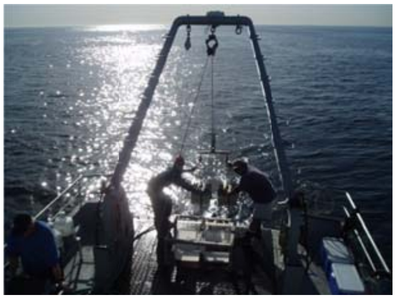
chapter 5

MACROBENTHIC INVERTEBRATE COMMUNITIES



Chapter 5
MACROBENTHIC INVERTEBRATE COMMUNITIES

INTRODUCTION

The District monitors the composition of the macrobenthic infaunal invertebrate community (small organisms, such as worms, clams, and burrowing shrimps) that lives in ocean sediments to assess the possible effects of the wastewater discharge. Infauna are sensitive indicators of environmental change due to their limited mobility and susceptibility to the effects of changes in sediment quality resulting from both natural (e.g., depth, grain size, and geochemistry) and anthropogenic (e.g., organic enrichment and chemical contaminants) influences (Pearson and Rosenberg 1978). In accordance with the District's NPDES ocean discharge permit the macrobenthic communities are monitored to determine if the wastewater discharge has degraded the biological community in the monitoring area beyond the zone of initial dilution (ZID), which is the area within 60 m in any direction of the outfall diffuser (See box).

The District's outfall pipe sits on the San Pedro Shelf between the Newport and San Gabriel submarine canyons (Figure 5-1). Since natural processes strongly influence infaunal assemblages, outfall effects are discerned from natural influences by comparing invertebrate communities near the outfall to reference sites located away from the outfall.

The outfall pipe and the associated ballast rock make one of the largest artificial reefs in southern California. The outfall structure alters current flow and sediment characteristics near the pipe (e.g., grain size and sediment geochemistry), which in turn influences the structure of the infaunal community. The physical structure of the pipe as well as the predatory fish and invertebrates that it attracts also affect the macrobenthic community in the surrounding area (OCSD 1995, 1996; Diener and Riley 1996; Diener et al. 1997). Release of the treated wastewater produces direct effects, such as organic enrichment that tends to enhance infaunal abundances.

Compliance Criteria Pertaining to Benthic Infaunal Communities Contained in the District's NPDES Ocean Discharge Permit (Order No. R8-2004-0062, Permit No. CAO110604.

Criteria	Description
C.5.a Marine Biological Communities	Marine communities, including vertebrates, invertebrates, and algae shall not be degraded.

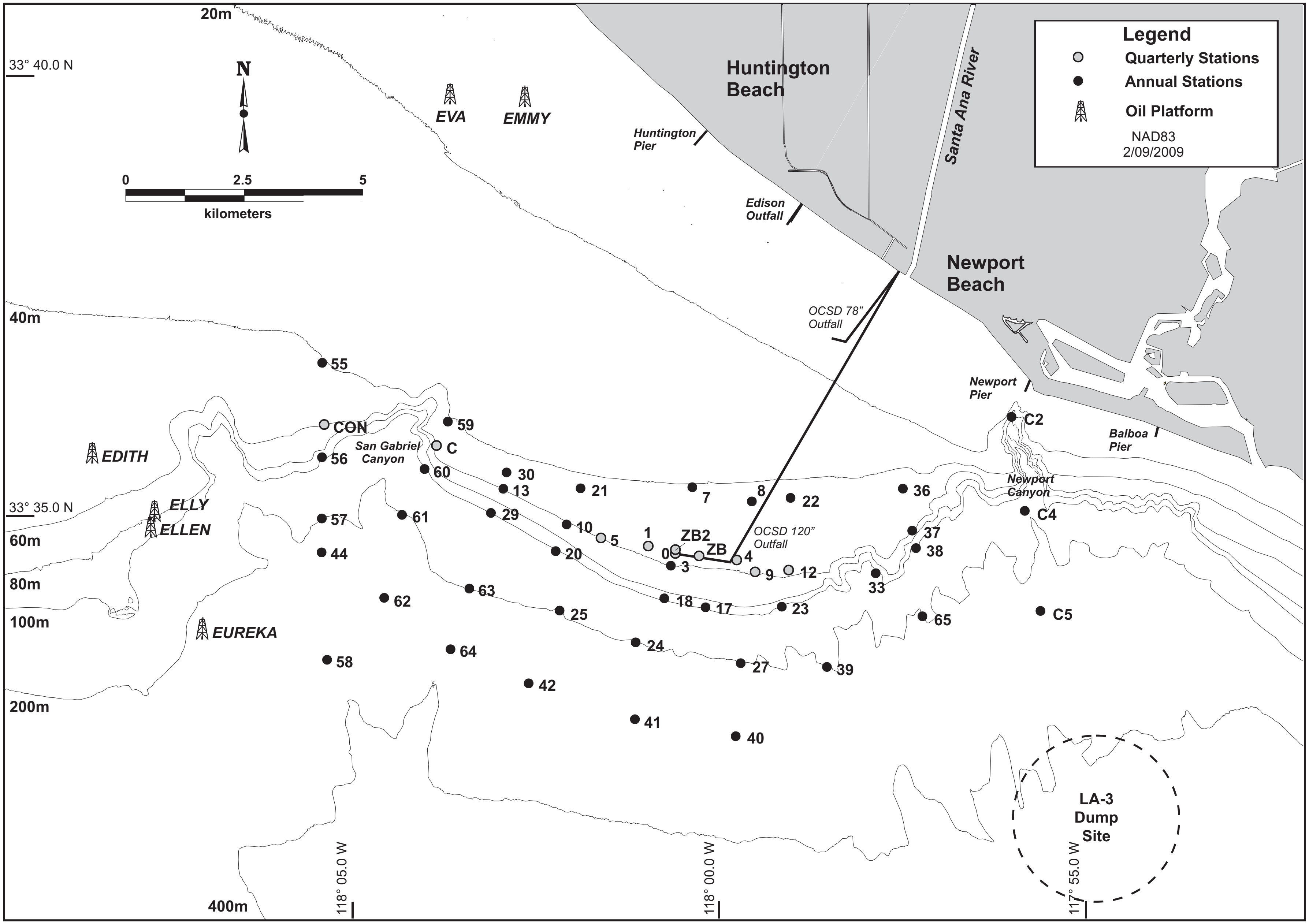


Figure 5-1. Benthic infauna sampling stations for annual and quarterly surveys, 2009-10.

Orange County Sanitation District, California.

Natural features of the environment account for most of the variability in the distribution of infaunal species in the monitoring area, with depth-related factors being the most important (OCSD 1996, 2003). However, there is a distinct assemblage near the outfall that is influenced by the wastewater discharge (e.g., OCSD 2007–2010). Previous monitoring efforts and special studies have shown that impacts from the discharge are generally localized near the outfall and can be characterized as either reef effects related to the outfall structure or as direct and/or indirect effects of the wastewater discharge. However, since 2005 infaunal community structure at the point of discharge has changed to the point of being classified as degraded, though no impacts were noted beyond the zone of initial dilution (ZID).

The District has undertaken three treatment process changes in the last 9 years that have altered effluent characteristics. The first was the initiation of effluent disinfection by chlorination with hypochlorite bleach followed by de-chlorination with sodium bisulfate, which began in August 2002. Second, the District is under a consent decree issued in 2002 to achieve secondary treatment standards by 2012. This effort has involved significant construction and changes in treatment processes that have resulted in effluent quality that is near the 30 mg/L secondary treatment levels for total suspended solids (TSS) and biological oxygen demand (BOD). Lastly, the Ground Water Replenishment System (GWRS) water reclamation project was initiated in January 2008. This project has decreased the volume of effluent discharged into the ocean from 237 MGD in 2006-07 to 167 MGD in 2009-10. While the effluent volume has decreased the mass balance of contaminants being discharged is approximately the same, resulting in a more concentrated effluent. What affect, these treatment changes have had or might have on the surrounding biota are still being assessed.

METHODS

A 0.1 m² modified paired Van Veen sediment grab sampler was used to collect infaunal samples. Three replicate samples were collected quarterly at 10 stations of depths between 55–60 m (referred to herein as the 60 m or outfall-depth sites). An additional 39 "annual" stations, with depths ranging from 40 to 303 m, were sampled in July 2009 (Figure 5-1). The purpose of the quarterly surveys is to determine long-term trends and potential effects along the 60-m depth contour, while the annual survey is primarily to assess the spatial extent of the influence of the effluent discharge. Analysis of the annual survey data included the first replicate sample from the July quarterly stations as well as the 39 annual stations (n=49 stations). While data for annual Station 36 was included in tables, it was excluded as an outlier from all data analyses and station comparisons. No determination was made for the anomalously low values, however adjacent stations showed normal values making an effluent discharge affect unlikely.

The measures used to assess infaunal community health and function were total number of species, total abundance of individuals, total biomass, Shannon-Wiener Diversity (H'), Margalef Species Richness (d), Schwartz' 75% Dominance Index (Dominance), Species Evenness (J'), Infaunal Trophic Index (ITI), and Benthic Response Index (BRI). Biomass measurements are sometimes influenced by the occurrence of occasional, large organisms, so they tend to be much more variable than other community measures. For that reason, organisms having large biomass (e.g., sea stars and large mollusks) are removed from the sample calculation. The measures of diversity are based on the number of species and the equitability of their distribution. H', J', and Dominance are more sensitive to the distribution of species within a sample, while d is more sensitive to the number of species.

The Infaunal Trophic Index (ITI) is an index developed by Word (1978) and modified in 1980 (Version 2) to provide a measure of infaunal community "health." ITI values greater than 60 are considered indicative of a "normal" community; 30–60 represent a "changed" community, while values less than 30 indicate a "degraded" community. The Benthic Response Index (BRI) measures the pollution tolerance of species on an abundance-weighted average basis (Bergen et al. 1998). This measure is scaled inversely to ITI with low values (<25) representing reference conditions and high values (>72) representing the defaunation or exclusion of most species; The intermediate value ranges of 25–34 indicates a marginal deviation from reference conditions, 35–44 indicates a loss of biodiversity, and 45–72 indicates a loss of community function. The BRI was used to determine compliance with NPDES permit conditions. It is a commonly used southern California benchmark for infaunal community structure and was developed with the input of regulators.

The presence or absence of certain indicator species (pollution sensitive and pollution tolerant) was also determined for each station. Indicator species are those organisms that show strong abundance gradients relative to the wastewater discharge and some can dominate the calculation of community measures (e.g., *Capitella* "*capitata*" complex). Patterns of these species are used to assess the spatial and temporal influence of the wastewater discharge in the receiving environment. The presence of the pollution sensitive species tends to indicate the existence of a healthy environment, while the occurrence of the pollution tolerant species may indicate stressed or organically enriched environments. Pollution sensitive species include the red brittle star *Amphiodia urtica* (echinoderm) and amphipod crustaceans from the genera *Ampelisca* and *Rhepoxynius*. The pollution tolerant species include *Capitella* "*capitata*" species complex (polychaete) and *Euphilomedes carcharodonta* (ostracod crustacean).

PRIMER v6 (Plymouth Routines in Multivariate Ecological Research) multivariate statistical software was used to examine the spatial patterns of infaunal invertebrate communities in the monitoring area. Analyses included hierarchical clustering with group-average linking based on Bray-Curtis similarity indices, and ordination clustering of the data using non-metric multidimensional scaling (MDS). Data were truncated to include only the shallow- and mid-shelf stations since depth is a strong environmental factor in delineating species clusters (OCSD 2010). Clarke and Warwick (2001) warn that clustering is less useful and may be misleading where there is a strong environmental forcing, such as depth. Prior to the calculation of the Bray-Curtis indices, the data were 4th-root transformed in order to down-weight the highly abundant species and incorporate the importance of the less common species (Clarke and Warwick 2001). The SIMPER ("similarity percentages") routine was also used to determine inter- and intra-group species differences.

Depth-related gradients were assessed using linear regression analysis and relationships with sediment concentrations of the sewage marker total linear alkylbenzenes (tLAB) were assessed using Pearson Product Moment Correlation with the Minitab® Statistical Software package. Data was transformed where appropriate. Statistical significance was set at $p \leq 0.05$.

Temporal trends were evaluated at the quarterly stations graphically using grouped data to increase the sample size at each station and decrease the variability of each data point on the graph. Each community measure was represented as a line graph to show the inter-annual variability and as a best-fit line to show the overall direction (increasing/decreasing) of changes. The quarterly stations were divided into five stations groups based on their proximity to the outfall diffuser: farfield upcoast (FFU = Stations C and CON); nearfield upcoast (NFU = Stations 1 and 5); nearfield downcoast (NFD = Station 9 and 12); within ZID upcoast (WZU = Stations 0 and ZB2); and within ZID downcoast (WZD = Station 4 and ZB).

Infaunal organisms are classified into five “major taxa” for ease of comparison between stations and depth strata: polychaeta (worms), molluska (snails, clams, etc.), crustaceans (shrimps, crabs, etc.), echinodermata (sea stars, sea urchins, sea cucumbers), and minor phyla (e.g., cnidaria, nemertea, echiura, etc.).

A more complete summary of methods for the analyses and the indices used in this chapter are presented in Appendix A.

RESULTS AND DISCUSSION

Taxa and Abundance

A total of 710 taxa comprising 58,773 individuals were collected in the 2009-10 monitoring year (Table 5-1). This represented increases of 22 taxa and 561 individuals from the 2008-09 monitoring year. The number of species and/or the number of individuals of a major taxonomic group was largely related to depth and proximity to the outfall. For example, the mean number of crustacean taxa and abundance generally decreased with increased station depth and proximity to the outfall (i.e., mid-shelf ZID stations). Polychaete diversity was greatest between 91–100 m, but decreased at mid-shelf ZID stations. However, in contrast to the crustaceans, the mean number of polychaete individuals was higher within the ZID. This was due to the high abundances of Capitellid species, particularly *Capitella capitata* complex (see the discussion later in this chapter on indicator species).

Community Indicators

Number of species

The number of species collected across all 49 stations in July 2009 ranged from 14 at slope Station 44 to 119 at shallow-shelf Station 8, and generally decreased with increasing depth (Table 5-2; Figure 5-2).

Regression analysis showed a significant relationship between station depth and the number of species (R^2=0.53). The mean number of species was lower at the 60 m within-ZID (67) stations relative to non-ZID (91) stations. Although there was a general decline in species richness along the 60 m contour, the within ZID stations decreased by 15 species relative to 2008 while the other 60 m stations decreased by only 7. The number of species was negatively correlated with sediment tLAB concentrations (R=-0.41) indicating an influence from discharged particulates, particularly at sites within the ZID (Figure 4-2).

Along the 60 m contour, quarterly within-ZID stations had lower species richness than non-ZID stations. The mean number of species at quarterly non-ZID station was 94, but only 66 at within-ZID stations (Table 5-3). Unlike previous years, the mean number of species at within-ZID Stations 0, ZB, and ZB2 were less than the Bight’03 large POTW (LPOTW) and non-POTW mid-shelf means. The mean number of species at within-ZID Station 0 was below the historical range of number of species for the

Table 5-1. Major taxonomic groups by station depth and location within or outside the zone of initial dilution (ZID). Values represent the mean and (range) of values for stations within a depth range.

Orange County Sanitation District, California.

Community Measure	Depth (m)	Polychaeta	Crustacea	Mollusca	Echinodermata	Misc. Phyla
Number of Species	Shallow shelf (40–46)	42 (0–67)	22 (4–30)	11 (1–16)	5 (0–9)	6 (1–12)
	Mid-shelf ZID (56–60)	36 (19–45)	14 (8–22)	11 (9–12)	2 (0–4)	5 (3–9)
	Mid-shelf non-ZID (56–60)	47 (33–65)	20 (2–31)	13 (8–23)	5 (1–9)	5 (2–9)
	Outer shelf (91–100)	57 (40–74)	15 (5–22)	15 (10–17)	5 (4–6)	7 (5–9)
	Slope (187–241)	24 (10–35)	6 (0–16)	9 (3–14)	2 (0–6)	1 (0–3)
	Basin (296–300)	15 (8–21)	6 (4–9)	6 (3–9)	2 (0–4)	1 (0–4)
Abundance of Individuals	Shallow shelf (40–46)	134 (0–239)	71 (9–114)	22 (1–42)	39 (0–70)	9 (1–20)
	Mid-shelf ZID (56–60)	343 (215–472)	43 (28–74)	35 (21–50)	3 (0–5)	14 (5–22)
	Mid-shelf non-ZID (56–60)	167 (98–254)	73 (2–109)	40 (13–79)	34 (2–82)	10 (3–19)
	Outer shelf (91–100)	238 (186–316)	48 (15–113)	60 (26–105)	107 (58–186)	11 (7–16)
	Slope (187–241)	62 (19–113)	14 (0–50)	28 (6–61)	3 (0–13)	1 (0–3)
	Basin (296–300)	34 (10–50)	9 (5–15)	15 (6–32)	2 (0–6)	1 (0–4)

Table 5-2. Summary of infaunal community measures for all stations, July 2009 annual survey sorted by depth.

Orange County Sanitation District, California.

Station	Depth (m)	Total Number of Species	Total Abundance	Total Biomass (g)	Shannon-Wiener Diversity (H')	Margalef Species Richness (d)	Schwartz' 75% Dominance Index	Species Evenness (J')	Infaunal Trophic Index (ITI)	Benthic Response Index (BRI)
Shallow Shelf (40 – 46 meters)										
7	41	103	318	6.37	4.18	17.7	42	0.90	88	16
8	44	119	436	3.38	4.10	19.4	37	0.86	83	17
21	44	74	222	3.54	3.78	13.5	27	0.88	92	9
22	45	99	293	4.68	3.98	17.3	38	0.87	95	12
30	46	100	327	5.43	3.96	17.1	33	0.86	86	15
36**	45	7	12	0.15	1.59	2.4	4	0.82	67	8
55	40	89	229	2.33	4.03	16.2	36	0.90	88	15
59	40	108	366	1.68	3.92	18.1	36	0.84	78	15
Mean		**87**	**275**	**3.44**	**3.69**	**15.2**	**32**	**0.86**	**85**	**13**
Mid-Shelf Within-ZID (56 – 60 meters)										
0 *	56	60	511	1.82	2.56	9.5	11	0.63	13	33
4 *	56	88	378	2.09	3.63	14.7	23	0.81	49	25
ZB *	56	39	282	1.57	1.79	6.7	4	0.49	12	40
ZB2 *	56	81	578	1.64	2.62	12.6	11	0.60	11	32
Mean		**67**	**437**	**1.78**	**2.65**	**10.9**	**12**	**0.63**	**21**	**33**
Mid-Shelf Non-ZID (56 – 60 meters)										
1 *	56	98	415	3.33	3.69	16.1	27	0.80	63	21
3	60	98	447	2.24	3.73	15.9	26	0.81	57	24
5 *	59	92	334	4.16	3.89	15.7	29	0.86	75	13
9 *	59	94	296	3.17	3.87	16.3	32	0.85	64	14
10	60	82	318	3.53	3.65	14.1	25	0.83	81	13
12 *	58	93	324	2.30	3.92	15.9	31	0.86	70	13
13	59	93	319	4.16	3.82	16.0	31	0.84	90	10
37	56	117	322	5.96	4.28	20.1	46	0.90	74	14
C *	56	87	335	3.96	3.85	14.8	28	0.86	83	14
C2	56	49	183	9.27	3.25	9.2	16	0.83	58	44
CON *	59	95	266	2.05	4.08	16.8	36	0.90	87	8
Mean		**91**	**324**	**4.01**	**3.82**	**15.5**	**30**	**0.85**	**73**	**17**
Outer Shelf (91–-100 meters)										
17	91	109	503	6.90	4.03	17.4	30	0.86	78	15
18	91	98	391	6.81	4.03	16.3	32	0.88	82	12
20	100	110	565	7.18	3.63	17.2	21	0.77	87	18
23	100	92	366	4.99	3.79	15.4	25	0.84	85	15
29	100	108	470	4.90	3.77	17.4	26	0.80	83	19
33	100	86	441	4.65	3.57	14.0	20	0.80	80	20
38	100	110	598	5.59	3.68	17.0	23	0.78	80	21
56	100	76	376	4.97	3.07	12.6	16	0.71	85	17
60	100	86	480	5.46	3.45	13.8	18	0.78	83	14
Mean		**97**	**466**	**5.72**	**3.67**	**15.7**	**23**	**0.80**	**83**	**17**

Table 5-2 Continues.

Table 5-2 Continued.

Station	Depth (m)	Total Number of Species	Total Abundance	Total Biomass (g)	Shannon-Wiener Diversity (H’)	Margalef Species Richness (SR)	Schwartz’ 75% Dominance Index	Species Evenness (J’)	Infaunal Trophic Index (ITI)	Benthic Response Index (BRI)
Slope (187 – 241 meters)										
24	200	56	125	1.30	3.63	11.4	25	0.90	79	20
25	200	54	167	3.70	3.50	10.4	19	0.88	54	27
27	200	52	129	1.73	3.56	10.5	24	0.90	77	24
39	200	60	215	2.00	3.18	11.0	16	0.78	77	18
44	241	14	26	0.80	2.49	4.0	8	0.94	33	32
57	200	35	70	1.40	3.30	8.0	18	0.93	62	24
61	200	35	76	2.35	3.25	7.9	17	0.92	62	30
63	200	50	95	0.99	3.61	10.8	27	0.92	71	27
65	200	32	67	2.13	3.17	7.4	16	0.92	67	32
C4	187	33	108	8.46	2.99	6.8	13	0.86	60	37
Mean		**42**	**108**	**2.49**	**3.27**	**8.8**	**18**	**0.89**	**64**	**27**
Basin (296 – 300 meters)										
40	303	38	82	0.37	3.32	8.4	18	0.91	65	29
41	303	27	48	0.61	3.12	6.7	15	0.95	76	32
42	303	33	76	1.58	2.88	7.4	14	0.82	69	27
58	300	26	42	0.80	3.12	6.7	16	0.96	57	31
62	300	21	42	1.50	2.56	5.4	11	0.84	60	35
64	300	39	87	3.03	3.27	8.5	18	0.89	53	27
C5	296	31	60	5.73	3.17	7.3	16	0.92	76	36
Mean		**31**	**62**	**1.95**	**3.06**	**7.2**	**15**	**0.90**	**65**	**31**

* Mean of 3 replicates reported for quarterly stations.

**Results presented determined to be outliers and not used in chapter analyses.

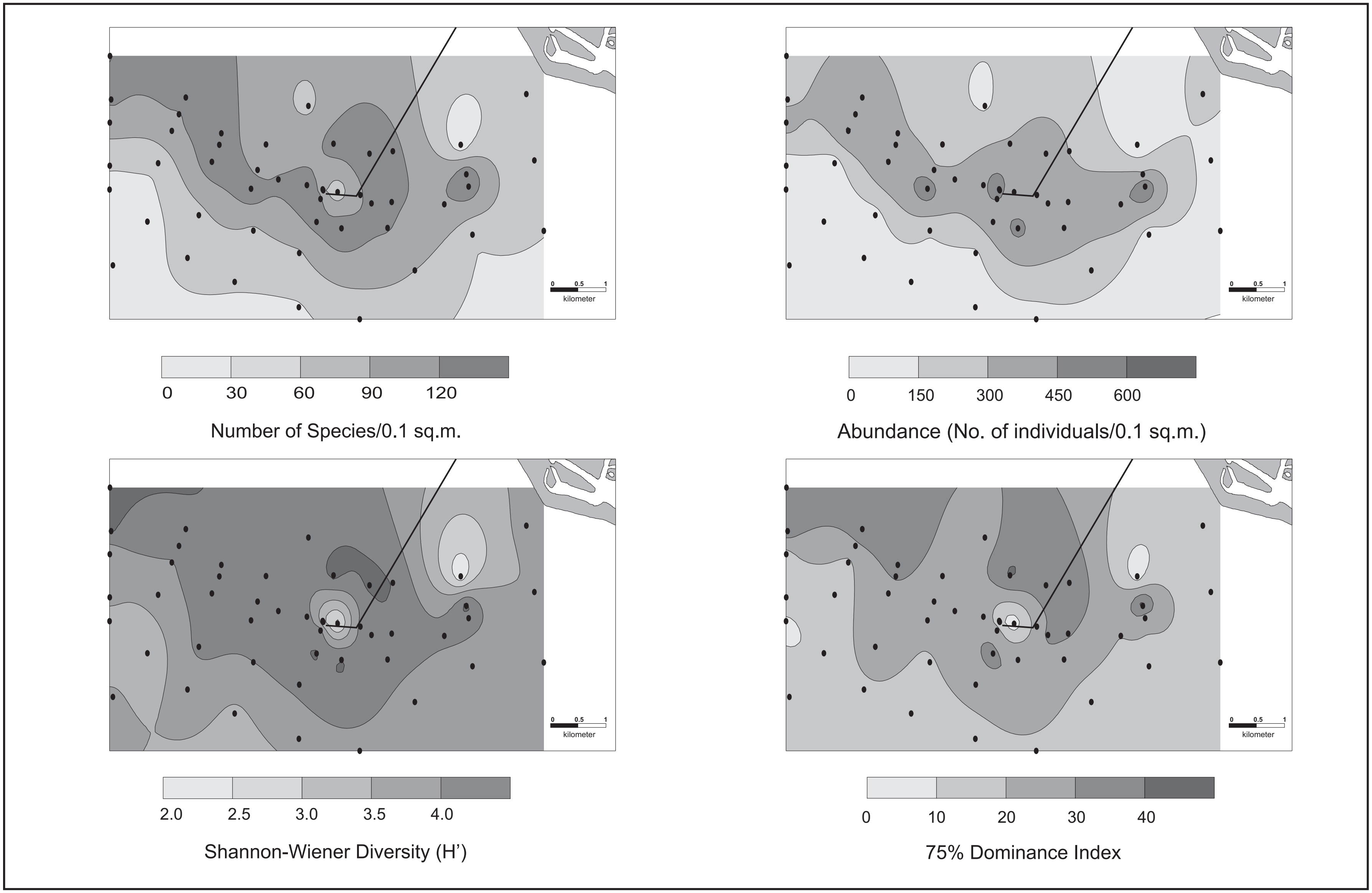


Figure 5-2. **Spatial distributions of number of species, abundance, Shannon-Wiener diversity (H'), and 75% Dominance Index during July 2009.**

Orange County Sanitation District, California.

Table 5-3. Station means for community measures and diversity indices for quarterly 60 m stations in 2009-10 (n=12) compared to regional and historical values.

Orange County Sanitation District, California.

Station	Station Location Relative to the Outfall	Number of Species	Total Abundance	Total Biomass (g)	Shannon-Wiener Diversity (H')	Margalef Species Richness (SR)	Schwartz' 75% Dominance Index	Evenness (J')	Infaunal Trophic Index (ITI)	Benthic Response Index (BRI)
Within-ZID Stations										
0	WZU	54	883	1.79	1.38	8.04	3	0.35	4	41
ZB2	WZU	66	744	2.57	1.87	10.1	5	0.45	6	37
4	WZD	82	263	1.86	3.81	14.6	29	0.87	56	23
ZB	WZD	61	320	1.62	2.74	10.5	13	0.67	20	36
Mean		**66**	**553**	**1.96**	**2.45**	**10.8**	**13**	**0.59**	**22**	**34**
Non-ZID Stations										
1	NFU	102	421	2.59	3.87	16.8	31	0.84	57	22
5	NFU	93	363	3.31	3.81	15.5	28	0.85	78	13
9	NFD	89	277	3.30	3.85	15.7	31	0.86	72	16
12	NFD	87	248	4.10	3.94	15.8	35	0.88	77	14
C	FFU	103	351	4.32	4.00	17.4	35	0.87	85	15
CON	FFU	89	254	2.65	4.07	16.0	36	0.91	89	12
Mean		**94**	**319**	**3.38**	**3.92**	**16.2**	**33**	**0.87**	**76**	**15**
Regional Reference Values										
Bight'03 *	LPOTW	90	396	NC	3.68	NC	29	0.81	NC	17
Bight'03 *	Mid-shelf-non-POTW	76	321	NC	3.60	NC	26	0.83	NC	14
1985–2008	OCSD Quarterly Station Min.–Max.	57–158	213–1,591	0.56–19.3	2.64–4.14	9.92–19.5	9.08–41.3	0.62–0.91	8.34–92.9	9.17–39.8

WZU = Within ZID Upcoast; WZD = Within ZID Downcoast; NFU = Nearfield Upcoast; NFD = Nearfield Downcoast; FFU = Farfield Upcoast; ZID = Zone of Initial Dilution.
NC = Not Calculated
* Ranasinghe et al. 2006

quarterly stations, while Stations ZB and ZB2 were near the low end of the range (Table 5-3). The mean number of species at non-ZID stations this year was comparable to the 2008-09 surveys, but there was a decrease of 16 species at the within-ZID stations, primarily crustaceans and polychaetes.

Abundance

Station abundances during the annual survey ranged from 26 at slope Station 44 to 598 at outer-shelf Station 38 and were generally distributed according to depth (Table 5-2; Figure 5-2). There was a significant relationship between station depth and total abundance (R^2=0.45), but not to tLAB concentrations, which implies no outfall impact. Abundances were highest at outer shelf stations due to high abundances of echinoderms, mollusks, and polychaetes (Table 5-1). Mean abundances at the 60-m stations were higher at within-ZID stations compared to mid-shelf non-ZID stations at 437 and 324, respectively. The increased abundances at within-ZID stations 0, ZB, and ZB2 were due primarily to very high abundances of the polychaete *C. capitata*, and elevated abundances of the polychaetes *Aricidea (Acmira) catherinae*, *Lumbrineris cruzensis*, and *Mediomastus* sp, the mollusks *Axinopseta serricata*, *Solemya reidi*, and *Tellina modesta*, the crustacean *E. carcharodonta*, and the cnidarian *Acanthoptilum* sp compared to non-ZID stations.

The quarterly non-ZID station mean abundance was 319 compared to 553 at the within-ZID stations (Table 5-3). The higher within-ZID abundances were due primarily to the above-mentioned species, particularly *C. capitata*. Within-ZID Stations 4 and ZB, and non-ZID Stations 9, 12, and CON were all below the Bight'03 large POTW and mid-shelf non-POTW means. The mean abundances at non-ZID stations this year was comparable to the 2008-09 surveys (319 and 349 individuals, respectively). Mean abundances at within-ZID stations increased from 411 in 2008-09 to 553 in 2009-10. The increase was primarily due to high abundances of *C. capitata*. This is in contrast to the decrease in the number of species at within-ZID stations indicating the exclusion of some species by *C. capitata*.

Biomass

Biomass at the annual stations ranged from 0.37 g at basin Station 40 to 9.27 g at mid-shelf non-ZID Station C2 (Table 5-2). Though it is at mid-shelf depth, Station C2 is located near the head of the Newport Canyon and has been determined to be more impacted by regional influences (e.g., the Santa Ana River) than by the outfall (SAIC, 2003). Biomass was highest on the mid- and outer-shelf and in the Newport Canyon and lowest at the outfall, inshore, and in the basin. The high biomass on the mid- and outer-shelf was due largely to high abundances of the red brittle star *A. urtica* and spionid polychaetes, particularly *Spiophanes berkeleyorum*. Biomass was negatively correlated with tLAB sediment concentrations (R=-0.37). There was a very small, but significant ($P<0.05$) relationship of biomass to station depth (R^2=0.10).

Unlike previous years, mean biomass was less at the quarterly ZID stations (1.96 g) relative to the non-ZID stations (3.38 g) (Table 5-3). This is likely due to the exclusion of larger species by *C. capitata*. All biomass measurements were within the historical range for the quarterly stations.

Diversity Indices

Four diversity and species equitability indices are calculated. All results are reported in tables and figures, but due to the similarity in results only Shannon-Wiener Diversity (H') and Schwartz' 75% Dominance (Dominance) are discussed.

Shannon-Wiener Diversity (H')

Annual H' scores ranged from 1.79 at within-ZID Station ZB to 4.28 at mid-shelf non-ZID Station 37 (Table 5-2; Figure 5-2). Consistent with previous annual surveys (e.g., OCSD 2010), the 2009 annual survey showed a pattern of higher values at the shallow- and non-ZID mid-shelf stations with values generally decreasing with increasing depth and proximity to the outfall (Table 5-2; Figure 5-2). Regression analysis showed environmentally relevant relationship of H' to station depth, while correlation analysis showed a moderate inverse relationship of tLAB to H' (R=-0.37), indicating an outfall influence. This is in contrast to July 2008, when H' showed a much stronger relationship to depth (R^2=0.50). This was likely influenced by the decrease in H' at within-ZID stations from a mean of 3.45 in July 2008 to 2.65 in July 2009.

The quarterly non-ZID station mean value was 3.92 compared to 2.45 at the within-ZID stations (Table 5-3). All non-ZID stations exceeded both Bight'03 LPOTW and mid-shelf non-POTW values and were within the long-term range of values at OCSD quarterly stations. Within-ZID means ranged from 1.38 to 3.81. H' values at within-ZID Stations 0, ZB, and ZB2 were below Bight'03 LPOTW and mid-shelf non-POTW values, and values at Stations 0 and ZB2 were below the long-term quarterly station means (Table 5-3). H' values were 3.93 and 3.92 at non-ZID stations in 2008-09 and 2009-10, respectively. However, values at within-ZID stations decreased from 3.45 in 2008-09 to 2.45 in 2009-10 demonstrating the degree of change in community structure near the outfall.

Schwartz' 75% Dominance (Dominance)

Dominance scores ranged from 4 at within-ZID Station ZB to 46 at mid-shelf non-ZID Station 37 where lower values describe assemblages dominated by fewer species, a sign of lessened community function. Dominance scores were highest in the shallow-shelf stations and tended to decrease with increasing depth (Table 5-2; Figure 5-2). Regression analysis showed a small relationship of Dominance to station depth (R^2=0.18), while correlation analysis showed a moderate inverse relationship of tLAB to Dominance (R=-0.41), indicating an outfall influence.

Dominance was low at stations within the ZID. Mean Dominance scores were 13 at the quarterly within-ZID stations relative to 33 at the non-ZID station (Table 5-3). Dominance scores at non-ZID stations were nearly identical in 2008-09 (33), while within-ZID means decreased from 21 in 2008-09 to 13 this year. All non-ZID station scores were comparable to Bight'03 scores, while scores at within-ZID Station 0, ZB, and ZB2 were below Bight'03 scores and Stations 0 and ZB2 were below the OCSD quarterly station long-term range (Table 5-3). The increased abundances in polychaete species (e.g., *C. capitata*, *A. catherinae*, and *L. cruzensis*) largely account for the decrease in Dominance scores at the within-ZID sites.

Infaunal Trophic Index and Benthic Response Index

Infaunal Trophic Index (ITI)

In July 2009, Infaunal Trophic Index (ITI) scores ranged from 11 at within-ZID Station ZB2 to 95 at shallow-shelf Station 22 (Table 5-2). The majority of ITI scores at stations outside the ZID indicated a normal community with the exception of mid-shelf Stations 3 and C2, slope Stations 25, 44, 65, and C4, and basin Stations 58, 62, and 64, which had scores indicating a changed community. Historically, mid-shelf Station C2 has characterized differently from the other 60 m shelf stations, including ZID stations, in sediment characteristics (See Chapter 4 Sediment Geochemistry) and infaunal communities. However, mid-shelf Station 3, located only 0.3 km offshore from the outfall terminus, has generally characterized as normal per the ITI, but showed a changed community in July 2009. In general, values were lower in the San Gabriel Canyon and near the ZID, increasing with distance upcoast and inshore from the outfall (Figure 5-3). Regression analysis showed a moderate relationship of ITI scores to station depth (R^2=0.49) and correlation analysis showed a moderate negative correlation of ITI scores and sediment tLAB (R=-0.52), indicating both outfall- and depth-related influences on infaunal community structure; tLAB is very weakly related to station depth (Chapter 4, R^2=0.09).

Quarterly station mean ITI scores were 76 at non-ZID stations and 22 at within-ZID stations (Table 5-3). The ITI scores at within-ZID Stations 0, ZB, and ZB2 all indicated degraded communities (ITI<30) exist at these stations. The ITI scores at all non-ZID stations fell within the long-term range of values and all indicated normal infaunal communities were present (i.e., ITI>60), except Station 1 which indicated a changed community (Table 5-3). Station 1 had scores of 42 in January 2010 and 57 in October 2009, both indicating a changed invertebrate community at that station. Station 1 is located 0.6 km upcoast from the outfall terminus, the predominant direction of current flow at outfall depth. The changed community here, as well as at Station 3, suggests that changes in community structure occurring at the with-ZID stations may be expanding.

<u>Benthic Response Index (BRI)</u>

Benthic Response Index (BRI) scores in the July annual survey ranged from 8 at Station CON to 44 at Station C2 (Table 5-2). With the exception of the within-ZID stations and Station C2, BRI scores were fairly uniform on the San Pedro Shelf, generally increasing with station depth and decreasing with distance from the outfall (Figure 5-3). All shallow and mid-depth stations beyond the ZID had BRI scores indicating reference conditions. Several stations along the slope and basin had BRI scores indicating marginal deviation from reference conditions, while the scores at the three Newport Canyon Stations (C2, C4, and C5) indicated a loss of biodiversity. Similar to ITI, regression analysis showed a small relationship of BRI scores to station depth (R^2=0.27), while correlation analysis showed a moderate correlation to sediment tLAB (R=0.41), indicating both outfall- and depth-related influences on infaunal community structure.

The mean BRI score at quarterly non-ZID stations was 15 (reference condition), but was 34 (marginal deviation from reference) at within-ZID stations (Table 5-3). Mean BRI scores at within-ZID stations ranged from 23 at Station 4 to 41 at Station 0. Station 4 characterized as reference while Station 0, ZB, and ZB2 characterized as having a loss of biodiversity.
All BRI scores at non-ZID stations were within the long-term range of values, comparable to Bight'03 means, and indicated reference conditions

Temporal (long-term) Trend Analysis

With the addition of the 2009-10 data, long-term trends for several community measures have changed relative to previous years. The majority of these changes occurred at the within-ZID station groups, but some changes were also seen in nearfield and farfield station groups (Figure 5-4). For example, from 1985 through 2009, annual community diversity measures, such as H', d, J', and Dominance, showed trends towards increasing diversity over time in all station groups. With the addition of the 2009-10 data, numbers of species, H', and J' all show a decreasing trend at WZU, while d and Dominance have leveled off and show

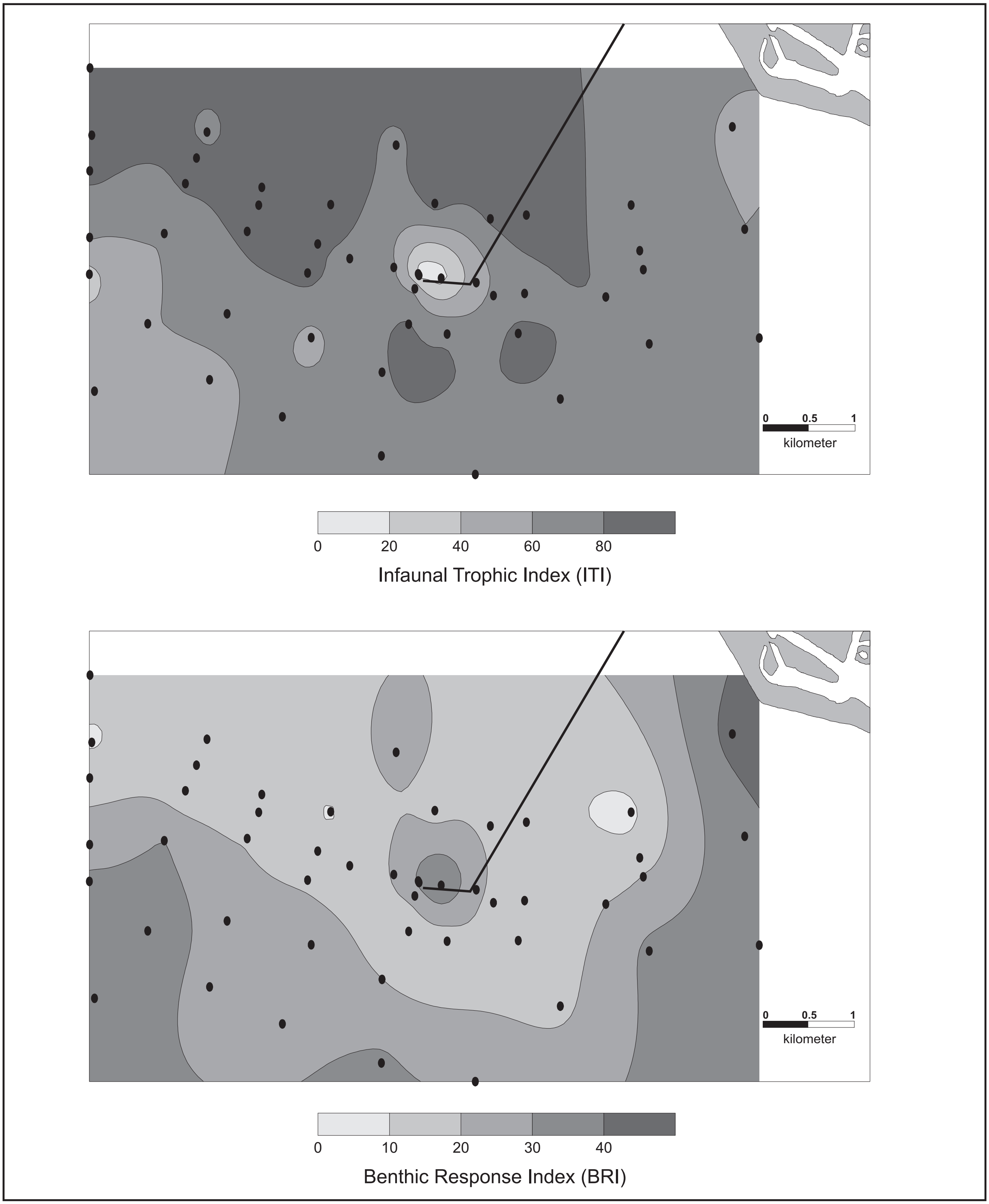


Figure 5-3. Spatial distributions of infaunal trophic index (ITI) and benthic response index (BRI) during July 2009.

Orange County Sanitation District, California.

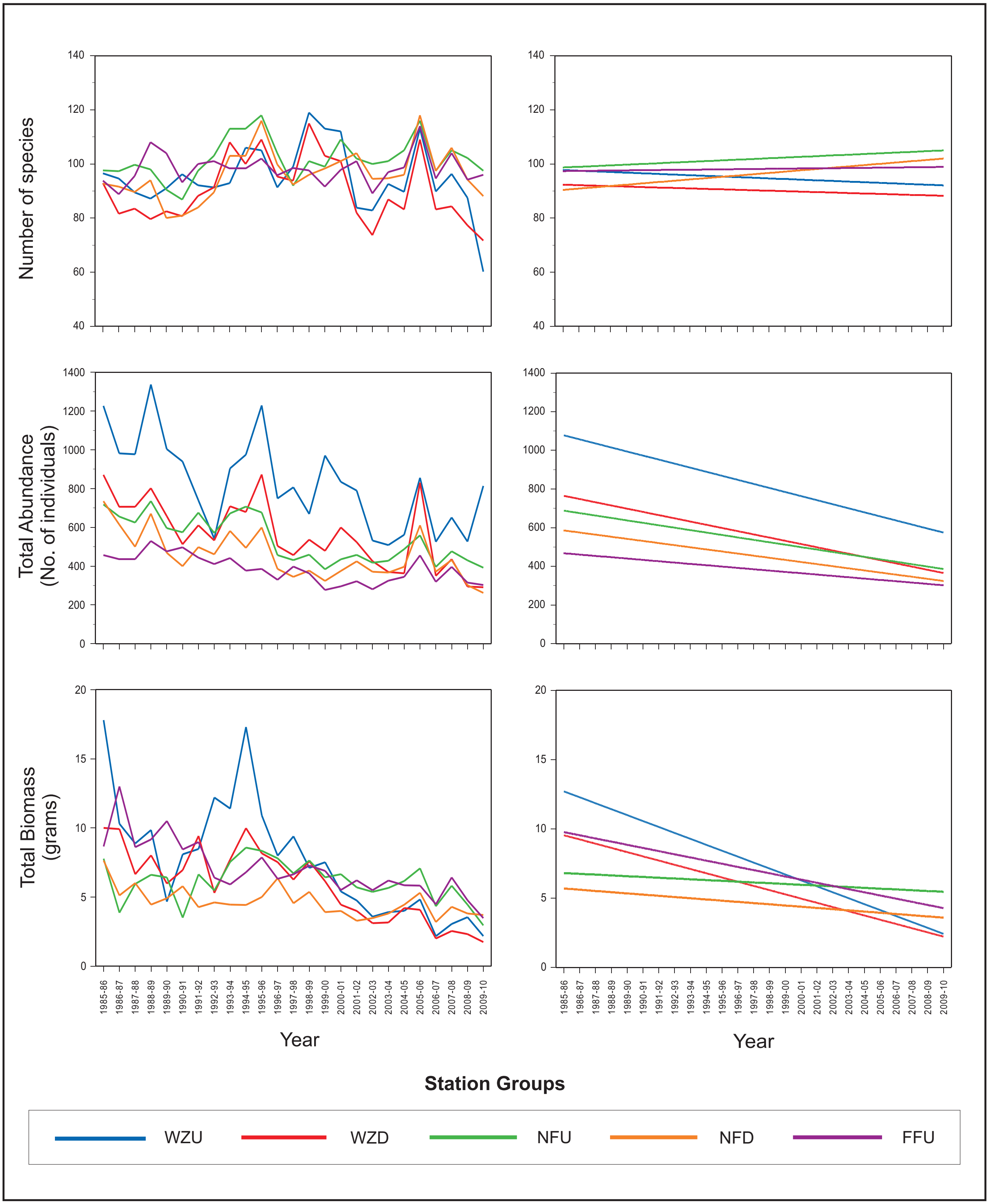


Figure 5-4. **Annual mean values for benthic infauna parameters for the period 1985–2010: No. of species, abundance, biomass, Shannon-Wiener diversity (H'), Margalef species richness (d), Schwartz's 75% dominance, species evenness (J'), infaunal trophic index (ITI), and benthic response index (BRI).**

Orange County Sanitation District, California.

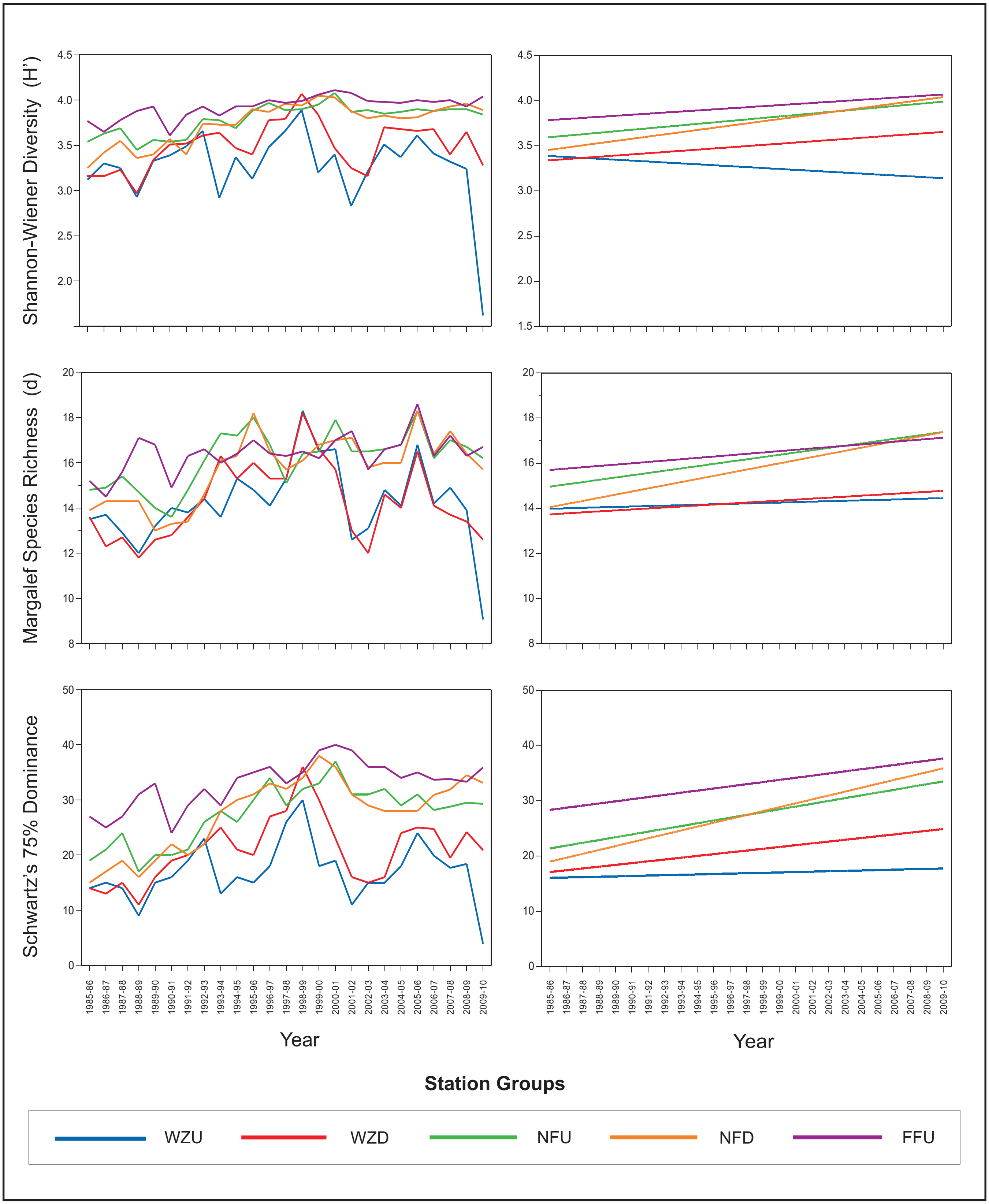


Figure 5-4 continued.

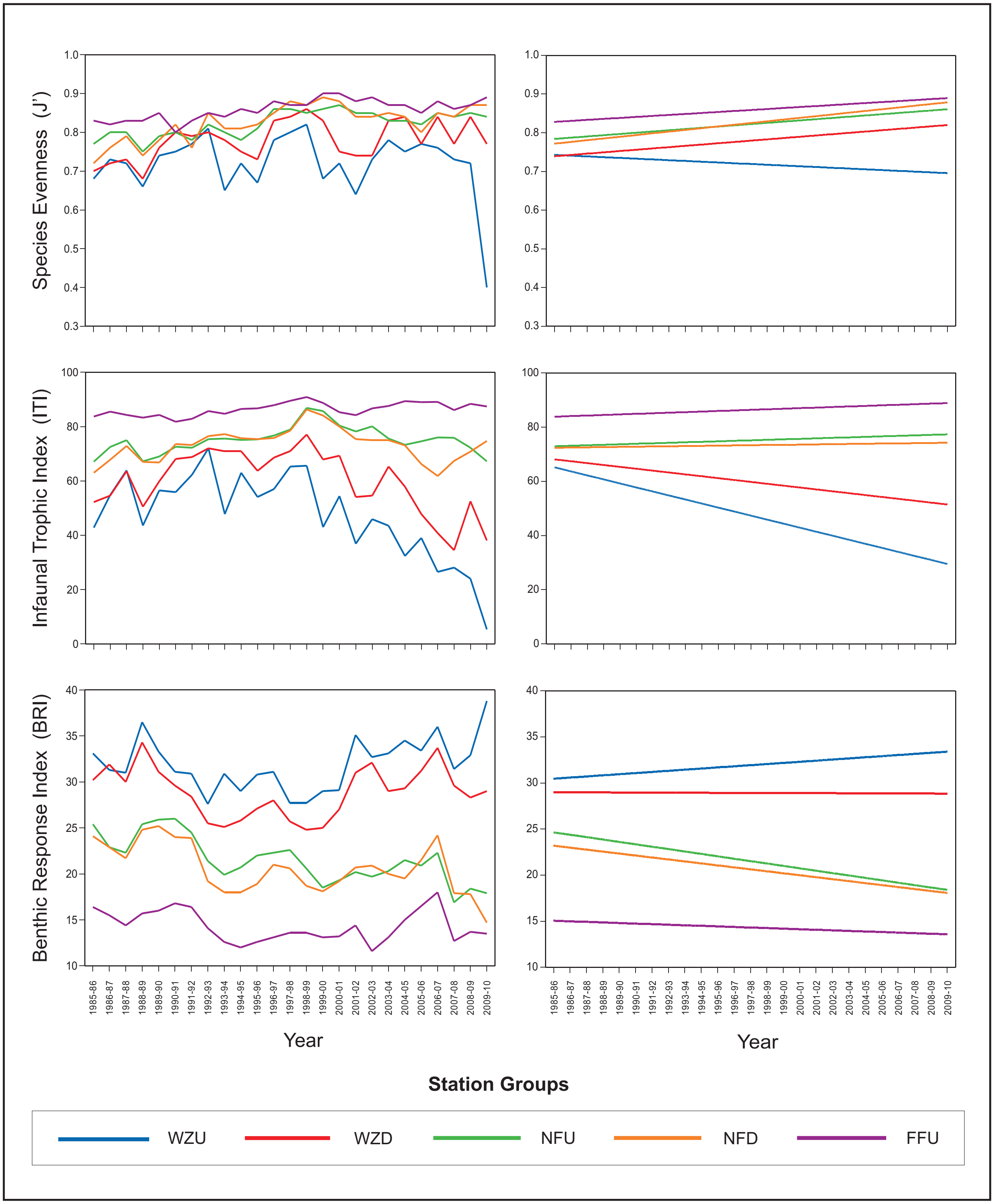


Figure 5-4 continued.

no change over time. The slope of the lines for BRI and ITI also changed at the WZU group as a result of new high BRI and low ITI values at these stations, indicating the severity of change at this station group. In addition, the ITI scores at NFU were the second lowest historically and the lowest since 1985-86, indicating declining conditions at the upcoast stations closest to the ZID.

When these data are binned into 1985–2000 and 2001–2010 groups that approximate the years before and after significant changes in the treatment processes had occurred, the trends often changed (Table 5-4). For example, the number of species increased in all groups from 1985 to 2000, but decreased at WZU, WZD, NFU, and NFD from 2001 to 2010. Abundance decreased in all groups from 1985 to 2000 and at WZU, WZD, NFU, and NFD from 2001 to 2010, while FFU shows a slight increase from 2001 to 2010. Biomass increased in NFU stations from 1985 to 2000, but decreased from 2001 to 2010, while FFU stations show an increase from 2001 to 2010. H', J', d, and Dominance all show increases from 1985 to 2000 in all station. These indices are all decreasing over time at WZU and NFU groups from 2001 to 2010. During this same time period H' shows no change at NFD and FFU groups, J' is decreasing at NFU and FFU groups, d is decreasing at WZD and NFD groups, while showing no change at FFU, and Dominance is decreasing at FFU. BRI scores decreased in all station groups from 1985 to 2000, but have been increasing since 2000, indicating declining community health, at WZU and show no change over time at WZD and FFU groups. ITI scores are increasing, indicating declining community health, at WZU, WZD, NFU, and NFD groups, while increasing at FFU. These results indicate that infaunal assemblages in the area at and near the outfall diffuser have declined over the last 10 years, with the greatest change occurring since 2005.

Indicator Species

<u>Pollution Tolerant Species</u>

Capitella capitata

The July annual survey, as in previous years, included high abundances of *C. capitata* at within-ZID stations where they were a major factor in the low ITI and high BRI scores (Figure 5-5). There was a 2- to 6-fold increase in the number of *C. capitata* at within-ZID Stations 0, ZB, and ZB2 from the July 2008 survey. Historically, *C. capitata* was only present sporadically at stations outside the ZID and generally at abundances of 1 to 2 individuals. The July 2009 survey is the second consecutive year with increased abundances of *C. capitata* at the stations nearest the outfall terminus (Station 1and 3 had abundances of 5 and 9, respectively). While these numbers are low, they represent a continued change in the community relative to historic abundances of 0 to 1 at these stations. Regression analysis showed that *C. capitata* abundances were not significantly related to station depth, but they were significantly correlated with tLAB concentrations (R=0.31). However, this result is driven by high abundances within the ZID. When ZID stations are removed from the analysis there is no significant correlation, indicating that the influence of the wastewater discharge on *C. capitata* abundances is localized to near the outfall.

Abundances of *C. capitata* in summer surveys at the ten 60 m stations and annual Station 3 from 2000 to 2009 were reviewed for trends (Figure 5-6). Within-ZID Stations 4 and ZB2 showed a decreasing trend, while ZID Stations 0 and ZB and non-ZID Stations 1 and 3 show increasing trends. There were changes over time at non-ZID Stations 5, 9, 12, C, and CON with station abundances at these five stations ranging

Table 5-4. Long-term trends in community attributes at the quarterly benthic stations: 1985 to 2010, 1985 to 2000, and 2001 to 2010.

Orange County Sanitation District, California.

Attribute	WZU			WZD			NFU			NFD			FFU		
	85-10	85-00	01-10	85-10	85-00	01-10	85-10	85-00	01-10	85-10	85-00	01-10	85-10	85-00	01-10
Number of Species	D	I	D	D	I	D	I	I	D	I	I	D	I	I	N
Abundance	D	D	D	D	D	D	D	D	D	D	D	D	D	D	I
Biomass	D	D	D	D	D	D	D	I	D	D	D	D	D	D	I
Shannon-Wiener Diversity	D	I	D	I	I	I	I	I	D	I	I	N	I	I	N
Species Evenness	D	I	D	I	I	I	I	I	D	I	I	I	I	I	D
Margalef Species Evenness	**I**	**I**	**D**	**I**	**I**	**D**	**I**	**I**	**D**	**I**	**I**	**D**	**I**	**I**	**N**
Schwartz' 75% Dominance	N	I	D	I	I	I	I	I	D	I	I	I	I	I	D
Benthic Response Index	I	D	I	N	D	N	D	D	D	D	D	D	D	D	N
Infaunal Trophic Index	D	I	D	D	I	D	I	I	D	I	I	D	I	I	I

WZU=Stations 0 and ZB2, WZD=Stations 4 and ZB, NFU=Station 1 and 5, NFD=Stations 9 and 12, FFU=Stations C and CON.
D=Decreasing trend, I=Increasing trend, N=No change over time.

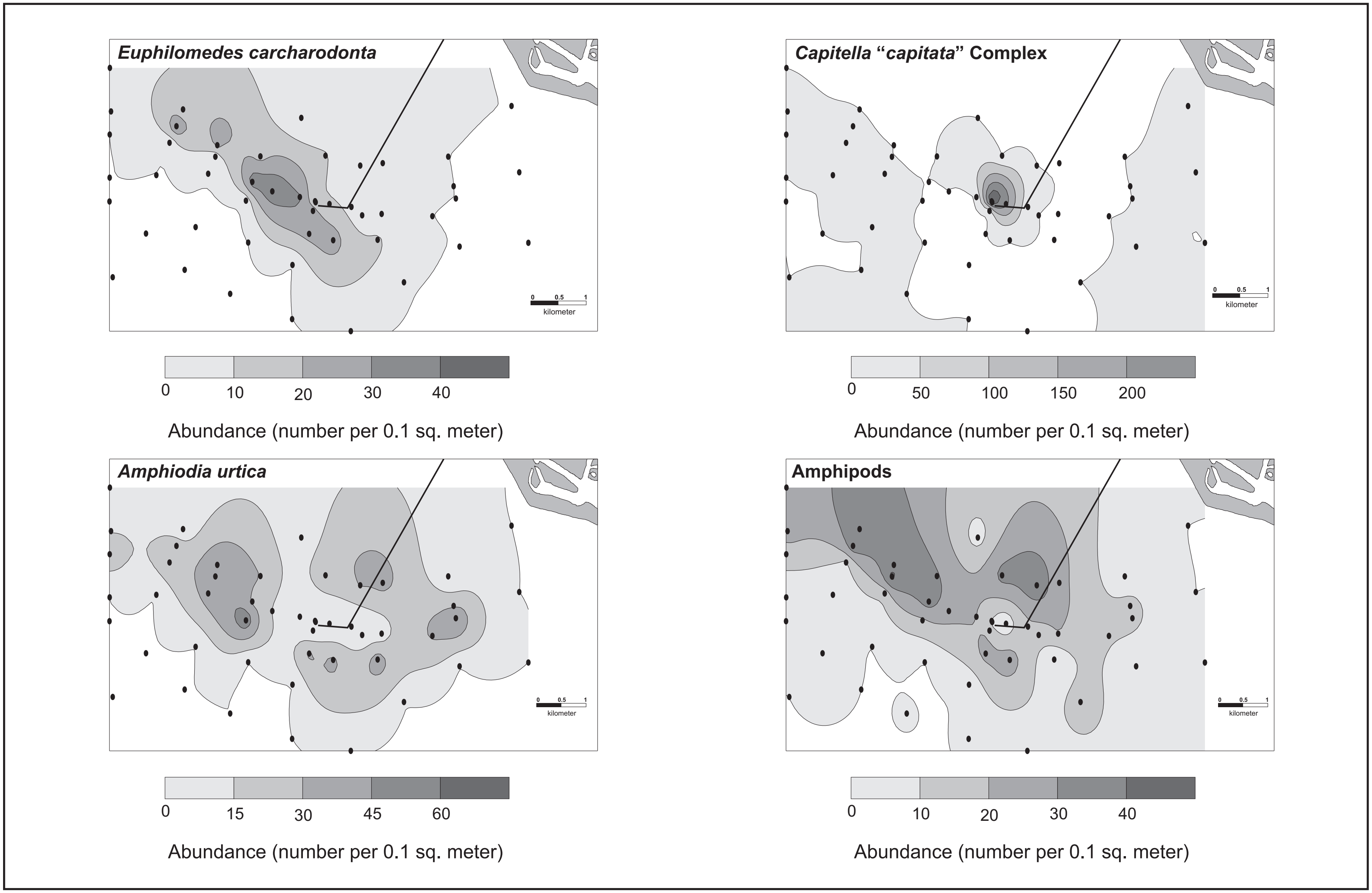


Figure 5-5. **Spatial distribution of abundance of *Euphilomedes carcharodonta*, *Capitella "capitata"* complex, *Amphiodia urtica,* and selected amphipods during July 2009.**

Orange County Sanitation District, California.

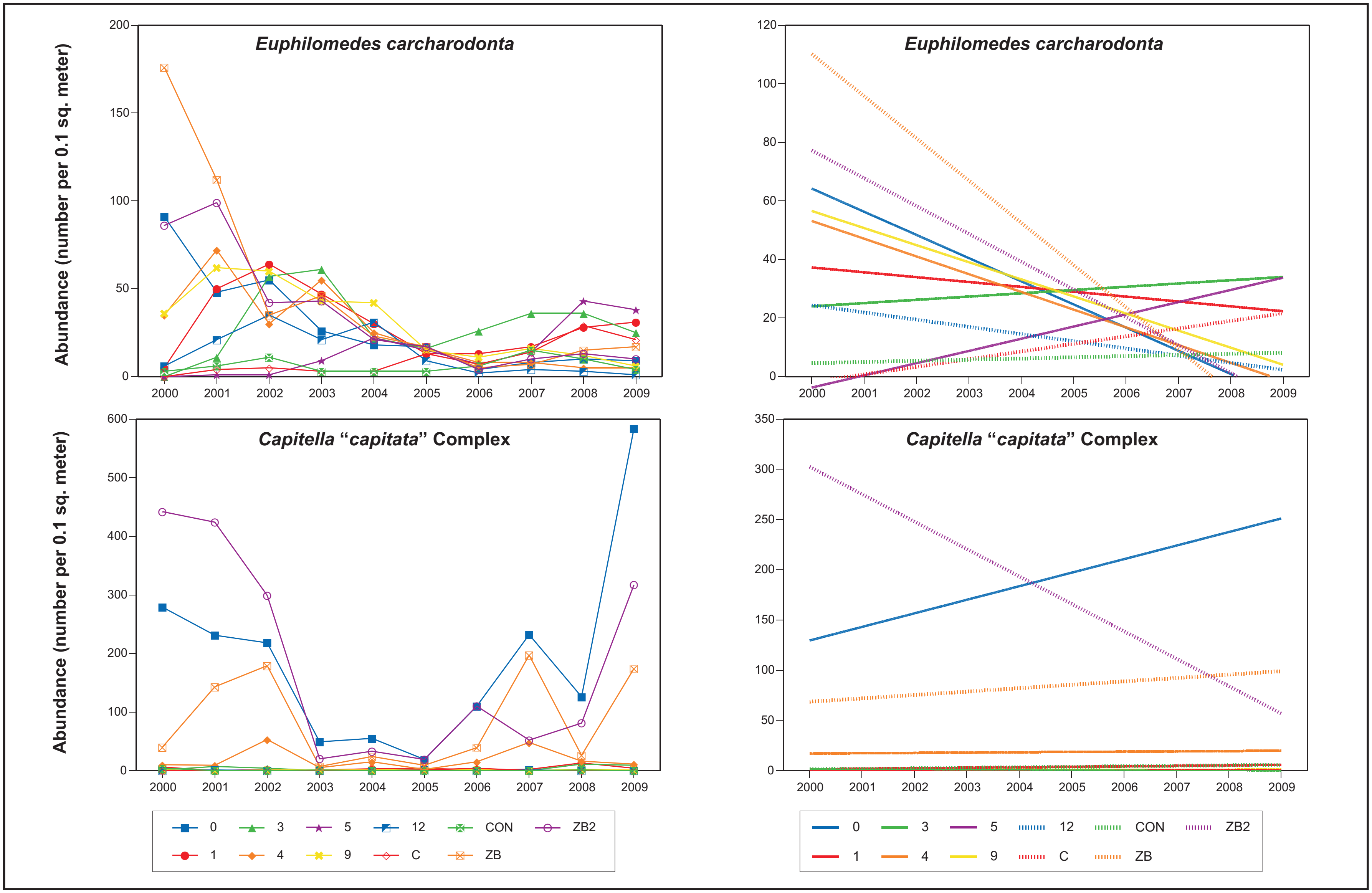


Figure 5-6. **Annual mean values of abundance for the period 2000–2009: *Euphilomedes carcharodonta*, *Capitella* "*capitata*" Complex, *Amphiodia urtica*, and amphipods.**

Orange County Sanitation District, California.

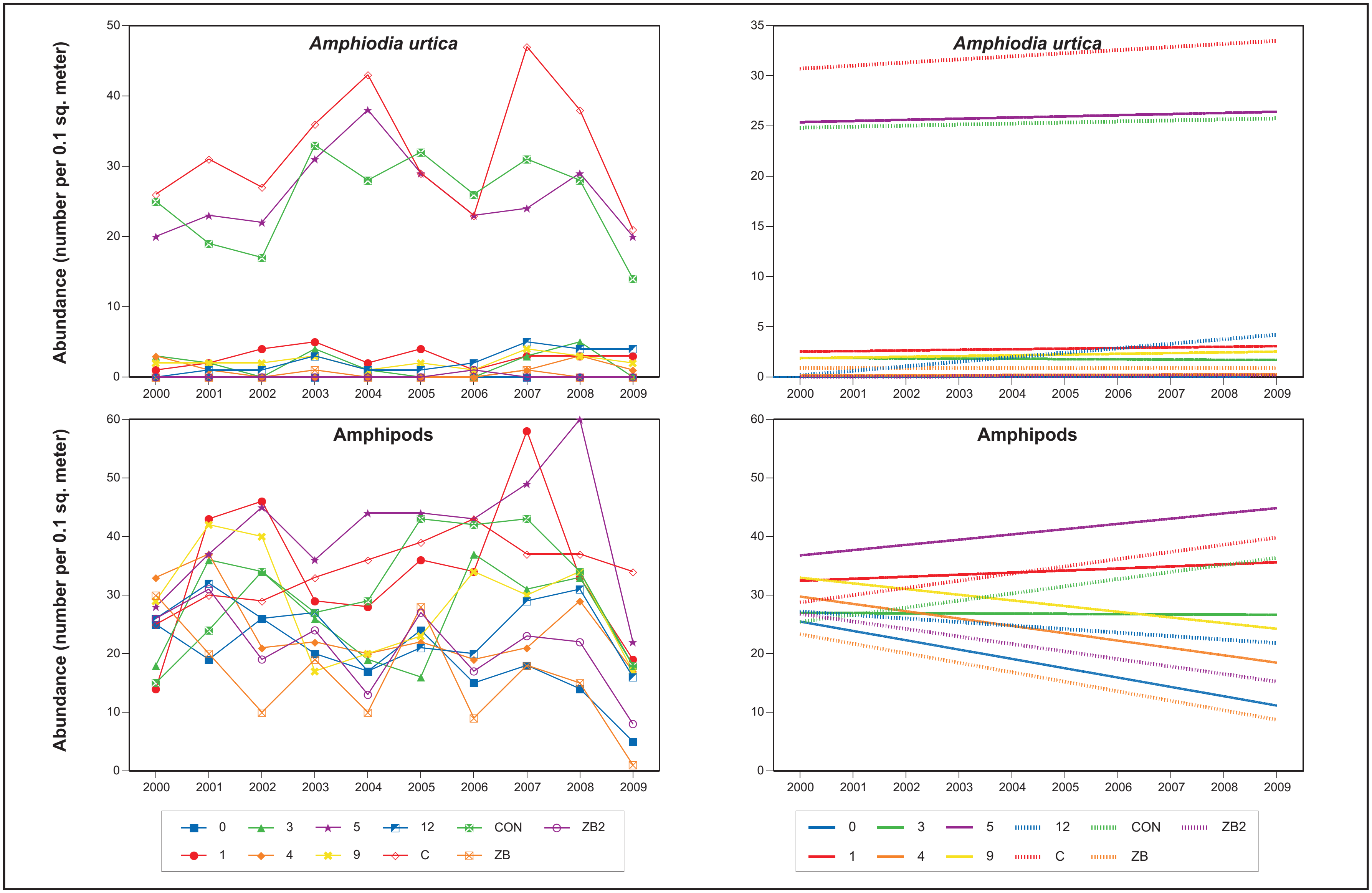


Figure 5-6 continued.

from only 0 to 5 per survey (Figure 5-6). There were large abundances of *C. capitata* at within-ZID stations from 2000 to 2002, which decreased in 2003, and then slowly increased again beginning in 2006. Large increases occurred at Stations 0, ZB, and ZB2 in 2008 and 2009. The overall increasing trend at Station 0 is driven by the large recruitment of *C. capitata* in 2009, while the decreasing trends at the other within-ZID sites are due to the high abundances in 2000 to 2002.

The large abundances of *C. capitata* within the ZID from 2000 to 2002 were not accompanied by a significant decrease in community diversity as measured by the BRI and ITI, indicating that other species were not excluded. There was also no change in community structure outside the ZID. Since 2007, there has been a decrease in species and degradation of community health at within-ZID stations concomitant with the increases in *C. capitata* abundances indicating that this opportunistic, pollution-tolerant species is now excluding species. The slight increases in *C. capitata* at nearfield Stations 1, 3, and 5, suggest changing conditions outside the ZID.

Euphilomedes carcharodonta

E. carcharodonta abundances during the annual survey were highest in the areas just offshore and upcoast of the outfall diffuser (Figure 5-5). The distribution of *E. carcharodonta* was partially related to depth (R^2 = 0.21), but was not related to sediment tLAB concentrations indicating no relationship with the District's effluent discharge.

E. carcharodonta abundances were highest at sites within the ZID and at non-ZID Stations 1, 3, and 9 from 2000 through 2003 (Figure 5-6). Similar to *C. capitata*, *E. carcharodonta* abundances decreased from 2004 to 2007 at most sites, but began to rise at Station 3. Since 2008, *E. carcharodonta* abundances have increased at within-ZID stations and non-ZID nearfield upcoast Stations 1, 3, and 5 suggesting changing conditions outside the ZID.

<u>Pollution Sensitive Species</u>

Amphiodia urtica

In July 2009, *A. urtica* distribution was strongly influenced by station depth. While all stations are within their known depth range, the slope and basin stations are beyond the common depth range (15–85 m) for this species (Bergen 1995), which explains their absence in the deeper strata. At shelf stations, abundances were fairly uniform except near the outfall (Figure 5-5). There was a negative correlation to tLAB (R=-0.35), suggesting an effluent discharge influence on *A. urtica* distribution.

A. urtica abundances decreased at 15 of the 49 annual survey stations from July 2008 to July 2009 with decreases ranging from 1 to 56 individuals per station. The largest decreases were at outer-shelf Stations 29 (56) and 38 (46), and mid-shelf non-ZID Stations 10 (17) and 5 (12).

A. urtica abundances at nearfield upcoast Station 5 and farfield upcoast Stations C and CON ranged from 20 to 47 per station per survey with large inter-annual variability at each station (Figure 5-6). Although the trend lines are either increasing (Station C) or neutral (Stations 5 and CON), abundances of *A. urtica* have been in decline recently. In contrast, other stations had abundances of 0 to 5 per survey with no temporal trend evident.

Amphipods

Abundances of Rhepoxynid and Ampelsicid amphipods in the July survey were lowest in the canyons and slope areas, and highest on the San Pedro Shelf upcoast and inshore of the outfall pipe (Figure 5-5). Regression analysis showed that amphipod abundance significantly decreased with increasing depth (R^2=0.41). Correlation analysis showed a moderate inverse relationship between amphipod abundance and sediment tLAB concentrations (R=-0.39) suggesting that both depth and the effluent discharge may be affecting amphipod distribution.

Amphipod abundances decreased at 36 of the 49 annual stations from the July 2008 to July 2009 surveys with decreases ranging from 1 to 54 individuals per station. The largest decreases in mean abundance occurred in shallow- (12) and mid-shelf non-ZID (13) stations. The five non-ZID stations nearest the outfall (Stations 1, 3, 5, 9, and 12) had a mean decrease of 24 amphipods per station with decreases ranging from 5 at Station 12 to 54 at Station 5. Within the ZID, declines in amphipod abundance ranged from 2 at Station 4 to 12 at Stations ZB and ZB2.

From 2000 to 2009, abundances of amphipods are decreasing at all stations except Stations 3, 5, C, and CON (Figure 5-6). However, all stations showed a decrease from 2008 to 2009. The smallest decrease occurred at farfield upcoast Station C (3 individuals), but the greatest decrease occurred at nearfield upcoast Station 5 (38 individuals).

The recent pattern of decreases in pollution sensitive taxa (*A. urtica* and amphipods) and the increases in pollution tolerant species (*C. capitata* and *E. carcharodonta*), along with the overall increase in polychaetes and the decrease in crustaceans indicate that community structure is undergoing change beyond the zone of initial dilution.

Spatial Analysis

Cluster Analysis

Historically, cluster analysis was performed on all 49 stations sampled in the summer survey (39 annual + 10 quarterly stations) to look for patterns in infaunal assemblages. Results consistently showed that stations clustered primarily by depth. Clarke and Warwick (2001) state that cluster analysis should not be used when known gradients (i.e., depth-related gradients) are present. The 2009-10 cluster analysis confirmed that the depth-related station groupings were present. A cluster analysis was then performed using only the shallow- and mid-shelf stations to exclude the depth-related gradient. This analysis is discussed below.

Cluster analysis on the July 2009 abundance data identified seven major station clusters and several sub-clusters within three of those clusters (Figure 5-7). The station clusters generally follow distance and direction from the outfall diffuser (Figure 5-8). These station groups were corroborated through non-metric multidimensional scaling (MDS) using 4^{th} root transformed data and Bray-Curtis similarity as the resemblance matrix (Figure 5-9). The output stress was low (2D = 0.13; 3D = 0.10) indicating good ordination.

Station Cluster 1 (SC1) includes only Station C2, located at the head of the Newport Submarine Canyon near Newport Pier at a depth of 54 m. SIMPER analysis could not be applied to this group. Polychaetes dominated this station, comprising 69% of the species and 83% of the individuals. The five most abundant species were the polychaetes *Cossura candida* (25), *Paraprionospio alata* (24), Oligochaeta (23), *Mediomastus* sp (11), and *Scalibregma californicum* (8). These five taxa comprised 50% of the abundance. This was the only station cluster where the polychaetes *C. candida*, *Glycera Americana*, *Glycera macrobranchia*, *Heteromastus filobranchus*, *Lepidasthenia berkeleyae*, Oligochaeta, *Podarkeopsis glabrus*, and the mollusks *Caesia perpinguis* and *Loy thomsoni* were collected.

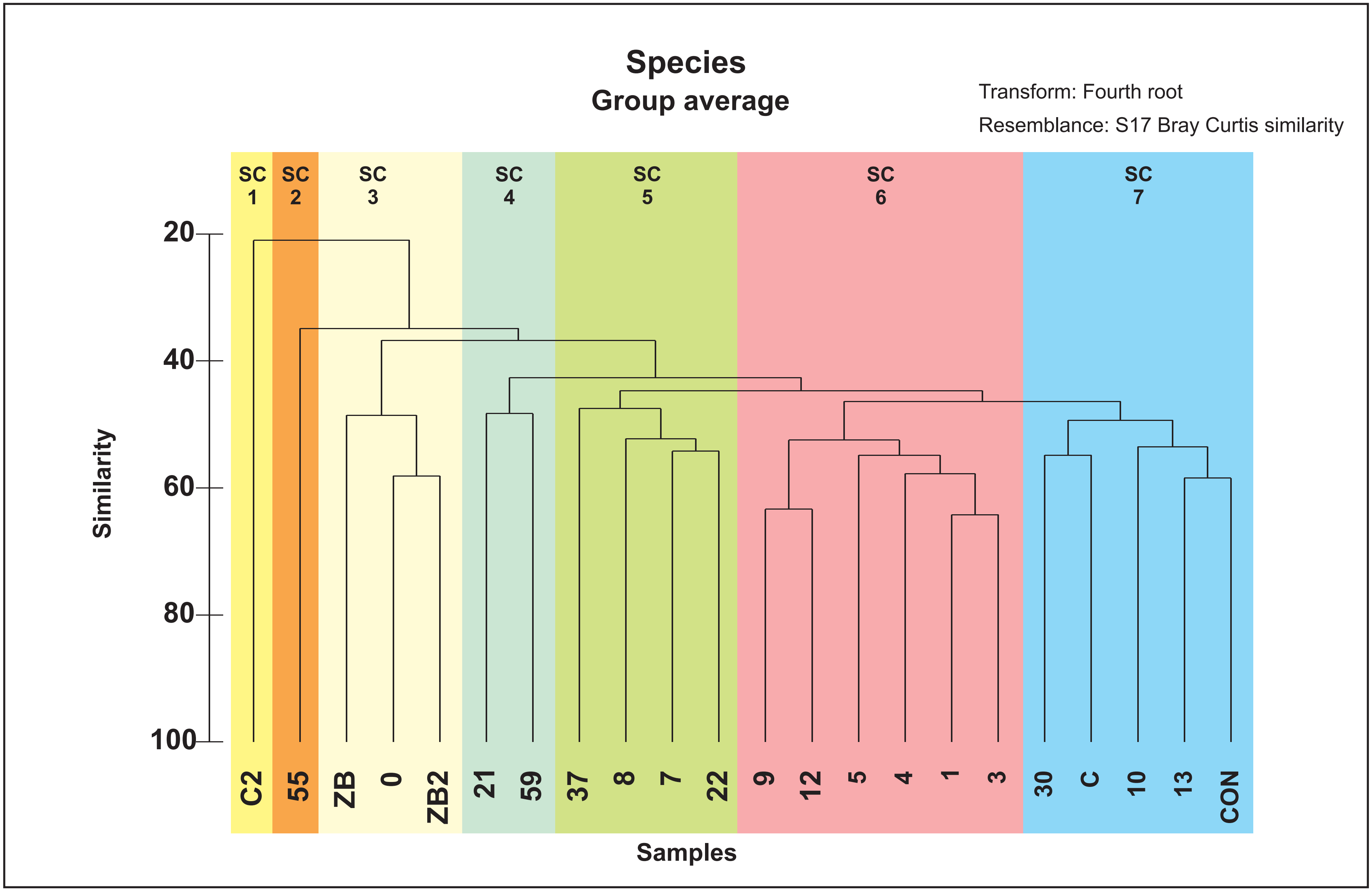


Figure 5-7. **Summary of cluster analysis and relationships among stations and infaunal species groups for July 2009.**

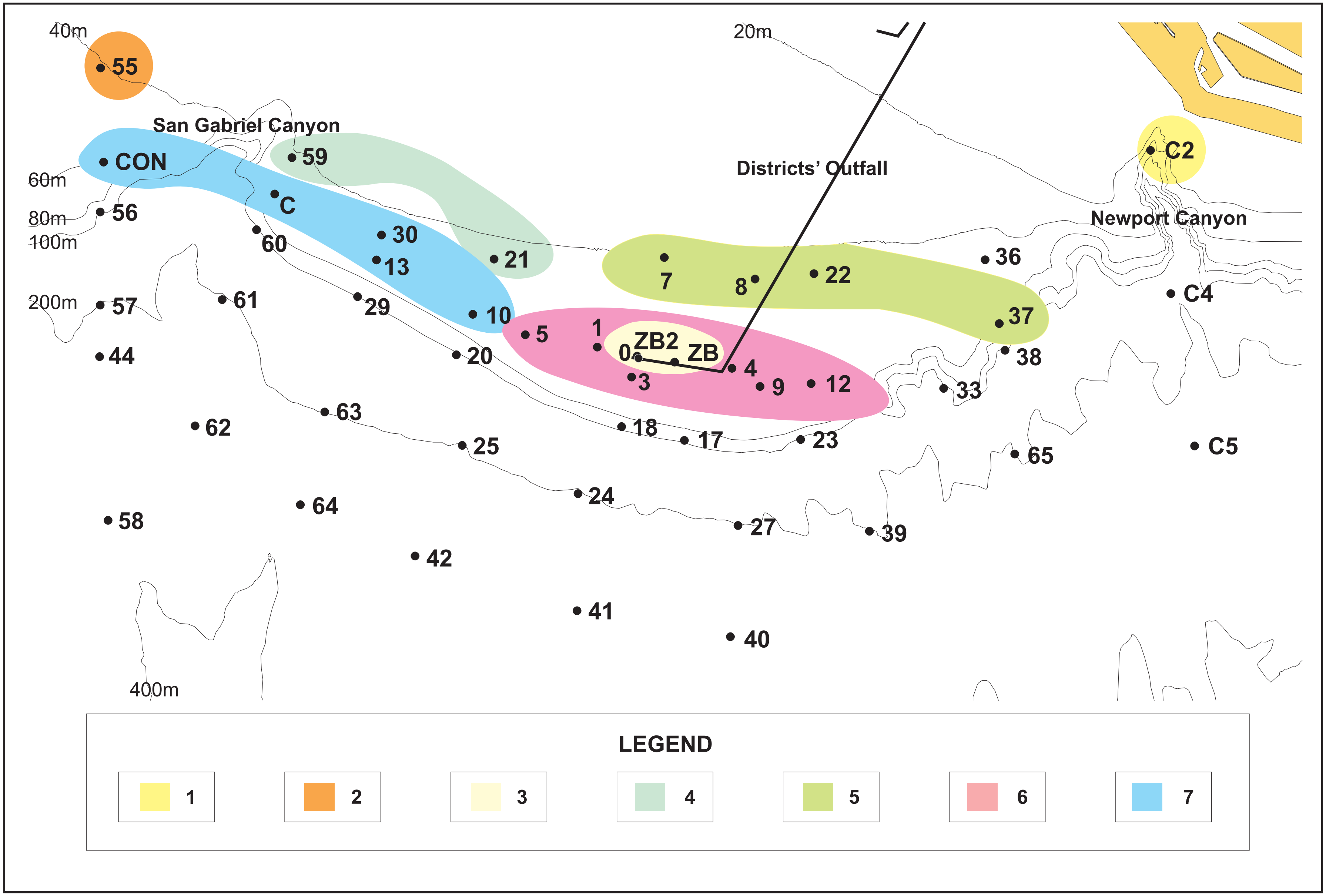


Figure 5-8. **Map of station groups from cluster analysis for July 2009.**

Orange County Sanitation District, California.

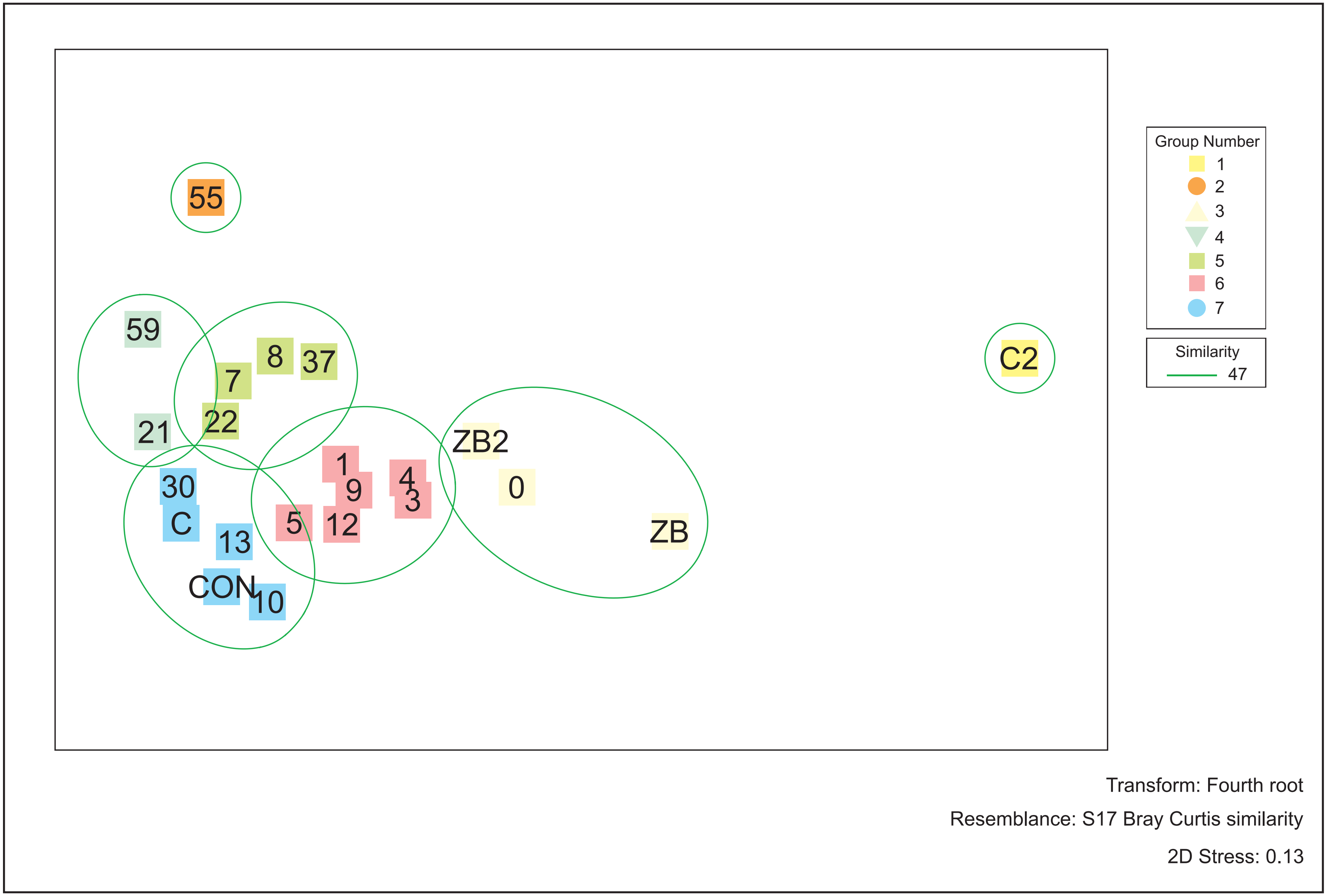


Figure 5-9. Non-metric multi-dimensional scaling (MDS) station plot with cluster analysis overlay. Station symbols correspond to cluster analysis station groupings (group numbers).

Orange County Sanitation District, California.

Station Cluster 2 (SC2) consists of only Station 55, which is located 8.4 km upcoast from the outfall at a depth of 40 m. SIMPER analysis, to determine characteristic species cannot be applied to clusters composed of a single site (Clarke and Warwick 2001). Polychaetes comprised 49% of the species and 57% of the individuals, while crustaceans accounted for 28% of both species and individuals (Table 5-5). The five most abundant species were the polychaetes *S. berkeleyorum* (18), *C. columbiana* (15), *Spiophanes bombyx* (13), *Pista estavanica* (10), and *Chone veleronis* (9) comprising 29% of the total abundance. Species found only at this station cluster were the crustaceans *Bemlos concavus*, *Caprella* sp, *Diastylis californica*, *Hemiproto* sp *A*, *Rhepoxynius lubricans*, the polychaetes *Drilonereis filum*, *Notomastus lineatus*, *Owenia collaris*, and the echinoderm *Dougaloplus amphocanthus*.

Station Cluster 3 (SC3) is composed of three within-ZID stations: 0, ZB, and ZB2. There are two sub-clusters: Sub-cluster A consists of Stations 0 and ZB2, and Sub-cluster B consists of Station ZB. Sub-cluster A differs from Sub-cluster B in both species richness and abundance. Sub-cluster A had species and abundance means of 57 and 1138, respectively, while Sub-cluster B had means of 85 species and 399 individuals. Polychaetes dominated SC3 with 54% of the species and 86% of the total abundance. The pollution tolerant species *C. capitata* accounted for 58% of the total abundance of individuals with station means ranging from 36% at Station ZB to 91% at Station ZB2. SIMPER analysis showed that SC3 was characterized by the polychaetes *C. capitata*, *A. catherinae*, *P. alata*, the mollusk *A. serricata* and the crustacean *E. carcharodonta*. The top five numerically dominate species in this station cluster were the polychaetes *C. capitata* (749), *A. catherinae* (92), *S. berkeleyorum* (23), the crustacean *E. carcharodonta* (39), and the mollusk *A. serricata* (37). These five taxa comprised 71% of the abundance of individuals. Species unique to SC3 are the polychaetes *Dorvillea* sp, *Exogone breviseta*, *Leitoscoloplos* sp *A*, *Polycirrus* sp I, and the crustacecan *Rubilemboides* sp.

Station Cluster 4 (SC4) consists of shallow-shelf stations 21 and 59, located upcoast and inshore from the outfall diffuser. Polychaetes and crustaceans dominated SC4 comprising 47% and 30% of the species and 49% and 33% of the total abundance, respectively. SIMPER analysis showed that SC4 was characterized by the crustaceans *E. Carcharodonta* and the polychaetes *Euclymeninae* sp *A*, *C. columbiana*, *Lumbrineris lingulata*, and *Praxillella berkeleyorum*. The top five numerically dominate species in SC4 comprised 28% of the total abundance and included the polychaetes *Pseudofabriciola californica* (73), *Lumbrineris lingulata* (19), *Euclymemninae* sp *A* (16), *A. urtica* (30), and *E. carcharodonta* (27). Species unique to SC4 are the crustaceans *Ericthonius brasiliensis*, *Hamatoscalpellum californicum*, *Melphisana bola* complex, *Photis macrotica*, *Polydora limicola*, the polychaetes *Dipolydora bidentata*, *Pseudofabriciola californica*, the mollusk *Solen sicarius*, and the cnidarian *Limnactinidae* sp *A*.

Station Cluster 5 (SC5) consisted of shallow-shelf Stations 7, 8, 22, and mid-shelf Station 37. Stations 7, 8, and 22 are located inshore of the outfall diffuser, while Station 37 is located inshore and downcoast from the outfall. There are two sub-clusters: Sub-cluster A consists of Station 37, and Sub-cluster B consists of Stations 7, 8, and 22. Sub-cluster A has species and abundance means of 114 and 318, respectively, while Sub-cluster B has means of 106 species and 348 individuals. Sub-clusters A and B are separated at the

Table 5-5. Percent of abundance by taxa for cluster analysis station groups.

Orange County Sanitation District, California

Station Group	Percent of Abundance				
	Polychaeta	Crustacea	Mollusca	Echinodermata	Minor Phyla
1	49	28	10	7	6
2	69	4	17	2	8
3	54	20	15	2	9
4	47	30	12	6	5
5	50	20	15	5	10
6	50	22	16	4	8
7	49	22	14	7	8

48% resemblance level. Polychaetes dominated SC5 comprising 50% and 49% of the species and total abundance, respectively. Crustaceans accounted for 20% of both the species and abundance. Though echinoderms comprised only 5% of the species, they accounted for 18% of the abundance, primarily due to high abundances of amphiurid brittle stars (225), such as *A. urtica*. SIMPER analysis showed that SC5 was characterized by the echinoderm *A. urtica*, the polychaetes *Euclymeninae* sp A, *S. berkeleyorum*, and the crustaceans *R. bicuspidatus* and *Caecagnatha crenulatifrons*. The top five numerically dominate species in SC5 were the echinoderm *A. urtica*, the polychaetes *S. berkeleyorum, A. catherinae*, *Mediomastus* sp, and the *crustacean C. crenulatifrons*. They represented 24% of the total abundance. There were 33 species unique to SC5. Of those, 10 were found only in Sub-cluster A, 21 in Sub-cluster B, and 2 common to both sub-clusters. This unique grouping included 15 polychaetes, 7 minor phyla, 6 crustaceans, and 5 mollusks.

Station Cluster 6 (SC6) consisted of within-ZID Station 4 and 5 non-ZID mid-shelf stations (1, 3, 5, 9, and 12) closest to the outfall. Station distances range from 0.3 (Station 3) to 2.4 km (Station 12) from the outfall diffuser. Polychaetes dominated SC6 and comprised 50% and 61% of the species and total abundance, respectively. Crustaceans accounted for 22% of the species and 20% of the abundance. There were two sub-clusters: Sub-cluster A consists of Stations 1, 3, 4, and 5, and Sub-cluster B consists of Stations 9 and 12. Stations 1 and 5 are located 0.6 and 1.6 km upcoast, respectively, and Station 3 is 0.3 km offshore of the outfall diffuser. All three sites are located in the predominate direction of bottom current flow and presumed deposition. Station 4 lies within the ZID at the downcoast end of the diffuser. Stations 9 and 12 are nearfield stations located 0.5 and 1.1 km downcoast of the diffuser, respectively. Sub-clusters A and B had similar species and abundance means of 93 and 94 and 392 and 310, respectively. The sub-clusters separated at the 55% resemblance level. The species responsible for the separation include the polychaetes *C. capitata* and *P. alata*, which were found only in Sub-cluster A, and several species common to both sub-clusters, but found in abundances 3 to 6 times higher in Sub-cluster A. These species include *Acanthoptilum* sp, *A. catherinae*, *C. Columbiana*, *A. serricata*, *E. carcharodonta*, *Mediomastus* sp, and *T. carpenteri*. SIMPER analysis showed that SC6 was characterized by the polychaetes *C. columbiana*, *A. catherinae*, *Mediomastus* sp, *L. cruzensis*, and the crustacean *Leptochaelia dubia*. The top six numerically dominate species in SC6 were the polychaetes *C. columbiana* (293), *A. catherinae* (142), *L. cruzensis* (83), *Mediomastus* sp (78), the *crustacean E. carcharodonta* (99), and the mollusk *A. serricata* (78). These taxa comprised 35% of the abundance of individuals. There were 33 species unique to SC6. Of those, 20 were found only in Sub-cluster A, 8 in Sub-cluster B, and 5 common to both sub-clusters. These species included 13 polychaetes, 11 crustaceans, 6 mollusks, 2 minor phyla, and 1 echinoderm.

Station Cluster 7 (SC7) consists of Stations 10, 13, 30, C, and CON with depths ranging from 43 (Station 30) to 60 m (Station 10). Stations C and CON are considered farfield control stations, while Stations 10, 13, and 30 are intermediate between the outfall and the farfield control stations. Station distances from the outfall diffuser range from 2.4 km (Station 10) to 7.9 km (Station CON). Polychaetes dominated SC7 representing 49% and 40% of the species and total abundance, respectively, while crustaceans accounted for 22% of the species and 29% of the abundance. Echinoderms comprised only 7% of the species, but accounted for 18% of the abundance due primarily to large numbers of brittle stars, particularly *A. urtica*. SIMPER analysis showed that SC7 was characterized by the pollution-sensitive echinoderm *A. urtica*, the crustaceans *R. bicuspidatus* and *E. carcharodonta*, the mollusk *A. serricata*, and the polychaete *A. catherinae*. The top five numerically dominate species made up 29% of the overall abundance and included the echinoderm *A. urtica* (146), the crustaceans *E. carcharodonta (99)* and *R. bicuspidatus* (61), the mollusk *A. serricata* (94), the polychaete *A. catherinae* (51). Amphiurid brittle stars comprised 17% of the abundance. Unlike station clusters at and near the outfall, SC7 had only 2 *C. capitata* among the five stations. There are two sub-clusters: Sub-cluster A consists of Stations 10, 13, and CON, and Sub-cluster B consists of Stations C and 30. The sub-clusters separate at the 49% resemblance level. Sub-cluster A had species and abundance means of 90 and 300, respectively, while Sub-cluster B had means of 94 species and 331 individuals. The sub-clusters separated at the 49% resemblance level. The species responsible for the separation include the polychaetes *Chloeia pinnata*, *L. cruzensis* and *L. lingulata*, the mollusk *A. serricata*, and the crustacean *E. carcharodonta*. There were 31 species unique to SC7. Of those, 12 were found only in Sub-cluster A, 17 in Sub-cluster B, and 2 common to both sub-clusters. Species included 17 polychaetes, 6 minor phyla, 5 crustaceans, 2 echinoderms, and 1 mollusk.

Overall, depth and sediment-related factors continue to be the most significant in determining infaunal distribution and abundance throughout the entire monitoring area. On the San Pedro Shelf, proximity to the outfall appears to be the dominant factor with diversity and community health generally increasing with distance from the outfall diffuser. The main factors determining the station clusters were the abundances of polychaetes. *C. capitata* and *A. catherinae* were most important at within-ZID and nearfield stations. Historically, the within-ZID stations, particularly Stations 0, ZB, and ZB2, form a separate station cluster from the non-ZID shelf stations (see OCSD 2009, Figure 5-7). However, the nearfield stations (SC6) generally do not separate from the other shelf stations as was seen this year. This occurrence appears to correlate with changes in species assemblages at nearfield stations described earlier.

CONCLUSIONS

Monitoring data have documented a general decline in community health at stations within the ZID since 2005 (OCSD 2007-10). The 2009-10 data indicate that degraded conditions now exist at the three ZID stations located from the middle to the upcoast end of the outfall diffuser. This includes loss of community biodiversity and large increases in pollution-tolerant species. This year also represents the first time that impacts have been measured at stations beyond the ZID, with nearfield upcoast Station 1 and mid-shelf Station 3 classifying as changed per the ITI. This is coupled with decreases in pollution-sensitive species and increases in pollution-tolerant species at several of these nearfield stations. These changes indicate that the discharge is impacting sediment quality and invertebrate community health up to 0.6 km beyond the ZID. Other stations that classified as stressed were limited to specific areas within the submarine canyons, slope, and basin areas, and it is not clear if these were related to the effluent discharge. The cause of these changes is not known since there were no strong correlations to the suite of contaminants and sediment physical parameters measured in the District’s core monitoring program. Other stations in the monitoring area classify as either reference or marginally deviated from reference. District staff has initiated the process of formulating a research plan to investigate the extent and causes of these changes in benthic assemblages.

The majority of stations outside the ZID classified as reference condition per the BRI. Minor impacts were observed at several stations immediately outside the ZID, but there were no strong correlations to measured sediment contaminants. This indicates that sediments and biota outside the ZID were not degraded and that permit criterion 5.3.a. was met.

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