Chapter 6. Demersal Fishes and Megabenthic Invertebrates

INTRODUCTION

Demersal (bottom dwelling) fishes and relatively large (megabenthic), mobile invertebrates are collected and analyzed for the South Bay Ocean Outfall (SBOO) monitoring program to evaluate possible effects of wastewater discharge on their communities. These fishes and invertebrates are conspicuous members of continental shelf habitats and are therefore important to the ecology of the southern California coastal shelf, serving vital functions in wide ranging capacities. More than 100 species of demersal fishes inhabit the Southern California Bight (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 SBOO, the most common trawl-caught fishes include speckled 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), mollusks (e.g., marine snails, octopuses) and other taxa. Because such organisms live in close proximity to the seafloor, they can be impacted by changes in sediments affected by 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; see Chapter 4). For these reasons, their assessment has become an important focus of ocean monitoring programs throughout the world, but especially in the SCB where they have been sampled extensively for almost 40 years on the mainland shelf (Cross and Allen 1993).

Demersal fish and megabenthic invertebrate communities are inherently variable and are influenced by many factors. Therefore, distinguishing changes in these communities caused by anthropogenic influences such the SBOO wastewater discharge from other, more natural, sources is an important aspect of the ocean monitoring program. 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).

This chapter presents analyses and interpretations of the trawl survey data collected during 2010, as well as a long-term assessment of these communities from 1995 through 2010. The primary goals are to: (1) identify possible effects of wastewater discharge on demersal fishes and megabenthic invertebrates, (2) determine the presence or absence of biological impacts near the discharge site, and (3) identify spatial or temporal trends in demersal community structure in the region.

Materials and Methods

Field Sampling

Trawl surveys were conducted at seven fixed monitoring stations around the SBOO during 2010 (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

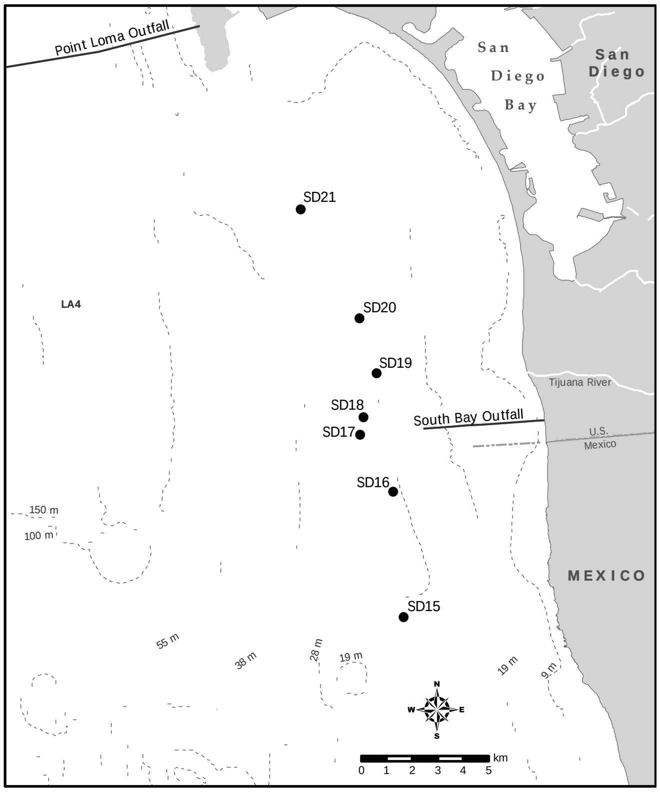

Figure 6.1
Otter trawl station locations, South Bay Ocean Outfall Monitoring Program.

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 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, lesions, 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 taxa combined, though large or exceptionally abundant taxa were weighed separately.

Data Analyses

Populations of each fish and invertebrate species were summarized as percent abundance per haul, frequency of occurrence among stations, 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/survey. For historical comparisons, 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 outfall wye).

Multivariate analyses of demersal fish communities sampled in the region were performed using data collected from 1995 through 2010. In order to reduce statistical noise due to seasonal variation in population abundances, analyses were limited to data from the July surveys only. PRIMER software was used to examine spatio-temporal patterns in the overall similarity of fish assemblages in the region (Clarke 1993, Warwick 1993, Clarke and Gorley 2006). These analyses included classification by hierarchical agglomerative clustering with group-average linking and ordination by non-metric multidimensional scaling (nMDS). 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 an abundance value of 1 was added to all samples prior to computing similarities (Clarke and Gorley 2006). Similarity profile (SIMPROF) analysis was used to confirm non-random structure of the dendrogram (Clarke et al. 2008). Similarity percentages (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.

Table 6.1

Demersal fish species collected in 28 trawls in the SBOO region during 2010. 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	49	100	114	114	Basketweave cuskeel	<1	7	<1	3
California lizardfish	21	96	49	51	Fantail sole	<1	18	<1	1
Yellowchin sculpin	6	54	15	27	Vermilion rockfish	<1	14	<1	2
English sole	5	64	12	19	Pink seaperch	<1	7	<1	3
White croaker	4	39	10	25	Stripetail rockfish	<1	11	<1	2
Roughback sculpin	3	64	7	11	California skate	<1	11	<1	1
Pacific pompano	3	18	7	37	Kelp bass	<1	4	<1	4
California tonguefish	1	75	3	5	Pygmy poacher	<1	14	<1	1
Longfin sanddab	1	57	3	6	Spotted cuskeel	<1	11	<1	1
Hornyhead turbot	1	82	3	4	Spotted turbot	<1	11	<1	1
Longspine combfish	1	43	2	6	Diamond turbot	<1	7	<1	2
Queenfish	1	25	2	6	Sarcastic fringehead	<1	11	<1	1
Shiner perch	<1	29	1	3	Barcheek pipefish	<1	7	<1	1
Plainfin midshipman	<1	36	1	2	California butterfly ray	<1	4	<1	2
California scorpionfish	<1	29	1	2	Curlfin sole	<1	7	<1	1
Northern anchovy	<1	18	1	3	Pacific angel shark	<1	7	<1	1
Specklefin midshipman	<1	11	1	5	Bigmouth sole	<1	4	<1	1
California halibut	<1	25	<1	1	Brown rockfish	<1	4	<1	1
Ocean whitefish	<1	14	<1	2	Kelp perch	<1	56	<1	1
Round stingray	<1	14	<1	2	Kelp pipefish	<1	4	<1	1
Shovelnose guitarfish	<1	25	<1	1	Pacific electric ray	<1	4	<1	1
Thornback	<1	18	<1	2					

Results

Demersal Fish Community Parameters

Forty-three species of fish were collected from the monitoring stations surrounding the SBOO in 2010 (Table 6.1, Appendix E.1). The total catch for the year was 6570 individuals, representing an average of 235 fish per trawl. As in previous years, the speckled sanddab was the dominant species collected. This species occurred in every haul, accounted for 49% of all fishes collected, and averaged 114 individuals per haul. California lizardfish were also abundant, and accounted for 21% of the total number of fishes collected. This species occurred in 96% of hauls, and averaged 49 fish per haul. Together, Pacific sanddab and California lizardfish accounted for 70% of all fishes collected in 2010. Other species collected frequently (≥50% of the trawls) included yellowchin sculpin, English sole, roughback sculpin, hornyhead turbot, California tonguefish, and longfin sanddab. The majority of species sampled in the South Bay outfall region tended to be relatively small fish with an average length <25 cm (see Appendix E.1). Although larger fishes such as the Pacific angel shark, Pacific electric ray, shovelnose guitarfish, California halibut, California skate, round stingray, California butterfly ray, and thornback were also caught during the year, these species were relatively rare.

During 2010, species richness (number of taxa) and diversity (H') values were relatively low compared to values reported previously for other areas of the SCB (Allen et al. 1998, 2002, 2007), while abundance and biomass values varied widely (Table 6.2). No more than 18 species occurred in any one haul, and all corresponding H' values were less than 2.14. As in previous years, trawls from station SD15 located the farthest south in Mexican waters had the lowest species richness (mean = 8 species; Figure 6.2) and

Table 6.2

Summary of demersal fish community parameters for SBOO trawl stations sampled during 2010. 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	9	9	8	6	8	1	SD15	127	121	435	293	244	150
SD16	12	10	11	13	12	1	SD16	159	148	425	441	293	162
SD17	7	12	8	10	9	2	SD17	62	95	392	379	232	178
SD18	15	15	8	7	11	4	SD18	143	286	432	217	270	123
SD19	12	13	10	12	12	1	SD19	158	79	453	158	212	165
SD20	15	13	9	8	11	3	SD20	86	123	312	199	180	100
SD21	18	14	14	11	14	2	SD21	127	61	311	348	212	140
Survey Mean	12	12	10	10			Survey Mean	123	130	394	291		
Survey SD	4	2	2	3			Survey SD	37	75	59	104		
Diversity							*Biomass*						
SD15	0.95	0.52	0.68	0.79	0.73	0.18	SD15	3.0	1.8	14.0	3.9	5.7	5.6
SD16	1.27	1.09	1.21	1.47	1.26	0.16	SD16	3.9	2.0	5.2	9.1	5.0	3.0
SD17	1.63	1.85	1.33	1.60	1.60	0.21	SD17	2.6	2.6	4.3	4.8	3.6	1.1
SD18	1.82	1.44	0.87	1.00	1.28	0.43	SD18	9.5	11.8	4.4	2.7	7.1	4.3
SD19	1.54	1.43	1.16	1.54	1.42	0.18	SD19	6.7	2.3	5.1	4.1	4.5	1.8
SD20	1.71	1.20	1.48	1.31	1.43	0.22	SD20	3.4	3.4	4.5	4.9	4.0	0.8
SD21	2.09	2.14	1.28	1.83	1.83	0.39	SD21	29.3	5.4	3.9	6.0	11.1	12.1
Survey Mean	1.57	1.38	1.15	1.36			Survey Mean	8.3	4.2	5.9	5.1		
Survey SD	0.37	0.53	0.28	0.36			Survey SD	9.5	3.6	3.6	2.0		

diversity (mean H' = 0.73) values. Total abundance ranged from 61 to 453 fishes per haul over all stations and quarters, which generally mirrored variation in abundances of speckled sanddabs, California lizardfish, white croaker, yellowchin sculpin, and English sole (Figure 6.3, Appendix E.2). Biomass varied from 1.8 to 29.3 kg per haul, with higher values coincident with greater numbers of fishes or the presence of large individual fish (Appendices E.2, E.3). For example, the highest biomass measured during the year was 29.3 kg at station SD21 in January, which included the catch of a single Pacific angel shark weighing 23 kg.

Although average species richness values at SBOO monitoring sites have remained within a narrow range over the years (i.e., 4–14 species/station/year), the average abundance per haul has varied considerably (i.e., 28–308 fish/station/year), mostly in response to population fluctuations of a few dominant species (Figures 6.2, 6.3). For example, average abundance at four of the seven stations decreased between 2009 and 2010 (stations SD17, SD19, SD20, SD21); these reductions followed drops in average speckled sanddab numbers at the same stations. In contrast, overall abundances increased at stations SD15, SD16 and SD18, reflecting greater numbers of yellowchin sculpin and California lizardfish. Whereas fluctuations of common 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 that occurred primarily at station SD21 in 1996; (2) a large haul of northern anchovy that occurred in a single haul from station SD16 in 2001; (3) a large

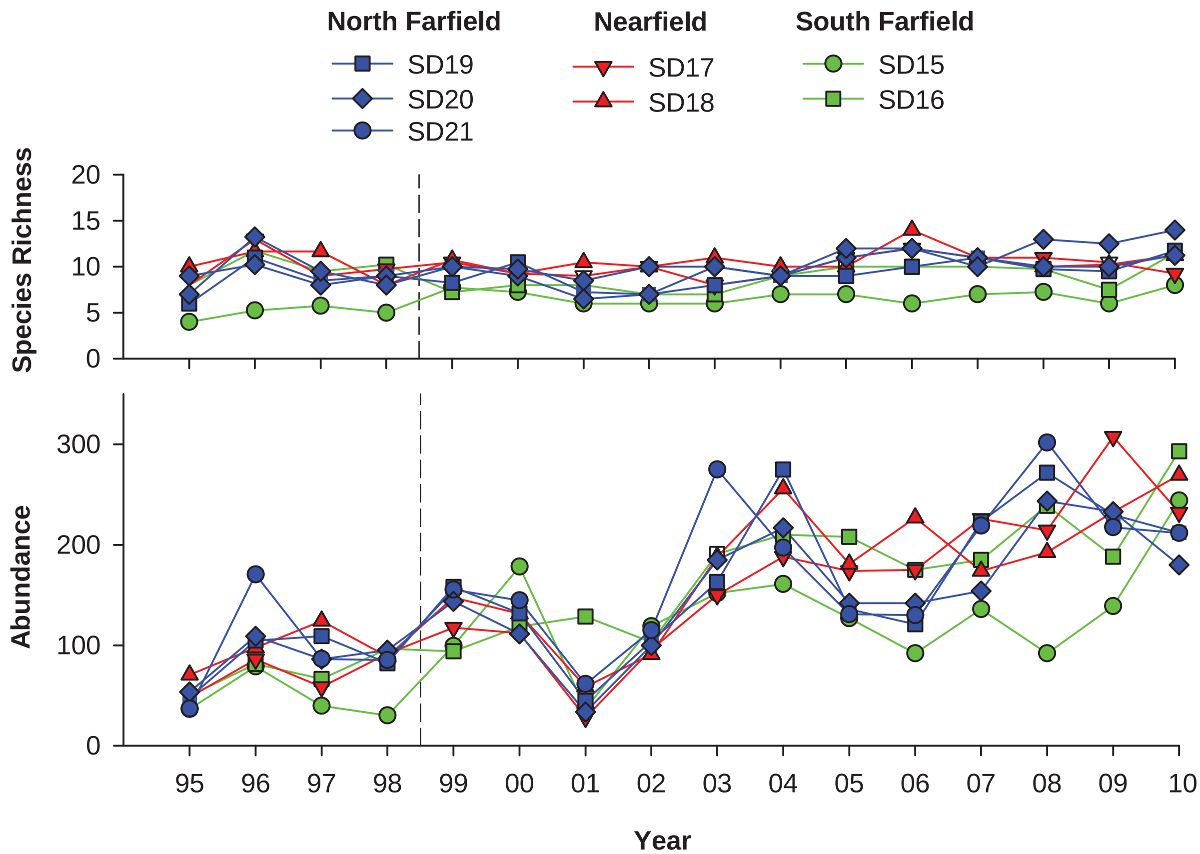

Figure 6.2
Species richness and abundance of demersal fish collected at each SBOO trawl station between 1995 and 2010. Data are annual means; $n=2$ in 1995 and $n=4$ between 1996–2010. Dashed line represents initiation of wastewater discharge.

haul of Pacific pompano that 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 of Demersal Fish Assemblages

Ordination and cluster analyses performed on data collected between 1995 and 2010 (July surveys only) discriminated between five main types of fish assemblages in the South Bay outfall region (Figure 6.4). These assemblages (cluster groups A–E) were distinguished by differences in the relative abundances of the common species present, although most were dominated by speckled sanddabs. The distribution of assemblages in 2010 was generally similar to that seen in previous years, especially between 2003–2009, 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.

Cluster group A consisted of trawls from stations SD16 and SD17 sampled in July 2006 (Figure 6.4). This group was unique in that it averaged more than 200 California lizardfish per haul, more than an order of magnitude greater than in any other cluster group (Table 6.3). The second and third most abundant species composing this group were the speckled sanddab (~56 fish/haul) and yellowchin sculpin (~15 fish/haul). The relatively high numbers of California lizardfish and low numbers of speckled sanddabs helped distinguish these trawls from others included in cluster groups B, C, D (see Appendix E.4).

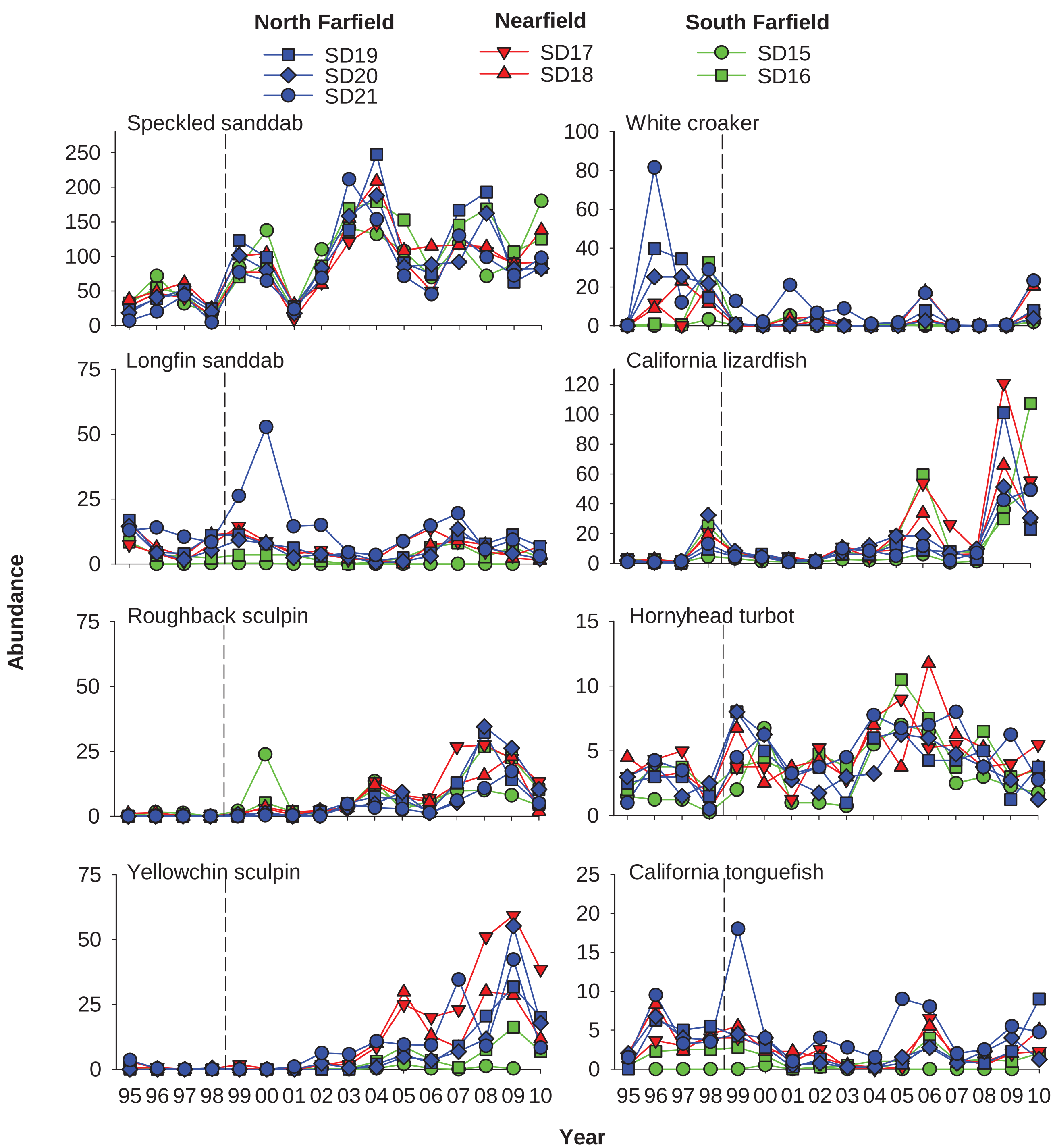

Figure 6.3

The eight most abundant fish species collected in the SBOO region between 1995 and 2010. Data are annual means per station; n=2 in 1995 and n=4 between 1996–2010. Dashed line represents initiation of wastewater discharge.

Cluster group B was the largest group, representing 45 trawls collected between 2003 and 2010 (Figure 6.4). Assemblages represented by this group had the highest number of speckled sanddabs (~157 fish/haul) and yellowchin sculpin (~33 fish/haul), and moderate numbers of California lizardfish (~34 fish/haul) (Table 6.3). In particular, the relatively high numbers of speckled sanddabs helped distinguish this cluster from the other groups (Appendix E.4), as did the relative abundance of yellowchin sculpin, California lizardfish, longfin sanddabs and roughback sculpin.

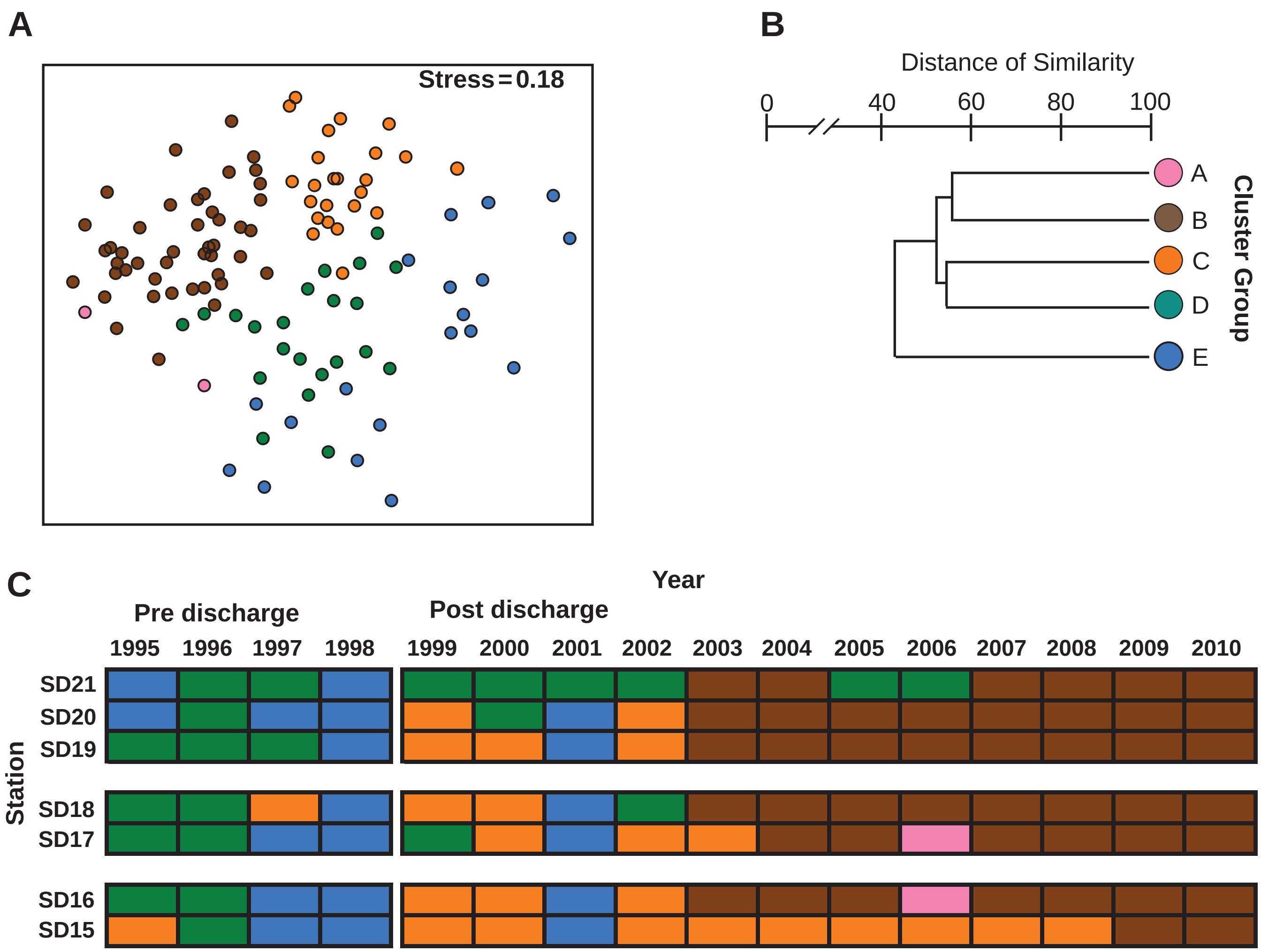

Figure 6.4

Results of multivariate analyses of demersal fish assemblages collected at SBOO trawl stations between 1995 and 2010 (July surveys only). Data are presented as (A) nMDS ordination, (B) a dendrogram of major cluster groups, and (C) a matrix showing distribution of cluster groups over time.

Cluster group C was the second largest group and comprised 24 trawls that occurred at a mix of sites sampled during all years except 1996, 1998, 2001, 2009 and 2010 (Figure 6.4). This mix of sites included station SD15 in 10 out of 16 surveys and a majority of the other stations sampled during 1999, 2000 and 2002. Group C was characterized by the second highest average abundance of speckled sanddabs (~105 fish/haul) and very few other species (Table 6.3). The lack of other relatively common species helped distinguish this group from the other cluster groups (Appendix E.4).

Cluster group D was the third largest group and comprised most stations sampled during 1995 and 1996, plus one or two stations during almost every survey conducted between 1997 and 2006. Seven of these latter hauls occurred at station SD21. In comparison to other cluster groups, assemblages represented by this cluster group were characterized by moderate numbers of speckled sanddabs (~62 fish/haul); as well as relatively high numbers of longfin sanddabs (~24 fish/haul) and hornyhead turbot (~6 fish/haul). The relative abundance of speckled and longfin sanddabs, California tonguefish, and English sole helped distinguish these trawls from those that occurred in other cluster groups (Appendix E.4).

Cluster group E comprised trawls from years associated with warmer water conditions, including 1995, 1997–1998, and 2001 (Figure 6.4). This group was characterized by the lowest overall

Table 6.3

Description of cluster groups A–E 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 analysis (i.e., greatest percentage contribution to within-group similarity).

	Group A	Group B	Group C	Group D	Group E
Number of Hauls	2	45	24	22	19
Mean Species Richness	8	10	6	10	8
Mean Abundance	299	259	117	117	48
Species	**Mean Abundance**				
California lizardfish	212	34	3	3	11
Speckled sanddab	56	**157**	**105**	**62**	**18**
Yellowchin sculpin	15	33	<1	3	<1
Longfin sanddab	5	8	<1	24	5
Hornyhead turbot	4	4	3	6	3
Roughback sculpin	3	11	<1	1	—
California tonguefish	3	2	1	5	1
English sole	2	3	<1	3	2
California scorpionfish	1	1	1	1	1
Spotted turbot	—	1	2	1	2

abundance (48 fish/haul on average), with very low numbers of speckled sanddabs (18 fish/haul) and most other common species (Table 6.3). The overall low number of fish present in these trawls helped distinguish them from those that occurred in other cluster groups (Appendix E.4).

Physical Abnormalities and Parasitism

Demersal fish populations appeared healthy in the South Bay outfall region during 2010. There were no incidences of fin rot, discoloration, skin lesions, tumors, or other noticeable physical abnormalities or indicators of disease among fishes collected during the year. Evidence of parasitism was also low for trawl-caught fishes in the region. Only four external parasites were observed associated with their hosts. These included leeches (Annelida, Hirudinea) found attached to a single curlfin sole collected from station SD21 in April, two hornyhead turbots collected from SD17 and SD18 in July, and a speckled sanddab collected at station SD21 in October. In addition, the parasitic isopod *Elthusa vulgaris* was 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 (Brusca 1978, 1981).

Megabenthic Invertebrate Community Parameters

A total of 1924 megabenthic invertebrates (~69 per trawl), representing 68 taxa, were collected during 2010 (Table 6.4, Appendix E.5). The shrimp *Crangon nigromaculata* was the most abundant species; it accounted for 31% of the total invertebrate abundance and occurred in 68% of the trawls, at a rate of 32 shrimp per occurrence. The sea star *Astropecten verrilli* was the most frequently collected species, occurring in 86% of the hauls, but it accounted for only 14% of the total abundance. With the exception of *C. nigromaculata* and *A. verrilli*, all of the species collected averaged no more than six individuals per haul. The only other species that occurred frequently (≥50% of the trawls) was the crab *Metacarcinus gracilis*.

Table 6.4

Species of megabenthic invertebrates collected in 28 trawls in the SBOO region during 2010. 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
Crangon nigromaculata	31	68	21	32	*Philine auriformis*	<1	11	<1	1
Astropecten verrilli	14	86	10	11	*Heptacarpus palpator*	<1	7	<1	2
Doryteuthis opalescens	8	7	6	82	*Podochela hemphillii*	<1	7	<1	2
Dendraster terminalis	6	25	4	18	*Pteropurpura festiva*	<1	7	<1	2
Portunus xantusii	4	25	3	12	*Scyra acutifrons*	<1	4	<1	3
Ophiura luetkenii	4	18	3	16	*Strongylocentrotus franciscanus*	<1	4	<1	3
Ophiothrix spiculata	4	32	3	9	*Aphrodita refulgida*	<1	7	<1	1
Octopus rubescens	3	36	2	5	*Forreria belcheri*	<1	7	<1	1
Dendronotus iris	3	29	2	6	*Glossaulax reclusianus*	<1	7	<1	1
Metacarcinus gracilis	2	50	1	3	Hirudinea	<1	7	<1	1
Sicyonia ingentis	2	4	1	39	*Megasurcula carpenteriana*	<1	7	<1	1
Pyromaia tuberculata	2	32	1	4	*Pleurobranchaea californica*	<1	7	<1	1
Heterocrypta occidentalis	2	29	1	4	*Aphrodita armifera*	<1	4	<1	2
Platymera gaudichaudii	1	46	1	2	*Acanthoptilum* sp	<1	4	<1	1
Elthusa vulgaris	1	43	1	2	*Alpheus clamator*	<1	4	<1	1
Farfantepenaeus californiensis	1	18	1	4	*Antiplanes catalinae*	<1	4	<1	1
Kelletia kelletii	1	46	1	1	*Caesia perpinguis*	<1	4	<1	1
Pisaster brevispinus	1	32	1	2	*Calliostoma canaliculatum*	<1	4	<1	1
Flabellina iodinea	1	32	1	2	*Crassispira semiinflata*	<1	4	<1	1
Crangon alba	1	14	1	4	*Lamellaria diegoensis*	<1	4	<1	1
Acanthodoris brunnea	1	25	<1	2	*Luidia armata*	<1	4	<1	1
Randallia ornata	1	29	<1	1	*Luidia foliolata*	<1	4	<1	1
Lytechinus pictus	1	21	<1	2	*Megastraea turbanica*	<1	4	<1	1
Heptacarpus stimpsoni	1	14	<1	3	*Ophiopteris papillosa*	<1	4	<1	1
Pandalus danae	1	11	<1	4	*Orthopagurus minimus*	<1	4	<1	1
Sicyonia penicillata	<1	21	<1	1	*Paguristes ulreyi*	<1	4	<1	1
Cancridae	<1	14	<1	2	*Panulirus interruptus*	<1	4	<1	1
Pagurus spilocarpus	<1	18	<1	1	*Paraxanthias taylori*	<1	4	<1	1
Crossata californica	<1	14	<1	1	*Pinnixa franciscana*	<1	4	<1	1
Acanthodoris rhodoceras	<1	7	<1	3	*Romaleon antennarius*	<1	4	<1	1
Hemisquilla californiensis	<1	14	<1	1	*Sicyonia disedwardsi*	<1	4	<1	1
Metacarcinus anthonyi	<1	14	<1	1	*Spirontocaris prionota*	<1	4	<1	1
Paguristes bakeri	<1	7	<1	2	*Triopha maculata*	<1	4	<1	1
Loxorhynchus grandis	<1	11	<1	1	*Tritonia diomedea*	<1	4	<1	1

Megabenthic invertebrate community structure varied among stations and between surveys during the year (Table 6.5). Species richness ranged from 5 to 19 species per haul, diversity (H') values ranged from 0.7 to 2.5 per haul, and total abundance ranged from 11 to 215 individuals per haul. The biggest hauls were characterized by large numbers of various species collected at multiple stations during each survey (Appendix E.6). For example, the shrimp *C. nigromaculata*, the crab *Portunus xantusii*, and the brittle star *Ophiothrix spiculata* dominated the hauls taken at stations SD18 and SD21 in January, whereas the squid *D. opalescens*, the sea star *A. verrilli*, the brittle star *Ophiura luetkenii*, and the sand dollar *Dendraster terminalis* dominated hauls from stations SD15 and SD17 in October. Biomass varied from 0.1 to 7.0 kg per haul, with higher biomass values reflecting large abundances

Table 6.5

Summary of megabenthic invertebrate community parameters for SBOO trawl stations sampled during 2010. 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	9	7	6	7	7	1	SD15	75	42	90	121	82	33
SD16	11	12	12	11	12	1	SD16	83	100	77	45	76	23
SD17	9	6	16	8	10	4	SD17	87	26	44	215	93	85
SD18	18	9	19	16	16	5	SD18	157	72	58	73	90	45
SD19	12	5	10	8	9	3	SD19	39	20	26	19	26	9
SD20	10	8	7	8	8	1	SD20	51	11	43	17	31	19
SD21	17	13	10	11	13	3	SD21	212	55	19	47	83	87
Survey Mean	12	9	11	10			Survey Mean	101	47	51	77		
Survey SD	4	3	5	3			Survey SD	62	32	26	71		
Diversity							*Biomass*						
SD15	1.6	1.3	0.8	1.0	1.2	0.3	SD15	0.5	0.1	0.5	0.7	0.4	0.3
SD16	1.8	1.4	1.6	1.6	1.6	0.2	SD16	1.5	1.1	0.4	1.2	1.0	0.5
SD17	0.8	1.3	2.2	0.9	1.3	0.6	SD17	0.8	1.6	1.2	5.6	2.3	2.2
SD18	1.3	0.7	2.5	2.0	1.6	0.8	SD18	7.0	0.7	0.9	1.9	2.6	3.0
SD19	1.8	1.0	2.0	1.9	1.7	0.5	SD19	1.5	1.2	1.0	1.4	1.3	0.2
SD20	1.3	1.9	1.4	1.8	1.6	0.3	SD20	0.6	0.9	0.5	1.9	1.0	0.6
SD21	1.2	1.6	1.8	1.6	1.6	0.2	SD21	2.2	3.7	0.1	3.8	2.4	1.7
Survey Mean	1.4	1.3	1.8	1.6			Survey Mean	2.0	1.3	0.7	2.4		
Survey SD	0.4	0.4	0.6	0.4			Survey SD	2.3	1.1	0.4	1.7		

such as those described above, or the collection of relatively big animals such as large sea stars or crabs (Appendix E.6).

Variations in megabenthic invertebrate community structure in the South Bay outfall region generally reflect changes in species abundance (Figures 6.5, 6.6). Although species richness has varied little over the years (e.g., 4–16 species/trawl), annual abundance values have averaged between 7 and 548 individuals per haul. These large differences typically have been due to fluctuations in populations of several dominant species, including the sea urchin *Lytechinus pictus*, as well as *D. terminalis* and *C. nigromaculata* as previously mentioned. For example, station SD15 has had the highest average abundance for 9 of the last 15 years due to relatively large hauls of *A. verrilli* 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 trawl-caught invertebrate communities appears to be related to the South Bay outfall.

Discussion

As in previous years, speckled sanddabs continued to dominate fish assemblages surrounding the SBOO during 2010. This species occurred at all stations and accounted for 49% of the total catch. Other characteristic, but less abundant species included the California lizardfish, yellowchin sculpin, English sole, roughback sculpin, hornyhead turbot, California tonguefish and longfin sanddab. Most of these common fishes were relatively small, averaging less than 25 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,

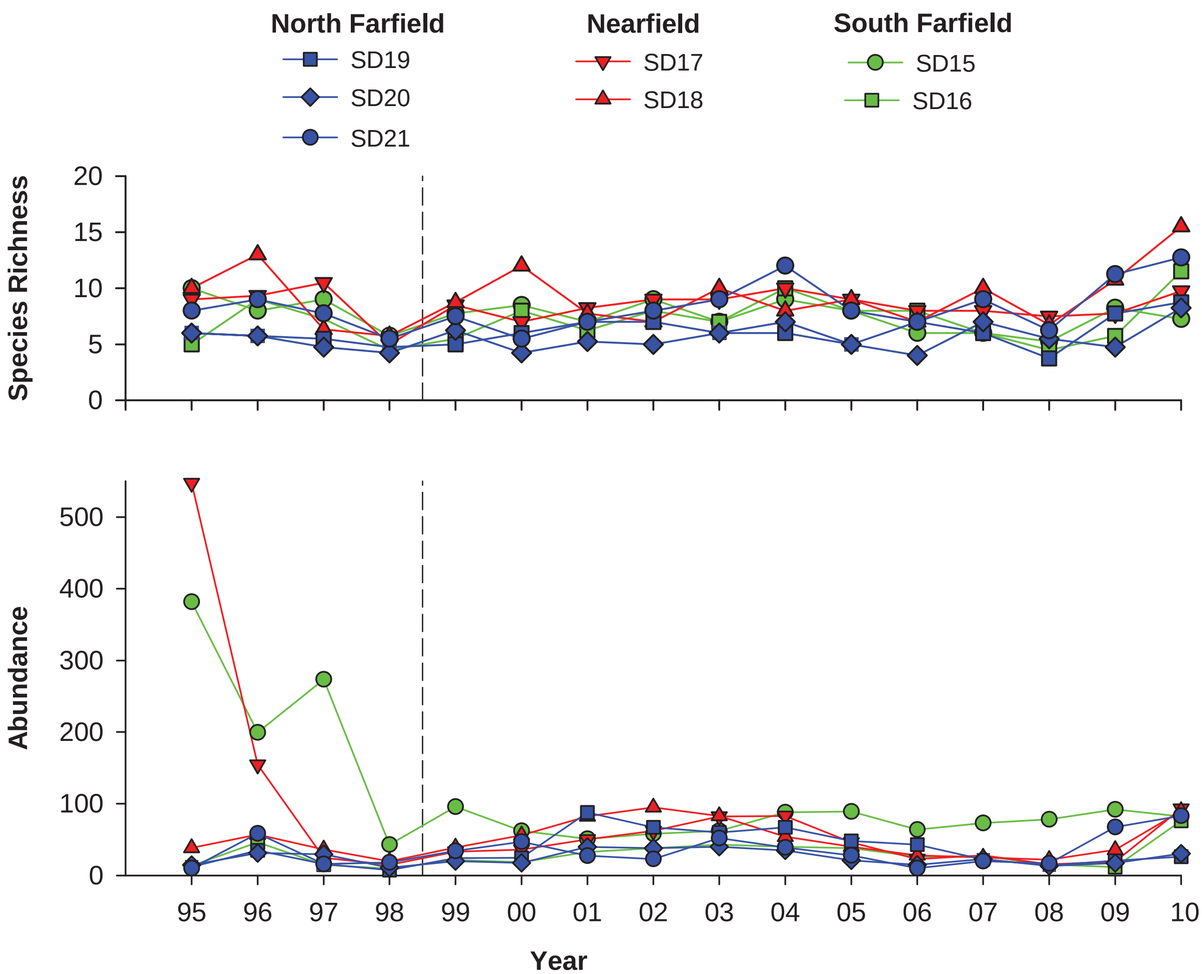

Figure 6.5

Species richness (number of species) and abundance (number of individuals) of megabenthic invertebrates collected at each trawl station between 1995 and 2010. Data are annual means; $n = 2$ in 1995 and $n = 4$ between 1996–2010. Dashed line represents initiation of wastewater discharge.

California lizardfish, white croaker, yellowchin sculpin and English sole populations.

During 2010, assemblages of megabenthic invertebrates in the region were dominated by the shrimp *Crangon nigromaculata* and the sea star *Astropecten verrilli*. Variations in community structure of the trawl-caught invertebrates generally reflect changes in the abundance of these two species, as well as other common species such the sand dollar *Dendraster terminalis*, the crab *Portunus xantusii*, the brittle stars *Ophiothrix spiculata* and *Ophiura luetkeni*, the shrimp *Sicyonia ingentis*, and the squid *Doryteuthis opalescence*.

Overall, results of the 2010 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 wastewater discharge through the SBOO in January 1999. Instead, the high degree of variability observed during 2010 was similar to that observed in previous years (City of San Diego 2006–2010), 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 2010 surveys are consistent with what is expected for the relatively shallow, sandy habitats in which the SBOO stations are located (Allen 1982, Allen et al. 1998, 2002,

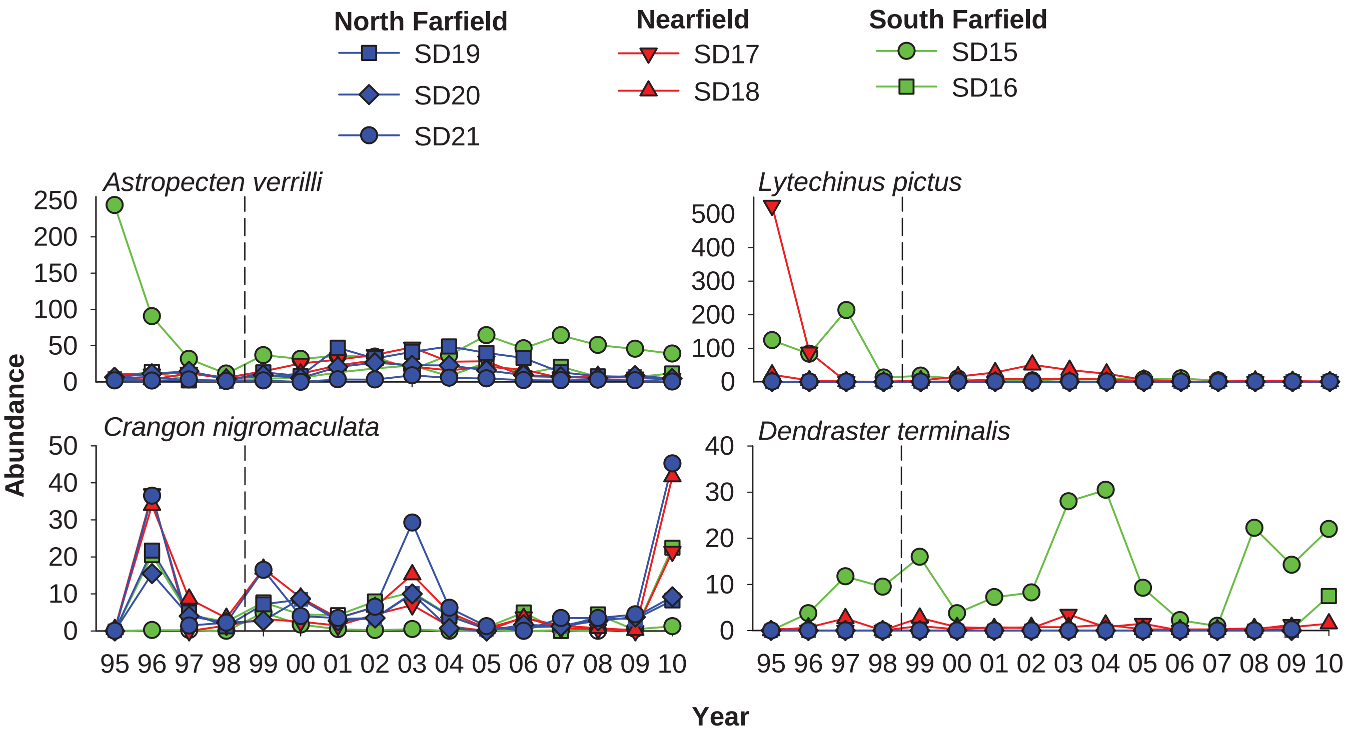

Figure 6.6
The four most abundant megabenthic invertebrate species collected in the SBOO region from 1995 through 2010. Data are annual means; $n=2$ in 1995 and $n=4$ between 1996–2010. Dashed line represents initiation of wastewater discharge.

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.

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