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LONG-TERM CHANGES IN ROCKY BOTTOM COMMUNITIES OFF PALOS VERDES

In 1930, the Palos Verdes Peninsula was bordered by extensive kelp beds that spanned the entirety of the rocky coast-line (North 1973). For the several decades that followed, the nearshore rocky subtidal environment at Palos Verdes was one of the most popular diving and sportfishing regions on the southern California coast. Then, during the 1950's, the kelp beds and invertebrate and fish communities began a major decline in diversity and abundance. This condition was first described by Conrad Limbaugh in 1954,[2] who detected changes in the composition and abundance of benthic species and fish extending 1 to 3 km from Los Angeles County Sanitation Districts' municipal wastewater outfall system, located off Whites Point on the Peninsula.

Los Angeles County began discharging sewage effluent in the ocean off Whites Point in 1934. The volume of the discharge, initially 16 mgd (60 million liters/day), has gradually increased over the years to a level of 350 mgd (1,300 million liters/day) in 1977. Although prior to 1969, very little research had been done in the area, the Whites Point discharge was considered to be a major factor in the decline of the biota. For this reason, I conducted a survey off Palos Verdes in 1969 (Grigg and Kiwala 1969) and found that the reduction in species diversity of nearshore benthic species and fish did appear to be correlated with the deposition of wastewater particulates.

Since that time, there has been a partial recovery in the kelp beds along the Peninsula, along with some improvement in offshore conditions (U.S. Environmental Protection Agency 1976). Also, research conducted by Los Angeles County Sanitation Districts and, more recently, by the Coastal Water Research Project has produced a large body of information on changes in benthic communities and other bio-logical and oceanographic conditions in response to effluents discharged off Palos Verdes and elsewhere in southern California (Coastal Water Research Project 1973, 1974, 1975, 1976, 1977). Given this background, a followup study, designed to repeat the 1969 survey but in consider-ably more detail, was conducted in 1977. The results, which

1. Hawaii Institute of Marine Biology, University of Hawaii.
2. Unpublished report. Institute of Marine Resources, University of California, La Jolla.

are described in this paper, show a partial recovery in the algae, invertebrates, and fish, although reduced species diversity and abundance still prevails in an area near the outfall system. The purpose of this report is to summarize the results of the 1977 study and to describe long-term trends and suggest possible causal relationships.

METHODS

To the extent practical, the same methods used in the 1969 survey were again employed in 1977. Departures were made only when modifications proved to be desirable. Hence, a series of stations 50 feet (15 meters) in depth were selected to approximately coincide in position with the 1969 stations (Stations 1-50 through V-50, Figure 1). Added to this were (1) a series of shallow stations 20 feet (6 meters) in depth positioned directly inshore of the 50-foot stations, (2) a set of control stations at 20- and 50-foot depths off Bluff Cove, approximately 15 km from the outfall system (Stations VI-2Q and VI-50, Figure 1) and (3) a set of control stations at 20- and 50-foot depths off Boomer Beach, La Jolla, California. No 20-foot stations were studied in 1969.

At each 50-foot station, a 50-meter-long line was placed on the bottom, and counts (numbers/sq meter) of macroscopic epibenthos (organisms larger than 1 cm) were made at ten randomly selected and previously marked points on the line. Color photographs of each meter-square quadrat were taken and later used to verify field records. The square-meter counts were not made at 20-foot stations because kelp was too thick.

Qualitative estimates of the abundance of algae, invertebrates, and fish over much larger areas (about 5,000 sq meters) were also made at each station. Species represented by fewer than 10 individuals were scored as rare, between 10 and 50 as moderate, and over 50 as abundant. All species that could not be identified in the field were collected and identified in the laboratory.

Two samples of bottom sediment and flock (a layer of light particulate matter that is easily resuspended) were collected at each station. Bottom sediments were taken in situ by inserting a hand-held syringe corer 5 cm into sediments present between rocks. Samples were capped within the syringe and later frozen. Flock samples were collected from rock surfaces by suction, using a diver-held slurp gun. Each flock sample consisted of a mixture of approximately 2 liters of seawater and flock. In the laboratory, samples were filtered through a 500-micron Nitex filter, centrifuged, and frozen. Both sediment and flock samples were later analyzed for trace metals and chlorinated hydrocarbons, using previously described methods (Hershelman et al. 1976; Heesen and Young 1977). All samples were analyzed for silver, cadmium, chromium, copper, nickel, lead, zinc, and the chlorinated hydrocarbons, total DDT and total PCB.

All samples were collected between 8 June and 21 July 1977. The 1969 survey was also conducted in the months of June and July.

RESULTS

Sediment and Flock

At all stations, the substratum was primarily rocky. Sediments existed only within interstitial spaces between rock surfaces. Virtually all rock surfaces at the stations off Palos Verdes and at the control stations off La Jolla were covered by varying amounts of light flocculent material.

Visual observations revealed that both sediment and flock off Palos Verdes were thicker and darker in color at stations progressively closer to the outfalls. On every transect, including the controls, sediment and flock were thicker at 50 feet than at 20 feet.

Chemical analysis of sediment and flock samples showed clear and consistent patterns associated with the outfalls (Tables 1 and 2). In general, the concentrations of both metals and chlorinated hydrocarbons along isobaths were inversely correlated to distance upcoast from the outfalls. An exception to this trend, especially for the flock, was Transect V off Palos Verdes Point, where some metals and chlorinated hydrocarbons showed a moderate but localized increase. Another general pattern in the distribution of metals and chlorinated hydrocarbons in both sediment and flock was higher concentrations at the deeper stations. However, samples were only collected from two depths--too few to establish a trend.

Maximum values for metals and chlorinated hydrocarbons in both sediments and flock were generally about one order of magnitude greater at stations near the outfalls than at the control stations. The most surprising result was that the trace contaminants tended to be about two or three times more concentrated in the flock than in the adjacent sediments.

Observations of the flock under a microscope showed that it consisted of organic, amorphous particulate matter with varying amounts of fecal pellets, clastic material of terrestrial origin, algal fragments, and skeletal fragments of benthic foraminifera and diatoms. Fecal pellets were a particularly large component of the flock (up to 80 percent) at stations near the outfalls. The flock was also characterized by a rich infauna, consisting of many small copepods, ostracods, polychaetes, cumaceans, Heptacarpus shrimps, amphipods, nematodes, caprellids, crab larvae, mysids, and small snails such as *Maxwellia gemma, Murexiella santarosana, Crassispira semiinflata*, and *Pteropurpura festiva*.

Biological Conditions

A total of 30 species of algae. 111 species of invertebrates, and 54 species of fish were observed during the 1977 survey. The total number of species recorded at each station is listed in Table 3 and is plotted in Figure 2, along with the numbers of species recorded in 1969 at the same stations. Patterns in the distribution and abundance of organisms that appear to be related to the Whites Point outfalls are summarized in Table 4 and described in the following sections.

Algae. In 1977, a total of 26 species of algae were recorded at the stations along the Palos Verdes Peninsula. Estimates of the abundances of these species, and four others found only at the La Jolla control stations, are given in Table 5. Of the Palos Verdes stations, those on Transect V had the greatest number of species at both 20 and 50 feet--17 and 13 species, respectively. These species counts are comparable to those for the control stations off La Jolla, where 17 and 15 species were found at 20 and 50 feet, respectively; the comparison suggests that Transect V is near normal in terms of algal diversity. The fewest number of species at both 20 and 50 feet were found on Transect II, which is directly shoreward of the outfall system. Overall, there was a significant positive correlation between number of species and distance from the outfalls at 50-foot stations (Figure 3, Part A; Table 4).[3] This correlation was evident in both 1969 ($r = 0.91$, $p < 0.05$) and 1977 ($r = 0.92$, $p < 0.05$).

Other temporal and spatial patterns in the distribution of algae off Palos Verdes were evident (Table 4). First, the numbers of species at stations 50 feet in depth in 1977 were considerably greater than at all equivalent stations in 1969 (Figure 3, Part A). The increase was greatest at Stations 1-50 and V-50, where there were nine more species in 1977 than in 1969. The smallest increase in number of species occurred on Transect II, directly inshore of the outfalls.

Another pattern was that 20- and 50-foot stations were consistently different in species richness and abundance in 1977. On every transect, the average number of species at 20 feet was twice the number at 50 feet (mean = 2.05, range is 1.1 to 3.75; Figure 3, Part A). The abundance of algae (numbers of plants) was about half an order of magnitude greater at 20 feet than at 50 feet on every transect except Transect V and the controls (Figure 3, Part B). The majority of biomass at 20-foot stations was due to three species, *Cystoseira osmundacea*, *Egregia menziesii*, and *Dictyopteris undulata*.

In 1977, the giant kelp, *Macrocystis pyrifera*, was generally rare along the Palos Verdes coast; however, small but thick patches were noted at Stations 11-20, 1V-20, and VI-20. No giant kelp plants were observed growing at depths greater than 30 feet. in 1969, *M. pyrifera* was absent along the entire Palos Verdes Peninsula.

The patterns of distribution for individual species show responses similar to the trends described above. At 50-foot stations in 1977, the general trend of increasing abundance with distance from the outfalls was characterized by the distributions of *Bossiella* spp., *Dictyopteris undulata*, *Eisenia arborea*, and *Rhodymenia*. spp. (Figure 4). The abundance of *E. arborea* at Station V-50 and *Rhodumenia* spp. at Station VI-50 appeared to be enhanced (higher than at the 50-foot control station).

Near Station 11-20, a natural seep of sulfur-rich water was found. It appeared to influence an area of about 300 sq meters. All algae within this area were covered by a sulfurphilic fungus, and the bottom was coated with a white slime and underlying layer of black, odorous sediment. Surprisingly, the effects of the seep appeared to be highly localized and were undetectable more than 10 meters away. The diversity of macroscopic benthos in the area of the seep was significantly reduced. For this reason, transect data for this station were collected 50 meters downcoast.

Invertebrates. The responses of benthic invertebrate populations to the Whites Point outfalls illustrate different patterns in time and space. Collectively, the differences between the total numbers of species present in 1969 and 1977 were small (Figure 5, Part A), although there were slight factors of increase at Stations III-50 (1.43), IV-50 (1.46), and V-50 (1.38). About half of the increases registered can be attributed to the counting of smaller organisms in 1977 (1 cm) than in 1969 (3 cm).

In both 1969 and 1977, the total number of species of invertebrates at 50 feet was depressed near the outfalls. At the 20-foot stations surveyed in 1977, there were also fewer species near the outfalls than at more distant sites. The zone of greatest change at both 20- and 50-foot depths was between Transects III and IV, 2.5 to 6 km northwest of the outfalls. Station V-20, which had the greatest abundance of algae, also supported the greatest number of invertebrate species at this depth (54). The largest number of invertebrate species recorded at the 50-foot stations (50) was at Station VI-50. Counts at Stations V-20 and VI-50 were both greater than control values, suggesting enhancement .

Estimates of abundance of species of invertebrates recorded during the 1977 survey are listed in Table 6. When species are considered individually, patterns of distribution and abundance are more varied and complex. Again, effects must be distinguished in space and time. Spatially, at least four patterns of abundance with respect to the outfalls can be described--species that are unaffected, species that are enhanced or depressed near the outfalls, and species that are sparse or absent near the outfalls but more abundant than normal at intermediate distances away from the outfalls (Table 7).

Species that appeared to be unaffected were generally either very rare or very abundant. However, because of the methods used to record abundance (scores for 1 to 10, 10 to 50, and 50 to 100 individuals), real response patterns for species that were rare or abundant may not be evident.

Species with patterns clearly showing a depression in abundance near the outfalls included *Parastichopus parvimensis* and *Strongylocentrotus franciscanus* (Figure 6) , *S. purpuratus*, *Ophioderma* sp., *Cucumaria* sp., *Haliotis* spp., *Paracyathus stearnsii*, and *Diopatra* sp. Effects were more pronounced at the 50-foot stations. Host of these species are deposit or filter feeders. Interestingly, *S. franciscanus* appeared to have declined in abundance drastically since 1969, at least on Transect V.

Many invertebrates that were increasingly more abundant at stations near the outfalls are bottom grazers or browsers. Notable examples are *Cypraea spadicea* (Figure 6), *Scyra acutifrons*, *Murexiella santarosana*, and Maxwellia *gemma*. *Pisaster brevispinus*, normally more abundant on soft bottoms, also was enhanced in abundance around the outfalls.

Many species showed a pattern of enhanced abundance at intermediate distances from the outfalls in 1977. *Kelletia kelletii*, *Patiria miniata*, and *Muricea californica* (Figure 6) are good examples. *K. kelletii*, *Corynactis californica*, and *P. miniata* exhibited similar behavior in 1969. This pattern of response, is characteristic of so many species (including algae and fish) off Palos Verdes that a generalized name seems appropriate and useful. The term "halo" distribution is suggested here, referring to the halo-like or circular zone of enhanced abundance that these species exhibit at intermediate distances from the outfall system.

One species with a halo distribution, the bat-star *Patiria miniata*, also exhibited unusual feeding behavior. This was true especially in areas where it was abundant, where many individuals appeared to be browsing on gorgonians (*Muricea californica*). Examinations of the stomach contents of the bat-stars revealed the presence of gorgonian spicules. I have studied *M. californica* throughout its range (Grigg 1970) and have never observed predation by bat-stars.

The patterns of response described above for invertebrates (unaffected, depressed, enhanced, and halo) tend to be off-setting, which may explain why estimates of total abundance for all species of invertebrates do not show a more clear-cut outfall effect (Figure 5, Part B). Fish. In the 1977 survey, 54 species of fish belonging to 23 families were recorded off Palos Verdes and La Jolla. Estimates of abundance of these species are given in Table 8. Response patterns associated with the outfalls were not well delineated for most individual species--only 9 of the 53 species recorded off Palos Verdes showed clear patterns. Of these, five species appeared to be depressed near the outfalls; these were *hypsypops rubicunda, Pimelometopon pulchrum, Halichoeres semicinctus, Girella nigricans,* and *Sebastes mystinus*. Three species were enhanced or more abundant near the out falls--*Sebastes dalli* at 50 feet and *Coryphopterus nicholsi* and *Paralabrax clathratus* at 20 feet. And one species, *Chromis punctipinnis*, appeared to have a halo distribution in that it was absent at Stations 111-20 and 111-50, 2.5 km northwest of the outfalls, but abundant at adjacent stations.

Between 1969 and 1977, there was a rather large increase in the number of species of fish at the 50-foot stations on Transects I through IV (Figure 7, Part A). In sharp contrast, the number of species of fish at Station V-50 was virtually unchanged between 1969 and 1977. Station VI-50, which had an enhanced number of species of invertebrates in 1977, also showed enhancement in numbers of species of fish, having 30 species compared to the 21 at the control station. Despite the improvement in numbers of fish species between 1969 and 1977, a clear pattern of reduced abundance of fish still characterized 20- and 50-foot stations near the outfalls in 1977 (Figure 7, Part B; Table 4).

DISCUSSION

The variety and complexity of responses of species of algae, invertebrates, and fish associated with the ocean outfalls at Palos Verdes suggests that a number of factors may be operating simultaneously. Hence, several hypotheses must be considered in attempting to account for the observed patterns of distribution and abundance. Possible causative factors that have received particular attention in the past include increases in available nutrients, turbidity, sedimentation, and concentrations of trace contaminants on suspended and settled particulates with increasing proximity to the outfalls (U.S. Environmental Protection Agency 1976). Changes in biological processes such as competition or predation, and even commercial and sport fishing in the area, may also have affected certain species. Each of these factors will be examined in light of the results presented here. However, since most of these factors change in a similar fashion as a function of distance from the outfalls, it is very difficult to isolate particular cause-and-effect relationships.

The characteristics of southern California municipal wastewater discharges have been described by Schafer (1977) and Mearns et al. (1977). Between 1970 and 1976, the Whites Point discharge registered a slight decrease in flow and concentration of suspended and settleable solids, any of which might affect the nutrient content of the effluent (nitrogen, phosphorus, etc.), the turbidity of the water column, the deposition of sediments, and the effluent content of toxic substances.

Let us consider nutrients first. Thomas (1972) has shown that chlorophyll is somewhat enhanced in the water column over some major southern California outfalls, indicating increased standing crops of phytoplankton. The passage of this material through the food chain could contribute to bottom sediment and flock in the form of particulate matter and fecal pellets. As noted above, the flock near the Whites Point outfalls consists primarily of fecal pellets. The increases in abundance of certain species of grazers (*Cypraea spadicea*) and browsers (small molluscs) , which feed on bottom particulates, suggest a chain of cause and effect ultimately related to nutrient enrichment from the discharge. Nutrient enrichment, and the subsequent stimulation of primary and secondary production, may also explain the large increases in abundance of pollution tolerant species, such as the deposit feeder *Capitella capitata*, in deeper water (200 feet, or 60 meters) off Palos Verdes (U.S. Environmental Protection Agency 1976). In addition, increases in primary production resulting from nutrient enrichment may exert a significant effect on benthic community structure by contributing to the turbidity of the water column, which in turn reduces the amount of light reaching the bottom.

The patterns of distribution and abundance of benthic algae off Palos Verdes and La Jolla strongly suggest that light is limiting at depths below about 50 feet on Transects I through IV off Palos Verdes (Figure 3). For example, the correlation between species of algae and distance away from the outfalls is 0.92 ($p < 0.05$) for 50-foot stations but only 0.46 ($p < 0.05$) for 20-foot stations (Table 4). Also, the depression in species richness on Transect II is 73 percent at 50 feet and only 30 percent at 20 feet. These effects are dramatically illustrated in Figure 3, Part B, which shows a half-order-of-magnitude difference in algal abundance between 20 and 50 feet on Transects I through IV.

Between 1974 and 1977, Los Angeles County Sanitation Districts collected data on water turbidity at stations near Transect I through IV;[4] Peterson (1974) collected similar data near Transect V off Palos Verdes Point in 1974. These data (Secchi disk readings plotted in Figure 8) support the hypothesis that differences in the amount of light reaching the bottom are the major causes of differences in algal abundance. The average depth at which the Secchi disk was no longer visible near Transects I through IV was about 20 feet. In contrast, the average Secchi disk value near Transect V was over 60 feet (18 meters; Figure 8). The sharp increase in depth of Secchi disk values between Transects IV and V corresponds to a half-order-of-magnitude increase in algal abundance between 50-foot stations on these transects (Figure 3).

Measurements of the incident light reaching the bottom at the outer edge of *Macrocystis pyrifera* kelp beds in Abalone Cove in 1975 and 1976 suggest that 10 percent of surface illumination is necessary before juvenile *M. pyrifera* plants become established (Deal 1976). A similar value has been computed by Peterson (1974). The 10 percent isophote for 1975 and 1976 is plotted in Figure 8; values near Transects I through IV were all close to 30 feet, while the value near Transect V was 54 feet. The outer edge of the *M. pyrifera* kelp beds historically (predischarge) was at 60-foot depths (North 1967).

Los Angeles County Sanitation Districts' Secchi disk data were also used to compute the depths on Transects I through IV at which light was 1 percent of the surface value (generally considered to be the compensation point for the majority of algae). Mean depths ranged between 46 and 59 feet, supporting the hypothesis that, in recent years, light has been a limiting factor for most algae near the outfalls at depths greater than about 50 feet. Data from the 1977 survey on the distribution and abundance of red algae of the genus *Rhodymenia* also support this hypothesis: Red algae are known to be umbraphilic (shade adapted; Holmes 1957), and *Rhodymenia* spp. were the most abundant species of algae on Transects I through IV (Figure 4).

Although the principal factor limiting algae at depths greater than about 50 feet (30 feet for *Macrocystis pyrifera*) off Palos Verdes appears to be light, other factors may also affect algal diversity and abundance. For example, at

4. John D. Parkhurst, Chief Engineer and General Manager, Los Angeles County Sanitation Districts, Whittier, Calif., unpublished data.

Station 11-20, where light did not appear to be limiting, the depression in number of species of algae was 30 percent (Table 4). This reduction in algal species diversity could be the result of the effects of DDT or trace metals, which are most concentrated at stations near the outfalls (Tables 1 and 2), on certain algal species. Predation by herbivorous fishes also could be retarding what appears to be a general recovery in algae all along the Palos Verdes Peninsula. For example, in the 1977 survey, many *M. pyrifera*, plants at Station V-20 were observed to be heavily grazed.

The potential inhibitory effects of toxins associated with wastewater particulates and the deposition of these particulates are hard to separate. As with turbidity and nutrient enrichment, both tend to decrease as a function of distance from the outfalls. Hence, simple correlation of abundance or species diversity and either of these parameters cannot alone be interpreted as evidence for cause and effect. Instead, it is necessary to consider the distribution and abundance and life requirements of various species or species-groups. Thus, to test the hypothesis that sedimentation has modified otherwise suitable substrata and is a major factor in the reduction of the diversity of epibenthic communities on rocky bottoms near the outfalls (Grigg and Kiwala 1970) , patterns of abundance of species that require clean-swept substrata for settlement were examined. The gorgonian Mur-icea califovn-ica is such a species (Grigg 1970) and, indeed, exhibited a pattern of depressed abundance skewed to the northwest of the outfalls (Figure 6). The sponge *Tethya aurantia*, the serpulid polychaete *Salmacina tribranchiata*, and the bryozoan *Diaperoecia californica* (Figure 6), which were not present on Transects I through III, may be other examples of response to excessive sedimentation in the outfall area. All bryozoans are extremely sensitive to sedimentation, and none are generally found in areas where rapid deposition of fine sediment was taking place (Soule and Soule, in press).

The distribution and thickness of organic-rich sediments in 1969 (Grigg and Kiwala 1970) and in 1977 closely mirrored these species patterns of distribution around the outfalls, but so did the patterns of particulate concentrations of trace metals and DDT. Nevertheless, when the habitat preferences of these species are. considered (clean substratum and relatively little sedimentation), sedimentation is the more likely cause of their depressed abundance near the outfall system.

The sea cucumber. *Parastichopus parvimensis*, on the other hand, is not sensitive to sedimentation. However, in both 1969 and 1977, it was missing on Transects I through IV and rare on Transects V and VI (Figure 6). This species is found on rocks, sand, or mud and feeds by sweeping the bottom with mucus-covered tentacles (MacGinitie and MacGinitie 1949). As excessive sedimentation of wastewater particulates would not be expected to affect this species, it is likely that some substance in the flock or sediment is inhibiting this species in areas near the outfalls. Laboratory experiments would be necessary before the cause could be more precisely defined.

This leaves commercial or sport fishing or collecting of organisms as a final topic for consideration. Mearns (1977) noted that the outfall areas along the southern California coast receive about ten times more fishing pressure than the Southern California Bight as a whole. Fishing activities off Palos Verdes include gill netting, trapping of fish and crabs, and collecting of sea urchins, lobster, abalone, and other shellfish by scuba divers. In 1969, two species of Cancer' crabs were abundant (0.1 individuals/ sq meter) at Stations 11-50 and III-50; in 1977, they were rare at the same stations. The abundance of sea urchins (*Strongylocentrotus* spp.) at Station V-50 also declined between 1969 and 1977. Both changes may well be consequences of fishing. In view of the heavy fishing pressure described by Mearns (1977) , it is perhaps significant that the abundance of fish at Stations V-20 and V-50 off Palos Verdes is slightly greater than at the control stations off La Jolla. This observation could be interpreted as evidence of enhancement of fish populations on Transect V off Palos Verdes.

The various hypotheses suggested above to account for biotic response patterns associated with the Whites Point outfalls are not mutually exclusive. It is possible that all factors discussed exert some influence on the distribution and abundance of the biota, and some factors may be synergistic. Further research, especially in the laboratory, will be necessary before specific cause-and-effect relationships can be isolated. Hopefully, the results of this survey will be useful in the design of such research.

SUMMARY AND CONCLUSIONS

The results of 1969 and 1977 surveys of epibenthic and fish communities near the Whites Point outfall system off Palos Verdes show clearly a long-term pattern of reduced diversity and abundance of algae, invertebrates, and fish around the outfalls; however, there is strong evidence of partial recovery since 1969. The most significant evidence of recovery is in the number of species of algae and fish present at stations near the outfalls. In 1969, the greatest number of species of algae recorded at any 50-foot station was 3; the maximum number counted at the same stations in 1977 was 13, an increase of over 400 percent. The increase in numbers of species of fish at 50-foot stations within 6 km upcoast of the outfalls between 1969 and 1977 averaged 240 percent. Increases in the number of invertebrate species were less significant and may in part reflect the fact that smaller organisms were counted in 1977.

Recovery is also indicated by the reappearance of the giant kelp, *Macrocystis pyrifera*, off Palos Verdes. In 1954, *M. pyrifera* was less abundant than expected;[5] in my 1969 survey, not a single *M. pyrifera* plant was observed along the entire Palos Verdes Peninsula. But in 1977, small but locally dense aggregations of this kelp species were noted at three localities

5. Conrad Limbaugh, unpublished report. Institute of Marine Resources, University of California, La Jolla.

(Mearns et al. (1977) have given a more complete and detailed description of the recovery of *M. pyrifera* off Palos Verdes).

Enhanced numbers (greater than control levels) of species of algae, invertebrates, and fish on Transect V, about 11 km northwest of the outfalls, is another indication of general recovery off Palos Verdes. Unusually heavy beds of brown algae (*Cystoseira osmundacia, Egregia menziesii*, and *Dictyopteris undulata*) at shallow depths less than 30 feet all along the Peninsula may also reflect enhancement, possibly caused by wastewater-related nutrient enrichment.

In spite of the evidence for recovery of the benthos off Palos Verdes, a condition of reduced species diversity and abundance still prevails in the vicinity of the outfalls. In general, this depression is more pronounced on the northwest side of the outfalls, producing an asymmetric field of influence that extends at least 2.5 km southeast and 6 km northwest of the sewer pipelines. Effects are much greater at 50 feet than at 20 feet, especially with respect to algae. The magnitude of the reduction, when compared to levels at a control transect off La Jolla, is about 40 percent at 50 feet and 30 percent at 20 feet (Table 4).

The 1954 survey by Limbaugh indicated that the field of impact of the outfall system extended then about 1 to 3 km along the shore. In 1969, the length of coastline significantly affected was about 9.5 km, essentially the same distance affected in 1977. Continuing research by the Coastal Water Research Project (1976, 1977) has shown that biotic response patterns presently associated with the outfalls extend offshore to depths of at least 650 feet (200 meters). At these depths, species diversity is generally reduced, and pollution-tolerant species are more abundant than normal.

The present study has provided evidence that factors causing the response patterns of individual species in rocky bottom communities off Palos Verdes are varied and complex. Four types of response patterns are evident: Unaffected, depressed, enhanced, and halo (the latter is a pattern of distribution in which abundance is depressed near the outfalls but significantly enhanced at intermediate distances away from the outfalls). Several hypotheses to account for the observed effects are considered, but no single hypothesis is sufficient to account for all observed effects, and no two are mutually exclusive. It is possible that all factors considered exert some influence on the distribution and abundance of the biota.

The most unequivocal result of the study is the delineation of the relationship between the amount of light reaching the bottom and the distribution and abundance of algae. Light appears to be limiting at depths below about 50 feet for most brown algae within the field of influence of the Palos Verdes discharge--2.5 km southeast and 6 km northwest of the outfalls. In this area. *Macrocystis pyrifera* is not found at depths greater than 30 feet, yet at other localities along the coast, *M. pyrifera* normally extends offshore on rocky bottoms to depths of 80 feet (25 meters; Quasi 1968). It appears that the potential area for growth of *M. pyrifera* off Palos Verdes has been reduced by about 4 sq km. Essentially, the habitat of this species has been compressed shoreward.

Other factors, such as nutrient enrichment, may be producing conditions that favor certain browsers (snails) or deposit feeders (polychaetes). Sedimentation appears to have been detrimental to species such as gorgonians and bryozoans, which require a firm, clean-swept substratum for settlement. Increased concentrations of trace metals and chlorinated hydrocarbons in bottom sediments may account for the absence of bottom feeders, such as *Parastichopus parvimensis*, that ordinarily thrive in eutrophic environments. Grazing of herbivorous fishes appears to be retarding the recovery of the giant kelp. *Macrocystis pyrifera*. And fishing has most likely reduced the numbers of Cancer crabs and red urchins in recent years.

The causes of the observed conditions cannot be determined with certainty because of the multitude of factors acting in combination. Even so, the above examples demonstrate that cause can be predicted with reasonable likelihood if there is sufficient knowledge of the biological requirements of certain species or species-groups and their patterns of response to stress.

Hence, the general survey is of value because it often suggests specific hypotheses, which can then be tested in the field and laboratory. For example, *Parastichopus parvimensis* could be exposed to a number of sewage constituents in the laboratory to test the hypothesis mentioned above. An even more important result of general surveys is that a description of the scale and magnitude of the impact is produced. In the case of Palos Verdes, it is clear that recovery has occurred since 1969; however, an area of reduced species diversity still prevails near the outfalls.

Future improvements in source control of toxicants and treatment of the effluents discharged off Palos Verdes can be expected to produce a continuing pattern of recovery of nearshore rocky bottom communities.

ACKNOWLEDGMENTS

I thank John D. Isaacs, Chairman of the Project's Consulting Board, and Willard Bascom, Project Director, for providing the encouragement and facilities for this research, which was conducted during a 6-month sabbatical from the University of Hawaii. The staff of the Project were involved in the design of the study and the collection and analysis of the data. All diving operations were under the direction of Harold H. Stubbs. Michael D. Moore accompanied me on all dives and collected all the data on fishes. Jack Q. Word, Brad L. Myers, and Leslie H. Harris provided invaluable assistance in identifying invertebrates and algae. All of the personnel in the Project's chemistry laboratory, under the direction of Dr. David R. Young, were involved in the analysis of sediment and flock samples for trace metals and chlorinated hydrocarbons. The manuscript was critically reviewed by Dr. Alan J. Mearns, head of the biology division. In sum, this report is the result

of a team effort, and I am very grateful to the entire Project staff for their cooperation and support.

REFERENCES

Coastal Water Research Project. 1973. The ecology of the Southern California Bight: Implications for water quality management. TR 104, El Segundo, Calif.

______. 1974, 1975, 1976, and 1977. Annual reports. El Segundo, Calif.
Deal, K. 1976. Light attenuation in nearshore waters off Palos Verdes. Monthly report, Los Angeles County Sanitation Districts Office, 1955 Workman Mill Road, Whittier, Calif.

Grigg, R.W. 1970. Ecology and population dynamics of the gorgonians, *Muricea californica* and *Muricea fruticosa*. Ph.D. thesis, Univ. of Calif, at San Diego.

Grigg, R.W., and R.S. Kiwala. 1970. Some ecological effects of discharged wastes on marine life. *Calif. Fish Game* 56:145-55.

Heesen, T.C., and D.R. Young. 1977. Halogenated hydrocarbons: Knowns and unknowns. In Annual report, 1977, pp. 33-38. Coastal Water Research Project, El Segundo, Calif.

Hershelman, G.P., T.K. Jan, and H.A. Schafer. 1977. Pollutants in sediments off Palos Verdes. In Annual report, 1977, pp. 63-74. Coastal Water Research Project, El Segundo, Calif.

Holmes, R.W. 1957. Solar radiation. In Treatise on marine ecology and paleoecology, vol. 1, ed. J.W. Hedgpeth. *Geol. Soc. of Amer. Mem*. 67:109-28.

MacGinitie, G.E., and N. MacGinitie. 1949. Natural history of marine animals. New York: McGraw Hill.

Mearns, A.J. 1977. Coastal gradients in sportfish catches. In Annual report, 1977, pp. 27-32. Coastal Water Research Project, El Segundo, Calif.

Mearns, A.J., D.A. Hanan, and L. Harris. 1977. Recovery of kelp forest off Palos Verdes. In Annual-report, 1977, pp. 99-108. Coastal Water Research Project, El Segundo, Calif.

North, W.J. 1967. Kelp Habitat Improvement Program, annual report, 1 April 1966 to 30 June 1977. W.M. Keck Laboratory of Environmental Health Engineering, California Institute of Technology, Pasadena.

_____ . 1973. Kelp Habitat Improvement Program, annual report, 1972-73. W.M. Keck Laboratory of Environmental Health Engineering, California Institute of Technology, Pasadena.

Peterson, L.L. 1974. The propagation of sunlight and the size distribution of suspended particles in a municipally polluted ocean water. Ph.D. dissertation. Calif. Inst. of Technology, Pasadena.

Quast, J.C. 1968. Some physical aspects of the inshore environment particularly as it affects kelp bed fishes. In Utilization of kelp-bed resources in Southern California, ed. W.J. North and C.L. Hubbs. Div. of Fish and Game, *Fish. Bull*. 139:25-34.

Schafer, H.A. 1977. Characteristics of municipal wastewater discharges, 1976. In Annual report, 1977, pp. 19-23. Coastal Water Research Project, El Segundo, Calif.

Soule, J., and D. Soule. The Bryozoa. *In Reef and shore fauna of Hawaii*, ed. D.M. Devaney and L.G. Eldredge. Honolulu, Hawaii: Bishop Museum Press. In press.

Thomas, W.H. 1972. Nutrients, chlorophyll and phytoplankton productivity near Southern California sewage outfalls. IMR Ref. 72-19, Institute of Marine Resources, Univ. of Calif., La Jolla.

U.S. Environmental Protection Agency and Sanitation Districts of Los Angeles County. 1976. Draft, EIS and EIR for the Joint Outfall System Facilities Plan of the Sanitation Districts of Los Angeles County, Report No. C-06-1015-010, SCH-740-506-05, U.S. Environmental Protection Agency, Region IX, San Francisco.

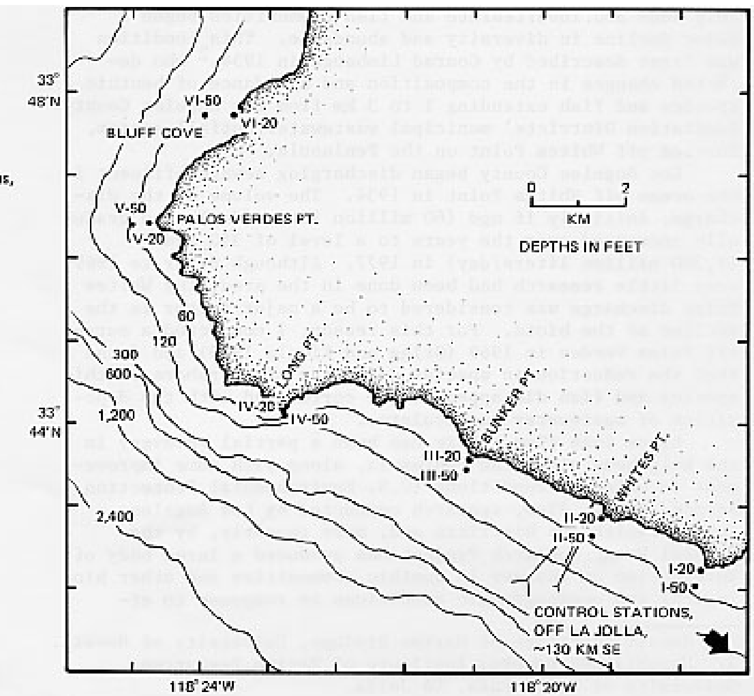

Figure 1. Station locations, survey of rocky bottom communities.

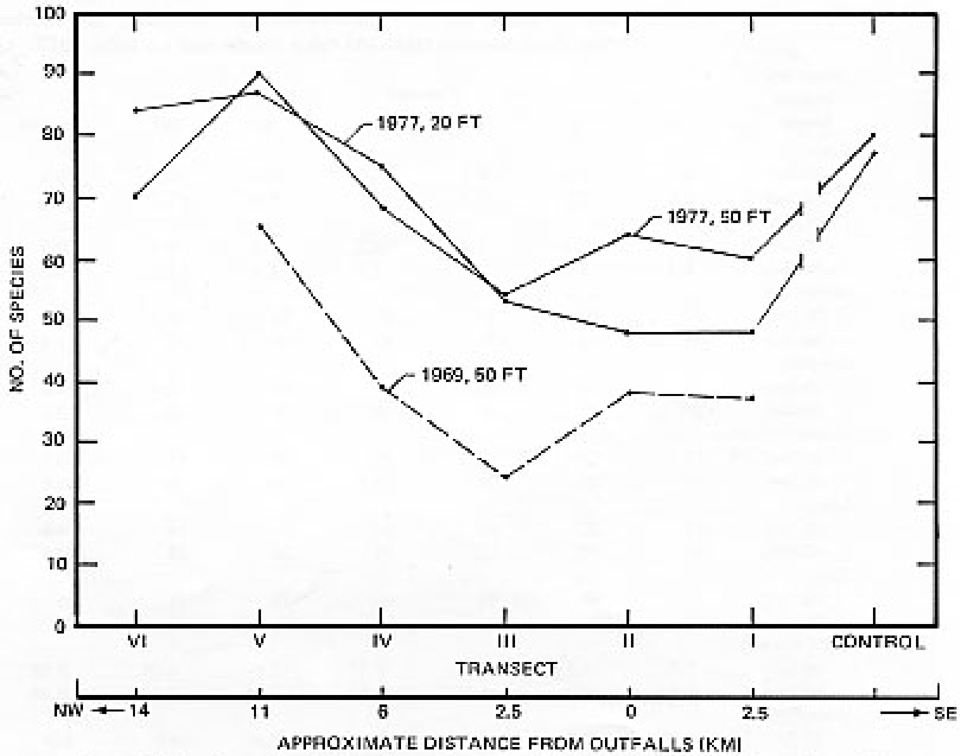

Figure 2. Total number of alga, invertebrate, and fish species observed at stations off Palos Verdes and La Jolla in 1969 and 1977 surveys.

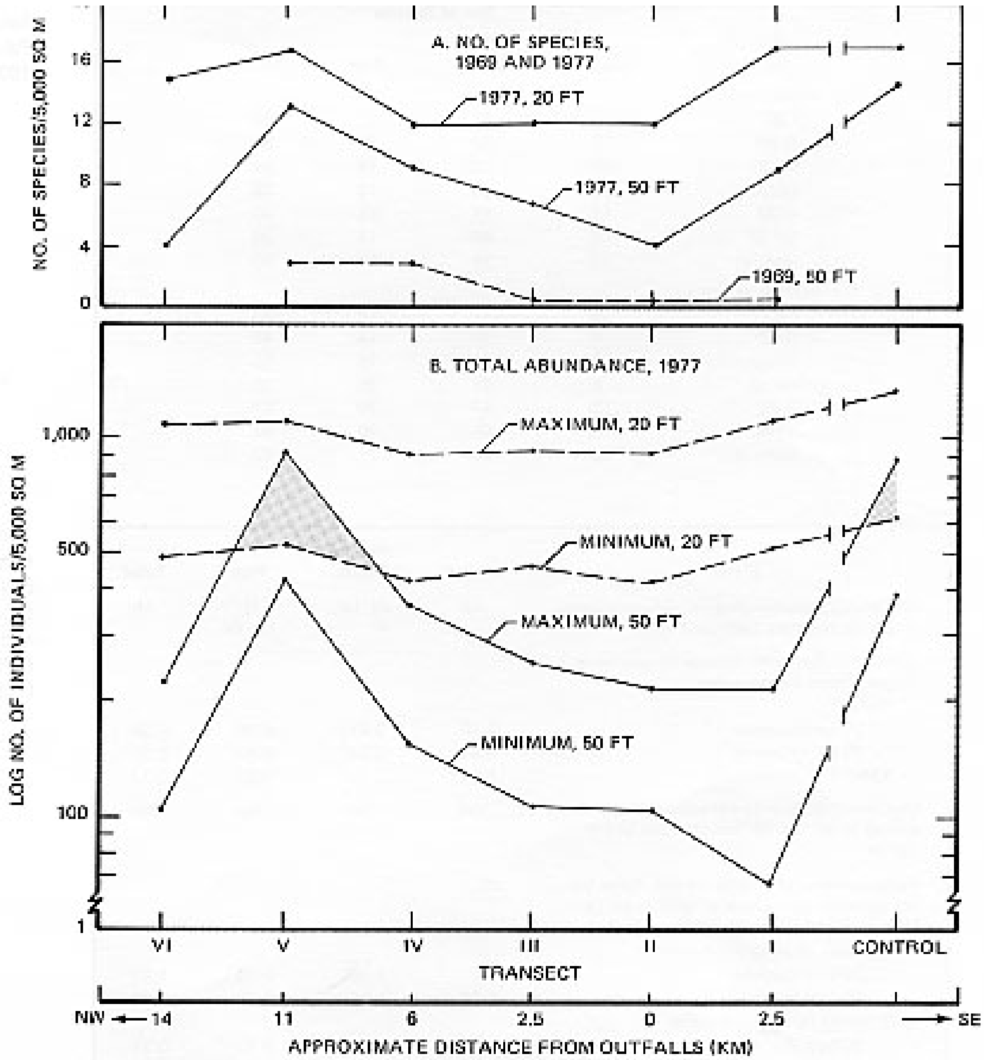

Figure 3. Number of species of algae observed at stations off Palos Verdes and La Jolla in 1969 and 1977 surveys and their cumulative abundance at 20- and 50-ft depths in 1977. Cumulative abundance was calculated twice, assuming all species were present in minimum or maximum abundance. Shaded area represents zone where estimates of abundance at 20 and 50 feet overlap.

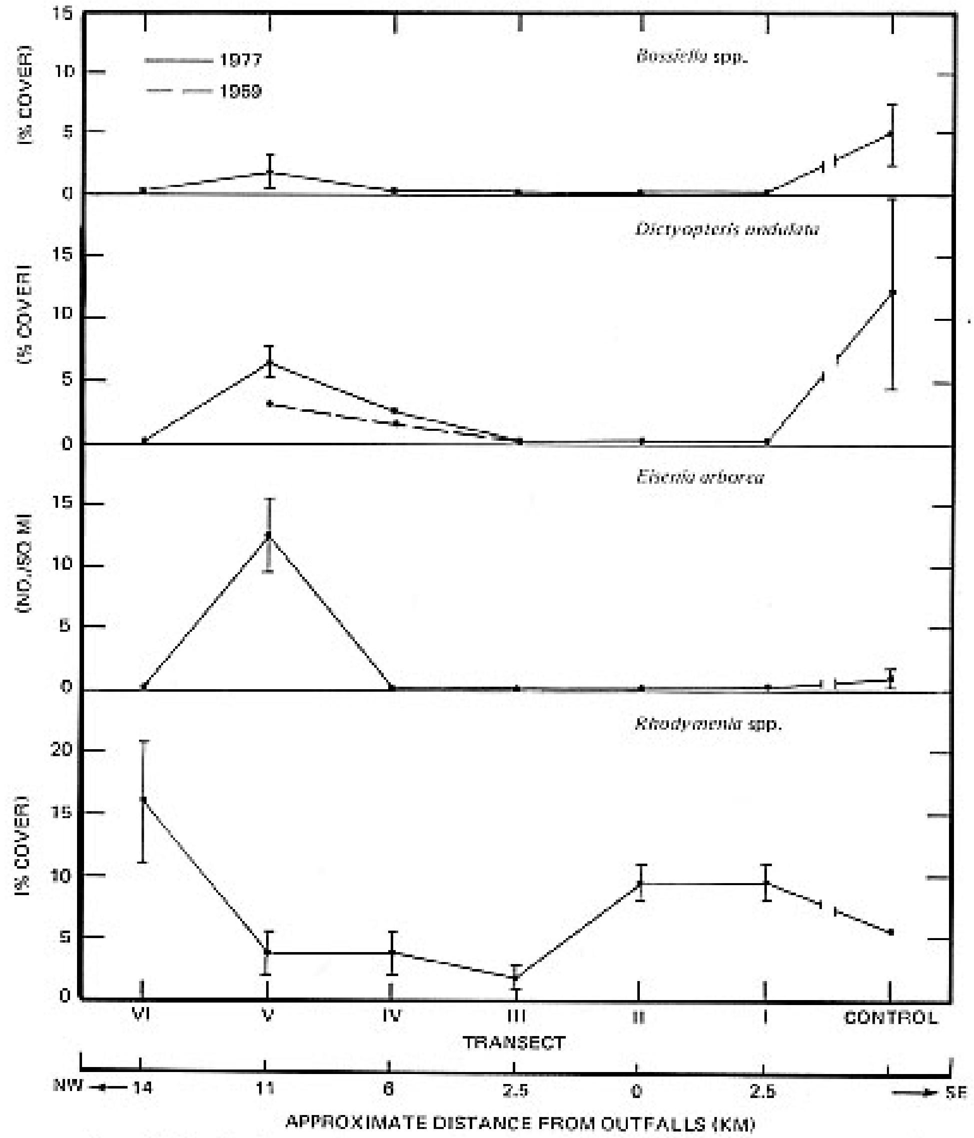

Figure 4. Distributions and abundance (mean density and standard error) of four species of algae off Palos Verdes and La Jolla, 1969 and 1977.

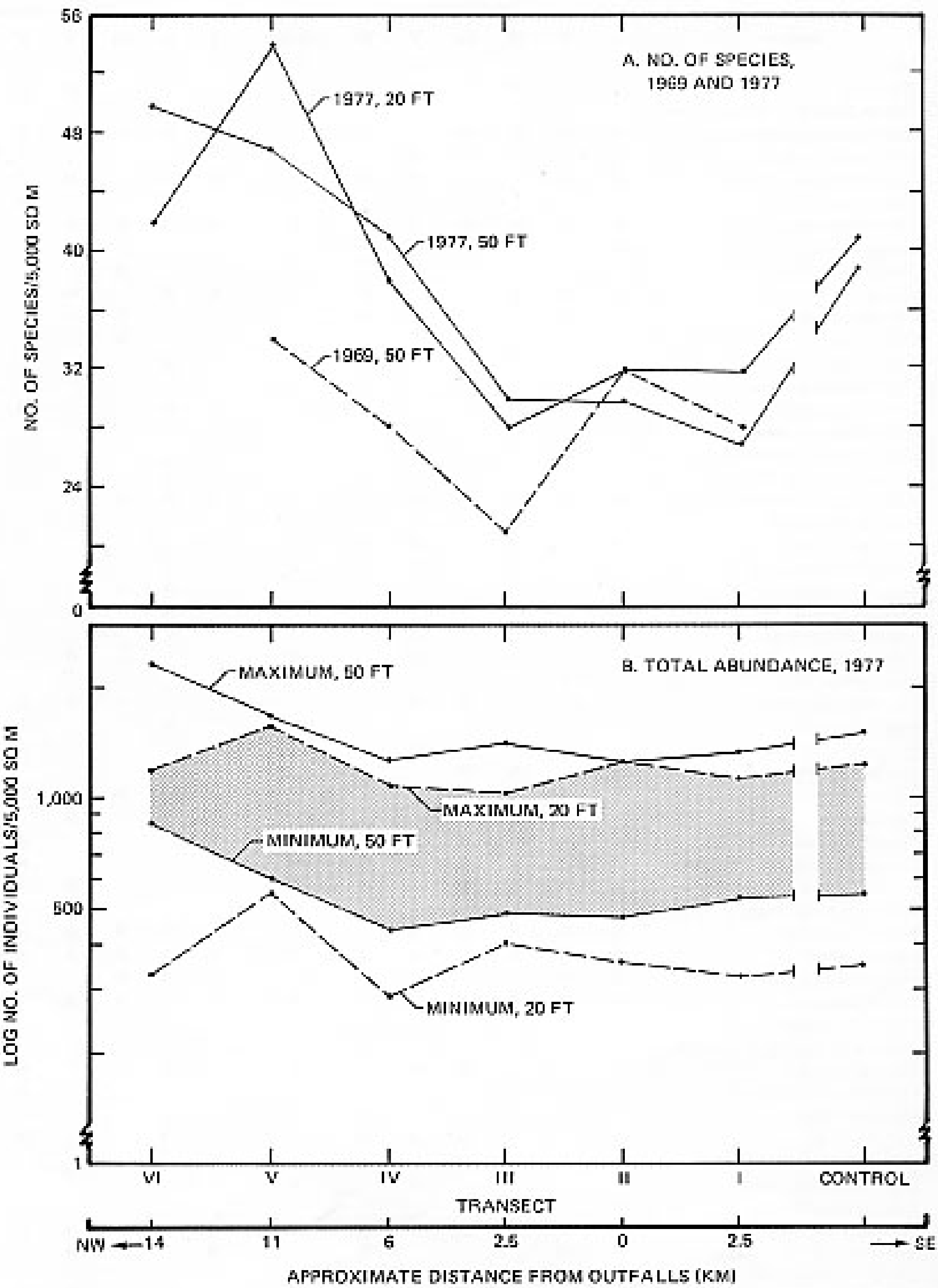

Figure 5. Number of species of invertebrates observed at stations off Palos Verdes and La Jolla in 1969 and 1977 surveys and their cumulative abundance at 20- and 50-ft depths in 1977. Cumulative abundance was calculated twice, assuming all species were present in minimum or maximum abundance. Shaded area represents zone where estimates of abundance at 20 and 50 feet overlap.

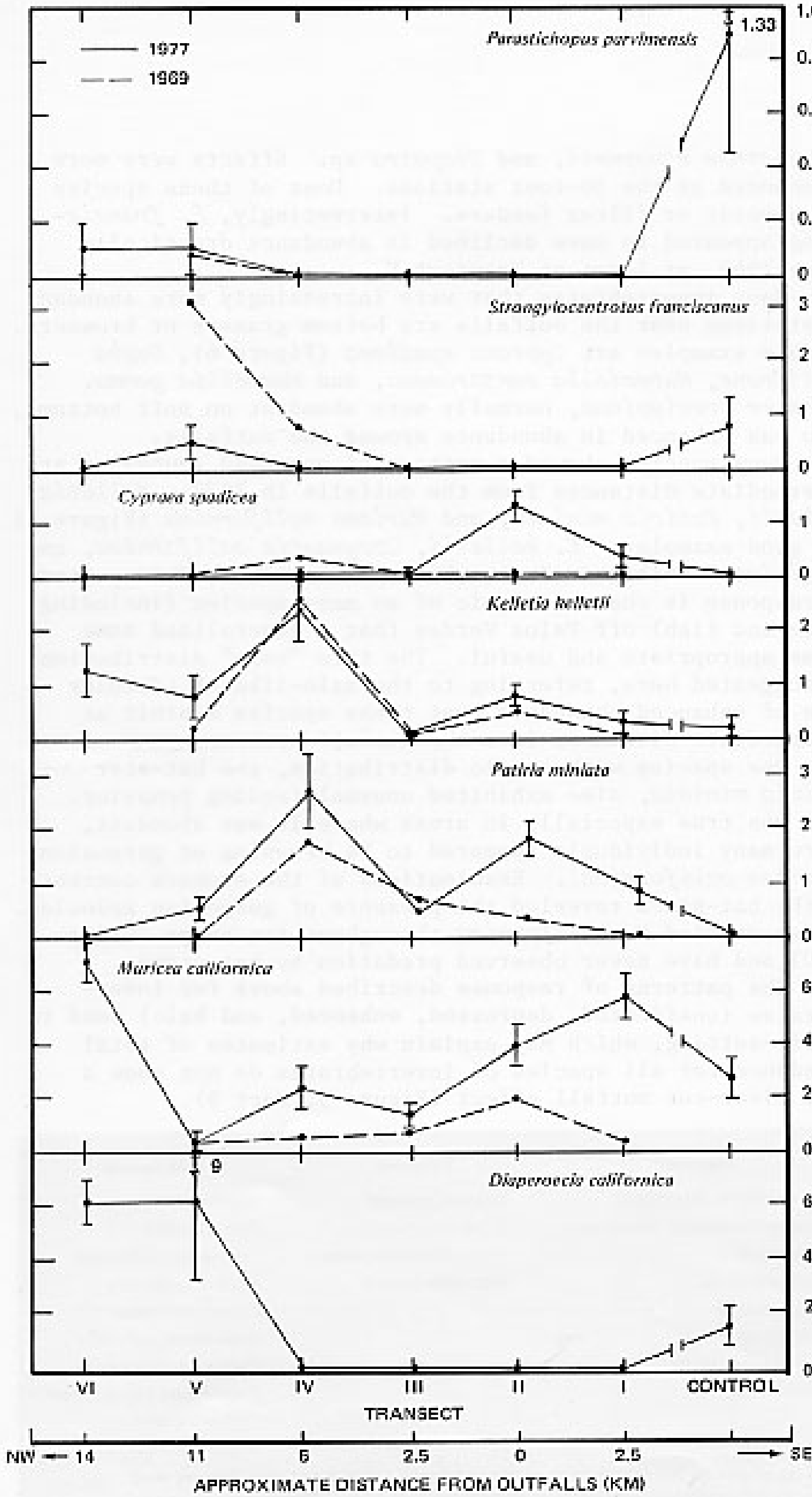

Figure 5. Distributions and abundance (mean density and standard error) of seven species of invertebrates off Palos Verdes and La Jolla, 1969 and 1977.

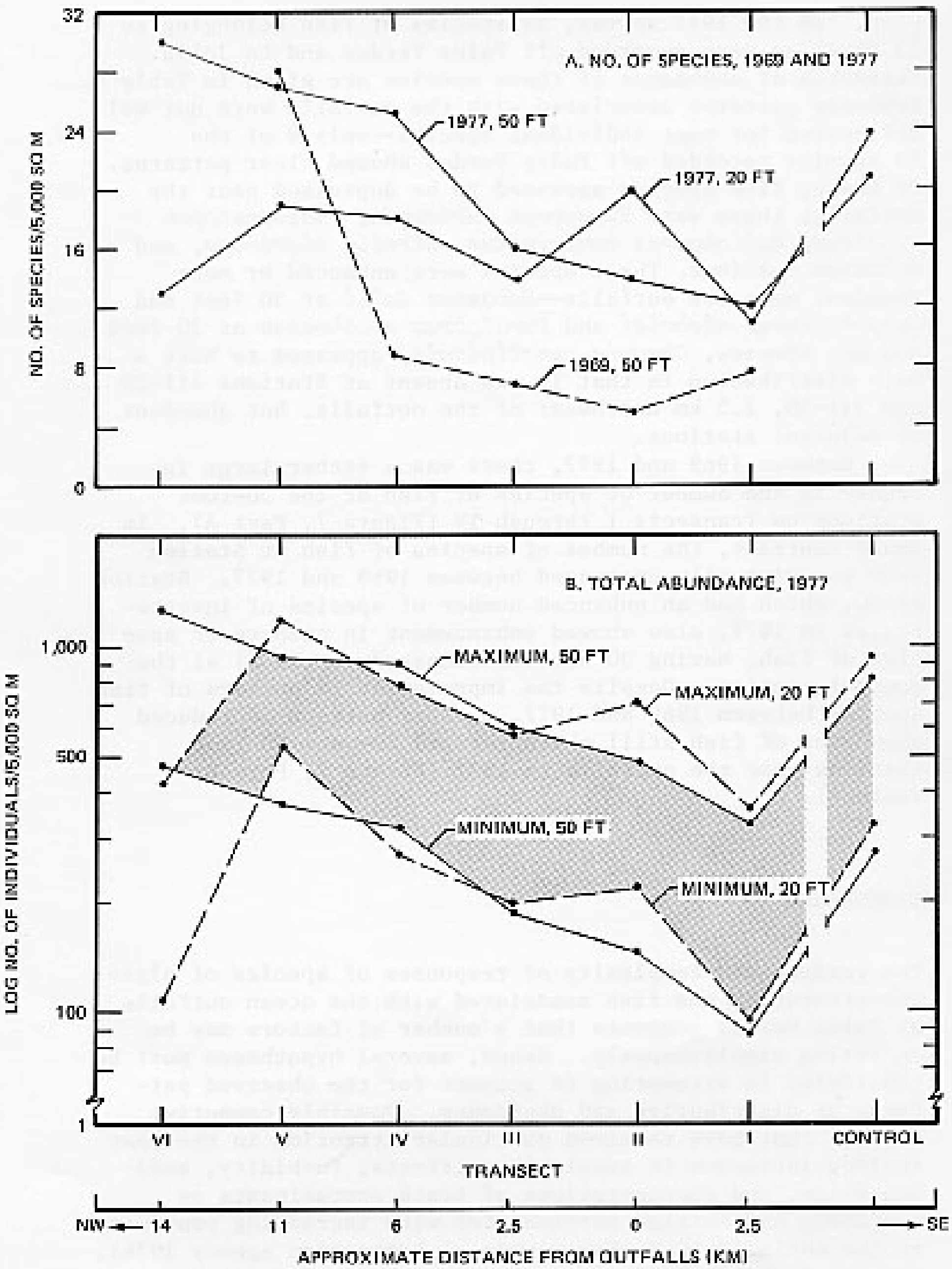

Figure 7. Number of species of fish observed at stations off Palos Verdes and La Jolla in 1969 and 1977 surveys and their cumulative abundance at 20- and 50-ft depths in 1977. Cumulative abundance was calculated twice, assuming all species were present in minimum or maximum abundance. Shaded area represents zone where estimates of abundance at 20 and 50 feet overlap.

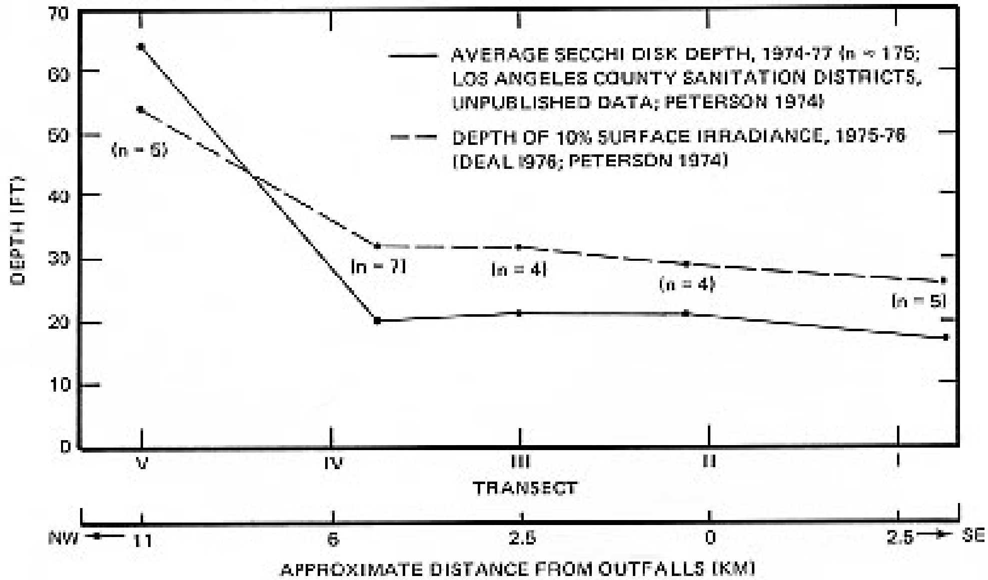

Figure 8. Light attenuation off Palos Verdes.

Table 1. Concentrations (ppm) of trace metals and chlorinated hydrocarbons in surface sediments (0 to 5 cm) taken off Palos Verdes and La Jolla, 1977.

Metal and Station Depth	Transect I	II	III	IV	V	VI	Control	Ratio, Maximum Value, I-VI, to Control Value
Silver								
20 feet	<0.3	<0.8	<0.3	<0.3	<0.3	<0.4	<0.4	2
50 feet	<0.5	0.5	<0.5	<0.6	<0.4	<0.9	<0.4	2
Cadmium								
20 feet	<0.2	4.6	<0.5	0.5	0.4	1.1	<0.3	15
50 feet	0.8	1.6	0.7	0.5	<0.2	1.5	<0.2	8
Chromium								
20 feet	11	18	11	14	3.9	16	2.8	6
50 feet	30	40	33	21	6.2	18	2.2	18
Copper								
20 feet	5.7	8.0	6.2	10	2.1	5.9	0.2	40
50 feet	14	21	9.1	11	4.1	5.0	0.5	42
Nickel								
20 feet	10	12	6.0	7.5	1.9	17	<1.2	10
50 feet	16	18	5.2	6.9	2.2	16	<1.1	16
Lead								
20 feet	3.7	12	6.7	8.6	1.7	3.4	<1.5	8
50 feet	18	22	20	11	6.0	2.1	<1.5	15
Zinc								
20 feet	40	49	26	33	13	33	8.5	6
50 feet	66	80	47	40	20	3.8	12	7
Total DDT								
20 feet	0.03	0.20	0.23	0.13	0.02	0.03	ND	–
50 feet	0.77	1.7	1.2	0.56	0.12	0.03	ND	–
Total PCB								
20 feet	ND	0.02	0.0	0.28	ND	ND	ND	–
50 feet	0.06	0.15	0.08	0.16	0.02	ND	0.01	16

Table 2. Concentrations (ppm) of trace metals and chlorinated hydrocarbons in 2-liter flock samples taken off Palos Verdes and La Jolla, 1977.

Metal and Station Depth	Transect I	II	III	IV	V	VI	Control	Ratio, Maximum Value, I-VI, to Control Value
Silver								
20 feet	0.9	0.8	<0.7	<1.0	<3.2	<0.9	<0.3	11
50 feet	0.6	0.8	1.5	0.5	1.3	<1.2	<0.6	2.5
Cadmium								
20 feet	2.1	2.3	1.4	1.2	4.1	1.1	<0.2	20
50 feet	2.3	3.2	2.7	1.2	2.2	1.6	0.6	5
Chromium								
20 feet	61	49	31	59	54	32	4.8	13
50 feet	54	100	130	49	105	50	7.4	18
Copper								
20 feet	24	16	10	24	30	6.4	1.6	15
50 feet	27	43	62	16	33	13	2.8	22
Nickel								
20 feet	17	17	8.5	15	24	11	0.7	34
50 feet	17	20	28	9.3	20	15	<1.5	19
Lead								
20 feet	31	30	20	31	61	14	4.0	13
50 feet	30	46	62	24	56	23	4.6	13
Zinc								
20 feet	76	64	44	66	135	31	14	10
50 feet	81	105	125	51	97	50	32	4
Total DDT								
20 feet	1.3	1.1	0.67	0.31	1.1	0.01	0.04	32
50 feet	1.8	2.4	1.2	0.51	0.94	0.04	0.34	7
Total PCB								
20 feet	0.09	0.05	0.04	0.17	0.45	ND	ND	–
50 feet	0.20	0.24	0.08	0.14	0.17	0.02	0.29	0.8

Table 3. Number of species of algae, invertebrates, and fish observed at stations off Palos Verdes and La Jolla, 1977.

Station Number	No. of Species Algae	Inverte-brates	Fish	Total
20-foot stations				
I-20	17	32	11	60
II-20	12	32	20	64
III-20	12	28	14	54
IV-20	12	38	18	68
V-20	17	54	19	90
VI-20	15	42	13	70
Control	17	39	24	80
50-foot stations				
I-50	9	27	12	48
II-50	4	30	14	48
III-50	7	30	16	53
IV-50	9	41	25	75
V-50	13	47	27	87
VI-50	4	50	30	84
Control	15	41	21	77

Table 4. Spatial and temporal patterns in the distribution of organisms off Palos Verdes that appear to reflect the influence of the Whites Point outfall system.*

Effect	Algae	Inverte-brates	Fish	Total
50-foot stations showing increase in number of species between 1969 and 1977	All	III, IV, V	I, II, III, IV	All
Correlation between number of species and distance from outfall pipes				
1977				
20-foot stations	0.46	0.91†	0.30	0.86
50-foot stations	0.92†	0.94†	0.92†	0.97†
1969, 50-foot stations	0.91†	0.40†	0.88	0.77
Significant difference between number of species at 20 and 50 feet near outfalls in 1977?	Yes	No	No	No
Ratio, number of species on two Palos Verdes transects to number of species on La Jolla control transect in 1977				
Transect V, away from outfalls				
20-foot stations	1.0	1.38	0.79	1.12
50-foot stations	0.86	1.15	1.29	1.13
Transect II, outfall transect				
20-foot stations	0.70	0.82	0.83	0.71
50-foot stations	0.27	0.73	0.67	0.62

*Transect VI, the Palos Verdes transect farthest from the outfalls, was not considered in these calculations because it is inside of Santa Monica Bay and appears to be affected by factors unrelated to the Whites Point outfall system.

†Significant at the 0.05 level.

Table 5. Distribution and estimates of abundance of species of algae off Palos Verdes and La Jolla, California, 1977. Species listed as rare (R) were represented by fewer than 10 individuals; those listed as moderate (M) or abundant (A) were represented by 10 to 50 or more than 50 individuals, respectively.

Species	20-Foot Stations							50-Foot Stations						
	I	II	III	IV	V	VI	Control	I	II	III	IV	V	VI	Control
Agarum fimbriatum														R
Macrocystis pyrifera		A	R	A	R	A	R	R		R	R	R		R
Cystoseira osmundacea	A	A	A	A	A	M	M	R	R		R	M		A
Egregia menziesii	A	R	A	M	A	M	A			R		A		A
Eisenia arborea		A	A	A	A	A	A				R	A		M
Dictyopteris undulata	A	A	A	A	A	A		R		R	A	A	R	A
Dictyota sp.	A				M	A	A			R	R			A
Bossiella spp.	A	M	A	A	A	A	A				R	A		A
Botryocladia pseudodichotoma														R
Gelidium sp.	M	M	R		A	M	A	R	R			M		R
Griffithsia pacifica														R
Rhodymenia spp.	A	A	A	A	A	A	A	A	A	A	A	A	A	M
Corallina spp.	A	A	A	A	A	A	A					A		M
Lithothamnium spp.	A	A	A	A	A	A	A	M	A	A	A	A	A	A
Lithothrix aspergillum					R									
Calliarthron spp.	A	A	A	A	A	A	A					A		
Colpomenia peregrina					R		R							
Pterygophora californica	A							R				R		
Ulva sp.					R									
Gigartina sp.	R													
Enteromorpha sp.								R						
Prionitis cornea	M	R			R			R						
Zostera marina						R								
?*Laminaria* sp.	R					R	M			R			R	A
Phyllospadix torreyii							A							
Nienburgia andersoniana	R													
Codium fragile					R		M							
Opuntiella californica	R													
Cladophora sp.			R	R			R					R		
Plocamium cartilagineum	R			R		R	M				R			
Total species	17	12	12	12	17	15	17	9	4	7	9	13	4	15

Table 6. Distribution and estimates of abundance of species of invertebrates off Palos Verdes and La Jolla, California, 1977. Species listed as rare (R) were represented by fewer than 10 individuals; those listed as moderate (M) or abundant (A) were represented by 10 to 50 or more than 50 individuals, respectively.

	20-Foot Stations							50-Foot Stations						
Species	I	II	III	IV	V	VI	Control	I	II	III	IV	V	VI	Control
Tethya aurantia	R	M			A		M	A	M	M	A	A	A	A
Leucosolenia eleanor	R				M	R	M						M	M
Yellow sponge					A							R		
Verongia aurea				R		R	M	R						R
Plocamia sp.						R								
Craniella arb				R		R							A	
Muricea fruticosa	R			R	R	R	R	A	A	M	M	R	A	M
Muricea californica	R	R		M	R	M	R	A	A	A	A	A	A	A
Eugorgia rubens				R							R			
Lophogorgia chilensis								R		A	R			R
Anthopleura elegantissima		M	R		A	R	M						R	R
Epiactis prolifera	M					R	R							
Corynactis californicus			R	A		M	R	A	A	A	A	A	A	M
Balanophyllia elegans														M
Coenocyathus bowersi								R					R	
Astrangia lajollaensis					R									
Paracyathus stearnsii				R				R			R	R	R	
Pachycerianthus sp.					R	R		A	M	A	R	M	R	R
Tealia sp.				R										
Bugula neritina						R								
Membranipora membranacea		A			R	R	A						M	M
Phidolopora pacifica					R	M	R	R				M	R	M
Scrupocellaria sp.	M	M			M		A					A	M	A
Diaperoecia californica	M				A	M						A	A	A
Serpulidae							R					M	M	M
Phragmatopoma californica					R		A							
Eudistylia polymorpha	M			R		M	R		R	R	R	R	R	R
Chaetopterus sp.													R	R
Diopatra sp.	M	A	R	R	R	R		M	R	R	R	M	A	
Salmacina tribranchiata	R	R		R	R	R		A	M		A	R	R	
Tegula sp.		R												
Haliotis fulgens			R				R		R		R			
Haliotis rufescens			R	R	R									
Haliotis walallensis					R									
Haliotis cracherodii	R		R	M	R	R								
Megathura crenulata	M	M	M		A	A	M					R	A	R
Acmaea mitra	R				R									
Diodora aspera									R					
Astraea gibberosa												R		
Serpulorbis squamigerus		M			R	M	M					R	R	
Norrisia norrisi		M	A	M	R	A	R			R				R
Astraea undosa			R	R		R	R				R			A
Calliostoma spp.					R			M				R	R	
Nassarius mendicus										R	R			
Murexiella santarosana				M		R				R	R	R		
Ocenebra lurida											R			
Maxwellia gemma			R	M	R	R	R	R	R	R	R	R	R	R
Pteropurpura festiva	M	M			R	R				A	R			
Bursa californica													R	
Kelletia kelletii	M	R	A	A	R	A	R	A	A	A	A	R	A	M
Conus californicus		M			A	R	M			M	M		A	R
Simnia sp.										M	R			
Cypraea spadicea	M	M	A	R	R	R		A	A	M	M	R	M	R
Crassispira semiinflata					R			R	R	R	R		M	
Mitra idae			R	R	R			R			R	R	R	

(Continued)

Species	20-Foot Stations I	II	III	IV	V	VI	Control	50-Foot Stations I	II	III	IV	V	VI	Control
Semele decisa					R		R							
Chamidae	R		R	R							R	R		
Trachycardium quadragenarium													R	
Pododesmus macrochisma	M	M	R	R					R	R	R	R	M	R
Lithophaga plumula					M							A	M	
Chaceia ovoidea (Pholad)	M	R			M	M	R	R	R		M	R		A
Ventricolaria fordii												R		
Hinnites giganteus	R	R	R	R	R	R	R	M	A	M	R		A	R
Siliqua lucida	R													
Saxidomus nuttalli					R					M				
Gari sp.		R	R			R		M	R		M			
Olivella biplicata		M				R				R				
Octopus sp.					R					M				R
Cadlina sp.									R				R	
Hypselodoris porterae													M	
Dorid nudibranchs			R					R	M			R	M	
Doriopsilla albopunctata													R	
Hermissenda crassicornis		R												
Diaulula sandiegensis													R	
Flabellinopsis iodinea	R	M		M	R			M	R	M	R	R		M
Aplysia californica					M								R	
Aplysia vaccaria	R		M		M	R						R		R
Panulirus interruptus		R			R		M							
Cancer antennarius									R	R				
Cancer anthonyi									R				R	
Lophopanopeus sp.														R
Pagurus sp.		R	R		R		R				R			
Heptacarpus sp.		R												
Lysmata californica				R	R						R	R		
Pugettia producta			A				R		R					
Loxorhynchus crispatus					R							R		
Loxorhynchus grandis	R		R	R			R		R				R	
Scyra acutifrons			R	R					M	M		R	R	
Pelia tumida											R			
Parastichopus parvimensis				R	A	R	M					A	A	A
Strongylocentrotus purpuratus	A	R	M	A	R	R	M					R		R
Strongylocentrotus franciscanus	A	A	A	M	A	M	A				R	A	M	A
Lytechinus anamesus												A		R
Pisaster ochraceus	R	R	R	R	R				R	R	R	R		
Pisaster giganteus	A	M	A	A	A	A	M	M	A	M	A	A	A	R
Pisaster brevispinus	R	R						R	R	M				
Patiria miniata	A	A	A	A	R		R	A	A	A	A	M		R
Mediaster aequalis														R
Henricia leviuscula													R	R
Ophioderma sp.				R	R		R				R	M		
Ophioplocus esmarki												R		
Ophionereis sp.							R							
Cucumaria sp.	R			M	R	M						R	A	
Dermasterias imbricata				R										
Astrometis sertulifera					R		R						R	
Linckia columbiae				R										
Synoicum parfustis				M	R	M	M				M	R		
Euherdmania claviformis	R	M				R		R			R			
Styela montereyensis						R								M
Cystodytes lobatus					R	R	M				R	R	M	R
Clavelina huntsmani												M	R	
Total species	32	32	28	38	54	42	39	27	30	30	41	47	50	41

Table 7. Patterns of response of rocky bottom benthic invertebrates to the Whites Point outfall system.*

Depressed	Enhanced	Halo Species
Parastichopus parvimensis	*Cypraea spadicea*	*Kelletia kelletii*
Strongylocentrotus franciscanus	*Scyra acutifrons*	*Patiria miniata*
S. purpuratus	*Maxexiella santarosana*	*Corynactis californicus*
Ophioderma sp.	*Maxwellia gemma*	*Muricea californica*
Cucumaria sp.		*Conus californicus*
Haliotis spp.		*Diaperoecia californica*
Paracyathus stearnsii		*Phidolophora pacifica*
Diopatra sp.		*Anthopleura elegantissima*
		Tethya aurantia
		Megathura crenulata

*A list of species that appear to be unaffected by the outfall is not given because most species in this category are so rare or so abundant that their time-response patterns are obscured by the method in which data were collected.

Table 8. Distribution and estimates of abundance of species of fish off Palos Verdes and La Jolla, California, 1977. Species listed as rare (R) were represented by fewer than 10 individuals; those listed as moderate (M) or abundant (A) were represented by 10 to 50 or more than 50 individuals, respectively.

	20-Foot Stations							50-Foot Stations						
Species	I	II	III	IV	V	VI	Control	I	II	III	IV	V	VI	Control
Torpedo californica		R												
Triakis semifasciata	R													
Myliobatis californica									R					
Gymnothorax mordax			R	R			R				R	R		
Citharichthys stigmaeus							R	R		R			R	R
Pleuronichthys coenosus							R				R	R		R
Pleuronichthys verticalis									R					R
Paralabrax clathratus	M	M	A	A	A	M	M		R	M	M	A	R	M
Paralabrax nebulifer							R	R	R				R	M
Cheilotrema saturnum		R								R				
Embiotoca jacksoni			R	R	A		M	R	M	R	R	A	A	
Hypsurus caryi										R				
Phanerodon furcatus		R	M				R					R		
Rhacochilus toxotes				R	A		M		R	M	R	R	R	A
Damalichthys vacca	M	A		R	A	R	R				R	R	R	
Chromis punctipinnis	M	A		M	A		A	R	A		A	A	A	M
Hypsypops rubicundus	R		R	M	A	M	A				M	R	M	
Oxyjulis californica	A	A	A	A	A	A	A	M	A	A	A	A	A	A
Pimelometopon pulchrum	R			M	A	R	A				M	M	A	A
Halichoeres semicinctus			R		A		A						R	M
Girella nigricans			M	M	A	R	R		R		A	R		R
Medialuna californiensis		R		M		M	R				M	M	M	R
Scorpaena guttata	R						R		R	R	R	R	R	
Sebastes atrovirens		M	R	R	R					R	R		M	
Sebastes auriculatus		M	R		R	R				R	R	R		
Sebastes dalli							M	M	M	A	R		M	R
Sebastes carnatus											R		R	
Sebastes mystinus	M	R		R	R	M	R	R	R		R	A	A	
Sebastes paucispinis			R											
Sebastes rastrelliger						R		R		M			R	
Sebastes serranoides					M			R				M	A	
Sebastes serriceps										R		R	R	R
Sebastes chrysomelas													R	
Oxylebius pictus	R	M		R	R		M	R	M	R	R	M	M	M
Scorpaenichthys marmoratus											R			
Cottid		R			R								R	
Ulvicola sanctaerosae							R							
Coryphopterus nicholsii		M	A	A	R	M	R	A	M	A	A	A	A	M
Neoclinus stephensae					R							R	A	R
Lythrypnus dalli										R		R	M	
Lythrypnus zebra													R	
Clinid		R												R
Alloclinus holderi		R											R	
Paralichthys californicus	R													
Brachyistius frenatus		R	M		M		M				R	R	R	A
Gibbonsia elegans												R		
Heterostichus rostratus		M					R							
Amphistichus argenteus			M	R		R		M			M	R		R
Anisotremus davidsonii												R		
Engraulis mordax				A		R					A			
Artedius creaseri												R	R	R
Sarda chiliensis				R							M			
Hyperprosopon argenteum		R												
Zaniolepis latipinnis		R												
Total species	11	20	14	16	19	13	24	12	14	16	25	27	30	21