia dubia	Arthropoda	62.0	44.8	23.5	32.7
***Mediomastus* spp.**	Annelida	59.5	72.7	23.8	97.1

* All Maldanids except 11 identified species (See Appendix H).

Table 13. Community characteristics in mid-depth POTW areas compared to mid-depth non-POTW areas. Values are weighted. Values that are significantly different ($p < 0.05$) are indicated by a box. CI = Confidence interval.

	POTW Mid-depth n = 45		Mid-depth n = 90	
	Mean	(95% CI)	Mean	(95% CI)
Number of Taxa / sample	93.23	9.18	94.83	7.10
Shannon-Wiener Diversity Index (H')	3.42	0.15	3.64	0.10
Dominance	0.08	0.02	0.06	0.01
Evenness	0.49	0.03	0.46	0.02
Total Abundance / m^2	5448.4	1149.1	4430.18	443.40
Percent Abundance as:				
Annelida	57.9	3.8	47.8	2.6
Arthropoda	13.9	2.4	18.6	1.9
Ophiuroidea	14.9	4.0	16.8	2.8
Misc. Echinodermata	0.6	0.2	0.5	0.1
Mollusca	7.2	1.6	7.6	1.1
Other Phyla	5.2	1.3	8.3	1.5
Total Biomass (gm wet weight / m^2)	73.63	17.11	73.83	10.68
Percent Biomass as:				
Annelida	34.8	6.5	30.2	3.3
Arthropoda	4.9	1.1	4.7	0.8
Ophiuroidea	41.4	7.8	37.1	5.0
Misc. Echinodermata	5.1	3.5	5.4	1.8
Mollusca	8.2	3.0	10.1	2.3
Other Phyla	5.6	1.5	12.5	3.1

Table 14. Frequency of occurrence and average abundance of species in mid-depth publicly owned treatment work (POTW) areas and mid-depth non-POTW areas. Species with frequency greater than 60% and average abundance of at least 20 / m^2 in either area are included.

Species	Taxonomic Group	Frequency (Percent) POTW	Frequency (Percent) Non-POTW	Average Abundance (Number / m^2) POTW	Average Abundance (Number / m^2) Non-POTW
Spiophanes missionensis	Annelida	100.0	100.0	652.8	454.9
Pectinaria californiensis	Annelida	91.1	82.2	109.6	64.8
***Phoronis* sp.**	Phoronida	88.9	81.1	101.3	65.1
Amphiodia urtica	Ophiuroidea	88.9	86.7	373.2	355.3
***Prionospio* sp. A**	Annelida	86.7	80.0	66.4	63.3
***Lumbrineris* spp.**	Annelida	86.7	80.0	55.1	49.5
Paraprionospio pinnata	Annelida	84.4	81.1	56.4	50.0
Ampelisca brevisimulata	Arthropoda	80.0	83.3	45.2	46.1
Glycera nana	Annelida	75.6	60.0	28.6	19.0
Parvilucina tenuisculpta	Mollusca	75.6	63.3	39.8	35.8
Sthenelanella uniformis	Annelida	75.6	76.7	89.1	70.4
Maldanidae*	Annelida	73.3	83.3	56.4	98.9
Spiochaetopterus costarum	Annelida	73.3	56.7	24.7	14.0
Ampelisca pugetica	Arthropoda	73.3	65.6	22.9	19.0
***Euclymeninae* sp. A**	Annelida	71.1	58.9	30.6	27.2
Lineidae	Annelida	68.9	60.0	22.5	19.0
Gnathia crenulatifrons	Arthropoda	64.4	72.2	37.7	23.8
Heterophoxus oculatus	Arthropoda	64.4	61.1	33.9	32.7
Axinopsida serricata	Mollusca	64.4	50.0	53.6	12.0
***Mediomastus* spp.**	Annelida	64.4	77.8	70.4	91.8
Tellina carpenteri	Mollusca	62.2	58.9	33.8	24.0
Monticellina dorsobranchialis	Annelida	62.2	52.2	24.0	21.0
Ophiuroconis bispinosa	Ophiuroidea	62.2	53.3	28.2	13.0
Ampelisca pacifica	Arthropoda	62.2	50.0	20.2	16.1
Leptochelia dubia	Arthropoda	62.2	68.9	28.0	45.6
Tubulanus polymorphus	Nemertea	55.6	66.7	36.0	22.6
Euphilomedes carcharodonta	Arthropoda	48.9	66.7	54.0	48.8

* All Maldanids except 11 identified species (See Appendix H).

Table 15. Community characteristics in shallow stormwater areas compared to shallow non-stormwater areas. Values are weighted. Values that are significantly different ($p < 0.05$) are indicated by a box. CI = Confidence interval.

	Stormwater Shallow n = 30		Shallow n = 31	
	Mean	(95% CI)	Mean	(95% CI)
Number of Taxa / sample	64.20	7.99	70.50	8.73
Shannon-Wiener Diversity Index (H')	3.49	0.17	3.59	0.11
Dominance	0.06	0.02	0.05	0.01
Evenness	0.46	0.04	0.48	0.03
Total Abundance / m^2	2389.0	433.0	2761.44	611.17
Percent Abundance as:				
Annelida	46.9	4.7	50.2	4.8
Arthropoda	24.4	4.4	21.8	4.4
Mollusca	18.3	4.5	15.1	3.6
Ophiuroidea	1.6	0.6	1.3	0.5
Misc. Echinodermata	0.8	0.5	0.7	0.3
Other Phyla	8.1	1.4	10.8	1.8
Total Biomass (gm wet weight / m^2)	38.37	12.18	30.91	86.93
Percent Biomass as:				
Annelida	37.1	7.0	33.8	5.5
Arthropoda	11.8	3.8	12.6	4.4
Mollusca	25.0	6.7	34.3	6.7
Ophiuroidea	7.0	2.9	6.7	2.7
Misc. Echinodermata	8.8	6.7	3.6	1.4
Other Phyla	10.3	3.2	8.9	2.3

Table 16. Frequency of occurrence and average abundance of species in shallow stormwater areas and shallow non-stormwater areas. Species with frequency greater than 60% and average abundance of at least 20 / m^2 in either area are included.

Species	Taxonomic Group	Frequency (Percent) Stormwater	Frequency (Percent) Non Stormwater	Average Abundance (Number / m^2) Stormwater	Average Abundance (Number / m^2) Non Stormwater
Paraprionospio pinnata	Annelida	86.7	100.0	77.3	125.3
Spiophanes bombyx	Annelida	76.7	77.4	44.0	90.0
Spiophanes	Annelida	73.3	96.8	29.7	101.9
Ampharete labrops	Annelida	73.3	67.7	36.0	35.0
Ampelisca cristata	Arthropoda	73.3	67.7	31.3	51.5
Tellina modesta	Mollusca	73.3	87.1	42.7	62.8
Apoprionospio	Annelida	70.0	83.9	43.7	64.7
Cooperella	Mollusca	66.7	48.4	58.0	16.3
Carinoma mutabilis	Nemertea	66.7	71.0	23.7	30.9
***Lumbrineris* spp.**	Annelida	66.7	80.6	47.7	64.5
Macoma yoldiformis	Mollusca	63.3	74.2	47.3	70.4
Maldanidae*	Annelida	63.3	74.2	80.7	114.8
Amphideutopus	Annelida	63.3	74.2	102.0	91.9
Owenia collaris	Annelida	63.3	77.4	41.3	67.9
Glottidia albida	Brachiopo	63.3	87.1	48.7	64.9
***Mediomastus* spp.**	Annelida	60.0	61.3	62.0	85.6
Amphicteis	Annelida	60.0	61.3	19.0	26.6
Chaetozone corona	Annelida	56.7	64.5	38.7	38.2
Ampelisca	Arthropoda	56.7	71.0	19.0	24.9
Tubulanus	Nemertea	53.3	61.3	33.0	31.9
***Phoronis* sp.**	Phoronida	46.7	64.5	13.0	35.4

* All Maldanids except 11 identified species (See Appendix H).