Chapter 5. Macrobenthic Communities

INTRODUCTION

Sediments on the southern California coastal shelf typically contain a diverse community of macrofaunal invertebrates (Fauchald and Jones 1979, Thompson et al. 1992, Bergen et al. 2001). These animals are essential members of the marine ecosystem, serving vital functions in wide ranging capacities. For example, many species of benthic invertebrates provide the prey base for fish and other organisms, while others decompose organic material as a crucial step in nutrient cycling. The structure of macrofaunal communities is influenced by many factors including sediment conditions (e.g., particle size and sediment chemistry), water conditions (e.g., temperature, salinity, dissolved oxygen, and current velocity) and biological factors (e.g., food availability, competition, and predation). While human activities can affect these factors, natural processes largely control the structure of invertebrate communities in marine sediments. Therefore, in order to determine whether changes in community structure are related to human impacts or natural processes, it is necessary to have documentation of background or reference conditions for an area. Such information is available for the region surrounding the Point Loma Ocean Outfall (PLOO) and the San Diego region in general (e.g., City of San Diego 1995, 1999, 2003).

Benthic macrofauna living in marine soft sediments can be sensitive indicators of environmental disturbance (Pearson and Rosenberg 1978). Because benthic macrofauna have limited mobility, many are unable to avoid adverse conditions such as those brought about by natural stressors (e.g., El Niño/La Niña events) or human impacts (e.g., toxic contamination and organic enrichment from anthropogenic sources). Consequently, the assessment of benthic communities has been used to monitor the effects of municipal wastewater discharge on the ocean environment (see Zmarzly et al. 1994, Diener et al. 1995, Bergen et al. 2000). This chapter presents analyses and interpretation of the macrofaunal data collected during 2004 at fixed stations surrounding the PLOO discharge site off San Diego, California. Included are descriptions and comparisons of the different assemblages that inhabit soft bottom sediments in the area and analysis of benthic community structure.

MATERIALS AND METHODS

Collection and Processing of Samples

Benthic samples were collected at 22 stations that span 8 km south and 11 km north of the outfall terminus along the 88, 98, and 116-m depth contours (**Figure 5.1**). A total of 68 benthic grabs were taken during two surveys in 2004. All 22 stations were sampled during the January survey while the July sampling was limited to the 12 primary core stations located along the 98-m contour due to a regulatory agreement to conduct a special sediment mapping study of the region (see City of San Diego 2005, Appendix A). Detailed methods for locating the stations and conducting benthic grabs are described in the City of San Diego Quality Assurance Plan (City of San Diego in prep).

Samples for benthic community analysis were collected from two replicate 0.1 m^2 van Veen grabs per station during each survey. The criteria established by the United States Environmental Protection Agency to ensure the consistency of grab samples were followed with regard to sample disturbance and depth of penetration (USEPA 1987). All samples were sieved aboard ship through a 1.0 mm mesh screen. Organisms retained on the

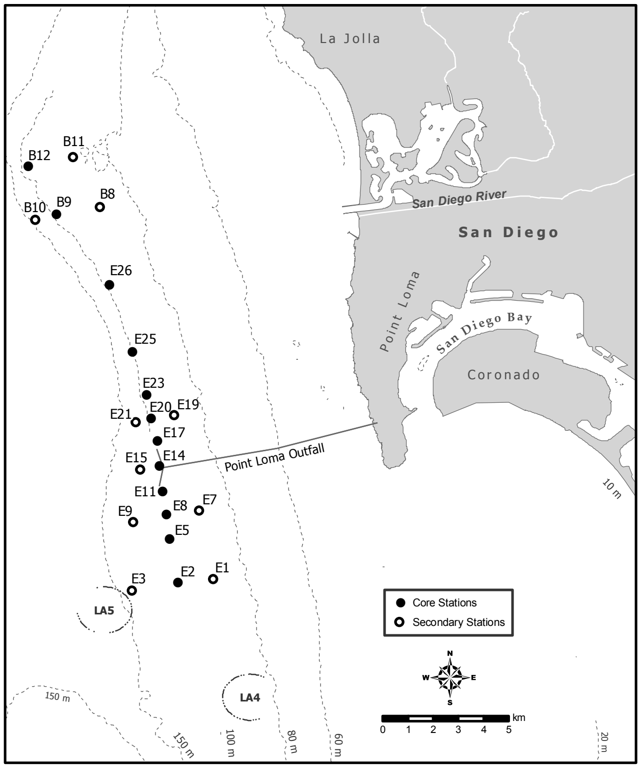


Figure 5.1
Benthic stations surrounding the Point Loma Ocean Outfall. Core stations (filled circles) were sampled in January and July 2004. Secondary core stations (open circles) were sampled only in July 2004.

screen were relaxed for 30 minutes in a magnesium sulfate solution and then fixed in buffered formalin (see City of San Diego in prep). After a minimum of 72 hours, each sample was rinsed with fresh water and transferred to 70% ethanol. All organisms were sorted from the debris into major taxonomic groups then identified to species or the lowest taxon possible and enumerated.

Statistical Analyses

Multivariate analyses were performed using PRIMER v5 software to examine spatio-temporal patterns in the overall similarity of benthic assemblages in the region (see Clarke 1993, Warwick 1993). These analyses included classification (cluster analysis) by hierarchical agglomerative clustering with group-average linking and ordination by non-metric multidimensional scaling (MDS). Prior to analysis, macrofaunal abundance data were square-root transformed and the Bray-Curtis measure of similarity was used as the basis for comparison in both classification and ordination. Analyses were run on mean abundances of replicate grabs per station/survey to identify distinct cluster groups from 68 samples among 22 stations.

Annual means for the following community parameters were calculated for each station and each cluster group: species richness (number of species per grab); total number of species (i.e., cumulative of two replicate samples); abundance (number of individuals per grab); biomass (grams per grab, wet weight); Shannon diversity index (H′ per grab); Pielou's evenness index (J′ per grab); Swartz dominance index (minimum number of species accounting for 75% of the abundance in each grab; see Swartz 1978); Infaunal Trophic Index (ITI per grab; see Word 1980) and Benthic Response Index (BRI per grab; see Smith et al. 2001).

A BACIP (Before-After-Control-Impact-Paired) statistical model was used to test the null hypothesis that there were no changes in various community parameters due to discharge through the Point Loma outfall (see Bernstein and Zalinski 1983, Stewart-Oaten et al. 1986, 1992, Osenberg et al. 1994). Briefly, the BACIP model tests differences between control (reference) and impact sites at times before (i.e., July 1991–October 1993) and after (i.e., January 1994–July 2004) an "impact" event (i.e., the onset of discharge). The analyses presented in this report are based on 2.5 years (10 quarterly surveys) of before impact data and 11 years (41 quarterly or semi-annual surveys) of after impact data. The E stations, located within 8 km of the outfall, are the most likely to be affected by the discharge. Station E14 was selected as the impact site for all analyses; this station is located nearest the Zone of Initial Dilution (ZID) and is probably the site most susceptible to impact. In contrast, the B stations are located farther from the outfall (>11 km) and are the obvious candidates for reference or control sites. However, benthic communities differed between the B and E stations prior to discharge (Smith and Riege 1994, City of San Diego 1995). Thus, two stations (E26 and B9) were selected to represent separate control sites in the BACIP tests. Station E26 is located ~8 km from the outfall and is considered the E station least likely to be impacted. Previous analyses suggested that station B9 was one of the most appropriate B stations for comparison with the E stations (Smith and Riege 1994, City of San Diego 1995). Six dependent variables were analyzed, including three community parameters (number of species, infaunal abundance, ITI) and abundances of three taxa that are considered sensitive to organic enrichment. These indicator taxa included ophiuroids in the genus *Amphiodia* (mostly *A. urtica*) and amphipods in the genera *Ampelisca* and *Rhepoxynius*. All BACIP analyses were interpreted using a Type I error rate of α=0.05.

RESULTS AND DISCUSSION

Community Parameters: Site Comparisons and Region-wide Summaries

Number of Species

In total, 491 macrofaunal taxa were identified during the 2004 PLOO surveys. Mean values of species richness ranged from 72 to 106 species per 0.1 m^2 (**Table 5.1**). As in previous years, the number of species was highest at the northern reference station B11, as well as stations characterized by coarser sediments (e.g., B12 and E3) (City of San Diego 2003). The lowest species richness was found at stations B8 and E7, which are characterized by the finest sediments in the region (see chapter 4).

Polychaetes were the most diverse taxa in the region, accounting for approximately 53% of all species collected during 2004. Crustaceans accounted for 23% of the species, molluscs 13%, echinoderms 7%, and all remaining taxa combined accounted for approximately 4% of the species.

Macrofaunal Abundance

Mean macrofaunal abundance among sites averaged 167 to 639 animals per 0.1 m^2 in 2004 (Table 5.1). The greatest number of animals occurred at stations B11 (n=639) and E26 (n=637), while the fewest were collected at stations E21 (n=167) and E7 (n=170). The remaining sites ranged from 215 to 458 animals per 0.1 m^2.

Polychaetes were the most numerous organisms collected, accounting for 59% of the mean abundance. Crustaceans accounted for 16% of mean abundance, echinoderms 14%, molluscs 9%, and all other phyla combined about 2%. Station E14, located nearest to the outfall, had the third highest relative abundance of polychaetes among all stations (70%) and the lowest relative abundance of echinoderms (4%). These values generally were similar to those reported for 2003 (see City of San Diego 2004). The two most abundant species collected in 2004 were the polychaete worm, *Myriochele striolata* (4137 individuals), and the ophiuroid, *Amphiodia urtica* (1846 individuals).

Species Diversity and Dominance

Species diversity (H′) among sites during 2004 was similar to that observed prior to wastewater discharge (see City of San Diego 1995). Mean diversity values ranged from 2.5 to 4.2 during the year (Table 5.1). The highest diversity occurred at stations B10, E3, and E9 located along the 116-m contour, B12 along the 98-m contour, and station E2, nearest the LA5 disposal dumpsite. Diversity was lowest at station E26.

Species dominance was expressed as the Swartz 75% dominance index, the minimum number of species comprising 75% of a community by abundance. Therefore, lower index values (i.e., fewer species) indicate higher dominance. Benthic assemblages in 2004 were characterized by relatively high numbers of evenly distributed species. Dominance averaged 30 species per station, similar to the 28 species per station present in 2003 (see City of San Diego 2004). Dominance index values were lowest at stations E26 and B8, averaging 11 and 14 species, respectively. Evenness (J′) values have also remained stable over time, with mean values ranging from 0.6 to 0.9 among all stations (Table 5.1).

Environmental Disturbance Indices

Benthic response index (BRI) mean values ranged

Table 5.1

Benthic community parameters at PLOO stations sampled during 2004. Data are expressed as annual means for: species richness, no. species/0.1 m^2 (SR); total cumulative no. species for the year (Tot Spp); abundance/0.1 m^2 (Abun); diversity (H′); evenness (J′); Swartz dominance (Dom); benthic response index (BRI); infaunal trophic index (ITI). n values indicate number of grabs as statistical replicates. n values for total species data are given in parentheses.

	n	SR	Tot Spp	Abun	H′	J′	Dom	BRI	ITI
88-m									
B11	2 (1)	105	148	639	2.8	0.6	20	5	76
B8	2 (1)	73	103	367	2.9	0.7	14	4	82
E19	2 (1)	78	113	232	3.7	0.8	29	5	87
E7	2 (1)	72	103	170	3.7	0.9	31	5	86
E1	2 (1)	88	129	279	3.6	0.8	29	2	84
98-m core									
B12	4 (2)	106	148	327	4.2	0.9	39	8	78
B9	4 (2)	88	127	348	3.2	0.7	20	0	77
E26	4 (2)	86	125	637	2.5	0.6	11	4	73
E25	4 (2)	93	124	428	3.6	0.8	25	5	79
E23	4 (2)	75	105	227	3.7	0.9	29	7	84
E20	4 (2)	74	102	234	3.8	0.9	28	6	81
E17	4 (2)	88	119	288	3.9	0.9	32	9	82
E14	4 (2)	97	137	458	3.4	0.7	25	13	72
E11	4 (2)	78	110	215	3.9	0.9	32	11	82
E8	4 (2)	86	121	287	3.8	0.9	30	5	83
E5	4 (2)	86	119	257	3.9	0.9	33	4	82
E2	4 (2)	99	144	276	4.1	0.9	39	4	82
116-m									
B10	2 (1)	98	132	297	4.2	0.9	38	9	78
E21	2 (1)	74	109	167	3.9	0.9	34	8	83
E15	2 (1)	90	123	254	4.0	0.9	39	5	82
E9	2 (1)	98	148	248	4.2	0.9	43	3	82
E3	2 (1)	103	155	221	4.2	0.9	49	6	83
All Stations									
Mean		88	125	312	3.7	0.8	30	6	81
Min		72	102	167	2.5	0.6	11	0	72
Max		106	155	639	4.2	0.9	49	13	87

from 0 to 13 at the various stations in 2004. These values suggest that benthic communities in the region are relatively undisturbed, as BRI values below 25 (on a scale of 100) are indicative of reference conditions (see Smith et al. 2001). Mean annual ITI values ranged from 72 to 87 per station in 2004 (Table 5.1). These values were similar to those reported in previous years (see City of San Diego 2004), with the lowest value again occurring at station E14 located nearest the discharge site. Nevertheless, mean ITI values remained >60 at all stations

Table 5.2

Dominant macroinvertebrates at PLOO benthic stations sampled during 2004. Included are the 10 most abundant taxa overall and per occurrence, and the 10 most widely occurring taxa. Data are expressed as: MAS=mean abundance per sample; MAO=mean abundance per occurrence; and PO=percent occurrence.

Species	Higher Taxa	MAS	MAO	PO
Most Abundant				
Myriochele striolata[1]	Polychaeta: Oweniidae	60.8	89.9	68
Amphiodia urtica	Echinodermata: Ophiuroidea	27.1	27.1	100
Proclea sp A	Polychaeta: Terebellidae	9.9	10.2	97
Amphiuridae	Echinodermata: Ophiuroidea	8.3	8.8	94
Chaetozone hartmanae	Polychaeta: Cirratulidae	7.5	7.7	97
Euphilomedes carcharodonta	Crustacea: Ostracoda	7.5	8.2	91
Myriochele gracilis	Polychaeta: Oweniidae	7.3	7.3	100
Chloeia pinnata	Polychaeta: Amphinomidae	6.7	8.1	82
Euphilomedes producta	Crustacea: Ostracoda	5.9	5.9	100
Rhepoxynius bicuspidatus	Crustacea: Amphipoda	5.1	5.2	97
Most Abundant per Occurence				
Myriochele striolata	Polychaeta: Oweniidae	60.8	89.9	68
Amphiodia urtica	Echinodermata: Ophiuroidea	27.1	27.1	100
Caecum crebricinctum	Mollusca: Gastropoda	1.0	11.8	9
Proclea sp A	Polychaeta: Terebellidae	9.9	10.2	97
Amphiuridae	Echinodermata: Ophiuroidea	8.3	8.8	94
Euphilomedes carcharodonta	Crustacea: Ostracoda	7.5	8.2	91
Chloeia pinnata	Polychaeta: Amphinomidae	6.7	8.1	82
Chaetozone hartmanae	Polychaeta: Cirratulidae	7.5	7.7	97
Myriochele gracilis	Polychaeta: Oweniidae	7.3	7.3	100
Adontorhina cyclia	Mollusca: Bivalvia	4.4	6.0	74
Most Frequently Collected				
Amphiodia urtica	Echinodermata: Ophiuroidea	27.1	27.1	100
Myriochele gracilis	Polychaeta: Oweniidae	7.3	7.3	100
Euphilomedes producta	Crustacea: Ostracoda	5.9	5.9	100
Prionospio (*Prionospio*) *jubata*	Polychaeta: Spionidae	4.9	4.9	100
Amphiodia sp	Echinodermata: Ophiuroidea	4.5	4.5	100
Sternaspis fossor	Polychaeta: Sternaspidae	4.4	4.4	100
Clymenura gracilis	Polychaeta: Maldanidae	2.5	2.5	100
Proclea sp A	Polychaeta: Terebellidae	9.9	10.2	97
Chaetozone hartmanae	Polychaeta: Cirratulidae	7.5	7.7	97
Rhepoxynius bicuspidatus	Crustacea: Amphipoda	5.1	5.2	97

[1]*Myrochele striolata* was identified as *Myrochele* sp M in previous reports.

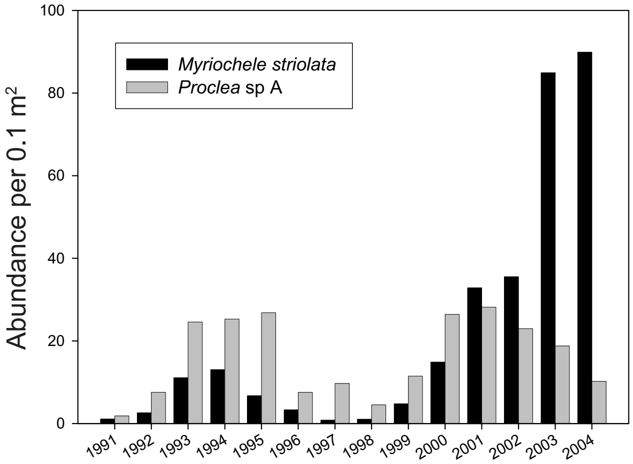


Figure 5.2
Mean annual abundance of *Myriochele striolata* and *Proclea* sp A at the PLOO benthic stations, 1991–2004.

in 2004, indicating undisturbed sediments or "normal" environmental conditions (see Bascom et al. 1979).

Dominant Species

The dominant animals that occurred off Point Loma during 2004 are listed in **Table 5.2**. Various polychaetes species were dominant throughout the region. The two most abundant polychaetes were the oweniid *Myriochele striolata* (previously reported as *Myriochele* sp M) and the terebellid *Proclea* sp A averaging 61 and 10 individuals per 0.1 m^2, respectively. The ophiuroid *Amphiodia urtica* was the second most abundant species, averaging 27 individuals per 0.1 m^2. However, since juvenile ophiuroids usually cannot be identified to species and are recorded at the generic or familial level (i.e., *Amphiodia* sp or Amphiuridae), this number underestimates actual populations of *A. urtica*. The only other species of *Amphiodia* that occurred in 2004 was *A. digitata*, which accounted for about 6% of ophiuroids in the genus that could be identified to species (i.e., *A. urtica* = about 94%). If the values for these taxa are adjusted accordingly, then the estimated population size for *A. urtica* off Point Loma is about 39 animals per 0.1 m^2.

Many of these abundant species were dominant prior to discharge in 1993 and have remained so since the initiation of outfall operation (e.g., City of San Diego 1995, 1999, 2004). For example, *A. urtica* has been among the most abundant and most commonly occurring species along the outer shelf since sampling began. In contrast, densities of some numerically dominant polychaetes have been far more cyclical. For instance, while *M. striolata* and *Proclea* sp A were the most abundant polychaetes in 2004, their populations have varied considerably over time (**Figure 5.2**). Such variation can have significant effects on other descriptive statistics (e.g., dominance, diversity, abundance) and environmental indices such as ITI and BRI, which use the abundance of indicator species in their equations.

Table 5.3
Results of BACIP t-tests for number of species (SR), infaunal abundance, ITI, and the abundance of several representative taxa around the Point Loma Ocean Outfall (1991–2004). Impact site=near-ZID station E14; Control sites=far-field station E26 or reference station B9. Before Impact period=July 1991 to October 1993 (n=10); After Impact period=January 1994 to July 2004 (n=41). Critical t value=1.680 for α=0.05 (one-tailed t-tests, df=49). ns=not significant.

Variable	Control vs Impact	t	p
SR	E26 v E14	-3.262	0.001
	B9 v E14	-3.855	<0.001
Abundance	E26 v E14	-1.415	ns
	B9 v E14	-2.797	0.004
ITI	E26 v E14	-3.679	<0.001
	B9 v E14	-2.252	0.014
Amphiodia spp	E26 v E14	-7.530	<0.001
	B9 v E14	-5.136	<0.001
Ampelisca spp	E26 v E14	-1.466	ns
	B9 v E14	-0.870	ns
Rhepoxynius spp	E26 v E14	-0.493	ns
	B9 v E14	-0.568	ns

Environmental Disturbance Indices

Significant differences were found between the impact site (station E14) and the control sites (stations E26 and B9) in seven out of twelve BACIP t-tests (**Table 5.3**). For example, there has been a net change in the mean difference between impact and control sites in species richness, ITI values, and ophiuroid abundance (*Amphiodia* spp).

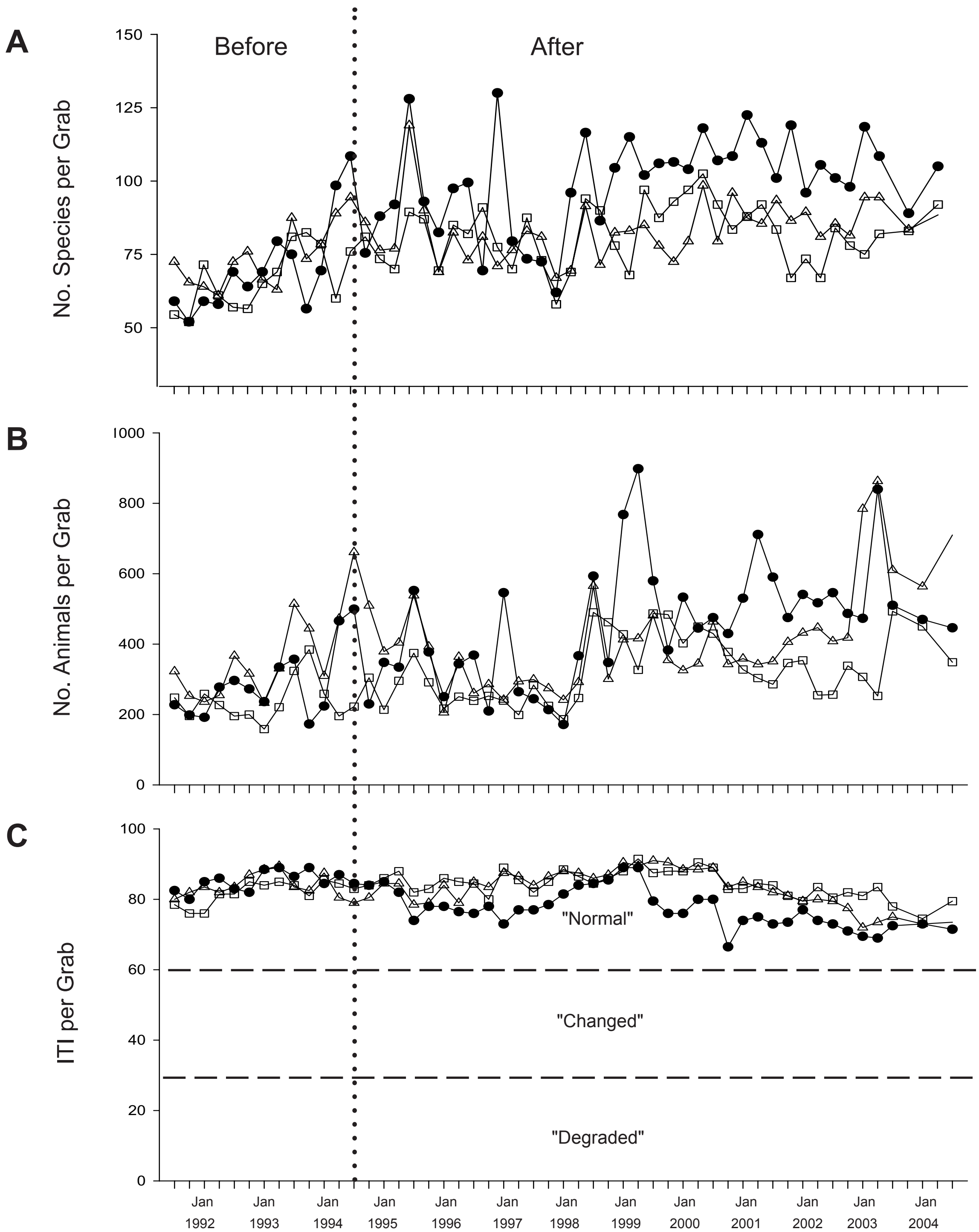


Figure 5.3

Comparison of several parameters at "impact" site (station E14) and "control" sites (stations E26, B9) used in BACIP analyses (see Table 5.3). Data for each station are expressed as quarterly means per 0.1 m^2 (n=2). (A) Number of infaunal species; (B) infaunal abundance; (C) infaunal trophic index (ITI); (D) abundance of *Ampelisca* spp (Amphipoda); (E) abundance of *Amphiodia* spp (Ophiuroidea).

The difference in species richness may be due to the increased variability and higher numbers of species at the impact site (**Figure 5.3a**). Results for *Amphiodia* populations mostly reflect a decrease in the number of these ophiuroids collected at the impact site since discharge began (Figure 5.3e). Similarly, the difference in ITI is due to generally lower index values at station E14 since the outfall began operation (Figure 5.3c). These decreased ITI values may in part be explained by the lower

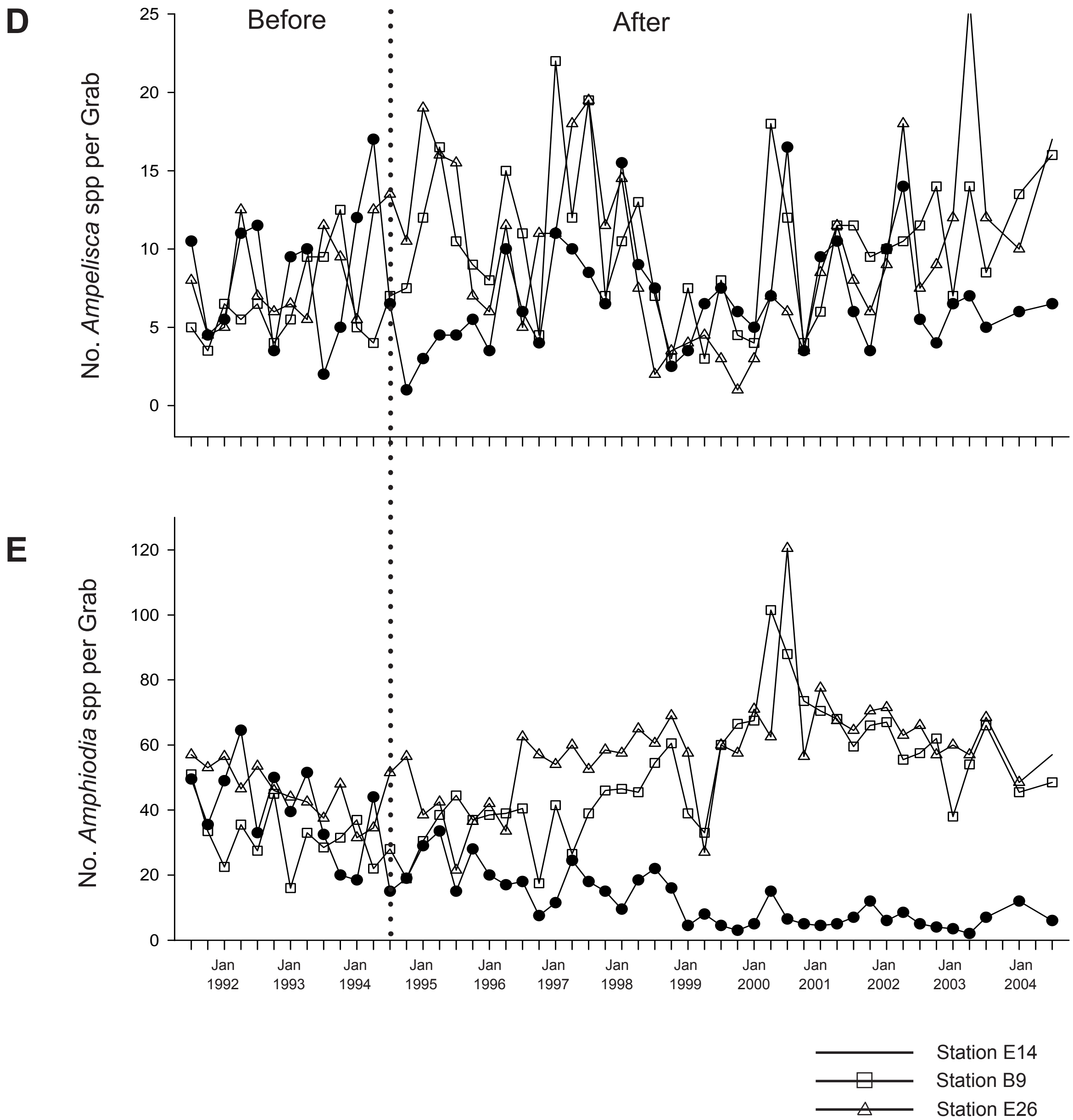


Figure 5.3 *Continued*

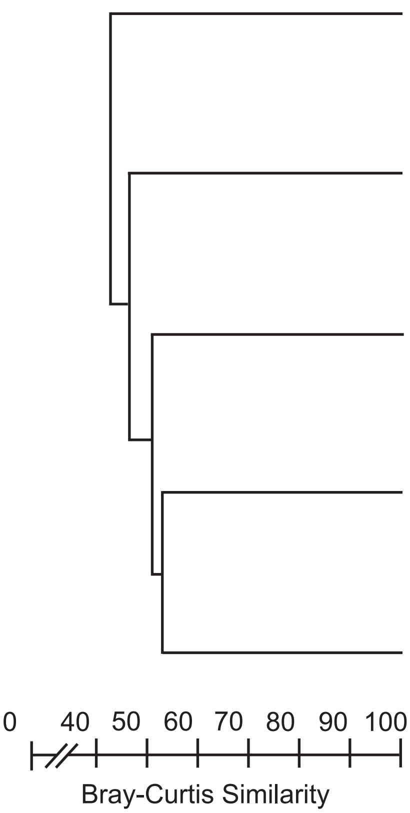
numbers of *Amphiodia*. The results for infaunal abundances were more ambiguous (Figure 5.3b). Although a significant change was indicated between the impact site and station B9, no such pattern was found regarding the second control site (E26). Finally, there was no net change in the average difference between impact and control sites in numbers of ampeliscid or phoxocephalid amphipods.

Classification of Benthic Assemblages

Classification analyses discriminated differences between five main benthic assemblages (cluster groups A–E) during 2004 (**Figures 5.4, 5.5**). These assemblages differed in terms of their species composition, including the specific taxa present and their relative abundances. The dominant species for each assemblage are listed in **Table 5.4**. MDS ordination of the survey entities confirmed the validity of cluster groups A–E (Figure 5.4).

Cluster group A included deeper sites along the 98 and 116-m contours. Sediments associated with cluster group A had the highest percentage of

A



CG	SR	ABUN	% FINES	Top Three Taxa
A (n=4)	103.3 (78–124)	281 (179–428)	28.9 (25.1–31.9)	*Chloeia pinnata*, *Myriochele striolata*, *Euphilomedes producta*
B (n=4)	92 (79–107)	264 (185–369)	40.5 (34.9–47.2)	*Myriochele striolata*, *Amphiodia urtica*, *Myriochele gracilis*
C (n=2)	97 (82–121)	458 (301–639)	30.2 (29.2–31.3)	*Myriochele striolata*, *Chloeia pinnata*, *Euphilomedes carcharodonta*
D (n=9)	88 (69–108)	463 (201–969)	44.3 (38.4–57.8)	*Myriochele striolata*, *Amphiodia urtica*, *Proclea* sp A
E (n=15)	81 (62–101)	245 (149–364)	33.8 (28.1–45.7)	*Amphiodia urtica*, *Proclea* sp A, Amphiuridae

B

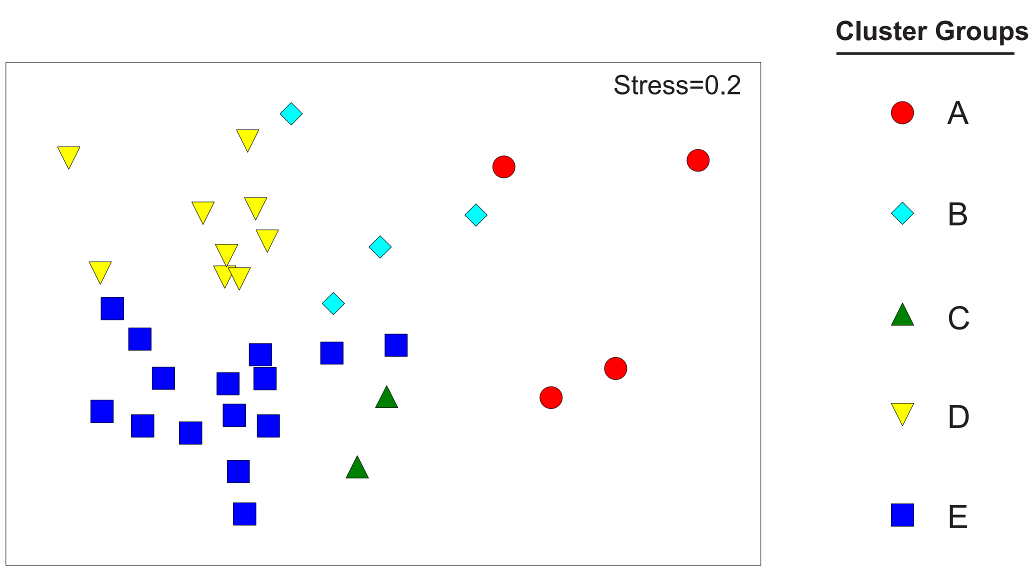


Figure 5.4

(A) Cluster results of the macrofaunal abundance data for the PLOO benthic stations sampled during 2004. Data are expressed as mean values per 0.1 m^2 grab over all stations in each group. CG=cluster group; SR=number of species; ABUN=number of individuals; % Fines=percent of silt + clay fractions in the sediment. Ranges in parentheses are for individual grab samples. (B) MDS ordination of PLOO benthic stations sampled during 2004. Plot based on square-root transformed macrofaunal abundance data for each station/survey entity. Cluster groups superimposed on station/surveys illustrate a clear distinction between faunal assemblages.

coarse particles (16%) and the lowest percentage of fine particles (29%) compared to the other groups. As is typical of these sites, species richness was relatively high, approximately 103 species per 0.1 m^2. The amphinomid polychaete *Chloeia pinnata* was among the dominant animals in this assemblage. Other dominant species included the oweniid polychaete *Myriochele striolata* and the ostracod crustacean *Euphilomedes producta.* This cluster group had the highest average abundance of the ophiuroid *Amphiodia digitata* and the gastropod *Caecum crebricinctum* which are usually associated with coarser grain sediments.

Cluster group B represented three southern stations along the 88 and 98-m contours. The sediments at these station were mainly composed of fine sands and silt. This assemblage averaged 264 individuals and 92 species per 0.1 m^2. The dominant species in this group were the polychaetes *M. striolata* and *M. gracilis* as well as the ophiuroid, *Amphiodia urtica*.

Cluster group C comprised station E14 located nearest to the PLOO discharge. Sediments here were characterized as sandy silt with some coarse particles. This assemblage was heavily dominated by *M. striolata* which averaged 146 individuals per 0.1 m^2. The polychaete *Chloeia pinnata* and the ostracod *Euphilomedes carcharodonta* also were prominent. The opportunistic polychaete *Capitella* "*capitata*" (spp complex) was much less abundant in this assemblage compared to previous years. When present in high numbers, this species is considered an indicator of organic enrichment (Reish 1971, Grassle and Grassle 1974, Pearson and Rosenberg 1978, Zmarzly et al. 1994). Only two individuals were collected at E14 during 2004 compared to an average of 14 individuals per 0.1 m^2 in 2003. Although *A. urtica* was present, it occurred in low densities (6.3 per 0.1 m^2) relative to most other assemblages.

Cluster group D comprised six northern stations along the 88 and 98-m contours. The sediments in this group had the highest percentage of fine particles (44%) among all cluster groups and highest macrofaunal abundance (463 individuals per 0.1 m^2 on average), but the second lowest species richness (88 species per 0.1 m^2) compared to the other cluster groups. The most abundant organisms were *M. striolata*, *A. urtica,* and the terebellid polychaete, *Proclea* sp A.

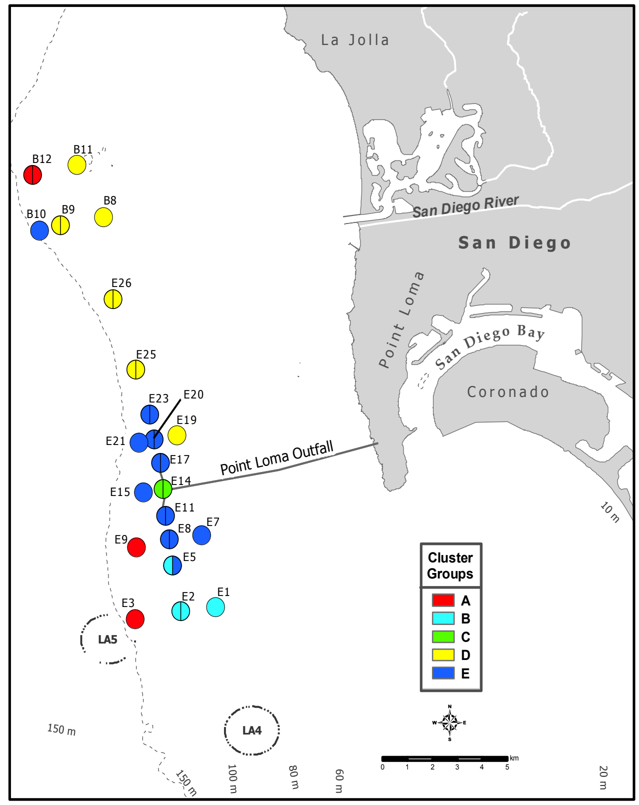


Figure 5.5
Results of ordination and classification analyses of macrofaunal abundance data during 2004. Cluster groups are color-coded on the map to reveal spatial patterns in the distribution of benthic assemblages.

Cluster group E was the largest assemblage, comprising 10 stations and 44% of the samples collected during 2004. Silty sand characterized the sediments at the sites comprising this cluster group. This group averaged 245 individuals and 81 species per 0.1 m^2, the lowest among all cluster groups. Dominant species included *A. urtica*, immature ophiuroids (i.e., Amphiuridae), and *Proclea* sp A. *Myriochele striolata*, a dominant species in all other cluster groups, was much less abundant here than elsewhere in the region.

Table 5.4

Summary of the most abundant taxa composing cluster groups A–E from the PLOO benthic stations surveyed in 2004. Data are expressed as mean abundance per sample (no./0.1m^2) and represent the ten most abundant taxa in each group. Animals absent from a cluster group are indicated by a dash. The three most abundant taxa in each cluster group are bolded.

		Cluster Group				
Species/Taxa	**Higher Taxa**	**A** (n=4)	**B** (n=4)	**C** (n=2)	**D** (n=9)	**E** (n=15)
Adontorhina cyclia	Mollusca: Bivalvia	0.3	0.1	1.3	11.4	2.9
Amphiodia digitata	Echinodermata: Ophiuroidea	7.6	1.3	0.3	1.0	0.8
Amphiodia sp	Echinodermata: Ophiuroidea	2.6	6.6	2.5	5.2	4.4
Amphiodia urtica	Echinodermata: Ophiuroidea	3.4	26.1	6.3	45.3	25.7
Amphiuridae	Echinodermata: Ophiuroidea	2.9	7.5	3.3	7.5	11.1
Axinopsida serricata	Mollusca: Bivalvia	0.1	0.5	8.0	8.4	3.4
Caecum crebricinctum	Mollusca: Gastropoda	8.9	—	—	—	—
Chaetozone hartmanae	Polychaeta: Cirratulidae	4.4	8.3	13.5	7.6	7.3
Chloeia pinnata	Polychaeta: Amphinomidae	12.9	1.9	25.8	3.8	5.5
Euphilomedes carcharodonta	Crustacea: Ostracoda	4.3	4.1	18.8	2.6	10.7
Euphilomedes producta	Crustacea: Ostracoda	9.1	3.5	7.5	4.8	6.1
Mediomastus sp	Polychaeta: Capitellidae	3.6	1.4	8.8	2.3	1.6
Myriochele gracilis	Polychaeta: Oweniidae	7.5	9.4	5.3	7.4	7.0
Myriochele striolata	Polychaeta: Oweniidae	11.4	27.9	146.0	178.9	0.6
Paradiopatra parva	Polychaeta: Onuphidae	5.0	3.5	5.3	4.4	2.7
Photis californica	Crustacea: Amphipoda	3.5	1.6	7.5	0.4	—
Prionospio (Prionospio) jubata	Polychaeta: Spionidae	5.6	1.4	17.3	3.2	5.0
***Proclea* sp A**	Polychaeta: Terebellidae	0.8	7.5	4.3	14.2	11.2
Rhepoxynius bicuspidatus	Crustacea: Amphipoda	0.5	1.9	4.0	6.6	6.4
Spiophanes duplex	Polychaeta: Spionidae	2.5	5.5	1.0	6.0	5.0
Sternaspis fossor	Polychaeta: Sternaspidae	2.4	5.4	4.0	5.6	4.1
Urothoe varvarini	Crustacea: Amphipoda	7.8	—	—	1.3	0.2

SUMMARY AND CONCLUSIONS

Benthic communities around the PLOO continue to be dominated by ophiuroid-polychaete based assemblages, with few major changes having occurred since monitoring began (see City of San Diego 1995, 2004). Polychaete worms continue to dominate the fauna in numbers of species and abundance. Although many of the 2004 assemblages were dominated by similar species, the relative abundance of these species varied between sites. The oweniid polychaete, *Myriochele striolata,* was dominant in all assemblages except the ten sites forming cluster group E. *Amphiodia urtica* was the second most abundant species and the most widespread benthic invertebrate in the region, being dominant or co-dominant in assemblages that comprised 86% of the samples. Assemblages similar to those off Point Loma have been described for other areas in the Southern California Bight (SCB) by Barnard and Ziesenhenne (1961), Jones (1969), Fauchald and Jones (1979), Thompson et al. (1987, 1992, 1993), Zmarzly et al. (1994), Diener and Fuller (1995), and Bergen et al. (1998, 2000).

Although variable, benthic communities off Point Loma generally have remained similar between years in terms of the number of species, number of individuals, and dominance (City of San Diego 1995, 2004). In addition, values for these parameters in 2004 were similar to those described for other sites throughout the SCB (e.g., Thompson et al. 1992, Bergen et al. 1998, 2001). In spite of this overall stability, there has been an increase in the number of species and macrofaunal abundances since discharge began (see City of San Diego 1995, 2004). However, the increase in species has been most pronounced nearest the outfall, suggesting that significant environmental degradation is not occurring at the PLOO. In addition, the observed increases in abundance at most stations have been accompanied by decreases in dominance, patterns inconsistent with predicted pollution effects. Whatever the cause of such changes, benthic communities around the PLOO are not numerically dominated by a few pollution tolerant species.

Changes near the outfall suggest some effects coincident with anthropogenic activities. Indicative of organic enrichment or disturbance was a decrease in the infaunal trophic index (ITI) at station E14 after discharge began (see City of San Diego 1995, 2004). In addition, benthic response index (BRI) values are higher at E14 than at other sites in the region. However, both ITI and BRI values at this and all other sites remain characteristic of undisturbed areas. In addition, the increased variability in number of species and infaunal abundance at near-ZID station E14 since discharge began may be indicative of community destabilization (see Warwick and Clarke 1993, Zmarzly et al. 1994). The instability or patchiness of sediments near the PLOO and the corresponding shifts in assemblages suggest that changes in this area may be related to localized physical disturbance (e.g., shifting sediment types) associated with the structure of the outfall pipe as well as to organic enrichment associated with the discharge of effluent.

Populations of some indicator taxa revealed changes that correspond to organic enrichment near the outfall, while populations of others revealed no evidence of impact. For example, there has been a significant change in the difference between ophiuroid (*Amphiodia* spp) populations that occur near the outfall (i.e., station E14) and those present at reference sites. This difference is due mostly to decreased numbers of ophiuroids near the outfall as compared to those at the control sites during the post-discharge period. Although changes in *Amphiodia* populations at E14 are likely to be related to organic enrichment, they may also be due in part to increased predation pressure from fish living near the outfall pipe. Whether or not these changes are related to enrichment, predation, altered sediment composition or some other factor, abundances of *Amphiodia* off Point Loma are still within the range of those occurring naturally in the SCB (Barnard and Ziesenhenne 1961, Jones 1969). In addition, natural population fluctuations of these and other resident organisms (e.g. *M. striolata* and *Proclea* sp A) are common off San Diego (Zmarzly et al. 1994, Deiner et al. 1995). Further complicating the picture, patterns of change in populations of pollution sensitive amphipods (i.e., *Rhepoxynius, Ampelisca*) have shown no outfall-related effects.

While it is difficult to detect specific effects of the PLOO on the offshore benthos, it is possible to see some changes occurring near the discharge site (i.e., E14). Because of the minimal extent of these changes, it has not been possible to determine whether any effect is due to the physical structure of the outfall pipe or to organic enrichment in the area. Such impacts have spatial and temporal dimensions that vary depending on a range of biological and physical factors. In addition, abundances of soft bottom invertebrates exhibit substantial spatial and temporal variability that may mask the effects of any disturbance event (Morrisey et al. 1992a, 1992b, Otway 1995). The effects associated with the discharge of advanced primary treated (APT) and secondary treated sewage may also be negligible or difficult to detect in areas subjected to strong currents that facilitate the dispersion of the wastewater plume (see Diener and Fuller 1995). Although some changes in benthic assemblages have appeared near the outfall, assemblages in the region are still similar to those observed prior to discharge and to natural indigenous communities characteristic of the southern California continental shelf.

LITERATURE CITED

Barnard, J.L., and F.C. Ziesenhenne. (1961). Ophiuroidea communities of southern Californian coastal bottoms. Pac. Nat., 2: 131–152.

Bascom, W., A.J. Mearns, and J.Q. Word. (1979). Establishing boundaries between normal, changed, and degraded areas. In: Southern California Coastal Water Research Project Annual Report, 1978. Long Beach, CA. pp. 81–95.

Bergen, M., D.B. Cadien, A. Dalkey, D.E. Montagne, R.W. Smith, J.K. Stull, R.G. Velarde, and S.B. Weisberg,. (2000). Assessment of benthic infaunal condition on the mainland shelf of southern California. Env. Monit. Assmt. 64:421–434.

Bergen, M., S.B. Weisberg, D. Cadien, A. Dalkey, D. Montagne, R.W. Smith, J.K. Stull, and R.G. Velarde. (1998). Southern California Bight 1994 Pilot Project: IV. Benthic Infauna. Southern California Coastal Water Research Project, Westminster, CA. 260 pp.

Bergen, M., S.B. Weisberg, R.W. Smith, D.B. Cadien, A. Dalkey, D.E. Montagne, J.K. Stull, R.G. Velarde, and J.A. Ranasinghe. (2001). Relationship between depth, sediment, latitude, and the structure of benthic infaunal assemblages on the mainland shelf of southern California. Mar. Biol., 138: 637–647.

Bernstein, B.B., and J. Zalinski. (1983). An optimum sampling design and power tests for environmental biologists. J. Environ. Manage., 16: 35-43.

City of San Diego. (1995). Outfall Extension Pre-Construction Monitoring Report. City of San Diego Ocean Monitoring Program, Metropolitan Wastewater Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

City of San Diego. (1999). San Diego Regional Monitoring Report for 1994–1997. City of San Diego Ocean Monitoring Program, Metropolitan Wastewater Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

City of San Diego. (2003). Annual Receiving Waters Monitoring Report for the South Bay Ocean Outfall, 2002. City of San Diego Ocean Monitoring Program, Metropolitan Wastewater Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

City of San Diego. (2004). Annual Receiving Waters Monitoring Report for the Point Loma Ocean Outfall, 2003. City of San Diego Ocean Monitoring Program, Metropolitan Wastewater Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

City of San Diego. (in prep). EMTS Division Laboratory Quality Assurance Project Plan. City of San Diego Ocean Monitoring Program, Metropolitan Wastewater Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

Clarke, K.R. (1993). Non-parametric multivariate analyses of changes in community structure. Aust. J. Ecol., 18: 117–143.

Diener, D.R., and S.C. Fuller. (1995). Infaunal patterns in the vicinity of a small coastal wastewater outfall and the lack of infaunal community response to secondary treatment. Bull. Southern Cal. Acad. Sci., 94: 5–20.

Diener, D.R., S.C. Fuller, A Lissner, C.I. Haydock, D. Maurer, G. Robertson, and R. Gerlinger. (1995). Spatial and temporal patterns of the infaunal community near a major ocean outfall in Southern California. Mar. Poll. Bull., 30: 861–878.

Fauchald, K., and G.F. Jones. (1979). Variation in community structures on shelf, slope, and basin macrofaunal communities of the Southern California Bight. In: Southern California outer continental shelf environmental baseline study, 1976/1977 (second year) benthic program. Vol. II, Principal Invest. Reps., Ser. 2, Rep. 19. Available from: NTIS, Springfield, Virginia; PB80 16601. Science Applications, Inc., La Jolla, CA.

Grassle, J.F., Grassle, J.P. (1974). Opportunistic life histories and genetic systems in marine benthic polychaetes. J. Mar. Res., 32: 253–284.

Jones, G.F. (1969). The benthic macrofauna of the mainland shelf of southern California. Allan Hancock Monogr. Mar. Biol., 4: 1–219.

Morrisey, D.J., L. Howitt, A.J. Underwood, and J.S. Stark. (1992a). Spatial variation in soft sediment benthos. Mar. Ecol. Prog. Ser., 81: 197–204.

Morrisey, D.J., A.J. Underwood, L. Howitt, and J.S. Stark. (1992b). Temporal variation in soft sediment benthos. J. Exp. Mar. Biol. Ecol., 164: 233–245.

Osenberg, C.W., R.J. Schmitt, S.J. Holbrook, K.E. Abu-Saba, and R. Flegel. (1994). Detection of environmental impacts: Natural variability, effect size, and power analysis. Ecol. Appl., 4: 16–30.

Otway, N.M. (1995). Assessing impacts of deepwater sewage disposal: a case study from New South Wales, Australia. Mar. Poll. Bull., 31: 347–354.

Pearson, T.H., and R. Rosenberg. (1978). Macrobenthic succession in relation to organic enrichment and pollution of the marine environment. Oceanogr. Mar. Biol. Ann. Rev., 16: 229–311.

Reish, D.J. (1971). Effect of pollution abatement in Los Angeles Harbours. Mar. Poll. Bull., 2: 71–74.

Smith, R.W., M. Bergen, S.B. Weisberg, D. Cadien, A. Dalkey, D. Montagne, J.K. Stull, and R.G. Velarde. (2001). Benthic response index for assessing infaunal communities on the southern California mainland shelf. Ecological Applications, 11(4): 1073–1087.

Smith, R.W., and L. Riege. (1994). Optimization and power analyses for the Point Loma monitoring design. Unpublished report to City of San Diego, Metropolitan Wastewater Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

Stewart-Oaten, A., W.W. Murdoch, and K.R. Parker. (1986). Environmental impact assessment: “Pseudoreplication” in time? Ecology, 67: 929–940.

Stewart-Oaten, A., Bence, J.R., and C.W. Osenberg. 1992. Assessing effects of unreplicated perturbations: no simple solutions. Ecology 73:1396-1404.

Swartz, R.C. (1978). Techniques for sampling and analyzing the marine macrobenthos. U.S. Environmental Protection Agency (EPA), Doc. EPA-600/3-78-030, EPA, Corvallis, Oregon. 27 pp.

Thompson, B., J. Dixon, S. Schroeter, and D.J. Reish. (1993). Chapter 8. Benthic invertebrates. In: Dailey, M.D., D.J. Reish, and J.W. Anderson (eds.). Ecology of the Southern California Bight: A Synthesis and Interpretation. University of California Press, Berkeley, pp. 369–458.

Thompson, B.E., J.D. Laughlin, and D.T. Tsukada. (1987). 1985 reference site survey. Tech. Rep. No. 221, Southern California Coastal Water Research Project, Long Beach, CA.

Thompson, B.E., D. Tsukada, and D. O’Donohue. (1992). 1990 reference survey. Tech. Rep. No. 355, Southern California Coastal Water Research Project, Long Beach, CA.

[USEPA] United States Environmental Protection Agency. (1987). Quality Assurance and Quality Control (QA/QC) for 301(h) Monitoring Programs: Guidance on Field and Laboratory Methods. EPA Document 430/9-86-004. Office of Marine and Estuarine Protection. 267 pp.

Warwick, R.M. (1993). Environmental impact studies on marine communities: pragmatical considerations. Aust. J. Ecol., 18: 63–80.

Warwick, R.M., and K.R. Clarke. (1993). Increased variability as a symptom of stress in marine communities. J. Exp. Mar. Biol. Ecol., 172: 215–226.

Word, J.Q. (1980). Classification of benthic invertebrates into infaunal trophic index feeding groups. In: Bascom, W. (ed.). Biennial Report for the Years 1979 1980, Southern California Coastal Water Research Project, Long Beach, CA. pp. 103–121.

Zmarzly, D.L., T.D. Stebbins, D. Pasko, R.M. Duggan, and K.L. Barwick. (1994). Spatial patterns and temporal succession in soft bottom macroinvertebrate assemblages surrounding an ocean outfall on the southern San Diego shelf: Relation to anthropogenic and natural events. Mar. Biol., 118: 293–307.

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