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 (Snelgrove et al. 1997). For example, 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 persist under altered conditions (Gray 1979). Because various species respond differently to environmental stress, monitoring macrobenthic assemblages can help to identify anthropogenic impact (Pearson and Rosenberg 1978, Bilyard 1987, Warwick 1993, Smith et al. 2001). Also, since many animals in these assemblages are relatively stationary and long-lived, they can integrate local environmental conditions (Hartley 1982, Bilyard 1987). 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 of southern California typically vary along sediment particle size and/or depth gradients (Bergen et al. 2001). Therefore, in order to determine whether changes in community structure are related to human impacts, 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, 2008; Ranasinghe et al. 2003, 2007).

This chapter presents analyses and interpretations of the macrofaunal data collected at fixed stations surrounding the PLOO during 2008. 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 at 22 benthic stations in the PLOO region during 2008 located along the 88, 98, or 116-m depth contours (Figure 5.1). These sites included 17 "E" stations located from approximately 5 km south to 8 km north of the outfall, and five "B" stations located about 11 km or further north of the outfall. All 22 stations were sampled during the January 2008 survey, while the following July 2008 sampling was limited to 12 "primary core" stations along the 98-m contour to accommodate additional sampling for the Bight'08 regional project (see Chapter 1). The four stations considered to represent "nearfield" conditions herein (i.e., E11, E14, E15, E17) are located between about 100 and 750 m of the outfall wye or diffuser legs.

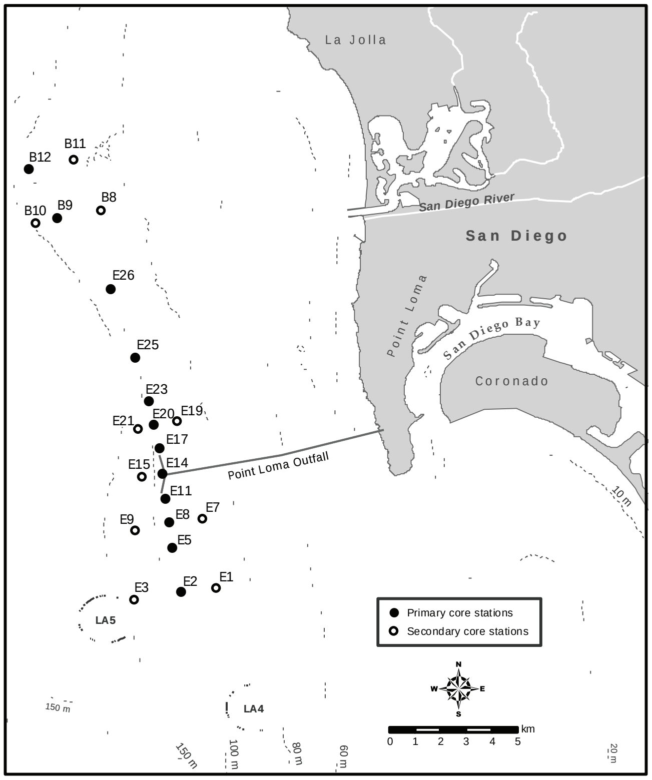


Figure 5.1
Benthic station locations, Point Loma Ocean Outfall Monitoring Program.

Samples for benthic community analyses were collected from two replicate 0.1-m^2 van Veen grabs per station during each survey. 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 (U.S. EPA) were followed with regard to sample disturbance and depth of penetration (U.S. EPA 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 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 (number of individuals), Shannon diversity index (H'), Pielou's evenness index (J'), Swartz dominance (see Swartz et al. 1986, Ferraro et al. 1994), benthic response index (BRI; see Smith et al. 2001), and infaunal trophic index (ITI; see Word 1980). 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 (Clarke 1993, Warwick 1993, Clarke and Gorley 2006). 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 classification. SIMPROF (similarity profile) analysis was used to confirm non-random structure of the dendrogram (Clarke et al. 2008). SIMPER (similarity percentages) analysis was used to identify individual species that typified each cluster group.

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 compares differences between control (reference) and impact sites at times before (i.e., July 1991–October 1993) and after (i.e., January 1994–July 2008) 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 15 years (49 quarterly or semi-annual surveys) of after impact data. The E stations, located between about 0.1 and 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 north of 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 478 macrofaunal taxa (mostly species) were identified during the 2008 PLOO surveys. Of these, approximately 28% (n=132) represented rare taxa that were recorded only once. Mean values of species richness ranged from 61 species per 0.1 m^2 at B8 to 101 species per 0.1 m^2 at B11 (Table 5.1), which is consistent with previous values and patterns for these two northern reference sites (e.g., see City of San Diego 2008). Average values for the other 20 sites sampled during the year ranged between 70 and 90 species per grab. In addition, species richness in 8 of the 12 primary core stations showed a general decrease compared to 2007 (e.g., see City of San Diego 2008).

Macrofaunal abundance

A total of 17,270 macrofaunal individuals were counted in 2008 with mean abundance values ranging from 199 to 307 animals per 0.1 m^2 sample (Table 5.1). The largest number of animals occurred at station E19, which was the only station to average more than 300 animals per sample. The fewest animals (<212 per 0.1 m^2) were collected at stations B8 and E8, while the remaining sites had abundances ranging between 228 and 282 animals per grab. Overall, there was an 8% decrease in macrofaunal abundance at the 12 primary core stations between 2007 and 2008, with the largest difference occurring at station E14 (e.g., see City of San Diego 2008). This site averaged 410 and 237 individuals per grab in 2007 and 2008, respectively.

Species diversity, evenness, and dominance

Species diversity (H') averaged from 3.2 to 4.0 per station during 2008 (Table 5.1), which was generally similar to that seen in previous years (e.g., City of Diego 1995, 2008). The lowest diversity (H'≤3.4) continued to occur at stations E1 and B8, while most of the remaining stations (n=17) had mean H' values between 3.8 and 4.0 during the year. There were no apparent patterns relative to distance from the outfall discharge site. Evenness (J') compliments diversity, with higher J' values (on a scale of 0–1) indicating that species are more evenly distributed (i.e., not dominated by a few highly abundant species). During 2008, J' values averaged between 0.77 and 0.91 per station, with spatial patterns similar to those for diversity.

Dominance was expressed as the Swartz dominance index, which is calculated as the minimum number of species whose combined abundance accounts for 75% of the individuals in a sample (Swartz et al. 1986, Ferraro et al. 1994). Therefore, lower index values (i.e., fewer species) indicate higher numerical dominance. Benthic assemblages in 2008 were characterized by relatively high numbers of evenly distributed species with index values averaging 30 species per station (Table 5.1). The highest dominance of 20 species was seen for the assemblage at station B8, while the lowest dominance (values ≥37) occurred at stations E2 and B11. Overall, these results are similar to historical values for the PLOO region (see City of San Diego 2007).

Table 5.1

Summary of macrobenthic community parameters for PLOO stations sampled during 2008. 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. Nearfield stations in bold. Data are expressed as annual means (n=4 for primary core stations, n=2 for all others).

	Station	SR	Tot Spp	Abun	H'	J'	Dom	BRI	ITI
88-m contour	B11	101	159	274	4.0	0.87	39	10	76
	B8	61	89	212	3.2	0.78	20	8	86
	E19	81	104	307	3.6	0.83	25	13	80
	E7	81	113	262	3.6	0.82	28	10	85
	E1	76	111	282	3.4	0.77	24	10	87
*98-m contour**	B12	80	168	254	3.8	0.88	29	12	72
	B9	83	164	261	3.9	0.88	32	7	80
	E26	84	157	280	3.8	0.86	28	10	78
	E25	80	147	281	3.8	0.86	27	11	77
	E23	80	149	259	4.0	0.90	34	12	78
	E20	83	168	272	3.9	0.89	31	12	77
	E17	**81**	**165**	**262**	**3.9**	**0.88**	**29**	**19**	**72**
	E14	**70**	**139**	**237**	**3.7**	**0.88**	**25**	**23**	**67**
	E11	**77**	**142**	**228**	**3.9**	**0.90**	**32**	**15**	**77**
	E8	70	140	199	3.8	0.90	28	10	80
	E5	87	165	273	3.9	0.88	33	8	82
	E2	90	191	245	4.0	0.88	37	11	82
116-m contour	B10	80	115	243	3.9	0.90	32	15	73
	E21	78	109	230	3.9	0.89	31	10	79
	E15	**74**	**107**	**228**	**3.9**	**0.91**	**30**	**10**	**78**
	E9	85	118	245	3.9	0.87	33	13	78
	E3	83	122	254	3.8	0.87	32	12	77
All stations	Mean	80	138	254	3.8	0.87	30	12	78
	Std error	2	6	7	0.2	0.01	1	1	1
	Min	56	89	139	3.1	0.76	18	4	60
	Max	110	191	365	4.3	0.93	49	26	87

*primary core stations

Environmental disturbance indices

Benthic response index (BRI) values averaged from 7 to 23 at the various PLOO stations in 2008 (Table 5.1). This suggests 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, as well as at station B10 located about 11 km north of the outfall.

Mean infaunal trophic index (ITI) values ranged from 67 to 87 per station in 2008 (Table 5.1), which is similar to values reported in previous years. These relatively high values (i.e., ITI>60) have also been considered 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 2008 (Table 5.2). For example, seven polychaete, two echinoderm, and one mollusc taxa were among the 10 most abundant macroinvertebrates sampled during the year (Table 5.3). Polychaetes were the most diverse of the major taxa, accounting for 53% of all species collected. Crustaceans accounted for 24% of the species, molluscs 13%, echinoderms 6%, and all other taxa combined for the remaining 4%. Polychaetes were also the most numerous animals, accounting for 52% of the total abundance. Crustaceans accounted for 19% of the animals, molluscs 14%, echinoderms 13%, and the remaining phyla 2%. Overall, the above distributions were very similar to those observed in 2007 (see City of San Diego 2008).

Table 5.2

Percent composition of species and total abundance by major macrofaunal taxa (phyla) for all PLOO stations sampled during 2008. Data are expressed as annual means (n=22 stations) for the region with ranges in parentheses.

Phyla	Species (%)	Abundance (%)
Annelida (Polychaeta)	53 (41-62)	52 (20-76)
Arthropoda (Crustacea)	24 (13-30)	19 (7-32)
Mollusca	13 (4-22)	14 (3-33)
Echinodermata	6 (4-11)	13 (3-40)
Other Phyla	4 (1-7)	2 (0-5)

The two most abundant taxa were the ophiuroid *Amphiodia urtica* and the capitellid polychaete *Mediomastus* sp, averaging 22 and 17 individuals per 0.1 m^2, respectively. 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, 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 27 per grab sample, similar to that observed in 2007.

Many of the abundant species in 2008 were also dominant prior to discharge and ever since (e.g., City of San Diego 1995, 1999, 2006, 2008). For example, *A. urtica* has been among the most abundant and most commonly occurring species along the outer shelf off Point Loma since sampling began. In contrast, *Mediomastus* sp has

Table 5.3

Dominant macroinvertebrates at the PLOO benthic stations sampled during 2008. The 10 most abundant 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
Amphiodia urtica	Echinodermata: Ophiuroidea	21.5	21.5	100
Mediomastus sp	Polychaeta: Capitellidae	17.1	17.1	100
Prionospio (*Prionospio*) *jubata*	Polychaeta: Spionidae	10.6	10.6	100
Aricidea (*Acmira*) *catherinae*	Polychaeta: Paraonidae	6.7	6.7	100
Amphiodia sp	Echinodermata: Ophiuroidea	4.9	4.9	100
Tellina carpenteri	Mollusca: Bivalvia	4.3	4.3	100
Sternaspis fossor	Polychaeta: Sternapsidae	4.3	4.3	100
Aphelochaeta monilaris	Polychaeta: Cirratulidae	3.0	3.0	100
Chaetozone hartmanae	Polychaeta: Cirratulidae	4.6	4.8	97
Lumbrineris cruzensis	Polychaeta: Lumbrineridae	4.2	4.3	97

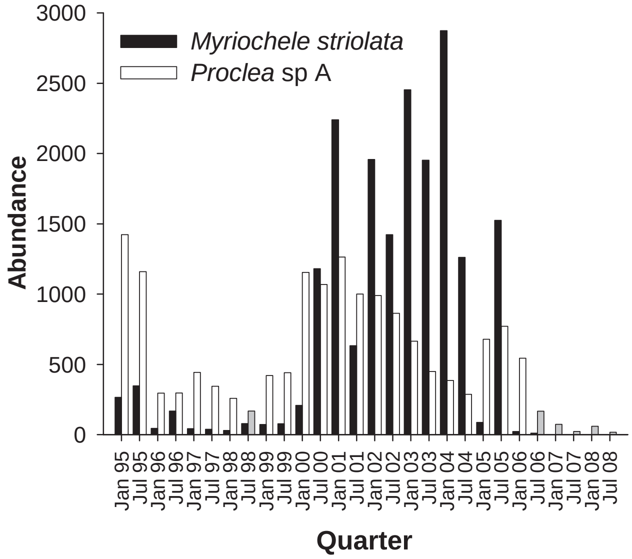


Figure 5.2
Total abundance of the polychaetes, *Myriochele striolata* and *Proclea* sp A for each survey at the PLOO benthic stations from 1995–2008.

Table 5.4
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 (1991–2008). Impact site=near-ZID station E14; Control sites=farfield station E26 or reference station B9. Before impact period=July 1991 to October 1993 (n=10); After impact period=January 1994 to July 2008 (n=49). Critical t value=1.680 for α=0.05 (one-tailed t-tests, df=57). ns=not significant.

Variable	Control vs Impact	t	p
SR	E26 v E14	-3.01	0.002
	B9 v E14	-3.46	0.001
Abundance	E26 v E14	-1.42	ns
	B9 v E14	-2.68	0.005
BRI	E26 v E14	-15.25	<0.001
	B9 v E14	-10.34	<0.001
Ampelisca spp	E26 v E14	-1.62	ns
	B9 v E14	-1.28	ns
Amphiodia spp	E26 v E14	-6.63	<0.001
	B9 v E14	-4.65	<0.001
Rhepoxynius spp	E26 v E14	-0.75	ns
	B9 v E14	-0.65	ns

not been among the most abundant species in past years. Abundances of this polychaete remained relatively low in the region until about 2005, after which they have generally increased each year (see City of San Diego 1995, 1999, 2006, 2007, 2008). However, densities of other polychaetes such as the oweniid *Myriochele striolata* and the terebellid *Proclea* sp A that have been numerically dominant over time have been more cyclical (Figure 5.2). For instance, both of these species were among the most abundant polychaetes between 1999 and 2005, while their densities have decreased during recent 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 the BRI 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 5.4). There also has been 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 between 1997 and 2007 (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 2008 were similar to the low densities that have occurred since about 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 at this site 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 control site (E26). Finally, no significant changes

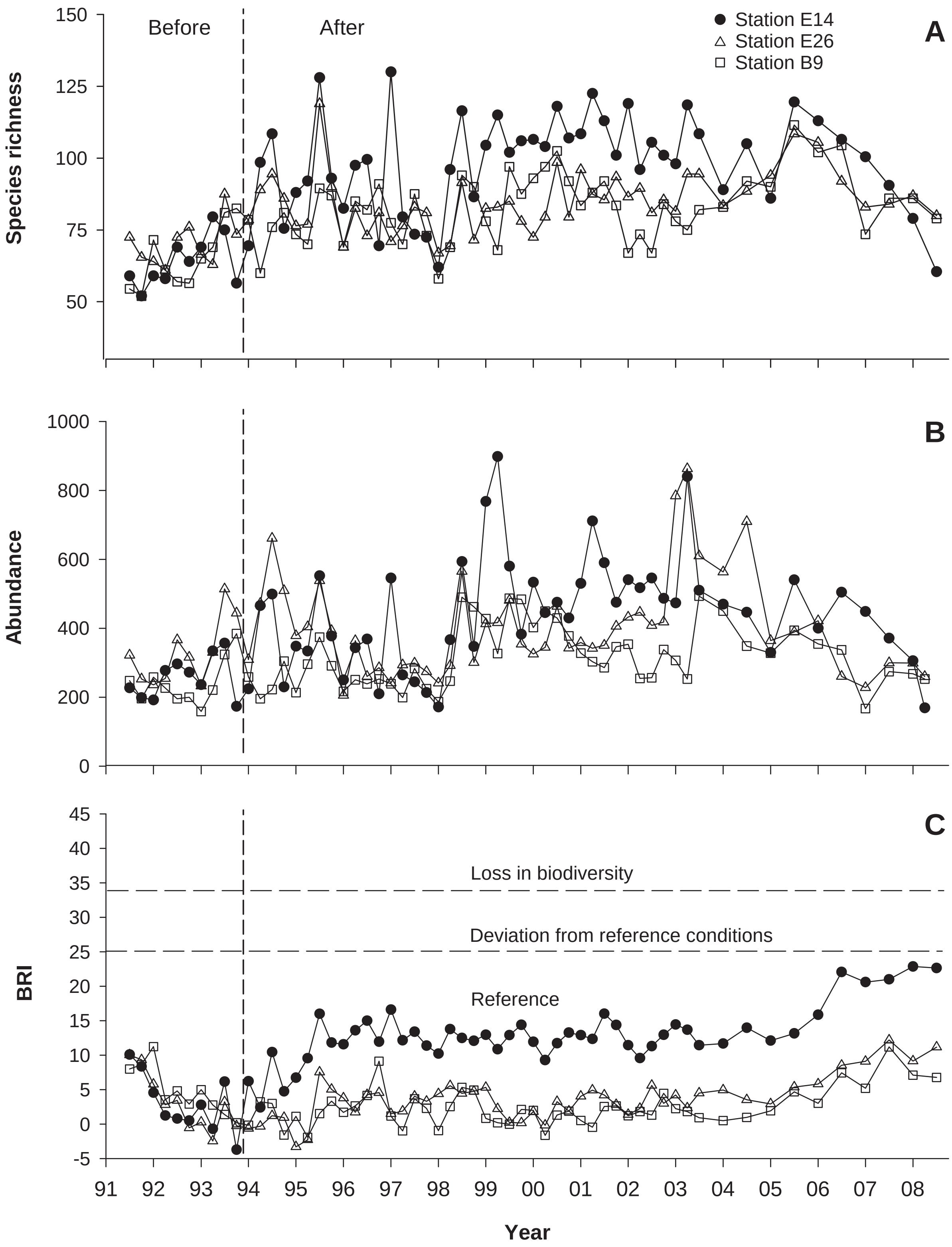


Figure 5.3

Comparison of several parameters at "impact" site (station E14) and "control" sites (stations E26, B9) used in BACIP analyses (see Table 5.4). Data for each station are expressed as means per 0.1 m^2 (n=2 per survey). (A) species richness; (B) infaunal abundance; (C) benthic response index (BRI); (D) abundance of *Ampelisca* spp (Amphipoda); (E) abundance of *Amphiodia* spp (Ophiuroidea).

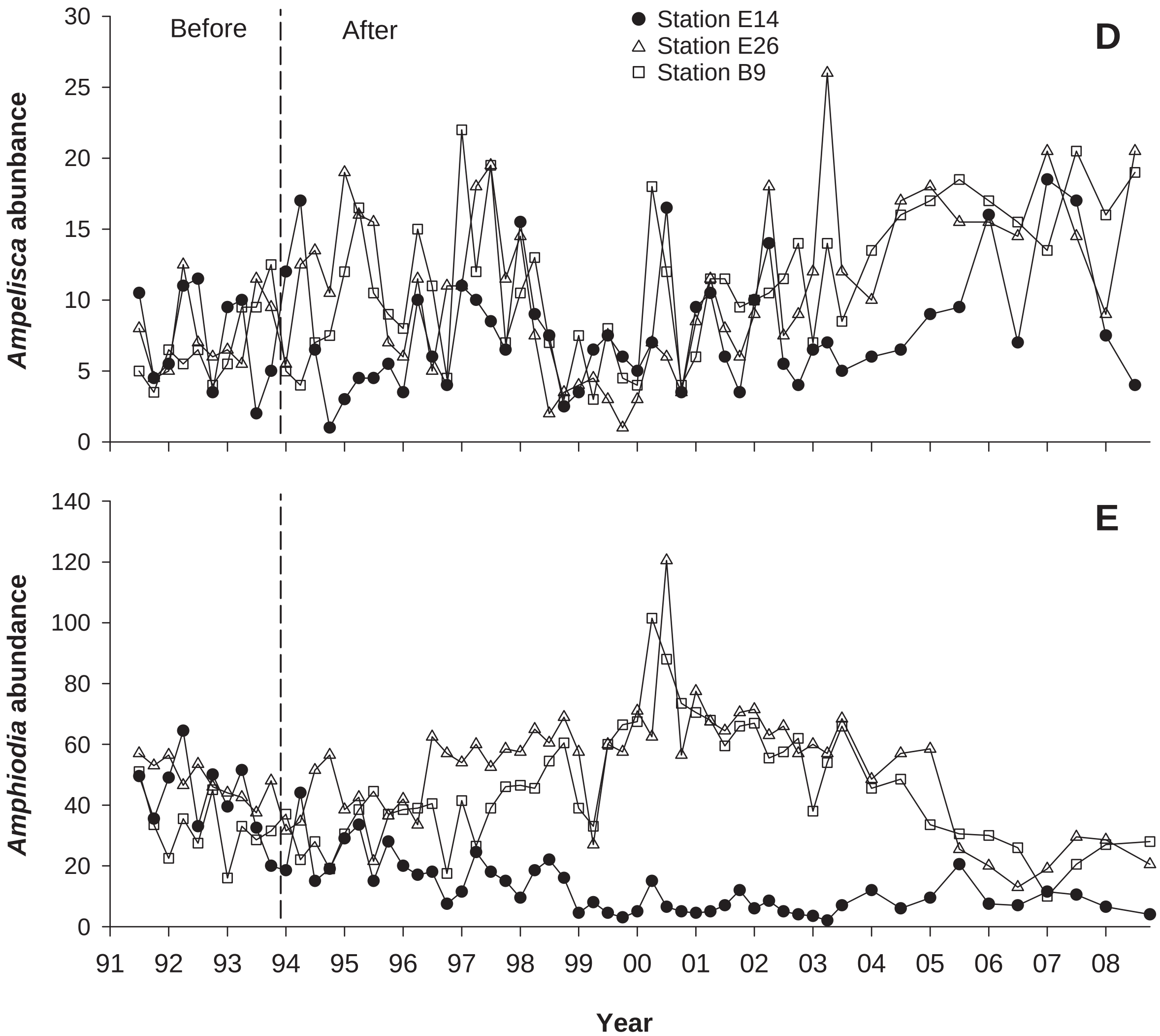


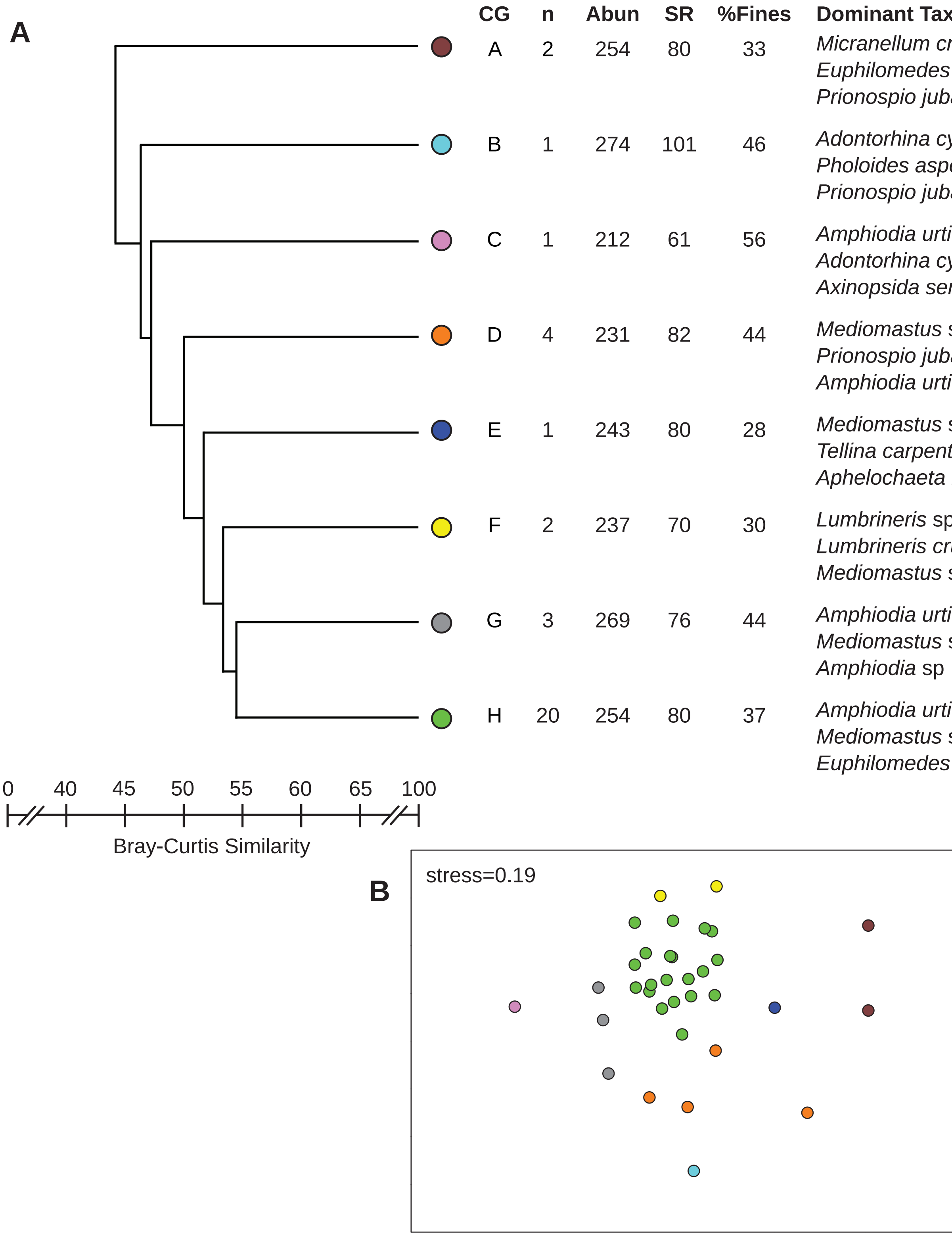
Figure 5.3 *continued*

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 Macrobenthic Assemblages

Results of the ordination and cluster analyses discriminated eight habitat-related macrobenthic assemblages (Figures 5.4 and 5.5). These assemblages (cluster groups A–H) varied in terms of species composition (i.e., specific taxa present) and the relative abundance of each species, and occurred at sites separated by different depths and/or sediment types (microhabitats). The SIMPROF procedure indicated statistically significant non-random structure among samples (π=3.29, $p<0.01$) and an MDS ordination of the station/survey entities supported the validity of the cluster groups (Figure 5.4B). SIMPER analysis was used to identify species that were characteristic, though not always the most abundant, of some assemblages; i.e., the three most characteristic species for each cluster group are indicated in Figure 5.4A. A complete list of all species comprising each group and their relative abundances can be found in Appendix D.1.

Cluster group A represented an assemblage restricted to both surveys from one northern reference site (station B12). Abundance averaged 254 individuals and species richness averaged 80 taxa per 0.1 m^2. The dominant species that characterized this assemblage included the gastropod *Micranellum crebricinctum* (formerly



CG	n	Abun	SR	%Fines	Dominant Taxa
A	2	254	80	33	*Micranellum crebricinctum* *Euphilomedes producta* *Prionospio jubata*
B	1	274	101	46	*Adontorhina cyclia* *Pholoides asperus* *Prionospio jubata*
C	1	212	61	56	*Amphiodia urtica* *Adontorhina cyclia* *Axinopsida serricata*
D	4	231	82	44	*Mediomastus* sp *Prionospio jubata* *Amphiodia urtica*
E	1	243	80	28	*Mediomastus* sp *Tellina carpenteri* *Aphelochaeta monilaris*
F	2	237	70	30	*Lumbrineris* sp group I *Lumbrineris cruzensis* *Mediomastus* sp
G	3	269	76	44	*Amphiodia urtica* *Mediomastus* sp *Amphiodia* sp
H	20	254	80	37	*Amphiodia urtica* *Mediomastus* sp *Euphilomedes producta*

Figure 5.4

(A) Cluster results of the macrofaunal abundance data for the PLOO benthic stations sampled during winter and summer 2008. Data for infaunal abundance (Abun), species richness (SR), and percent fines 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.

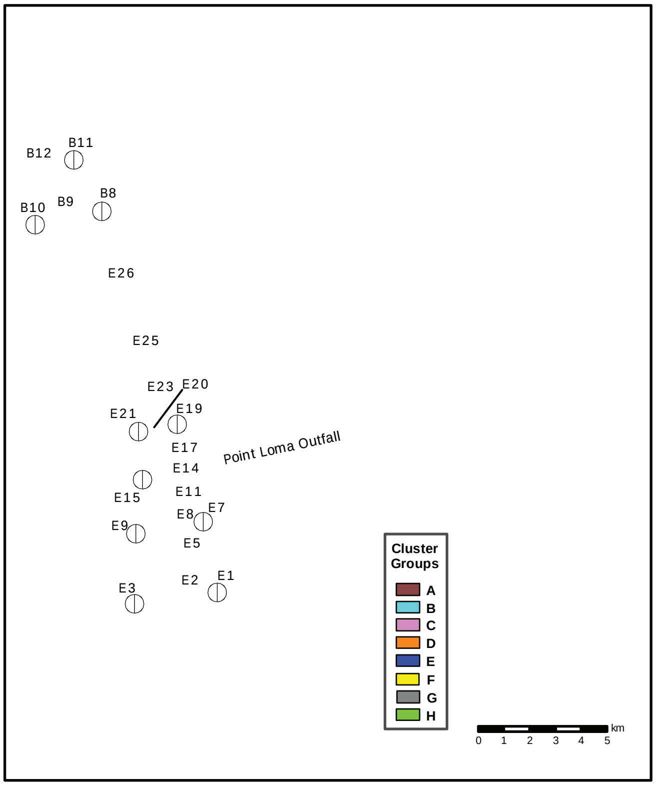


Figure 5.5
Distribution of macrobenthic assemblages off Point Loma delineated by ordination and classification analyses. Empty half cirlces represent secondary core stations not sampled in July 2008.

Caecum crebricinctum), the ostracod *Euphilomedes producta*, and the spionid polychaete *Prionospio jubata*. Sediments at this site averaged 33% fines over the two surveys.

Cluster group B comprised the assemblage that occurred at station B11 during the January survey (i.e., this station was not sampled during July 2008; see Materials and Methods). This station is located farthest north of the PLOO discharge site at a depth of 88 m. The B11 assemblage had the highest mean abundance (274 per 0.1 m^2) and species richness (101 taxa per 0.1 m^2) values compared to the other cluster groups. The bivalve *Adontorhina cyclia* was the dominant species characterizing this assemblage. The next two characteristic species were both polychaetes, and included the pholoid *Pholoides asperus* as well as *Prionospio jubata*. Sediments at this site were mixed, comprised of about 46% fines along with coarser materials such as shell hash and some small rocks.

Cluster group C represented the assemblage at station B8, another northern site located along the 88-m depth contour, which was also only sampled during the January survey similar to station B11 (see above). This assemblage averaged 212 organisms and 61 taxa per 0.1 m^2, the lowest for both parameters among all groups. The dominant species in this assemblage were the ophiuroid *Amphiodia urtica*, followed by the bivalves *Adontorhina cyclia* and *Axinopsida serricata*. The habitat was characterized by sediments containing 56% fine particles, the highest among all groups.

Cluster group D represented an assemblage characteristic of three of the southernmost sites located along the 98 and 116-m depth contours and nearest to the LA-5 dredged materials disposal site. This assemblage averaged 231 individuals and 82 taxa per 0.1 m^2. The three most characteristic species of this group were the capitellid polychaete *Mediomastus* sp, *Prionospio jubata*, and *Amphiodia urtica*. Sediments at these sites averaged 44% fines.

Cluster group E represented an assemblage from northern station B10 located along the 116-m contour, which was only sampled during January similar to stations B8 and B11 (i.e., cluster groups C and B, respectively) as described above. This assemblage averaged 243 individuals and 80 species per 0.1 m^2. The dominant species included *Mediomastus* sp, the bivalve *Tellina carpenteri*, and the cirratulid polychaete *Aphelochaeta monilaris*. The sediments associated with this group were mixed, composed of 28% fines with some shell hash.

Cluster group F represented a near-ZID assemblage sampled at station E14 during both the January and July surveys in 2008. Abundance averaged 237 individuals and species richness averaged 70 taxa per 0.1 m^2. The three most abundant species in this assemblage were all polychaetes, which included two lumbrinerids (*Lumbrineris* sp group I and *L. cruzensis*) along with *Mediomastus* sp. Sediments at this site were relatively coarse, comprised of black sand, shell hash, and an average of about 30% fines.

Cluster group G represented the assemblage at stations E1, E7, and E19 located along the 88-m contour, which were only sampled during January similar to those comprising groups B, C, and E (see above). This assemblage averaged 269 individuals and 76 taxa per 0.1 m^2. The brittle star *Amphiodia urtica* was the dominant species, while the next two most characteristic taxa for this assemblage were *Mediomastus* sp and juvenile *Amphiodia*. Sediments associated with this group averaged 44% fines.

Cluster group H represented the most widespread macrobenthic assemblage present in 2008, comprising animals from 59% of the samples and 11 stations. Average abundance for this group was 254 individuals per 0.1 m^2, while species richness averaged 80 taxa per sample. The dominant species characterizing group H were *Amphiodia urtica*, *Mediomastus* sp, and *Euphilomedes producta*. The sediments associated with this assemblage were characterized by some shell hash with 37% fines.

Summary and Conclusions

Benthic communities surrounding 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, 2008). Polychaetes and ophiuroids are the most abundant and diverse infauna taxa in the region. Although many of the 2008 assemblages were dominated by similar species, the relative abundance of these species varied among sites. The brittle star *Amphiodia urtica* was the most abundant and widespread taxon, while the capitellid polychaete *Mediomastus* sp was the second most widespread benthic invertebrate, being dominant in five of the eight 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, 1993a), Zmarzly et al. (1994), Diener and Fuller (1995), and Bergen et al. (1998, 2000, 2001).

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, 2007). In addition, values for these parameters in 2008 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, 2007). In addition, the recent observed decreases in abundance at most stations in 2006 and 2008 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 76 individual *C. capitata* were collected off Point Loma in 2008, with all occurring at stations located nearest the PLOO discharge site (i.e., E11, E14, E17). Densities of this polychaete at these three sites averaged 13 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 2007). 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 still remain characteristic of undisturbed areas (see City of San Diego 1995, 2007; Smith et al. 2001). 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 2007). This suggests 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 have revealed changes over time that may 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 both a decrease in ophiuroid numbers 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 substantial outfall-related effects.

While it is difficult to detect specific effects of the PLOO on the offshore benthos region-wide, 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 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 macrobenthic 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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