Chapter 6. Demersal Fishes and Megabenthic Invertebrates

Introduction

Bottom dwelling (demersal) fishes and relatively large (megabenthic) mobile invertebrates are monitored by the City of San Diego (City) to examine potential effects of wastewater discharge on marine environments around both the Point Loma and South Bay Ocean Outfalls (PLOO and SBOO, respectively). These fish and invertebrate communities are conspicuous members of continental shelf habitats and are targeted for monitoring because they are known to play critical ecological roles on the southern California coastal shelf, serving vital functions in wide ranging capacities (Allen et al. 2006, Thompson et al. 1993a,b). 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 Southern California Bight (SCB) where they have been sampled extensively on the mainland shelf for the past three decades (Stein and Cadien 2009).

In healthy ecosystems, fish and invertebrate communities are known to be inherently variable and influenced by many natural factors. These factors 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, Stein and Cadien 2009). The mobile nature of many species allows them to migrate toward or away from different habitats, and natural ambient conditions throughout the SCB affect migration patterns of adult fishes and the recruitment of juveniles into different areas (Murawski 1993). Therefore, an understanding of background or reference conditions is necessary before determining whether observed differences in community structure may be related to anthropogenic activities. Pre-discharge or regional monitoring efforts by the City and other researchers since 1994 provide baseline information on spatial variability of demersal fish and megabenthic communities in the San Diego region critical for comparative analysis (e.g., City of San Diego 2000, Allen et al. 1998, 2002, 2007, 2011).

To detect potential wastewater impacts on these communities, the City relies on a suite of scientifically-accepted community parameters and statistical analyses. These include community structure metrics such as species richness, abundance and the Shannon diversity index, while multivariate analyses are used to detect spatial and temporal differences among communities (e.g., Warwick 1993). The use of multiple analyses provides better resolution than single parameters for determining anthropogenically-induced environmental impacts. In addition, trawled organisms are inspected for evidence of fin rot, tumors, skeletal abnormalities, exoskeletal lesions, spine loss, or other anomalies that have been found previously to be indicators of degraded habitats (e.g., Cross and Allen 1993, Stull et al. 2001). All together, the data are used to determine whether fish and invertebrate populations near outfalls are similar to populations from habitats with similar depth and sediment characteristics, or whether observable impacts from the outfalls or other sources occur. This weight-of-evidence approach is the basis by which the City attains its monitoring objectives.

This chapter presents analyses and interpretations of trawl survey data collected during 2011, as well as a long-term assessment of these communities from 1995 through 2011. The primary goals are to: (1) document the demersal fish and megabenthic invertebrate communities present during the year,

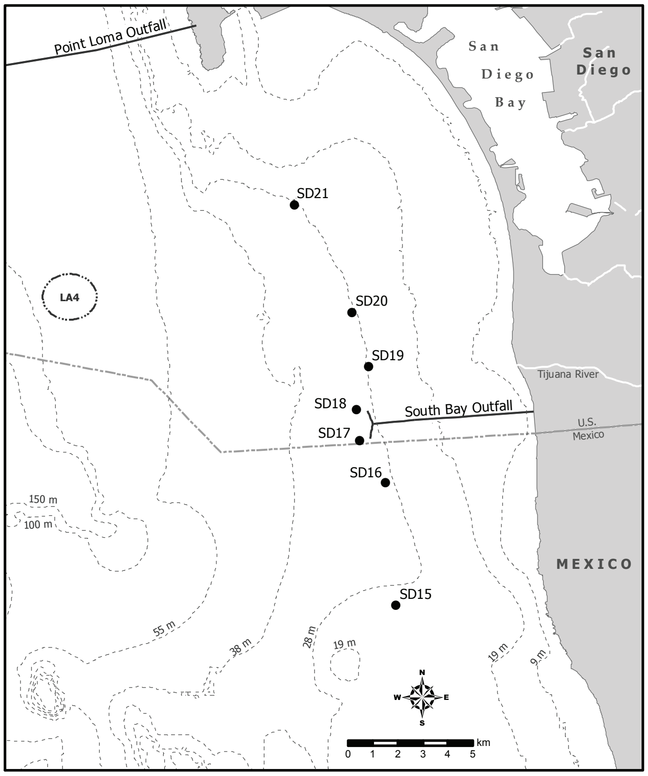

Figure 6.1
Otter trawl station locations sampled around the South Bay Ocean Outfall as part of City of San Diego's Ocean Monitoring Program.

(2) determine the presence or absence of biological impacts associated with wastewater discharge, and (3) identify other potential natural and anthropogenic sources of variability to the local marine ecosystem.

Materials and Methods

Field Sampling

Trawl surveys were conducted at seven fixed monitoring sites in the SBOO region during January, April, July, and October 2011 (Figure 6.1). These trawl stations, designated SD15, SD16, SD17, SD18, SD19, SD20 and SD21, are located along the 28-m depth contour, and encompass an area ranging from 7 km south to 8.5 km north of the SBOO. The two stations considered to represent "nearfield" conditions (i.e., SD17, SD18) are located within 1000 m of the outfall wye. 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 of bottom time at a speed of about 2.0 knots along a predetermined heading.

The total catch from each trawl was brought onboard the 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, indicators of disease (e.g., tumors, fin erosion, discoloration), as well as the presence of external parasites. Lengths of individual fish were measured to centimeter size class on measuring boards; total length (TL) was measured for cartilaginous fishes and standard length (SL) was measured for bony fishes. 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 (number of individuals of a single species/total number of individuals of all species), frequency of occurrence (percentage of stations at which a species was collected), mean abundance per haul (number of individuals of a single species/total number sites sampled), and mean abundance per occurrence (number of individuals of a single species/number of sites at which the species was collected). Additionally, the following community structure parameters were calculated for each trawl for fishes and invertebrates: species richness (number of species), total abundance (number of individuals), Shannon diversity index (H'), and total biomass.

Multivariate analyses of demersal fish communities sampled in the region were performed using data collected from 1995 through 2011. In order to reduce statistical noise due to seasonal variation in population abundances, analyses were limited to

Table 6.1
Demersal fish species collected in 28 trawls conducted in the SBOO region during 2011. 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	66	100	119	119	California scorpionfish	<1	21	<1	2
California lizardfish	12	93	22	24	California halibut	<1	25	<1	1
Longspine combfish	3	64	6	9	Fantail sole	<1	21	<1	1
Yellowchin sculpin	3	64	6	9	Kelp pipefish	<1	14	<1	1
Hornyhead turbot	3	100	5	5	Pacific sanddab	<1	4	<1	5
Roughback sculpin	2	82	4	5	California skate	<1	14	<1	1
California tonguefish	2	75	4	5	Round stingray	<1	4	<1	3
Longfin sanddab	2	61	3	6	Pacific pompano	<1	7	<1	1
English sole	2	75	3	4	Pacific staghorn sculpin	<1	7	<1	1
White croaker	2	18	3	16	Copper rockfish	<1	4	<1	2
Curlfin sole	<1	36	1	2	Spotfin sculpin	<1	4	<1	2
Plainfin midshipman	<1	39	1	2	Basketweave cusk-eel	<1	4	<1	1
Shiner perch	<1	18	1	4	Bigmouth sole	<1	4	<1	1
Pygmy poacher	<1	29	1	2	Bluebanded ronquil	<1	4	<1	1
Spotted turbot	<1	18	<1	3	Greenstriped rockfish	<1	4	<1	1
Spotted cusk-eel	<1	32	<1	1	Vermilion rockfish	<1	4	<1	1

data from July surveys only. PRIMER software was used to examine spatio-temporal patterns among fish assemblages (Clarke 1993, Warwick 1993, Clarke and Gorley 2006). Abundance data were square-root transformed to lessen the influence of common species and increase the importance of rare species, and a Bray-Curtis similarity matrix was created using station and year as factors. 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). A 2-way crossed ANOSIM (maximum number of permutations = 9999) was conducted to determine whether communities varied by station or year across the region. To visually depict the relationship of individual trawls to each other based on fish composition, a cluster dendrogram was created. Similarity profile (SIMPROF) analyses were used to confirm the non-random structure of the resultant cluster dendrograms (Clarke et al. 2008). Major ecologically-relevant SIMPROF-supported clades with < 55.99% similarity were retained. Similarity percentages (SIMPER) analysis was used to identify which species were responsible for the greatest contribution to within-group similarities (i.e., characteristic species).

Results

Demersal Fish Communities

Thirty-two species of fish were collected in the area surrounding the SBOO in 2011, with no new species recorded (Table 6.1, Appendix E.1). The total catch for the year was 5055 individuals (Appendix E.2), representing an average of 181 fish per trawl. As in previous years, speckled sanddabs were dominant. This species occurred in every haul and accounted for 66% of all fishes collected at an average of 119 individuals per trawl. No other species contributed to more than 12% of the total catch during the year. For example, hornyhead turbots also occurred in every trawl, but at much lower numbers (~5/haul). Other species collected frequently (≥ 50% of the trawls) but in relatively low numbers (≤ 22/haul) included California lizardfish, California tonguefish, English sole, longfin sanddab, longspine combfish, roughback sculpin, and yellowchin sculpin. Although the majority of fishes captured in the region tended to be relatively small with an average length ≤ 21 cm, small numbers of three relatively large species were also documented (Appendix E.1). These

Table 6.2

Summary of demersal fish community parameters for SBOO trawl stations sampled during 2011. Data are included for species richness, abundance, diversity (H'), and biomass (kg, wet weight). SD = standard deviation.

Station	Jan	Apr	Jul	Oct	Annual Mean	Annual SD
Species richness						
SD15	8	7	9	9	8	1
SD16	9	11	9	13	11	2
SD17	9	13	8	11	10	2
SD18	10	14	9	10	11	2
SD19	13	9	9	11	11	2
SD20	13	9	9	11	10	2
SD21	10	10	15	15	13	3
Survey Mean	10	10	10	11		
Survey SD	2	2	2	2		
Diversity						
SD15	0.7	0.3	0.5	0.4	0.5	0.2
SD16	1.5	1.5	1.0	1.2	1.3	0.2
SD17	1.6	1.1	0.8	1.2	1.2	0.3
SD18	1.8	1.0	0.8	1.0	1.1	0.5
SD19	1.2	1.2	1.2	1.4	1.3	0.1
SD20	1.5	1.2	1.1	1.1	1.2	0.2
SD21	1.6	1.2	1.9	1.7	1.6	0.3
Survey Mean	1.4	1.1	1.0	1.1		
Survey SD	0.4	0.4	0.4	0.4		

Station	Jan	Apr	Jul	Oct	Annual Mean	Annual SD
Abundance						
SD15	73	267	392	293	256	134
SD16	58	129	131	235	138	73
SD17	33	244	218	232	182	100
SD18	47	205	187	189	157	74
SD19	260	162	130	180	183	55
SD20	204	227	128	173	183	43
SD21	96	129	243	190	165	65
Survey Mean	110	195	204	213		
Survey SD	87	56	95	43		
Biomass						
SD15	1.5	2.4	7.6	7.6	4.8	3.3
SD16	3.5	2.7	5.0	5.4	4.1	1.3
SD17	1.3	8.5	2.5	7.6	5.0	3.6
SD18	10.1	4.5	4.2	4.9	5.9	2.8
SD19	7.5	1.8	2.8	4.8	4.2	2.5
SD20	3.6	3.5	3.0	3.8	3.5	0.3
SD21	1.9	3.7	9.6	5.6	5.2	3.3
Survey Mean	4.2	3.9	5.0	5.7		
Survey SD	3.4	2.2	2.7	1.4		

large fishes included eight California halibut that measured 30–67 cm in length, four California skate that were 36–53 cm long, and three round stingray that were 32–38 cm long.

No more than 15 species of fish occurred in any one haul during 2011, and the corresponding diversity (H') values were all ≤1.9 (Table 6.2). Total abundance for all species combined ranged from 33 to 392 fishes per haul. This high variation in abundance was mostly due to differences in the numbers of speckled sanddab and California lizardfish captured at each station (Appendix E.2). Total fish biomass ranged from 1.3 to 10.1 kg per haul, with higher values coincident with either greater numbers of fishes or the presence of large individuals (Appendix E.3). For example, two California halibut accounted for about 8 kg of the total biomass at station SD18 in January, whereas 175 speckled and 6 longfin sanddabs accounted for about 5 kg of the biomass at station SD17 in April. No spatial patterns related to the outfall were observed for species richness, diversity, abundance, or biomass.

Although average species richness values for SBOO trawl-caught demersal fish assemblages 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 changes of a few dominant species (Figures 6.2, 6.3). Whereas oscillations of common species such as speckled sanddab, California lizardfish, roughback sculpin, hornyhead turbot, 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

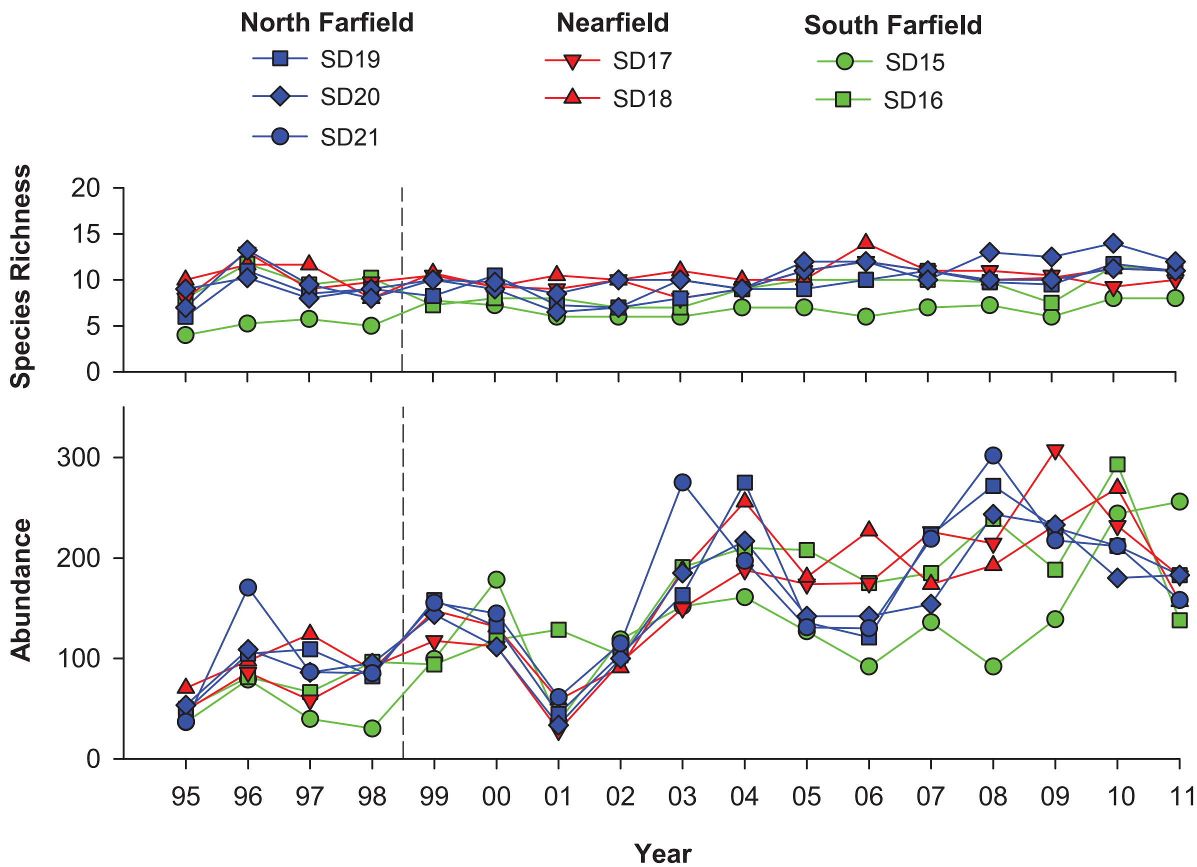

Figure 6.2
Species richness and abundance of demersal fish collected at each SBOO trawl station between 1995–2011. Data for each station are expressed as annual means ($n=4$) except: $n=2$ in 1995 (all stations); $n=3$ for SD17 and SD18 in 1996; $n=2$ for SD7 in 1997; $n=3$ for SD18 in 1997. Dashed lines indicate onset of wastewater discharge.

of northern anchovy that occurred in a single haul from station SD16 in 2001; (3) a large 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 Fish Assemblages

Multivariate analyses performed on data collected between 1995 and 2011 (July surveys only) discriminated between five main types of fish assemblages in the South Bay outfall region (Figure 6.4). ANOSIM results revealed that fish communities in the region differed significantly by site and by year (Appendix E.4). However, the distribution of assemblages in 2011 was generally similar to that seen in previous years, especially between 2003–2010, and there were no discernible patterns 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. 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 composition and main characteristics of each cluster group are described below.

Cluster group A comprised four outliers; three trawls from SD15 in 1997, 1998, and 2001, and one from SD17 in 2001 (Figure 6.4). This group had the lowest species richness (~5 species/haul) and the lowest abundance (~22 fishes/haul) of any cluster group (Table 6.3). These low values reflect

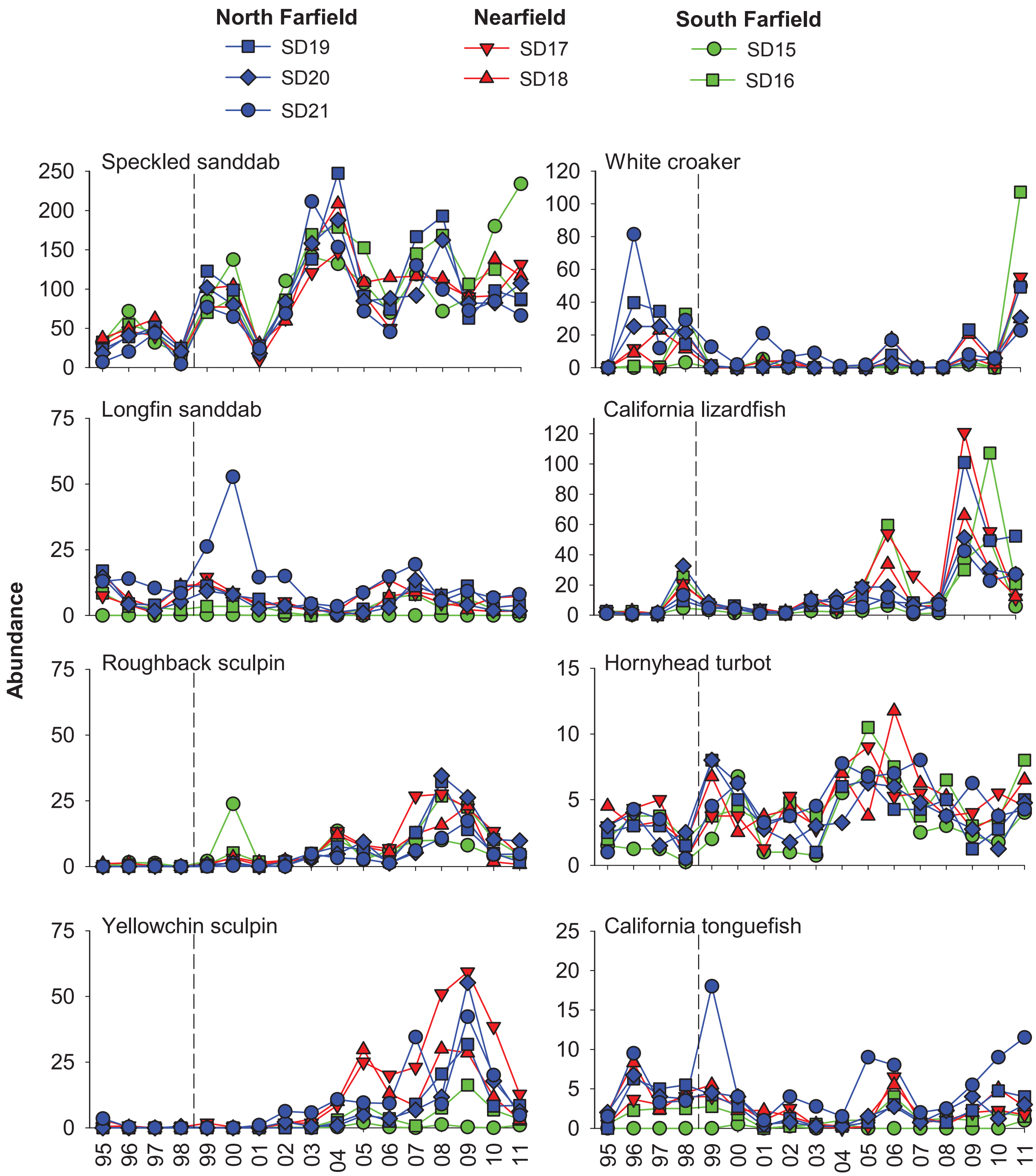

Figure 6.3
The eight most abundant fish species collected in the SBOO region between 1995–2011. Data for each station are expressed as annual means ($n=4$) except: $n=2$ in 1995 (all stations); $n=3$ for SD17 and SD18 in 1996; $n=2$ for SD7 in 1997; $n=3$ for SD18 in 1997. Dashed lines indicate onset of wastewater discharge.

the absence of common species such as English sole, California tonguefish, and yellowchin sculpin, as well as relatively low numbers of hornyhead turbot and longfin sanddab, and the second lowest abundance of speckled sanddab (Table 6.3). SIMPER revealed speckled sanddab, spotted turbot, and hornyhead turbot to be the three most characteristic species for this group.

Cluster group B consisted of a single outlier from station SD21 in 2011 (Figure 6.4). This haul contained the most species (~14 species/haul), and

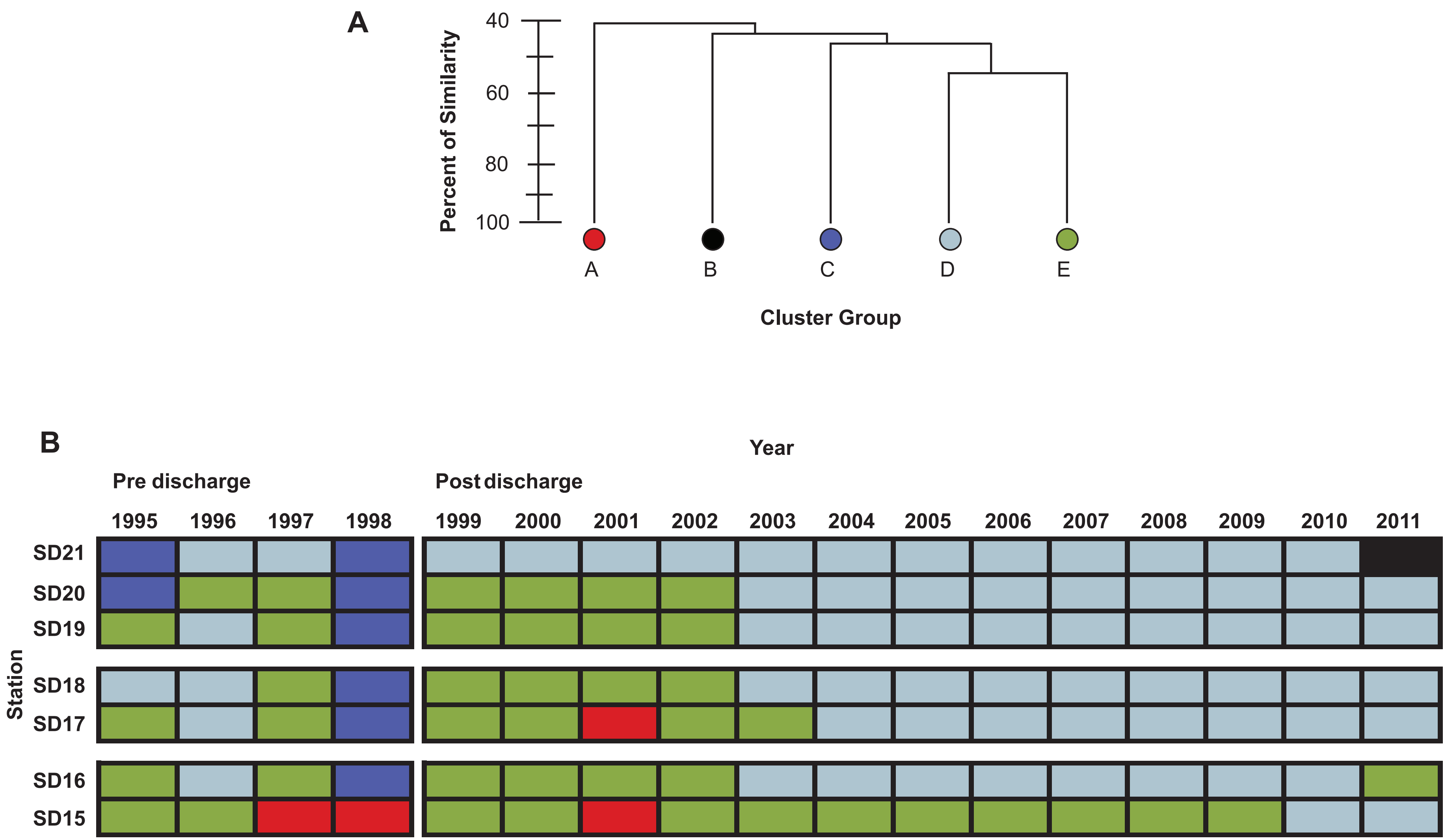

Figure 6.4
Results of cluster analysis of demersal fish assemblages collected at SBOO trawl stations between 1995–2011 (July surveys only). Data are presented as (A) a dendrogram of major cluster groups and (B) a matrix showing distribution of cluster groups over time.

Table 6.3

Description of demersal fish 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 top six most abundant species. Bold values indicate species that were considered most characteristic of that group according to SIMPER analysis.

	Cluster Groups				
	A	B	C	D	E
Number of Hauls	4	1	8	64	42
Mean Species Richness	5	14	9	10	7
Mean Abundance	22	218	64	235	97
Species	**Mean Abundance**				
Speckled sanddab	**14**	26	**12**	**138**	**81**
California lizardfish	4	75	**24**	**31**	**4**
Spotted turbot	**1**		<1	<1	**2**
Hornyhead turbot	**1**	3	**3**	**5**	**4**
California scorpionfish	<1	2	<1	1	1
Fantail sole	<1		1	<1	<1
Longfin sanddab	<1	8	**12**	**13**	2
Longspine combfish		79	**<1**	**<1**	
White croaker		22		1	
California tonguefish		6	**2**	**3**	<1
English sole		6	**5**	**3**	<1
Roughback sculpin		5		**8**	<1
Yellowchin sculpin		5	1	**26**	<1

the second highest abundance (~218 fishes/haul) compared to the other groups (Table 6.3). It was also unique in that it had 79 longspine combfish, more than an order of magnitude greater than in any other cluster group. California lizardfish and white croaker were also present in relatively high numbers (75 and 22, respectively). Conversely, numbers of most other species were low, including speckled sanddabs.

Cluster group C comprised eight outliers from two years associated with warmer water conditions, including two hauls from stations SD20 and SD21 in 1995 and seven hauls in 1998 from all stations except SD15 (Figure 6.4). This group was characterized by relatively few species per haul (~9 species/haul), the second lowest overall abundance (~64 fishes/haul) and the fewest speckled sanddabs (~12 individuals/haul) (Table 6.3). SIMPER revealed that speckled and longfin sanddabs, California lizardfish, hornyhead turbot, longspine combfish, California tonguefish and English sole were the characteristic species for this group.

Cluster groups D and E may represent "normal" or "background" conditions in the SBOO region during two different periods. Together, these groups comprise 89% of all trawls taken over the past 17 years. Group D consisted of 64 hauls and occurred at a mix of sites sampled during all years except 1998 (Figure 6.4). The assemblages represented by this group were sampled at just station SD18 in 1995 and only at station SD21 between 1997–2002; however, it occurred at five to seven stations per year in 1996 and between 2003–2011. This group had the highest overall abundance (~235 fishes/haul) and the highest numbers of the following species: speckled sanddabs (~138 individuals/haul), yellowchin sculpin (~26 individuals/haul), longfin sanddabs (~13 individuals/haul), roughback sculpin (~8 individuals/haul), and hornyhead turbot

(~5 individuals/haul). SIMPER revealed that these and several other species (California lizardfish, longspine combfish, California tonguefish, English sole) were characteristic of the assemblages represented by group D.

Cluster group E consisted of 42 trawls, including hauls from four to seven stations sampled in 1995 and between 1997–2002, as well as seven of nine hauls from SD15 between 2003–2011. This group had the second lowest species richness (~7 species/haul) and the third lowest abundance (~97 fishes/haul). It had the second highest number of speckled sanddabs (~81 individuals/haul) but relatively low numbers of most other species. SIMPER revealed that speckled sanddabs, California lizardfish, spotted turbot, and hornyhead turbot were characteristic of the assemblages represented by group E.

Physical Abnormalities and Parasitism

Demersal fish populations appeared healthy in the SBOO region during 2011. There were no incidences of fin rot, discoloration, skin lesions, tumors, or any other 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 associated with their hosts, including the one eye parasite *Phrixocephalus cincinnatus* found attached to a hornyhead turbot at station SD20 in April, and two individuals of the parasitic cymothoid isopod *Elthusa vulgaris* found attached to a hornyhead turbot and an English sole at stations SD20 in January and SD17 in April, respectively. Additionally, 58 *E. vulgaris* were identified as part of the trawl catch during 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).

Megabenthic Invertebrate Communities

A total of 1811 megabenthic invertebrates (~65 per trawl) representing 61 taxa were collected in 2011, with no new species recorded (Table 6.4, Appendix E.5). The sea star *Astropecten californicus* was the most abundant and most frequently captured species, accounting for 35% of the total invertebrate abundance and occurring in 96% of the trawls. Other species collected frequently (≥50% of the trawls) but in relatively low numbers (≤6/haul) included the parasitic isopod *Elthusa vulgaris*, the crab *Metacarcinus gracilis*, the nudibranch *Acanthodoris brunnea*, the opisthobranch *Pleurobranchaea californica,* and the octopus *Octopus rubescens.*

Megabenthic invertebrate community structure varied among stations and between surveys during the year (Table 6.5). For each haul, species richness ranged from 5 to 17 species, diversity (H') ranged from 0.3 to 2.3 units, biomass ranged from 0.2 to 2.6, and total abundance ranged from 16 to 219 individuals. Elevated numbers of invertebrates (≥107) occurred primarily at station SD15 during all four surveys, but the largest haul was taken at station SD17 in April. Two species, *A. californicus* and *Dendraster terminalis,* primarily drove abundances at station SD15, while *Ophiura luetkenii* dominated the haul at station SD17 (Appendix E.6).

Variations in megabenthic invertebrate community structure in the South Bay outfall region generally reflect changes in species abundance (Figure 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 *A. californicus* and *D. terminalis* as previously mentioned. For example, station SD15 has had the highest average abundance for 10 of the last 17 years due to relatively large hauls of the latter two species. In addition, the high abundances

Table 6.4
Species of megabenthic invertebrates collected in 28 trawls conducted in the SBOO region during 2011. 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 californicus	35	96	22	23	*Podochela hemphillii*	<1	7	<1	2
Ophiura luetkenii	15	39	10	25	*Doryteuthis opalescens*	<1	4	<1	3
Philine auriformis	11	46	7	15	*Heptacarpus palpator*	<1	7	<1	2
Dendraster terminalis	7	18	4	25	*Calliostoma tricolor*	<1	4	<1	2
Metacarcinus gracilis	6	64	4	6	*Pagurus spilocarpus*	<1	7	<1	1
Elthusa vulgaris	3	75	2	3	*Loxorhynchus grandis*	<1	7	<1	1
Acanthodoris brunnea	3	54	2	4	*Calliostoma canaliculatum*	<1	7	<1	1
Heterocrypta occidentalis	2	25	1	5	*Euspira lewisii*	<1	4	<1	2
Pyromaia tuberculata	2	39	1	3	*Paguristes ulreyi*	<1	7	<1	1
Pleurobranchaea californica	2	50	1	2	*Aphrodita* sp	<1	4	<1	1
Octopus rubescens	2	50	1	2	*Stylatula elongata*	<1	4	<1	1
Luidia foliolata	2	29	1	4	*Paguristes bakeri*	<1	4	<1	1
Caesia perpinguis	<1	14	<1	4	*Megasurcula carpenteriana*	<1	4	<1	1
Hamatoscalpellum californicum	<1	7	<1	8	*Sinum scopulosum*	<1	4	<1	1
Kelletia kelletii	<1	43	<1	1	*Armina californica*	<1	4	<1	1
Ophiothrix spiculata	<1	32	<1	2	*Aglaja ocelligera*	<1	4	<1	1
Hemisquilla californiensis	<1	32	<1	2	*Strongylocentrotus purpuratus*	<1	4	<1	1
Heptacarpus stimpsoni	<1	4	<1	12	*Aphrodita refulgida*	<1	4	<1	1
Sicyonia ingentis	<1	14	<1	2	*Acanthodoris rhodoceras*	<1	4	<1	1
Pisaster brevispinus	<1	21	<1	2	*Pandalus platyceros*	<1	4	<1	1
Crangon alba	<1	14	<1	2	*Metacarcinus anthonyi*	<1	4	<1	1
Platymera gaudichaudii	<1	25	<1	1	*Farfantepenaeus californiensis*	<1	4	<1	1
Lytechinus pictus	<1	14	<1	2	*Sicyonia penicillata*	<1	4	<1	1
Loxorhynchus crispatus	<1	21	<1	1	*Pandalus danae*	<1	4	<1	1
Flabellina iodinea	<1	18	<1	1	*Aphrodita armifera*	<1	4	<1	1
Luidia armata	<1	18	<1	1	*Megastraea undosa*	<1	4	<1	1
Crangon nigromaculata	<1	11	<1	2	*Pteropurpura festiva*	<1	4	<1	1
Randallia ornata	<1	14	<1	1	*Spirontocaris prionota*	<1	4	<1	1
Crossata californica	<1	14	<1	1	*Pagurus armatus*	<1	4	<1	1
Dendronotus iris	<1	7	<1	2	*Pugettia producta*	<1	4	<1	1
Halosydna latior	<1	11	<1	1					

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

Speckled sanddabs dominated fish assemblages surrounding the SBOO in 2011 as they have since monitoring began in 1995. This species occurred at all stations and accounted for 66% of the total catch. Other commonly captured, but less abundant species, included California lizardfish, California tonguefish, English sole, hornyhead turbot, longfin sanddab, longspine combfish, roughback sculpin, and yellowchin sculpin. The majority of these fishes tended to be relatively small with an average length ≤21 cm. Although the composition and structure of the fish assemblages varied among stations, these differences were mostly due to natural fluctuations of common fish populations.

Table 6.5

Summary of megabenthic invertebrate community parameters for SBOO stations sampled during 2011. Data are included for species richness, abundance, and diversity (H') and biomass(kg, wet weight). SD = standard deviation..

Station	Jan	Apr	Jul	Oct	Annual Mean	Annual SD
Species richness						
SD15	5	11	6	8	8	3
SD16	8	6	11	16	10	4
SD17	11	14	16	11	13	2
SD18	7	13	14	11	11	3
SD19	10	10	7	10	9	2
SD20	10	11	9	9	10	1
SD21	8	13	17	12	13	4
Survey Mean	8	11	11	11		
Survey SD	2	3	4	3		
Diversity						
SD15	0.3	1.2	0.8	0.5	0.7	0.4
SD16	1.8	1.3	1.7	1.8	1.6	0.2
SD17	1.5	1.1	2.2	1.7	1.6	0.5
SD18	1.5	1.7	2.3	1.9	1.8	0.4
SD19	1.7	1.4	1.6	2.1	1.7	0.3
SD20	1.8	1.6	1.9	1.9	1.8	0.1
SD21	0.5	1.8	2.3	2.2	1.7	0.8
Survey Mean	1.3	1.4	1.8	1.7		
Survey SD	0.6	0.3	0.6	0.6		

Station	Jan	Apr	Jul	Oct	Annual Mean	Annual SD
Abundance						
SD15	107	139	144	123	128	17
SD16	16	27	34	48	31	13
SD17	55	219	63	54	98	81
SD18	25	89	56	64	59	26
SD19	61	51	24	28	41	18
SD20	33	48	20	35	34	11
SD21	87	63	62	36	62	21
Survey Mean	55	91	58	55		
Survey SD	33	67	42	32		
Biomass						
SD15	0.4	1.7	0.4	2.6	1.3	1.1
SD16	0.2	1.1	1.6	2.1	1.2	0.8
SD17	2.0	0.7	0.2	2.0	1.2	0.9
SD18	0.2	1.4	0.1	0.5	0.5	0.6
SD19	0.3	0.4	0.1	0.7	0.4	0.2
SD20	0.9	1.0	0.4	1.8	1.0	0.6
SD21	0.5	2.1	1.8	1.5	1.5	0.7
Survey Mean	0.6	1.2	0.7	1.6		
Survey SD	0.6	0.6	0.7	0.8		

Assemblages of megabenthic, trawl-caught invertebrates in the region were dominated by the sea star *Astropecten californicus*, which occurred in 96% of trawls and accounted for 35% of the total invertebrate abundance. Other species collected frequently included the parasitic isopod *Elthusa vulgaris*, the crab *Metacarcinus gracilis*, the nudibranch *Acanthodoris brunnea*, the opisthobranch *Pleurobranchaea californica,* and the octopus *Octopus rubescens*. As with demersal fishes in the SBOO region, the composition and structure of megabenthic assemblages varied among stations, reflecting population fluctuations in the species mentioned above.

Overall, results of the 2011 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 present during the year was similar to that observed in previous years (City of San Diego 2006–2011), including the period before initiation of wastewater discharge (City of San Diego 2000). In addition, low species richness and abundances of fish and invertebrates are consistent with what is expected for the relatively shallow, sandy habitats in which the SBOO stations are located (Allen 2005, 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.

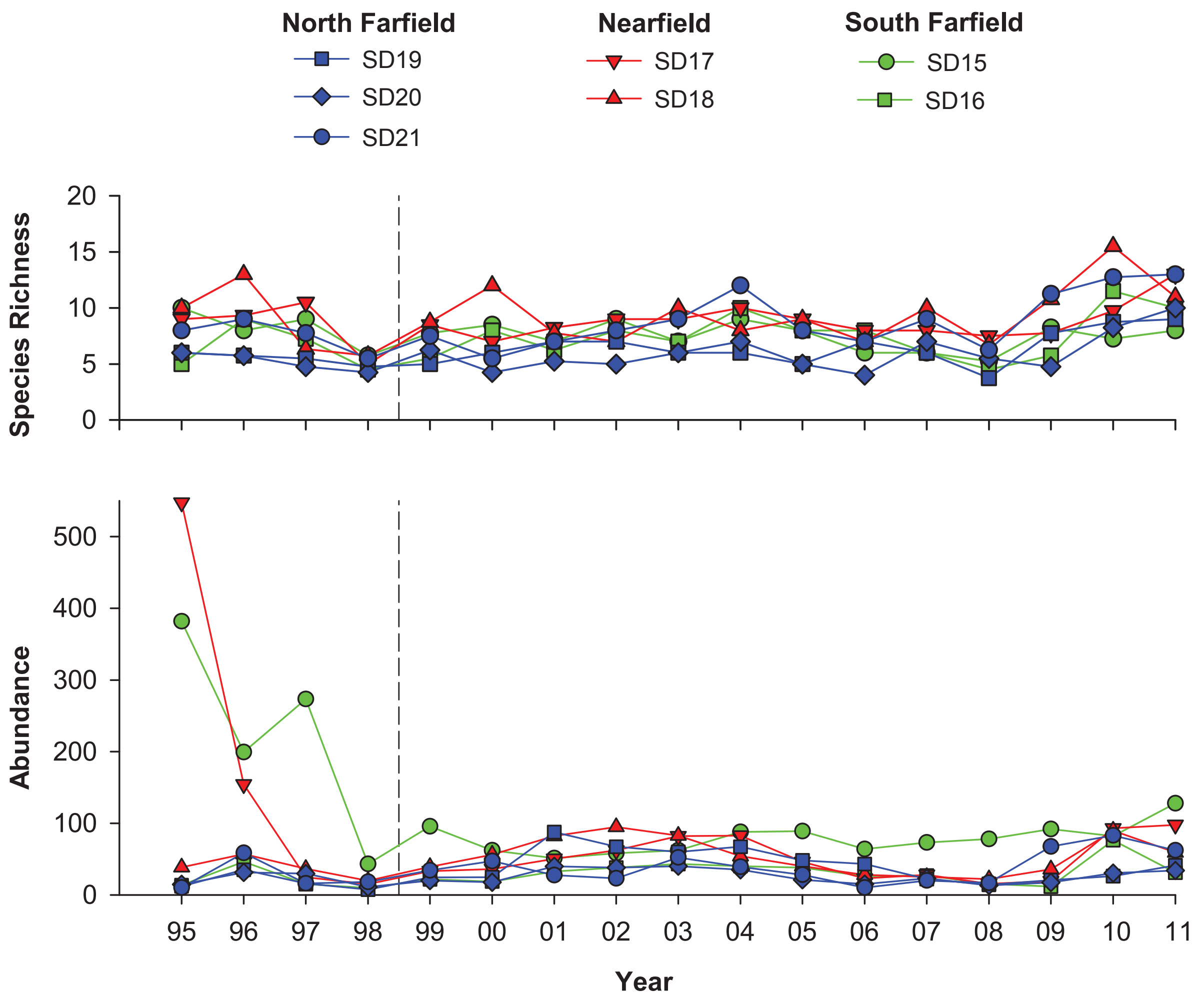

Figure 6.5

Species richness and abundance of megabenthic invertebrates collected at each trawl station between 1995–2011. Data for each station are expressed as annual means ($n=4$) except: $n=2$ in 1995 (all stations); $n=3$ for SD17 and SD18 in 1996; $n=2$ for SD7 in 1997; $n=3$ for SD18 in 1997. Dashed lines indicate onset of wastewater discharge.

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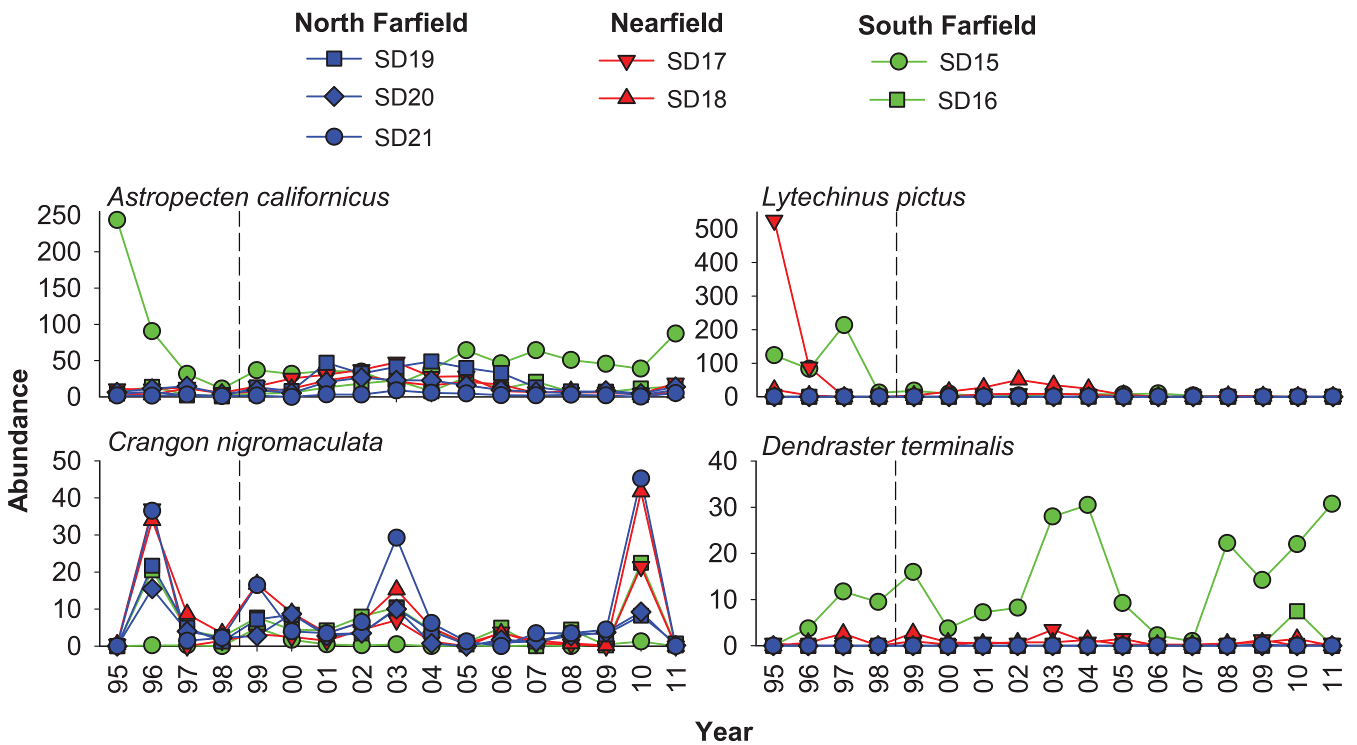

Figure 6.6

The four most abundant megabenthic invertebrate species collected in the SBOO region between 1995–2011. Data for each station are expressed as annual means ($n=4$) except: $n=2$ in 1995 (all stations); $n=3$ for SD17 and SD18 in 1996; $n=2$ for SD7 in 1997; $n=3$ for SD18 in 1997. Dashed lines indicate onset of wastewater discharge.

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