COASTAL WATER RESEARCH PROJECT

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THE 60-METER CONTROL SURVEY

A fundamental question that must be considered in every environmental survey is: What are the normal or natural conditions? A continuing difficulty with past studies of California coastal conditions in general, and wastewater outfall areas in particular, has been the uncertainty about what values to use for "controls." These control or reference values are the ones against which data from any possibly polluted area must be compared. Control stations used in the past often have been in areas already changed by acts of man or were unlike the study areas in their exposure to waves and currents. Therefore, we planned a survey that would cover enough territory to ensure that many similar areas with unchanged conditions would be included. The results are summarized here.

The survey covered stations located at 10-km intervals between Point Conception and the U.S./Mexico border. Grab samples and trawls were taken at 60-meter depths, the average depth of discharge of the large wastewater outfalls, so as to minimize any problems in comparing changes caused by wastes with natural conditions.

After having analyzed the data from the 71 stations surveyed, we selected as controls the locations where control species of benthic infaunal animals dominated and where no excesses of possible pollutants could be detected in the sediments. There were 29 such benthic stations located off areas of the coast away from the urban effects of Los Angeles and San Diego. The data from these stations give a reliable picture of the variations in natural conditions.

METHODS

Between 28 April and 9 August 1977, 71 benthic infaunal samples, 71 benthic chemistry samples, 53 trawl samples, and 67 water quality samples were taken at 71 stations between Point Conception and the U.S./Mexico border (Figure 1). The stations were located at intervals of approximately 10 km

along the 360 km of coastline at a depth of approximately 60 meters. In areas near the major municipal wastewater outfalls, stations were more closely spaced. In all, thirteen 1- to 3-day cruises were conducted.

The benthic grab samples were collected with the modified 0.1-sq meter Van Veen grab sampler selected as best during the Project's comparison of grab samplers (Word 1976; Word 1977). Trawl samples were taken with a 7.6-meter (headrope length), semiballoon otter trawl built for the Project by Willis Netmakers, Morro Bay (Bascom 1977; Word and Mearns, in press); trawling procedures were those recommended by Mearns and Allen (1978). Water samples for dissolved oxygen determinations were collected with Van Dorn remote samplers, continuous temperature measurements were made with a 135-meter bathythermograph, and water clarity was measured with a Secchi disk.

Biological Measurements

Two replicate grab samples were taken at all stations, and the sediment type, color, odor and depth of grab penetration were noted. The samples were sieved in the field through a stacked set of screens with square mesh sizes of 2.5, 1.0, and 0.5 mm (the biological data reported here utilized only the material collected on the 2.5- and 1.0-mm screens). The organisms collected were sorted into eight groups (molluscs, arthropods, crustaceans, polychaetes, ophiuroid discs, ophiuroid fragments, other echinoderms, and miscellaneous phyla) and weighed by group. The organisms in each group were then identified to the lowest possible taxonomic unit, and the number of organisms in each unit was recorded. The resulting data were analyzed using several of the statistical measures of community structure in common use as well as the Infaunal Trophic Index.

One trawl sample was taken at each of 53 stations. The organisms collected in each sample were identified, counted, weighed, and externally examined aboard ship. All fish were measured for standard board length; members of abundant species (more than 10 individuals) were measured to the nearest centimeter, and individuals representing less abundant species were measured to the nearest millimeter. The carapaces of all specimens of the larger decapods were also measured to the nearest millimeter, and the sex and reproductive condition of each individual was noted.

Trawl-caught organisms showing signs of disease, parasitism, or abnormalities were preserved and returned to the laboratory for further examination. Individuals from selected species of fish and invertebrates were rapidly frozen using methods appropriate for later trace metal and chlorinated hydrocarbon analyses (Word and Mearns, in press); the

results of these analyses (not yet completed) will be reported in the future.

Physical/Chemical Measurements

Certain physical and chemical data on the water column and sediments were collected. For example, a temperature profile of the water column was made, samples of surface and bottom (within 1 meter) waters were collected for dissolved oxygen measurements, and water clarity was measured. Subsamples of the upper 2 and 5 cm of sediment were carefully removed from the grab sample for chemical analysis. The sample for chlorinated hydrocarbon analysis was sealed in a glass container; samples for metals and natural organic material analyses were stored in plastic. All were rapidly frozen on dry ice.

The sediment samples were analyzed for concentrations of seven trace metals (silver, cadmium, copper, chromium,

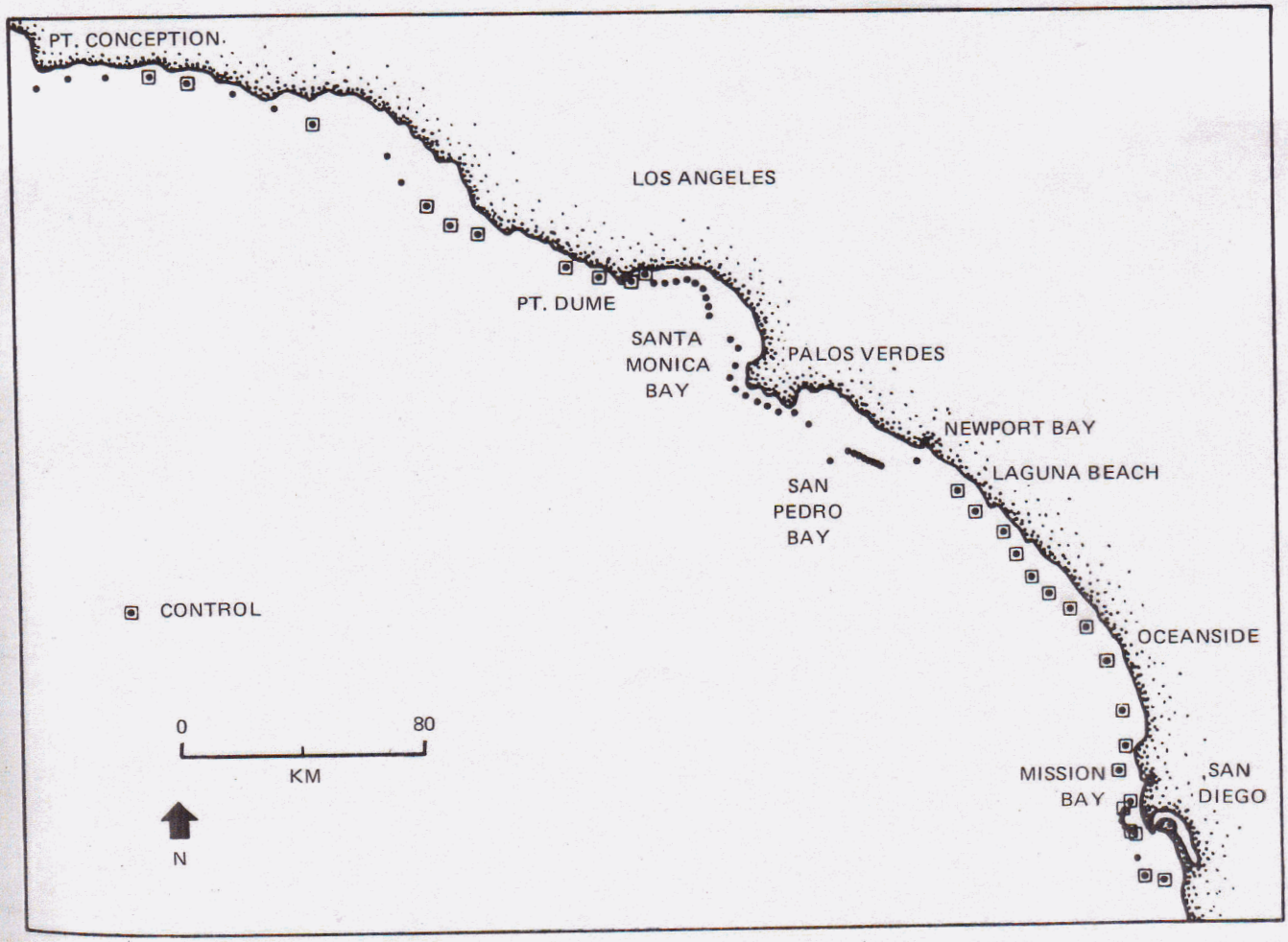

Figure 1. Station locations, 60-meter control survey, 1977.

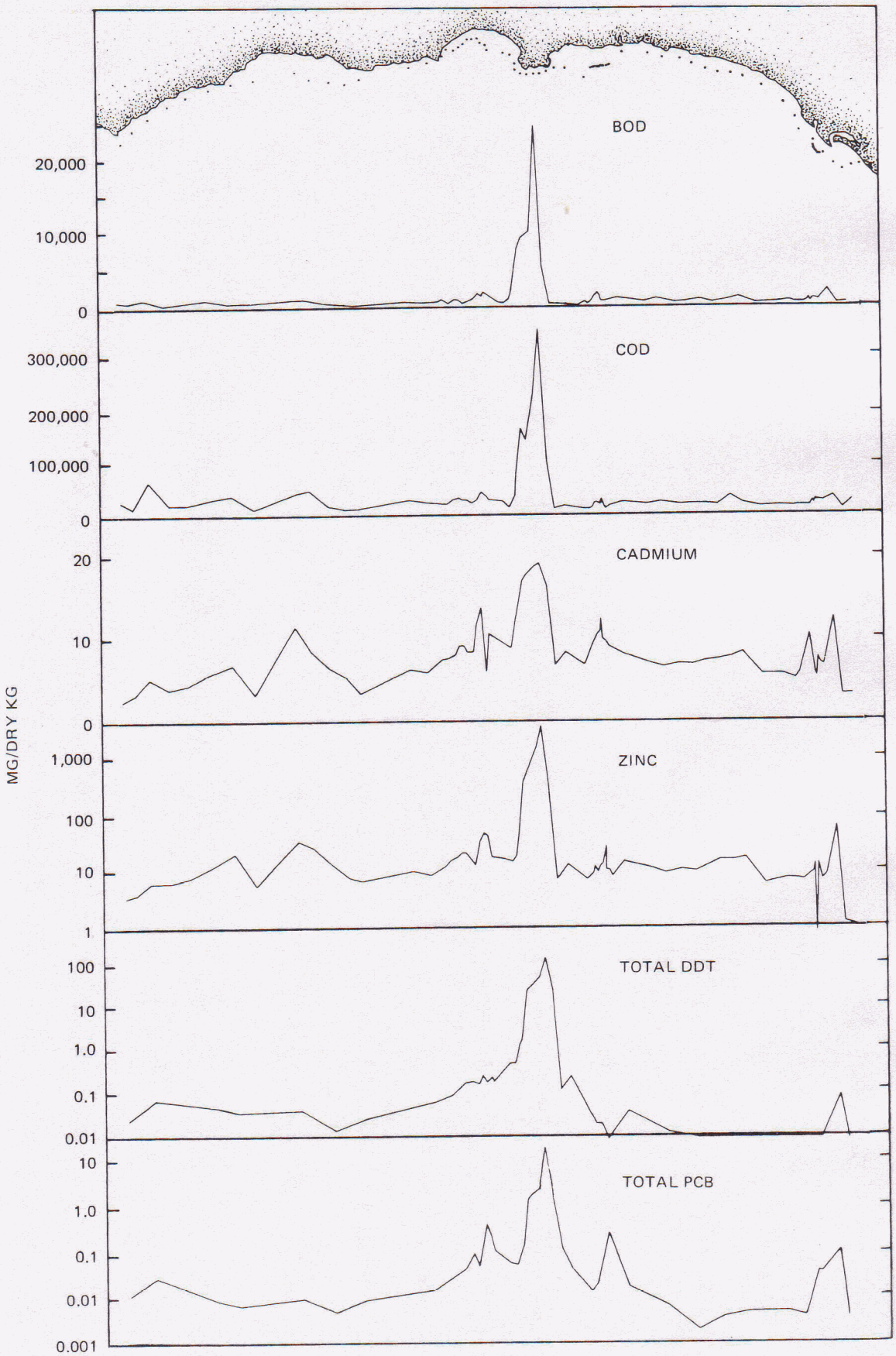

Figure 2. Concentrations of six chemical substances, 60-meter survey, 1977

nickel, lead, and zinc), total DDT, total PCB, hexane extractable materials (HEM), 5-day biochemical oxygen demand (BOD_5 at 20°C), chemical oxygen demand (COD), organic (Kjeldahl) nitrogen, acid volatile sulfides, and volatile solids. The analytical methods for each type of chemical determination are explained in detail in another publication (Word and Mearns, in press).

RESULTS

Over 1,140 chemical determinations were made on surface sediment samples from this survey. The samples from all stations, including those most remote from human activities, contained measurable quantities of BOD, COD, volatile solids, Kjeldahl nitrogen, hexane extractable materials, acid volatile sulfides, all seven trace metals, and chlorinated hydrocarbons.

Plots of the results of chemical analyses of the sediment samples revealed a wide range of background values and obvious enhancements or depressions at stations adjacent to urban areas, wastewater outfalls, and natural oil seeps. Results from six of the analyses--those for BOD, COD, copper, and zinc and total DDT and PCB--are shown in Figure 2. As one might expect, there are peaks in sediment concentrations of these substances along the Palos Verdes Peninsula, where the values are well above those for other coastal areas and other outfall sites.

Over 37,000 specimens and 710 species of animals were found in the 71 biological grab samples taken during this survey. Generally, the fauna were dominated by polychaetes (303 species), crustaceans (194 species), molluscs (135 species), and echinoderms (30 species). No sample was devoid of macroscopic marine organisms, although there were large variations in abundances of individual species off both urban and rural areas. In Figures 3 and 4, the coastal trends in infaunal characteristics are clearly visible, as are the effects of the large outfalls.

The 53 trawl samples taken in this survey contained over 23,500 specimens of vertebrates (representing 64 species and 22 families of sharks, rays, and bony fishes) and nearly 20,400 specimens of invertebrates (representing 224 species). Catches were dominated by rockfish (*Sebastes* genus, 19 species) and bothid and pleuronectid flatfish (6 species in each family). Among the invertebrates taken were 57 species of crustaceans (including crabs and shrimp), 65 species of molluscs (including octopus, squid, bivalves,

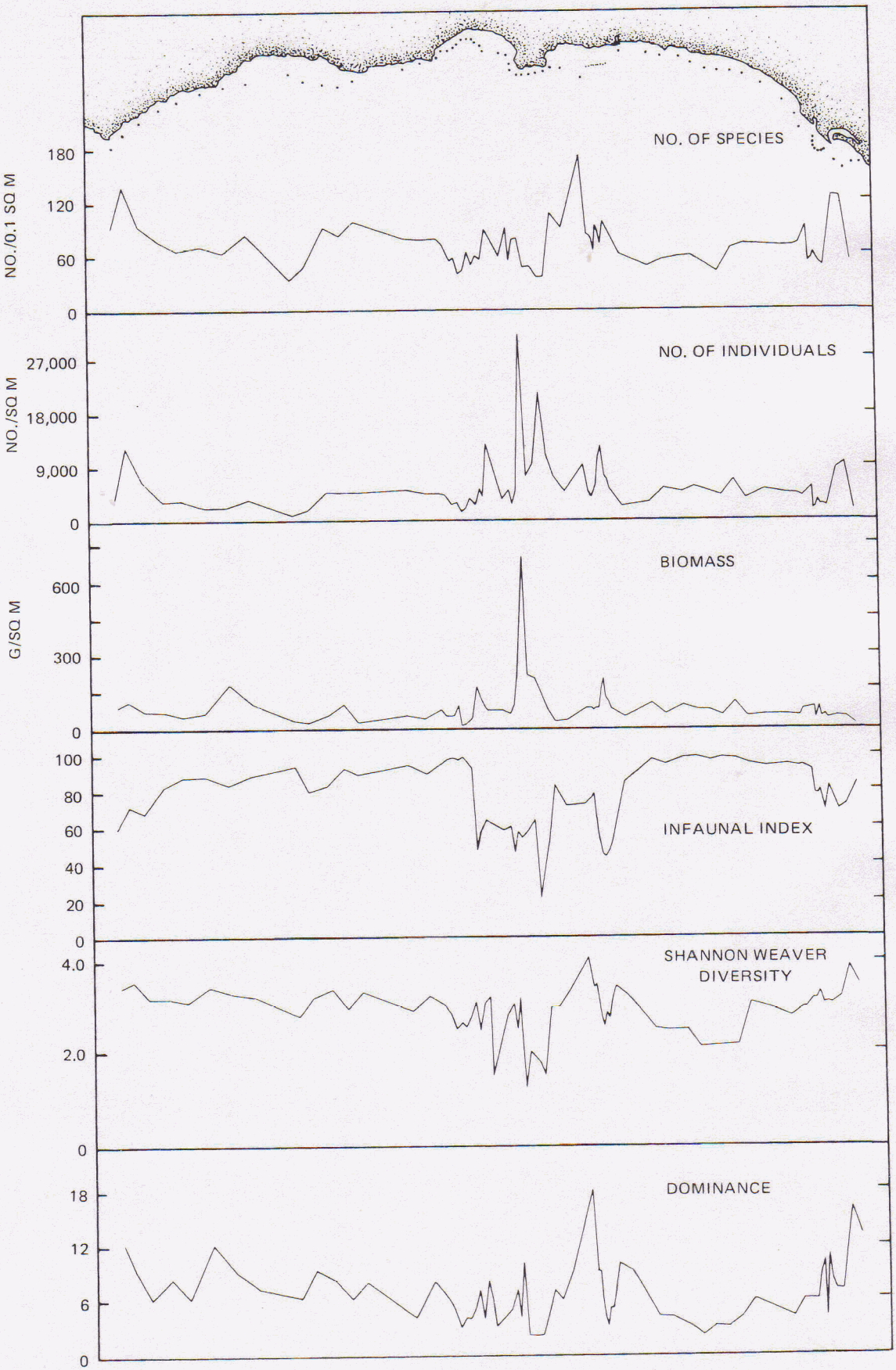

Figure 3. Abundance, variety, and diversity of benthic infauna, 60-meter survey, 1977. Dominance is the minimum number of species required to account for 60% of the number of individuals in a sample.

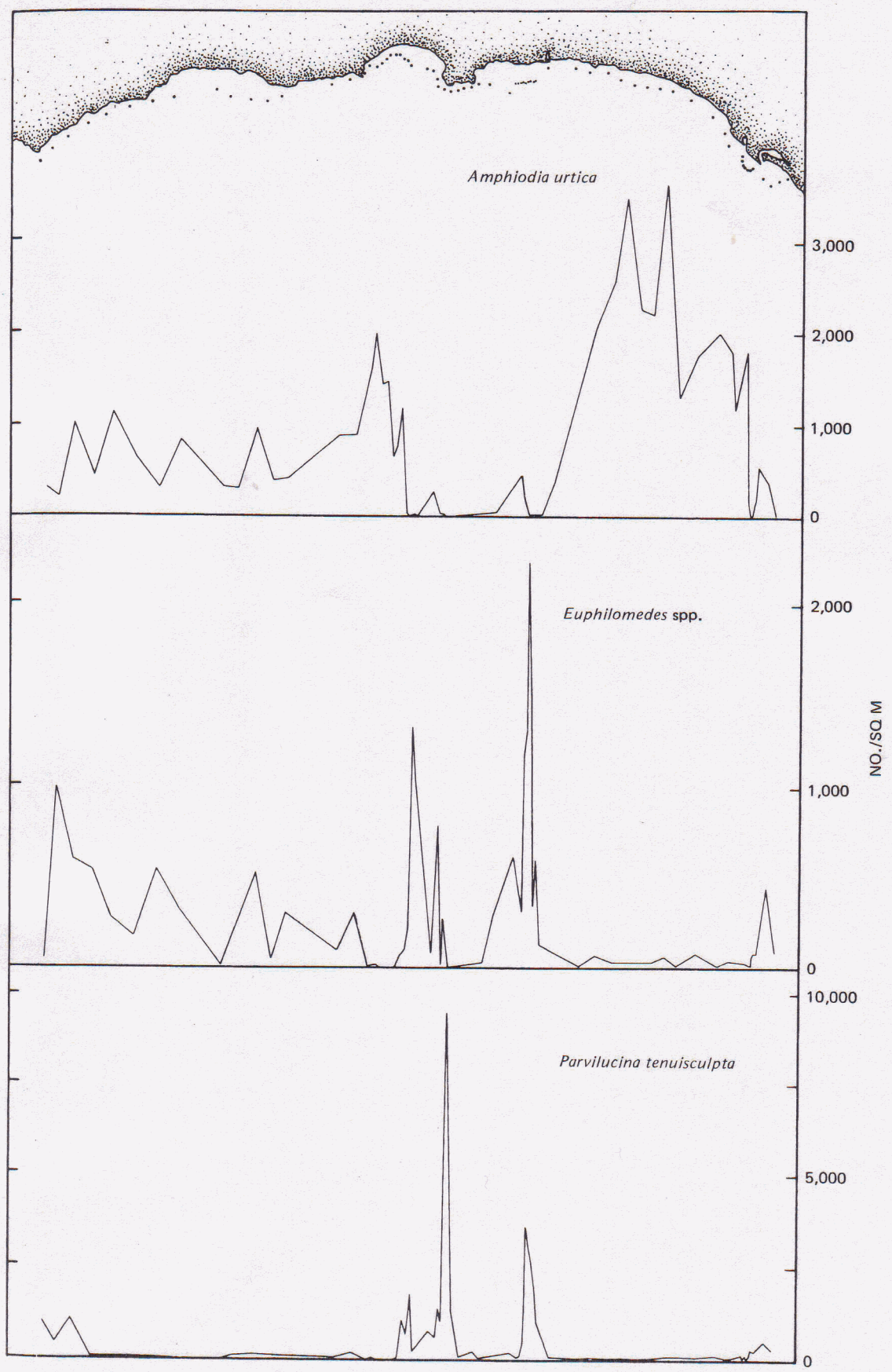

Figure 4. Abundance of three species of benthic invertebrates (a brittlestar, ostracod, and a pelecypod) taken in 60-meter survey, 1977.

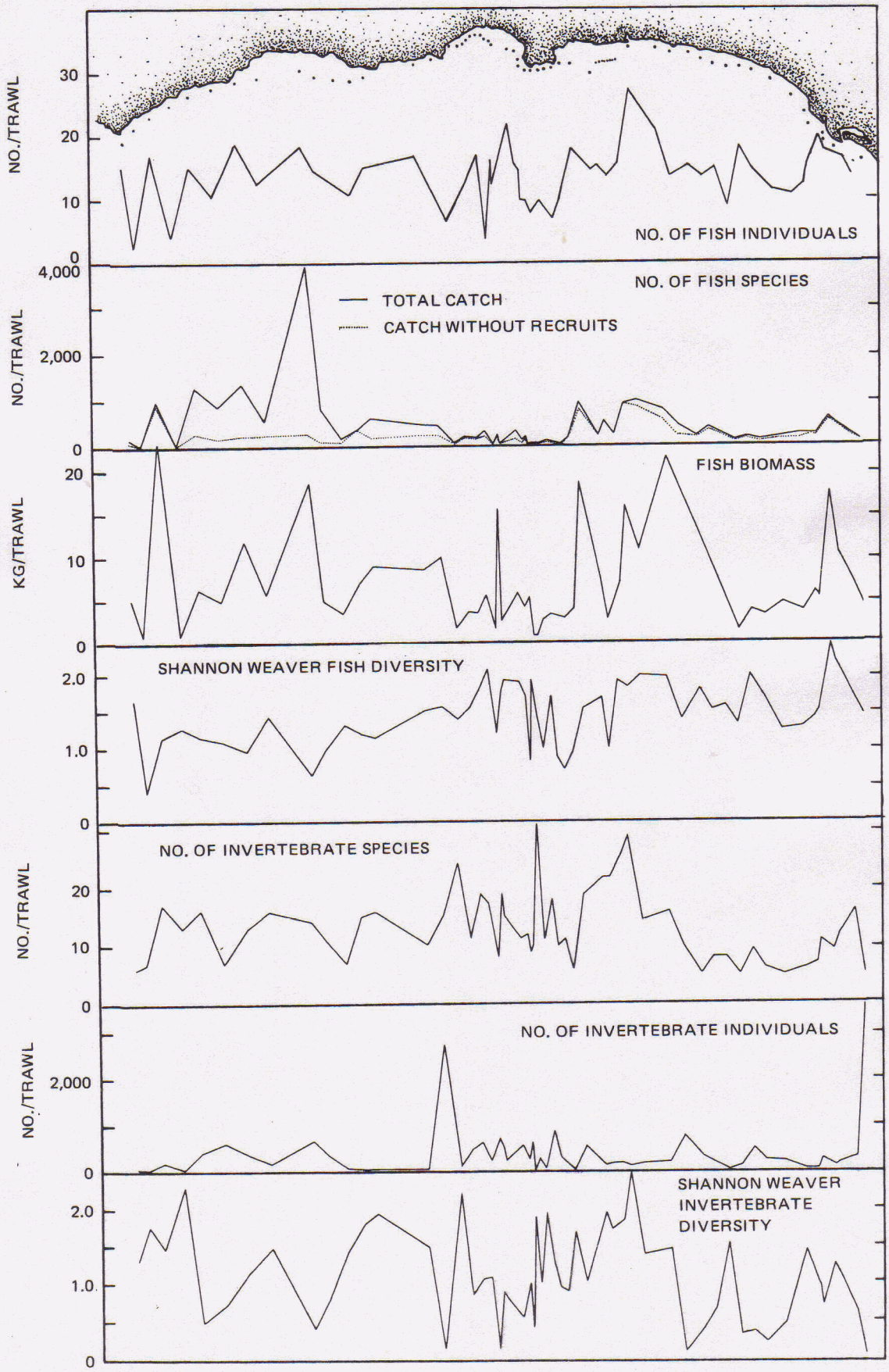

Figure 5. Abundance, variety, and diversity of trawl-caught fishes and invertebrates, 60-meter survey, 1977.

etc.), and 23 species of echinoderms. The most abundant species were the following:

Common Name	Species Name	No. of Individuals
Urchin	*Lytechinus anamesus*	10,801
Stripetail rockfish	*Sebastes saxicola*	8,074
Pacific sanddab	*Citharichthys sordidus*	5,895
Ridgeback prawn	*Sicyonia ingentis*	5,663
Calico rockfish	*Sebastes dalli*	2,812
Plainfin midshipman	*Porichthys notatus*	1,507
Sandstar	*Astropecten verrilli*	1,478
Speckled sanddab	*Citharichthys stigmaeus*	1,076
Yellowchin sculpin	*Icelinus quadriseriatus*	736

Some of the statistics above reflect catches of large numbers of small (recently recruited) fish and invertebrates.

There was considerable alongshore variation in trawl catch statistics (Figure 5), and patterns reflecting the presence of urban areas, outfalls, or oil seeps are not obvious as they are in the infauna data. Small and large catches (in terms of numbers of species as well as abundance) were taken off both rural and urban areas. However, the Shannon Weaver Index showed a pattern of increase in fish diversity with increasing distance to the south: Values ranged from about 1.3 near Point Conception to 1.8 to 2.1 off San Diego. Some of this variation may be due to the larger number of newly recruited fish taken in the northern areas of the coast.

The alongshore distributions of several trawl-caught species provide some insight into the causes of overall variation in trawl statistics (Figure 6). For example, Dover sole *(Microstomus pacificus)* were most abundant at several discharge sites while otherwise occurring in low densities. Pacific sanddabs had a much different alongshore distribution, occurring in lower abundances off Palos Verdes and in Santa Monica Bay than to the west or the south. Stripetail rockfish were most abundant at stations along the Santa Barbara coast (primarily because of the large numbers of recent recruits present at these stations) and decreased in density to the south. Finally, yellowchin sculpin ap-

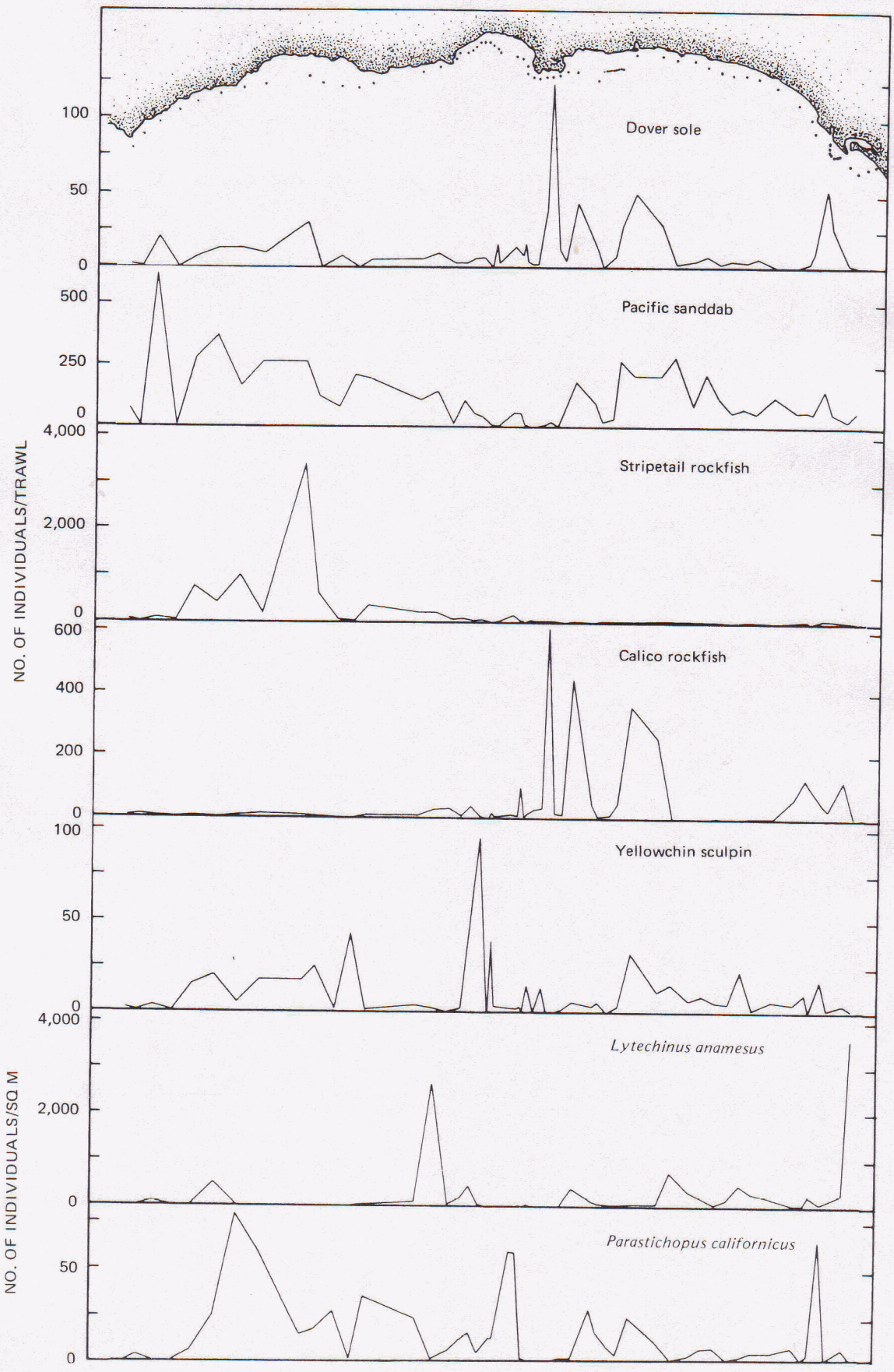

Figure 6. Abundance of seven trawl-caught species (five fishes and an urchin and a sea cucumber), 60-meter survey, 1977.

peared in modest densities throughout the study area but was nearly absent off Palos Verdes.

Selection of Benthic Control Stations

The principal objective of this survey was to define what can be considered to be the normal condition of sediment chemistry and benthic organisms at 60-meter depths off southern California. As a first step in identifying areas where these conditions would prevail, we eliminated stations adjacent to the large urban centers around Los Angeles, Orange County, and San Diego--those between Point Dume and the entrance to Newport Bay, and those south of Mission Bay near San Diego.

We then examined the data from the remaining stations, looking for what could be called a natural range of variation in the chemical parameters considered in this survey. The chemistry data for some of the stations (e.g., those near harbors or natural oil seeps) contained values that seemed anomalously high, and these stations were eliminated from consideration. We also eliminated stations with Infaunal Index values lower than 80, as such values had been shown in another study (see Word, this report) to indicate that control organisms are not dominant in the infaunal community.

Finally, we examined data from a 1957-58 survey of the southern California shelf,[1] and calculated Infaunal Index values for stations similar in depth and location to those being considered here. Past and present values were compared; only one of the candidate control stations was eliminated as a result of this comparison. The other stations did not appear to have changed significantly in the past 20 years in infaunal community structure (as indicated by a difference of 10 Infaunal Index units).

When the process of elimination was completed, 29 stations remained. As a check on the reliability of our selection, we asked Dr. Robert W. Smith, a consulting ecologist, to apply a numerical classification technique (the Bray-Curtis similarity coefficient) to our data. The results showed the 29 stations to be "biologically similar" to each other and distinct as a group from stations near wastewater discharges.

A summary of the conditions at the 29 control stations is given in Table 1. Infaunal Index values are 83 and above.

1. State Water Resources Control Board survey conducted by the Allan Hancock Foundation, University of Southern California. See Figure 4, Word, this report.

The 0.1-sq-meter grab samples average 71 species of animals, 423 individuals, and a biomass of 7 grams.

The estimates of average background (or control) trawl catch statistics are given in Table 2. Because of the apparent north/south differences in some catch statistics and species distributions, we have also made calculations for

Table 1. Sediment conditions, 60-meter survey, 1977.

	Control Values			Range of Values	
	Mean	95% CL*	No. of Stations	Control Stations	All Stations
Sand (%)	40.1	31.8-48.3	28	7.6-83.7	5.2-90.0
Volatile solids (%)	2.8	2.6-3.1	28	1.8-3.8	1.8-27
Other chemical characteristics (mg/dry kg)					
BOD	632	554-709	28	266-1,017	172-25,048
COD	20,160	9,200-38,400	28	17,780-25,600	9,200-372,600
Organic (K) nitrogen	671	575-768	16	392-926	295-8,140
HEM	243	95-279	28	0-1,150	0-39,400
Total DDT	0.02	0-0.04	12	<0.001-0.09	<0.001-175.2
Total PCB	0.01	0.002-0.02	12	<0.002-0.04	<0.002-10.9
Silver	0.38	0.2-0.5	28	0.06-1.7	0.04-18
Cadmium	0.39	0.3-0.5	28	0.1-1.4	0.1-61
Chromium	23.1	19.8-26.4	28	6.5-43	6.5-1,317
Copper	9.1	6.9-11.2	28	2.8-31	2.3-782
Nickel	12.2	8.6-15.9	28	1.6-35	1.6-107
Lead	6.6	5.7-7.6	28	2.7-12	1.8-537
Zinc	42.2	37.1-47.1	28	9.8-62	9.8-2,096
Biological characteristics (per 0.1 sq meter)					
Total					
No. of species	71	64-78	29	40-124	32-167
No. of individuals	423	375-471	29	229-654	91-3,057
Arthropods					
No. of species	21	18-24	29	8-34	2-43
No. of individuals	61	50-72	29	19-124	2-271
Molluscs					
No. of species	13	12-14	29	9-19	5-23
No. of individuals	44	37-51	29	24-83	6-1,004
Echinoderms					
No. of species	5	4-6	29	2-9	0-10
No. of individuals	141	104-178	29	9-365	0-365
Polychaetes					
No. of species	26	22-30	28	13-58	11-68
No. of individuals	136	110-162	28	62-367	15-1,964
Miscellaneous phyla					
No. of species	6	5-7	29	2-12	2-28
No. of individuals	35	27-48	29	7-110	3-110
Infaunal Trophic Index	93.5	91.6-95.4	24	83.1-98.3	21-99
Shannon Weaver diversity	3.05	2.89-3.21	27	2.19-3.98	1.34-4.16
Species dominance**	6.4	5-8	27	2-16	2-18
Individuals/species	5.9	5.3-6.6	27	3.6-10.1	3.1-39.2
Biomass (grams)	7.0	6.1-8.0	29	2.8-11.2	1.5-70.7

*95% confidence limits.

**Minimum number of species required to account for 60% of the individuals in a sample.

the set of 16 "northern" control sites and 12 "southern" control sites. Recent analyses of the fish data indicate that most catch statistics for the major wastewater discharge sites are either statistically similar to those for control sites or, in some cases, higher.

As a result of examining much similar data taken at other depths, we believe that the ranges of control values for 60-meter depths given here are valid at depths between 20 and 200 meters; that is, that control values for 20 to 200 meters will fall within these ranges. Outside those depths, both the chemistry of the sediments and the animal communities are altered beyond these accepted ranges. In shallower waters, wave action has removed many of the fine particles to which pollutants adhere; in deeper water, there is a natural increase in volatile solids of the sediments. Animal communities are also changed at depths outside the range of 20 to 200 meters because sediment grain size, wave motion, light levels, and available food are different. Therefore, these control values should only be used for comparison with data from stations at depths between 20 and 200 meters.

		Control Stations		
	All Stations (53)	All Controls (28)	Northern Controls* (16)	Southern Controls* (12)
Fish				
No. of individuals				
Median	242	378	515	225
95% CL	186-347	186-623	177-1,005	158-440
No. of species				
Median	15	14.5	14	14.5
95% CL	13-16	12-16	11-18	12-19
Biomass (kg)				
Median	4.4	4.7	10.9	4.0
95% CL	3.2-5.2	3.2-7.9	3.2-9.1	2.55-10.2
Shannon-Weaver Diversity, H'				
Median	1.56	1.38	1.25	1.58
95% CL	1.41-1.68	1.22-1.57	1.11-1.53	1.31-2.00
Invertebrates				
No. of individuals				
Median	198	181	170	191
95% CL	136-308	90-351	80-483	29-351
No. of Species				
Median	11.5	10.5	14.5	7.5
95% CL	10-14	7-14	10-16	5-10
Biomass (kg)				
Median	6.0**	7.4†	12.2	2.25
95% CL	3.1-12.5	2.5-12.5	5.2-15.1	1.7-4.2

*See Figure 1.
**Based on data from 40 samples.
†Based on data from 20 samples.

Table 2. Number of species, number of individuals, and biomass per sample of fishes and invertebrates taken by trawl in the 60-meter survey, 1977.

Fish Health

As in previous studies, we found Dover sole bearing skin tumors all along the coast. The disease is found primarily in the young of the year (fish less than 120 mm long); in this survey, it was seen in Dover sole from all regions, except the area between Laguna Beach and Point Loma, where catches contained few young fish. Prevalences of fish with tumors ranged from 1.7 percent off Point Loma to 6.7 percent off Newport Beach (Table 3); the prevalence in the control region between Point Conception and Point Dume was 3.3 percent.

Skin tumors were only observed in Dover sole in this survey. However, in other sampling during the same time period (1977), we collected a Pacific hake *(Merluccius productus)* and a stripetail rockfish bearing similar tumors; both fish were taken off Point Conception (Mearns et al. 1978).

Another disease, fin erosion, was prevalent in Dover sole collected in this survey. However, this disease was only found in catches taken off the Palos Verdes shelf; 31 percent of the 201 specimens collected there were afflicted with the disease.

Pacific sanddabs bearing copepod eye parasites *(Phrixocephalus cinncinatus)* were conspicuous in catches from all coastal areas except the Palos Verdes shelf (where catches of this fish were relatively low). The prevalence of sanddabs with the eye parasites averaged 2 to 3 percent.

SUMMARY OF FINDINGS

This survey has produced an overall picture of the variations in sediment chemistry and invertebrate and benthic

Table 3. Prevalence of fin erosion and tumors in Dover sole, 60-meter survey, 1977.

	Pt. Conception to Pt. Dume	Santa Monica Bay	Palos Verdes	Southern San Pedro Bay	Laguna Bch. to Pt. La Jolla	Pt. Loma
No. of trawls	13	8	7	3	12	3
Total No. of individuals	120	53	201	36	66	81
Average catch/trawl	9.2	6.6	28.7	12.0	5.5	27.0
Fin erosion						
No. of individuals afflicted	0	0	63	0	0	0
% of total Dover sole catch			31%			
Tumors in young (≤120 mm,SL) Dover sole						
No. of young fishes	90	16	147	15	18	58
No. of young with tumors	3	1	3	1	0	1
% of young fishes afflicted	3.3%	6.2%	2.0%	6.7%		1.7%

fish populations along the coast of southern California. In some of the figures presented here, one can see at a glance the effects of municipal wastewater outfalls relative to natural conditions and the response of marine animals to the extra nutrients and pollutants that the discharges provide. Mainly, the survey has been successful in obtaining basic data on natural conditions on the coastal shelf that will be useful to everyone monitoring ocean conditions or making chemical/biological surveys.

Some of the information from the control sites was a little surprising. For example, there are substantial variations from station to station in both biological and chemical values. Natural areas are not all the same--control conditions are best defined by a range of values rather than any single number. Materials such as trace metals, BOD, and chlorinated hydrocarbons that can be pollutants under some circumstances may be present in natural areas. Along a large part of our coast, natural conditions prevail; conditions equal to those at control sites exist in the western part of Santa Monica Bay as well as close to the outfalls at Ventura and San Diego.

It is difficult to make any useful generalization about fish populations and control conditions or outfall effects. With the exception of the fin erosion disease in Dover sole near Palos Verdes, the bottom fish and their diseases seem to be randomly distributed along the coast.

The control data presented here are used extensively in the succeeding papers.

ACKNOWLEDGMENTS

This survey was a team effort in which we made intensive use of the talents of all of our associates at the Project at every step. We thank them all.

Of those outside the Project who were drawn into this work to varying degrees, we especially appreciate the assistance of the following representatives of our sponsoring agencies, who cooperated in various ways: Joe Nagano (City of Los Angeles), Joe Meistrell and Dr. Irwin Haydock (Los Angeles County Sanitation Districts), Greg Pamson, Michael Heinz and Tom Pesich (Orange County Sanitation Districts), and Bill Conn and Richard Ebipane (City of San Diego). We also thank the skippers of the boats used during the survey: John Keller (Marine Surveyor), John Hass (Fury II), Mac MacCallister (Van Tuna), and Fred Munson (Enchanter IV). A special thanks to the people who donated their time and experience in the identification of the benthic infaunal organisms. They are listed in Appendix A.

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