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. 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 impact (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 document both existing conditions and trends over time.

The structure of benthic communities is influenced by many factors including depth, sediment conditions (e.g., particle size and sediment chemistry), water conditions (e.g., temperature, salinity, dissolved oxygen, and current velocity), and biological factors (e.g., food availability, competition, and predation). For example, benthic assemblages on the coastal shelf off San Diego typically vary along sediment particle size and/or depth gradients. However, both human activities and natural processes can influence the structure of invertebrate communities in marine sediments. Therefore, in order to determine whether changes in community structure are related to human impacts, it is necessary to have documentation of background or reference conditions for an area. Such information is available for the area surrounding the South Bay Ocean Outfall (SBOO) and the San Diego region in general (e.g., City of San Diego 1999, 2000).

This chapter presents analyses and interpretations of the macrofaunal data collected at fixed stations surrounding the SBOO during 2007. Descriptions and comparisons of soft-bottom macrofaunal assemblages in the area and analysis of benthic community structure are included.

MATERIAL AND METHODS

Collection and Processing of Samples

Benthic samples were collected during winter (January and March) and summer (July) 2007 at 27 stations surrounding the SBOO. These stations range in depth from 18 to 60 m and are distributed along four main depth contours. Listed from north to south along each contour, these stations include: I35, I34, I31, I23, I18, I10, and I4 (19-m contour); I33, I30, I27, I22, I14, I16, I15, I12, I9, I6, I2, and I3 (28-m contour); I29, I21, I13, and I8 (38-m contour); I28, I20, I7, and I1 (55-m contour) (**Figure 5.1**).

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

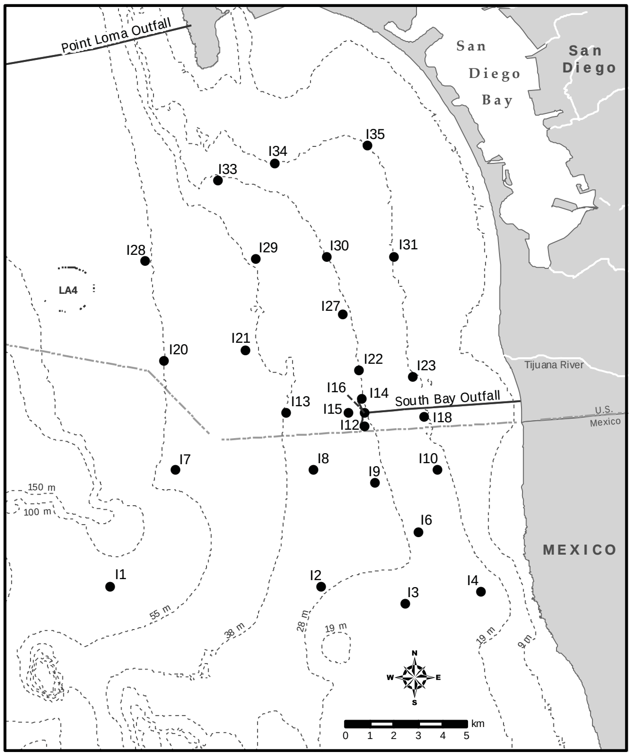


Figure 5.1
Macrobenthic station locations, South Bay Ocean Outfall Monitoring Program.

(USEPA 1987). All samples were sieved aboard ship through a 1.0-mm mesh screen. Organisms retained on the screen were relaxed for 30 minutes in a magnesium sulfate solution and then fixed in buffered formalin. After a minimum of 72 hours, each sample was rinsed with fresh water and transferred to 70% ethanol. All organisms were sorted from the debris into major taxonomic groups by a subcontractor then animals were 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: species richness (mean number of species per 0.1 m^2), annual total number of species per station, abundance (mean number of individuals per 0.1 m^2), Shannon diversity index (mean H' per 0.1 m^2, see Shannon and Weaver 1949), Pielou's evenness index (mean J' per 0.1 m^2, see Pielou 1966), Swartz dominance (mean minimum number of species accounting for 75% of the total abundance in each 0.1 m^2, see Swartz et al. 1986), Infaunal Trophic Index (mean ITI per 0.1 m^2, see Word 1980), and Benthic Response Index (mean BRI per 0.1 m^2, see Smith et al. 2001).

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).

Results and Discussion

Community Parameters

Species Richness

A total of 799 macrobenthic taxa were identified during 2007. Of these, 24% represented rare or unidentifiable taxa that were recorded only once. The average number of taxa per 0.1 m^2 grab ranged from 37 to 146, and the cumulative number of taxa per station ranged from 82 to 289 (**Table 5.1**). This wide variation in species richness is consistent with previous years, and can probably be attributed to different habitat types in the region (see City of San Diego 2005, 2006, 2007). Higher numbers of species, for example, have occurred at stations such as I28 and I29 (see City of San Diego 2006). In addition, species richness varied between the 2007 surveys, averaging about 30% higher in summer than in winter (see **Figure 5.2B**). Although species richness varied spatially and

Table 5.1

Benthic community parameters at SBOO stations sampled during 2007. SR=Species richness, no. species/0.1 m^2; Tot Spp=total cumulative no. species for the year; Abun=Abundance, no. individuals/0.1 m^2; H'=Shannon diversity index; J'=Evenness; Dom=Swartz dominance, no. species comprising 75% of a community by abundance; 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
19-m stations								
I35	98	193	842	3.2	0.70	17	32	69
I34	56	148	766	2.8	0.72	9	9	73
I31	73	158	294	3.6	0.85	25	23	77
I23	74	179	210	3.8	0.89	29	22	74
I18	58	125	151	3.6	0.88	25	21	75
I10	65	142	202	3.6	0.88	24	22	81
I4	37	82	186	2.9	0.81	11	2	57
28-m stations								
I33	114	241	553	3.6	0.76	27	28	74
I30	73	164	272	3.7	0.87	27	24	79
I27	80	182	327	3.6	0.85	28	24	80
I22	98	216	462	3.4	0.75	24	26	74
I14	88	194	314	3.7	0.83	29	25	76
I16	81	193	329	3.2	0.72	21	23	74
I15	72	180	603	2.5	0.59	15	22	71
I12	58	145	372	2.6	0.64	14	17	73
I9	115	251	621	3.7	0.78	26	26	77
I6	62	141	1579	2.0	0.51	14	13	74
I2	39	93	125	3.0	0.82	14	14	72
I3	47	102	338	2.3	0.61	7	12	67
38-m stations								
I29	96	262	381	3.7	0.84	30	15	82
I21	49	116	202	3.2	0.84	16	9	85
I13	53	121	174	3.3	0.84	18	11	82
I8	56	118	219	3.1	0.78	17	18	75
55-m stations								
I28	146	289	536	4.4	0.89	50	14	79
I20	60	153	167	3.4	0.86	22	7	89
I7	59	128	165	3.6	0.89	24	4	84
I1	71	162	218	3.7	0.87	25	13	82
Mean	73	166	393	3.3	0.79	22	18	76
SE of Mean	3	10	44	0.1	0.02	1	1	1
Min	37	82	125	2.0	0.51	7	2	57
Max	146	289	1579	4.4	0.89	50	32	89

temporally, there were no apparent patterns relative to distance from the outfall.

Polychaete worms comprised the greatest proportion of species, accounting for 36–57% of the taxa per site during 2007. Crustaceans composed 9–32% of the species, molluscs from 8 to 20%, echinoderms from 2 to 10%, and all other taxa combined about 6–21%. These percentages are generally similar to those observed during previous years (e.g., see City of San Diego 2000, 2004).

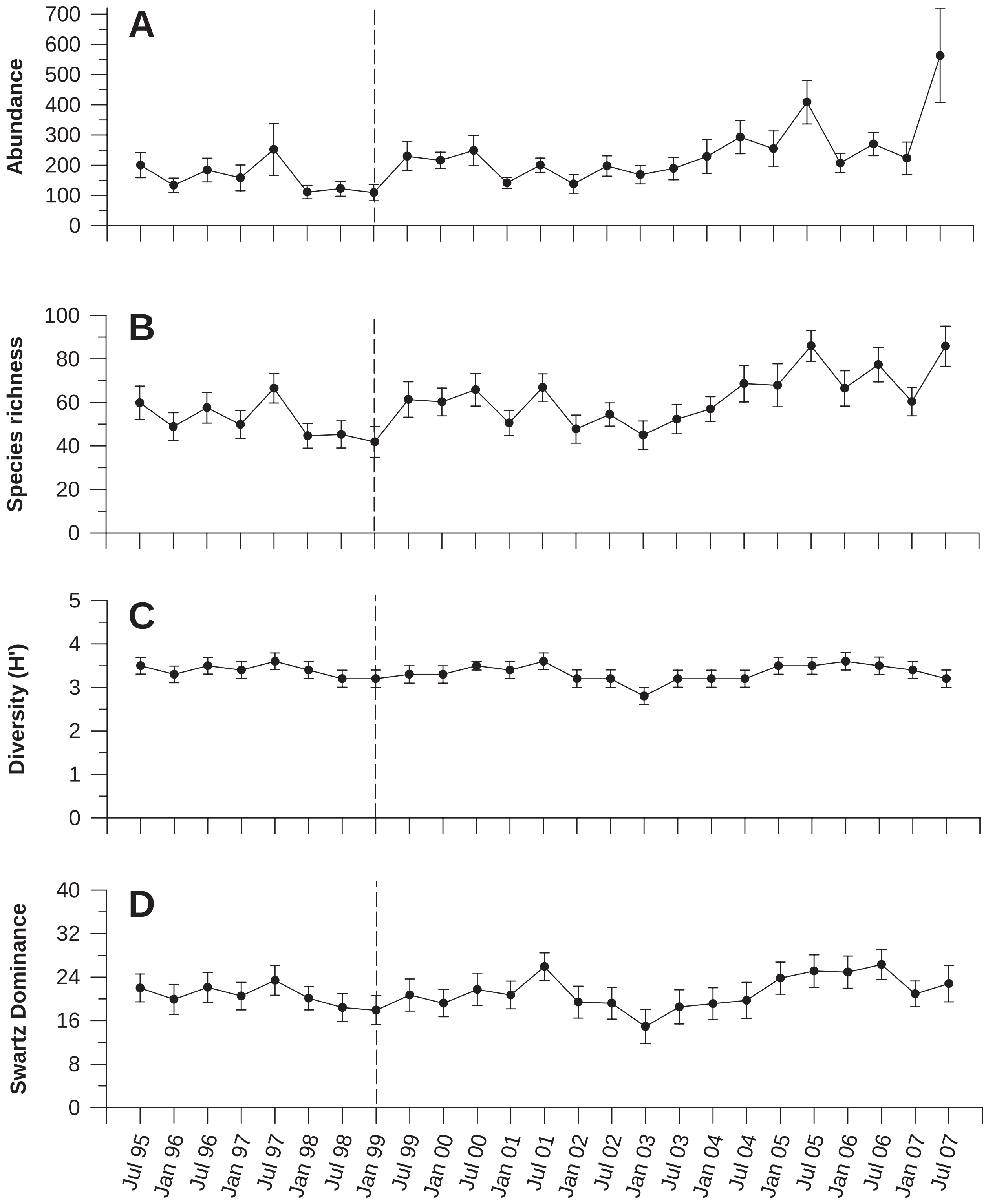


Figure 5.2

Summary of benthic community structure parameters surrounding the South Bay Ocean Outfall from 1995–2007: Abundance; Species richness; Diversity=Shannon diversity index (H'); Swartz dominance index; BRI=Benthic response index; ITI=Infaunal trophic index. Data are expressed as means per 0.1 m^2 pooled over all stations for each survey (n=54). Error bars represent 95% confidence limits. Dashed line indicates onset of discharge from the SBOO. Some stations from the winter 2007 survey (i.e., Jan 07) were sampled in March.

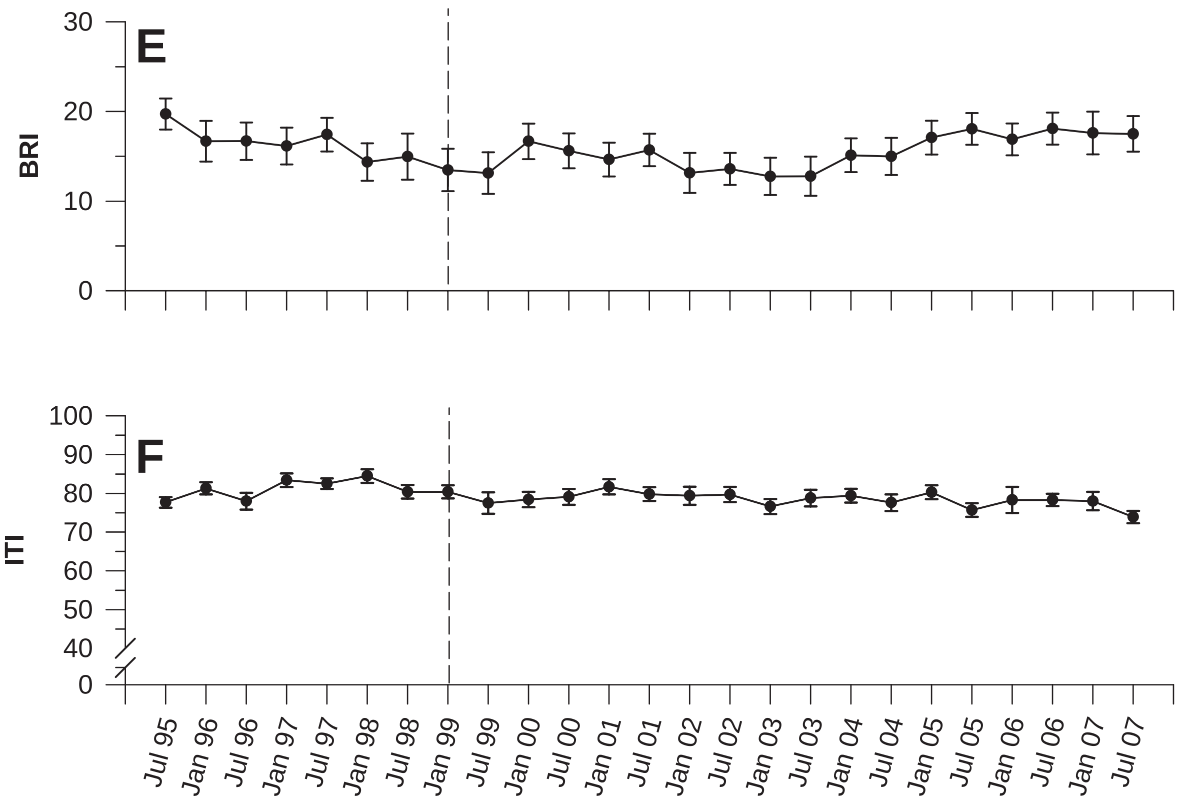


Figure 5.2 *continued*

Macrofaunal abundance

Macrofaunal abundance ranged from a mean of 125 to 1579 animals per 0.1 m^2 in 2007 (Table 5.1). The greatest number of animals occurred at stations I6 and I35, which averaged over 1500 and 800 individuals per sample, respectively. In contrast, station I2 averaged the fewest number of animals (125 per 0.1 m^2). Abundance averaged about 60% higher in summer than in winter (Figure 5.2A). Much of that increase was due to high abundances of the spionid polychaete *Spiophanes bombyx*, which accounted for 37% of all macrofauna collected in July 2007.

Polychaetes were the most abundant animals in the region, accounting for 41–95% of the different samples during 2007. Crustaceans averaged 2–44% of the animals at a station, molluscs averaged 1–16%, echinoderms averaged 0–8%, and all remaining taxa about 1–17% combined.

Species diversity and dominance

The Shannon diversity index (H') describes the abundance weighted number of different species in a sample. H' values increase with increasing number of species in a sample and with their increasing abundances. Diversity varied during 2007, ranging from 2.0 to 4.4 (Table 5.1). Average diversity values in the region generally were similar to previous years (Figure 5.2C), and there were no apparent patterns relative to distance from the outfall. Evenness compliments diversity in that it calculates the amount each species are represented in a sample. Higher J' values indicate that species are evenly distributed (i.e. not dominated by a few highly abundant species). The spatial patterns in evenness were similar to those for diversity and ranged from 0.51 to 0.89. Most sites with evenness values below the mean (0.79) were dominated by polychaetes.

Species dominance was measured 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). Consequently, the Swartz dominance index is

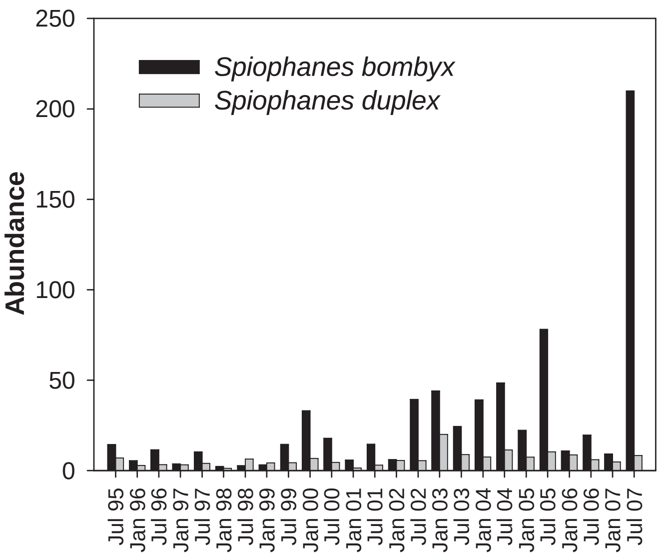


Figure 5.3

Abundance of the polychaetes *Spiophanes bombyx* and *Spiophanes duplex* for each survey at the SBOO benthic stations from July 1995 to July 2007. Data are expressed as mean number per 0.1 m^2, n≥44. Some stations from the winter 2007 survey (i.e., Jan 07) were sampled in March.

inversely proportional to numerical dominance, such that low index values indicate communities dominated by few species. Values at individual stations averaged from 7 to 50 species per station during the year (Table 5.1). This range reflects the dominance of a few species at some of the SBOO stations (I34, I3, and I4) versus other stations with many taxa contributing to the overall abundance (e.g., I28, I29). Dominance values for 2007 were similar to historical values (Figure 5.2D). No clear patterns relative to the outfall were evident in dominance values.

Environmental disturbance indices

Benthic response index (BRI) values averaged from 2 to 32 at the various SBOO stations during 2007 (Table 5.1). Index values below 25 (on a scale of 100) are considered to represent undisturbed communities or “reference conditions,” while those between 25–33 represent “a minor deviation from reference conditions,” and may reflect anthropogenic impact (Smith et al. 2001). Stations I9, I22, I33, and I35 were the only stations that had a BRI value above 25 (i.e., BRI=26–32). There was no gradient of BRI values relative to distance from the outfall, and index values at sites nearest the discharge do not suggest any deviation from reference conditions.

The infaunal trophic index (ITI) characterizes infaunal feeding groups within a sample and is used to model benthos response to organic enrichment. ITI averaged from 57 to 89 at the various sites in 2007 (Table 5.1). There were no patterns with respect to the outfall, and all values at sites nearest the discharge were characteristic of undisturbed sediments (i.e., ITI>60). The only ITI value below 60 was from station I4 (57), located south of the USA/Mexico border. This value was inconsistent with the BRI value of 2 for that station, suggesting that differences in indicator species used by each index can sometimes produce conflicting results (see Word 1980 and Smith et al. 2001 for a discussion of the species used to calculate each index). Average annual ITI among all sites has changed little since monitoring began (see Figure 5.2F).

Dominant Species

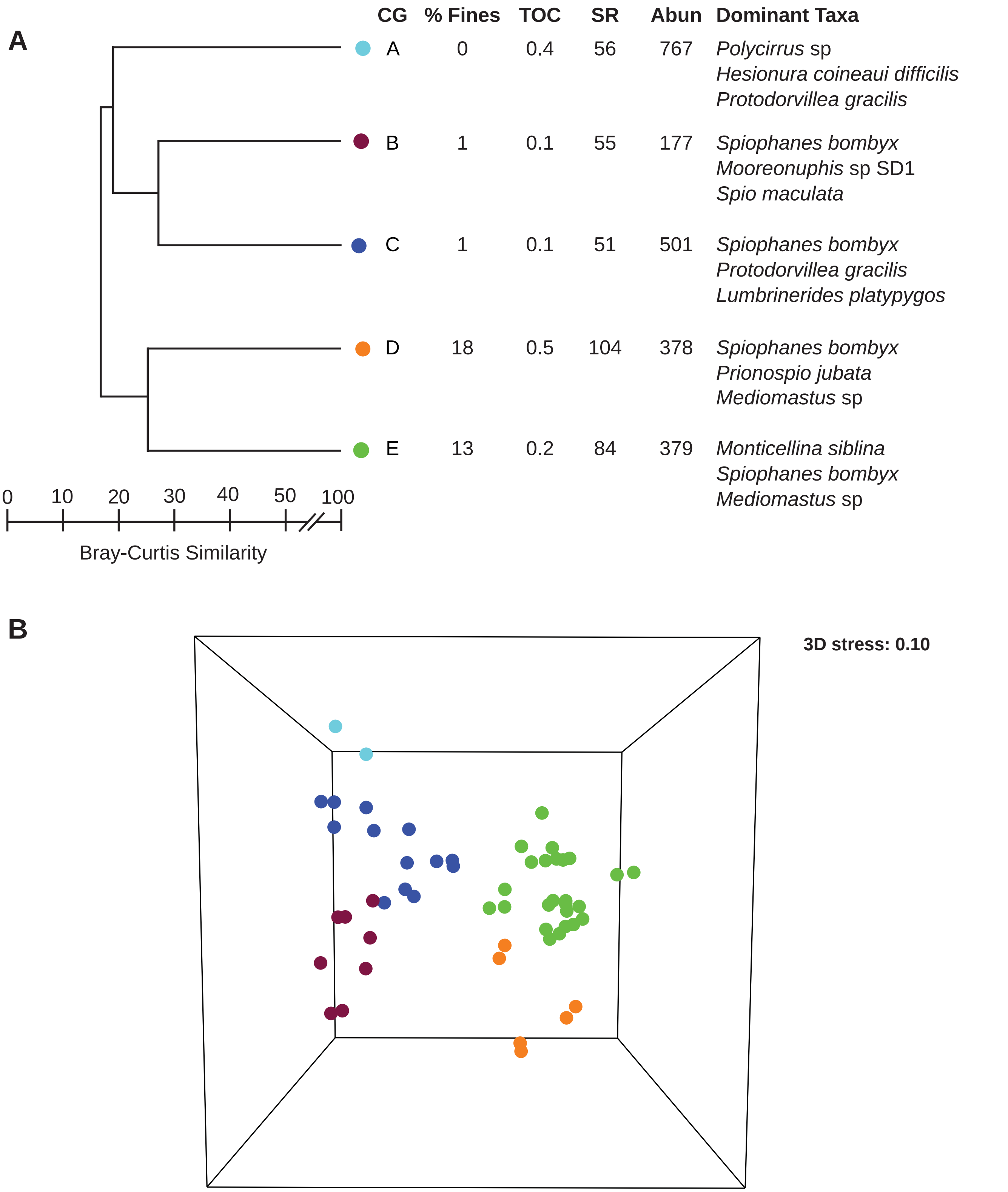
Most assemblages in the SBOO region were dominated by polychaete worms. For example, the list of dominant fauna in **Table 5.2** includes 18 polychaetes, three crustaceans, and nematodes.

The most abundant species collected was the spionid polychaete *Spiophanes bombyx*, which averaged 110 animals per sample. *S. bombyx* also was the most ubiquitous species, occurring in 98% of the samples. Overall, *S. bombyx* accounted for 28% of all individuals collected during 2007, which is much greater than in all previous surveys (**Figure 5.3**).

Polychaetes comprised all of the top ten most abundant species per occurrence (Table 5.2). In addition, the cirratulid polychaete *Monticellina siblina* and the phyllodocid polychaete *Hesionura coineaui difficilis* were found in relatively high numbers at only a few stations. Few macrobenthic species were widely distributed, and of these only *Spiophanes bombyx*, *Mediomastus* sp, *Scoloplos armiger*, and unidentified maldanid polychaetes and nematodes occurred in 80% or more of the samples. Two of the most frequently collected

Table 5.2
Dominant macroinvertebrates at the SBOO benthic stations sampled during 2007. The ten most frequently collected (or widely distributed) species, ten most abundant species overall, the ten most abundant species per occurrence are included. 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
Most frequently collected				
Spiophanes bombyx	Polychaeta: Spionidae	98	109.5	111.6
Mediomastus sp	Polychaeta: Capitellidae	83	11.5	13.8
Maldanidae	Polychaeta: Maldanidae	81	2.9	3.6
Nematoda	Nematoda	81	2.9	3.5
Scoloplos armiger complex	Polychaeta: Orbiniidae	80	2.3	2.9
Prionospio jubata	Polychaeta: Spionidae	78	4.4	5.7
Leptochelia dubia	Crustacea: Tanaidacea	78	4.2	5.4
Ampelisca cristata cristata	Crustacea: Amphipoda	78	3.5	4.5
Euphilomedes carcharodonta	Crustacea: Ostracoda	78	3.3	4.2
Onuphis sp A	Polychaeta: Onuphidae	74	2.4	3.2
Most abundant				
Spiophanes bombyx	Polychaeta: Spionidae	98	109.5	111.6
Monticellina siblina	Polychaeta: Cirratulidae	67	25.8	38.8
Mediomastus sp	Polychaeta: Capitellidae	83	11.5	13.8
Polycirrus sp	Polychaeta: Terebellidae	44	8.7	19.6
Spiophanes berkeleyorum	Polychaeta: Spionidae	67	7.8	11.7
Euclymeninae sp A	Polychaeta: Maldanidae	70	4.7	6.7
Protodorvillea gracilis	Polychaeta: Dorvilleidae	39	4.6	11.8
Prionospio jubata	Polychaeta: Spionidae	78	4.4	5.7
Nereis procera	Polychaeta: Nereididae	50	4.4	8.8
Apoprionospio pygmaea	Polychaeta: Spionidae	52	4.3	8.3
Most abundant per occurrence				
Spiophanes bombyx	Polychaeta: Spionidae	98	109.5	111.6
Monticellina siblina	Polychaeta: Cirratulidae	67	25.8	38.8
Saccocirrus sp	Polychaeta: Saccocirridae	7	1.6	22.0
Hesionura coineaui difficilis	Polychaeta: Phyllodocidae	19	3.6	19.7
Polycirrus sp	Polychaeta: Terebellidae	44	8.7	19.6
Mediomastus sp	Polychaeta: Capitellidae	83	11.5	13.8
Protodorvillea gracilis	Polychaeta: Dorvilleidae	39	4.6	11.8
Spiophanes berkeleyorum	Polychaeta: Spionidae	67	7.8	11.7
Eulalia sp SD1	Polychaeta: Phyllodocidae	4	0.4	11.5
Micropodarke dubia	Polychaeta: Hesionidae	4	0.4	10.8



CG	% Fines	TOC	SR	Abun	Dominant Taxa
A	0	0.4	56	767	*Polycirrus* sp *Hesionura coineaui difficilis* *Protodorvillea gracilis*
B	1	0.1	55	177	*Spiophanes bombyx* *Mooreonuphis* sp SD1 *Spio maculata*
C	1	0.1	51	501	*Spiophanes bombyx* *Protodorvillea gracilis* *Lumbrinerides platypygos*
D	18	0.5	104	378	*Spiophanes bombyx* *Prionospio jubata* *Mediomastus* sp
E	13	0.2	84	379	*Monticellina siblina* *Spiophanes bombyx* *Mediomastus* sp

Figure 5.4

(A) Cluster results of the macrofaunal abundance data for the SBOO benthic stations sampled during winter and summer 2007. Data 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.

species were also among the top ten taxa in terms of abundance (i.e., *S. bombyx* and *Mediomastus* sp).

Multivariate Analyses

Classification analysis discriminated between five habitat-related benthic assemblages (cluster groups A–E) during 2007 (**Figure 5.4**). These assemblages differed in terms of their species composition, including the specific taxa present and their relative abundances. An MDS ordination of the station/survey entities confirmed the validity of cluster groups A–E (Figure 5.4). These analyses identified no significant patterns regarding proximity to the discharge site but showed some separation based on depth gradients (**Figure 5.5**). Further, the distribution of cluster groups varied based on sediment types, and to some degree, total organic carbon (**Figure 5.6**). The dominant species composing each group are listed in **Table 5.3**.

Cluster group A represented the winter and summer surveys for station I34 located along the 19-m contour. Sediments for these samples were comprised almost entirely of sand and coarse materials (i.e., <1% fines). Species richness averaged 56 taxa and 767 individuals per 0.1 m^2. Total organic carbon (TOC) concentrations for the sediment samples from this site averaged 0.4%. The polychaete *Polycirrus* sp was the most abundant species in the group. As in previous years this assemblage was somewhat unique for the region (see City of San Diego 2006, 2007); it was dominated by nematode worms and several polychaete species commonly found in sediments with coarse particles and/or high organic content (e.g., *Hesionura coineaui difficilis*, *Protodorvillea gracilis*, and *Pisione* sp).

Cluster group B comprised two stations located along the 55-m depth contour and at two stations along the 38-m contour. Sediments at these mid-shelf sites contained <1% of fine particles. TOC concentrations for this group averaged 0.1%. The group B assemblage was characterized by the second lowest species richness and lowest abundance, averaging 55 taxa and 177 individuals per 0.1^2 m. The

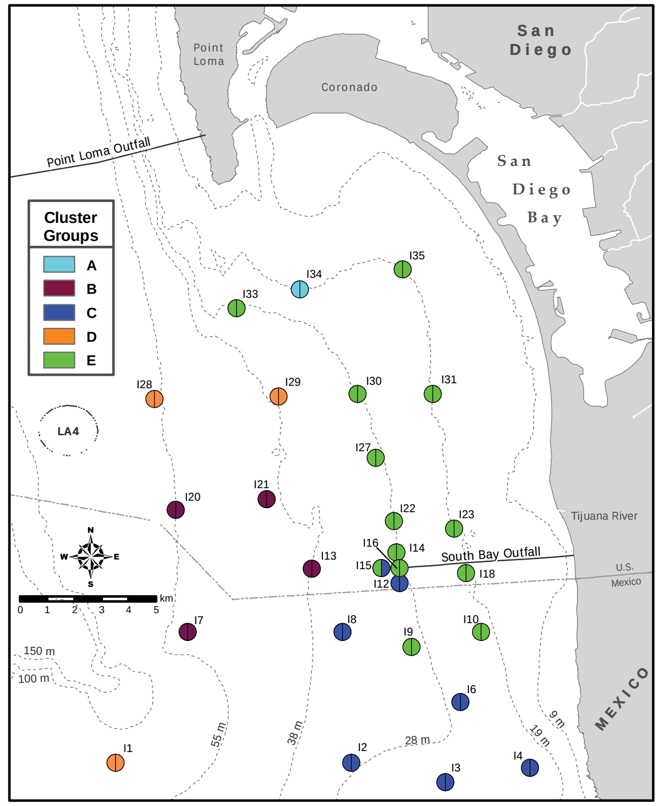


Figure 5.5

Results of ordination and classification analyses of macrofaunal abundance data during 2007. Cluster groups are color-coded on the map to reveal spatial patterns in the distribution of benthic assemblages.

three most abundant species were the polychaetes *Spiophanes bombyx*, *Mooreonuphis* sp SD1, and *Spio maculata*.

Cluster group C comprised sites that were located on or near the 28-m depth contour, mostly located south of the SBOO. Sediments at these sites had a low percentage of fines, with some stations containing relict red sands and shell hash. TOC concentrations at group C were low (0.1%). The group C assemblage averaged 51 taxa and 501 individuals per 0.1 m^2. *Spiophanes bombyx* was numerically dominant in this group, foll-owed by the polychaetes *Protodorvillea gracilis* and *Lumbrinerides platypygos*.

Cluster group D comprised stations located along the 38-m and 55-m contour that were characterized by mixed sediments (i.e., coarse particles, fines, and relict red sand). TOC concentrations for this

Table 5.3

Summary of the most abundant taxa composing cluster groups A–E from the 2007 surveys of SBOO 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.

		Cluster Group				
Species/Taxa	Taxa	A (2)	B (8)	C (13)	D (6)	E (25)
Ampelisca agassizi	Crustacea	—	—	—	11.4	0.9
Ampelisca careyi	Crustacea	—	—	—	5.1	—
Ampelisca cristata cristata	Crustacea	—	7.4	2.3	—	—
Apoprionospio pygmaea	Polychaeta	—	—	0.8	—	8.6
Axinopsida serricata	Mollusca	—	—	—	10.7	—
Branchiostoma californiense	Chordata	33.5	—	1.2	0.7	—
Cnemidocarpa rhizopus	Chordata	—	1.8	3.6	—	—
Dendraster terminalis	Echinodermata	—	0.5	5.4	—	—
Euclymeninae sp A	Polychaeta	—	0.6	—	—	8.7
Eusyllis sp SD2	Polychaeta	—	7.9	—	0.5	—
Hesionura coineaui difficilis	Polychaeta	**84.3**	0.6	0.7	2.5	—
Lanassa venusta venusta	Polychaeta	—	4.6	—	—	—
Leptochelia dubia	Crustacea	25.8	1.8	4.3	9.7	1.8
Lumbrinerides platypygos	Polychaeta	—	—	**6.9**	—	—
Mediomastus sp	Polychaeta	—	0.6	1.6	**12.1**	**20.8**
Monticellina siblina	Polychaeta	—	—	3.4	4.9	**52.9**
Mooreonuphis sp SD1	Polychaeta	—	**10.9**	0.9	0.8	—
Nematoda	Nematoda	31.5	1.3	2.2	1.9	1.7
Nereis procera	Polychaeta	—	—	0.6	—	9.1
Pisione sp	Polychaeta	22.3	—	—	0.8	—
Polycirrus sp	Polychaeta	**214.5**	3.5	—	0.5	—
Prionospio jubata	Polychaeta	—	1.0	0.5	**12.3**	6.1
Protodorvillea gracilis	Polychaeta	**61.0**	2.1	**8.2**	—	—
Saccocirrus sp	Polychaeta	40.3	—	—	1.3	—
Scoloplos armiger complex	Polychaeta	—	—	6.5	—	—
Spio maculata	Polychaeta	—	**9.8**	4.4	4.0	—
Spiophanes berkeleyorum	Polychaeta	—	3.4	2.7	4.7	13.2
Spiophanes bombyx	Polychaeta	13.8	**18.8**	**348.2**	**21.4**	**43.2**
Spiophanes duplex	Polychaeta	—	0.8	—	11.8	6.1
Syllis sp SD1	Polychaeta	23.0	2.8	—	—	—

group averaged 0.5%. This group averaged 104 taxa and 378 individual organisms per 0.1 m^2. Polychaetes numerically dominated this group, with *Spiophanes bombyx*, *Prionospio jubata*, and *Mediomastus* sp comprising the three most abundant taxa.

Cluster group E included sites primarily located along the 19 and 28-m depth contours, where sediments contained the second highest amount of fine particles (13% fines). TOC concentrations at stations within this group averaged 0.2%. This assemblage averaged 84 taxa and 379 individuals

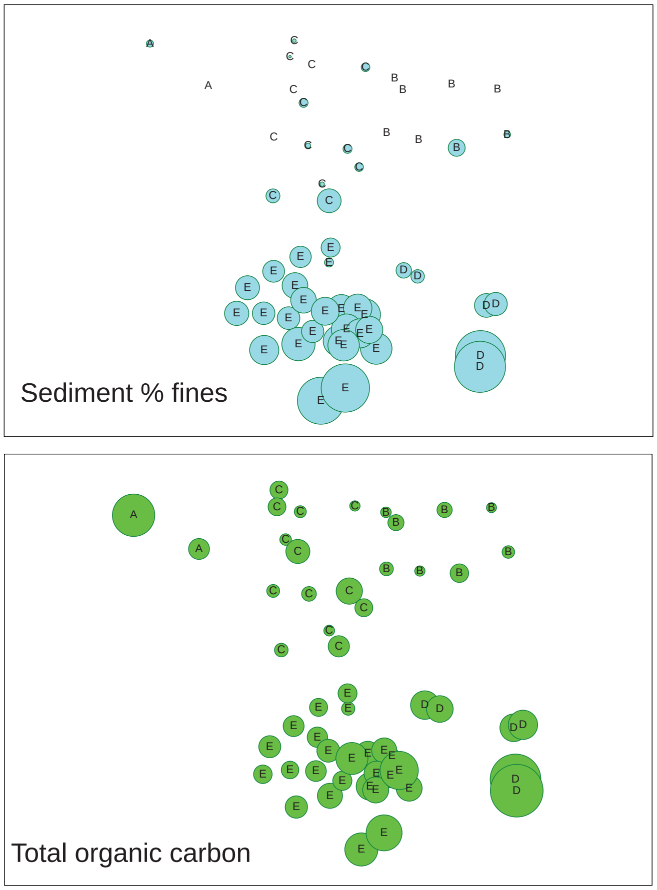


Figure 5.6
MDS ordination of SBOO benthic stations sampled during winter and summer 2007. Cluster groups A–E are superimposed on station/surveys. Percentages of fine particles and total organic carbon in the sediments are further superimposed as circles that vary in size according to the magnitude of each value. Plots indicate associations of benthic assemblages with habitats that differ in sediment grain size. Stress=0.15.

per 0.1 m^2. The numerically dominant species in this group were the polychaetes *Monticellina siblina*, *Spiophanes bombyx*, and *Mediomastus* sp.

Summary and Conclusions

Benthic macrofaunal assemblages surrounding the SBOO were similar in 2007 to those that occurred during previous years including the period before initiation of wastewater discharge (e.g., see City of San Diego 2000, 2007). In addition, these assemblages were typical of those occurring in other sandy, shallow- and mid-water habitats throughout the Southern California Bight (SCB) (e.g., Thompson et al. 1987, 1993b, City of San Diego 1999, Bergen et al. 2001). For example, assemblages found at the majority of stations (e.g., groups C and E) contained high numbers of the spionid polychaete *Spiophanes bombyx*, a species characteristic of shallow-water environments in the SCB (see Bergen et al. 2001). These two groups represented sub-assemblages of the shallow SCB benthos that differed in the relative abundances of dominant and co-dominant species. Such differences probably reflect variation in sediment structure. Consistent with historical values, sediments in the shallow SBOO region generally were coarser south of the outfall relative to northern stations (see Chapter 4). In contrast, the group B assemblage occurs in mid-depth shelf habitats that probably represent a transition between the shallow sandy sediments common in the area and the finer mid-depth sediments characteristic of much of the SCB mainland shelf (see Barnard and Ziesenhenne 1961, Jones 1969, Fauchald and Jones 1979, Thompson et al. 1987, 1993a, b, EcoAnalysis et al. 1993, Zmarzly et al 1994, Diener and Fuller 1995, Bergen et al. 2001). A second mid-depth assemblage (group D) occurred where black coarse sands and relict red sands were present. Polychaetes dominated group D, including the ubiquitous *S. bombyx*. The group A assemblage at station I34 was different from assemblages found at any other station. Nematode worms and several species of polychaetes (i.e., *Polycirrus* sp, *Protodorvillea gracilis*, *Hesionura coineaui difficilis*, *Saccocirrus* sp, *Syllis* (*Typosyllis*) sp SD1, and *Pisione* sp) in these samples were not common elsewhere in the region. This assemblage is similar to that sampled previously at station I34 in 2003, 2004, 2005, and 2006. Analysis of the sediment chemistry data provides some evidence to explain the occurrence of this assemblage (Figure 5.6) as mean sediment grain sizes were the highest measured among all stations for 2007 (see Chapter 4). The presence of animals associated with coarse sediments and/or high organic content can reflect the variation in microhabitats or the amounts of shell hash and organic detritus at a site.

Results from multivariate analyses revealed no clear spatial patterns relative to the outfall. Comparisons of the biotic data to the physico-chemical data indicated that macrofaunal distribution and abundance in the region varied primarily along gradients of sediment type and depth and to a lesser degree, organic carbon (see Hyland et al. 2005 for a discussion on TOC as an indicator of benthos stress). Numbers of *Spiophanes bombyx* collected during 2007 were the highest recorded since monitoring began in 1995. The high numbers of this species influenced overall abundance values in the SBOO region. Patterns of region-wide abundance fluctuations over time appear to mirror historical abundance patterns of *S. bombyx* (see Figures 5.2A and 5.3). However, temporal fluctuations in the populations of this and similar taxa occur elsewhere in the region and often correspond to large-scale oceanographic conditions (see Zmarzly et al. 1994). Overall, temporal patterns suggest that the benthic community has not been significantly impacted by wastewater discharge via the SBOO. For example, while mean values for species richness and abundance during 2007 were at their historical highs, they were still similar to those seen in previous years (see City of San Diego 2005, 2006, 2007). In addition, environmental disturbance index values such as the BRI and ITI generally were characteristic of assemblages from undisturbed sediments.

Anthropogenic impacts have spatial and temporal dimensions that can vary depending on a range of biological and physical factors. Such impacts can be difficult to detect, and specific effects of the SBOO discharge on the macrobenthos could not be identified during 2007. Furthermore, benthic invertebrate populations exhibit substantial spatial and temporal variability that may mask the effects of any disturbance event (Morrisey et al. 1992a, b, Otway 1995). Although some changes have occurred near the SBOO over time, benthic assemblages in the area remain similar to those observed prior to discharge and to natural indigenous communities characteristic of similar habitats on the southern California continental shelf.

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