# Chapter 9. San Diego Regional Survey Macrobenthic Communities

## INTRODUCTION

Macrobenthic invertebrates fulfill essential roles as nutrient recyclers and bioeroders, and are a source of food for higher trophic levels in marine ecosystems throughout the world, including the Southern California Bight (SCB). Additionally, because of their ability to serve as reliable indicators of pollution or other environmental stressors, benthic macrofauna have been sampled extensively for the past several decades in order to monitor potential changes around SCB ocean outfalls and other point sources at small spatial scales (Stull et al. 1986, 1996, Swartz et al. 1986, Ferraro et al. 1994, Zmarzly et al. 1994, Diener and Fuller 1995, Diener et al., 1995, Stull 1995). Examples of such local assessments include the regular ongoing surveys conducted each year around the ocean outfalls operated by the City of Los Angeles, the City of San Diego, the Los Angeles County Sanitation District, and the Orange County Sanitation District, the four largest wastewater dischargers in the region (City of Los Angeles 2007, 2008, City of San Diego 2010a, b, LACSD 2010, OCSD 2011). In order to place data from these localized surveys into a broader biogeographic context, larger-scale regional monitoring efforts of the entire SBC have also become an important tool for evaluating benthic conditions and sediment quality in southern California (Bergen et al. 1998, 2000, Hyland et al. 2003, Ranasinghe et al. 2003, 2007, USEPA 2004).

The City of San Diego has conducted annual regional benthic surveys off the coast of San Diego since 1994 (see Chapter 1). The primary objectives of these summer surveys, which typically range from Del Mar to the USA/Mexico border, are to (1) describe the overall condition and quality of the diverse benthic habitats that occur off San Diego, (2) characterize the ecological health of the soft-bottom marine benthos in the region, and (3) gain a better understanding of regional variation in order to distinguish anthropogenically-driven changes from natural fluctuations. These surveys typically occur at an array of 40 stations selected each year using a probability-based, random stratified sampling design as described in Bergen (1996), Stevens (1997), and Stevens and Olsen (2004). During 1995–1997, 1999–2002 and 2005–2007, the surveys off San Diego were restricted to continental shelf depths (<200 m), while the area of coverage was expanded in 2009 and 2010 to also include deeper habitats along the upper slope (200–500 m). No survey of randomly selected sites was conducted in 2004 due to sampling for a special sediment mapping project (Stebbins et al. 2004), while surveys in 1994, 1998, 2003 and 2008 were conducted as part of larger, multi-agency surveys of the entire SCB (Bergen et al. 1998, 2001, Ranasinghe et al. 2003, 2007, 2010).

This chapter presents results of the analysis and interpretation of the benthic macrofauna data collected during the 2010 regional survey of the continental shelf and upper slope off San Diego. Included are descriptions and comparisons of the soft-bottom macrobenthic assemblages present and analyses of benthic community structure for the region. Results of benthic sediment quality analyses at the same sites are presented in Chapter 8.

## Materials and Methods

### Collection and Processing of Samples

The July 2010 regional survey covered an area ranging from off Del Mar in northern San Diego County south to the USA/Mexico border (Figure 9.1). Overall, the 2010 survey included 40 stations ranging in depth from 9 to 433 m and spanning four distinct depth strata as characterized by the SCB regional monitoring programs (Ranasinghe et al. 2007). These included 8 stations along the inner shelf (5–30 m), 19 stations along the mid-shelf (30–120 m), 6 stations along the outer shelf (120–200 m), and 7 stations on the upper slope (200–500 m).

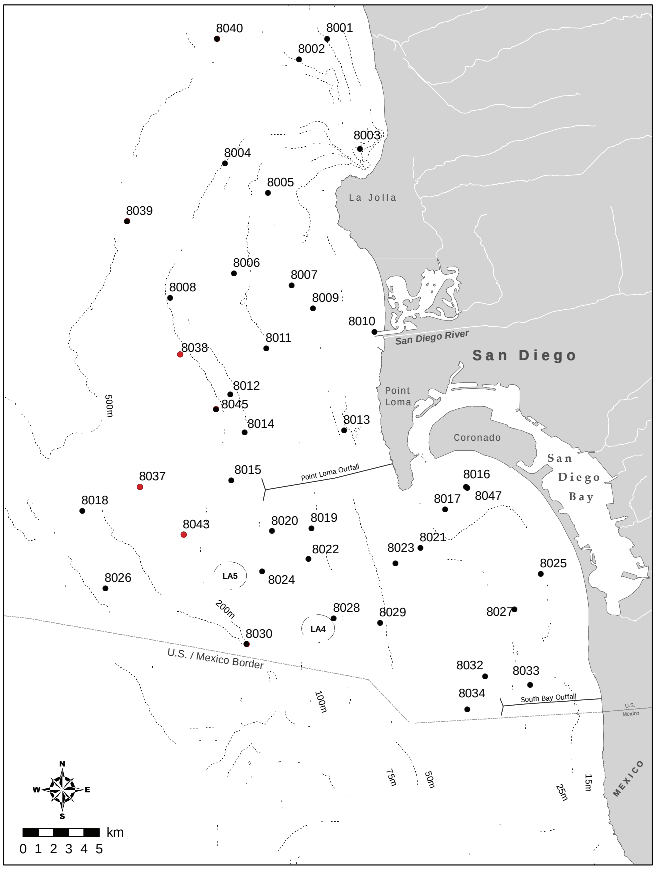



**Figure 9.1**
Regional benthic survey stations sampled during July 2010 as part of the South Bay Ocean Outfall Monitoring Program. Black circles represent shelf stations and red circles represent slope stations.

At each of the 40 stations, samples for benthic community analysis were collected using a double 0.1-m$^2$ Van Veen grab; one of the grabs from each cast was used to sample macrofauna, while the adjacent grab was used for sediment quality analysis (see Chapter 8). To ensure consistency of grab samples, protocols established by the United States Environmental Protection Agency (USEPA) were followed to standardize sample disturbance and depth of penetration (USEPA 1987). All samples were sieved aboard ship through a 1.0-mm mesh screen, and organisms retained on the screen were collected and relaxed for 30 minutes in a magnesium sulfate solution before fixing 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 subcontracted laboratory and then identified to species (or the lowest taxon possible) and enumerated by City of San Diego marine biologists.

### Data Analyses

The following community metrics were calculated for each station per 0.1-m$^2$ grab: species richness (number of taxa), abundance (number of individuals), Shannon diversity index (H'), Pielou's evenness index (J'), Swartz dominance (minimum number of taxa accounting for 75% of the total abundance in a sample) (Swartz et al. 1986, Ferraro et al. 1994), and the benthic response index (BRI) developed by Smith et al. (2001). These data are summarized for the inner shelf, mid-shelf, outer shelf, and upper slope depth strata described above for the SCB.

To examine spatio-temporal patterns of benthic macrofaunal assemblages, analyses were performed using PRIMER (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 (nMDS). 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 resulting dendrograms (Clarke et al. 2008), while the similarity percentages routine (SIMPER) identified species that were characteristic, though not always the most abundant, within assemblages. Patterns in the distribution of the resultant assemblages were subsequently compared to several environmental variables by overlaying the physico-chemical data onto nMDS plots based on the macrofauna data (Field et al. 1982, Clarke and Ainsworth 1993).

## Results

### Community Parameters

***Species richness***
A total of 728 macrobenthic taxa (mostly species) were identified during the summer 2010 regional

survey. Of these, 267 (~37%) were rare species or unidentifiable taxa (e.g., juveniles or damaged specimens) that occurred only once. Species richness values from all four strata combined ranged from 18–174 species per station, with the range of values found within each stratum overlapping considerably (Table 9.1). However, average species richness values indicated that mid-shelf sites typically possessed a higher number of taxa than other strata, while the inner shelf and upper slope strata both contained sites with the lowest species richness (although species diversity may differ between inner shelf and upper slope locations) (Figure 9.2A).

***Macrofaunal abundance***

Macrofaunal abundance at the three shelf depths surveyed ranged from 85–811 animals per site, with ranges within each stratum exhibiting significant overlap (Table 9.1). Abundance varied with depth across the shelf, with inner, mid-, and outer shelf assemblages averaging ~275, 382, and 229 animals/grab, respectively (Figure 9.2B). The greatest number of animals documented in 2010 occurred at the relatively shallow mid-shelf stations 8023 and 8032, both of which possessed >800 animals per grab (Table 9.1), and at station 8013 (also a shallow mid-shelf site) which possessed 645 animals per grab. In contrast, upper slope sites exhibited relatively low abundance values ranging from 76–227 animals/site, with an average of 117 animals/site (Table 9.1, Figure 9.2B).

***Diversity and evenness***

During 2010, diversity (H') ranged from 2.0 to 4.5 across all strata (Table 9.1). Although diversity ranges overlapped among strata, average values indicate that sites along the inner shelf possessed lower diversity than in deeper areas (Figure 9.2C). The eight stations with the highest diversity (i.e., H'≥4.0) occurred predominantly along the mid-shelf stratum, although one outer shelf site also exhibited an H' value of 4.1 (Table 9.1). The lowest diversity occurred at station 8047, a shallow inner shelf station located near the mouth of San Diego Bay (Table 9.1). Evenness (J') compliments diversity, with higher J' values (on a scale of 0–1) indicating that species are more evenly distributed and that an assemblage is not dominated by a few highly abundant species. During 2010, J' values across all strata ranged between 0.58–0.95 (Table 9.1), with evenness tending to increase with depth (Figure 9.2D). Thus, inner shelf regions possessed the lowest average evenness values while upper slope sites possessed the greatest evenness values.

***Dominance***

Swartz dominance values across the three shelf strata ranged between 4–55 taxa per station during 2010, while values at upper slope sites ranged between 7–30 (Table 9.1). Average dominance was notably higher (i.e., lower index values) at inner shelf and upper slope sites than at mid- and outer slope sites (Figure 9.2E). As expected, dominance values followed patterns similar to diversity values. For example, the three sites with the lowest dominance (stations 8001, 8003, 8024; index values≥45) also exhibited high H' values (≥4.2), while the few stations with dominance index values <10 (stations 8010, 8016, 8027, 8039, 8040, 8047) had relatively low H' values of 2.0 to 2.7 (Table 9.1).

***Benthic response index (BRI)***

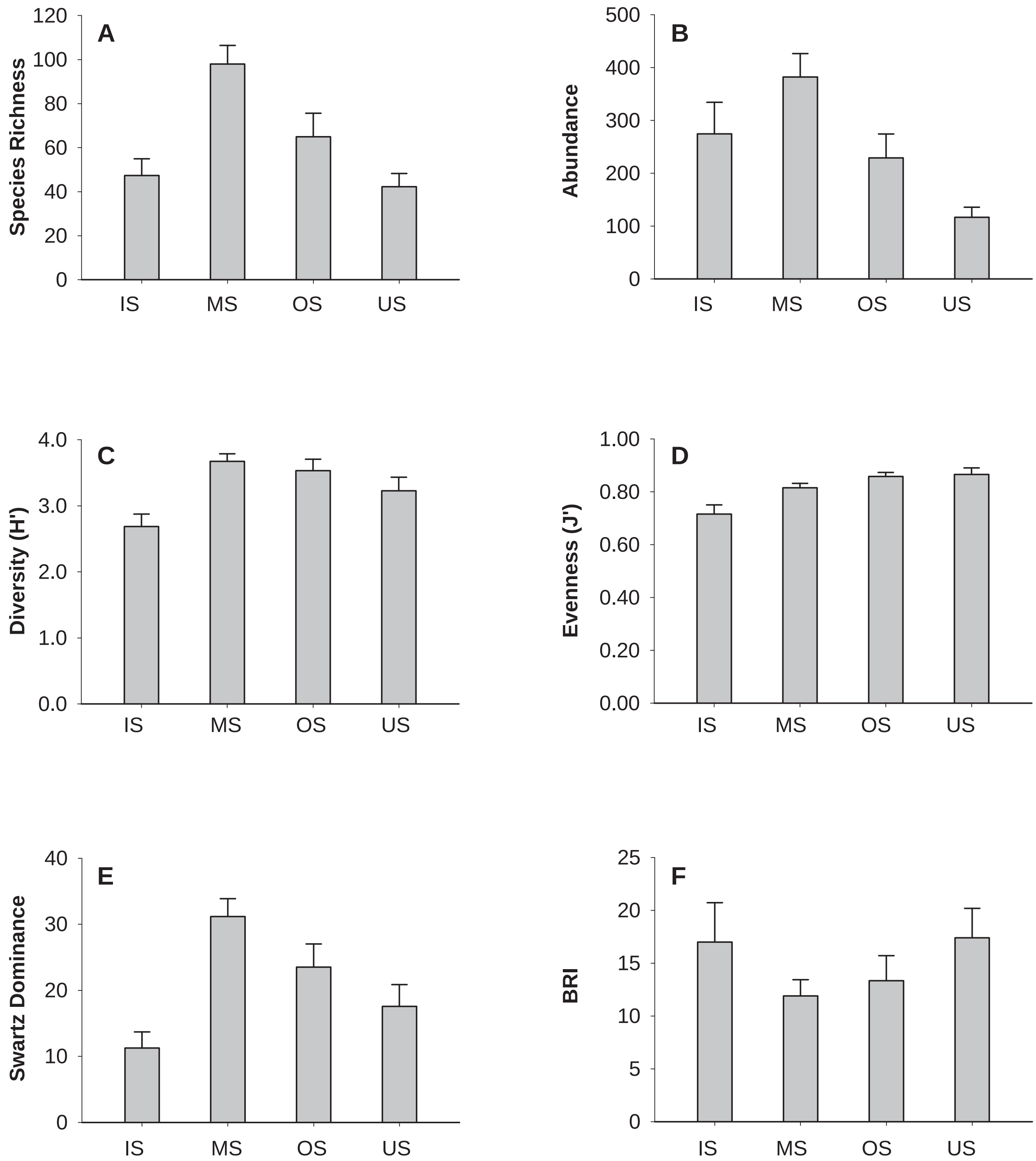
The benthic response index (BRI) is a useful tool for evaluating environmental conditions in soft-bottom benthic habitats off southern California; however, it has only been calibrated for depths from 10 to 324 m (Smith et al. 2001). BRI values <25 are considered indicative of reference conditions, while values between 25–34 represent a minor or marginal deviation from reference conditions. High BRI values >34 represent progressive levels of impact, including losses in biodiversity or community function, and ultimately defaunation. In 2010, regional BRI values ranged from 2–28 (Table 9.1), with three stations (8032, 8033 located immediately north of the South Bay Ocean Outfall, 8037 located offshore of the Point Loma Ocean Outfall) possessing BRI values ≥25 and indicating a slight deviation from reference conditions. Average BRI values varied by depth strata, with inner, mid-, and outer shelf sites possessing average BRI values of 17, 12, and 13, respectively (Figure 9.2F). BRI values

## Table 9.1

Macrofaunal community parameters calculated per 0.1-$m^2$ grab at regional stations sampled during 2010. SR = species richness; Abun = abundance; H' = Shannon diversity index; J' = evenness; Dom = Swartz dominance; BRI = benthic response index; *n* = 1.

| | Station | Depth (m) | SR | Abun | H' | J' | Dom | BRI |
|---|---|---|---|---|---|---|---|---|
| Inner Shelf | 8016 | 9 | 29 | 253 | 2.4 | 0.71 | 6 | na |
| | 8047 | 9 | 18 | 102 | 2.0 | 0.70 | 4 | na |
| | 8010 | 10 | 32 | 344 | 2.2 | 0.64 | 5 | 2 |
| | 8017 | 12 | 53 | 178 | 3.4 | 0.86 | 20 | 10 |
| | 8025 | 17 | 37 | 100 | 2.7 | 0.74 | 12 | 22 |
| | 8027 | 21 | 74 | 535 | 2.5 | 0.58 | 9 | 19 |
| | 8033 | 22 | 74 | 497 | 2.8 | 0.65 | 11 | 25 |
| | 8021 | 24 | 62 | 189 | 3.5 | 0.85 | 23 | 24 |
| Mid-shelf | 8023 | 31 | 174 | 808 | 3.8 | 0.74 | 41 | 19 |
| | 8032 | 33 | 140 | 811 | 3.6 | 0.74 | 26 | 26 |
| | 8013 | 36 | 157 | 645 | 4.2 | 0.83 | 40 | 24 |
| | 8034 | 38 | 52 | 241 | 2.8 | 0.71 | 13 | 12 |
| | 8003 | 40 | 131 | 460 | 4.4 | 0.90 | 49 | 19 |
| | 8001 | 50 | 105 | 335 | 4.2 | 0.91 | 45 | 13 |
| | 8009 | 52 | 115 | 430 | 4.1 | 0.86 | 39 | 14 |
| | 8029 | 52 | 34 | 86 | 3.1 | 0.89 | 15 | 12 |
| | 8007 | 58 | 87 | 414 | 3.8 | 0.85 | 28 | 10 |
| | 8005 | 62 | 117 | 444 | 4.0 | 0.85 | 40 | 13 |
| | 8011 | 78 | 65 | 225 | 3.1 | 0.74 | 23 | 2 |
| | 8028 | 80 | 89 | 280 | 3.4 | 0.76 | 27 | 5 |
| | 8019 | 81 | 62 | 167 | 3.2 | 0.79 | 24 | 5 |
| | 8006 | 84 | 71 | 238 | 3.4 | 0.79 | 24 | 3 |
| | 8022 | 85 | 79 | 308 | 3.1 | 0.71 | 19 | 5 |
| | 8002 | 94 | 73 | 377 | 3.2 | 0.75 | 19 | 9 |
| | 8020 | 96 | 98 | 350 | 3.9 | 0.85 | 31 | 8 |
| | 8024 | 101 | 129 | 348 | 4.5 | 0.92 | 55 | 13 |
| | 8014 | 112 | 84 | 298 | 4.0 | 0.91 | 34 | 14 |
| Outer Shelf | 8012 | 123 | 99 | 345 | 4.1 | 0.89 | 36 | 11 |
| | 8008 | 125 | 94 | 371 | 3.7 | 0.82 | 27 | 15 |
| | 8026 | 155 | 43 | 208 | 3.1 | 0.82 | 12 | 4 |
| | 8018 | 161 | 37 | 85 | 3.0 | 0.83 | 16 | 12 |
| | 8015 | 167 | 52 | 152 | 3.5 | 0.89 | 23 | 17 |
| | 8004 | 196 | 65 | 215 | 3.8 | 0.90 | 27 | 21 |
| Upper Slope | 8030 | 203 | 71 | 227 | 3.9 | 0.91 | 30 | 14 |
| | 8045 | 212 | 44 | 100 | 3.5 | 0.91 | 20 | 17 |
| | 8043 | 222 | 49 | 101 | 3.7 | 0.95 | 25 | 16 |
| | 8038 | 263 | 48 | 110 | 3.5 | 0.90 | 21 | 12 |
| | 8037 | 317 | 28 | 76 | 2.7 | 0.81 | 11 | 28 |
| | 8040 | 421 | 28 | 114 | 2.6 | 0.77 | 7 | na |
| | 8039 | 433 | 28 | 91 | 2.7 | 0.81 | 9 | na |

na = not applicable




## Figure 9.2

Comparison of macrofaunal community structure metrics for the four major depth strata sampled at the regional stations during 2010. Data are expressed for each depth stratum as means + one standard error (per 0.1 $m^2$). IS = inner shelf (5–30 m; *n* = 8); MS = mid-shelf (30–120 m; *n* = 19); OS = outer shelf (120–200 m; *n* =6); US = upper slope (200–500 m; *n* = 7).

were not calculated for the two shallowest inner shelf stations (< 10 m depth) and the two deepest upper slope stations (> 324 m depth) because calibration of the index for depths encountered at those locations has never occurred. Overall, 92% of the sites where BRI was calculated were similar to reference conditions while the remaining 8% showed only marginal deviation from reference conditions.

### Dominant Taxa

As in previous years, 2010 macrofaunal communities in the San Diego region were dominated by polychaete worms (Table 9.2) in terms of diversity, where they accounted for 54% of all species collected. Arthropods (mostly crustaceans, but also including pycnogonids) and molluscs were the next two most diverse taxa, accounting for 19% and 13% of species, respectively. Echinoderms accounted for 6% of all taxa, while all other phyla combined (e.g., Chordata, Cnidaria, Nematoda, Nemertea, Phoronida, Platyhelminthes, Sipuncula) accounted for the remaining 8%. Patterns apparent in the proportions of major taxa across shelf strata include: (1) the contribution of polychaetes to overall macroinvertebrate diversity increased from 42% along the inner shelf, to 55% along the mid-shelf, to 65% along the outer shelf, (2) the percentage of echinoderms increased slightly as depth increased, and (3) the proportions of crustaceans and the other phyla typically decreased with depth (Figure 9.3A). The greatest difference in invertebrate assemblages occurred between the continental shelf and upper slope when the percentage of molluscs increased sharply and the proportion of polychaetes decreased. The proportion of echinoderms remained about the same between upper slope and outer shelf sites.

Polychaetes were also the most numerous invertebrates collected, accounting for 59% of the total abundance (Table 9.2). Crustaceans accounted for 14% of the animals, molluscs 12%, echinoderms 10%, and the remaining phyla 5%. Abundance patterns varied among strata (Figure 9.3B) with the proportion of polychaetes being lower at inner and mid-shelf stations (i.e., ~54% each) than along either the outer shelf or upper slope (i.e., 74% and 62%, respectively). The lower proportional abundance of polychaetes along mid- and inner shelf sites corresponded to considerably higher numbers of ophiuroids (i.e., 18%) and crustaceans (i.e., 23%) at these depths, respectively.

**Table 9.2**
The percent composition of species and abundance by phyla for regional stations sampled during 2010. Data are expressed as means (range) for all stations combined; $n = 40$.

| Phyla | Species (%) | Abundance (%) |
|---|---|---|
| Annelida (Polychaeta) | 54 (14–79) | 59 (4–86) |
| Arthropoda (Crustacea) | 19 (0–62) | 14 (0–76) |
| Mollusca | 13 (1–43) | 12 (1–38) |
| Echinodermata | 6 (0–14) | 10 (0–42) |
| Other Phyla | 8 (0–19) | 5 (0–32) |

As expected, dominant species encountered varied across strata (Table 9.3). For example, the 10 most abundant species along the inner shelf included six polychaetes, three amphipod crustaceans, and one anthozoan. Of these, the spionid polychaete *Spiophanes norrisi* was clearly dominant averaging about 62 individuals per 0.1-$m^2$ grab. All other species averaged < 24 animals/grab. Additionally, *S. norrisi* was the most widely distributed of the common inner shelf species, occurring at all eight sites surveyed. In contrast, the oweniid polychaete *Owenia collaris* exhibited a more restricted distribution, occurring at only one site. The top 10 dominant species along the mid-shelf included one ophiuroid, eight polychaetes, and one bivalve. Of these, the brittle star *Amphiodia urtica* was the most common species, averaging about 41 animals per grab and occurring at 74% of the sites. *Spiophanes norrisi* was the next most abundant species, and averaged about 32 animals per grab. All other species averaged < 11 animals/grab. The top 10

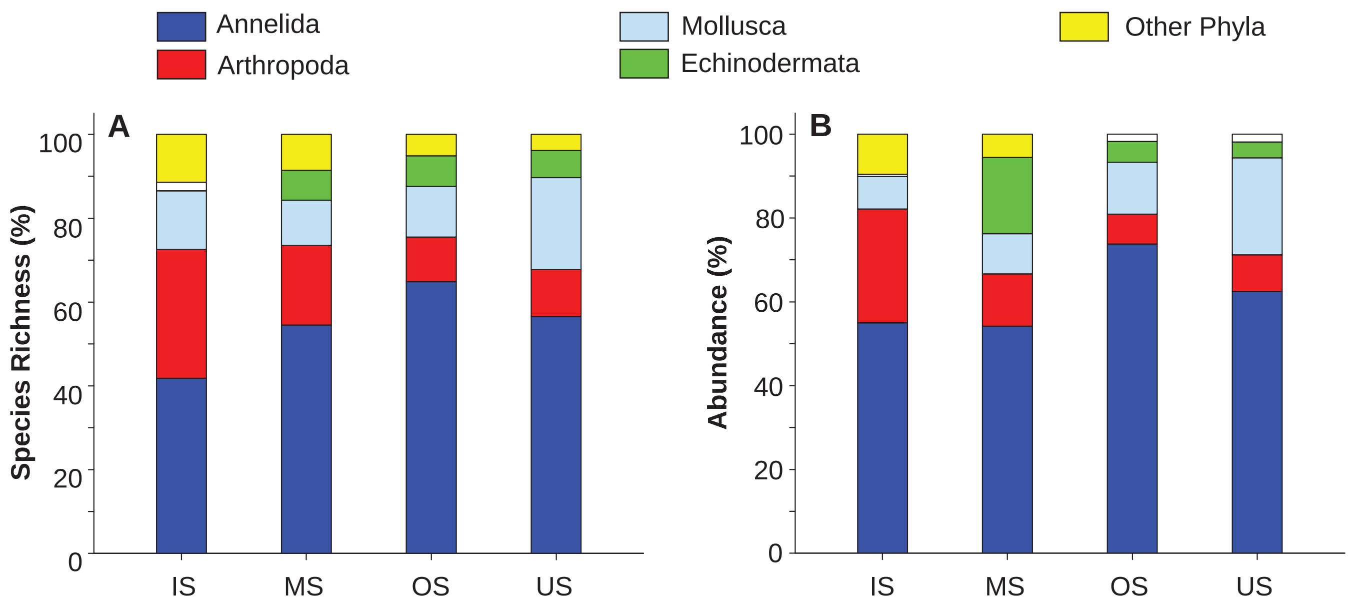



**Figure 9.3**
Comparison of percent composition of species and abundance by major phylum for each depth stratum sampled at the regional stations during 2010. IS = inner shelf (5–30 m; *n* = 8); MS = mid-shelf (30–120 m; *n* = 19); OS = outer shelf (120–200 m; *n* =6); US = upper slope (200–500 m; *n* = 7).

species recorded along the outer shelf included eight polychaetes and two bivalves. Of these, the cirratulid polychaete *Aphelochaeta glandaria* was most abundant, averaging 24 animals per grab, while none of the other dominant outer shelf species exceeded mean densities of 10 animals per grab. The 10 most abundant species along the upper slope included seven polychaetes and three bivalves. The maldanid polychaete *Maldane sarsi* was the most abundant upper slope species with an average of 11 animals/grab, while the second most abundant species was the bivalve *Yoldiella nana*, which averaged 5 animals/grab.

### Classification of Macrobenthic Assemblages

Classification (cluster) and ordination analyses were used to discriminate between the major macrobenthic assemblages that occurred at the regional stations sampled off San Diego. Seven main habitat-related assemblages were identified in 2010 based on results of these cluster analyses (Figure 9.4A, Table 9.4). 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 encompassed sites from varying depth regimes and/or sediment microhabitats (Figures 9.4B, 9.5). The SIMPROF procedure indicated statistically significant non-random structure among samples ($\pi = 7.42$, $p < 0.001$), and an nMDS ordination supported the validity of the cluster groups (Figure 9.4C). SIMPER analysis identified species that were characteristic, though not always the most abundant, within assemblages; a comparison of the most abundant taxa for each cluster group combined with SIMPER results is indicated in Table 9.4. A list of species identified by SIMPER as discriminating between individual cluster groups is presented in Appendix H.1. Overall, clusters were very similar and no single species strongly discriminated between groups. On average, 121 species contributed to 75% of the dissimilarity between any two cluster groups.

Cluster group A represents inner shelf assemblages that occurred at four stations sampled in relatively shallow waters (9–12 m) near the mouths of Mission Bay and San Diego Bay. Sites within this cluster were characterized by an average of 33 taxa and 219 individuals per 0.1 $m^2$ grab. Overall, the most abundant species were the megaluropid amphipod *Gibberosus myersi* with ~24 animals/grab and unidentified anthozoans (Actiniaria) with ~21 animals/grab. Although only recorded at one

## Table 9.3

The 10 most abundant macroinvertebrates collected at regional benthic stations sampled during 2010. AS = abundance/survey; PO = percent occurrence (percent of total annual samples for which the species was collected); AO = abundance/occurrence. Abundance values are expressed as mean number of individuals per 0.1-$m^2$ grab sample.

| Strata | Species | Higher Taxa | AS | PO | AO |
|---|---|---|---|---|---|
| Inner Shelf | *Spiophanes norrisi* | Annelida: Spionidae | 62.1 | 100.0 | 62.1 |
| | *Apoprionospio pygmaea* | Annelida: Spionidae | 23.4 | 87.6 | 27.0 |
| | *Owenia collaris* | Annelida: Oweniidae | 18.3 | 12.6 | 146.0 |
| | *Gibberosus myersi* | Arthropoda: Amphipoda | 12.3 | 50.0 | 24.9 |
| | *Spiophanes duplex* | Annelida: Spionidae | 12.0 | 37.5 | 32.1 |
| | Actiniaria | Cnidaria: Anthozoa | 10.8 | 50.0 | 21.6 |
| | *Monticellina siblina* | Annelida: Cirratulidae | 6.3 | 50.0 | 12.9 |
| | *Metharpinia jonesi* | Arthropoda: Amphipoda | 6.0 | 50.0 | 11.7 |
| | *Mediomastus* sp | Annelida: Capitellidae | 5.4 | 62.4 | 8.7 |
| | *Rhepoxynius menziesi* | Arthropoda: Amphipoda | 5.4 | 50.0 | 10.8 |
| Mid-shelf | *Amphiodia urtica* | Echinodermata: Ophiuroidea | 40.5 | 73.8 | 55.2 |
| | *Spiophanes norrisi* | Annelida: Spionidae | 32.4 | 47.4 | 68.4 |
| | *Axinopsida serricata* | Mollusca: Bivalvia | 10.5 | 57.9 | 18.3 |
| | *Mediomastus* sp | Annelida: Capitellidae | 6.0 | 89.4 | 6.9 |
| | *Polycirrus* sp A | Annelida: Terebellidae | 5.4 | 78.9 | 6.9 |
| | Euclymeninae sp A | Annelida: Maldanidae | 5.1 | 68.4 | 7.5 |
| | *Spiophanes berkeleyorum* | Annelida: Spionidae | 4.8 | 68.4 | 7.2 |
| | *Aricidea* (*Acmira*) *catherinae* | Annelida: Paraonidae | 4.8 | 52.5 | 9.0 |
| | *Sternaspis fossor* | Annelida: Sternaspidae | 4.2 | 73.8 | 5.4 |
| | *Monticellina cryptica* | Annelida: Cirratulidae | 4.2 | 68.4 | 6.0 |
| Outer Shelf | *Aphelochaeta glandaria* Cmplx | Annelida: Cirratulidae | 23.7 | 100.0 | 23.7 |
| | *Monticellina siblina* | Annelida: Cirratulidae | 9.6 | 66.6 | 14.4 |
| | *Chaetozone* sp SD5 | Annelida: Cirratulidae | 9.6 | 50.0 | 18.9 |
| | *Spiophanes kimballi* | Annelida: Spionidae | 6.9 | 83.4 | 8.1 |
| | *Mediomastus* sp | Annelida: Capitellidae | 6.6 | 100.0 | 6.6 |
| | *Tellina carpenteri* | Mollusca: Bivalvia | 5.4 | 100.0 | 5.4 |
| | *Aricidea* (*Acmira*) *catherinae* | Annelida: Paraonidae | 5.4 | 83.4 | 6.3 |
| | *Polycirrus* sp A | Annelida: Terebellidae | 5.4 | 50.0 | 10.8 |
| | *Axinopsida serricata* | Mollusca: Bivalvia | 5.1 | 83.4 | 6.0 |
| | *Chaetozone hartmanae* | Annelida: Cirratulidae | 4.2 | 50.0 | 8.7 |
| Upper Slope | *Maldane sarsi* | Annelida: Maldanidae | 10.5 | 85.8 | 12.3 |
| | *Yoldiella nana* | Mollusca: Bivalvia | 4.5 | 28.5 | 15.6 |
| | *Eclysippe trilobata* | Annelida: Ampharetidae | 4.2 | 28.5 | 14.4 |
| | *Spiophanes kimballi* | Annelida: Spionidae | 3.9 | 57.0 | 6.9 |
| | *Tellina carpenteri* | Mollusca: Bivalvia | 3.6 | 57.0 | 6.3 |
| | *Mediomastus* sp | Annelida: Capitellidae | 3.6 | 42.9 | 8.7 |
| | *Myriochele gracilis* | Annelida: Oweniidae | 3.3 | 57.0 | 5.7 |
| | *Ampharete finmarchica* | Annelida: Ampharetidae | 3.0 | 57.0 | 5.4 |
| | *Macoma carlottensis* | Mollusca: Bivalvia | 2.7 | 42.9 | 6.0 |
| | *Paraprionospio alata* | Annelida: Spionidae | 2.4 | 85.8 | 2.7 |

site in this cluster, the oweniid polychaete *Owenia collaris* (146 individuals at station 8010) is also historically characteristic for shallow, inner shelf regions off San Diego. SIMPER analysis revealed the two most characteristic animals for this cluster to be *G. myersi* and the phoxocephalid amphipod *Metharpinia jonesi*. Sediments at these sites were composed almost entirely of sand and shell hash with only 1% fines, and with a total organic carbon (TOC) content of 0.1% by weight (% wt).

Cluster group B represents assemblages from the two deepest sites sampled along the upper slope at depths of 421 and 433 m. These assemblages averaged 28 taxa and 103 individuals per grab, the lowest values among all seven cluster groups. Polychaetes and molluscs were numerically dominant, with the three most abundant species being the maldanid polychaete *Maldane sarsi* with ~20 animals/grab, the bivalve *Yoldiella nana* with ~16 animals/grab, and the ampharetid polychaete *Eclysippe trilobata* with ~15 animals/grab. SIMPER analysis revealed these three species to also be most characteristic of the group. Sediments at these two sites were finer (i.e., 71% fines) than those occurring in the other cluster groups (i.e., 0–64% fines), and had an average TOC value of 1.9% wt.

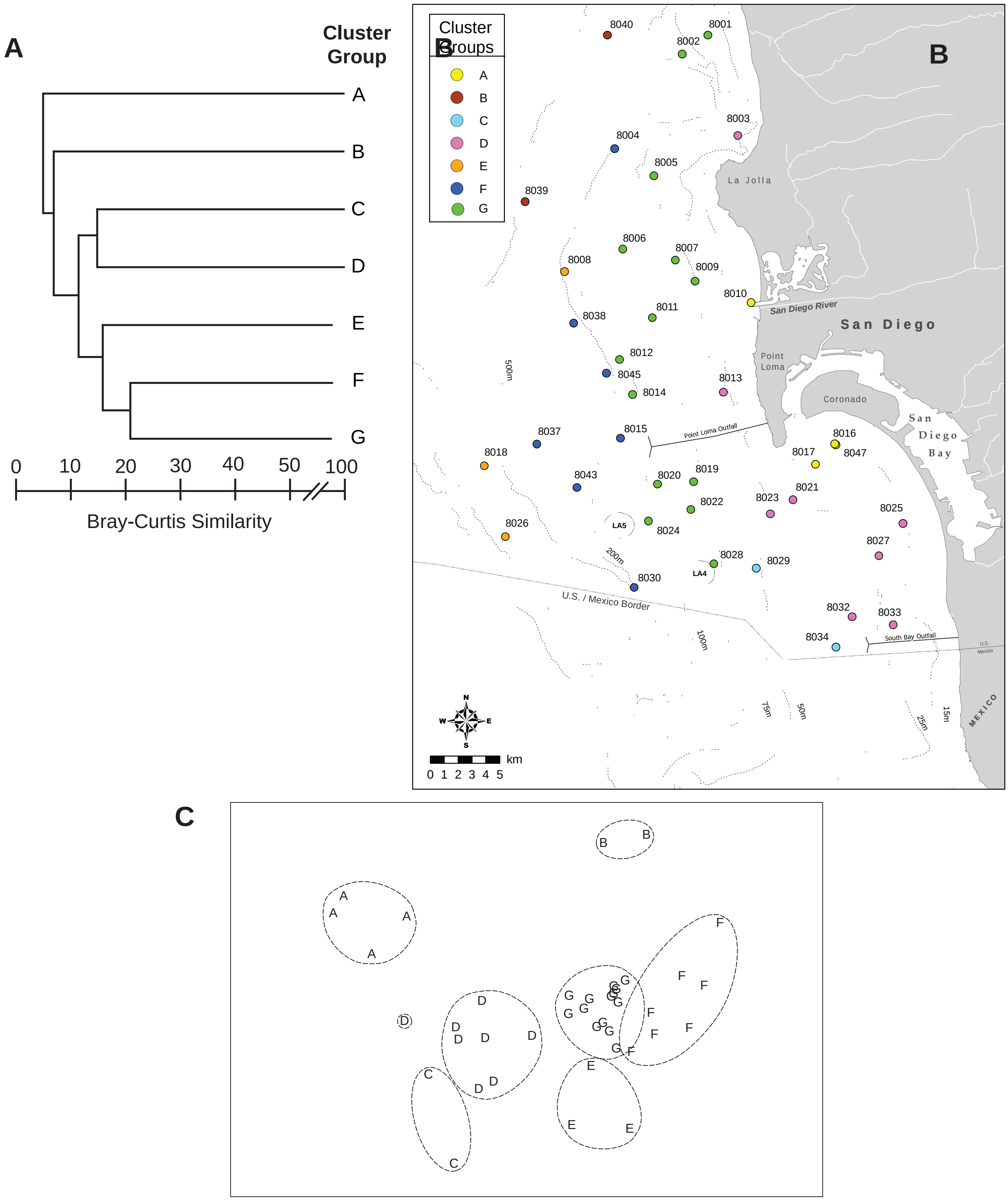
Cluster group C represents mid-shelf assemblages that occurred at depths of 38 and 52 m. Species richness within these assemblages averaged 43 taxa, while abundance averaged 164 individuals per 0.1 $m^2$. Polychaetes and crustaceans were numerically dominant, with the three most abundant species being the spionid polychaetes *Spiophanes norrisi* (~45 animals/grab) and *Spio maculata* (~19 animals/grab), and the terebellid polychaete *Lanassa venusta venusta* (7 animals/grab). SIMPER found *S. norrisi* to characterize the assemblages in this clade, along with the cirolanid isopod *Eurydice caudata* and the terebellid polychaete *Polycirrus* sp A. Sediments at these sites were composed entirely of sand and other coarse particles (i.e., 0% fines), including black sand and red relict sand, with no measurable TOC present.

Cluster group D is a sister group to cluster C (Figure 9.4A), and represents inner shelf to shallow mid-shelf assemblages that occurred at depths ranging from 17 to 40 m. These assemblages were typical of relatively shallow-water sites in the region with an average of 106 taxa and 506 individuals per 0.1 $m^2$. The dominant species at these sites included the spionids *Spiophanes norrisi* (~120 animals/grab), *Apoprionospio pygmaea* (~19 animals/grab), and *Spiophanes duplex* (~17 animals/grab). Characteristic species included *S. norrisi*, *S. duplex*, and the capitellid polychaete *Mediomastus* sp. Sediment composition at the sites within this group averaged 10% fines and 1.0% wt TOC.

Cluster group E represents outer shelf assemblages at depths of 125–161 m, including two sites along the Coronado Bank. These assemblages averaged 58 taxa and 221 individuals per 0.1 $m^2$. Dominant species included the cirratulid polychaetes *Aphelochaeta glandaria* with ~40 animals/grab, *Chaetozone* sp SD5 with 19 animals/grab, and *Monticellina siblina* with ~17 animals/grab. These species were also identified as most characteristic of the group based on SIMPER results. Sediments at these sites were relatively coarse containing gravel, rock, shell hash and only 22% fines. TOC content at these sites averaged 2.5% wt, which was the highest among the seven cluster groups (Figure 9.5).

Cluster group F contains five upper slope and two outer shelf sites that ranged in depth from 167–317 m (Figure 9.4A). These assemblages averaged 51 taxa and 140 individuals per 0.1 $m^2$. Dominant species included the spionid *Spiophanes kimballi* with ~9 animals/grab, *Mediomastus* sp with ~6 animals/grab, and *Maldane sarsi* with ~5 animals/grab, and the bivalve *Tellina carpenteri* with ~6 animals/grab. SIMPER revealed *S. kimballi* and *T. carpenteri* to characterize the group. The percentage of fines was the second highest for all cluster groups, averaging 64%. TOC averaged 1.7% wt.

Cluster group G is a sister group to cluster F (Figure 9.4A), and contains the majority of mid- and outer shelf sites at depths from 50–123 m. This group possessed the second highest average species richness (91 species) and averaged 326 individuals




# Figure 9.4

Results of multivariate analyses of macrofaunal abundance data for the regional benthic statons sampled during 2010. Data are presented as: (A) cluster results; (B) spatial distribution of sediment samples as delineated by cluster analysis; (C) nMDS ordination illustrating distribution of samples in multivariate space. nMDS plot stress = 0.15. Dashed ellipses enclose station groups within a similarity of 21%.

## Table 9.4

Description of cluster groups A–G defined in Figure 9.4. Data for percent fines, total organic carbon (TOC; % weight), depth (m), species richness, and infaunal abundance, are expressed as mean values per 0.1-$m^2$ grab over all stations in each group. Bold values indicate taxa that were considered most characteristic of that group according to SIMPER analysis (i.e., greatest percentage contribution to within-group similarity)

| | Group A | Group B | Group C | Group D | Group E | Group F | Group G |
|---|---|---|---|---|---|---|---|
| ***n*** | 4 | 2 | 2 | 8 | 3 | 7 | 14 |
| **Percent Fines** | 1 | 71 | 0 | 10 | 22 | 64 | 41 |
| **Depth** | 10 | 427 | 45 | 28 | 147 | 226 | 83 |
| **TOC** | 0.1 | 1.9 | 0.0 | 1.0 | 2.5 | 1.7 | 0.6 |
| **Species Richness** | 33 | 28 | 43 | 106 | 58 | 51 | 91 |
| **Abundance** | 219 | 103 | 164 | 506 | 221 | 140 | 326 |
| **Taxa** | **Mean Abundance** | | | | | | |
| *Owenia collaris* | 36.5 | | | | | | 0.1 |
| *Gibberosus myersi* | **23.5** | | 1.0 | 0.6 | | | |
| Actiniaria | 21.3 | 0.5 | | 0.6 | | | 0.1 |
| *Spiophanes norrisi* | 12.8 | 1.0 | **44.5** | **120.4** | | | 0.6 |
| *Metharpinia jonesi* | **11.8** | | | | | | |
| *Maldane sarsi* | | **20.0** | | | | 4.9 | 1.4 |
| *Yoldiella nana* | | **15.5** | | | | | |
| *Eclysippe trilobata* | | **14.5** | | | 1.3 | | 0.5 |
| *Myriochele gracilis* | | 10.0 | | | | 0.7 | 1.0 |
| *Phoronis* sp | | 4.0 | | 0.5 | | | 0.3 |
| *Spio maculata* | | | 18.5 | | | | |
| *Lanassa venusta venusta* | | | 7.0 | 0.1 | | 0.6 | 0.4 |
| *Eurydice caudata* | | | **6.5** | 0.6 | | | 0.4 |
| *Mooreonuphis* sp SD1 | | | 5.0 | | | | |
| *Apoprionospio pygmaea* | 10.3 | | | 18.6 | | | 0.1 |
| *Spiophanes duplex* | | | | **16.6** | 0.3 | 0.3 | 2.9 |
| *Mediomastus* sp | 0.5 | | 0.5 | **12.8** | 6.0 | 5.7 | 4.4 |
| *Monticellina siblina* | | | 0.5 | 10.9 | **17.3** | | 1.8 |
| *Aphelochaeta glandaria* Cmplx | | | | 0.4 | **40.3** | 2.7 | 1.6 |
| *Chaetozone* sp SD5 | | | 1.0 | 7.8 | **19.0** | 0.1 | 0.1 |
| *Mooreonuphis* sp | | | 2.0 | | 6.7 | | 0.1 |
| *Huxleyia munita* | | | | | 6.7 | | |
| *Spiophanes kimballi* | | | | | 2.0 | **8.6** | 0.9 |
| *Tellina carpenteri* | | | | | 4.0 | **6.4** | 0.7 |
| *Macoma carlottensis* | | | | | | 3.6 | 0.1 |
| *Amphiodia urtica* | | | 0.5 | 0.8 | | 1.0 | **55.6** |
| *Axinopsida serricata* | | | | | 4.7 | 2.7 | 14.5 |
| *Polycirrus* sp A | | | **2.0** | 1.6 | 1.0 | 1.7 | 8.4 |
| *Sternaspis fossor* | | | | 0.5 | 0.3 | 0.9 | **5.6** |
| *Prionospio* (*Prionospio*) *dubia* | | | | 0.3 | 1.7 | 0.3 | **5.4** |

per 0.1 $m^2$. Dominant species included the ophiuroid *Amphiodia urtica* (~56 animals/grab), the bivalve *Axinopsida serricata* (~15 animals/grab), and the terebellid Polycirrus sp A (~8 animals/grab). SIMPER identified *A. urtica*, the sternaspid polychaete *Sternaspis fossor* and the spionid *Prionospio* (*Prionospio*) *dubia* to be characteristic of the clade. Sediments associated with this cluster were mixed, averaging 41% fines, and with an average TOC concentration of 1.7% wt.

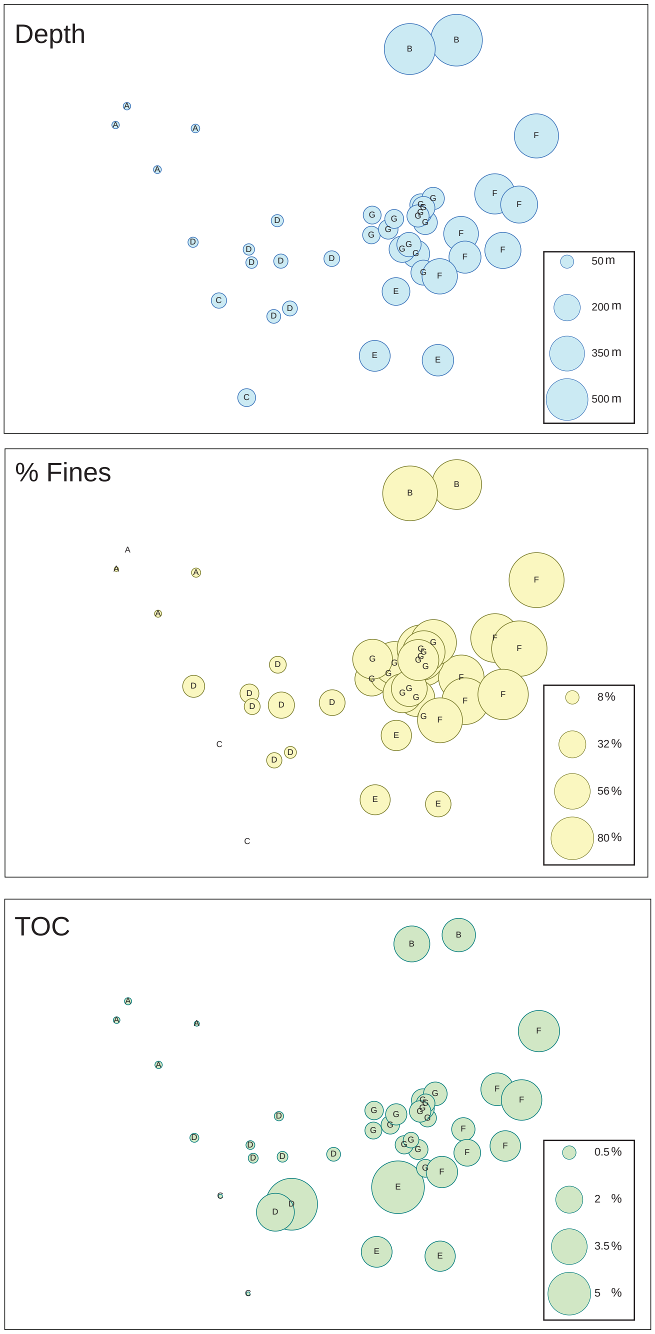



**Figure 9.5**
Ordination (nMDS) of macrofaunal abundance data for 2010 regional stations (see Figure 9.4), with superimposed circles representing station depth, and the amount of fine particles (% fines) and total organic carbon (TOC, % wt) in sediments. Circles vary in size according to the magnitude of each value. Stress = 0.15.

## Discussion

The SCB benthos has long been considered to be composed of "patchy" habitats, with the distribution of species and communities exhibiting considerable spatial variability. Results of regional surveys off San Diego support this characterization. Benthic assemblages surveyed during 2010 segregated by habitat characteristics such as depth and sediment grain size, and were similar to macrofaunal assemblages observed during previous regional surveys. Two distinct, relatively shallow nearshore macrofaunal assemblages occurred off San Diego and were similar to those found in shallow, sandy sediment habitats across the SCB (Barnard 1963, Jones 1969, Thompson et al. 1987, 1992, ES Engineering Science 1988, Mikel et al. 2007). These assemblages (cluster groups A and D) occurred at inner to mid-shelf sites (9–40 m) that were characterized by coarse sediments averaging between 1–10% fines. Typically, polychaetes such as *Owenia collaris* and *Spiophanes norrisi* are numerically dominant in these types of assemblages.

The largest number of sites sampled off San Diego in 2010 occurred in mid- to outer shelf areas (50–123 m depths), and were characterized by typical mixed sediment (i.e., 41% fines) macrofaunal assemblages dominated by the ophiuroid *Amphiodia urtica*. These cluster group G assemblages correspond to the *Amphiodia* "mega-community" described by Barnard and Ziesenhenne (1961), and are common in the Point Loma region off San Diego as well as other parts of the southern California mainland shelf (Jones 1969, Fauchald and Jones 1979, Thompson et al. 1987, 1993, Zmarzly et al. 1994, Diener and Fuller 1995, Bergen et al. 1998, 2000, 2001, Mikel et al. 2007, City of San Diego 2010a, 2011). Outer shelf stations at depths of 125–161 m with coarser sediments of ~22% fines (including sites along the Coronado Bank) were typically devoid of *A. urtica*, and were instead dominated by polychaete worms (especially the cirratulids *Aphelochaeta glandaria*, *Monticellina siblina* and *Chaetozone* sp SD5; i.e., cluster group E).

Similar to patterns observed in past years, upper slope habitats off San Diego were characterized by a high percentage of fine sediments with associated macrofaunal assemblages that were distinct from most shelf stations surveyed. Macrofaunal assemblages from five upper slope stations at depths <320 m clustered together with those from the two deepest outer shelf stations, and lacked the high abundances of *A. urtica* characteristic of most other outer and mid-shelf locations. Polychaetes, particularly *Spiophanes kimballi*, *Mediomastus* sp and *Maldane sarsi* were numerically dominant. In contrast, assemblages from the two deepest upper slope stations at 421−433 m clustered together in their own clade (cluster group B), and resided in the finest sediments of all sites surveyed. The characteristic species in this latter group included polychaetes and molluscs such as the maldanid *Maldane sarsi* and the bivalve *Yoldiella nana*.

Although benthic communities off San Diego vary across depth and sediment gradients, there was no evidence of disturbance during the 2010 regional survey that could be attributed to wastewater discharges, disposal sites or other point sources. Benthic macrofauna appear to be in good condition throughout the region, with 92% of the sites surveyed in 2010 being in reference condition based on assessments using the BRI. This is not unexpected as Ranasinghe et al. (2010) recently reported that 98% of the entire SCB was in good condition based on assessment data gathered during the 1994−2003 bight-wide surveys.

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