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 ecological 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 the effects of local environmental stressors (e.g., pollution or disturbance) over time (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, 2010; Ranasinghe et al. 2003, 2007).

This chapter presents analyses and interpretations of the macrofaunal data collected at fixed stations surrounding the PLOO during 2009. 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 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. During 2009, the January survey was limited to 12 “primary core” stations along the 98-m depth contour to accommodate additional sampling for the Bight’08 regional project (see Chapter 1), while the July survey included all 22 stations. 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.

Two replicate samples for benthic community analyses were collected per station during each survey using a double 0.1-m^2 Van Veen grab. One

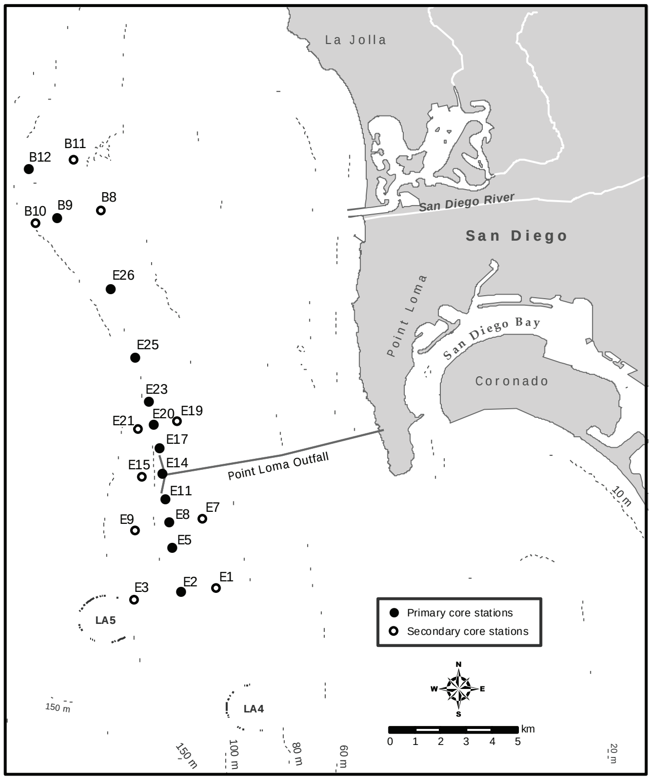

Figure 5.1

Benthic station locations sampled for the Point Loma Ocean Outfall Monitoring Program.

of the two grabs from the first cast was used for macrofauna, while the adjacent grab was used for sediment quality analysis (see Chapter 4); a second grab for macrofauna was then collected from a subsequent cast. Criteria established by the EPA to ensure consistency of grab samples 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). Macrofaunal abundance data were square-root transformed and the Bray-Curtis measure of similarity was used as the basis for classification. Similarity profile analysis (SIMPROF) was used to confirm non-random structure of the dendrogram (Clarke et al. 2008), while the 'similarity percentages' routine (SIMPER) was used to identify 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 2009) 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 16 years (51 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 (Smith and Riege 1994). Station E14 was selected as the impact site for all analyses; this station is located near the boundary of 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 one-tailed paired t-tests with a type I error rate of $\alpha = 0.05$.

Results and Discussion

Community Parameters

Species richness

A total of 483 macrofaunal taxa (mostly species) were identified during the 2009 PLOO surveys. Approximately 24% ($n = 117$) of these were rare species or unidentifiable taxa (e.g., juveniles or damaged specimens) that occurred only once. Mean species richness values (no. species/0.1 m^2) ranged from 76 species at station B8 to 124 species at station E9 (Table 5.1). Average values for the other 20 sites sampled during the year ranged between 77 and 105 taxa per grab. Overall, the average species richness among the 12 primary core stations increased about 10% since 2008 (e.g., see City of San Diego 2009).

Macrofaunal abundance

A total of 21,721 macrofaunal individuals were counted in 2009 with mean abundance values ranging from 234 to 518 animals per 0.1-m^2 sample (Table 5.1). The largest number of animals occurred at station E9, which was the only station to average more than 500 animals per grab. The fewest animals (mean = 234/grab) were collected at station E8, while the remaining sites had abundances averaging between 254 and 412 animals per grab. Overall, there was a 25% increase in macrofaunal abundance collected at the 12 primary core stations between 2008 and 2009, with the largest difference occurring at station E14 (e.g., see City of San Diego 2009). This near-ZID site averaged 237 and 412 individuals per grab in 2008 and 2009, respectively.

Species diversity, evenness, and dominance

Diversity index values (H') averaged from 3.2 to 4.2 at the PLOO stations during 2009 (Table 5.1), which was generally similar to that seen in previous years (e.g., City of San Diego 1995, 2009). The lowest diversity ($H' \leq 3.3$) continued to occur at stations E1 and B8, while the remaining stations had mean H' values ≥ 3.7. 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 2009, J' values averaged between 0.71 and 0.92 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 2009 were characterized by relatively high numbers of evenly distributed species with index values averaging 32 taxa per station (Table 5.1). The highest dominance (index value = 20) was seen at station B8, while the lowest dominance (index value = 41) occurred at station E3. 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 2009. 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 are in bold. Data are expressed as annual means ($n = 4$ for primary core stations, $n = 2$ for all others), except for Tot Spp ($n = 1$).

	Station	SR	Tot Spp	Abun	H'	J'	Dom	BRI	ITI
88-m Depth Contour	B11	105	149	340	4.1	0.88	40	10	79
	B8	76	111	294	3.3	0.75	20	7	83
	E19	81	111	261	3.7	0.83	30	9	83
	E7	96	131	372	3.9	0.86	33	10	83
	E1	91	128	332	3.2	0.71	28	6	89
*98-m Depth Contour**	B12	92	176	293	4.0	0.90	35	10	77
	B9	94	184	322	3.9	0.87	33	7	82
	E26	89	163	300	3.9	0.87	32	8	79
	E25	92	181	374	3.9	0.86	30	10	79
	E23	84	162	301	3.9	0.89	32	11	80
	E20	86	159	309	4.0	0.89	32	13	77
	E17	**84**	**151**	**327**	**3.9**	**0.87**	**29**	**15**	**75**
	E14	**97**	**203**	**412**	**3.8**	**0.84**	**27**	**20**	**67**
	E11	**87**	**162**	**323**	**3.8**	**0.85**	**28**	**13**	**78**
	E8	77	142	234	3.8	0.88	29	10	81
	E5	87	163	314	3.9	0.88	32	8	82
	E2	89	179	264	3.9	0.86	34	9	84
116-m Depth Contour	B10	98	138	354	4.0	0.86	34	12	78
	E21	97	126	303	4.1	0.89	37	7	85
	E15	**95**	**130**	**290**	**4.0**	**0.89**	**36**	**11**	**85**
	E9	124	177	518	3.9	0.81	36	9	79
	E3	97	144	254	4.2	0.92	41	6	84
All Stations	Mean	90	153	319	3.9	0.86	32	10	79
	Std Error	2	5	10	0.1	0.01	1	1	1
	Min	56	111	157	3.0	0.69	20	4	59
	Max	127	203	610	4.3	0.92	45	22	90

*Primary core stations

Environmental disturbance indices

Benthic response index (BRI) values ranged from 4 to 22 at the various PLOO stations in 2009 (Table 5.1). This indicated 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 occurred at station E14 (BRI = 20) located about 120 m west of the center of the outfall wye, stations E11 and E17 (BRI = 13, 15) located within 300 m of the ends of the south and north diffuser legs, respectively, and station E20 (BRI = 13) located about 1.2 km from the end of the northern diffuser leg.

Mean infaunal trophic index (ITI) values ranged from 67 to 89 per station in 2009 (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 2009 (Table 5.2). Polychaetes were the most diverse of the major taxa, accounting for 56% of all species collected. Crustaceans accounted for 25% of the species, molluscs 11%, echinoderms 5%, and all other taxa combined for the remaining 3%. Polychaetes were also the most numerous animals, accounting for 56% of the total abundance. Crustaceans accounted for 19% of the animals, molluscs 13%, echinoderms 11%, and the remaining phyla 1%. Overall, the above distributions were similar to those observed in 2008 (see City of San Diego 2009).

Five polychaetes, two molluscs, two arthropods, and one echinoderm were among the 10 most abundant macroinvertebrates sampled during the year (Table 5.3). The most abundant species was the ophiuroid *Amphiodia urtica*, which occurred at 97% of the PLOO stations and averaged 27 individuals per 0.1 m^2. However, since juvenile *A. urtica* usually cannot be identified to species and are recorded as *Amphiodia* sp or Amphiuridae, this number probably underestimates actual populations of this brittle star. Thus, if total *A. urtica* abundance is adjusted to include these unidentified individuals, the estimated density of this species would increase to about 32 brittle stars per grab, similar to that observed in 2008.

Table 5.2
The percent composition of species and abundance by major phyla for PLOO stations sampled during 2009. Data are expressed as annual means (range) for all stations combined; *n* = 22.

Phyla	Species (%)	Abundance (%)
Annelida (Polychaeta)	56 (47–62)	56 (27–76)
Arthropoda (Crustacea)	25 (18–30)	19 (8–28)
Mollusca	11 (7–17)	13 (4–32)
Echinodermata	5 (3–9)	11 (2–42)
Other Phyla	3 (1–6)	1 (1–3)

Many of the abundant species in 2009 were also dominant prior to discharge and ever since (e.g., City of San Diego 1995, 1999, 2006, 2009). 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, the capitellid *Mediomastus* sp,

Table 5.3
The 10 most abundant macroinvertebrates collected at the PLOO benthic stations sampled during 2009. Abundance values are expressed as mean number of individuals per 0.1-m^2 grab sample.

Species	Higher Taxa	Percent Occurrence	Abundance per Sample	Abundance per Occurrence
Amphiodia urtica	Echinodermata: Ophiuroidea	97	26.7	27.5
Axinopsida serricata	Mollusca: Bivalvia	97	16.0	16.5
Mediomastus sp	Polychaeta: Capitellidae	100	14.8	14.8
Euphilomedes producta	Arthropoda: Ostracoda	100	11.0	11.0
Polycirrus sp A	Polychaeta: Terebellidae	97	11.0	11.3
Aricidea (*Acmira*) *catherinae*	Polychaeta: Paraonidae	97	10.5	10.9
Chaetozone hartmanae	Polychaeta: Cirratulidae	97	7.1	7.3
Aphelochaeta glandaria complex	Polychaeta: Cirratulidae	94	6.4	6.8
Euphilomedes carcharodonta	Arthropoda: Ostracoda	97	6.0	6.2
Adontorhina cyclia	Mollusca: Bivalvia	74	5.7	7.7

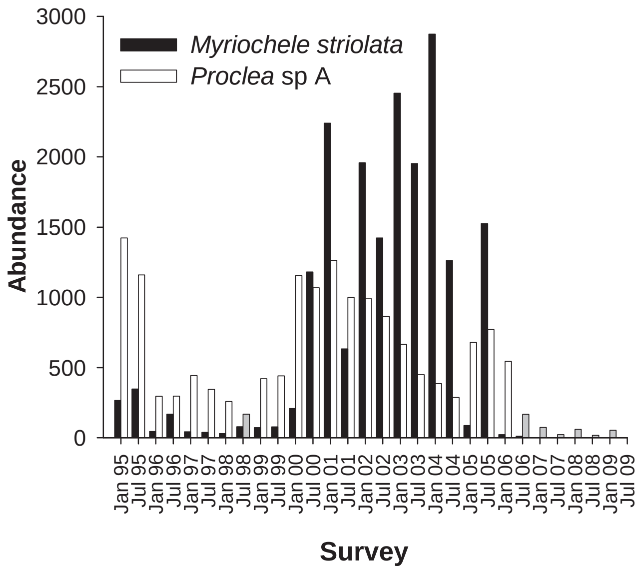

Figure 5.2

Total abundance (no./0.1 m^2) of the polychaetes, *Myriochele striolata* and *Proclea* sp A for each survey at the PLOO benthic stations from 1995–2009.

the third most abundant species collected in 2009, was not widespread until about 2005, after which abundances generally have increased each year (see City of San Diego 1995, 1999, 2006–2009). Other numerically dominant polychaetes in 2009 included the terebellid *Polycirrus* sp A, the paraonid *Aricidea catherinae*, and the cirratulids *Chaetozone hartmanae* and *Aphelochaeta glandaria*. The two most abundant crustaceans were the ostracods *Euphilomedes carcharodonta* and *E. producta*, while the two dominant molluscs were the bivalves *Axinopsida serricata* and *Adontorhina cyclia*.

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 seen prior to that time. Such variation can have significant effects on other community metrics (e.g., dominance, diversity, and abundance) or environmental indices such as the BRI that use the abundance of specific indicator species in their equations.

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 (1991–2009). 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 2009 (n = 51). Critical t-value = 1.680 for α = 0.05 (one-tailed t-tests, df = 59); ns = not significant.

Variable	Control vs Impact	t	*p*
SR	E26 vs E14	-2.89	0.003
	B9 vs E14	-3.27	0.001
Abundance	E26 vs E14	-1.39	ns
	B9 vs E14	-2.64	0.005
BRI	E26 vs E14	-15.50	<0.001
	B9 vs E14	-10.59	<0.001
Ampelisca spp	E26 vs E14	-1.74	0.044
	B9 vs E14	-1.25	ns
Amphiodia spp	E26 vs E14	-6.49	<0.001
	B9 vs E14	-4.62	<0.001
Rhepoxynius spp	E26 vs E14	-0.67	ns
	B9 vs E14	-0.58	ns

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 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 as well as a net change in *Ampelisca* spp abundance between E14 and E26. The change in species richness may be due to the increased variability and higher numbers of species at E14 between 1997 and 2007 (Figure 5.3A). Differences in *Amphiodia* populations reflect both a decrease in the number of ophiuroids collected at E14 and a general increase at the control stations through about 2001 (Figure 5.3E). *Amphiodia urtica* densities at station E14 in 2009 were similar to the low densities that have occurred since about 1999. While populations of this brittle star have declined in recent years at both control sites, their densities are more similar to pre-discharge values than near the

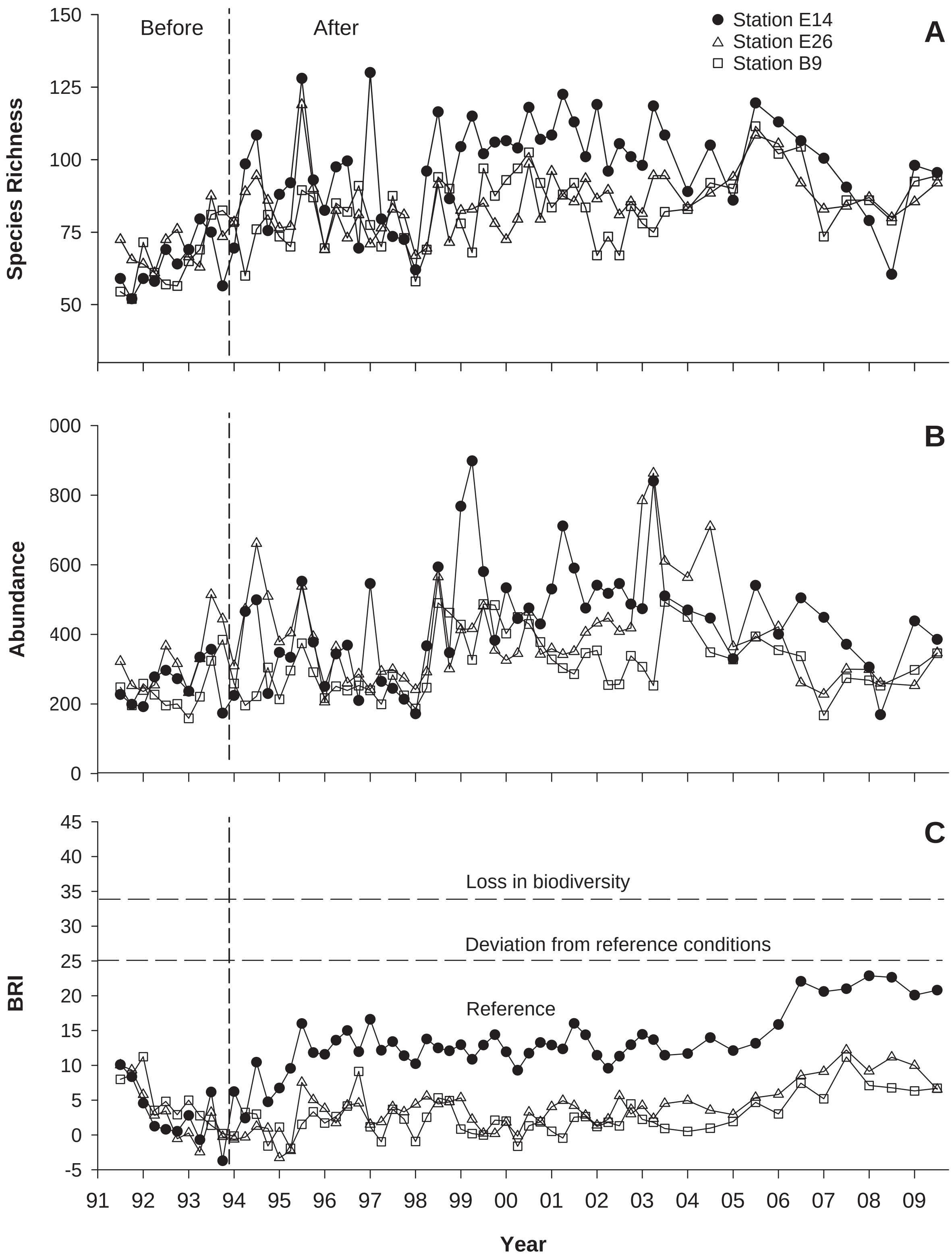

Figure 5.3

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

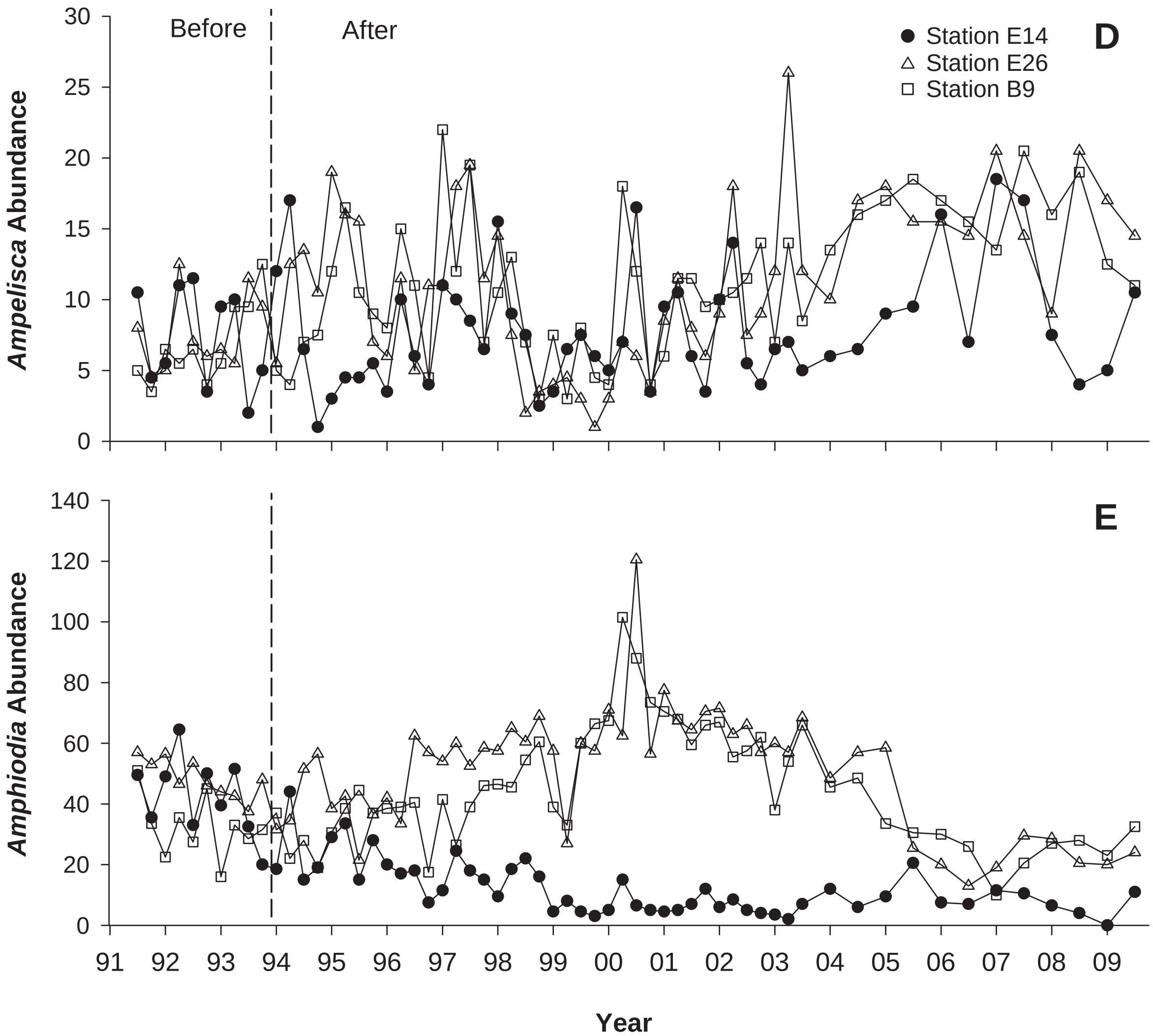

Figure 5.3 *continued*

outfall. Changes in BRI differences generally are due to increased index values at station E14 since 1994 (Figure 5.3C). The higher BRI values at this site may be explained in part by the lower numbers of *Amphiodia*. The BACIP results for total infaunal abundances were more ambiguous (Figure 5.3B, Table 5.3). While the difference in mean abundances between stations B9 and E14 has changed since discharge began, no significant change is apparent regarding the second control site (station E26). No significant changes in the difference in mean abundances of phoxocephalid amphipods (i.e., *Rhepoxynius*) at the impact and control sites have occurred over time (Table 5.4). However, there has been a significant change in the difference in mean abundance of ampeliscid amphipods (i.e., *Ampelisca*) between E14 and E26 (Figure 5.3D, Table 5.4).

Classification of Macrobenthic Assemblages

Results of the ordination and cluster analyses discriminated seven habitat-related macrobenthic assemblages (Figures 5.4 and 5.5). These assemblages, referred to herein as cluster groups A–G, varied in terms of the specific taxa (mostly species) present and the relative abundance of each taxon, and occurred at sites separated by different depths and/or sediment microhabitats. The SIMPROF procedure indicated statistically significant non-random structure among samples ($\pi = 3.34$, $p < 0.01$) and, to some extent an MDS ordination supported the validity of the cluster groups (Figure 5.4B). The SIMPER analysis in PRIMER was used to identify the characteristic species for each cluster group (assemblage) comprised of more than one sample (i.e., groups A, C, E and G), although these taxa are not always the most abundant. For single sample cluster groups (i.e., groups B, D and F), the most abundant taxa were used instead to characterize the assemblages. The top three characteristic or most abundant species for each cluster group as defined above are indicated in Figure 5.4A, while a complete list of all species and their relative abundances in each group is included in Appendix D.1.

Cluster group A represented an assemblage restricted to one northern reference site (station B12) during both the January and July surveys. Abundance averaged 293 individuals per 0.1 m^2, while species richness averaged 92 taxa per grab. The top three species that characterized this assemblage were all polychaetes, including the terebellid *Polycirrus* sp A, the cirratulid *Aphelochaeta glandaria*, and the paraonid *Aricidea catherinae*. Sediments at this site averaged 32% fines over both surveys.

Cluster group B represented a near-ZID assemblage restricted to station E14 sampled during January 2009. Abundance averaged 439 animals per 0.1 m^2 and species richness averaged 98 taxa per grab. The most abundant species that characterized this assemblage was the capitellid polychaete *Capitella teleta* (formerly *Capitella capitata* complex). In fact, *C. teleta* accounted for about 14% of average macrofaunal abundance at station E14 in January, which represented more than 60% of all individuals of this species captured during the year at all of the PLOO stations combined. The next two most abundant species comprising group B included the terebellid *Polycirrus* sp A, and the amphipod *Photis californica*. Sediments at this site were relatively coarse, comprised mostly of coarse sand, gravel and shell hash, along with about 30% fines.

Cluster group C comprised the assemblage that occurred at northern station B11 during July (i.e., this station was not sampled during January 2009; see Materials and Methods), as well as the southern stations E9 and E3. This assemblage had the second highest mean abundance (371 per 0.1 m^2) and the highest species richness (108 taxa) compared to the other cluster groups. The spionid polychaete, *Prionospio dubia* was the dominant species characterizing this assemblage. The next two characteristic species were also polychaetes, and included the cirratulid *Aphelochaeta* sp LA1 and the capitellid *Mediomastus* sp. Sediments at this site were mixed, comprised of about 42% fines along with coarser materials such as black sands, shell hash, gravel, and small rocks.

Cluster group D represented the assemblage at station B8, another northern site located along the 88-m depth contour and that was only sampled during the July survey. This assemblage averaged 294 organisms and 76 taxa per 0.1 m^2, the latter representing the lowest species richness among all groups. The three most abundant species in this assemblage were the ophiuroid *Amphiodia urtica*, followed by the bivalves *Adontorhina cyclia* and *Axinopsida serricata*. The sediments at this site were comprised of 57% fines, the finest sediments among all cluster groups.

Cluster group E represented an assemblage that occurred at two of the southernmost sites located about 2–3 km east of the LA-5 dredged materials disposal site along the 88 and 98-m depth contours. This assemblage averaged 287 individuals per 0.1 m^2 and 89 taxa per grab. The three most characteristic species of this group included the brittle star *Amphiodia urtica*, the bivalve *Ennucula tenuis*, and the spionid *Prionospio dubia*. Sediments at these sites were mixed, averaging 41% fines.

Cluster group F represented an assemblage from northern station B10 located along the 116-m depth contour, which was only sampled during July. This assemblage averaged 354 individuals and 98 taxa per 0.1 m^2. The three most abundant species included *Polycirrus* sp A, *Axinopsida serricata*, and the ostracod *Euphilomedes producta*. The sediments associated with this group were composed of 28% fines with some shell hash.

Cluster group G represented the most wide-spread macrobenthic assemblage present in 2009, comprising animals from 68% of the samples and 14 stations.

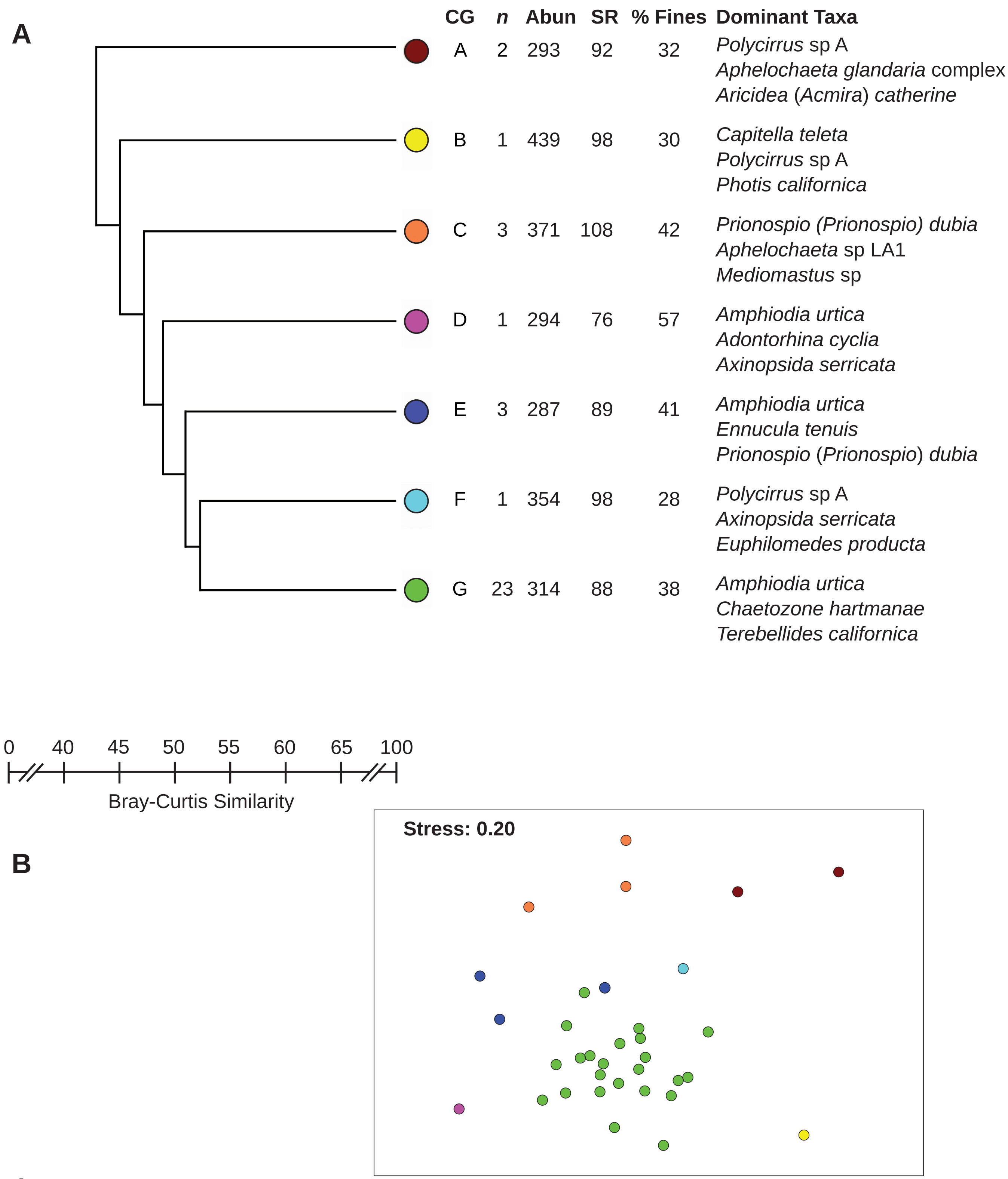

Figure 5.4

(A) Cluster results of the macrofaunal abundance data for the PLOO benthic stations sampled during winter and summer 2009. Data for percent fines, total organic carbon (TOC), species richness (SR), and infaunal abundance (Abun), are expressed as mean values per 0.1-m² grab over all stations in each group (CG). (B) MDS ordination based on square-root transformed macrofaunal abundance data for each station/survey entity. Cluster groups superimposed on station/surveys illustrate a distinction between faunal assemblages.

The average abundance for this group was 314 individuals per 0.1 m^2, while species richness averaged 88 taxa per sample. The top three species characterizing group G included *Amphiodia urtica* and two polychaetes, the latter including the cirratulid *Chaetozone hartmanae* and the terebellid *Terebellides californica*. The sediments associated with this assemblage were characterized by some shell hash with 38% 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, 2009). Polychaetes and ophiuroids are the most abundant and diverse infauna taxa in the region. Although many of the 2009 assemblages were dominated by similar taxa, the relative abundance of these taxa varied among sites. The brittle star *Amphiodia urtica* was the most abundant and widespread taxon, while the bivalve *Axinopsida serricata* was the second most widespread benthic invertebrate. 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 2009 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 at some PLOO stations during the post-discharge period (see City of San Diego 1995, 1999, 2007).

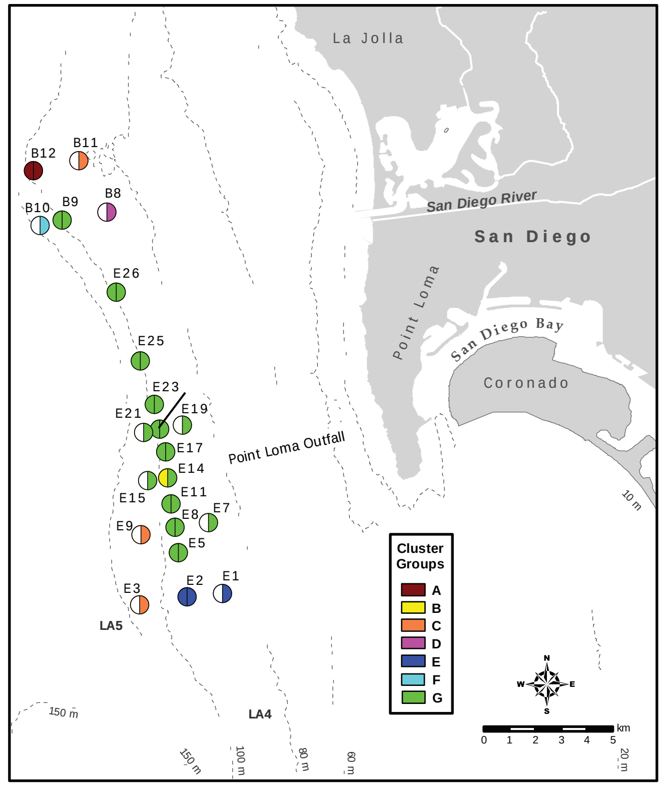

Figure 5.5
Spatial distribution of PLOO macrobenthic assemblages delineated by ordination and classification analyses (see Figure 5.4). Left half of circle represents cluster group affiliation for the January survey; right half represents the July survey.

A few changes near the outfall suggest some effects that may be indicative of anthropogenic activities such as organic enrichment or other types of disturbance. For example, BRI values have increased at near-ZID station E14 since discharge began and are generally higher at this and the two other stations nearest the outfall (E11 and E17) than elsewhere off Point Loma. However, BRI values at these and all other of the PLOO sites still remain characteristic of undisturbed areas (see Smith et al. 2001, Ranasinghe et al. 2010). 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 have also been changes in sediment composition at E14 since construction of the PLOO (see Chapter 4 herein, City of San Diego 2007). Consequently, changes in community structure near the outfall may be related to localized physical disturbance associated with the outfall pipe structure as well as to organic enrichment.

Populations of some indicator taxa have revealed changes over time that may correspond to organic enrichment near the outfall. For example, there has been a significant change in the difference between brittle star (*Amphiodia* spp) populations that occur nearest the outfall (i.e., station E14) and those present at reference sites since 1997. This difference appears due to both a decrease in ophiuroid numbers near station E14 and a concomitant increase at reference areas during the post-discharge period. Although long term changes in *Amphiodia* populations at E14 may be related to organic enrichment, factors such as altered sediment composition and increased predation pressure near the outfall may also be important. Regardless of the cause of these changes, abundances of *Amphiodia* off Point Loma remain within the range of natural variation in the SCB. Recent increases in populations of the opportunist polychaete *Capitella teleta* may also be indicative of changing benthic conditions. A total of 206 *C. teleta* were reported in 2009 of which 97% occurred at the three stations located within 300 m of the discharge site. Although these abundances represented a noticeable change, they are still relatively low compared to the high densities (e.g., $>5000/m^2$) indicative of polluted sediments (see Swartz et al. 1986). In addition, natural population fluctuations of other resident polychaetes including the oweniid *Myriochele striolata* and terebellid *Proclea* sp A are common off San Diego (Zmarzly et al. 1994, Diener et al. 1995). Further complicating the picture, relatively stable populations of pollution sensitive amphipods in the genus *Rhepoxynius* are not indicative of an outfall-related effect.

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 organic enrichment, the physical structure of the outfall pipe, or a combination of 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 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, most 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. Overall, benthic macrofauna appear to be in good condition off Point Loma, with all of the sites surveyed in 2009 being classified in reference condition based on assessments using the benthic response index. This is not unexpected as Ranasinghe et al. (2010) recently reported that 98% of the entire SCB was in good condition based on data gathered during the 1994−2003 bight-wide surveys.

Literature Cited

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

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

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

Bergen, M., S.B. Weisberg, D. Cadien, A. Dalkey, D. Montagne, R.W. Smith, J.K. Stull, and

R.G. Velarde. (1998). Southern California Bight 1994 Pilot Project: IV. Benthic Infauna. Southern California Coastal Water Research Project, Westminster, CA.

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

Bernstein, B.B. and J. Zalinski. (1983). An optimum sampling design and power tests for environmental biologists. Journal of Environmental Management, 16: 35–43.

Bilyard, G.R. (1987). The value of benthic infauna in marine pollution monitoring studies. Marine Pollution Bulletin, 18(11): 581–585.

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

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

City of San Diego. (2006). Annual Receiving Waters Monitoring Report for the Point Loma Ocean Outfall, 2005. City of San Diego Ocean Monitoring Program, Metropolitan Wastewater Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

City of San Diego. (2007). Appendix E. Benthic Sediments and Organisms. In: Application for Renewal of NPDES CA0107409 and 301(h) Modified Secondary Treatment Requirements, Point Loma Ocean Outfall. Volume IV, Appendices A thru F. Metropolitan Wastewater Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

City of San Diego. (2008). Annual Receiving Waters Monitoring Report for the Point Loma Ocean Outfall, 2007. City of San Diego Ocean Monitoring Program, Metropolitan Wastewater Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

City of San Diego. (2009). Annual Receiving Waters Monitoring Report for the Point Loma Ocean Outfall, 2008. City of San Diego Ocean Monitoring Program, Metropolitan Wastewater Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

City of San Diego. (2010). Annual Receiving Waters Monitoring Report for the South Bay Ocean Outfall (South Bay Water Reclamation Plant), 2009. City of San Diego Ocean Monitoring Program, Public Utilities Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

Clarke, K.R. (1993). Non-parametric multivariate analyses of changes in community structure. Australian Journal of Ecology, 18: 117–143.

Clarke, K.R. and R.N. Gorley. (2006). PRIMER v6: User Manual/Tutorial. PRIMER-E, Plymouth.

Clarke, K.R., P.J. Somerfield, and R.N. Gorley. (2008). Testing of null hypotheses in exploratory community analyses: similarity profiles and biota-environment linkage. Journal of Experimental Marine Biology and Ecology, 366: 56–69.

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

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

Fauchald, K. and G.F. Jones. (1979). Variation in community structures on shelf, slope, and basin macrofaunal communities of the Southern California Bight. Report 19, Series 2. In: Southern California Outer Continental Shelf Environmental Baseline Study, 1976/1977 (Second Year) Benthic Program. Principal Investigators Reports, Vol. II. Science Applications, Inc. La Jolla, CA.

Ferraro, S.P., R.C. Swartz, F.A. Cole, and W.A. Deben. (1994). Optimum macrobenthic sampling protocol for detecting pollution impacts in the Southern California Bight. Environmental Monitoring and Assessment, 29: 127–153.

Gray, J.S. (1979). Pollution-induced changes in populations. Philosophical Transactions of the Royal Society of London (Series B.), 286: 545–561.

Hartley, J.P. (1982). Methods for monitoring offshore macrobenthos. Marine Pollution Bulletin, 12: 150–154.

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

Morrisey, D.J., L. Howitt, A.J. Underwood, and J.S. Stark. (1992a). Spatial variation in soft-sediment benthos. Marine Ecology Progress Series, 81: 197–204.

Morrisey, D.J., A.J. Underwood, L. Howitt, and J.S. Stark. (1992b). Temporal variation in soft-sediment benthos. Journal of Experimental Marine Biology and Ecology, 164: 233–245.

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

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

Pearson, T.H. and R. Rosenberg. (1978). Macrobenthic succession in relation to organic enrichment and pollution of the marine environment. Oceanography and Marine Biology Annual Review, 16: 229–311.

Ranasinghe, J.A., A.M. Barnett, K. Schiff, D.E. Montagne, C. Brantley, C. Beegan, D.B. Cadien, C. Cash, G.B. Deets, D.R. Diener, T.K. Mikel, R.W. Smith, R.G. Velarde, S.D. Watts, S.B. Weisberg. (2007). Southern California Bight 2003 Regional Monitoring Program: III. Benthic Macrofauna. Southern California Coastal Water Research Project. Costa Mesa, CA.

Ranasinghe, J.A., D.E. Montagne, R.W. Smith, T.K. Mikel, S.B. Weisberg, D. Cadien, R. Velarde, and A. Dalkey. (2003). Southern California Bight 1998 Regional Monitoring Program: VII. Benthic Macrofauna. Southern California Coastal Water Research Project. Westminster, CA.

Ranasinghe, J.A., K.C. Schiff, D.E. Montagne, T.K. Mikel, D.B. Cadien, R.G. Velarde, and C.A. Brantley. (2010). Benthic macrofaunal community condition in the Southern California Bight, 1994–2003. Marine Pollution Bulletin, 60: 827–833.

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

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

Snelgrove P.V.R., T.H. Blackburn, P.A. Hutchings, D.M. Alongi, J.F. Grassle, H. Hummel, G. King, I. Koike, P.J.D. Lambshead, N.B. Ramsing, V. Solis-Weiss. (1997). The importance of marine sediment biodiversity in ecosystem processes. Ambio, 26: 578–583.

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

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

Swartz, R.C., F.A. Cole, and W.A. Deben. (1986). Ecological changes in the Southern California Bight near a large sewage outfall: benthic conditions in 1980 and 1983. Marine Ecology Progress Series, 31: 1–13.

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

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

Thompson, B.E., D. Tsukada, and D. O'Donohue. (1993b). 1990 reference site survey. Technical Report No. 269, Southern California Coastal Water Research Project, Long Beach CA.

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

Warwick, R.M. (1993). Environmental impact studies on marine communities: pragmatical considerations. Australian Journal of Ecology, 18: 63–80.

Warwick, R.M. and K.R. Clarke. (1993). Increased variability as a symptom of stress in marine communities. Journal of Experimental Marine Biology and Ecology, 172: 215–226.

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

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

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