Chapter 5. Macrobenthic Communities

Introduction

Small invertebrates (macrofauna) that live within or on the surface of soft-bottom habitats are monitored by the City of San Diego (City) to examine potential effects of wastewater discharge on the marine benthos from both the Point Loma and South Bay Ocean Outfalls (PLOO and SBOO, respectively). These benthic macrofauna are targeted for monitoring because they are known to play critical ecological roles in marine environments along the Southern California Bight (SCB) coastal shelf, serving vital functions in wide ranging capacities (Fauchald and Jones 1979, Thompson et al. 1993a, Snelgrove et al. 1997). In conjunction with their ecological importance, many benthic species are relatively stationary and long-lived and they integrate the effects of pollution or disturbance over time (Hartley 1982, Bilyard 1987). Various species also respond differently to environmental stressors, and monitoring changes in their populations or communities can help identify locations of anthropogenic impact (Pearson and Rosenberg 1978, Bilyard 1987, Warwick 1993, Smith et al. 2001). For example, species tolerant to pollution are often opportunistic and their populations predictably outcompete others in impacted environments, whereas pollution-sensitive species decrease in response to toxic contamination, oxygen depletion, nutrient loading, or other forms of environmental degradation (Gray 1979). Consequently, assessment of benthic community structure has become a major component of many ocean monitoring programs.

The structure of marine macrobenthic communities is influenced by natural factors such as ocean depth, sediment composition (e.g., percent of fine vs. coarse sediments), sediment quality (e.g., contaminant loads, toxicity), oceanographic conditions (e.g., temperature, dissolved oxygen and nutrient levels, currents), and biological interactions (e.g., competition, predation). For example, assemblages on the SCB coastal shelf typically vary along depth gradients and/or with sediment grain size (Bergen et al. 2001). Therefore, an understanding of background or reference conditions is necessary before determining whether observed differences in community structure may be related to anthropogenic activities. Pre-discharge or regional monitoring efforts by the City and other agencies since 1994 provide baseline information on spatial variability of invertebrate communities in the San Diego region critical for comparative analysis (e.g., see Chapter 9 herein and City of San Diego 1999, 2011, Ranasinghe et al. 2003, 2007, 2010, 2012).

To detect potential wastewater impacts on invertebrate communities, the City relies on a suite of scientifically-accepted community parameters and statistical analyses. Indices such as the Benthic Response Index (BRI), the Shannon diversity index, and Swartz dominance are used as metrics of invertebrate community structure, while multivariate analyses are used to detect spatial and temporal differences among communities (e.g., Warwick 1993, Smith et al. 2001). The use of multiple analyses provides better resolution than single parameters and some include established benchmarks for determining anthropogenically-induced environmental impacts. For example, the BRI was developed specifically for use in the SCB, which enhances its interpretability for the region. All together, the data are used to determine whether invertebrate populations in the San Diego region are similar to populations from habitats with similar depth and sediment characteristics, or whether observable impacts from outfalls or other sources occur. Minor organic enrichment caused by wastewater discharge should be evident through an increase in species richness and abundance, whereas major impacts to the environment will eventually lead to decreases in overall species diversity and richness coupled with dominance of a few pollution tolerant species (Pearson and Rosenberg 1978). Additionally, high BRI values (>34) will typically occur in impacted areas. This weight-of-evidence approach is the basis by which the City attains its monitoring objectives.

This chapter presents analyses and interpretations of the macrofaunal data collected during 2011 at fixed benthic monitoring stations surrounding the SBOO. Included are descriptions of benthic community structure and comparisons of the different invertebrate communities in the region. The primary goals are to: (1) document the benthic macrofaunal communities present during the year, (2) determine the presence or absence of biological impacts associated with wastewater discharge, and (3) identify other potential natural and anthropogenic sources of variability to the local marine ecosystem.

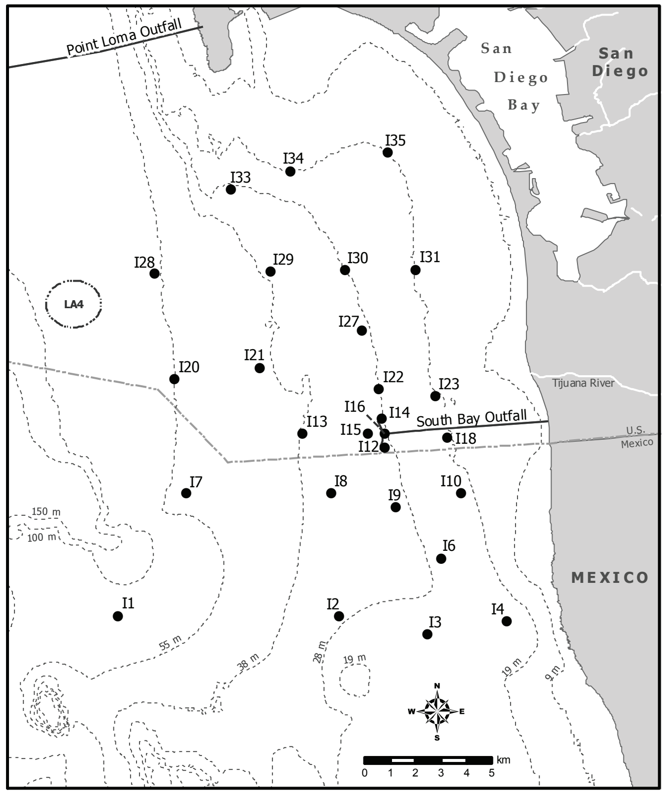


Figure 5.1
Benthic station locations sampled around the South Bay Ocean Outfall as part of the City of San Diego's Ocean Monitoring Program.

Materials and Methods

Collection and Processing of Samples

Benthic samples were collected at 27 stations in the SBOO region during January and July 2011 (Figure 5.1). These stations range in depth from 18 to 60 m and are distributed along or adjacent to four main depth contours. The four stations considered to represent "nearfield" conditions (i.e., I12, I14, I15, I16) are located within 1000 m of the outfall wye.

Two replicate samples for benthic community analyses were collected per station during each survey using a double 0.1-m^2 Van Veen grab. The first sample was used for analysis of macrofauna, while the adjacent grab in the same cast was used for sediment quality analysis (see Chapter 4). A second macrofaunal grab was then collected from a subsequent cast. Criteria established by the USEPA to ensure consistency of grab samples were followed with regard to sample disturbance and depth of penetration (USEPA 1987). All samples were sieved aboard ship through a 1.0-mm mesh screen. Macrofaunal organisms retained on the screen were collected and relaxed for 30 minutes in a magnesium sulfate solution and then fixed with buffered formalin. After a minimum of 72 hours, each sample was rinsed with fresh water and transferred to 70% ethanol. All macrofauna were sorted from the raw sample into major taxonomic groups by a subcontractor, returned to the City of San Diego Marine Biology Laboratory, and then identified to species (or the lowest taxon possible) and enumerated by staff marine biologists. All identifications followed current nomenclatural standards established by the Southern California Association of Marine Invertebrate Taxonomists (SCAMIT 2011).

Data Analyses

Samples from each grab were considered independent replicates, even if retrieved from the same station. 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), and benthic response index (BRI; see Smith et al. 2001). Additionally, the total or cumulative number of species over all grabs was calculated for each station.

To further examine spatial patterns among benthic communities in the SBOO region, multivariate analyses were conducted using PRIMER (Clarke and Warwick 2001, Clarke and Gorley 2006). Macrofaunal abundance data were square-root transformed to lessen the influence of common species and increase the importance of rare species, and a Bray-Curtis similarity matrix was created using depth stratum (i.e., inner and mid-shelf), and sediment type (see Appendix C.2) as factors. A 2-way crossed ANOSIM (maximum number of permutations = 9999) was conducted to determine whether communities varied by depth and/or sediment type across the region. To visually depict the relationship of individual grab samples to each other based on macrofaunal composition, a cluster dendrogram was created. Similarity profile (SIMPROF) analysis was used to confirm non-random structure of resultant clades in the dendrogram (Clarke et al. 2008), and major ecologically-relevant clusters supported by SIMPROF were retained at > 32.2% similarly. Similarity percentages (SIMPER) analyses were used to determine which organisms were responsible for the greatest contribution to within-group similarities (i.e. characteristic species), and to identify which species accounted for: (1) significant differences identified through ANOSIM, and (2) differences among clades occurring in the dendrogram.

Results

Community Parameters

Species richness

A total of 822 taxa were identified during the 2011 SBOO surveys. Of these, 539 taxa (66%) were identified to species level, 203 to genus, 42 to family, 19 to order, 15 to class, and 4 to phylum. Most taxa occurred at multiple sites, although about 21% (*n* = 172) represented unique taxa recorded only once. Three species new to the San Diego region were collected: the sigalionid polychaete *Sthenelais berkeleyi*, the sabellid polychaete *Pseudofabriciola californica*, and the gastropod *Astyris gausapata*. From 1995 to 2010, species richness in the region has ranged from 16 to 172 taxa per sample, with a mean of 62 taxa per 0.1 m^2 grab. Average species richness in 2011 was within this historical range, with a low of 45 taxa per grab at farfield stations I2 and I18 to a high of 158 taxa per grab at farfield station I28 (Table 5.1). Although the number of species occurring per site varied spatially, there were no apparent patterns relative to distance from the discharge site (Figure 5.2A).

Macrofaunal abundance

A total of 37,695 macrofaunal individuals were identified in 2011, with mean abundance values ranging from 118 to 579 animals per 0.1 m^2 (Table 5.1). The greatest number of animals occurred at farfield station I28, the same station that also possessed the highest species richness. Similarly, the fewest number of animals occurred at station I18 that also had the lowest species richness. No spatial patterns in abundance related to the outfall were observed, and substantial overlap existed among sites from different depth contours. Overall, values from 2011 are within range of historical data collected from 1995–2010, where total macrofaunal abundance varied from 39 to 1579 individuals with an average of 248 animals per 0.1 m^2.

Macrofaunal abundances across the region increased starting in 2007, and subsequent observed fluctuations were primarily associated with variation in *Spiophanes norrisi* populations (Figures 5.2B, 5.3; see Chapter 9). Since this trend in macrofaunal abundance was observed at both nearfield and farfield stations (Figure 5.2B), variation in *S. norrisi* abundances represents a regional trend that is not likely caused by outfall impacts. Starting in 2011, populations of *S. norrisi* and overall macrofaunal abundance

Table 5.1

Summary of macrofaunal community parameters for SBOO benthic stations sampled during 2011. Tot Spp = cumulative no. species for the year; SR = species richness (no. species/0.1 m^2); Abun = abundance (no. individuals/0.1 m^2); H' = Shannon diversity index; J' = evenness; Dom = Swartz dominance; BRI = benthic response index. Data for each station are expressed as annual means (n = 4 grabs) except Tot Spp (n = 1). Stations are listed north to south from top to bottom.

Station		Tot Spp	SR	Abun	H'	J'	Dom	BRI
19-m Stations								
I35		183	87	276	3.9	0.88	33	30
I34		167	62	562	2.2	0.53	6	14
I31		117	50	128	3.3	0.86	22	21
I23		194	69	513	3.4	0.81	22	21
I18		110	45	118	3.2	0.85	20	20
I10		154	74	183	3.9	0.90	33	20
I4		141	55	170	3.3	0.83	21	13
28-m Stations								
I33		204	99	378	3.7	0.81	32	26
I30		178	86	229	4.0	0.89	36	26
I27		151	68	178	3.7	0.87	28	25
I22		246	116	426	4.0	0.85	40	27
I14[a]		160	72	205	3.6	0.84	29	25
I16[a]		161	67	374	2.8	0.67	16	21
I15[a]		200	79	366	3.3	0.77	20	24
I12[a]		252	104	529	3.5	0.75	23	24
I9		224	115	465	4.1	0.87	38	25
I6		126	56	535	2.1	0.53	7	15
I2		101	45	206	2.7	0.71	12	19
I3		111	50	477	2.3	0.58	7	16
38-m Stations								
I29		296	126	552	4.0	0.82	36	22
I21		151	62	319	3.3	0.80	18	10
I13		168	67	335	3.1	0.75	17	14
I8		133	61	306	2.9	0.72	14	21
55-m Stations								
I28		320	158	579	4.3	0.86	52	16
I20		234	103	527	3.7	0.79	26	10
I7		143	61	201	3.4	0.82	20	9
I1		203	92	288	4.0	0.88	34	16
All Grabs	Mean	179	79	349	3.4	0.79	24	20
	95% CI	22	6	41	0.13	0.02	2	1.2
	Minimum	101	38	64	1.3	0.31	1	6
	Maximum	320	182	1425	4.5	0.97	57	31

[a] nearfield station

appears to be returning to lower historical means observed prior to 2007.

Species diversity, evenness, and dominance

Average species diversity (H') ranged from 2.1 at station I6 to 4.3 at station I28 during 2011 (Table 5.1). Historically, H' values have mostly been similar between nearfield and farfield stations (Figure 5.2C). Evenness (J') compliments diversity, with higher J' values (on a scale of 0–1) indicating that species are more evenly distributed and that the community is not dominated by a few highly abundant species. During 2011, J' values averaged between 0.53 at stations I6 and I34 and 0.9 at station I10 with spatial patterns similar to those for diversity (Figures 5.2C, D). Swartz dominance values averaged from 6 to 52 species per station during the year (Table 5.1). This range reflects the dominance of a few species at some sites (e.g., low values at stations I3, I6, and I34) versus other stations where many taxa contributed to the overall abundance (e.g., high values at stations I22 and I28).

Benthic response index

Benthic response index (BRI) values are an important tool for gauging possible anthropogenic impacts to marine environments throughout the SCB. Values below 25 are considered indicative of reference conditions, values within 25–33 represent "a minor deviation from reference conditions" that should be corroborated with additional information, while values ≥34 represent different levels of degradation (Smith et al. 2001). Historically, mean BRI values at the four nearfield stations in the SBOO region have been similar to mean values for 28-m contour farfield stations (Figure 5.2F), suggesting no immediate impact of the SBOO on the marine environment. In 2011, seven sites across the SBOO monitoring region possessed BRI values between 25 to 30. As in previous years, farfield station I35, located on the 19-m depth contour near the mouth of San Diego Bay, had the highest average BRI value encountered (BRI = 30). All remaining sites possessing values ≥25 were situated along the 28-m isobath where sediments differ from the surrounding area (see Chapter 4). Of these sites, I14 was the only nearfield site to possess a value of 25, with all remaining sites representing farfield stations situated north (four sites) or south (one site) of the outfall. Sites located along the 55-m depth contour exhibited among the lowest BRI values, with site I7 possessing the lowest value (BRI = 9) recorded for 2011.

Dominant Species

Macrofaunal communities in the SBOO region were dominated by polychaete worms in 2011, which accounted for 45% of all species collected (Table 5.2). Crustaceans accounted for 24% of species reported, while molluscs, echinoderms, and all other taxa combined accounted for the remaining 17%, 3%, and 11%, respectively. Polychaetes were also the most numerous animals, accounting for 71% of the total abundance. Crustaceans accounted for 14% of the animals collected, molluscs 6%, echinoderms 3%, and the remaining phyla 6%. Overall, the above distributions were very similar to those observed in 2010 (see City of San Diego 2011).

The 10 most abundant macroinvertebrates sampled during the year were all polychaetes (Table 5.3). The most abundant species was the spionid *Spiophanes norrisi*, which averaged 75 individuals per sample and occurred at 98% of the stations. Although widely distributed, *S. norrisi* abundances varied considerably among sites (range: 1–898). For example, four stations (I3, I6, I16, and I34) supported higher abundances of this species than the other sites, with a combined abundance of 3958 individuals out of a total of 8068 reported for the entire SBOO region. Overall, *S. norrisi* accounted for about 21% of the macrobenthic fauna sampled during 2011 and has been the most abundant species collected since monitoring began (Figure 5.3). Few other species were as ubiquitous as *S. norrisi* (Table 5.3), with only two other taxa, the chaetopterid and orbiniid polychaetes *Spiochaetopterus costarum* and *Scoloplos armiger* (both species complexes), respectively, occurring in at least 80% of the samples.

Some of the most abundant species collected in 2011 have been dominant in past years as well. For example, the capitellid polychaete *Mediomastus* sp and cirratulid polychaete *Monticellina siblina* were among the five most abundant taxa collected both historically and in 2011 (Figure 5.3). In contrast, other species occur in relatively high abundances only occasionally, and are often limited in distribution. For example, in 2011, the saccocirrid polychaete *Saccocirrus* sp occurred in abundances exceeding 220 individual/grab at station I23, but never occurred in densities >7 individuals/grab at any other station.

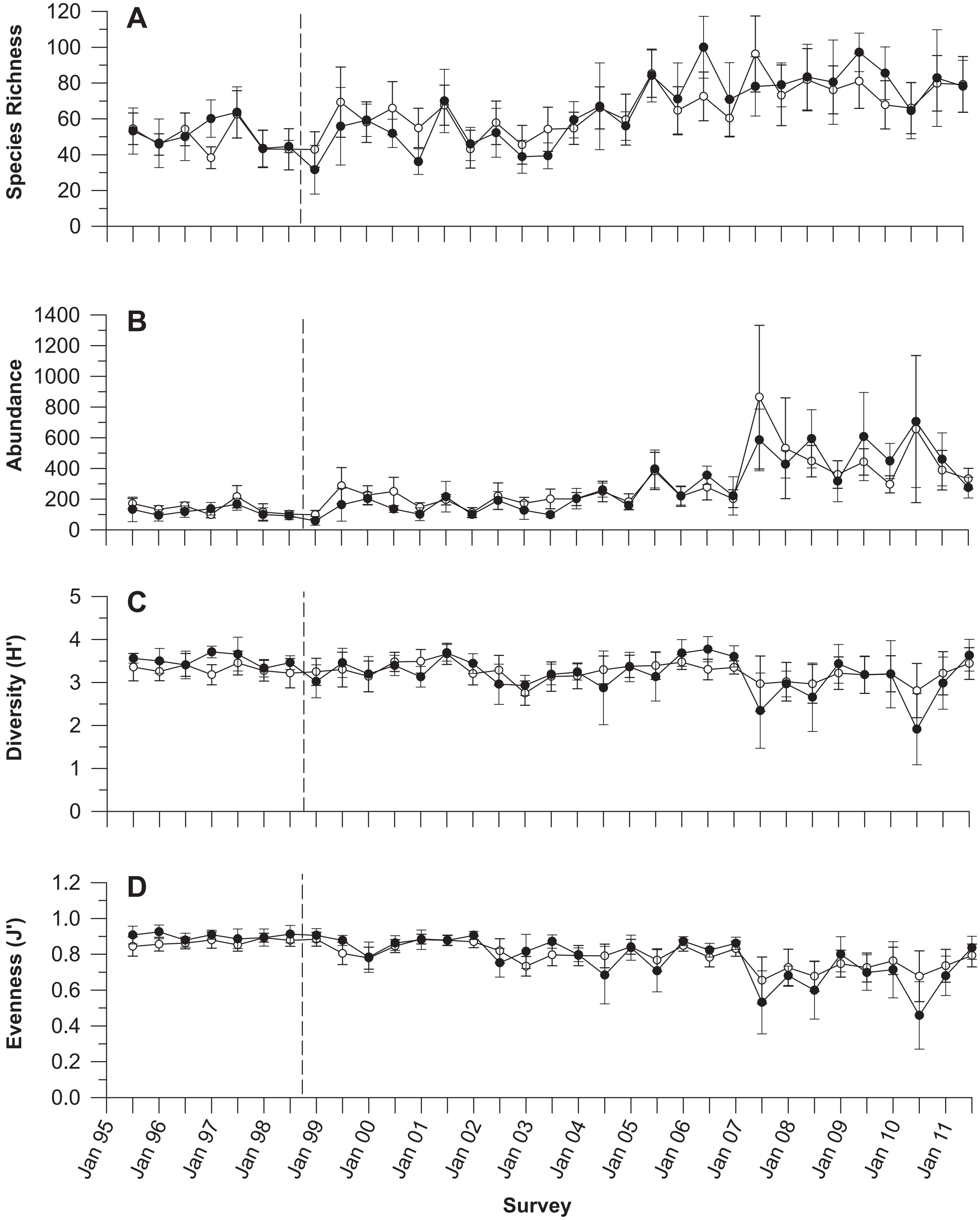


Figure 5.2

Macrofaunal community parameters at SBOO 28-m benthic stations sampled between 1995–2011. Data are expressed as means ± 95% confidence intervals per 0.1 m^2 pooled over nearfield station grabs (filled circles; $n = 8$) versus farfield station grabs (open circles; $n = 16$) for each survey. Dashed lines indicate onset of discharge from the SBOO.

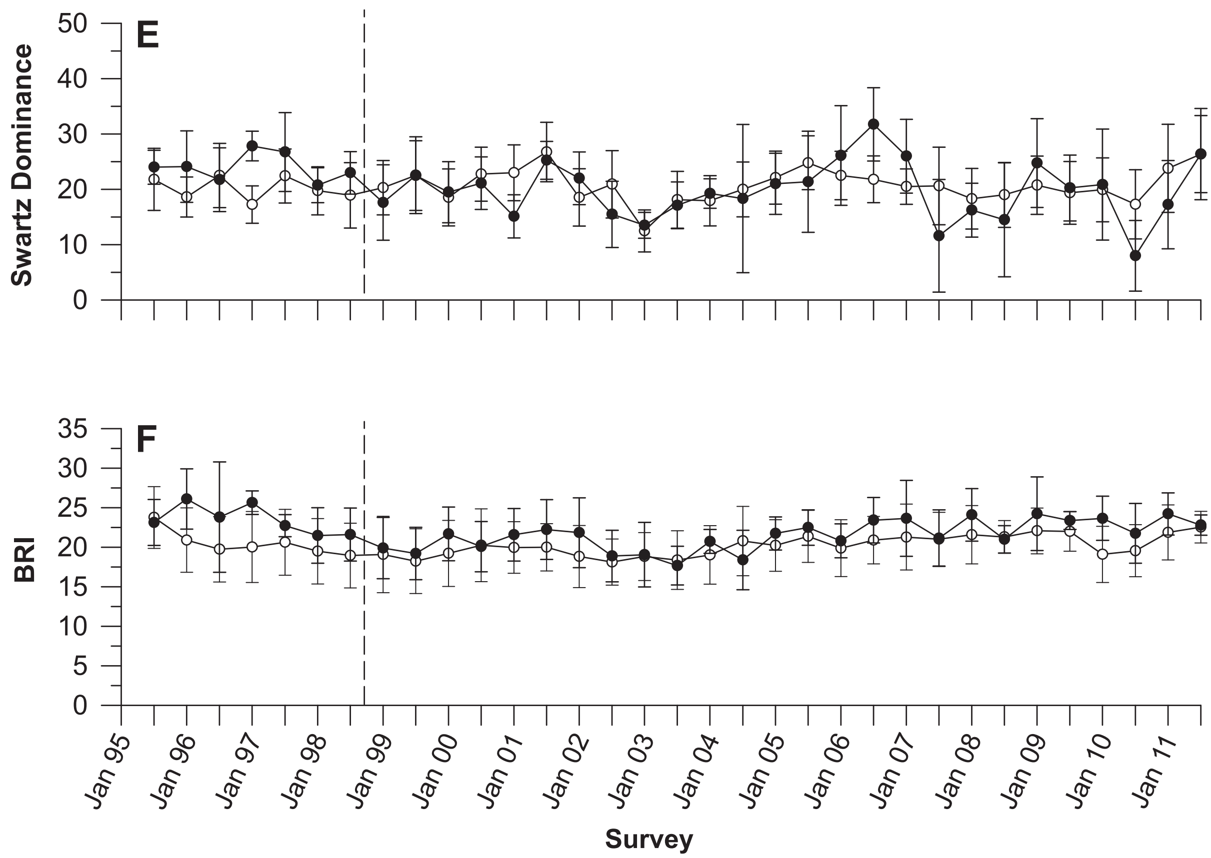


Figure 5.2 *continued*

Classification of Macrobenthic Assemblages

ANOSIM results revealed that benthic invertebrate communities in the South Bay outfall region differed significantly between inner shelf and mid-shelf depth strata and by sediment type (Appendix D.1). Differences between depth strata were due to minor variations in abundance of many common taxa rather than the presence or absence of discrete species. Similarly, relative abundances of common species such as *S. norrisi* were cumulatively responsible for the majority of differences among sediment types, the one exception to this generalization being coarse sediments with substantial sand fractions and high amounts of shell hash. These coarse sediments housed a unique fauna dissimilar from other sediment types, and were characterized by high population numbers of nematodes and the polychaetes *Hesionura coineaui difficilis*, *Pareurythoe californica*, *Pisione* sp, and *Saccocirrus* sp (see Cluster Group G description below). Pair-wise comparisons indicated the only two sediment types not to possess statistically distinct invertebrate communities were sand with a substantial fraction of fines, and sand with substantial fractions of both fine and coarse sediments.

Discrimination of cluster groups

Classification (cluster) analysis discriminated nine ecologically-relevant SIMPROF-supported groups (Figures 5.4. 5.5). These "assemblages," referred to herein as cluster groups A through I contained between 2−35 grabs each, and exhibited mean species richness values ranging from 48 to 158 taxa per grab and mean abundances of 101 to 579 individuals per grab (Table 5.4). Grabs within each cluster generally were collected from sites with similar depth or sediment characteristics or both (Appendix D.2).

Inner shelf assemblages

Macrofaunal communities were most similar between inner shelf cluster groups E and F, which shared 36 taxa not occurring in any of the other

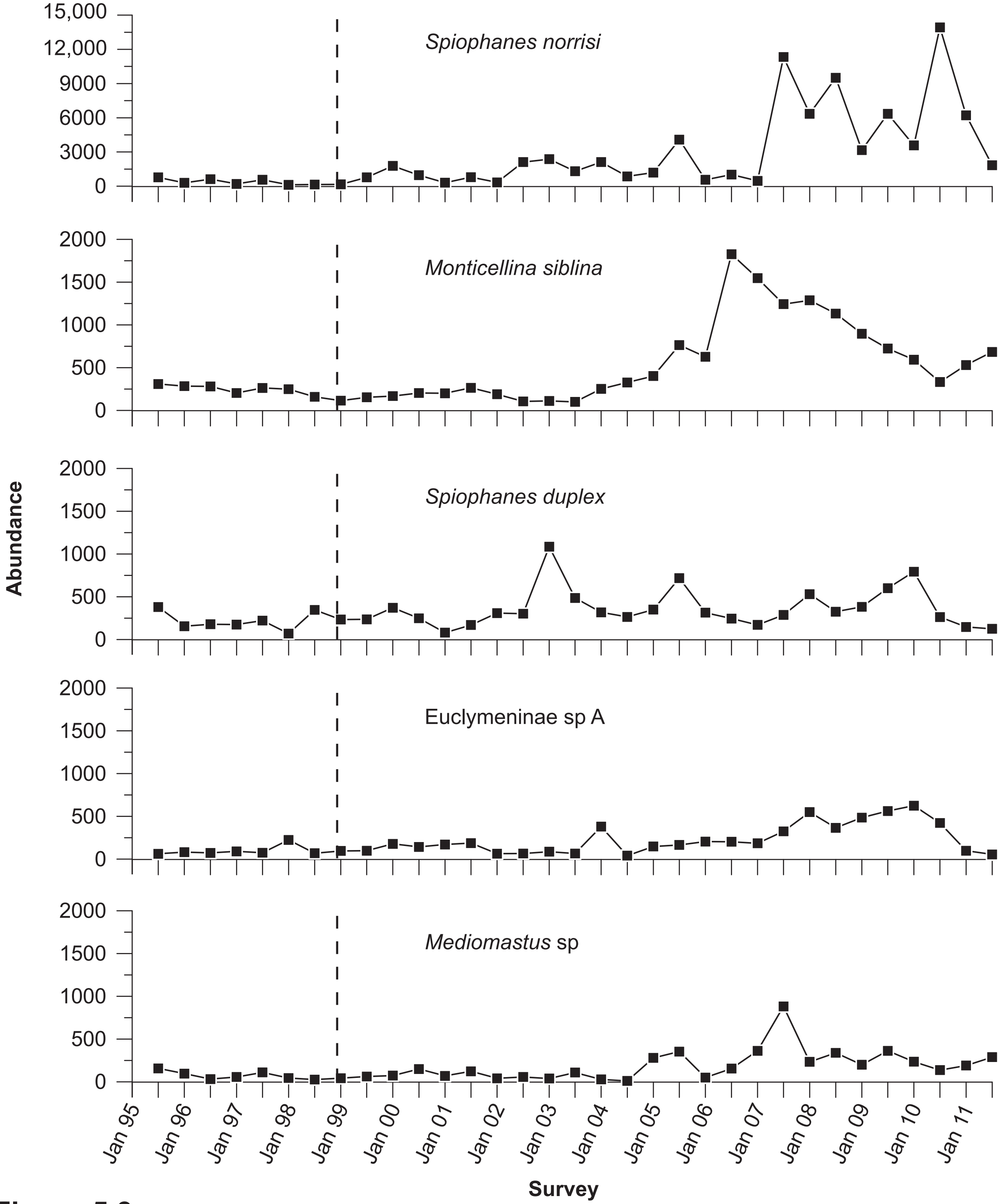


Figure 5.3
Total abundance per survey for each of the five most abundant species (taxa) at the SBOO benthic stations sampled between 1995–2011; note expanded scale for *Spiophanes norrisi.* Dashed lines indicate onset of wastewater discharge.

seven clusters (Figure 5.4, Appendix D.2). Together, these two cluster groups encompassed 46% of the 2011 grab samples and, except for four grabs collected along the 38-m isobath at stations I13 and I29, occurred along the 19-m and 28-m isobaths. All grabs from the 28-m sites located north of the outfall belonged to cluster group E, while grabs from 28-m sites surrounding or occurring south of the outfall belonged to either cluster group E or cluster group I (discussed below). The majority of

Table 5.2

Percent composition of species and abundance by major taxonomic group (phylum) for SBOO benthic stations sampled during 2011. Data are expressed as annual means (range) for all stations combined; $n = 27$.

Phyla	Species (%)	Abundance (%)
Annelida (Polychaeta)	45 (33–62)	71 (35–93)
Arthropoda (Crustacea)	24 (3–39)	14 (1–55)
Mollusca	17 (3–23)	6 (1–23)
Echinodermata	3 (1–18)	3 (1–27)
Other Phyla	11 (3–29)	6 (1–15)

grabs from the shallowest, 19-m isobath contained assemblages belonging to cluster group F. In addition to obvious depth differences between sites in these two cluster groups, group E typically contained sites possessing a higher percentage of fine sediments than cluster group F.

The remaining three inner shelf assemblages (cluster groups C, D and G) only possessed two to four grabs each. Sites in groups C and D occurred strictly in shallow sandy areas, and only during the July survey (Figure 5.4, Appendix D.2). Cluster group G possessed sites from varying depths and was characterized by coarse sediments with considerable shell hash.

Inner to mid-shelf transition zone assemblages

The assemblages comprising cluster groups H and I shared nine taxa not occurring in any other cluster group, and encompassed 37% of the grabs collected in 2011 (Figure 5.4, Appendix D.2). These two cluster groups were restricted to the southern half of the SBOO monitoring region, including areas immediately adjacent to the outfall (together with cluster group E, above). However, whereas cluster group I contained sites shallower than 36-m, cluster group H spanned 38-m to 55-m depths.

Mid-shelf shelf assemblages

Macrofaunal communities from mid-shelf groups A and B exhibited the second highest degree of similarity (30.4%) in the cluster analysis, and shared 12 taxa not occurring in any other cluster group. The nine grabs included in these two groups occurred at depths ≥55 m (Figure 5.4, Appendix D.2), with each cluster possessing different sediment habitats. For example, cluster group A included sites possessing a high fraction of coarse black sediments while several sites in cluster group B occurred in sandy areas with limited amounts of coarse sediment.

Description of cluster groups

Cluster group A consisted of all four grabs from station I28, located at a 55-m depth in the northern section of the South Bay outfall region (Figure 5.4). Grabs within this cluster exhibited the highest average species richness among all cluster groups, averaging 158 taxa/grab. Average abundance was 579 individuals/grab (Table 5.4). Sediments were composed of black sand with the highest percentage of fines found in any cluster group (21.3% to 23.3%; Appendix D.2). The five most abundant species were the polychaetes *Spiophanes norrisi*, *Monticellina siblina*, *Prionospio* (*Prionospio*) *dubia* and *Prionospio* (*Prionospio*) *jubata*, and the amphipod *Photis californica*; these species averaged between about 15–57 individuals/grab. No other species occurred at densities >12 individuals/grab. SIMPER revealed that *S. norrisi*, *P.* (*P.*) *dubia, P.* (*P.*) *jubata,* and another polychaete, *Glycera nana*, plus the amphipod *P. californica* to be the five most characteristic species that defined the clade.

Cluster group B consisted of all four grabs from station I1 and one July grab from station I20, located at 55-m and 60-m depths, respectively (Figure 5.4). Average species richness and abundance were 99 taxa and 326 individuals/grab, respectively (Table 5.4). Sediments were sandy with percent fines ranging from 8.6% to 9.7% (Appendix D.2). The five most abundant species were the polychaetes *Pista estevanica*, *Chloeia pinnata*, *Spiophanes norrisi*, and *Aricidea* (*Acmira*) *simplex*, and the amphipod *Photis*

Table 5.3

The 10 most abundant macroinvertebrates collected at the SBOO benthic stations during 2011. Abundance values are expressed as mean number of individuals per 0.1-m^2 grab sample. Percent occurrence = percent of total samples where the species was collected.

Species	Taxonomic Classification	Abundance per Sample	Percent Occurrence
Spiophanes norrisi	Polychaeta: Spionidae	74.7	98
Monticellina siblina	Polychaeta: Cirratulidae	11.3	59
Spio maculata	Polychaeta: Spionidae	9.8	35
Notomastus latericeus	Polychaeta: Capitellidae	7.3	65
Prionospio (*Prionospio*) *jubata*	Polychaeta: Spionidae	6.5	72
Spiochaetopterus costarum Cmplx	Polychaeta: Chaetopteridae	5.4	81
Mooreonuphis nebulosa	Polychaeta: Onuphidae	5.0	36
Mediomastus sp	Polychaeta: Capitellidae	4.4	61
Hesionura coineaui difficilis	Polychaeta: Phyllodocidae	4.0	7
Pista estevanica	Polychaeta: Terebellidae	4.0	39

californica; these species averaged between about 8–25 individuals/grab. No other species exhibited >5 individuals/grab. SIMPER revealed four of the above species (*P. estevanica*, *S. norrisi*, *A* (*A.*) *simplex,* and *P. californica*) plus another polychaete, *Scoloplos armiger* Cmplx, to be the five most characteristic species that defined the clade.

Cluster group C consisted of four July grabs from three adjacent sites (stations I18, I23, and I31) located along the 19-m isobath (Figure 5.4). Average values for species richness and abundance were lower in this cluster group than any other, consisting of only 48 taxa and 101 individuals/grab, respectively (Table 5.4). Sediments were sandy with the amount of percent fines ranging from 8.8% to 9.3% (Appendix D.2). Unlike other cluster groups where the most abundant species were primarily polychaete worms, this group was dominated by gammarid amphipods, including *Photis* sp OC1, *Gibberosus myersi*, *Gammaropsis thompsoni*, and *Aoroides inermis*, although the polychaete *Mediomastus* sp was also fairly abundant; these species averaged between 3–9 individuals/grab. No other species had average abundances >2/grab. The five most characteristic invertebrates found in these assemblages included *Photis* sp OC1 and *Mediomastus* sp as mentioned above, as well as the cumacean *Diastylopsis tenuis*, and the polychaetes Euclymeninae sp B and *Glycinde armigera*.

Cluster group D was the smallest of all cluster groups, consisting of only the two July grabs from station I4, the southernmost site along the 19-m isobath (Figure 5.4). Species richness and abundance were the second lowest of all cluster groups, averaging 56 taxa and 127 individuals/grab, respectively. Sediments were sandy with percent fines equaling 5.4% (Appendix D.2). The polychaetes *Spiophanes norrisi*, *Magelona sacculata*, *Ophelia pulchella* and *Mediomastus acutus,* and the amphipod *Ampelisca brachycladus* were the most abundant species encountered; these species averaged between about 5–11 individuals/grab. No other species averaged >4.0 individuals per grab. In addition to *S. norrisi, M. sacculata* and *M. acutus*, the polychaete *Lumbrinerides platypygos* and the cumacean *Hemilamprops californicus* constituted the five most characteristic species defining the group.

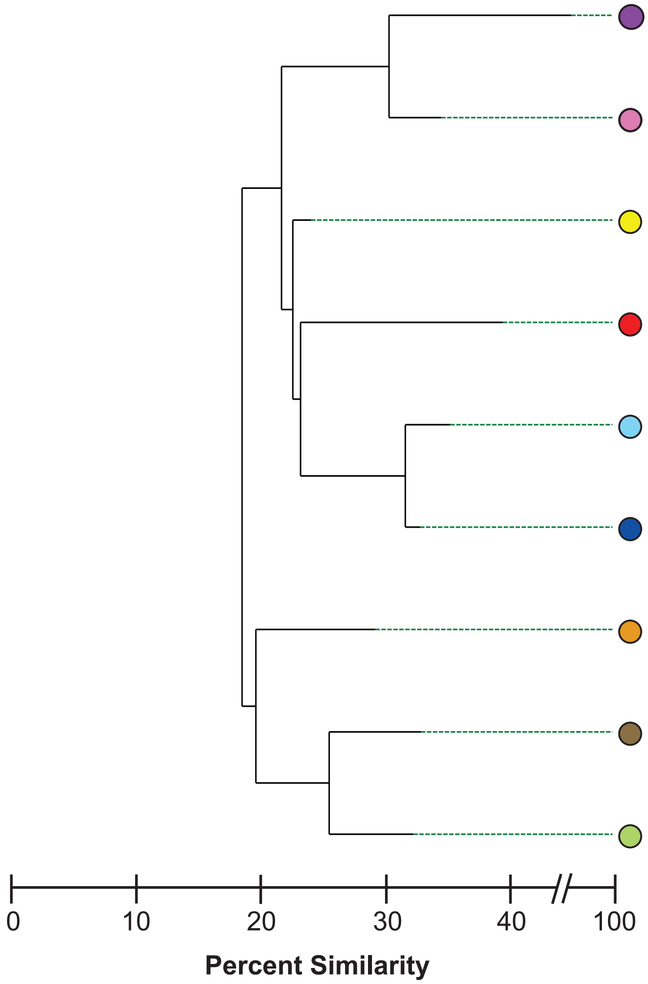
Cluster group E was the largest cluster group, containing 35 grabs from 11 nearfield (stations I12, I14, I15, I16) and farfield (stations I9, I13, I22, I27, I29, I30, I33) sites at depths from 28 m to 38 m (Figure 5.5). This group represents typical inner shelf assemblages for the SCB, and corresponds to cluster group D of the regional survey (see Chapter 9). Average species richness and abundance were 98 taxa and 377 individuals/grab, respectively. Most sites were characterized as sand mixed with fines with the percent fines ranging from 0% to 29% (Appendix D.2). The five most abundant species in this group were the polychaetes *Spiophanes norrisi*, *Monticellina siblina*, *Mooreonuphis nebulosa*, *Notomastus latericeus*, and *Prionospio* (*Prionospio*) *jubata*, which occurred at average densities between about 13–44 individuals/grab. No other species exhibited >8 individuals/grab. SIMPER revealed the same five species listed above to also be the five most characteristic species for the group.

Cluster group F contained 15 grabs from five sites (stations I10, I18, I23, I31, I35) that occurred along the 19-m isobath (Figure 5.4). Consistent with all other cluster groups co-occurring in this area, species richness and abundance were relatively low, averaging 70 taxa and 203 individuals/grab, respectively (Table 5.4). Sediments were sandy with percent fines ranging from 7.9% to 33.8% (Appendix D.2). The most abundant species in these samples were the polychaetes *Spiophanes norrisi*, *Mediomastus* sp, *Nereis* sp A and *Glycinde armigera*, and the nemertean *Carinoma mutabilis*; these species averaged between about 5–22 individuals/grab. No other taxon averaged >4 individuals/grab. SIMPER revealed four of the above species (*S. norrisi, Mediomastus* sp, *Nereis* sp A, *G. armigera*) to be among the five most characteristic species for the clade, with the fifth most characteristic species being another polychaete, *Monticellina siblina.*

Cluster group G comprised three grabs that possessed coarse sediments with substantial quantities of shell hash from stations I23, I29 and I34 (Figure 5.5). The macrofaunal communities that occur in these high energy environments are often referred to as "*Branchiostoma* communities" because of the relatively high abundance of these animals (see also cluster group A in Chapter 9). Grabs within this cluster averaged the highest abundance among all cluster groups at 823 individuals/grab. Average species richness was 77 taxa/grab (Table 5.4). Percent fines ranged from 0.5% to 25.6% (Appendix D.2). The polychaetes *Hesionura coineaui difficilis*, *Pisione* sp, *Saccocirrus* sp and *Spiophanes norrisi*, and unidentified nematodes were the most abundant taxa encountered; these taxa averaged between about 62–141 individuals/grab. No other taxon averaged >21 organisms/grab. The five most characteristic taxa for this clade included *H. coineaui difficilis, Pisione* sp, nematodes and *S. norrisi* listed above, plus the polychaete *Spio maculata*.

Cluster group H consisted of 14 grabs, including four grabs each from stations I7 and I21, and three grabs each from stations I13 and I20. Depths ranged from 38 to 55 m (Figure 5.4). Average species richness and abundance were 69 taxa and 318 individuals/grab, respectively (Table 5.4). Sediments were primarily sandy with a substantial coarse fraction, and percent fines ranged from 0% to 10.8% (Appendix D.2). The five most abundant species were the polychaetes *Spiophanes norrisi*, *Spio maculata*, *Lanassa venusta venusta*, and *Mooreonuphis* sp SD1, and the ophiuroid *Ophiuroconis bispinosa*; these species averaged between about 12–43 individuals/grab. No other species averaged >6 individuals/grab. SIMPER revealed three of the above species, *S. maculata*, *S. norrisi* and *L. venusta venusta*, plus the isopod *Eurydice caudata* and the amphipod *Ampelisca cristata cristata* to be the five most characteristic species that defined the clade.

Cluster group I was the second largest cluster, consisting of 26 grabs from nine sites (stations I2, I3, I4, I6, I8, I12, I14, I15, and I34) at depths ranging from 18 to 36 m (Figure 5.4). Average species richness and abundance were 55 taxa and 383 individuals/grab, respectively (Table 5.4). Sediment composition varied widely, but was predominantly characterized as sandy, with a percent fines component <5% (Appendix D.2). Abundance of the polychaete *Spiophanes norrisi* (196/grab) was over twice as high as any other cluster group. The other most abundant species at average densities between about 7–18 individuals/grab included the polychaetes *Spio maculata*, *Notomastus latericeus*, *Glycera oxycephala*, and *Lumbrinerides platypygos*. No other species averaged >4 individuals/grab.



Cluster Group	*n*	SR	Abun	Description
A	4	158	579	Mid-shelf
B	5	99	326	Mid-shelf
C	4	48	101	Inner shelf
D	2	56	127	Inner shelf
E	35	98	377	Inner shelf
F	15	70	203	Inner shelf
G	3	77	823	Inner shelf
H	14	69	318	Inner to mid-shelf transition zone
I	26	55	383	Inner to mid-shelf transition zone

Figure 5.4
Cluster analysis of macrofaunal assemblages at SBOO stations sampled during 2011. Data for species richness (SR) and infaunal abundance (Abun) are expressed as mean values per 0.1-m^2 over all stations in each group (*n*).

SIMPER revealed three of the above species (*S. norrisi*, *G. oxycephala,* and *N. latericeus*) plus two other polychaetes, *Scoloplos armiger* Cmplx and *Phyllodoce hartmanae,* to be the five most characteristic taxa that defined the clade.

Discussion

There was no evidence that wastewater discharged through the SBOO in 2011 affected macrobenthic communities in the region. For example, multivariate cluster analysis found all nearfield stations to possess invertebrate communities similar to farfield stations occurring along the 28-m isobath (the depth at which the outfall terminates). Additionally, species richness along the 28-m isobath in 2011 was similar to historical values, and any observed temporal fluctuations in macrofaunal abundances have co-occurred at both nearfield and farfield sites. Similarly, diversity and evenness values have remained relatively stable at both nearfield and farfield sites since monitoring began in 1995; however, farfield stations with high abundances of the spionid polychaete *Spiophanes norrisi* in 2011 exhibited relatively lower species diversity, evenness, and Swartz dominance values compared to other stations.

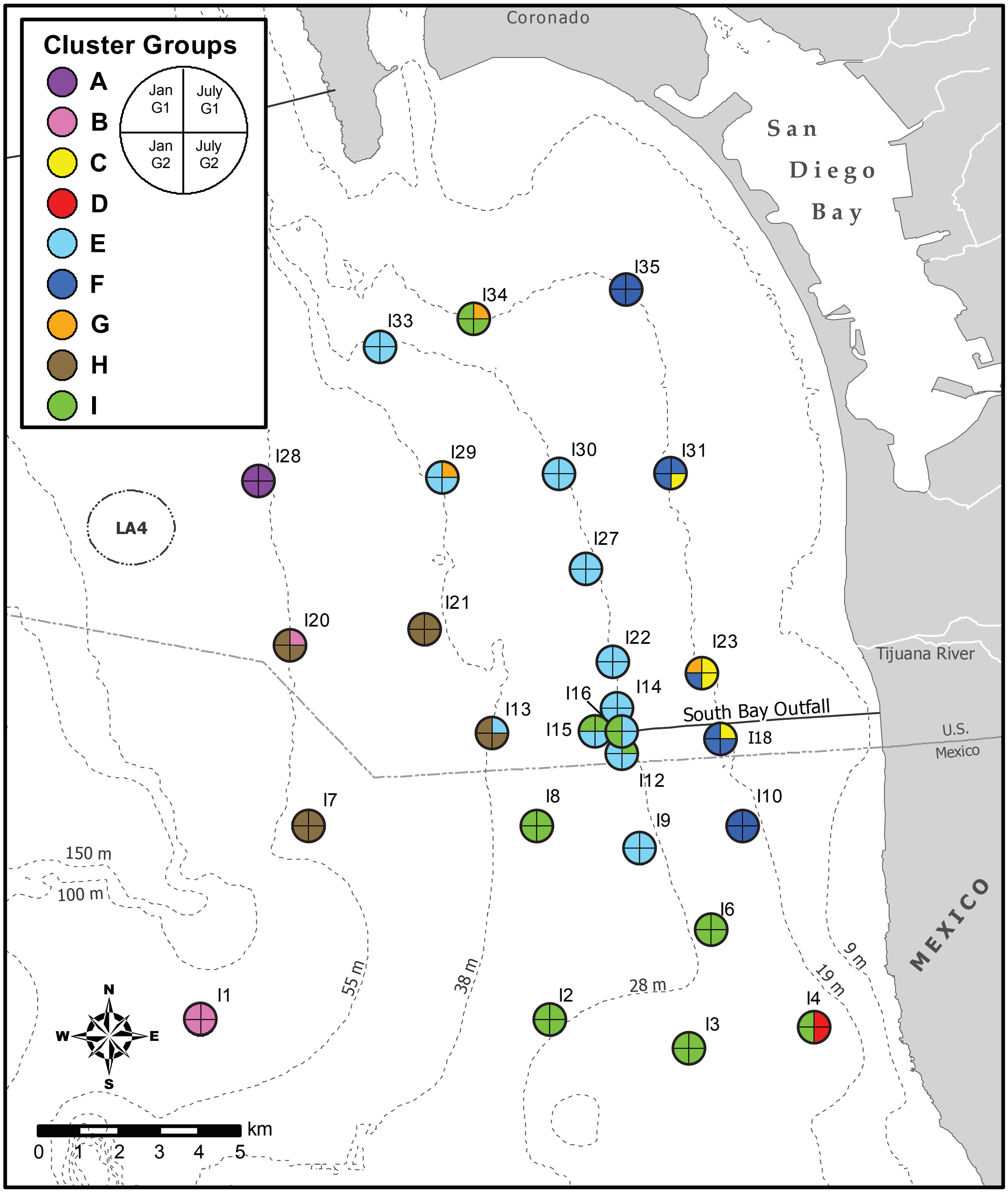


Figure 5.5
Spatial distribution of cluster groups in the SBOO region. Colors of each circle correspond to colors in Figure 5.4.

Benthic macrofaunal assemblages observed across the entire South Bay outfall region in 2011 were similar to those observed during previous years (City of San Diego 2000, 2011). These assemblages were also typical of those that occur in other sandy, shallow to mid-depth habitats throughout the SCB (Thompson et al. 1987, 1993b, City of San Diego 1999, Bergen et al. 2001, Ranasinghe et al. 2003, 2007, 2012, Mikel et al. 2007), and which often contain high population numbers of *Spiophanes norrisi* (Bergen et al. 2001). Benthic response index (BRI) values reported at most sites during the year were characteristic of undisturbed habitats, while the

Table 5.4

Mean abundance of the most common species found in cluster groups A–I (defined in Figure 5.4). Bold values indicate taxa that were considered most characteristic of that group according to SIMPER analysis.

	Cluster Group								
Taxa	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**
Spiophanes norrisi	**57.0**	**14.2**	1.3	**11.0**	**43.7**	**21.9**	**61.7**	**42.6**	**196.3**
Photis californica	**21.3**	**8.6**			0.3		0.3	4.2	
Monticellina siblina	19.0	0.4	1.3	2.0	**30.0**	**4.3**		0.1	0.5
Prionospio (*Prionospio*) *dubia*	**16.8**	1.0			0.1				
Prionospio (*Prionospio*) *jubata*	**15.5**	5.0	2.0	1.5	**13.0**	2.3	2.3	2.0	3.1
Pista estevanica		**25.2**			7.5			1.4	0.9
Chloeia pinnata	9.8	20.0		0.5				5.7	0.0
Aricidea (*Acmira*) *simplex*	12.3	**8.4**			0.1	0.1		0.1	0.1
Photis sp OC1		0.4	**9.3**	1.0	2.6	2.9		0.1	0.8
Mediomastus sp	6.0	0.8	**7.5**		6.7	**10.3**	5.3	0.1	0.6
Gibberosus myersi		0.6	4.5	3.5	0.3	0.7	0.3	0.1	0.8
Gammaropsis thompsoni	1.3	0.2	3.3		0.5	0.6			0.1
Aoroides inermis			2.5		0.0	0.1		0.2	0.5
Magelona sacculata			0.5	**8.0**	2.9	3.9			4.0
Ophelia pulchella				8.0			0.3	0.4	2.4
Mediomastus acutus				**4.5**		0.1			
Ampelisca brachycladus				4.5	0.4	0.8			0.1
Mooreonuphis nebulosa	2.5				**15.1**				0.2
Notomastus latericeus	0.3	1.4		0.5	**13.6**	0.9		0.2	**10.8**
Nereis sp A	0.3		1.8	3.0	4.6	**8.8**			1.2
Glycinde armigera	0.3		**2.0**	2.0	5.7	**7.6**		0.3	0.7
Carinoma mutabilis		0.6	1.8		1.9	5.2	0.7	0.4	2.6
Hesionura coineaui difficilis							**141.0**	0.7	
Pisione sp					0.0	0.1	**95.3**	1.6	
Saccocirrus sp							76.0		
Nematoda	2.0		0.8		1.3	0.7	**68.3**	3.2	1.0
Spio maculata	0.3					0.1	**17.0**	**38.8**	17.6
Lanassa venusta venusta	0.5	0.2			0.1	0.1	1.3	**24.9**	0.0
Ophiuroconis bispinosa	11.5	0.4			1.0		0.7	14.9	2.7
Mooreonuphis sp SD1		0.2			0.0			11.9	0.5
Glycera oxycephala		2.4		1.0	2.1	0.1		1.6	**8.4**
Lumbrinerides platypygos		0.2	0.3	**4.0**	0.2		21.0	2.7	6.9

results for only a few stations were suggestive of possible minor deviation from reference conditions. Since monitoring first began around the SBOO in 1995, mean BRI values at the 19-m and 28-m depth contour stations have typically been higher than along the deeper 38-m and 55-m contours. This pattern may occur because the BRI was developed to assess a depth gradient spanning 30–120 meters and is less efficient in shallower and deeper areas. Higher BRI values occurring at 19-m and 28-m depth contours in the SBOO region were observed prior to wastewater discharge and have remained consistent over time. A similar phenomenon is reported across the SCB where Smith et al. (2001) found a pattern of lower index values at mid-depth stations (25–130 m) versus shallower (10–35 m) or deeper (110–324 m) stations.

Although spionid polychaetes have been observed to form extensive communities in other areas of the world that naturally possess high organic matter (Díaz-Jaramillo et al. 2008), they are known to be a stable dominant component of many healthy environments in the SCB (Rodríguez-Villanueva et al. 2003). Thus, ubiquitous, high populations of *S. norrisi* observed at most SBOO stations from 2007–2011 suggest that their distribution is not indicative of habitat degradation related to wastewater discharge, and that population fluctuations of this species over the past few years likely correspond to natural changes in large-scale oceanographic conditions. Likewise, although fluctuations in populations of capitellid polychaetes have been shown to be possible indicators of polluted sediments near wastewater treatment plants in certain areas of the world (Swartz et al. 1986, Rodríguez-Villanueva et al. 2003), the abundance of *Mediomastus* sp in the SBOO region in 2011 was within the natural range of variation expected, with the highest abundances occurring along the 19-m isobath inshore of the outfall. Specifically, 21% of all *Mediomastus* enumerated (mean = 25.3/grab) occurred at station I35, which also possessed total sulfide and nitrogen values that were among the highest measured during the past year (see Chapter 4). The highest BRI value was also recorded at this site. It is unclear what is causing these effects at I35, but its location may be acting as a sediment sink for deposits from the Tijuana River and San Diego Bay.

In conclusion, anthropogenic impacts in marine environments are known to 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 wastewater discharge via the SBOO on the local macrobenthic community could not be identified during 2011. Furthermore, populations and communities of benthic invertebrates exhibit substantial natural 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 region remain similar to those observed prior to outfall operations and to natural indigenous communities characteristic of similar habitats on the southern California continental shelf.

Literature Cited

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.

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. (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. (2000). Final Baseline Monitoring Report for the South Bay Ocean Outfall (1995–1998). City of San Diego Ocean Monitoring Program, Metropolitan Wastewater Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

City of San Diego. (2011). Annual Receiving Waters Monitoring Report for the South Bay Ocean Outfall (South Bay Water Reclamation Plant), 2010. City of San Diego Ocean Monitoring Program, Public Utilities Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

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

Clarke, K.R. and R.M. Warwick. (2001). Change in marine communities: an approach to statistical analysis and interpretation. 2nd edition. PRIMER-E, Plymouth.

Clarke, K.R., P.J. Somerfield, and R.N. Gorely. (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

Díaz-Jaramillo, M., P. Muñoz, V. Delgado-Blas, and C. Bertrán. (2008). Spatio-temporal distribution of spionids (Polychaeta-Spionidae) in an estuarine system in south-central Chile. Revista Chilena de Historia Natural, 81: 501–514.

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.

Mikel T.K., J.A Ranasinghe, and D.E. Montagne. (2007). Characteristics of benthic macrofauna of the Southern California Bight. Appendix F. Southern California Bight 2003 Regional Monitoring Program, SCCWRP, Costa Mesa, CA.

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.

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., 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., 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, and 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., 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.

Ranasinghe, J.A., K.C. Schiff, C.A. Brantley, L.L. Lovell, D.B. Cadien, T.K. Mikel, R.G. Velarde, S. Holt, and S.C. Johnson. (2012) Southern California Bight 2008 Regional Monitoring Program:VI. Benthic Macrofauna. Technical Report No. 665, Southern California Coastal Water Research Project, Costa Mesa, CA.

Rodríguez-Villanueva, V., R. Martínez-Lara, and V. Macías Zamora. (2003). Polychaete community structure of the northwestern coast of Mexico: patterns of abundance and distribution. Hydrobiologia, 496: 385–399.

[SCAMIT] Southern California Association of Marine Invertebrate Taxonomists. (2011). *A taxonomic listing macro- and megainvertebrates from infaunal and epibenthic monitoring programs in the Southern California Bight*, edition 6. Southern California Associations of Marine Invertebrate Taxonomists, Natural History Museum of Los Angeles County Research and Collections, Los Angeles, CA. 211pp.

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.

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, and V. Solis-Weiss. (1997). The importance of marine sediment biodiversity in ecosystem processes. Ambio, 26: 578–583.

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., 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.

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.

[USEPA] 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.

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