Chapter 5. Macrobenthic Communities

INTRODUCTION

The southern California coastal shelf contains 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 are important prey for fish and other organisms, while others decompose organic material as a crucial step in nutrient cycling. The structure of marine macrofaunal communities is influenced by many factors including sediment conditions (e.g., particle size, sediment chemistry), water conditions (e.g., temperature, salinity, dissolved oxygen, current velocity), and biological factors (e.g., food availability, competition, predation). While human activities can affect these factors, natural processes largely control the structure of invertebrate communities in marine sediments. In order to determine whether changes in community structure are related to human impacts or natural processes, it is important 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, 2004, 2005).

Benthic macrofauna living in marine soft sediments can be sensitive indicators of environmental disturbance (Pearson and Rosenberg 1978). Because these animals 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, organic enrichment). Consequently, assessment of benthic communities has been used to monitor the effects of municipal wastewater discharges on the ocean environment (see Zmarzly et al. 1994, Diener et al. 1995, Bergen et al. 2000). Analyses and interpretation of the macrofaunal data collected during 2006 at fixed stations surrounding the PLOO discharge site off San Diego, California are presented in this chapter. Descriptions and comparisons of the different macrofaunal assemblages that inhabit soft bottom sediments in the area and analysis of benthic community structure are included.

MATERIALS AND METHODS

Collection and Processing of Samples

Benthic samples were collected at 22 stations that range from 8 km south to 11 km north of the outfall terminus and are located along the 88, 98, and 116-m depth contours (**Figure 5.1**). A total of 88 benthic grabs were taken during 2 surveys in

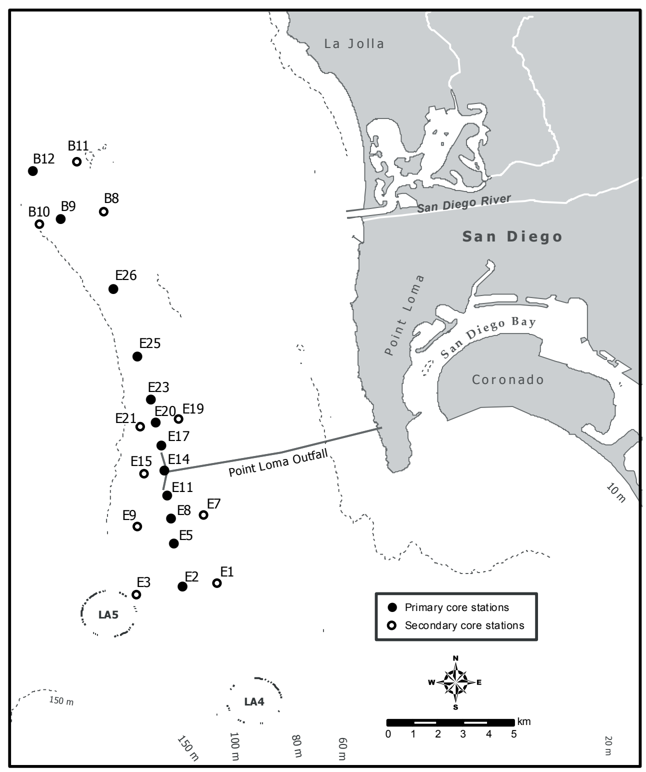


Figure 5.1
Benthic stations surrounding the City of San Diego's Point Loma Ocean Outfall.

2006. All 22 benthic stations were sampled in both January and July.

Samples for benthic community analysis were collected from 2 replicate grabs per station during each survey using a modified 0.1-m^2 chain-rigged, double van Veen grab. The criteria established by the USEPA to ensure 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 screen were relaxed for 30 minutes in a magnesium sulfate solution and then fixed in buffered formalin. After a minimum of 72 hours, each sample was rinsed with freshwater and transferred to 70% ethanol. All organisms were sorted from the debris into major taxonomic groups by a subcontractor, identified to species or the lowest taxon possible, and enumerated by City of San Diego marine biologists.

Statistical Analyses

Multivariate analyses were performed using PRIMER v6 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. SIMPER (similarity percentage) analysis was used to identify individual species that typified each cluster group. Analyses were run on mean abundances of replicate grabs per station/survey to identify distinct cluster groups from 44 combined samples among 22 stations.

Annual means for the following community parameters were calculated for each station and cluster group: species richness (number of species); total number of species per site (i.e., cumulative of 2 replicate samples); abundance (number of individuals); Shannon diversity index (H'); Pielou's evenness index (J'); Swartz dominance index (minimum number of species accounting for 75% of the total abundance in each grab; see Swartz et al. 1986, Ferraro et al. 1994); Infaunal Trophic Index (ITI; see Word 1980) and Benthic Response Index (BRI; see Smith et al. 2001).

A BACIP (Before-After-Control-Impact-Paired) statistical model was used to test the null hypothesis that there have been no changes in select community parameters due to operation of the Point Loma outfall (see Bernstein and Zalinski 1983, Stewart-Oaten et al. 1986, 1992, Osenberg et al. 1994). 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 2006) 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 13 years (45 quarterly or semi-annual surveys) of after impact data.

The E stations, located within 8 km of the outfall, are considered most likely to be affected by wastewater discharge. Station E14 was selected as the impact site for all analyses; this station is located nearest the Zone of Initial Dilution (ZID) and probably is 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, 2 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 3 community parameters (number of species, infaunal abundance, BRI) and abundances of 3 taxa that are considered sensitive to organic enrichment. These indicator taxa include 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

Number of species

A total of 621 macrofaunal taxa were identified during the 2006 PLOO surveys. Mean values of species richness ranged from 63 to 147 species per 0.1 m^2 (**Table 5.1**). Stations E3, E9, and E25 and northern reference stations B10, B11, and B12 were characterized by the most species, averaging 119–137 species per 0.1 m^2 (City of San Diego 2005, 2006a). This pattern is consistent with previous high species richness values for these sites (e.g., City of San Diego 2005, 2006a) In contrast, the lowest species richness was found at stations E1, E7, E11, E19, E20, and E23, all of which averaged fewer than 90 species per 0.1 m^2. In addition, species richness at approximately half of the stations showed a large decrease compared to 2005 (see City of San Diego 2006a).

Polychaetes were the most diverse of the major taxa in the region, accounting for 46% of all species collected during 2006. Crustaceans accounted for 24% of the species, molluscs 15%, echinoderms 6%, and all other taxa combined for 9% of the species.

Macrofaunal abundance

Mean macrofaunal abundance averaged 169–586 animals per 0.1 m^2 in 2006 (Table 5.1). The largest number of animals occurred at stations E9, E14, and B12, each of which averaged >450 animals per 0.1 m^2. The fewest animals (<300 per 0.1 m^2) were collected at stations E1, E19, E20, and E23, which were also low in species richness. The remaining sites had abundances ranging from 305 to 434 animals per 0.1 m^2. There was a 22% decline in overall abundance region wide in 2006 versus 2005, with the largest difference occurring at stations B11 and B8 (see City of San Diego 2006a). These sites averaged 1074 and 606 individuals per 0.1 m^2 respectively in 2005 but <350 in 2006.

Polychaetes were the most numerous animals, accounting for 57% of the total abundance. Crustaceans accounted for 23%, echinoderms 11%, molluscs 7%, and all other phyla combined 2%. The most apparent change in community structure was a decrease in polychaete abundances compared to 2005. Polychaete numbers decreased by 5% region wide. The largest decreases in polychaete abundance occurred at northern stations B11 (20%) and B8 (10%), which accounted for most of the decrease in the total abundances at these 2 stations in 2006. In contrast, mean abundances of echinoderms, molluscs, and crustaceans increased at station B11. The largest increase in echinoderm mean abundances was seen at station E1 (12%).

Species diversity, dominance, and evenness

Species diversity (H') ranged from 4.3 to 5.1 during the year (Table 5.1), which was similar to that observed prior to wastewater discharge (see City of San Diego 1995). The highest diversity (H' ≥5.0) occurred at the northern stations B10–B12 and stations E3 and E9, while the lowest (≤4.5) occurred at stations E1, E7, E17, and E19.

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 2006 were characterized by relatively high numbers of evenly distributed species (Table 5.1). The dominance index averaged 38 species per station, which is similar to that observed in 2005 (see City of San Diego 2006a). The highest values (≥50) occurred at stations E3 and E9, and station B11 while the lowest values (≤30) were seen at stations E7, E17, and E19. Evenness (J') varied little in 2006, with mean values ranging from 0.95 to 1.07.

Environmental disturbance indices

Mean Benthic Response Index (BRI) values ranged from 2 to 23 in 2006. These values suggest that

Table 5.1

Benthic community parameters from PLOO stations sampled in 2006. Data are expressed as annual means (±SE) for: Species richness, no. species/0.1 m^2 (SR); total cumulative no. species for the year (Tot spp); Abundance, no. individuals/0.1 m^2 (Abun); Shannon diversity index (H'); Evenness (J'); Swartz dominance, no. species comprising 75% of a community by abundance (Dom); Benthic Response Index (BRI); Infaunal Trophic Index (ITI). n=4. Minima and maxima represent values from all replicates.

Station	SR	Tot spp	Abun	H'	J'	Dom	BRI	ITI
88-m contour								
B11	137	281	418	5.1	1.03	53	6	79
B8	98	197	334	4.7	1.06	35	6	85
E19	82	153	287	4.5	0.99	27	6	86
E7	87	164	310	4.5	1.00	30	9	87
E1	89	190	293	4.4	0.96	31	7	89
98-m contour								
B12	132	239	504	5.0	1.02	45	9	76
B9	103	198	346	4.8	1.05	40	5	81
E26	99	178	341	4.8	1.03	37	7	79
E25	119	202	434	4.9	1.02	40	8	80
E23	89	164	294	4.7	1.06	35	7	81
E20	85	157	279	4.7	1.03	34	9	80
E17	95	175	393	4.5	0.98	30	12	77
E14	110	224	452	4.7	1.00	34	19	73
E11	87	167	305	4.6	1.02	31	12	79
E8	95	181	323	4.7	1.04	33	7	80
E5	100	185	344	4.7	1.01	33	7	82
E2	96	188	318	4.7	1.01	37	6	83
116-m contour								
B10	121	230	391	5.0	1.06	45	8	78
E21	97	180	338	4.7	1.02	35	9	80
E15	113	211	386	4.9	1.03	42	8	80
E9	132	243	451	5.0	1.00	50	8	79
E3	127	234	370	5.1	1.03	55	5	81
All stations								
Mean	104	197	359	4.7	1.02	38	8	81
Min	63	153	169	4.3	0.95	21	2	68
Max	147	281	586	5.1	1.07	61	23	90

benthic communities in the region are relatively undisturbed as BRI values below 25 are considered indicative of reference conditions (Smith et al. 2001). The highest mean values (≥12) were measured at stations E11, E14, and E17, located nearest the PLOO discharge site. Mean ITI values ranged from 68 to 90 per station in 2006 (Table 5.1), and were similar to those reported in previous years (see City of San Diego 2005, 2006a). These values are also indicative of undisturbed sediments or reference environmental conditions (see Bascom et al. 1979).

Dominant Species

Macrofaunal communities in the Point Loma region were dominated by polychaete worms (**Table 5.2**). For example, 8 polychaetes species, 2 crustaceans,

Table 5.2

Dominant macroinvertebrates at the PLOO benthic stations sampled during 2006. Included are the 10 most abundant species overall, the 10 most abundant per occurrence, and the 10 most frequently collected (or widely distributed) species. Abundance values are expressed as mean number of individuals per 0.1 m^2 grab sample.

Species	Higher taxa	Abundance per sample	Abundance per occurrence	Percent occurrence
Most abundant				
Amphiodia urtica	Echinodermata: Ophiuroidea	20.4	20.4	100
Prionospio jubata	Polychaeta: Spionidae	20.0	20.0	100
Euphilomedes producta	Crustacea: Ostracoda	12.9	13.2	98
Mediomastus sp	Polychaeta: Capitellidae	12.5	12.5	100
Euphilomedes carcharodonta	Crustacea: Ostracoda	11.9	11.9	100
Chaetozone hartmanae	Polychaeta: Cirratulidae	8.4	8.4	100
Spiophanes duplex	Polychaeta: Spionidae	8.3	8.3	100
Phisidia sanctaemariae	Polychaeta: Terebellidae	8.1	8.3	98
Proclea sp A	Polychaeta: Terebellidae	7.9	8.5	93
Paradiopatra parva	Polychaeta: Onuphidae	7.6	7.6	100
Most abundant per occurrence				
Amphiodia urtica	Echinodermata: Ophiuroidea	20.4	20.4	100
Prionospio jubata	Polychaeta: Spionidae	20.0	20.0	100
Euphilomedes producta	Crustacea: Ostracoda	12.9	13.2	98
Mediomastus sp	Polychaeta: Capitellidae	12.5	12.5	100
Euphilomedes carcharodonta	Crustacea: Ostracoda	11.9	11.9	100
Caecum crebricinctum	Mollusca: Gastropoda	1.1	11.9	9
Proclea sp A	Polychaeta: Terebellidae	7.9	8.5	93
Chaetozone hartmanae	Polychaeta: Cirratulidae	8.4	8.4	100
Phisidia sanctaemariae	Polychaeta: Terebellidae	8.1	8.3	98
Spiophanes duplex	Polychaeta: Spionidae	8.3	8.3	100
Most frequently collected				
Amphiodia urtica	Echinodermata: Ophiuroidea	20.4	20.4	100
Prionospio jubata	Polychaeta: Spionidae	20.0	20.0	100
Mediomastus sp	Polychaeta: Capitellidae	12.5	12.5	100
Euphilomedes carcharodonta	Crustacea: Ostracoda	11.9	11.9	100
Chaetozone hartmanae	Polychaeta: Cirratulidae	8.4	8.4	100
Spiophanes duplex	Polychaeta: Spionidae	8.3	8.3	100
Paradiopatra parva	Polychaeta: Onuphidae	7.6	7.6	100
Amphiuridae	Echinodermata: Ophiuroidea	6.9	6.9	100
Amphiodia sp	Echinodermata: Ophiuroidea	6.6	6.6	100

1 echinoderm, and 1 mollusc were among the dominant macroinvertebrates. The 2 most abundant species were the ophiuroid *Amphiodia urtica* and the spionid *Prionospio jubata*, each averaging >20 individuals per 0.1 m^2. However, since juvenile ophiuroids are usually identified to only the generic or familial level (i.e., *Amphiodia* sp or Amphiuridae), mean abundances per sample underestimate actual populations of *A. urtica*. The only other species of *Amphiodia* present off Point Loma in 2006 was *A. digitata*, which accounted for 3% of ophiuroids in the family Amphiuridae that could be identified to species (i.e., *A. urtica* = 97%). If values for these taxa are adjusted accordingly, then the estimated

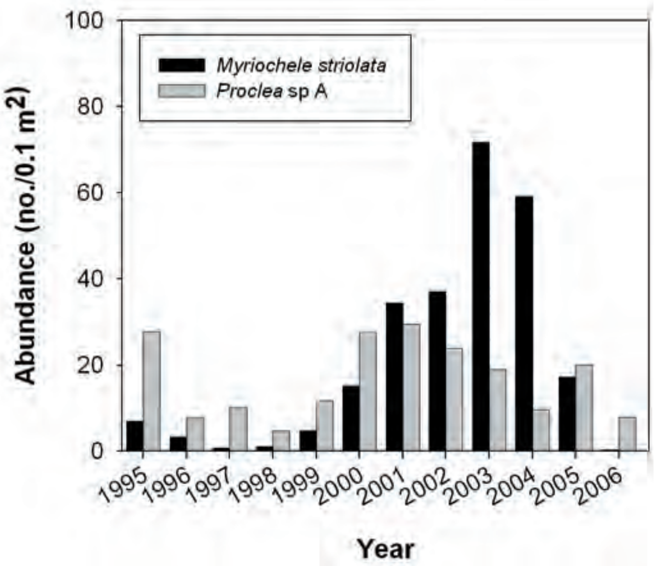


Figure 5.2
Mean annual abundance of *Myriochele striolata* and *Proclea* sp A at the PLOO benthic stations from 1995–2006.

population size for *A. urtica* becomes 28 animals per 0.1 m^2 off Point Loma.

Many of these abundant species were dominant prior to discharge and have remained so ever since (e.g., City of San Diego 1995, 1999, 2004, 2005, 2006a). For example, *A. urtica* has been among the most abundant and most commonly occurring species along the outer shelf since sampling began. However, densities of some numerically dominant polychaetes have been more cyclical. For instance, both *Myriochele striolata* and *Proclea* sp A were among the most abundant polychaetes in 2005, but their densities were much lower in 2006 and 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 BRI and ITI that use the abundance of indicator species in their equations.

BACIP Analyses

BACIP t-tests indicate that there has been a net change in the mean difference of species richness, BRI values, and *Amphiodia* spp abundance between the impact site E14 and both control sites since the onset of discharge from the PLOO (**Table 5.3**). There was also a net change in abundance between E14 and control site B9. The change in species richness may be due to the increased variability and higher numbers of species at the impact site over time (**Figure 5.3A**). Some of the change in species richness between 1995 and 2006 also may be due to increased taxonomic resolution of certain taxa. For example, the polynoid polychaete recorded as *Malmgreniella* sp in 1995 was split into 4 recognizable species by 2005. Differences in *Amphiodia* populations reflect a decrease in the number of these ophiuroids collected at E14 and an increase at the control stations since discharge began (Figure 5.3e). *Amphiodia urtica* densities declined at E14 in 2006 relative to July 2005 and remain similar to the low densities that occurred from 1999–2003, while densities at the 2 control stations are more similar to pre-discharge values. Differences in BRI are generally due to increased index values at station E14 since 1994 (Figure 5.3C). These increased BRI values may in part be explained by the historically lower numbers of *Amphiodia*.

Table 5.3
Results of BACIP t-tests for number of species (SR), infaunal abundance, BRI, and the abundance of several representative taxa around the Point Loma Ocean Outfall (1991–2006). Control sites=far-field station E26 or reference station B9. Impact site=near-ZID station E14; Before Impact period=July 1991 to October 1993 (n=10); After Impact period=January 1994 to July 2006 (n=45). Critical t value=2.007 for =0.05 (two-tailed t-tests, df=53). ns=not significant.

Variable	Control vs. Impact	t	p
SR	E26 v E14	-3.08	0.002
	B9 v E14	-3.51	<0.001
Abundance	E26 v E14	-1.42	ns
	B9 v E14	-2.70	0.005
BRI	E26 v E14	-14.60	<0.001
	B9 v E14	-9.93	<0.001
Amphiodia spp	E26 v E14	-6.99	<0.001
	B9 v E14	-4.94	<0.001
Ampelisca spp	E26 v E14	-1.57	ns
	B9 v E14	-1.04	ns
Rhepoxynius spp	E26 v E14	-0.95	ns
	B9 v E14	-0.99	ns

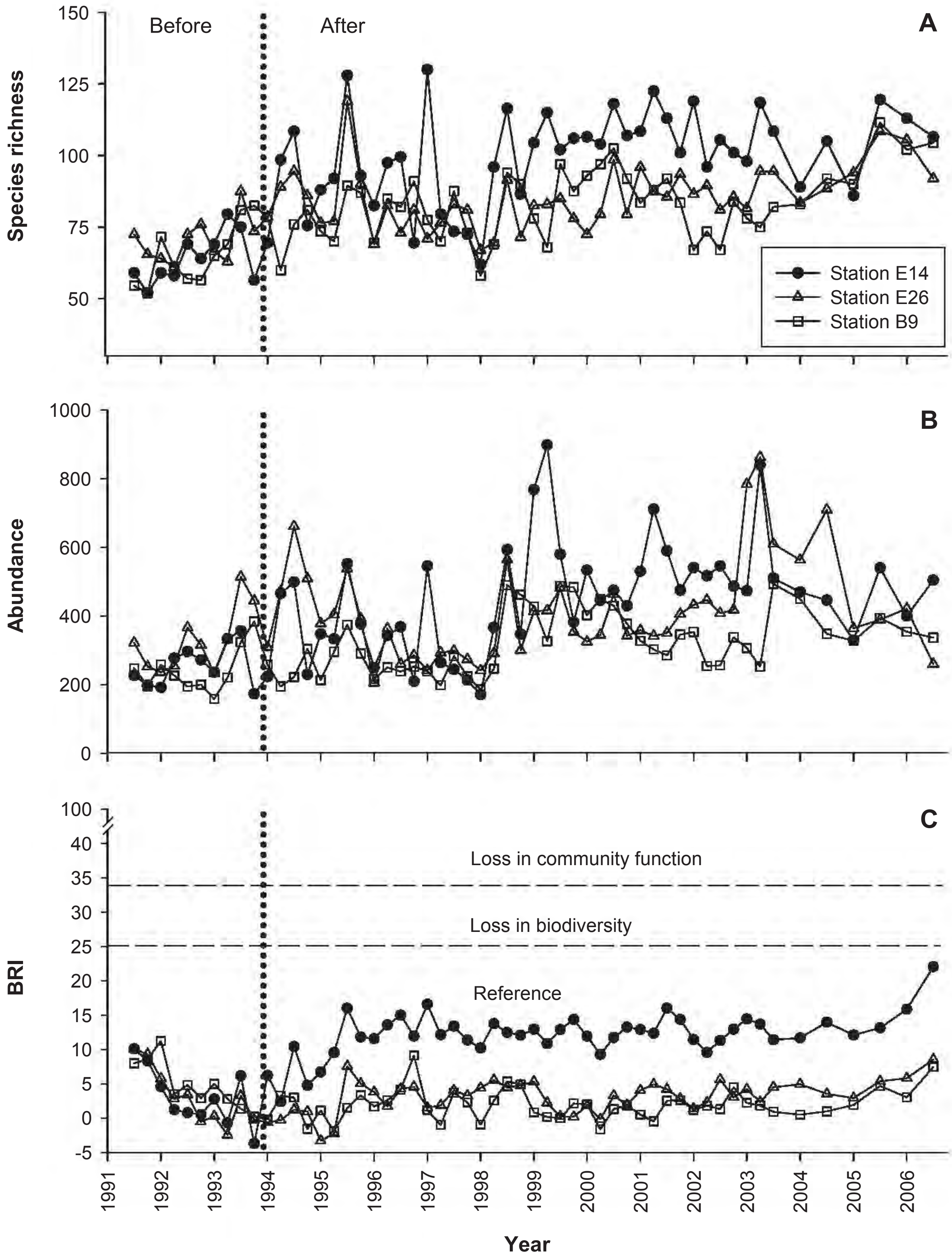


Figure 5.3

Comparison of several parameters at the "impact" site (station E14) and "control" sites (stations E26, B9) used in BACIP analyses (see Table 5.3). Before and After signify the onset of discharge through the PLOO outfall extension on November 24, 1993. Data for each station are expressed as means per 0.1 m^2 (n=2 per survey). (A) Number of infaunal species; (B) infaunal abundance; (C) benthic response index (BRI); (D) abundance of *Ampelisca* spp (Amphipoda); (E) abundance of *Amphiodia* spp (Ophiuroidea).

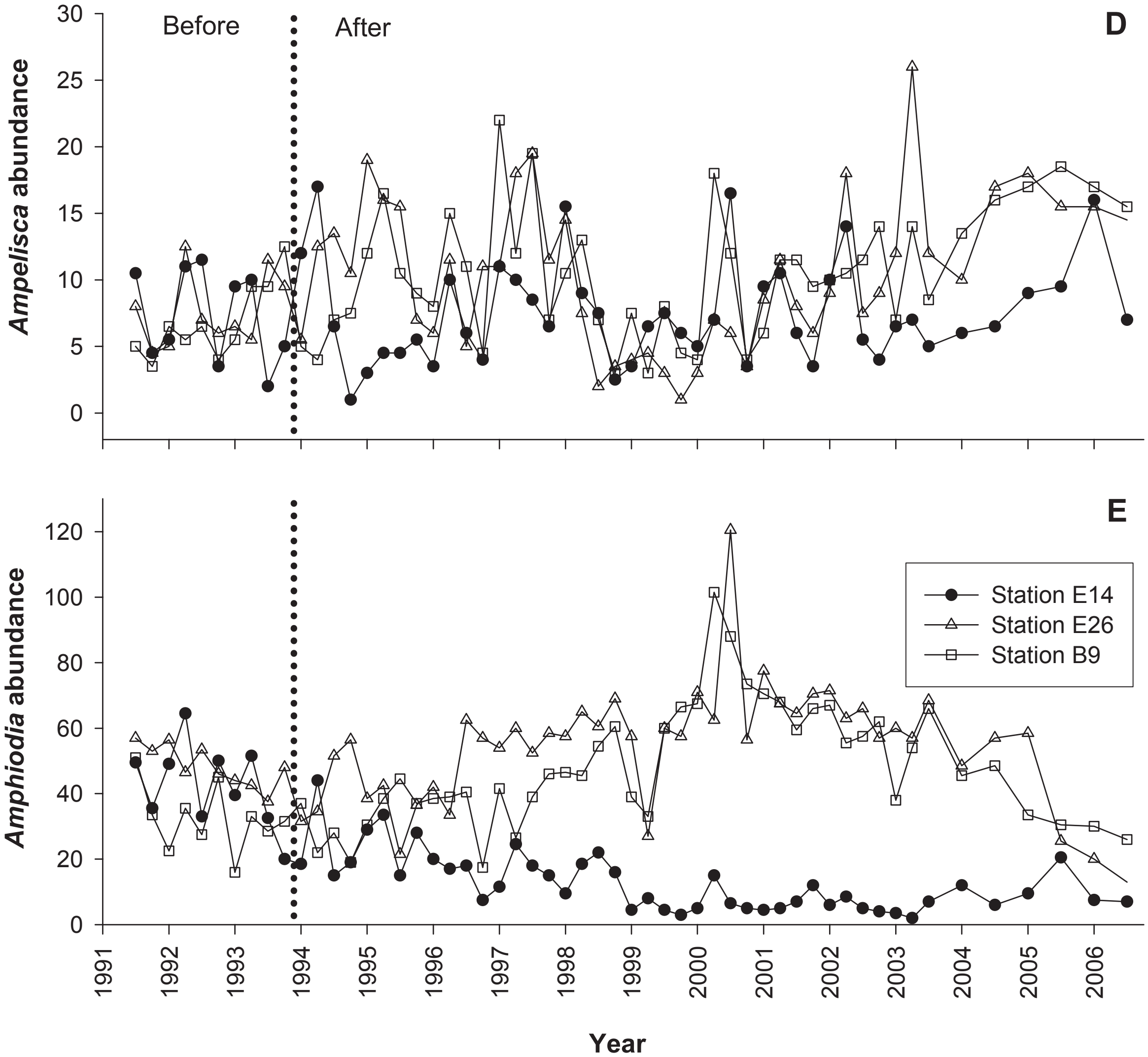


Figure 5.3 Continued

The results for total infaunal abundances were more ambiguous (Figure 5.3B, Table 5.3). While the difference in mean abundances between station B9 and the impact site has changed since discharge began, no such pattern is apparent regarding the second control site (E26). Finally, there were no post-discharge changes in the mean abundances of ampeliscid or phoxocephalid amphipods between impact and control sites.

Classification of Benthic Assemblages

Classification analyses discriminated differences between 5 main benthic assemblages (cluster groups A–E) in the Point Loma Region during 2006 **(Figures 5.4, 5.5)**. These assemblages differed in terms of species composition, including the specific taxa present and their relative abundances. The dominant species for each assemblage are listed in **Table 5.4**. Additionally, a MDS ordination of the survey entities confirmed the validity of the major cluster groups (Figure 5.4).

Cluster group A comprised the assemblage from the July survey of E14, located nearest the PLOO discharge. The spionid polychaete *Prionospio jubata* was the dominant species characterizing this assemblage. The next 2 most abundant species were the ostracod *Euphilomedes carcharodonta* and the bivalve *Axinopsida serricata*. This assemblage had the highest mean abundance (504 per 0.1 m^2) compared to the other cluster groups. Species

Table 5.4

Summary of the most abundant taxa composing cluster groups A–E from the PLOO benthic stations surveyed in 2006. Data are expressed as mean abundance per sample (no./0.1m^2) and represent the 10 most abundant taxa in each group. Animals absent from a cluster group are indicated by a dash. The 3 most abundant taxa in each cluster group are indicated in bold type.

Species/Taxa	Higher taxa	Cluster group A (n=1)	B (n=8)	C (n=2)	D (n=29)	E (n=4)
Ampelisca brevisimulata	Crustacea: Amphipoda	0.5	1.1	3.8	1.0	0.3
Ampelisca careyi	Crustacea: Amphipoda	0.5	4.4	4.0	1.5	3.0
Amphiodia sp	Echinodermata: Ophiuroidea	1.5	2.8	**25.5**	6.7	5.8
Amphiodia urtica	Echinodermata: Ophiuroidea	5.0	6.5	**59.5**	**22.3**	**18.6**
Amphiuridae	Echinodermata: Ophiuroidea	4.5	2.7	**13.8**	8.1	4.1
Axinopsida serricata	Mollusca: Bivalvia	**21.0**	3.6	4.3	2.0	1.9
Caecum crebricinctum	Mollusca: Gastropoda	—	5.9	—	—	—
Chaetozone hartmanae	Polychaeta: Cirratulidae	13.0	7.3	2.8	8.8	9.8
Decamastus gracilis	Polychaeta: Capitellidae	13.0	4.0	0.3	3.6	1.6
Euphilomedes carcharodonta	Crustacea: Ostracoda	**27.5**	5.5	5.8	**14.5**	5.1
Euphilomedes producta	Crustacea: Ostracoda	16.5	**21.4**	0.5	9.5	**26.1**
Glycera nana	Polychaeta: Glyceridae	18.5	5.6	5.0	4.5	5.3
Lanassa venusta venusta	Polychaeta: Terebellidae	—	3.1	3.5	4.2	7.3
Mediomastus sp	Polychaeta: Capitellidae	17.5	**13.4**	2.8	11.5	**21.4**
Nuculana elenensis	Mollusca: Bivalvia	13.5	0.9	2.0	2.1	1.0
Paradiopatra parva	Polychaeta: Onuphidae	4.5	10.6	5.0	6.8	9.6
Paraprionospio pinnata	Polychaeta: Spionidae	6.5	6.1	3.0	5.2	5.5
Parvilucina tenuisculpta	Mollusca: Bivalvia	19.0	1.6	0.3	0.9	0.3
Phisidia sanctaemariae	Polychaeta: Terebellidae	0.5	5.5	3.3	8.7	13.8
Prionospio dubia	Polychaeta: Spionidae	5.0	4.5	3.0	3.6	6.0
Prionospio jubata	Polychaeta: Spionidae	**41.5**	**19.6**	3.5	**21.2**	15.3
Proclea sp A	Polychaeta: Terebellidae	—	1.8	12.8	9.8	5.8
Spiophanes berkeleyorum	Polychaeta: Spionidae	4.5	7.3	0.8	5.9	4.3
Spiophanes duplex	Polychaeta: Spionidae	8.0	12.9	2.0	7.7	6.0
Spiophanes kimballi	Polychaeta: Spionidae	5.0	5.1	2.3	4.5	10.0

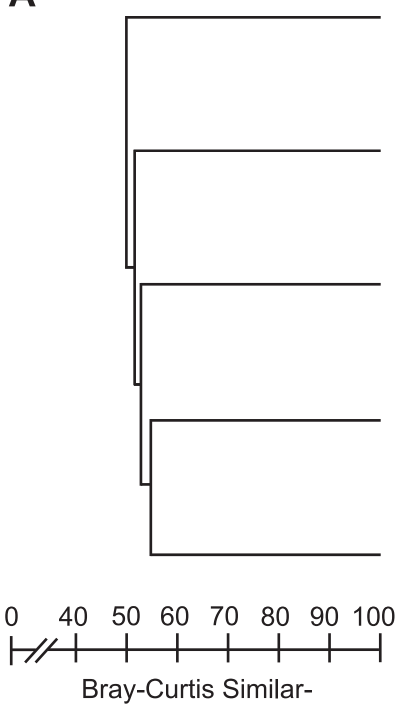
richness averaged 107 taxa per 0.1 m^2. Sediments at this site were mixed with 37% fine particles and 50% coarse materials including some coarse black sand, shell hash, and pebbles (see appendix B.2). Total organic carbon (TOC) concentration was 0.7%.

Cluster group B included animals from 3 northern reference stations and 1 southern station. The dominant species in this assemblage included the ostracod *Euphilomedes producta, P. jubata*, and the capitellid polychaete *Mediomastus* sp. Species richness was relatively high (129 species per 0.1 m^2) while abundance averaged 420 individuals. Sediments associated with this group contained 36% fine particles. The mean TOC value (2.1%) for this cluster group was higher than those from the other cluster groups.

Cluster group C represented animals from the southern station E1, along the 88-m contour. Dominant taxa included ophiuroids (*Amphiodia urtica*, *Amphiodia* sp, and Amphiuridae) and the terebellid polychaete *Proclea* sp A. This assemblage averaged 293 individuals and 89 species per 0.1 m^2. Sediments at E1 were mixed, composed of 44% fines, and coarse sands with some shell hash and gravel. TOC at stations within this group averaged 0.7%.

Cluster group D encompassed the largest assemblage in 2006, comprising animals collected

A



	CG	Abun	SR	%Fines	TOC	
●	A	504	107	37	0.7	*Prionospio jubata* *Euphilomedes carcharodonta* *Axionopsida serricata*
●	B	420	129	36	2.1	*Euphilomedes producta* *Prionospio jubata* *Mediomastus* sp
●	C	293	89	44	0.7	*Amphiodia urtica* *Amphiodia* sp, Amphiuridae *Proclea* sp A
●	D	336	96	38	0.7	*Amphiodia urtica* *Prionospio jubata* *Euphilomedes carcharodonta*
●	E	402	117	50	1.2	*Euphilomedes producta* *Mediomastus* sp *Amphiodia urtica*

B

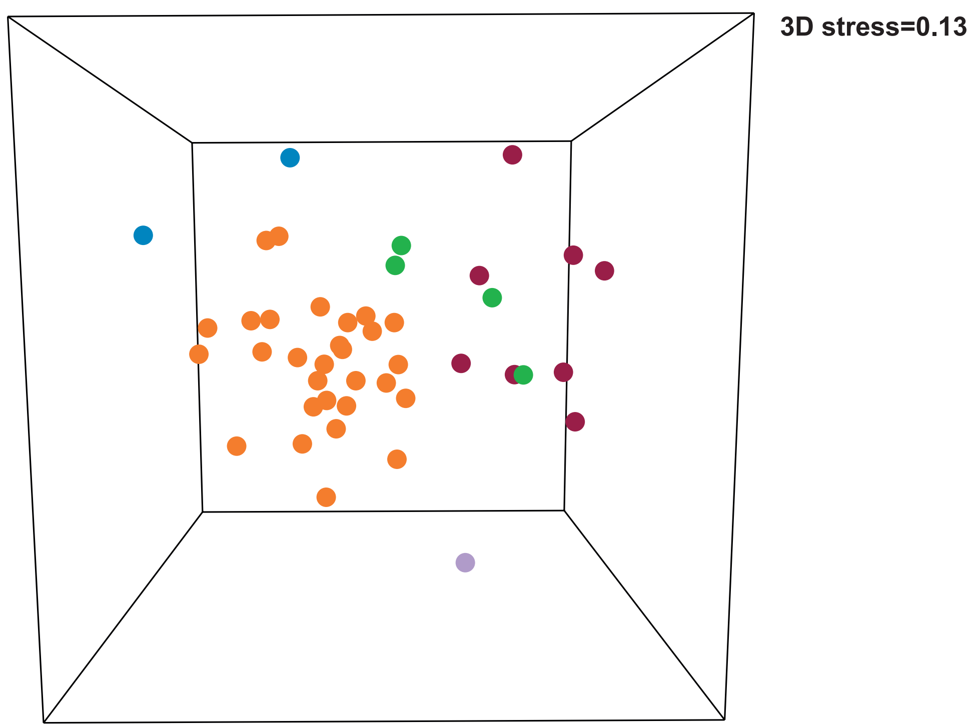


Figure 5.4

(A) Cluster results of the macrofaunal abundance data for the PLOO benthic stations sampled during 2006. Data are expressed as mean values per 0.1 m² grab over all stations in each group. CG=cluster group; SR=number of species; Abun=number of individuals. Ranges in parentheses are for individual grab samples. **(B)** MDS ordination of PLOO benthic stations sampled during 2006. 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 major faunal assemblages.

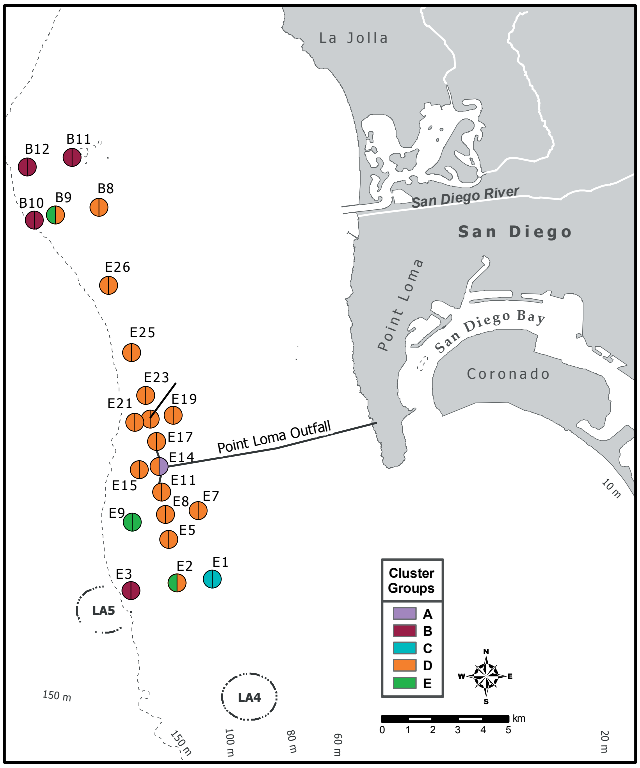


Figure 5.5

Summary of ordination and classification analyses results for macrofaunal abundance data during 2006. Cluster groups are color-coded on the map to reveal spatial patterns in the distribution of benthic assemblages.

from 66% of the samples from 16 stations. The dominant species in this group were *A. urtica*, *P. jubata*, and *E. carcharodonta*. Infauna averaged 336 individuals and 96 species per 0.1 m^2, the second lowest among all cluster groups. The January survey of station E14 was included in this group The sediments collected with this assemblage were characterized by silty sand with 38% fines and 0.7% TOC.

Cluster group E included animals collected from 3 sites primarily located along the 98 and 116-m depth contours. The numerically dominant species in this group were *E. carcharodonta*, *Mediomastus* sp, and *A. urtica*. This assemblage averaged 402 individuals and 117 taxa per 0.1 m^2. The stations associated with this assemblage had the highest percentage of fines (50%), and the second highest TOC (1.2%).

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, 2006a). Ophiuroids and polychaetes continue to be the most abundant and diverse infauna in the region. Although many of the 2006 assemblages were dominated by similar species, the relative abundance of these species varied between sites. In contrast to 2004 and 2005, the oweniid polychaete *Myriochele striolata* was not among the most abundant or widespread invertebrates in the PLOO region. Instead, the brittle star *Amphiodia urtica* (adults and juveniles combined) was the most abundant and widespread taxon. The Spionid polychaete *Prionospio jubata* was the second most widespread benthic invertebrate in the region, being dominant or co-dominant in most assemblages. 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, 2006a). In addition, values for these parameters in 2006 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 abundance during the post-discharge period (see City of San Diego 1995, 2006a). The increase in species has been most pronounced near the outfall, which suggests that significant environmental degradation has not occurred in the region. In addition, the observed decreases in abundance at most stations in 2006 were not accompanied by changes in dominance, a pattern inconsistent with predicted pollution effects. Whatever the cause of such changes, benthic communities around the PLOO are not dominated by a few pollution tolerant species. For example, the opportunistic polychaete *Capitella capitata*, which is often associated with degraded soft bottom habitats, continues to occur only in low numbers off Point Loma. A total of 16 individual *C. capitata* were collected off Point Loma in 2006, with 6 occurring at the 3 stations nearest the PLOO (E17, E14, E11). In contrast, this species can reach densities >500 individuals per 0.1 m^2 and constitute as much as 85% of the total abundance in heavily polluted sediments (Swartz et al. 1986).

A few changes near the outfall suggest some effects are coincident with anthropogenic activities. Benthic response index (BRI) values are higher at stations nearest the outfall (E17, E14, E11) than at other sites in the region In addition, increased values of the BRI at station E14 after discharge began may be considered indicative of organic enrichment or some other type of disturbance. However, BRI values at all sites remain characteristic of undisturbed areas (see City of San Diego 1995, 2006a). The increased variability in number of species and infaunal abundance at 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. For example, since 1997, 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 a decrease in numbers of ophiuroids near the outfall and a corresponding increase at the control sites during the post-discharge period. These differences have decreased over the past 2 years. Although long term changes in *Amphiodia* populations at E14 may likely be related to organic enrichment, altered sediment composition, or some other factor, abundances for the Point Loma region are still within the range of those occurring naturally in the SCB. In addition, natural population fluctuations of these and other resident organisms (e.g. *Myriochele striolata* and *Proclea* sp A) are common off San Diego (Zmarzly et al. 1994, Diener et al. 1995). Further complicating the picture, stable patterns in populations of pollution sensitive amphipods (i.e., *Rhepoxynius*, *Ampelisca*) and a limited presence of a pollution tolerant species (e.g., *C. capitata*) do not offer evidence of strong 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 nearest the discharge site (e.g., station E14). Because of the minimal extent of these changes, it has not been possible to determine whether observed effects are due to habitat alteration related to the physical structure of the outfall pipe, organic enrichment, or another related factor. 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 and secondary treated sewage may 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.

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