Chapter 5. Macrobenthic Communities

INTRODUCTION

Benthic macroinvertebrates along the coastal shelf of southern California represent a diverse faunal community that is important to the marine ecosystem (Fauchald and Jones 1979, Thompson et al. 1993a, Bergen et al. 2001). These animals serve vital functions in wide ranging capacities. Some species decompose organic material as a crucial step in nutrient cycling, other species filter suspended particles from the water column, thus affecting water clarity. Many species of benthic macrofauna also are essential prey for fish and other organisms.

Human activities that impact the benthos can sometimes result in toxic contamination, oxygen depletion, nutrient loading, or other forms of environmental degradation. Certain macrofaunal species are sensitive to such changes and rarely occur in impacted areas, while others are opportunistic and can thrive under altered conditions. Because various species respond differently to environmental stress, monitoring macrobenthic assemblages can help to identify anthropogenic impacts (Pearson and Rosenberg 1978, Bilyard 1987, Warwick 1993, Smith et al. 2001). Also, since the animals in these assemblages are relatively stationary and long-lived, they can integrate local environmental conditions (Gray 1979). Consequently, the assessment of benthic community structure is a major component of many marine monitoring programs, which are often designed to document both existing conditions and trends over time.

Overall, the structure of benthic communities may be influenced by many factors including depth, sediment composition and quality (e.g., grain size distribution, contaminant concentrations), oceanographic conditions (e.g., temperature, salinity, dissolved oxygen, ocean currents), and biological factors (e.g., food availability, competition, predation). For example, benthic assemblages on the coastal shelf off San Diego typically vary along sediment particle size and/or depth gradients. Therefore, in order to determine whether changes in community structure are related to human impacts or to natural events, it is necessary to have an understanding of background or reference conditions for an area. Such information is available for the monitoring area surrounding the Point Loma Ocean Outfall (PLOO) and the San Diego region in general (e.g., see City of San Diego 1999, 2007b).

This chapter presents analyses and interpretations of the macrofaunal data collected at fixed stations surrounding the PLOO during 2007. Descriptions and comparisons of the different macrofaunal assemblages that inhabit soft bottom habitats in the region and analysis of benthic community structure are included.

MATERIALS AND METHODS

Collection and Processing of Samples

Benthic samples were collected during January and July 2007 at 22 stations surrounding the PLOO (**Figure 5.1**). These stations are located along the 88, 98, and 116-m depth contours and range from about 8 km south to 11 km north of the outfall.

Samples for benthic community analyses were collected from two replicate 0.1-m^2 van Veen grabs per station during the 2007 surveys. An additional grab was collected at each station for sediment quality analysis (see Chapter 4). The criteria to ensure consistency of grab samples established by the United States Environmental Protection Agency (USEPA) 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 collected and 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 fresh water and transferred to 70% ethanol. All animals were sorted

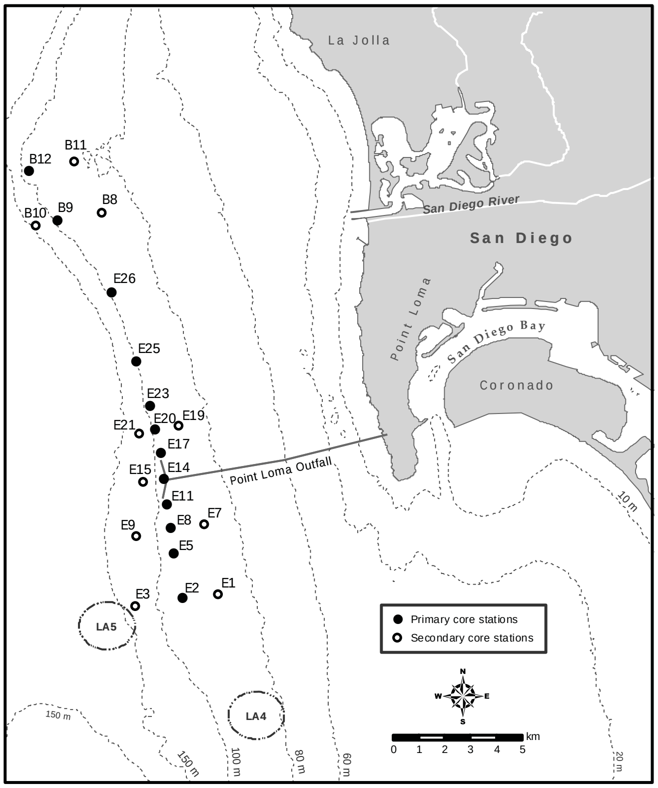


Figure 5.1
Benthic station locations, Point Loma Ocean Outfall Monitoring Program.

from the debris into major taxonomic groups by a subcontractor and then identified to species or the lowest taxon possible and enumerated by City of San Diego marine biologists.

Data Analyses

The following community structure parameters were calculated for each station per 0.1-m^2 grab: species richness (number of species), abundance (total number of individuals), Shannon diversity index (H'), Pielou's evenness index (J'), Swartz dominance (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). Additionally, the total or cumulative number of species over all grabs was calculated for each station.

Multivariate analyses were performed using PRIMER 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). The macrofaunal abundance data were square-root transformed and the Bray-Curtis measure of similarity was used as the basis for both classification and ordination. SIMPER analysis was used to identify individual species that typified each cluster group. Patterns in the distribution of macrofaunal assemblages were compared to environmental variables by overlaying the physico-chemical data onto MDS plots based on the biotic data (see Field et al. 1982).

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 PLOO (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 2007) 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 13.5 years (47 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, 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, BRI) and abundances of three 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

Species richness

A total of 565 macrofaunal taxa were identified during the 2007 PLOO surveys. Mean values of species richness ranged from 65 to 114 species per 0.1 m^2 (**Table 5.1**). Stations B11, B10 and E3 were characterized by the most species, averaging 100–114 species per grab. This pattern is consistent with previous species richness values for these sites (e.g., City of San Diego 2006, 2007a) In contrast, the lowest species richness was found at stations B8 and E21, which averaged 65 and 71 species per sample, respectively. In addition, species richness at more than half of the stations showed a general decrease compared to 2006 (see City of San Diego 2007a).

Macrofaunal abundance

Macrofaunal abundance averaged 207–410 animals B11, E1 and E25 were also relatively high, averaging 325–334 animals per sample. The fewest animals (<225 per 0.1 m^2) were collected at stations B8, B9, E21 and E23. The remaining sites had abundances ranging from 233 to 316 animals per grab. Overall, there was a 21% decrease in macrofaunal abundance at the PLOO sites between 2006 and 2007, with the largest difference occurring at station B12 (see City of San Diego 2007a). This site averaged 504 and 289 individuals per grab in 2006 and 2007, respectively.

Species diversity, dominance, and evenness

Species diversity (H') ranged from 3.4 to 4.2 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' ≥4.1) occurred at the northern stations B10 and B11, while the lowest diversity (H' ≤3.5) occurred at stations E1 and B8.

Dominance was expressed as the Swartz 75% dominance index, which equals the minimum number of species comprising 75% of a community by abundance. Therefore, lower index values (i.e., fewer species) indicate higher numerical dominance. Benthic assemblages in 2007 were characterized by relatively high numbers of evenly distributed species with index values averaging 32 species per station (Table 5.1). The lowest dominance (values ≥40) occurred at stations B10 and B11, while the highest dominance value of 23 species was seen for the assemblages at stations B8 and E1. Evenness (J') values averaged from 0.78 to 0.91 at the different stations during the year.

Environmental disturbance indices

Benthic response index (BRI) values averaged from 6 to 21 at the various PLOO stations in 2007 (Table 5.1). These values suggest that 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 (≥15) were measured at stations E11, E14, and E17 located nearest the discharge site. Mean infaunal trophic index (ITI) values ranged from 65 to 87 per station in 2007 (Table 5.1), which is similar to values reported in previous years (see City of San Diego 2006, 2007a). These relatively high ITI values (i.e., >60) 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 in 2007 (**Table 5.2**). For example, seven polychaete, two crustacean, one echinoderm, and one mollusc species were among the most dominant macroinvertebrates sampled during the year. Polychaetes were the most

Table 5.1

Summary of macrobenthic community parameters for PLOO stations sampled during 2007. SR = species richness, no. species/0.1 m^2; Tot Spp = cumulative no. species for the year; Abun = abundance, no. individuals/0.1 m^2; H' = Shannon diversity index; J' = Evenness; Dom = Swartz dominance, (see text); BRI = benthic response index; ITI = infaunal trophic index. Data are expressed as annual means (n=4).

Station	SR	Tot Spp	Abun	H'	J'	Dom	BRI	ITI
88-m contour								
B11	114	247	334	4.2	0.89	46	7	81
B8	65	127	207	3.5	0.83	23	6	87
E19	89	180	316	3.8	0.85	30	12	80
E7	88	161	311	3.9	0.86	32	9	84
E1	82	161	330	3.4	0.78	23	12	86
98-m contour								
B12	91	185	289	3.9	0.87	31	13	73
B9	80	164	221	3.9	0.90	32	8	78
E26	84	153	264	3.9	0.89	32	11	78
E25	90	167	325	3.9	0.87	31	11	76
E23	80	152	222	4.0	0.91	34	11	79
E20	84	162	233	4.0	0.90	35	13	79
E17	83	157	283	3.8	0.87	30	17	73
E14	96	181	410	3.8	0.83	29	21	65
E11	84	160	282	3.9	0.87	30	15	75
E8	81	160	248	3.9	0.89	32	10	78
E5	81	154	261	3.8	0.87	30	11	78
E2	97	186	292	4.0	0.88	36	8	83
116-m contour								
B10	100	211	289	4.1	0.89	40	12	74
E21	71	153	212	3.8	0.89	27	12	78
E15	80	158	296	3.7	0.85	26	13	77
E9	97	201	299	4.0	0.88	36	8	79
E3	100	204	295	4.0	0.87	38	7	77
All stations								
Mean	87	172	283	3.9	0.87	32	11	78
Std error	2	6	8	0.1	0.01	1	1	1
Min	65	127	207	3.4	0.78	23	6	65
Max	114	247	410	4.2	0.91	46	21	87

diverse of the major taxa, accounting for 50% of all species collected. Crustaceans accounted for 25% of the species, molluscs 14%, echinoderms 6%, and all other taxa combined for 5% of the species. Polychaetes were also the most numerous animals, accounting for 52% of the total abundance. Crustaceans accounted for 21%, echinoderms 13%, molluscs 12%, and all other phyla combined 2%. The most obvious change in benthic community structure was a decrease in polychaete abundances compared to 2006 with polychaete numbers decreasing by 5% overall. The largest decreases in polychaete abundance occurred at northern stations B8 (26%) and E23 (16%). In contrast, mollusc abundances increased throughout the region. The largest increase in mollusc populations occurred at stations B8 (16%) and E26 (12%).

The two most abundant species were the capitellid polychaete *Mediomastus* sp and the ophiuroid *Amphiodia urtica*, each averaging >20 individuals per 0.1 m^2. However, since juvenile ophiuroids usually

Table 5.2

Dominant macroinvertebrates at the PLOO benthic stations sampled during 2007. The 10 most abundant species overall, 10 most abundant species per occurrence, and the 10 most frequently collected (or widely distributed) species are included. Abundance values are expressed as mean number of individuals per 0.1 m^2.

Species	Higher taxa	Abundance per sample	Abundance per occurence	Percent occurence
Most abundant				
Mediomastus sp	Polychaeta: Capitellidae	25.1	25.1	100
Amphiodia urtica	Echinodermata: Ophiuroidea	20.2	20.2	100
Prionospio jubata	Polychaeta: Spionidae	12.0	12.0	100
Euphilomedes producta	Crustacea: Ostracoda	9.1	9.3	98
Aricidea catherinae	Polychaeta: Paraonidae	8.5	8.9	95
Amphiodia sp	Echinodermata: Ophiuroidea	8.0	8.0	100
Lumbrineris sp group I	Polychaeta: Lumbrineridae	6.4	6.9	93
Chaetozone hartmanae	Polychaeta: Cirratulidae	6.2	6.2	100
Axinopsida serricata	Mollusca: Bivalvia	6.1	6.6	93
Ampelisca pacifica	Crustacea: Amphipoda	5.7	5.7	100
Most abundant per occurence				
Mediomastus sp	Polychaeta: Capitellidae	25.1	25.1	100
Amphiodia urtica	Echinodermata: Ophiuroidea	20.2	20.2	100
Prionospio jubata	Polychaeta: Spionidae	12.0	12.0	100
Euphilomedes producta	Crustacea: Ostracoda	9.1	9.3	98
Aricidea catherinae	Polychaeta: Paraonidae	8.5	8.9	95
Amphiodia sp	Echinodermata: Ophiuroidea	8.0	8.0	100
Capitella capitata complex	Polychaeta: Capitellidae	1.5	7.6	20
Lumbrineris sp group I	Polychaeta: Lumbrineridae	6.4	6.9	93
Axinopsida serricata	Mollusca: Bivalvia	6.1	6.6	93
Chaetozone hartmanae	Polychaeta: Cirratulidae	6.2	6.2	100
Most frequently collected				
Mediomastus sp	Polychaeta: Capitellidae	25.1	25.1	100
Amphiodia urtica	Echinodermata: Ophiuroidea	20.2	20.2	100
Prionospio jubata	Polychaeta: Spionidae	12.0	12.0	100
Amphiodia sp	Echinodermata: Ophiuroidea	8.0	8.0	100
Chaetozone hartmanae	Polychaeta: Cirratulidae	6.2	6.2	100
Ampelisca pacifica	Crustacea: Amphipoda	5.7	5.7	100
Euphilomedes producta	Crustacea: Ostracoda	9.1	9.3	98
Amphiuridae	Echinodermata: Ophiuroidea	5.1	5.2	98
Sternaspis fossor	Polychaeta: Sternaspidae	3.2	3.2	98
Aricidea catherinae	Polychaeta: Paraonidae	8.5	8.9	95

cannot be identified to species and are recorded at the generic or familial level (i.e., *Amphiodia* sp or Amphiuridae, respectively), this number underestimates actual populations of *A. urtica*. If values for total *A. urtica* abundance are adjusted to include these unidentified individuals, the estimated density of this species increases to 28 per grab sample, similar to that observed in 2006.

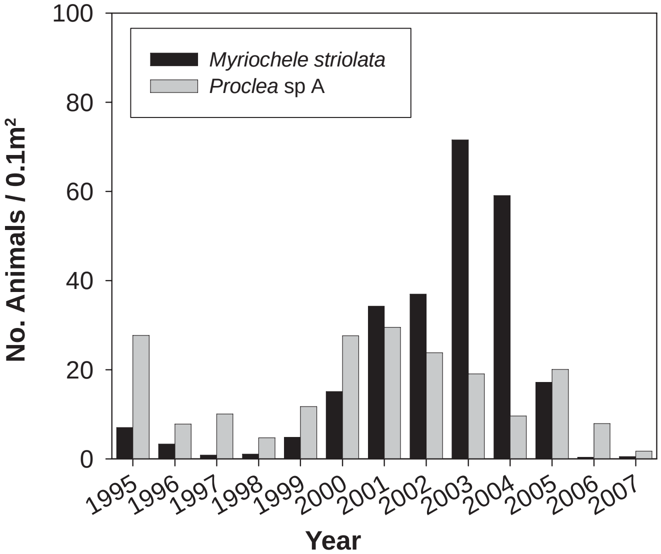


Figure 5.2
Average abundance of the polychaetes, *Myriochele striolata* and *Proclea* sp A at PLOO benthic stations from 1995–2007.

Many of the abundant species in 2007 were also dominant prior to discharge and ever since (e.g., City of San Diego 1995, 1999, 2006, 2007a). For example, *Amphiodia 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 such as the oweniid *Myriochele striolata* and the terebellid *Proclea* sp A have been more cyclical (**Figure 5.2**). For instance, both of these species were among the most abundant polychaetes between 1999–2005, while their densities have decreased during the last two years to levels similar to those observed in 1996–1998. Such variation can have significant effects on other descriptive statistics (e.g., dominance, diversity, and abundance) or 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 impact site E14 and both control (reference) sites since the onset of wastewater discharge from the PLOO (**Table 5.3**). There was also a net change in infaunal 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**). Differences in *Amphiodia* populations reflect a decrease in the number of these ophiuroids collected at E14 and a general increase at the control stations until about 2001 (Figure 5.3E). *Amphiodia urtica* densities at station E14 in 2007 were higher than in 2006 but remain similar to the low densities that have occurred since 1999. While densities of this brittle star have declined in recent years at both control sites, they are more similar to pre-discharge values than densities near the outfall. Differences in the BRI generally are due to increased index values at station E14 since 1994 (Figure 5.3C). These higher BRI values may be explained in part by the lower numbers of *Amphiodia*. 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

Table 5.3
Results of BACIP t-tests for number of species (SR), infaunal abundance, benthic response index (BRI), and the abundance of several representative taxa around the PLOO (1991–2007). 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 2007 (n = 47). Critical t value = 1.680 for $\alpha = 0.05$ (one-tailed t-tests, df = 55). ns = not significant .

Variable	Control vs Impact	t	p
SR	E26 v E14	-3.152	0.002
	B9 v E14	-3.671	<0.001
Abundance	E26 v E14	-1.415	ns
	B9 v E14	-2.712	0.004
BRI	E26 v E14	-3.775	<0.001
	B9 v E14	-2.239	<0.001
Amphiodia spp	E26 v E14	-7.381	<0.001
	B9 v E14	-5.004	<0.001
Ampelisca spp	E26 v E14	-1.598	ns
	B9 v E14	-0.041	ns
Rhepoxynius spp	E26 v E14	-0.830	ns
	B9 v E14	-0.922	ns

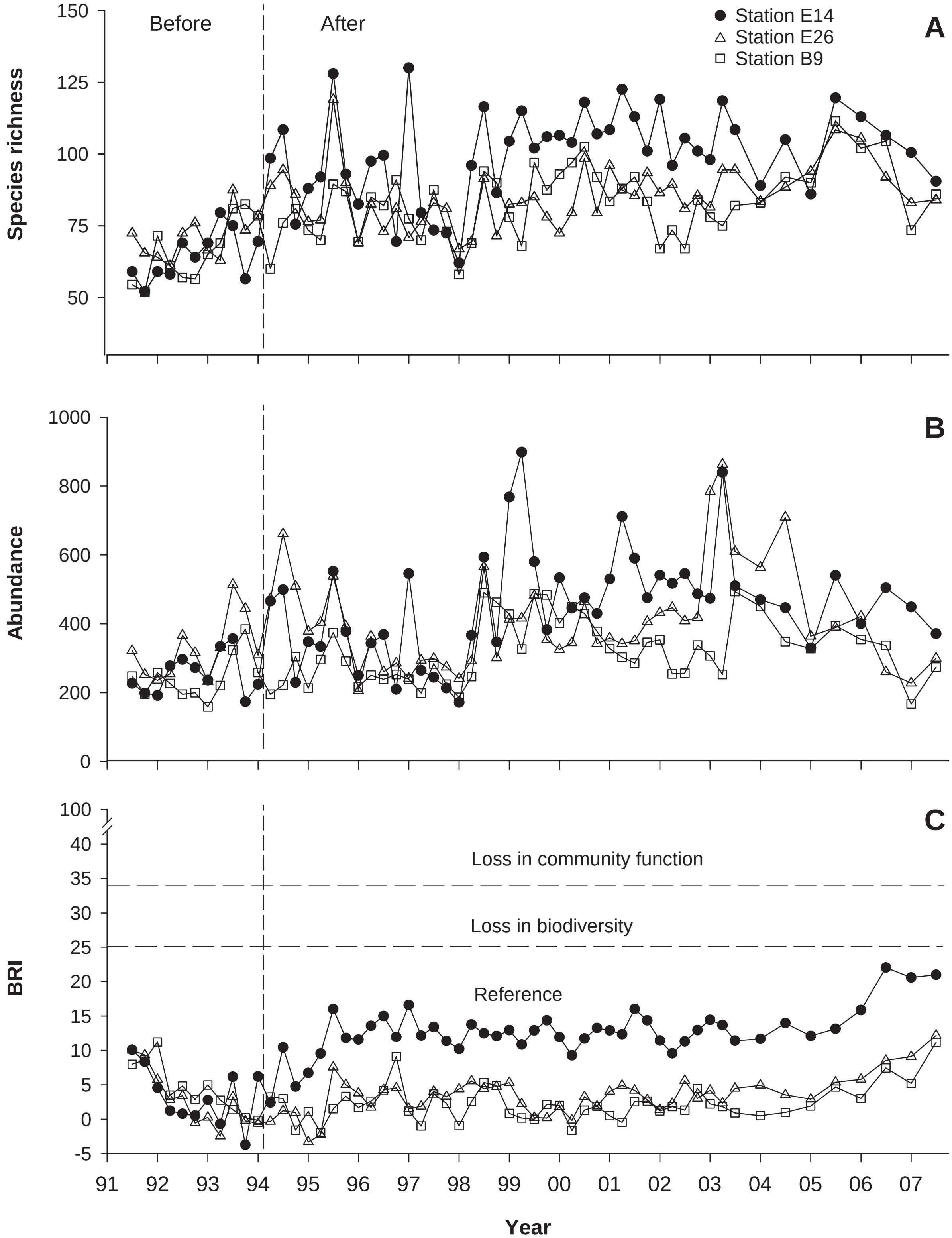


Figure 5.3

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 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).

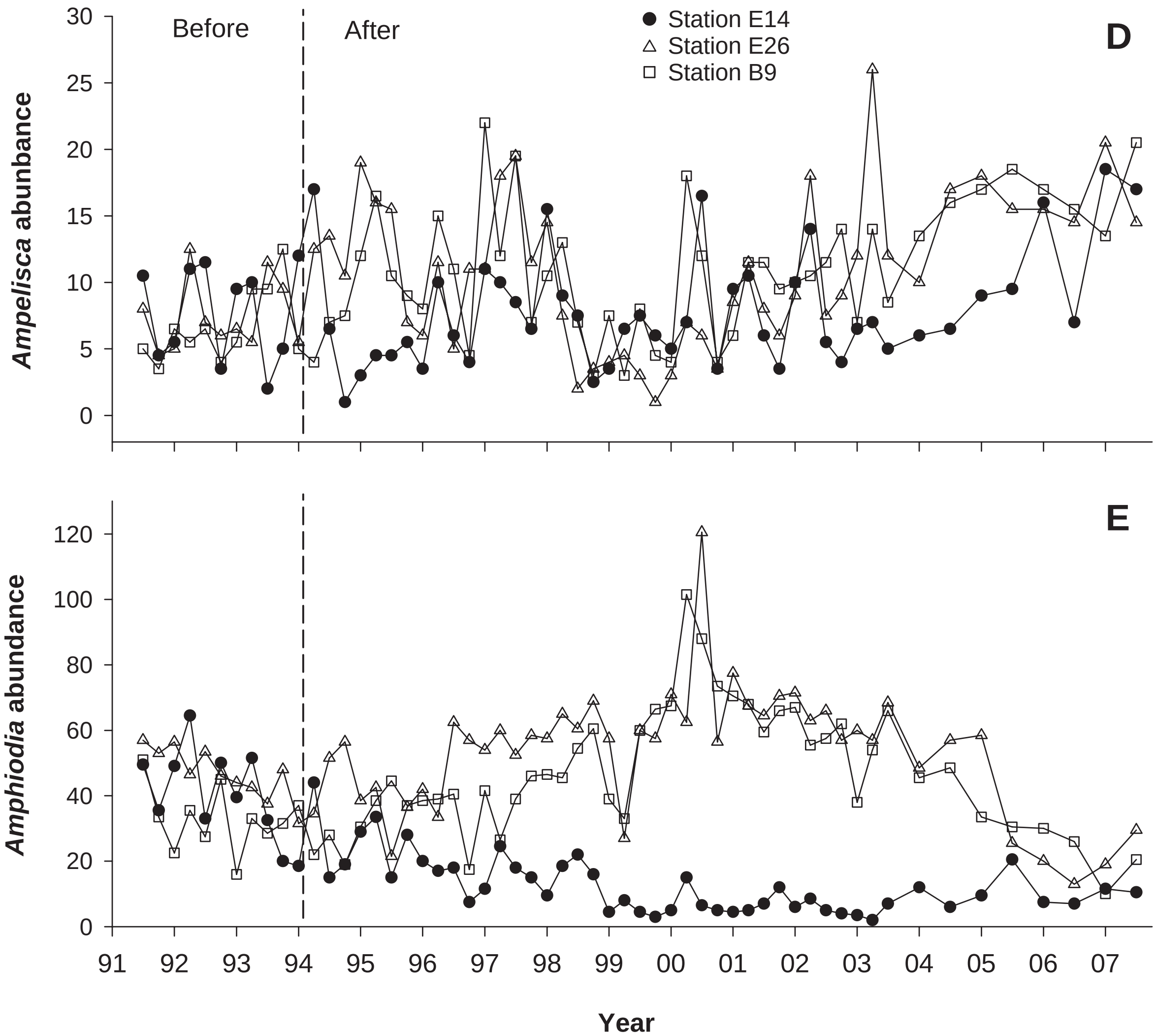


Figure 5.3 *Continued*

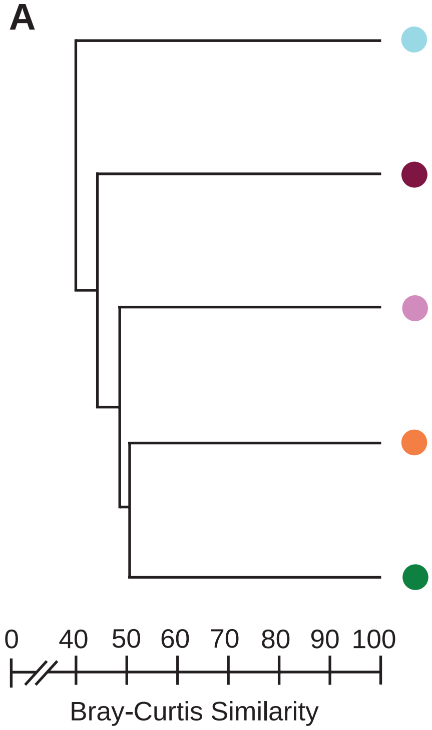
control site (E26). Finally, no significant changes in the difference in mean abundances of ampeliscid or phoxocephalid amphipods at the impact and control sites have occurred since discharge began (Figure 5.3D, Table 5.3).

Classification of Benthic Assemblages

Classification analyses discriminated differences between five main benthic assemblages (cluster groups A–E) in the Point Loma region during 2007 **(Figures 5.4, 5.5)**. These assemblages differed in terms of species composition, including the specific taxa present and their relative abundances. SIMPER analysis was used to identify species that were characteristic, though not always the most abundant, within each assemblage (Figure 5.4A). The numerically dominant species for each assemblage are listed in **Table 5.4**. Additionally, MDS ordination results confirmed the validity of the major cluster groups (Figure 5.4B).

Cluster group A comprised the assemblage from the January survey of B11, located farthest to the north from the PLOO discharge site. The ophiuroid *Amphiodia urtica* was the dominant species characterizing this assemblage. The next two characteristic species were the bivalve *Adontorhina cyclia* and the cirratulid polychaete *Chaetozone hartmanae*. This assemblage had the lowest mean abundance (246 per 0.1 m^2) compared to the other cluster groups. Species richness averaged 99 taxa per grab. Sediments at this site were mixed with 45% fine particles and with coarse materials

A



CG	Abun	SR	%Fines	TOC	Dominant Taxa
A	246	99	45	3.5	*Amphiodia urtica* *Adontorhina cyclia* *Chaetozone hartmanae*
B	292	95	35	2.2	*Mediomastus* sp *Euphilomedes producta* *Prionospio jubata*
C	289	100	30	1.4	*Mediomastus* sp *Chaetozone hartmanae* *Prionospio jubata*
D	321	104	52	1.4	*Mediomastus* sp *Amphiodia urtica* *Prionospio jubata*
E	276	82	39	0.7	*Amphiodia urtica* *Mediomastus* sp *Prionospio jubata*

B

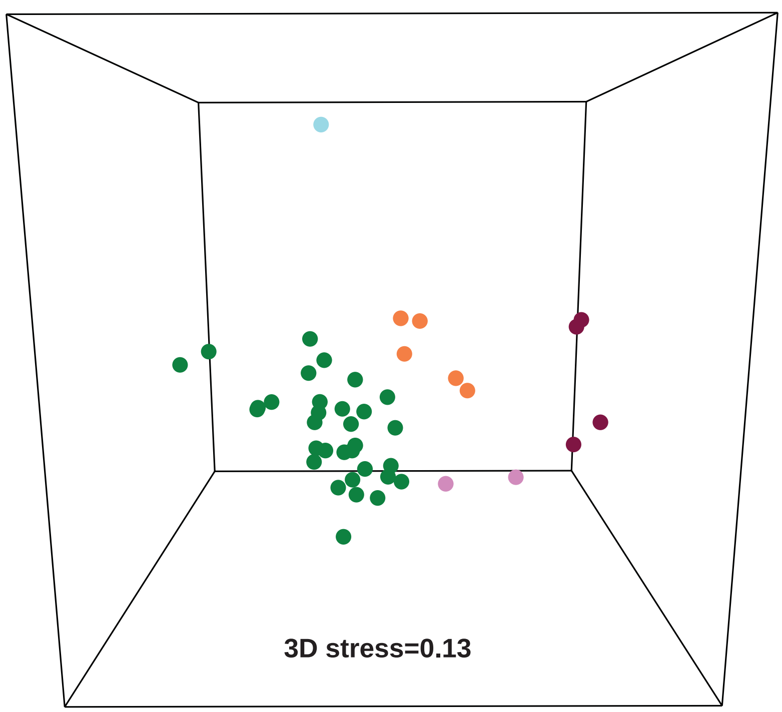


Figure 5.4

(A) Cluster results of the macrofaunal abundance data for the PLOO benthic stations sampled during winter and summer 2007. Data for infaunal abundance (Abun), species richness (SR), percent fines, and total organic carbon (TOC) are expressed as mean values per 0.1-m^2 grab over all stations in each group. (B) MDS ordination 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.

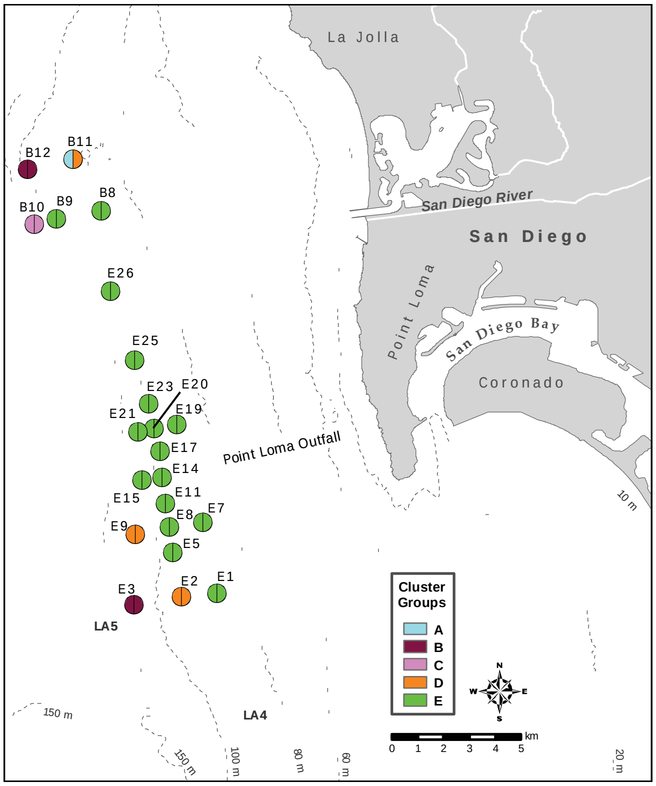


Figure 5.5

Distribution of macrobenthic assemblages off Point Loma delineated by ordination and classification analyses.

including some small rocks and shell hash. Total organic carbon (TOC) concentration was 3.5%, the highest among all cluster groups.

Cluster group B included animals from one northern reference site (station B12) and one site located south of the PLOO (station E3). Dominant species in this assemblage included the capitellid polychaete *Mediomastus* sp, the ostracod *Euphilomedes producta*, and the spionid polychaete *Prionospio jubata*. Species richness was 95 species per 0.1 m^2, while abundance averaged 292 individuals per grab. Sediments associated with this group contained 35% fine particles. The mean TOC value of 2.2% for the sites in this group was the second highest among the cluster groups.

Cluster group C represented animals from northern station B10 located along the 116-m contour. Dominant taxa included *Mediomastus* sp, *Chaetozone hartmanae* and *Prionospio jubata*. This assemblage averaged 289 individuals and 100 species per 0.1 m^2. Sediments at station B10 were mixed, composed of 30% fines with some shell hash and small rocks. TOC levels at stations within this group averaged 1.4%.

Cluster group D included animals collected from three widely dispersed sites. These included assemblages from the July survey of northern station B11 located along the 88-m contour, and both surveys from stations E2 (98 m) and E9 (116 m) located south of the PLOO. The numerically dominant species in this group were *Mediomastus* sp, *Amphiodia urtica*, and *Prionospio jubata*. This assemblage averaged 321 individuals and 104 taxa per 0.1 m^2. The stations associated with this assemblage had the highest percentage of fines (52%), while TOC concentrations averaged 1.4% similar to group C.

Cluster group E represented the most wide-spread assemblage in 2007, comprising animals from 66% of the samples and 16 stations. The dominant species in this group were *Amphiodia urtica*, *Mediomastus* sp, and *Prionospio jubata*. Average abundance for this was group was 276 individuals per 0.1 m^2, which was lower than for most other assemblages. Only cluster group A, which represented samples from only one station during a single survey (station B11) averaged fewer animals. Group E also had the lowest species richness of all groups, averaging just 82 species per grab. The sediments associated with this assemblage were characterized by silty sand with 39% fines. TOC averaged 0.7%, which was the lowest of all groups.

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, 1999, 2007b). Polychaetes and ophiuroids continue to be the most abundant and diverse infauna in the region. Although many of the 2007 assemblages were dominated by similar species, the relative abundance of these species varied among sites. In contrast to 2004 and 2005 but similar to 2006, the oweniid polychaete *Myriochele*

Table 5.4

Summary of the most abundant taxa composing cluster groups A–E from the 2007 surveys of PLOO benthic stations. Data are expressed as mean abundance per sample (no./0.1 m^2) and represent the most abundant taxa in each group. Values for the three most abundant species in each cluster group are in bold, n=number of station/survey entities per cluster group.

Species/Taxa	Higher taxa	Cluster group A (n=1)	B (n=4)	C (n=2)	D (n=5)	E (n=32)
Adontorhina cyclia	Mollusca: Bivalvia	**11.5**	0.3	5.8	5.9	4.3
Ampelisca careyi	Crustacea: Amphipoda	1.5	5.5	4.3	3.2	1.4
Ampelisca pacifica	Crustacea: Amphipoda	3.0	3.0	4.5	7.1	6.0
Amphiodia digitata	Echinodermata: Ophiuroidea	—	5.4	1.3	2.0	0.2
Amphiodia sp	Echinodermata: Ophiuroidea	4.5	2.1	2.0	8.5	9.2
Amphiodia urtica	Echinodermata: Ophiuroidea	**19.0**	1.5	3.0	**22.9**	**23.2**
Aphelochaeta monilaris	Polychaeta: Cirratulidae	—	0.8	10.5	1.2	1.8
Aricidea catherinae	Polychaeta: Paraonidae	—	5.0	8.3	6.8	9.5
Axinopsida serricata	Mollusca: Bivalvia	8.0	0.8	1.8	4.8	7.2
Caecum crebricinctum	Mollusca: Gastropoda	—	7.3	—	—	—
Chaetozone hartmanae	Polychaeta: Cirratulidae	**10.5**	1.9	**13.0**	4.9	6.4
Decamastus gracilis	Polychaeta: Capitellidae	—	6.6	9.0	3.0	4.3
Euphilomedes carcharodonta	Crustacea: Ostracoda	0.5	1.8	2.0	3.1	6.3
Euphilomedes producta	Crustacea: Ostracoda	3.5	**17.3**	9.8	12.2	7.7
Exogone lourei	Polychaeta: Syllidae	1.0	6.8	—	1.0	—
Glycera nana	Polychaeta: Glyceridae	4.5	4.5	2.3	4.3	3.1
Lumbrineris cruzensis	Polychaeta: Lumbrineridae	1.5	2.4	3.3	6.5	4.5
Lumbrineris sp group I	Polychaeta: Lumbrineridae	—	2.3	0.3	5.9	7.6
Mediomastus sp	Polychaeta: Capitellidae	1.0	**32.0**	**27.8**	**27.2**	**24.5**
Monticellina siblina	Polychaeta: Cirratulidae	—	5.8	1.5	0.9	1.3
Parvilucina tenuisculpta	Mollusca: Bivalvia	—	0.4	6.3	0.2	1.5
Pholoides asperus	Polychaeta: Pholoidae	6.0	0.6	0.5	0.6	—
Phoronis sp	Phoronida: Phoronidae	7.0	0.3	0.3	0.9	0.2
Piromis sp A	Polychaeta: Flabelligeridae	5.0	—	0.3	0.4	—
Prionospio dubia	Polychaeta: Spionidae	2.5	5.5	2.3	8.5	2.7
Prionospio jubata	Polychaeta: Spionidae	4.5	**21.4**	**11.8**	**13.2**	**10.9**
Sternaspis fossor	Polychaeta: Sternaspidae	1.5	1.6	7.0	2.1	3.3

striolata was not among the most abundant or widespread invertebrates in the region. Instead, the brittle star *Amphiodia urtica* was the most abundant and widespread taxon. The capitellid polychaete *Mediomastus* sp was the second most widespread benthic invertebrate, being dominant in four of the five main 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, 1993a), 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 from year to year in terms of the number of species, number of individuals, and dominance (e.g., City of San Diego 1995, 1999, 2007b). In addition, values for these parameters in 2007 were similar to those described for other sites throughout the SCB (e.g., Thompson et al. 1993b, Bergen et al. 1998, 2000, 2001, Ranasinghe et al. 2003, 2007). In spite of this overall stability, there has been some increase in the number of species and macrofaunal abundance during the post-discharge period (see City of San Diego 1995, 1999, 2007b).

The increase in species has also occurred near the outfall, which suggests that substantial environmental degradation has not occurred there. In addition, the recent observed decreases in abundance at most stations in 2006 and 2007 were not accompanied by changes in dominance, a pattern inconsistent with predicted pollution effects. Further, 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 in relatively low numbers off Point Loma. A total of 136 individual *C. capitata* were collected off Point Loma in 2007, with 129 occurring at several stations located nearest the PLOO discharge site (i.e., E11, E14 and E17). Densities of this polychaete at these three sites averaged 16 individuals per 0.1 m^2. In contrast, populations of *C. capitata* typically exceed densities of 500 individuals per 0.1 m^2 and constitute as much as 85% of the total abundance in polluted sediments (Swartz et al. 1986).

A few changes near the outfall suggest some effects are coincident with anthropogenic activities. BRI values are higher at stations nearest the outfall (E11, E14, E17) than at other sites in the region (see City of San Diego 2007b). In addition, increases in BRI that occurred at station E14 after discharge began may be considered indicative of organic enrichment or some other type of disturbance. However, BRI values at this and all other sites remain characteristic of undisturbed areas (see City of San Diego 1995, 2007b). 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). There has been some change in sediments at E14 since construction of the PLOO (see City of San Diego 2007b). This suggest that changes in community structure near the PLOO could be related to localized physical disturbance 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 nearest the outfall (i.e., station E14) and those present at reference sites. This difference is mostly due to a decrease in numbers of ophiuroids near station E14 and a concomitant increase at reference areas during the post-discharge period. However, these differences have decreased over the past three 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 in general are still within the range of those occurring naturally in the SCB. In addition, natural population fluctuations of these and other resident species (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., *Ampelisca*, *Rhepoxynius*) and a limited presence of a pollution tolerant species (e.g., *Capitella capitata*) do not offer evidence of significant 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. 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 a combination of factors. 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 Point Loma 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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