Chapter 6. Demersal Fishes and Megabenthic Invertebrates

INTRODUCTION

Marine fishes and invertebrates are conspicuous members of continental shelf habitats, and assessment of their communities has become an important focus of ocean monitoring programs throughout the world. Assemblages of bottom dwelling (demersal) fishes and relatively large (megabenthic), mobile invertebrates that live on the surface of the seafloor have been sampled extensively for more than 30 years on the mainland shelf of the Southern California Bight (SCB), primarily by programs associated with municipal wastewater and power plant discharges (Cross and Allen 1993). More than 100 species of demersal fishes inhabit the SCB, while the megabenthic invertebrate fauna consists of more than 200 species (Allen 1982, Allen et al. 1998, 2002, 2007). For the region surrounding the South Bay Ocean Outfall (SBOO), the most common trawl-caught fishes include speckled sanddab, longfin sanddab, hornyhead turbot, California halibut, and California lizardfish. Common trawl-caught invertebrates include various echinoderms (e.g., sea stars, sea urchins, sea cucumbers, sand dollars), crustaceans (e.g., crabs, shrimp), molluscs (e.g., marine snails, octopuses), and other taxa.

Demersal fish and megabenthic invertebrate communities are inherently variable and may be influenced by both anthropogenic and natural factors. These organisms live in close proximity to the seafloor and are therefore exposed to contaminants of anthropogenic origin that may accumulate in the sediments via deposition from both point and non-point sources (e.g., discharges from ocean outfalls and storm drains, surface runoff from watersheds, outflows from rivers and bays, disposal of dredge materials). Natural factors that may affect these organisms include prey availability (Cross et al. 1985), bottom relief and sediment structure (Helvey and Smith 1985), and changes in water temperatures associated with large scale oceanographic events such as El Niño/ La Niña oscillations (Karinen et al. 1985). These factors can affect migration patterns of adult fish or the recruitment of juveniles into an area (Murawski 1993). Population fluctuations that affect species diversity and abundance of both fishes and invertebrates may also be due to the mobile nature of many species (e.g., fish schools, urchin aggregations).

The City of San Diego has been conducting trawl surveys in the area surrounding the SBOO since 1995. These surveys are designed to monitor the effects of wastewater discharge on the local marine biota by assessing the structure and stability of the trawl-caught fish and invertebrate communities. This chapter presents analyses and interpretations of the data collected during the 2009 trawl surveys. A long-term analysis of changes in these communities from 1995 through 2009 is also presented.

Materials and Methods

Field Sampling

Trawl surveys were conducted at seven fixed monitoring stations around the SBOO during 2009 (Figure 6.1). These surveys were conducted during January (winter), April (spring), July (summer), and October (fall) for a total of 28 community trawls during the year. These stations, designated SD15–SD21, are located along the 28-m depth contour, and encompass an area ranging from south of Point Loma, California (USA) to an area off Punta Bandera, Baja California (Mexico). A single trawl was performed at each station during each survey using a 7.6-m Marinovich otter trawl fitted with a 1.3-cm cod-end mesh net. The net was towed for 10 minutes bottom time at a speed of about 2.0 knots along a predetermined heading.

The total catch from each trawl was brought onboard ship for sorting and inspection. All fishes and invertebrates captured were identified to species or to the lowest taxon possible. If an animal could

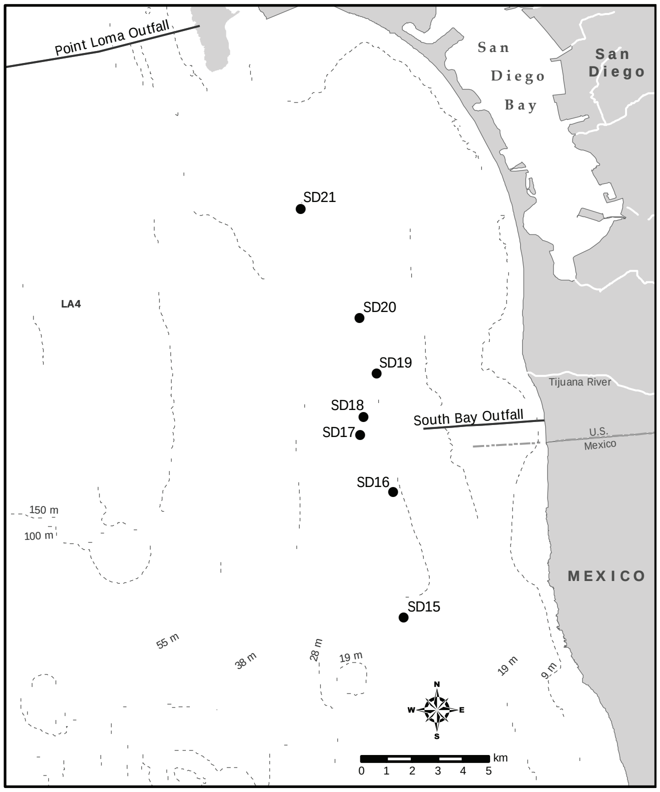

Figure 6.1
Otter trawl station locations, South Bay Ocean Outfall Monitoring Program.

not be identified in the field, it was returned to the laboratory for further identification. For fishes, the total number of individuals and total biomass (kg, wet weight) were recorded for each species. Additionally, each individual fish was inspected for physical anomalies or indicators of disease (e.g., tumors, fin erosion, discoloration) as well as the presence of external parasites, and then measured to the nearest centimeter size class (standard lengths). For invertebrates, the total number of individuals was recorded per species. Due to the small size of most organisms, invertebrate biomass was typically measured as a composite weight of all species combined; however, large or exceptionally abundant species were weighed separately.

Data Analyses

Populations of each fish and invertebrate species were summarized as percent abundance, frequency of occurrence, mean abundance per haul, and mean abundance per occurrence. In addition, species richness (number of taxa), total abundance, total biomass, and Shannon diversity index (H') were calculated for each station. For historical comparisons, the data were grouped as "nearfield" stations (SD17, SD18), "south farfield" stations (SD15, SD16), and "north farfield" stations (SD19, SD20, SD21). The two nearfield stations were those located closest to the outfall (i.e., within 1000 m of the north or south diffuser legs).

A long-term multivariate analysis of demersal fish communities in the region was performed using data collected from 1995 through 2009. However, in order to eliminate noise due to natural seasonal variation in populations, this analysis was limited to data for the July surveys only over these 15 years. PRIMER software was used to examine spatio-temporal patterns in the overall similarity of fish assemblages in the region (see Clarke 1993, Warwick 1993, Clarke and Gorley 2006). These analyses included classification (cluster analysis) by hierarchical agglomerative clustering with group-average linking, and ordination by non-metric multidimensional scaling (MDS). The fish abundance data were square root transformed and the Bray-Curtis measure of similarity was used as the basis for classification. Because species composition was sparse at some stations, a "dummy" species with a value of one was added to all samples prior to computing similarities (see Clarke and Gorley 2006). SIMPER analysis was subsequently used to identify which species primarily account for observed differences between cluster groups, as well as to identify species typical of each group.

Results and Discussion

Fish Community

Thirty-four species of fish were collected in the area surrounding the SBOO in 2009 (Table 6.1, Appendix E.1). The total catch for the year was 6192 individuals, representing an average of about 221 fish per trawl. As in previous years, speckled sanddabs were dominant, occurring in every haul and accounting for 38% of the total number of fishes collected. However, California lizardfish and

Table 6.1

Demersal fish species collected in 28 trawls in the SBOO region during 2009. PA = percent abundance; FO = frequency of occurrence; MAH = mean abundance per haul; MAO = mean abundance per occurrence.

Species	PA	FO	MAH	MAO	Species	PA	FO	MAH	MAO
Speckled sanddab	38	100	84	84	Pacific pompano	<1	4	<1	4
California lizardfish	29	100	64	64	Pink seaperch	<1	11	<1	1
Yellowchin sculpin	15	61	33	55	Bigmouth sole	<1	11	<1	1
Roughback sculpin	9	96	19	20	Juvenile rockfish	<1	7	<1	2
Longfin sanddab	2	64	5	8	Sarcastic fringehead	<1	4	<1	3
Longspine combfish	2	46	4	8	Barcheek pipefish	<1	4	<1	2
Hornyhead turbot	1	93	3	3	Bay pipefish	<1	4	<1	2
California tonguefish	1	64	2	4	Spotted cuskeel	<1	7	<1	1
Plainfin midshipman	1	54	1	2	White croaker	<1	4	<1	2
California scorpionfish	<1	39	1	2	Giant kelpfish	<1	4	<1	1
Shiner perch	<1	7	1	10	Kelp bass	<1	4	<1	1
English sole	<1	39	1	1	Kelp pipefish	<1	4	<1	1
Fantail sole	<1	32	<1	1	Northern anchovy	<1	4	<1	1
Pygmy poacher	<1	18	<1	1	Pacific sanddab	<1	4	<1	1
California skate	<1	21	<1	1	Juvenile sea bass	<1	4	<1	1
Specklefin midshipman	<1	14	<1	1	Señorita	<1	4	<1	1
California halibut	<1	14	<1	1	Spotted turbot	<1	4	<1	1

yellowchin sculpin were also abundant, accounting for 29% and 15% of the total number of fishes collected, respectively. Together these three species accounted for 82% of all fishes collected in 2009. Like the speckled sanddab, California lizardfish occurred in every haul, whereas yellowchin sculpin occurred in 61%. Other species collected frequently (>50% of the trawls) included roughback sculpin, longfin sanddab, hornyhead turbot, California tonguefish, and plainfin midshipman. The majority of species captured in the South Bay outfall region tended to be relatively small fish with an average length <20 cm (see Appendix E.1). Although larger species such as the California skate and California halibut were also caught during the year, they were relatively rare.

During 2009, species richness (number of taxa) and diversity (H') values for the South Bay fish assemblages were relatively low compared to values reported previously for other areas of the SCB (e.g., Allen et al. 1998, 2002, 2007), while abundance and biomass values varied widely (Table 6.2). No more than 14 species occurred in any one haul, and the corresponding H' values were all less than 2.2. As in previous years, trawls from station SD15 located the farthest south in Mexican waters had the lowest average species richness (6 species) and diversity (H' = 0.84) values. Total abundance ranged from 69 to 518 fishes per haul over all stations, which generally co-varied with populations of speckled sanddabs, California lizardfish, yellowchin sculpin, and roughback sculpin (see Appendix E.2). Biomass varied from 1.3 to 7.6 kg per haul, with higher biomass values coincident with greater numbers of fishes as expected (Appendix E.3).

Although average species richness values for SBOO demersal fish assemblages have remained within a narrow range over the years (i.e., 5–14 species/station/year), the average abundance per haul has fluctuated greatly (i.e., 28–308 fish/station/year) mostly in response to population fluctuations of a few dominant species (see Figure 6.2, 6.3). For example, average abundance at four of the seven stations decreased between 2008 and 2009 (SD16, SD19, SD20, SD21); these reductions match drops in average speckled sanddab numbers at the same stations. In contrast, overall abundances increased at stations SD15, SD17, and SD18, reflecting greater numbers of yellowchin sculpin and California lizardfish. Whereas population fluctuations of common

Table 6.2

Summary of demersal fish community parameters for SBOO stations sampled during 2009. Data are included for species richness (number of species), abundance (number of individuals), diversity (H'), and biomass (kg, wet weight); SD = standard deviation.

Station	Jan	Apr	Jul	Oct	Annual Mean	Annual SD	Station	Jan	Apr	Jul	Oct	Annual Mean	Annual SD
Species Richness							*Abundance*						
SD15	7	5	6	6	6	1	SD15	75	153	182	146	139	45
SD16	6	8	9	7	8	1	SD16	164	123	356	110	188	114
SD17	9	13	11	9	11	2	SD17	93	154	465	518	308	215
SD18	11	12	9	9	10	2	SD18	220	219	136	356	233	91
SD19	8	11	11	8	10	2	SD19	135	115	256	414	230	138
SD20	8	9	12	11	10	2	SD20	129	171	382	250	233	111
SD21	13	14	12	11	13	1	SD21	156	172	473	69	218	176
Survey Mean	9	10	10	9			Survey Mean	139	158	321	266		
Survey SD	2	3	2	2			Survey SD	48	35	133	169		
Diversity							*Biomass*						
SD15	0.97	0.62	0.89	0.86	0.84	0.15	SD15	2.3	2.6	2.3	1.8	2.2	0.3
SD16	0.85	1.03	1.44	1.20	1.13	0.25	SD16	1.8	4.7	4.5	2.9	3.5	1.4
SD17	1.18	1.61	1.34	0.98	1.28	0.27	SD17	1.5	7.6	4.2	4.6	4.5	2.5
SD18	1.50	1.77	1.30	1.30	1.47	0.22	SD18	4.4	5.2	2.3	3.7	3.9	1.2
SD19	0.88	1.57	1.67	0.89	1.25	0.43	SD19	2.0	3.7	5.3	4.2	3.8	1.4
SD20	0.88	1.16	1.61	1.68	1.33	0.38	SD20	1.3	3.8	5.8	2.8	3.4	1.9
SD21	1.83	1.83	1.60	2.11	1.84	0.21	SD21	3.7	7.2	6.2	3.1	5.0	2.0
Survey Mean	1.16	1.37	1.41	1.29			Survey Mean	2.4	5.0	4.4	3.3		
Survey SD	0.38	0.44	0.27	0.46			Survey SD	1.2	1.9	1.6	0.9		

species such as speckled sanddab, California lizardfish, roughback sculpin, and yellowchin sculpin tend to occur across large portions of the study area (i.e., over multiple stations), intra-station variability is most often associated with large hauls of schooling species that occur less frequently. Examples of this include (1) large hauls of white croaker which occurred primarily at station SD21 in 1996; (2) a large haul of northern anchovy which occurred in a single haul from station SD16 in 2001; (3) a large haul of Pacific pompano which was captured in a single haul at station SD21 in 2008. Overall, none of the observed changes appear to be associated with wastewater discharge.

Classification analyses of long-term data (1995–2009, July surveys only) discriminated between eight main types of fish assemblages in the South Bay region (Figure 6.4). These assemblages (cluster groups A–H) can be distinguished by differences in the relative abundances of the common species present, although most were dominated by speckled sanddabs. The distribution of assemblages in 2009 was generally similar to that seen in previous years, especially between 2003–2008, and no patterns appear to be associated with proximity to the outfall. Instead, most differences appear more closely related to large-scale oceanographic events (e.g., El Niño in 1998) or the unique characteristics of a specific station location. For example, station SD15 located far south of the outfall off northern Baja California often grouped apart from the remaining stations. The composition and main characteristics of each cluster group are described below (Table 6.3, Appendix E.4).

Cluster groups A, B, and C had the fewest fish per haul (i.e., 38 fish/4 species for group A;

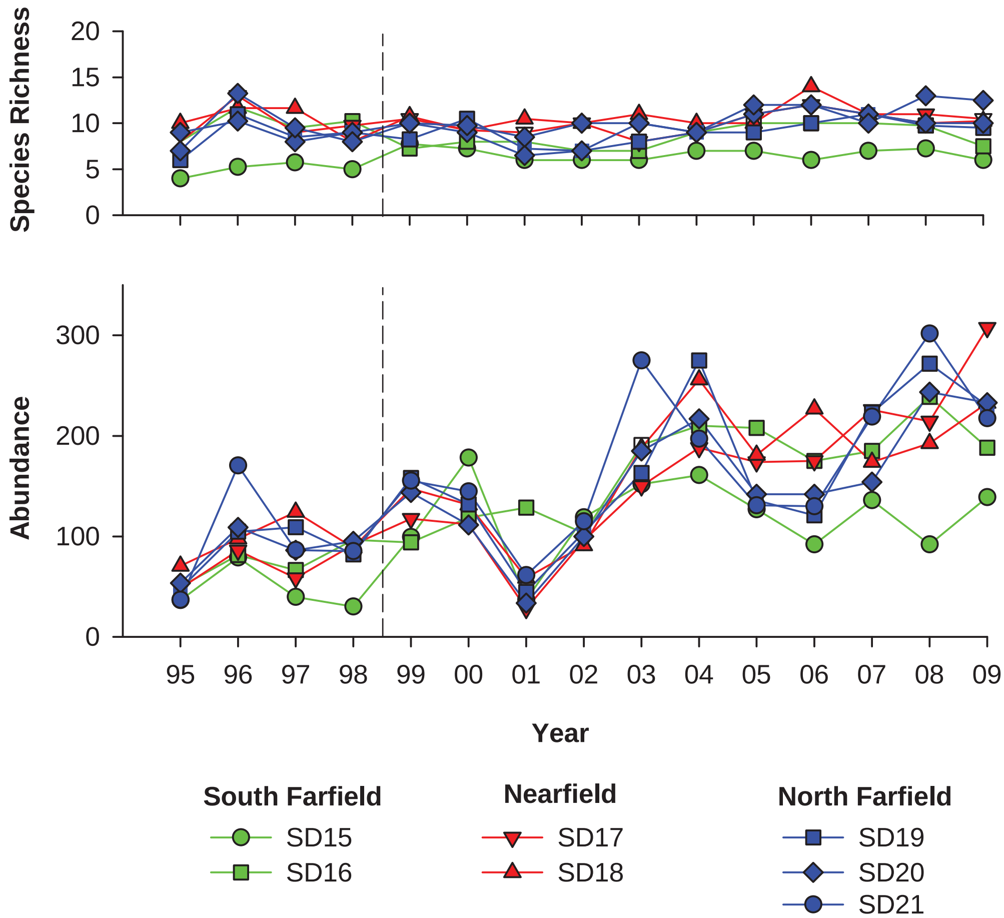

Figure 6.2

Species richness and abundance of demersal fish collected at each SBOO trawl station between 1995 and 2009. Data are annual means; n=2 in 1995 and n=4 between 1996–2009. Dashed line represents initiation of wastewater discharge.

17 fish/7 species for group B; 38 fish/7 species on average for group C), which reflected the relative lack of speckled sanddabs in these three groups compared to the other cluster groups (Table 6.3). These groups were further distinguished from the other cluster groups by their relative (but usually lower) abundance of several common species, including longfin sanddab, yellowchin sculpin, California lizardfish, hornyhead turbot, roughback sculpin and English sole (Appendix E.4). Assemblages represented by group C differed from those represented by groups A and B in the relative contribution of speckled sanddabs, California lizardfish, California scorpionfish, and hornyhead turbot. The assemblage represented by group A was from station SD15 in 1998 and the assemblage represented by group B was from station SD17 in 2001. The fish assemblages represented by group C were collected at four stations sampled in July 1997 (i.e., southern stations SD15 and SD16, station SD17 near the outfall, northern station SD20) and every station except SD17 and SD21 during July 2001 (Figure 6.4).

Cluster group D comprised assemblages from the two northernmost stations (SD20, SD21) sampled in 1995, as well as from every station except SD15 sampled during warm water conditions associated with the 1998 El Niño (Figure 6.4). This group averaged about 64 individuals and 9 species per haul, and was characterized by the second lowest abundance of speckled sanddabs (12 fish/haul) (Table 6.3). The dominant species in this group was California lizardfish (~24 fish/haul) followed by longfin sanddabs (~12 fish/haul) and speckled sanddabs (as above); the relative abundance of these species helped distinguish this group from all of the others (Appendix E.4).

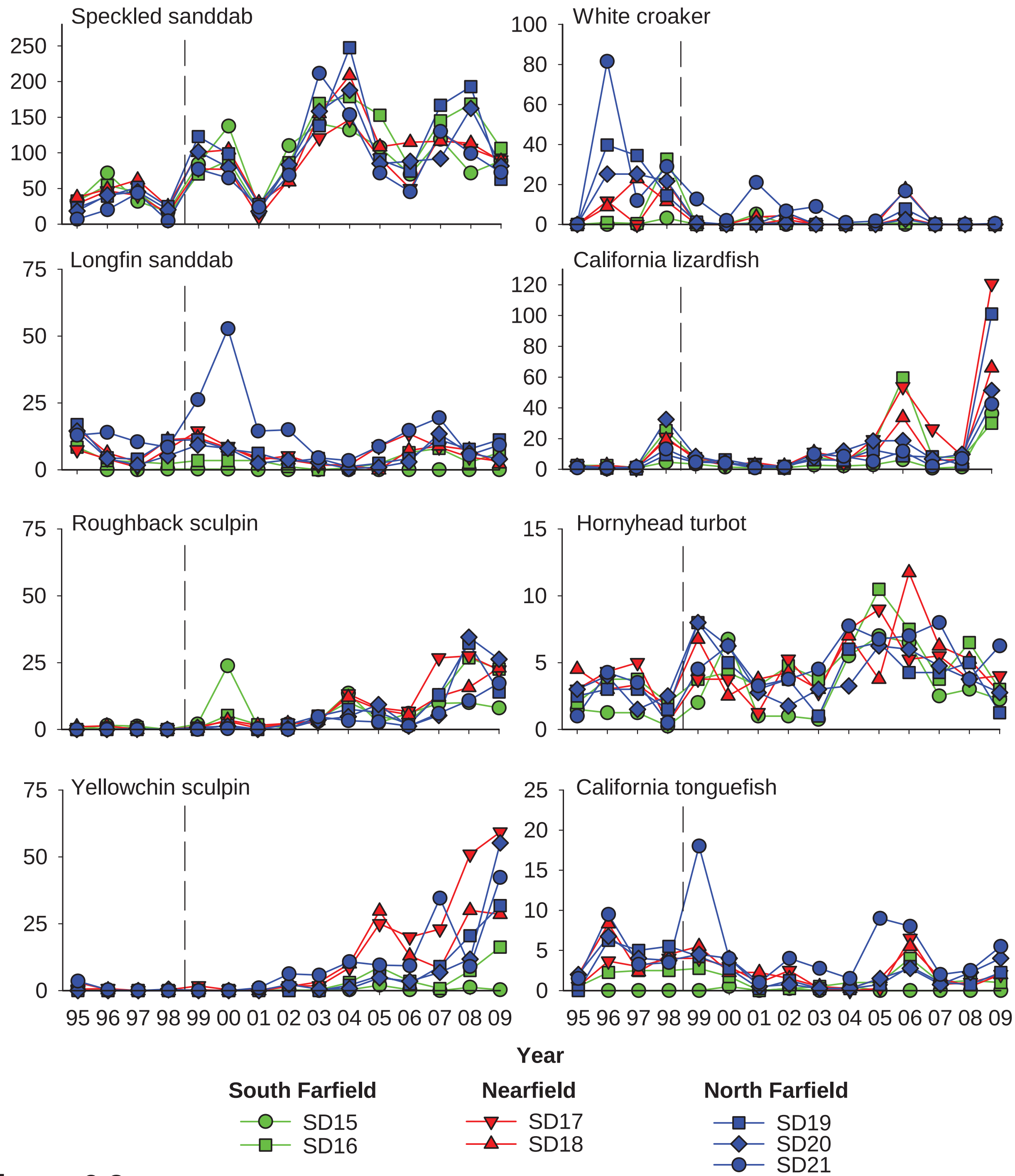

Figure 6.3
Abundance of the eight most abundant fish species collected in the SBOO region between 1995 and 2009. Data are annual means per station; $n=2$ in 1995 and $n=4$ between 1996–2009. Dashed line represents initiation of wastewater discharge.

Cluster group E was the third largest group and represented assemblages from 11 of the 14 station-surveys during 1995–1996 (i.e., representing all seven sites) and one or two stations each during 1997 (SD19, SD21), 1999 (SD17, SD21), 2000 (SD20, SD21), 2001 (SD21), and 2002 (SD18, SD21) (Figure 6.4). This group also represented assemblages from a few hauls at SD21 in 2005–2006. Similar to most other groups, the dominant species was the speckled sanddab (~62 fish/haul) (Table 6.3). Group E was also characterized by the greatest number of hornyhead turbots on average and had twice as many longfin sanddabs (~24 fish/haul) as in the other groups. The relative abundance of speckled

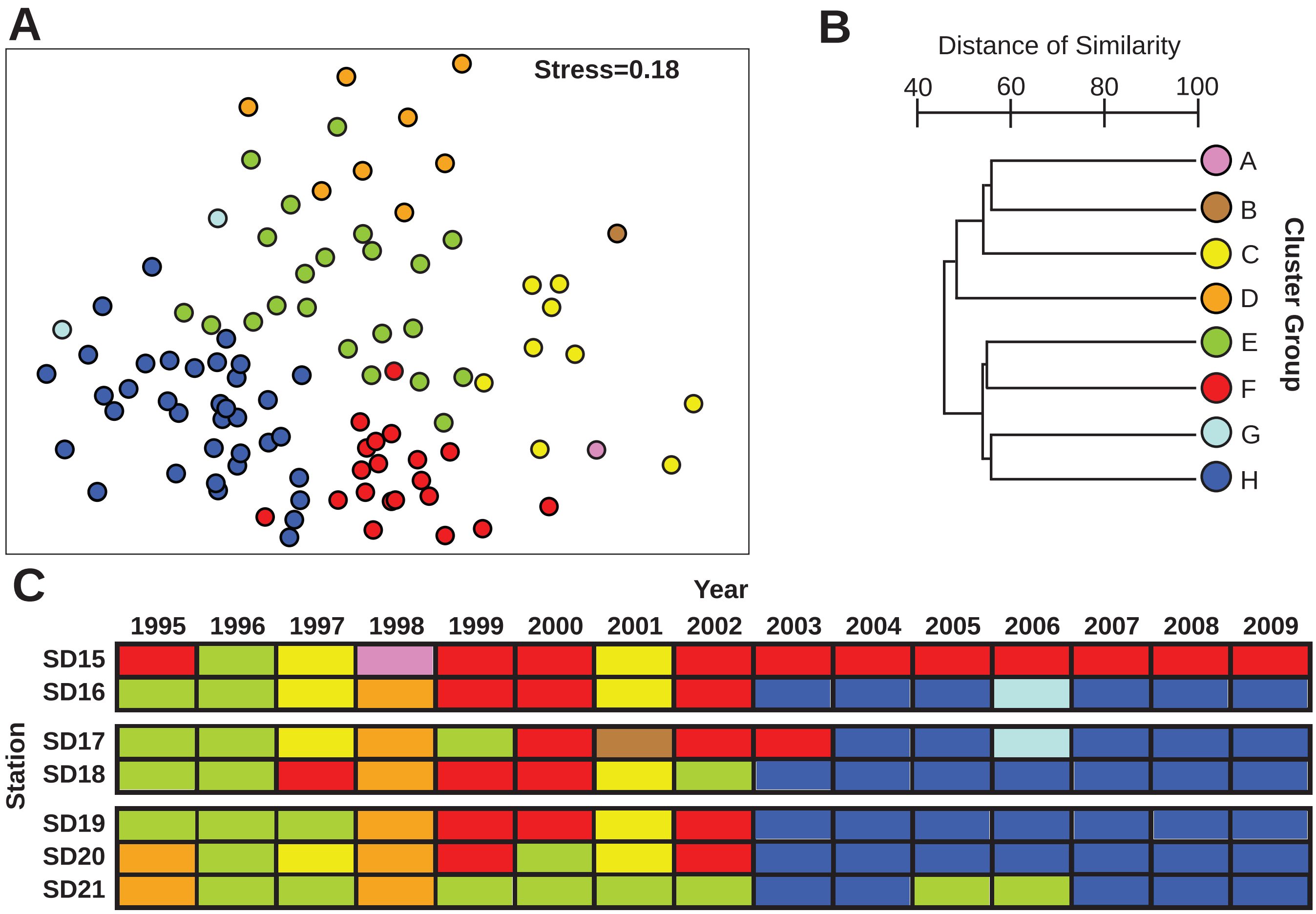

Figure 6.4
Results of multivariate analyses of demersal fish assemblages collected at SBOO stations SD15–SD21 between 1995 and 2009 (July surveys only). Data are presented as (A) MDS ordination, (B) a dendrogram of major cluster groups, and (C) a matrix showing distribution of cluster groups over time.

and longfin sanddabs, as well as California tonguefish, English sole, and hornyhead turbot distinguished this assemblage from the other cluster groups (Appendix E.4).

Cluster group F was the second largest group and comprised assemblages that occurred at a mix of sites sampled during all years except 1996, 1998, and 2001. This included station SD15 in 11 out of 15 surveys and a majority of the other stations sampled during 1999, 2000, and 2002 (Figure 6.4). Group F was characterized by the second highest average abundance of speckled sanddabs (~105 fish/haul) and very few other species (Table 6.3). The higher numbers of speckled sanddabs and lower numbers of various common species such as longfin sanddabs, California tonguefish, English sole, California lizardfish, yellowchin sculpin, and hornyhead turbot differentiated this group from the others (Appendix E.4).

Cluster group G represented the fish assemblages present only at stations SD16 and SD17 sampled in July 2006 (Figure 6.4). This group was unique in that it was characterized by more than 200 California lizardfish per haul, which was more than an order of magnitude greater for this species than in any other cluster group (Table 6.3). The second and third most abundant species comprising this group were the speckled sanddab (~56 fish/haul) and yellowchin sculpin (~15 fish/haul). The relative abundance of speckled sanddabs and hornyhead turbots distinguished this cluster group from the largest cluster group H (Appendix E.4).

Table 6.3

Description of cluster groups A–H defined in Figure 6.4. Data include number of hauls, mean species richness, mean total abundance, and mean abundance of the five most abundant species for each station group. Bold values indicate species that were considered "characteristic" of that group according to SIMPER analyses (i.e., similarity/standard deviation ≥ 2.0).

	Group A	Group B	Group C	Group D	Group E	Group F	Group G	Group H
Number of Hauls	1	1	9	8	22	25	2	37
Mean Species Richness	4	7	7	9	10	6	8	10
Mean Abundance	38	17	38	64	117	120	299	235
Species	**Mean Abundance**							
California lizardfish	14	2	1	24	3	5	**212**	23
Speckled sanddab	22	**8**	**25**	**12**	**62**	**105**	**56**	**145**
Yellowchin sculpin	—	—	—	1	3	<1	15	33
Longfin sanddab	—	1	<1	**12**	24	<1	5	8
Hornyhead turbot	—	**1**	4	3	**6**	3	**4**	**4**
Roughback sculpin	—	—	—	—	1	<1	3	11
California tonguefish	—	—	1	2	5	1	3	2
English sole	—	—	<1	5	3	<1	2	3
California scorpionfish	—	3	2	<1	1	1	1	1
Spotted turbot	1	—	3	1	1	2	—	1
Fantail sole	1	1	<1	1	1	<1	—	<1
California skate	—	1	<1	<1	—	<1	—	<1

Cluster group H represented the assemblages from about 76% of the trawls performed from 2003 through 2009 (Figure 6.4). Assemblages represented by this group were characterized by having the highest number of speckled sanddabs (~145 fish/haul; Table 6.3), and were also distinguished from the other cluster groups by relatively high numbers of yellowchin and roughback sculpin (Appendix E.4). The larger hauls of speckled sanddabs that started to occur in 1999 (e.g., represented by cluster group F) versus previous years (e.g., represented by cluster groups C, D, and E), and that continued to increase over the time period represented by group H coincide with colder water conditions associated with oceanographic events such as La Niña (see Chapter 2).

Physical Abnormalities and Parasitism

Demersal fish populations appeared healthy in the SBOO region during 2009. There were no incidences of fin rot, discoloration, skin lesions, tumors, or any other physical abnormalities or indicators of disease among fishes collected during the year. Evidence of parasitism was also very low for trawl-caught fishes in the region. Only three external parasites were observed still attached to their host. These included a leech (Annelida, Hirudinea) attached to a hornyhead turbot at station SD18 in October, the cymothoid isopod *Elthusa vulgaris* attached to a speckled sanddab at station SD15 in April, and an unidentified parasite attached to a speckled sanddab at station SD15 in January. In addition to the isopod specimen identified on the speckled sanddab mentioned above, eight other *E. vulgaris* were identified as part of the trawl catch throughout the year (see Appendix E.5). Since cymothoids often become detached from their hosts during retrieval and sorting of the trawl catch, it is unknown which fishes were actually parasitized by these isopods. However, *E. vulgaris* is known to be especially common on sanddabs and California lizardfish in southern California waters, where it may reach infestation rates of 3% and 80%, respectively (see Brusca 1978, 1981).

Invertebrate Community

A total of 1055 megabenthic invertebrates (~38 per trawl), representing 61 taxa, were collected during 2009 (Table 6.4, Appendix E.5). As in previous years, the asteroid *Astropecten verrilli*

Table 6.4

Species of megabenthic invertebrates collected in 28 trawls in the SBOO region during 2009. PA=percent abundance; FO=frequency of occurrence; MAH=mean abundance per haul; MAO=mean abundance per occurrence.

Species	PA	FO	MAH	MAO	Species	PA	FO	MAH	MAO
Astropecten verrilli	31	75	12	16	*Crossata californica*	<1	11	<1	1
Ophiothrix spiculata	15	25	6	22	*Pteropurpura festiva*	<1	11	<1	1
Ophiura luetkenii	7	11	3	26	*Randallia ornata*	<1	11	<1	1
Dendraster terminalis	6	32	2	7	*Crangon alba*	<1	7	<1	2
Crangon nigromaculata	5	39	2	5	*Halosydna latior*	<1	7	<1	2
Heptacarpus stimpsoni	3	11	1	11	*Aglaja ocelligera*	<1	7	<1	1
Orthopagurus minimus	3	7	1	16	*Armina californica*	<1	7	<1	1
Acanthodoris brunnea	3	32	1	3	*Megastraea turbanica*	<1	7	<1	1
Pisaster brevispinus	3	46	1	2	*Megasurcula carpenteriana*	<1	7	<1	1
Pyromaia tuberculata	2	39	1	2	*Metacarcinus gracilis*	<1	7	<1	1
Philine auriformis	2	18	1	4	*Portunus xantusii*	<1	7	<1	1
Platymera gaudichaudii	1	29	1	2	*Sicyonia penicillata*	<1	7	<1	1
Heterocrypta occidentalis	1	25	<1	2	*Thesea* sp B	<1	7	<1	1
Sicyonia ingentis	1	14	<1	3	*Calliostoma gloriosum*	<1	4	<1	2
Lytechinus pictus	1	25	<1	2	*Acanthoptilum* sp	<1	4	<1	1
Octopus rubescens	1	29	<1	1	*Amphissa undata*	<1	4	<1	1
Hemisquilla californiensis	1	25	<1	1	*Aphrodita refulgida*	<1	4	<1	1
Elthusa vulgaris	1	21	<1	1	*Calliostoma annulatum*	<1	4	<1	1
Kelletia kelletii	1	21	<1	1	*Calliostoma tricolor*	<1	4	<1	1
Flabellina iodinea	1	14	<1	2	*Calliostoma turbinum*	<1	4	<1	1
Heptacarpus fuscimaculatus	1	4	<1	8	*Cancer antennarius*	<1	4	<1	1
Acanthodoris rhodoceras	1	11	<1	2	*Conus californicus*	<1	4	<1	1
Aphrodita armifera	1	7	<1	3	*Harmothoe imbricata* complex	<1	4	<1	1
Pandalus danae	1	7	<1	3	*Luidia asthenosoma*	<1	4	<1	1
Melibe leonina	1	4	<1	6	*Lysmata californica*	<1	4	<1	1
Loxorhynchus grandis	<1	14	<1	1	*Metacarcinus anthonyi*	<1	4	<1	1
Nassarius perpinguis	<1	11	<1	2	*Pinnixa franciscana*	<1	4	<1	1
Pagurus spilocarpus	<1	14	<1	1	*Pleurobranchaea californica*	<1	4	<1	1
Dendronotus iris	<1	11	<1	1	*Romaleon jordani*	<1	4	<1	1
Podochela hemphillii	<1	11	<1	1	*Spirontocaris prionota*	<1	4	<1	1
Heptacarpus palpator	<1	7	<1	2					

was the most abundant and most frequently captured species. This sea star was captured in 75% of the trawls and accounted for 31% of the total invertebrate abundance. The remaining taxa occurred infrequently, with only five species occurring in 32% or more of the hauls. With the exception of *A. verrilli*, all of the species collected averaged no more than six individuals per haul.

Megabenthic invertebrate community structure varied among stations and between surveys during the year (Table 6.5). Species richness ranged from 3 to 20 species per haul, diversity (H') values ranged from 0.3 to 2.5 per haul, and total abundance ranged from 3 to 129 individuals per haul. The biggest hauls occurred at stations SD15 and SD21, and were characterized by large numbers of various species collected at these stations during each survey (Appendix E.6). For example, the brittle star *Ophiothrix spiculata* dominated the hauls taken at SD21 in January and April, whereas *A. verrilli* dominated the hauls taken at SD15 in April and October, the sand dollar *Dendraster terminalis* dominated SD15 in April and the brittlestar *Ophiura luetkeni* dominated SD15 in July. Although biomass was also somewhat variable (0.1–3.0 kg), the highest values generally corresponded to the collection of relatively large sea stars or crabs.

Table 6.5

Summary of megabenthic invertebrate community parameters for SBOO stations sampled during 2009. Data are included for species richness (number of species), abundance (number of individuals), diversity (H'), and biomass (kg, wet weight); SD = standard deviation.

					Annual							Annual	
Station	Jan	Apr	Jul	Oct	Mean	SD	Station	Jan	Apr	Jul	Oct	Mean	SD
Species Richness							*Abundance*						
SD15	12	8	8	5	8	3	SD15	46	109	84	129	92	36
SD16	5	6	7	5	6	1	SD16	10	14	9	14	12	3
SD17	4	11	7	9	8	3	SD17	5	24	13	35	19	13
SD18	6	8	9	20	11	6	SD18	9	24	11	99	36	43
SD19	4	7	9	11	8	3	SD19	8	24	22	28	21	9
SD20	3	3	5	8	5	2	SD20	3	37	7	22	17	16
SD21	9	14	15	7	11	4	SD21	118	108	33	10	67	54
Survey Mean	6	8	9	9			Survey Mean	28	49	26	48		
Survey SD	3	4	3	5			Survey SD	42	41	27	47		
Diversity							*Biomass*						
SD15	1.92	0.97	0.67	0.28	0.96	0.70	SD15	0.1	0.5	0.9	0.7	0.5	0.3
SD16	1.23	1.23	1.83	1.13	1.35	0.32	SD16	0.1	1.2	1.1	0.4	0.7	0.5
SD17	1.33	2.21	1.69	1.46	1.67	0.39	SD17	0.1	1.0	0.1	0.1	0.3	0.5
SD18	1.74	1.35	2.15	2.41	1.91	0.47	SD18	0.2	0.4	0.8	3.0	1.1	1.3
SD19	1.21	1.35	1.90	2.11	1.64	0.43	SD19	0.5	1.8	2.0	0.5	1.2	0.8
SD20	1.10	0.33	1.55	1.24	1.06	0.52	SD20	0.3	0.5	0.4	0.6	0.4	0.1
SD21	0.69	1.85	2.45	1.83	1.71	0.74	SD21	2.9	2.6	2.6	1.1	2.3	0.8
Survey Mean	1.32	1.33	1.75	1.50			Survey Mean	0.6	1.1	1.1	0.9		
Survey SD	0.41	0.60	0.56	0.71			Survey SD	1.0	0.8	0.9	1.0		

Variations in megabenthic invertebrate community structure in the South Bay region generally reflect changes in species abundance (Figure 6.5, 6.6). Although species richness has varied little over the years (e.g., 4–14 species/trawl), annual abundance values have averaged between 7 and 273 individuals per haul. These large differences have typically been due to fluctuations in populations of several dominant species, including *A. verrilli*, the sea urchin *Lytechinus pictus*, *D. terminalis*, and the shrimp *Crangon nigromaculata* (Figure 6.6). For example, trawls at station SD15 have had the highest average abundance compared to the other stations for 9 out of 15 years due to relatively large populations of *A. verrilli*, *L. pictus*, and *D. terminalis*. In addition, the high abundances recorded at station SD17 in 1996 were due to large hauls of *L. pictus*. None of the observed variability in the invertebrate communities appear related to the South Bay outfall.

Summary and Conclusions

As in previous years, speckled sanddabs continued to dominate fish assemblages surrounding the SBOO during 2009. This species occurred at all stations and accounted for 38% of the total catch. Other characteristic, but less abundant species included the California lizardfish, yellowchin sculpin, roughback sculpin, longfin sanddab, hornyhead turbot, California tonguefish, and plainfin midshipman. Most of these common fishes were relatively small, averaging less than 20 cm in length. Although the composition and structure of the fish assemblages varied among stations, these differences were mostly due to variations in speckled sanddab, California lizardfish, and yellowchin sculpin populations.

Assemblages of relatively large (megabenthic) invertebrates in the region were similarly dominated by

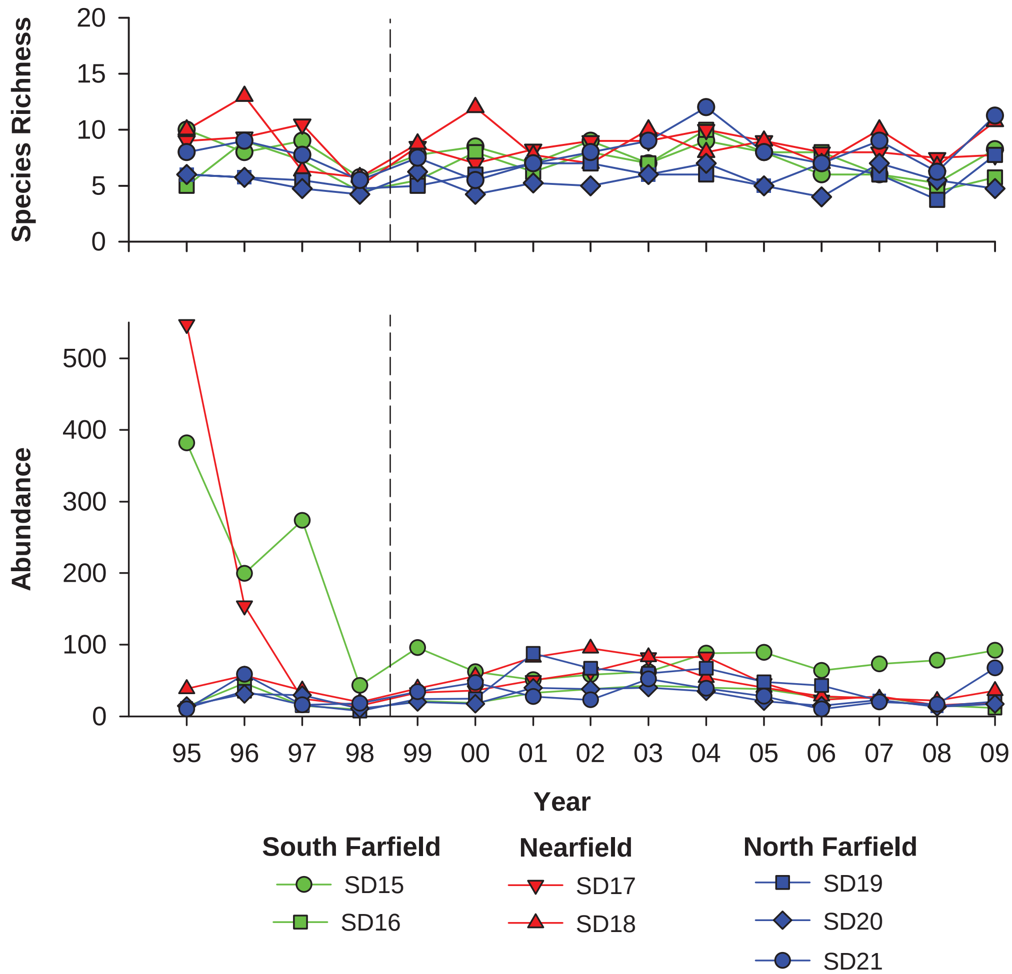

Figure 6.5
Species richness (number of species) and abundance (number of individuals) of megabenthic invertebrates collected in the SBOO region from 1995 through 2009. Data are annual means; $n = 2$ in 1995 and $n = 4$ between 1996–2009. Dashed line represents initiation of wastewater discharge.

one prominent species, the sea star *Astropecten verrilli*. Variations in community structure of the trawl-caught invertebrates generally reflect changes in the abundance of this sea star, as well as other dominant species such the sand dollar *Dendraster terminalis*, and the brittle stars *Ophiothrix spiculata* and *Ophiura luetkeni*.

Overall, results of the 2009 trawl surveys provide no evidence that wastewater discharged through the SBOO has affected either demersal fish or megabenthic invertebrate communities in the region. Although highly variable, patterns in the abundance and distribution of species were similar at stations located near the outfall and farther away, with no discernible changes in the region following the onset of the SBOO wastewater discharge in January 1999. Instead, the high degree of variability in these communities observed during 2009 was similar to those that occurred in previous years (e.g., City of San Diego 2006–2009), including the period before initiation of wastewater discharge (City of San Diego 2000). In addition, the low species richness and abundances of fish and invertebrates found during the 2009 surveys are consistent with what is expected for the relatively shallow, sandy habitats in which the SBOO stations are located (see Allen et al. 1998, 2002, 2007). Changes in these communities appear to be more likely due to natural factors such as changes in ocean water temperatures associated with large-scale oceanographic events (e.g., El Niño or La Niña) or to the mobile nature of many of the resident species collected. Finally, the absence of disease or other physical abnormalities in local fishes suggests that populations in the area continue to be healthy.

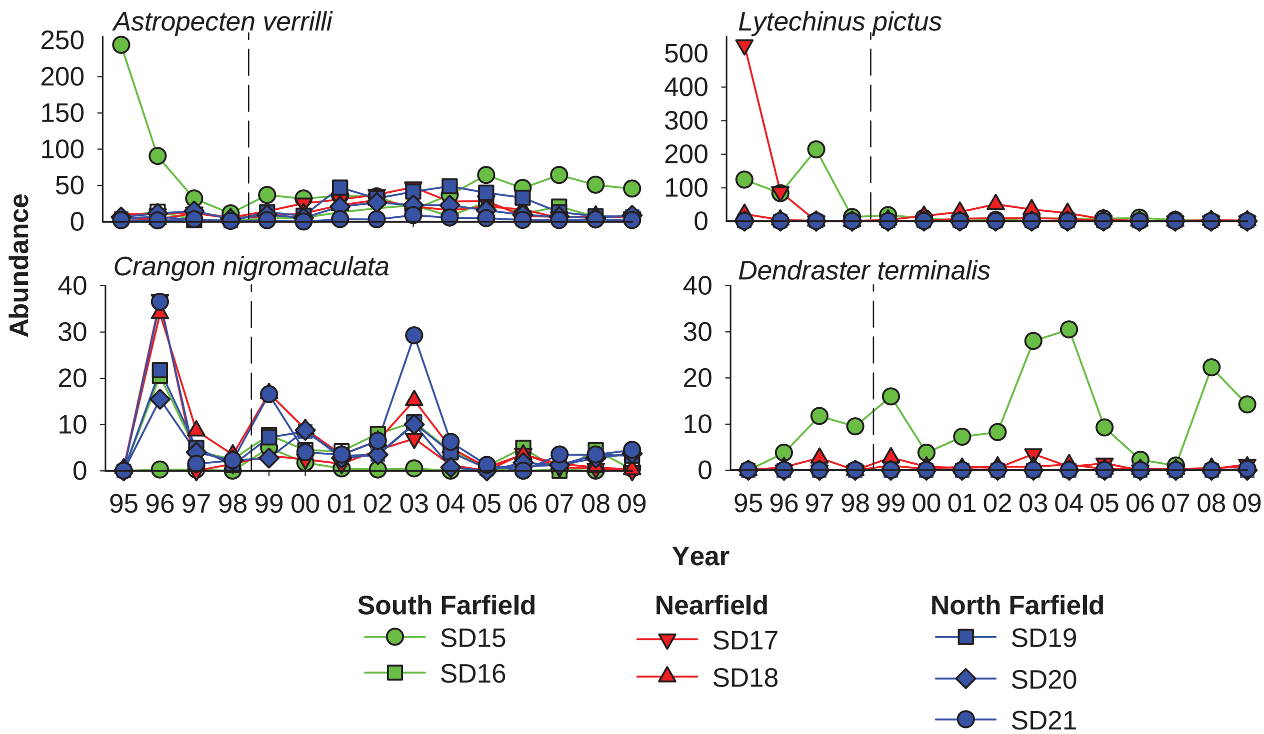

Figure 6.6
Abundance (number of individuals) of the four most abundant megabenthic species collected in the SBOO region from 1995 through 2009. Data are annual means; $n = 2$ in 1995 and $n = 4$ between 1996–2009. Dashed line represents initiation of wastewater discharge.

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