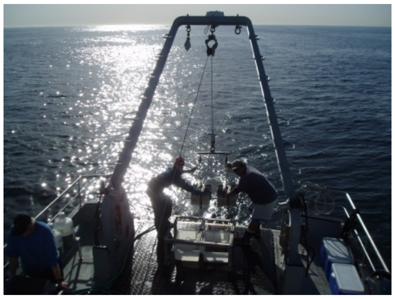
chapter 5

MACROBENTHIC INVERTEBRATE COMMUNITIES



Chapter 5
MACROBENTHIC INVERTEBRATE COMMUNITIES

INTRODUCTION

The District monitors the composition of the macrobenthic invertebrate community (small organisms, such as worms, clams, and burrowing shrimps) that lives on (epifauna) and in (infauna) sediments to assess the possible effects of the wastewater discharge. Infauna are sensitive indicators of environmental change (Pearson and Rosenberg 1978) due to their limited mobility and susceptibility to the effects of changes in sediment quality resulting from both natural (e.g., El Niño/La Niña events) and anthropogenic (organic enrichment and chemical contaminants) influences (Diener and Fuller 1995). In accordance with the District's NPDES ocean discharge permit (see Chapter 1) the macrobenthic communities monitored to determine if the wastewater discharge has degraded the biological community in the monitoring area beyond the zone of initial dilution (ZID) (See box).

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.

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 sites away from the outfall from comparable habitats.

Long-term analyses have shown that 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. 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.

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

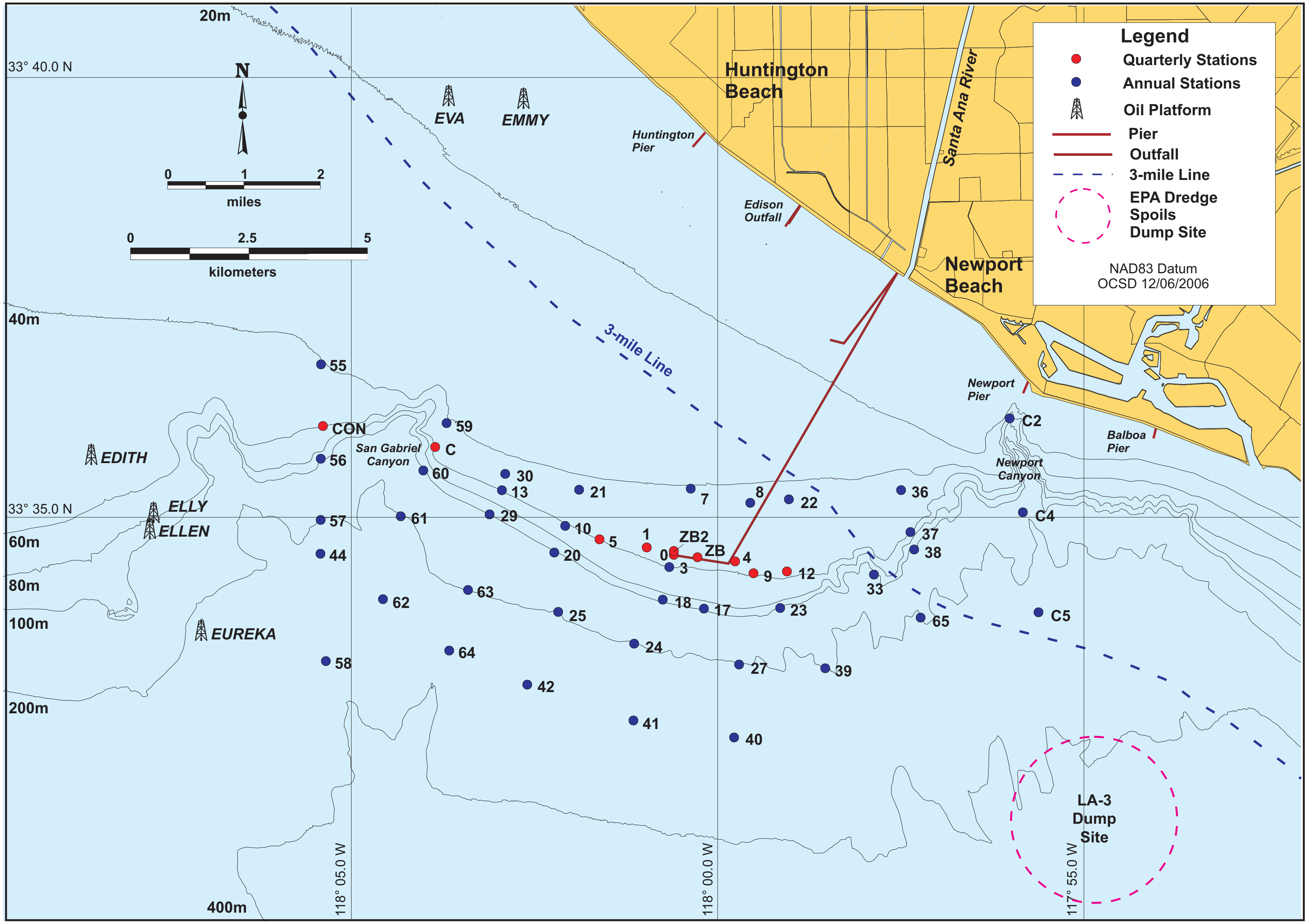


Figure 5-1. **Benthic infauna sampling stations for annual (blue) and quarterly (red) surveys, 2007-08.**

Orange County Sanitation District, California.

structure of the infaunal community. The physical structure of the pipe and 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 enhances infaunal abundances.

METHODS

A 0.1-m^2 modified paired Van Veen sediment grab sampler was used to collect infaunal samples. Three replicate samples were collected quarterly at ten stations of depths between 55-60 m (referred to herein as the 60-m or outfall-depth community). An additional 39 "annual" stations, with depths ranging from 40 and 303 m, were sampled in July 2007 (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. The annual survey assessment included the first repetition of the quarterly stations as well as the 39 annual stations (n=49 stations).

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 (SR), Schwartz' 75% Dominance Index (Dominance), Species Evenness (J'), Infauna 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 molluscs) are removed from the sample calculation. The measures of diversity are based on the number of species and the equitability of their distribution. Shannon-Wiener Diversity, J', and Dominance are more sensitive to the distribution of species within a sample, while SR 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 such that values below 25 represent reference conditions; 25–34 indicate a marginal deviation from reference conditions, 35–44 a loss of biodiversity, 45–72 a loss of community function, and 73–100 the defaunation or exclusion of most species.

In addition, the presence or absence of certain indicator species (pollution sensitive and pollution tolerant) was determined for each station. Indicator species are those organisms that show strong abundance gradients relative to the wastewater discharge and can dominate the calculation of community measures. 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), *Euphilomedes carcharodonta* (ostracod crustacean), and *Parvilucina tenuisculpta* (bivalve mollusc).

Statistically significant differences between stations in community measures and the presence/absence of indicator species were determined using one-way analysis of variance (One-way ANOVA) followed by a Tukey multiple comparison test. Seasonality in community measures is not consistent from year-to-year. For the purposes of this assessment, the simplifying assumption of no seasonality is made in order to pool the data from all four surveys and increase the power of the analysis. Depth-related gradients were measured using linear regression. Spatial trends were measured using cluster analysis and non-metric multidimensional scaling (MDS) techniques. Data was transformed where appropriate. ANOVA and regression analyses were performed using the Minitab® Statistical Software package, while cluster and MDS analyses were performed on the PRIMER (v6) software package.

A qualitative assessment of trends over time in the various community measures at the quarterly stations was performed. Trends are presented graphically using grouped data to increase the sample size at each station and decrease the variability of each data point on the graph. Each measure is represented as a line graph, which shows 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 (MEC 1997): farfield upcoast (FFU = Stations CON and C); 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).

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 (i.e., species) and individuals are grouped into five “major taxa” and reported in Table 5-1. The five major taxa are polychaeta (worms), mollusca (snails, clams, etc.), crustacea (shrimps, crabs, etc.), echinodermata (sea stars, sea urchins, sea cucumbers), and minor phyla (e.g., cnidaria, nemertea, echiura, etc.). Between July 2007 and June 2008, 602 taxa comprising 67,883 individuals were collected (Table 5-1). These values are similar to the 2006-07 monitoring effort (Table 5-1). The percent change in overall number of species was low with the greatest change an increase in mollusca (16%). Change in overall total abundance varied considerably ranging from a 19% decrease in minor phyla to 17% increases in echinodermata and 16% in polychaeta.

Community Indicators

The number of species collected across all 49 stations in July 2007 ranged from 17 at Station C5 to 146 at Station 22; 46 m depth) and generally decreased with increasing depth (Table 5-2; Figure 5-2). The number of species was highest and fairly constant at shallower shelf stations, with most stations having more than 100 species per station.

Table 5-1. Summary of total and average (number/sample) number of species and abundance for major taxa collected at quarterly and annual stations, 2007-08 compared to 2006-07 values.

Orange County Sanitation District, California.

Taxonomic Group	2006-07			2007-08		
	Quarterly	Annual	Combined	Quarterly	Annual	Combined
Polychaeta						
Number of species	218	214	256	232	195	256
Total abundance	28,543	8,914	37,366	38,731	5,588	44,319
Average number of species*	45	42	44	51	36	47
Average abundance	238	229	235	323	143	279
Mollusca						
Number of species	75	75	90	91	75	107
Total abundance	4,746	1,248	5,994	5,067	1,348	6,415
Average number of species*	15	12	14	16	14	15
Average abundance	40	32	38	42	35	40
Crustacea						
Number of species	137	123	167	136	107	159
Total abundance	10,072	2,134	12,293	9,930	2,211	12,141
Average number of species	22	16	21	22	14	20
Average abundance	84	55	77	83	57	76
Echinodermata						
Number of species	18	20	22	16	19	21
Total abundance	1,313	757	2,070	1,621	876	2,497
Average number of species*	3	3	3	3	2	3
Average abundance	11	19	13	14	23	16
Minor Phyla						
Number of species	54	45	61	56	39	59
Total abundance	2,467	638	3,109	2,066	445	2,511
Average number of species	8	6	7	8	5	7
Average abundance	21	16	20	17	11	16
Total						
Number of species	502	477	597	531	435	602
Total abundance	47,141	13,691	60,832	57,415	10,468	67,883
Average number of species*	92	79	89	99	71	92
Average abundance	393	351	383	479	268	427

* Quarterly average number of species was calculated as the mean number/station

Table 5-2. Summary of infaunal community measures for all stations, Summer 2007 annual survey sorted by depth group. (* Values reported for replicate 1 for quarterly stations.)

Orange County Sanitation District, California.

Station	Depth (m)	Total Number of Species	Total Abundance	Total Biomass	Shannon-Wiener Diversity (H')	Margalef Species Richness (SR)	Schwartz' 75% Dominance Index	Species Evenness (J')	Infaunal Trophic Index (ITI)	Benthic Response Index (BRI)
Group 1 (40 - 46 meters)										
7	41	131	637	8.50	4.22	20.3	39	0.87	83	16
8	44	135	596	6.63	4.24	21.7	41	0.86	85	18
21	44	123	590	11.7	3.96	19.6	29	0.82	80	18
22	45	146	597	9.75	4.37	22.7	47	0.88	88	16
30	46	105	468	16.2	3.79	16.9	25	0.81	84	19
36	45	125	588	9.45	3.93	20.2	31	0.81	86	16
55	40	96	359	1.38	4.05	16.1	33	0.89	86	14
59	40	88	321	2.08	3.86	15.1	27	0.86	80	15
Average		**119**	**520**	**8.21**	**4.05**	**19.1**	**34**	**0.85**	**84**	**17**
Group 2 (56 - 60 meters)										
0 *	56	114	691	4.77	3.73	17.3	24	0.79	38	33
1 *	56	115	450	9.17	4.11	18.7	35	0.87	80	25
3	60	99	380	6.53	3.96	16.8	33	0.86	72	16
4 *	56	105	588	2.58	3.75	16.3	26	0.81	44	31
5 *	59	100	363	4.99	4.02	16.8	34	0.87	85	19
9 *	59	117	633	11.4	3.92	18.0	28	0.82	51	25
10	60	85	289	5.63	3.88	15.2	31	0.87	94	13
12 *	58	120	522	4.43	4.02	19.0	36	0.84	71	18
13	59	100	405	7.38	3.93	16.5	33	0.85	92	13
37	56	114	473	5.26	4.00	18.8	37	0.84	75	15
C *	56	95	333	7.08	3.80	16.2	29	0.84	88	21
C2	56	27	147	6.24	2.24	5.21	5	0.68	1	64
CON *	59	112	431	6.71	4.09	18.3	35	0.87	84	16
ZB *	56	79	610	1.46	2.60	12.2	9	0.60	11	40
ZB2 *	56	95	397	1.81	3.77	15.7	26	0.83	36	33
Average		**99**	**848**	**5.70**	**3.72**	**16.1**	**28**	**0.82**	**62**	**26**
Group 3 (91 -100 meters)										
17	91	85	348	4.22	3.82	14.7	26	0.85	77	14
18	91	72	305	4.33	3.49	12.6	20	0.81	83	13
20	100	104	395	9.24	3.96	17.2	34	0.85	90	13
23	100	89	369	5.54	3.88	15.1	28	0.86	80	16
29	100	100	341	8.31	4.07	17.0	38	0.88	87	14
33	100	105	346	6.98	4.11	17.8	37	0.88	76	23
38	100	85	449	10.4	3.57	13.8	24	0.80	87	19
56	100	91	278	4.81	4.09	16.0	35	0.91	82	14
60	100	101	406	8.43	4.02	16.7	34	0.87	83	18
Average		**92**	**360**	**6.92**	**3.89**	**15.7**	**31**	**0.86**	**83**	**16**

Table 5-2 Continues.

Table 5-2 Continued.										
Station	**Depth (m)**	**Total Number of Species**	**Total Abundance**	**Total Biomass**	**Shannon-Wiener Diversity (H')**	**Margalef Species Richness (SR)**	**Schwartz' 75% Dominance Index**	**Species Evenness (J')**	**Infaunal Trophic Index (ITI)**	**Benthic Response Index (BRI)**
Group 4 (187 – 241 meters)										
24	200	48	103	3.04	3.64	10.1	23	0.94	86	18
25	200	47	86	2.00	3.64	10.3	26	0.95	71	26
27	200	57	146	3.50	3.65	11.2	26	0.90	80	18
39	200	57	269	1.40	2.99	10.0	13	0.74	75	18
44	241	22	36	5.90	2.93	5.91	14	0.95	71	41
57	200	28	49	7.00	3.14	6.94	16	0.94	86	18
61	200	35	54	4.32	3.37	8.52	22	0.95	81	25
63	200	25	54	2.60	2.94	6.02	12	0.91	75	25
65	200	33	76	3.56	3.27	7.39	16	0.94	24	71
C4	187	41	199	7.35	2.52	7.56	8	0.68	68	34
Average		**39**	**107**	**4.07**	**3.21**	**8.39**	**18**	**0.89**	**72**	**29**
Group 5 (296 – 300 meters)										
40	303	27	46	2.18	3.07	6.79	16	0.93	67	31
41	303	33	71	1.50	3.14	7.51	15	0.90	85	21
42	303	28	69	1.29	2.79	6.38	11	0.84	73	25
58	300	24	40	1.70	2.92	6.24	14	0.92	83	22
62	300	17	20	0.400	2.79	5.34	12	0.98	89	22
64	300	18	30	0.700	2.64	5.00	11	0.91	100	19
C5	296	17	33	1.40	2.69	4.58	9	0.95	67	28
Average		**23**	**44**	**1.31**	**2.86**	**5.98**	**13**	**0.92**	**81**	**24**

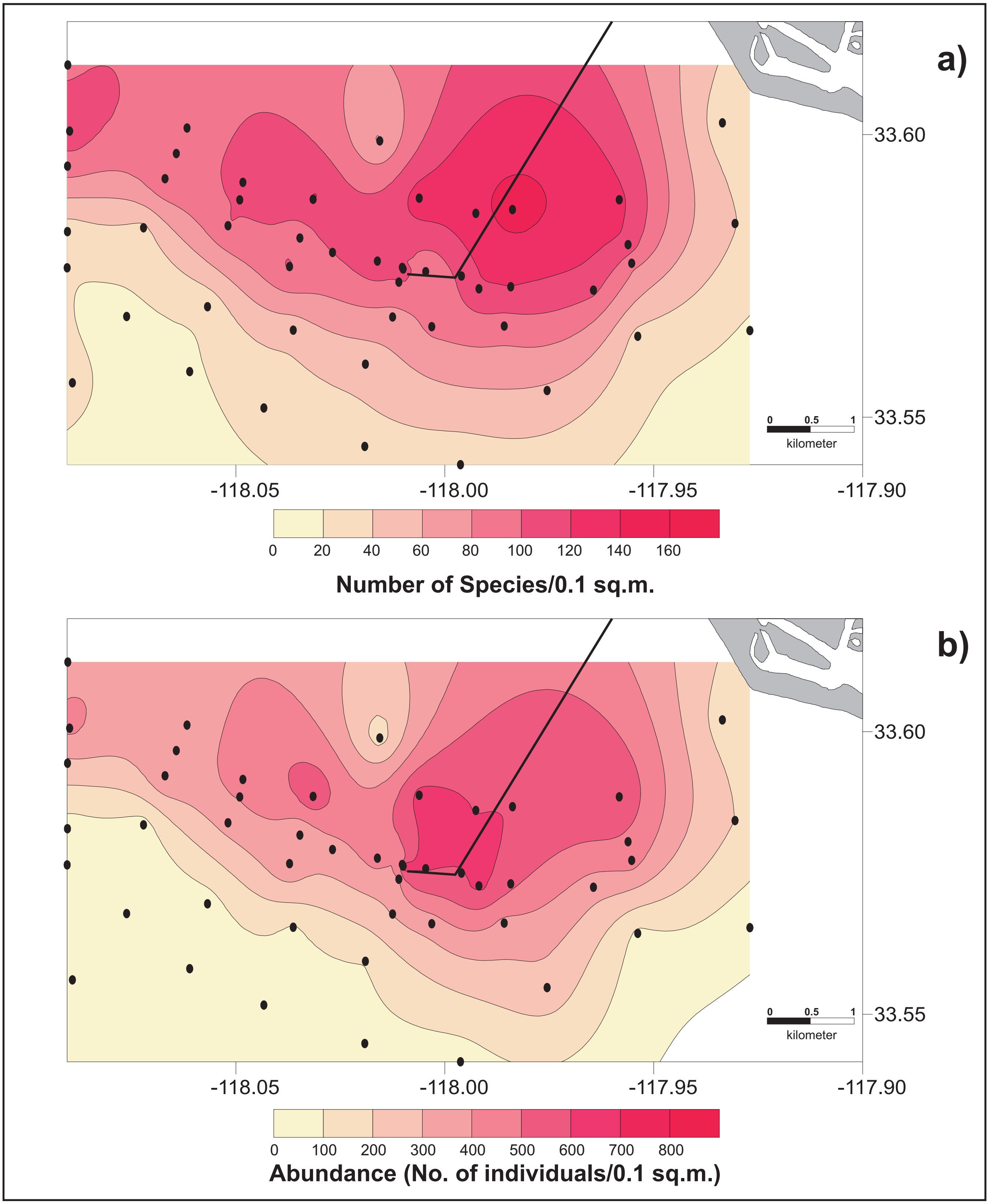


Figure 5-2. **Spatial contours of (a) number of species and (b) abundance during July 2007.**

Regression analysis showed that the difference among stations for number of species was primarily due to water depth (R^2 = 0.76, $p<0.001$).

In the 2007-08 monitoring year, the mean number of species at the quarterly stations ranged from 67.7 (Station ZB) to 118 (Station 1) (Table 5-3). The number of species at farfield Station CON was significantly different from only Station 1 ($p<0.001$; Table 5-4). All quarterly station means were within the historical range of values and comparable to the Southern California Bight (SCB) mid-depth POTW and Non-POTW averages, though the number of species at Station ZB was depressed compared to the Bight'98 values (Table 5-3).

Station abundances at the 49 annual stations ranged from 20 at Station 62 to 691 at Station 0 and were generally distributed according to depth (Table 5-2; Figure 5-2). Abundances were highest near the outfall, eastward at Stations 9 and 12, and inshore at Stations 7, 8, and 22. Mean abundance was highest at outfall-depth stations, followed by shallow stations, then upper slope, lower slope, and basin stations. Differences in total abundance among the annual stations were largely due to station depth (R^2 = 0.72, $p<0.001$).

Quarterly station mean abundances ranged from 321 (Station CON) to 664 (Station 0) (Table 5-3). Stations 0, ZB2, 1, 4, and C had significantly greater abundances than Station CON ($p<0.001$; Table 5-4). All station means were within historical range values. Mean abundance at Stations ZB, 5, and CON were lower than the Bight'98 POTW and Non-POTW means, while the remaining station abundances were comparable (Table 5-3).

In July 2007, sample total biomass ranged from 0.400 g at Station 62 to 16.2 g at Station 30 and generally decreased with increasing depth (Table 5-2). The only exception was at the upper slope stations, which were greater than outfall-depth stations. Regression analysis showed a small, but statistically significant correlation to depth (R^2 = 0.29, $p<0.001$).

Mean total biomass at the quarterly stations ranged from 1.60 g (Station ZB) to 7.54 g (Station C) (Table 5-3). Station CON had significantly higher mean biomass than the four within ZID stations (0, 4, ZB, and ZB2) ($p<0.001$; Table 5-4). With the exception of Station C, mean biomass measurements were consistently below SCB regional means values (Table 5-3). The mean biomass for all quarterly stations fell within the historical range of values (Table 5-3).

Diversity Indices

Values of Shannon-Wiener Diversity (H') at the 49 annual stations were fairly uniform on the San Pedro shelf and upper slope, but tended to decrease with increasing depth (Table 5-2; Figure 5-3). Stations C2 (2.24) and ZB (2.60) had H' values noticeably different from the outfall-depth station mean of 3.72. This was due to large abundances of the crustacean *Pinnixa occidentalis* and the polychaetes *C. capitata*, *Heteromastus filobranchus*, and *Paraprionospio pinnata* at Station C2, and the polychaetes *C. capitata*, *Mediomastus* sp., *Prionospio jubabta*, and the ostracod crustacean *E. carcharodonta* at

Table 5-3. Station means for community measures and diversity indices for quarterly 60 m stations in 2007-08, n=12.

Orange County Sanitation District, California.

Station	Station Group	Number of Species	Total Abundance	Total Biomass (g)	Shannon-Wiener Diversity (H')	Margalef Species Richness	Schwartz' 75% Dominance Index	Evenness (J')	Infaunal Trophic Index (ITI)	Benthic Response Index (BRI)
QUARTERLY STATIONS										
0	WZU	93.8	664	3.11	3.14	14.5	15.5	0.68	23.5	32.8
ZB2	WZU	98.8	638	3.00	3.49	15.2	19.9	0.76	32.9	29.8
4	WZD	101	489	3.48	3.76	16.2	24.8	0.82	46.8	24.9
ZB	WZD	67.7	384	1.60	3.03	11.3	14.1	0.72	22.3	34.3
1	NFU	118	566	6.42	3.90	18.4	29.7	0.82	68.9	20.5
5	NFU	93.3	388	5.22	3.89	15.5	27.8	0.86	83.1	13.3
9	NFD	105	455	4.57	3.87	17.0	29.8	0.83	66.1	19.2
12	NFD	107	408	4.01	3.99	17.8	33.9	0.85	68.8	16.7
C	FFU	112	470	7.54	4.00	18.1	33.8	0.85	85.8	13.6
CON	FFU	95.4	321	5.29	3.99	16.4	33.9	0.88	86.4	11.5
REGIONAL REFERENCE VALUES										
Bight'98 *	POTW	93	545	7.36	3.42	NC	NC	0.49	NC	NC
Bight'98 *	Non-POTW	95	443	7.38	3.64	NC	NC	0.46	NC	NC
1985–2007	All	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
NC = Not Calculated
* Ranasinghe et al. 2003

Table 5-4. **Results of ANOVA-Tukey analyses of community measures of infaunal organisms for quarterly stations during July 2007–April 2008.**
For stations (all seasons combined), n=12;
Transformations: nt = non-transformed data, rank = rank transformed, sqrt = square root transformed, 4th rt = 4th root transformed.

Orange County Sanitation District, California.

Index Tested	Transformation	ANOVA (p)	Mean Value (Untransformed) Tukey Station separation									
Number of Species	nt	<0.001	118 1	112 C	107 12	105 9	101 4	98.8 ZB2	95.4 CON	93.8 0	93.3 5	67.7 ZB
Abundance (No. of individuals)	4th rt	<0.001	664 0	638 ZB2	566 1	489 4	470 C	455 9	408 12	388 5	384 ZB	321 CON
Total Biomass (grams)	nt	<0.001	7.54 C	6.42 1	5.29 CON	5.22 5	4.57 9	4.01 12	3.48 4	3.11 0	3.00 ZB2	1.60 ZB
Shannon-Wiener Diversity (H')	rank	<0.001	4.00 C	3.99 CON	3.99 12	3.90 1	3.89 5	3.87 9	3.76 4	3.49 ZB2	3.14 0	3.03 ZB
Margalef Species Richness (SR)	nt	<0.001	18.4 1	18.1 C	17.8 12	17.0 9	16.4 CON	16.2 4	15.5 5	15.2 ZB2	14.5 0	11.3 ZB
75% Dominance Index (DOM75)	nt	<0.001	33.9 CON	33.9 12	33.8 C	29.8 9	29.7 1	27.8 5	24.8 4	19.9 ZB2	15.5 0	14.1 ZB
Species Evenness Index (J')	rank	<0.001	0.88 CON	0.86 5	0.85 12	0.85 C	0.83 9	0.82 1	0.82 4	0.76 ZB2	0.72 ZB	0.68 0
Infaunal Trophic Index (ITI)	rank	<0.001	86.4 CON	85.8 C	83.1 5	68.9 12	68.8 1	66.1 9	46.8 4	32.9 ZB2	23.5 0	22.3 ZB
Benthic Response Index (BRI)	sqrt	<0.001	34.3 ZB	32.8 0	29.8 ZB2	24.9 4	20.5 1	19.2 9	16.7 12	13.6 C	13.3 5	11.5 CON

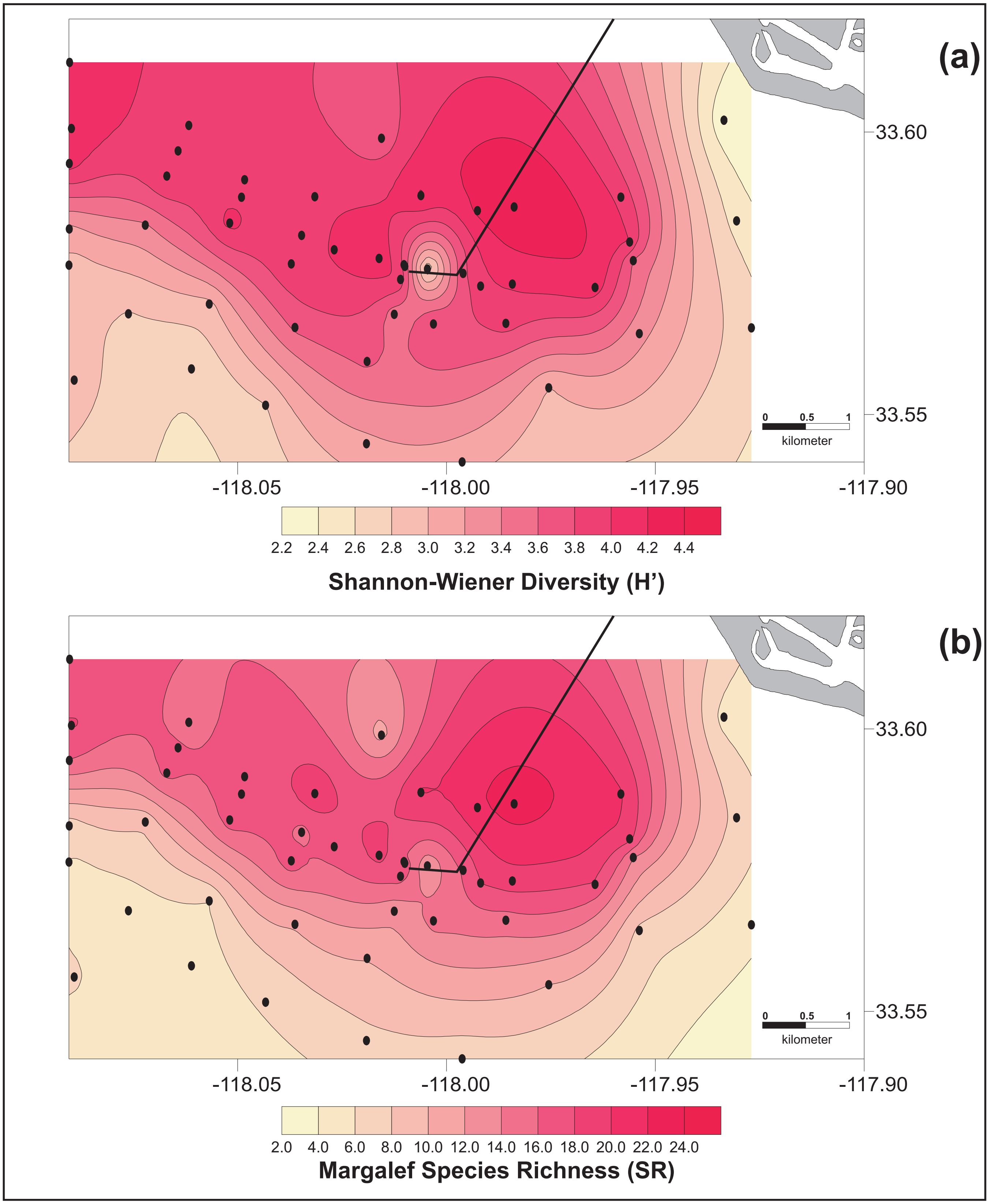


Figure 5-3. **Spatial contours of (a) Shannon-Wiener diversity (H') and (b) Margalef species richness (SR) during July 2007.**

Orange County Sanitation District, California.

Station ZB. There was relatively little variability in H' values within the other station-depth groups. Differences among stations were moderately due to depth-related factors (R^2 = 0.48, p<0.001).

At the quarterly stations, H' mean values ranged from 3.03 (Station ZB) to 4.00 (Station C) (Table 5-3). ANOVA showed that H' at Station CON was only significantly different from the four ZID stations (P<0.001; Table 5-4). Sample values were in the upper end of the range of historical values and non-ZID stations exceeded SCB regional averages for both mid-depth POTW and non-POTW areas (Table 5-3).

In July 2007, values for Margalef Species Richness (SR) showed a fairly uniform spatial pattern on the shelf, but decreased with increasing depth at Station C2 (Table 5-2; Figure 5-3). Regression analysis showed SR was significantly correlated with depth (R^2 = 0.73, p<0.001).

Quarterly station SR means ranged from 11.3 (Station ZB) to 18.4 (Station 1) (Table 5-3). Station CON (16.4) was only significantly different from Station ZB (P<0.001; Table 5-4). All SR values were in the upper end of the historical range of values (Table 5-2).

Schwartz' 75% Dominance Index (Dominance) values at the annual stations were also fairly uniform on the San Pedro Shelf and decreased with increasing depth and proximity to the ZID (Table 5-2; Figure 5-4). Dominance values were less than 10 at Newport Canyon Stations C2, C4, and C5 and at ZID Station ZB. The low value at Station ZB was due to large abundances of the polychaetes *C. capitata*, *Mediomastus* sp., *P. jubabta*, and the ostracod crustacean *E. carcharodonta*. Regression analysis showed that Dominance was moderately correlated with depth (R^2 = 0.46, p<0.001).

Quarterly station means for Dominance ranged from 14.1 (Station ZB) to 33.9 (Stations 12 and CON) (Table 5-3). ANOVA showed that Dominance at Station CON was significantly greater than the four ZID-stations and Station 5 (P<0.001; Table 5-4). All values fell within the long-term range, with only the ZID stations in the lower half (Table 5-3).

Species Evenness (J') values at annual the stations generally increased with increasing depth (Table 5-2; Figure 5-4). The exceptions to this were Stations ZB, C4, and 39. Species evenness was marginally related to depth (R^2 = 0.21, p = 0.001).

Species evenness ranged from 0.68 (Station 0) to 0.88 (Station CON) (Table 5-3). ANOVA found that J' values at Station CON were significantly greater than at all other quarterly stations except Stations 5 and 12 (P<0.001; Table 5-4). All values fell within the long-term range and were well above both mid-depth POTW and non-POTW area means (Table 5-3).

Infaunal Trophic Index and Benthic Response Index

In July 2007, Infaunal Trophic Index (ITI) values ranged from 1 to 100 at Stations C2 to 64, respectively (Table 5-2). The majority of ITI scores at stations outside the ZID indicated a normal community with the exception of Stations 9, C2, and 65. Station 9 is located just east of the outfall, while Stations C2 and 65 are along the border of the Newport Canyon; the latter two stations had ITI scores less than 30. In general, values were lower near the

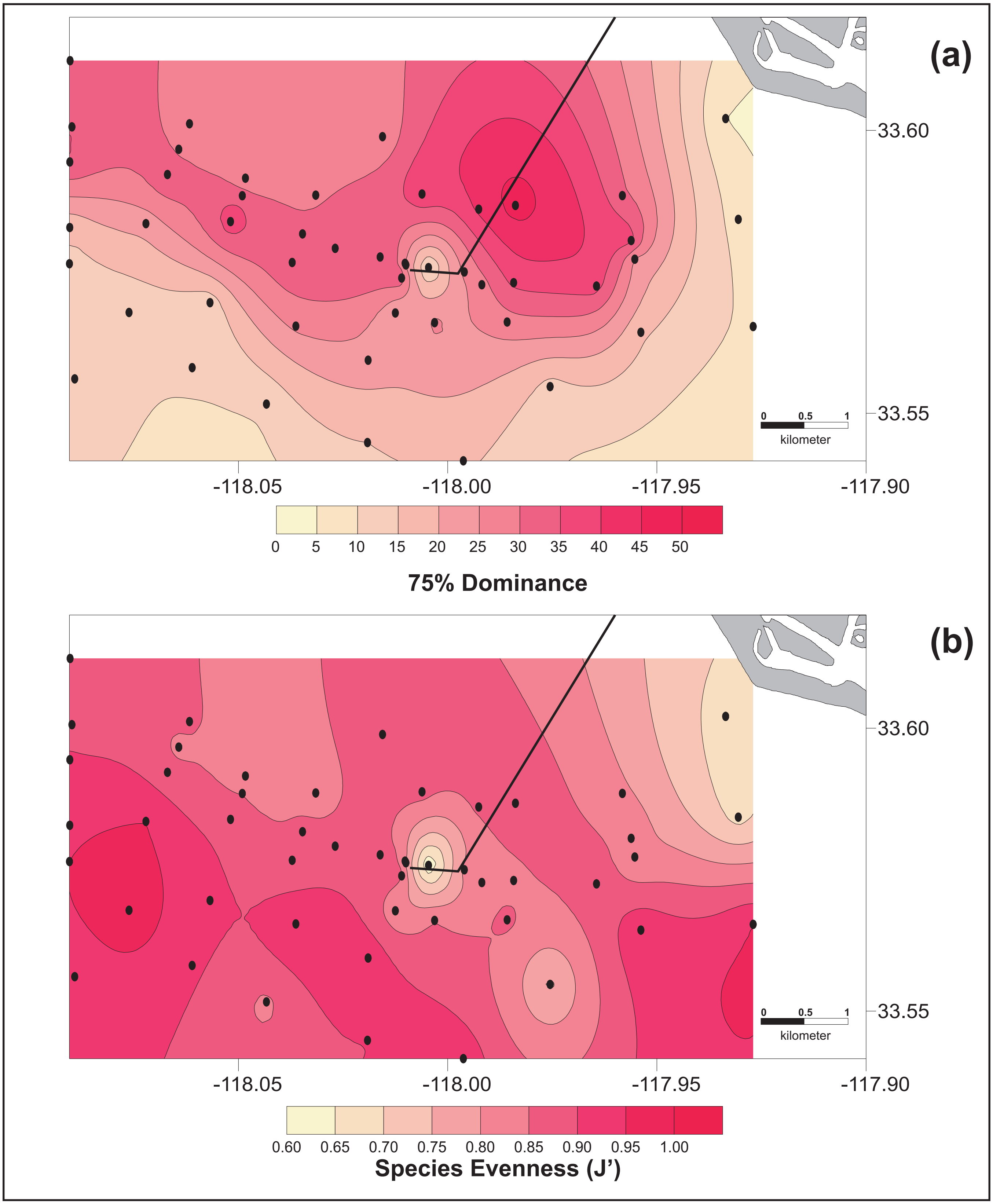


Figure 5-4. **Spatial contours of (a) 75% Dominance, and (b) Species Evenness (J') during July 2007.**

outfall and increased with distance from the outfall (Figure 5-5). Regression analysis showed no correlation of ITI values to station depth.

Quarterly mean ITI scores ranged from 22.3 (Station ZB) to 86.4 (Station CON) (Table 5-3). ANOVA showed significant differences among station (P<0.001). Stations CON, C, and 5 had significantly greater ITI scores than all other stations (Table 5-4). The mean ITI scores at Stations 1, 9, and 12, were significantly lower than Stations CON, C, and 5, but within the "normal" range. Scores at Stations 4 and ZB2 indicated changed conditions, while those at Stations 0 and ZB indicated degraded conditions (Table 5-3). The low ITI scores at the ZID-stations were largely due to high abundances of *C. capitata* and other deposit-feeding polychaetes. While there were measurable differences among non-ZID stations, all were still within the range for normal infaunal communities. All ITI scores fell within the long-term range of values (Table 5-3).

In July 2007, Benthic Response Index (BRI) scores ranged from 13 to 71 (Table 5-2). With the exception of ZID stations, BRI scores were fairly uniform on the San Pedro Shelf, but increased with depth and decreased with distance from the outfall (Figure 5-5). San Pedro Shelf shallow and outfall-depth stations had BRI scores indicating reference conditions. The exceptions to this were Stations 1 and 9 (located westward and eastward of the outfall, respectively), Stations 0, 4, and ZB2, which had scores indicating a marginal deviation from reference, and Station ZB with a score indicating a loss of biodiversity.

Quarterly mean BRI scores ranged from 11.5 (Station CON) to 34.3 (Station ZB) (Table 5-3). BRI scores at Stations CON, C, and 5 were significantly different from all other quarterly stations (P<0.001; Table 5-4). As with ITI, BRI scores indicated that a "reference" population is being maintained beyond the ZID (BRI scores <25), while ZID-stations are characterized as marginally deviated from the reference condition." BRI does not indicate the same degree of change that ITI does (i.e., degraded communities at Stations 0 and ZB), but it does indicate some change at all ZID-stations.

In July 2007, 33 stations (67%) were classified as reference according to BRI categories. Twelve (25%) showed marginal deviation from reference, and four (8%) showed a loss of biodiversity or a loss of community function. This is a 26% increase in the number of stations scored as reference and a 25% decrease in stations showing a loss of biodiversity from July 2006. The number of stations showing marginal deviation from reference increased by 5% and two stations had scores indicating a loss of community function, while none met this criterion in July 2006.

The lower ITI or higher BRI scores at the outfall stations may represent a localized wastewater effect and seems to be associated with higher abundances of selected species (e.g., *Capitella capitata*). The results of the 2005 and 2006 surveys both showed increases in the number of stations changing from the reference condition. The 2007 results, however, showed a marked increase in the number of stations that classify as reference. Whether this is due to improved conditions or natural environmental variability is not known.

Temporal (long-term) Trend Analysis

The number species is increasing over time in all station groups, with high inter-annual variability (Figure 5-6). The pattern of change is similar for most years in all station groups.

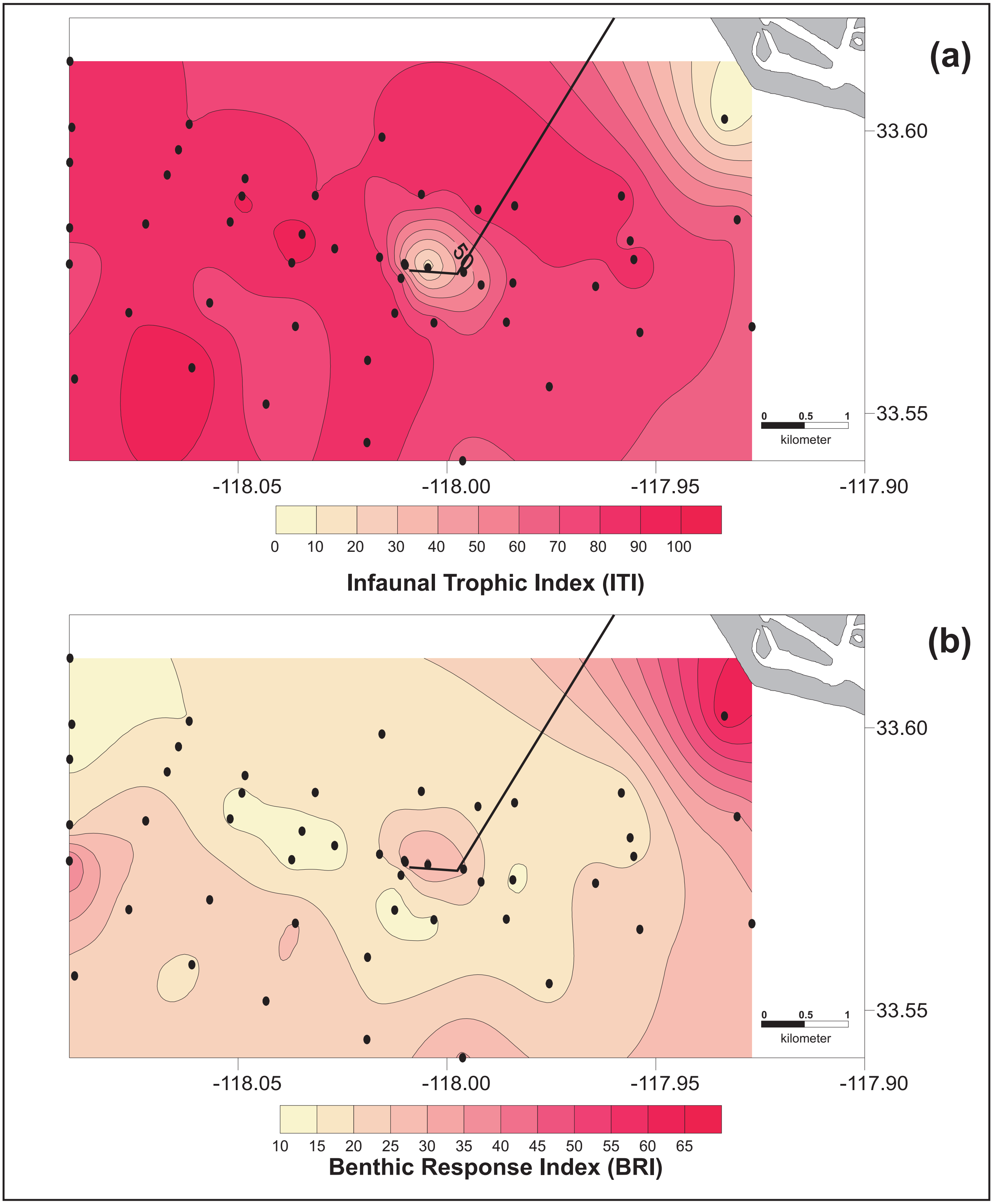


Figure 5-5. Spatial contours of (a) infaunal trophic index (ITI) and (b) benthic response index (BRI) during July 2007.

Orange County Sanitation District, California.

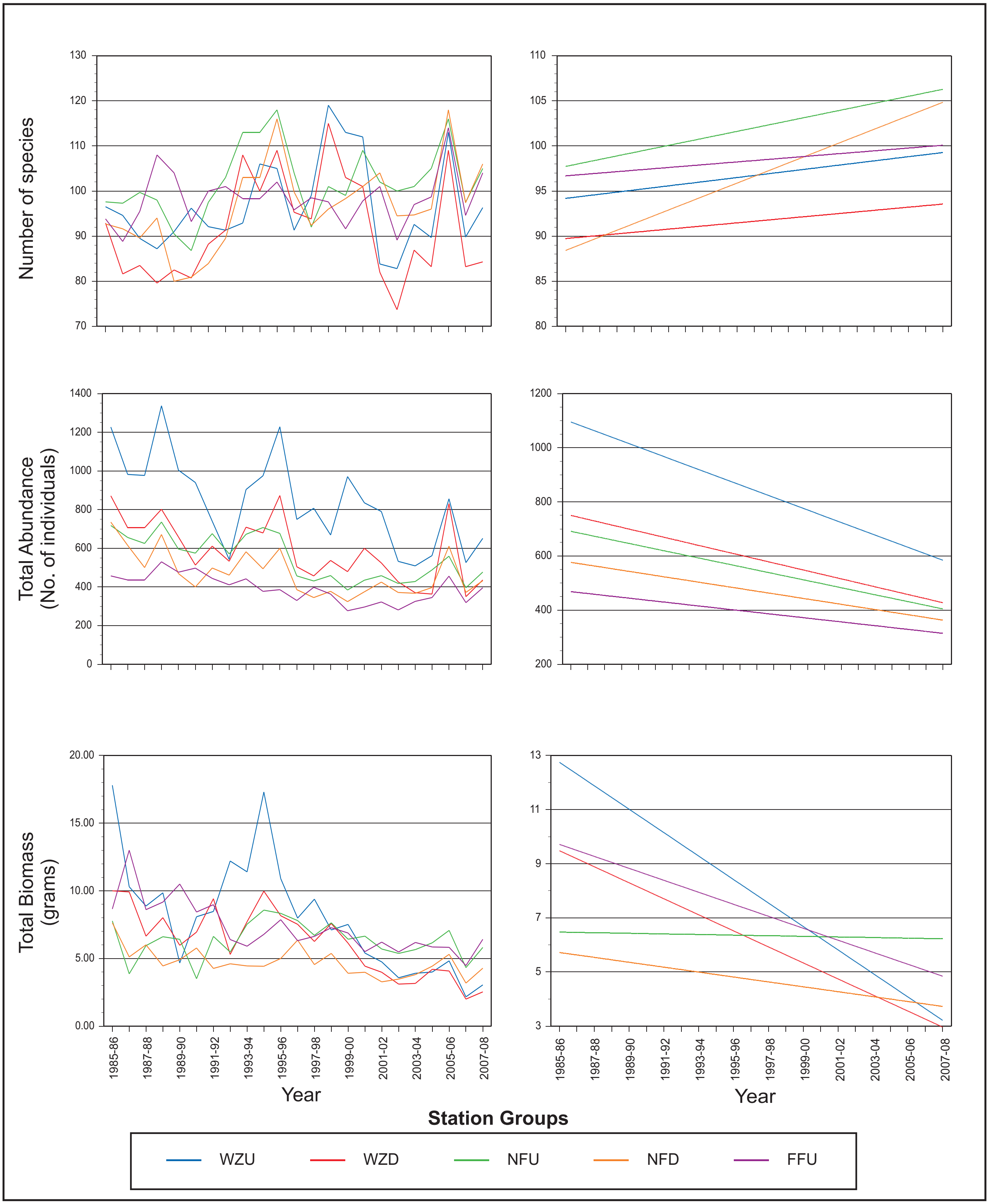


Figure 5-6. Annual mean values for benthic infauna parameters for the period 1985–2008: No. of species, abundance, biomass, Shannon-Wiener diversity (H'), Margalef species richness (SR), 75% dominance (DOM75), species evenness (J'), infaunal trophic index (ITI), and benthic response index (BRI).

Orange County Sanitation District, California.

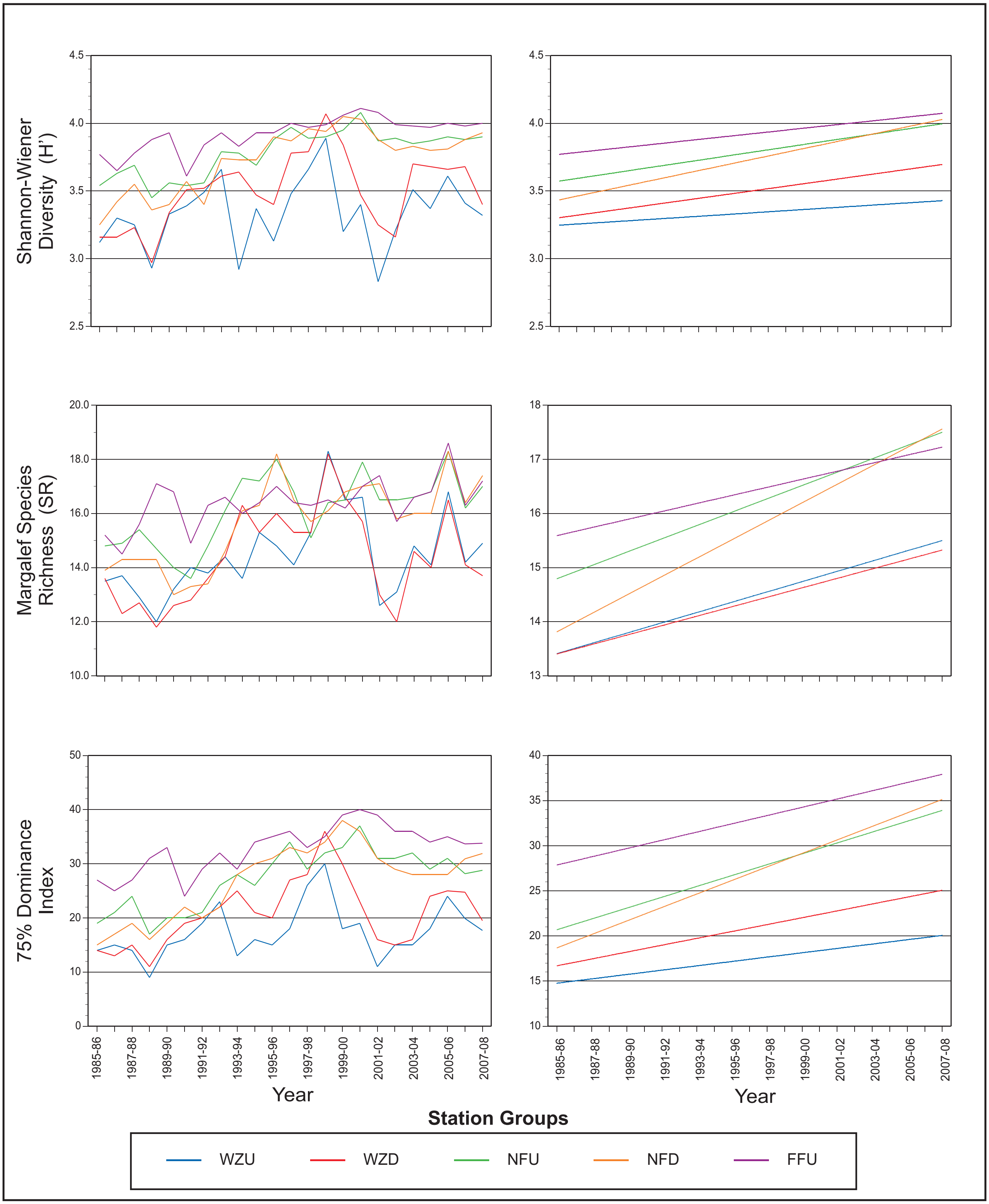


Figure 5-6 Continued.

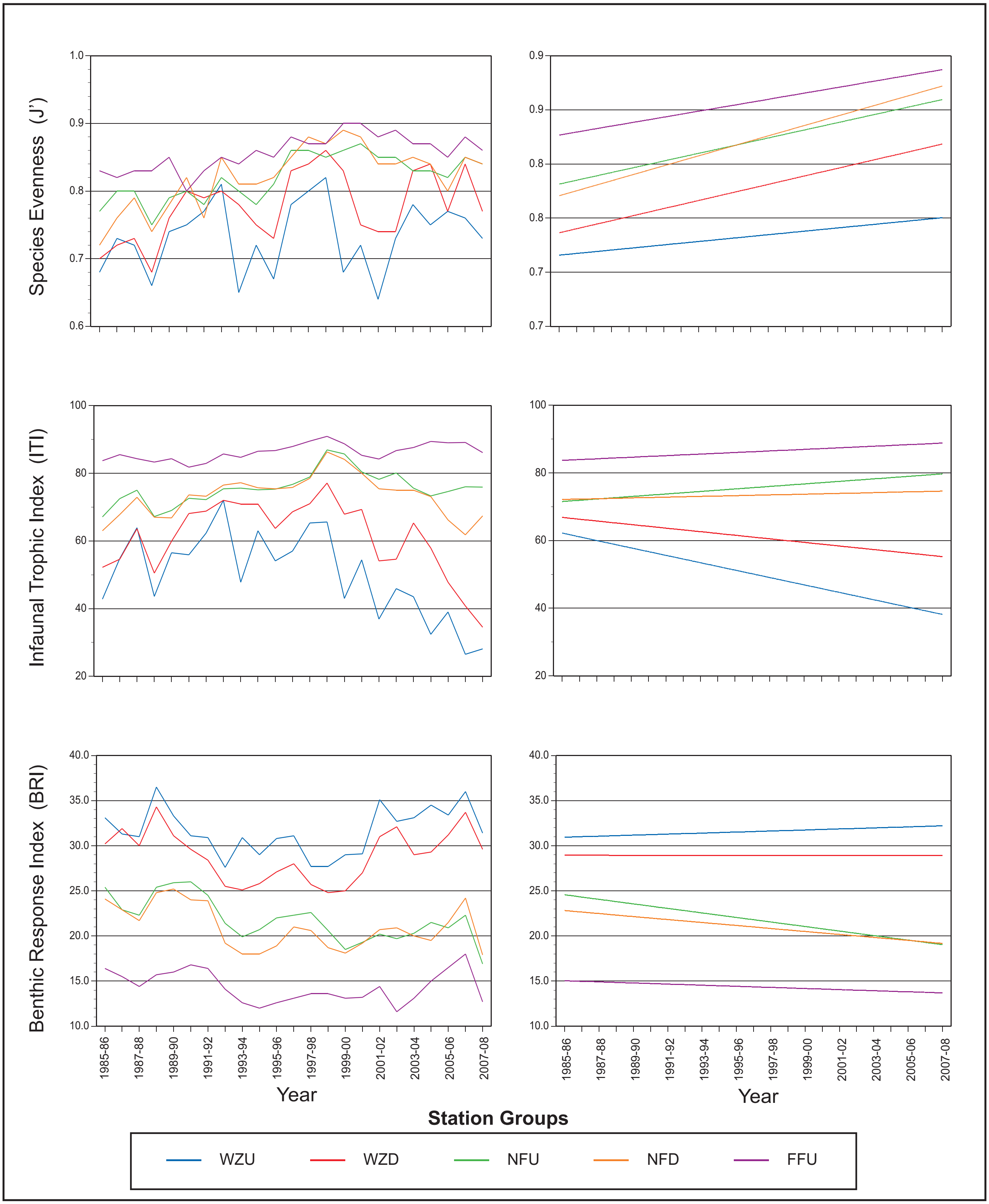


Figure 5-6 Continued.

However, the best-fit shows a rate of increase that varies among groups. The greatest rate of change is in the two nearfield groups. The two within ZID and farfield groups show a similar rate of increase, though the number of species in the WZD is, on average, about 5–7 less than WZU and FFU.

While the number of species is increasing over time, total abundance of individuals is decreasing at all station groups. The rate of decrease is greatest at WZU, while the other four station groups show a similar rate of decline. WZU has the highest inter-annual variability and the highest abundances. This is largely due to the number of pollution tolerant species (e.g., *C. capitata* and *E. carcharodonta*) found in this station group. Although long-term decreases in abundances are present throughout the monitoring area, an outfall influence is not indicated.

Total biomass is also decreasing at all station groups, but with greatly different rates of change among groups. The NFU station group is very consistent, while the steep decline at WZU is due to high biomass totals in 1985-86 and 1994-95. If these are considered as outliers, then the rate of decline becomes more in line with the other station groups.

Shannon-Wiener Diversity is increasing in all station groups, reflecting the increase in the number of species over time. The greatest rate of increase is in NFD, which also showed the highest rate of increase in the number of species (see above).

Margalef Species Richness is increasing in all station groups, which also corresponds to the increase in the number of species over time. NFD has the greatest rate of increase. WZU and WZD are virtually identical in their rates of change, and are about 2 points lower than the other station groups, indicating an outfall influence on SR values within the ZID. The rates of change for all station groups are comparable indicating an area-wide influence on time-related changes in this measure.

Dominance is increasing in all station groups suggesting a decreased influence of dominating species. NFD has the greatest rate of change, though all are similar. Inter-annual changes in Dominance show a similar pattern for all stations, though the values differ by about a factor of three between the WZU and FFU groups.

Species evenness values are increasing in all station groups at a similar rate. Evenness values are much more variable at WZU and WZD station groups than the other three station groups and are 0.1 to 0.2 lower than NFU, NFD, and FFU groups. This also suggests a lessening influence of dominating species in the monitoring area.

ITI scores are increasing slightly over time at NFU, NFD, and FFU, but have decreased steadily since about 2000 at WZU and WZD; WZU has the greatest rate of decline. ITI scores at NFU and NFD have also been decreasing since 2000 following a steady increase from 1988 through 1999. ITI scores at FFU have remained relatively constant (~85) since 1985. Even though NFD and NFU stations are showing a recent decline, all scores are within the range of “normal” values indicating that the invertebrate community outside the ZID is not degraded. The ITI scores at WZU and WZD currently indicate degraded and changed communities, respectively.

BRI scores are decreasing over time at NFU, NFD, and FFU with values in all three groups within the “reference condition” range of values (0–24). WZU and WZD show long-term trends of shallow U-shaped curves in the data. BRI scores at these two station groups have been increasing (~8–10 points) since about 1999. Scores at WZD have stayed within the “marginal deviation from reference” range of values (25–34), while WZU scores have, on occasion (e.g., 2006-07) increased from “marginal deviation” into the “loss of biodiversity” range (35–44).

Indicator Species

Pollution Tolerant Species

Euphilomedes carcharodonta
In July 2007, *E. carcharodonta* abundances were highest in the areas just offshore (Stations 3, 17 and 18) and upcoast (Stations 21 and 30) of the outfall diffuser (Figure 5-7). Abundance of *E. carcharodonta* was marginally correlated with depth ($R^2 = 0.17$, $p = 0.002$). At the quarterly stations, mean abundances per sample ranged from 4.42 at Station 12 to 27.7 at Station 1. Mean *E. carcharodonta* abundance at Stations 1, 5, and C were significantly greater than Station CON (Table 5-5).

Capitella capitata
In July 2007, as in previous years, the abundance of *C. capitata* was much higher near the outfall than at the other stations in the monitoring area (Figure 5-7) and was a major factor in the low ITI and high BRI scores at ZID stations. Regression analysis showed no relation between station depth and *C. capitata* abundance. At the quarterly stations, sample means ranged from <1 at Stations 5, 9, 12, C and CON to 192 at Station 0. One-way ANOVA showed all ZID stations and nearfield Station 1 had significantly greater abundances than Station CON (Table 5-5).

Parvilucina tenuisculpta
In July 2007, the abundance of *P. tenuisculpta* was low throughout the monitoring area, ranging from 0 to 9. The majority of station abundances ranged from 0 to 3 individuals with only Stations 3, 7, 23, and 38 having greater than five individuals per sample (Figure 5-7). Regression analysis showed a small, but significant relationship between station depth and abundance of *P. tenuisculpta* ($R^2 = 0.13$, $p = 0.007$). At the quarterly stations, sample means ranged from <1 at Stations 5, C, and CON to 2.83 at Station 12. One-way ANOVA showed that Stations 4, 9, and 12 were significantly different from Station CON (Table 5-5).

Pollution Sensitive Species

Amphiodia urtica
In July 2007, *A. urtica* abundance ranged from 0 at 20 different stations in all depth zones to 97 at Station 38. *A. urtica* distribution was patchy with abundance lowest in the canyons, on the slope, and near the outfall, and highest on the shelf increasing with increasing distance from the ZID (Figure 5-8). This pattern is similar to that seen in previous years (OCSD 2004). Regression analysis showed a small correlation between station depth and the abundance of *A. urtica* ($R^2 = 0.20$, $p = 0.001$). Mean abundances at the ten quarterly stations ranged from <1 at Stations 0, ZB, and ZB2 to 40 at Station C. One-way ANOVA showed that all quarterly stations except Stations C and 5 had significantly lower mean

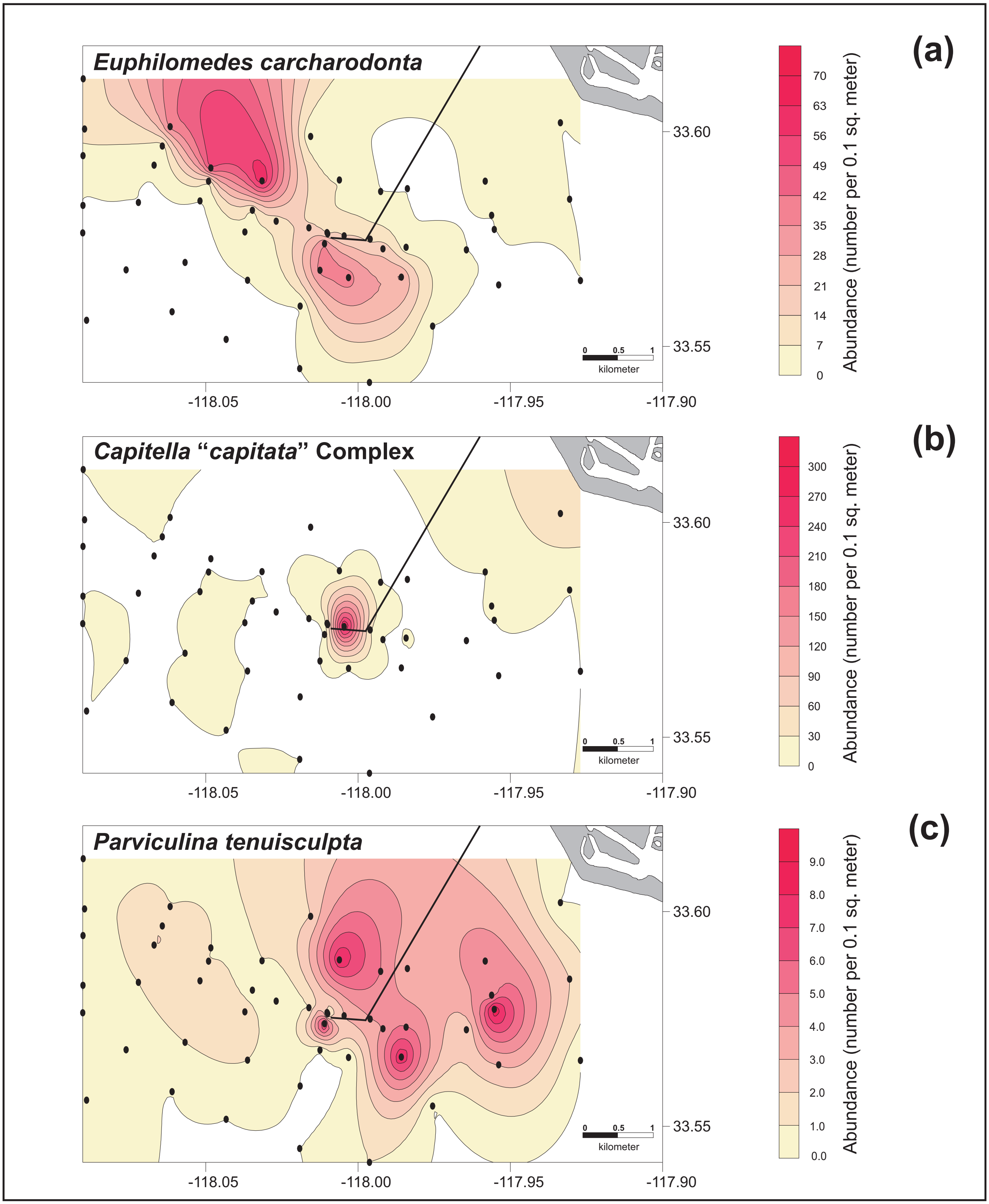


Figure 5-7. **Spatial contours of abundance of (a) *Euphilomedes carcharodonta*, (b) *Capitella "capitata"* complex, and (c) *Parvilucina tenuisculpta* during July 2007.**

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Table 5-5. Results of ANOVA-Tukey analyses of selected indicator species at quarterly stations during, July 2007–April 2008.

For stations (all seasons combined), n=12;
Transformations: nt = non-transformed data, rank = rank transformed, sqrt = square root transformed, 4th rt = 4th root transformed.

Orange County Sanitation District, California.

Index Tested	Transformation	ANOVA (p)	Mean Value (Untransformed) Tukey Station separation
Euphilomedes carcharodonta	sqrt	<0.001	27.7 22.2 20.8 17.9 13.0 9.17 9.33 9.17 6.92 4.42 1 5 C ZB2 0 ZB CON 9 4 12
Capitella “capitata”	4th rt	<0.001	192 122 122 31.2 3.58 0.750 0.500 0.333 0.583 0.167 0 ZB ZB2 4 1 9 12 CON 5 C
Parvilucina tenuisculpta	nt	<0.001	2.83 2.33 2.17 1.75 1.67 1.67 1.17 0.833 0.667 0.583 12 9 4 1 ZB ZB2 0 C 5 CON
Amphiodia urtica	rank	<0.001	39.6 23.2 21.0 8.00 4.67 2.50 2.50 0.333 0.250 0.167 C CON 5 12 1 9 4 ZB ZB2 0
Amphipods	sqrt	<0.001	43.3 42.3 40.9 29.6 27.3 24.5 21.2 20.6 18.5 15.1 5 1 C CON 9 12 ZB2 4 0 ZB

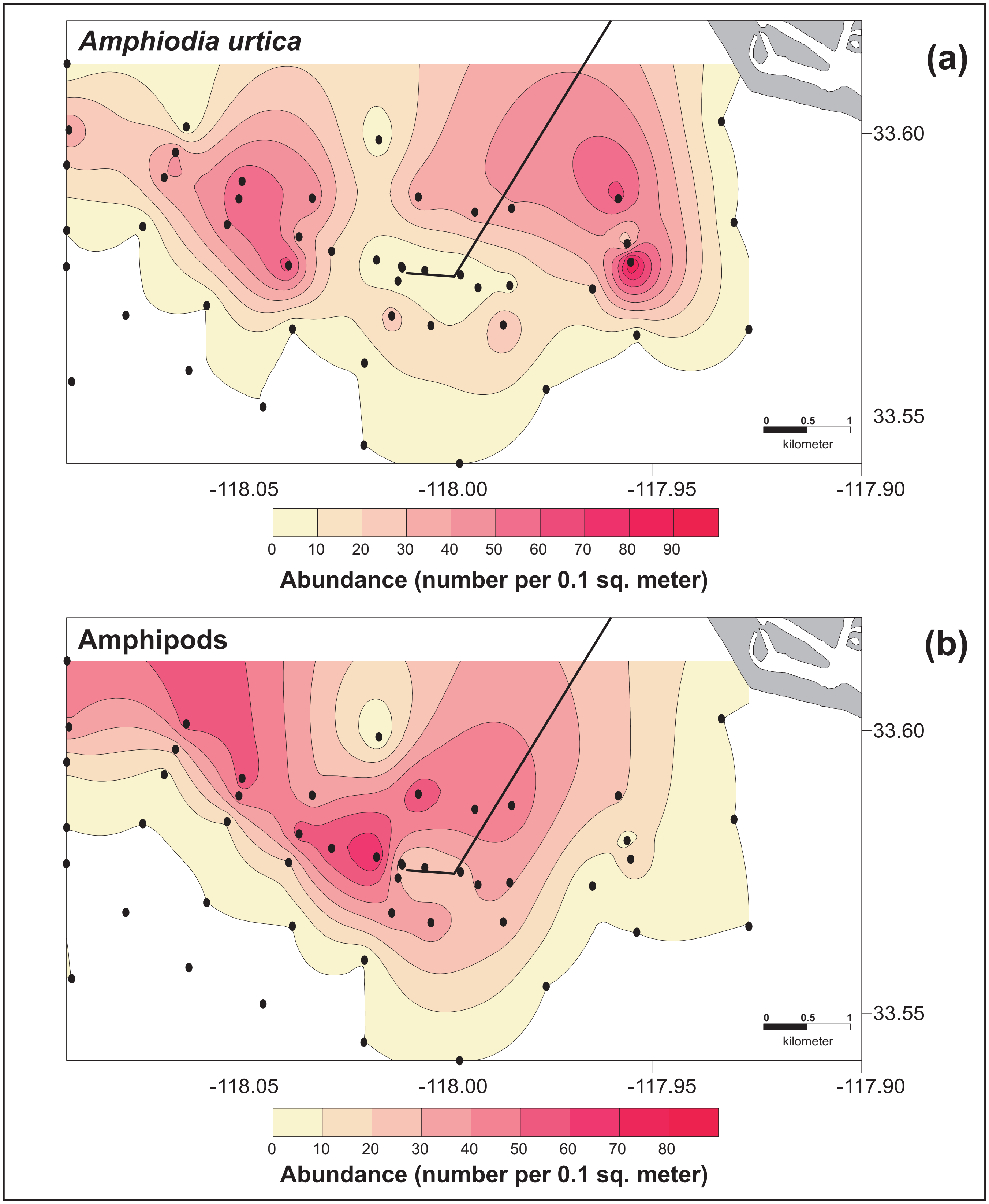

Figure 5-8. **Spatial contours of abundance for (a) *Amphiodia urtica* and (b) selected amphipods during July 2007.**

Orange County Sanitation District, California.

abundances than Station CON (Table 5-5). This general trend of decreasing abundance with proximity to the outfall is not unexpected as reef-dwelling predators (e.g., California scorpionfish *Scorpaena guttata*) likely prevent *A. urtica* from populating the sediments near the outfall (OCSD 2003).

Amphipods

In July 2007, abundances of Rhepoxynid and Ampelsicid amphipods were lowest in the canyons and slope areas, while they were highest on the San Pedro Shelf upcoast and inshore of the outfall pipe (Figure 5-8). Regression analysis showed that amphipod abundance significantly decreased with increasing depth ($R^2 = 0.52$, $P<0.001$). At the quarterly stations, sample means ranged from 15 at Station ZB to 43 at Station 5. One-way ANOVA showed that only Stations ZB and 5 were significantly different from Station CON (Table 5-5).

Spatial Analysis

Cluster Analysis

Cluster analysis on the July 2007 abundance data identified eight major station clusters (Figure 5-9). The station clusters generally follow depth contours and are similar to those reported in previous years (Figure 5-10). These station groups were confirmed through non-metric multidimensional scaling (MDS) using 4th root transformed data and Bray-Curtis similarity as the resemblance matrix (Figure 5-11). The output stress was low (2D = 0.11; 3D = 0.08) indicating good ordination.

Station Cluster 1 (SC1) consists of Stations 17, 18, 20, 23, 29, 33, 37, 38, 56, and 60. SC1 is characterized as having the highest percentage of echinoderms of the six station clusters (Table 5-6). SC4 has high abundances of the crustacean *E. carcharodonta*, the echinoderm *A. urtica*, molluscs *Adontorhina cyclia*, *Alvania rosana* (found only in SC4), *Gastropteron pacificum*, and the polychaetes *Aphelochaeta glandaria*, *Lumbrineris cruzensis*, *Petaloclymene pacifica*, *P. jubata*, and *Travisia pupa*.

Table 5-6. Percent taxa in each station cluster.

Orange County Sanitation District, California.

Station Cluster	Crustacea	Echinodermata	Minor Phyla	Mollusca	Polychaeta
1	10	22	3	12	53
2	30	2	3	9	56
3	9	1	3	6	81
4	19	9	3	10	59
5	10	0	1	10	79
6	8	4	2	32	54
7	16	5	3	38	38
8	17	3	2	30	48

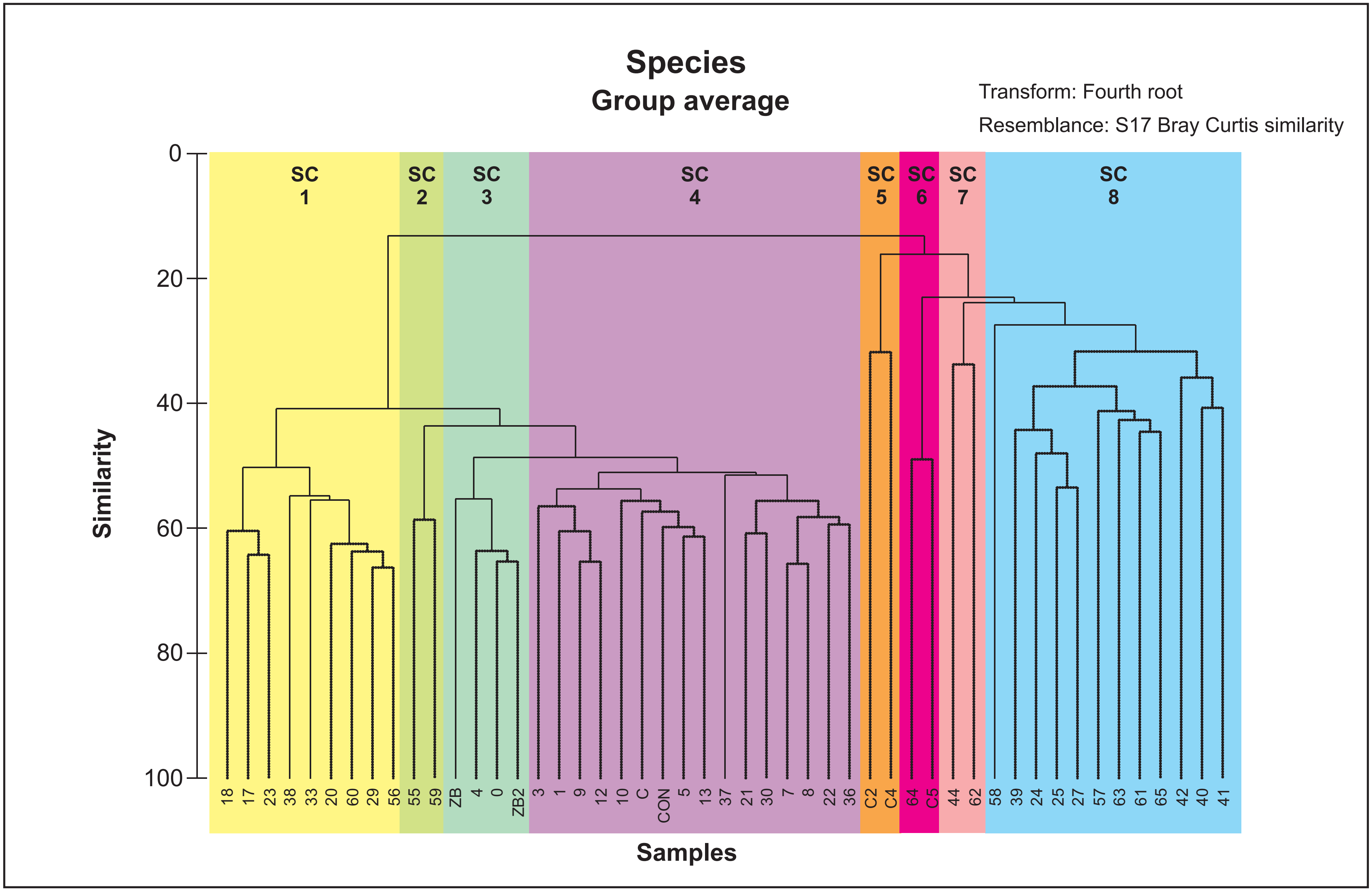

Figure 5-9. **Summary of cluster analysis and relationships among stations and infaunal species groups for July 2007.**

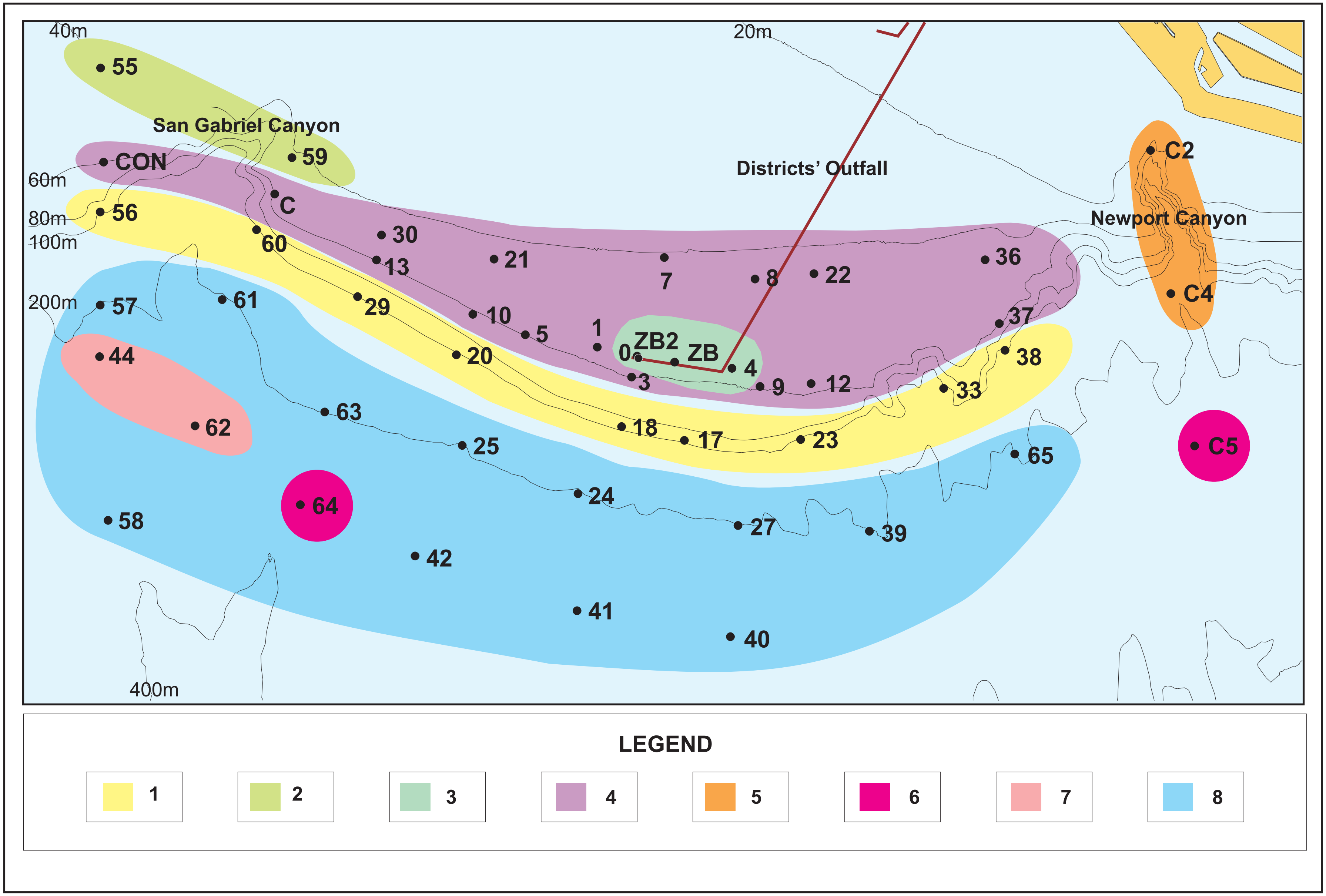

Figure 5-10. **Map of station groups from cluster analysis for July 2007.**

Orange County Sanitation District, California.

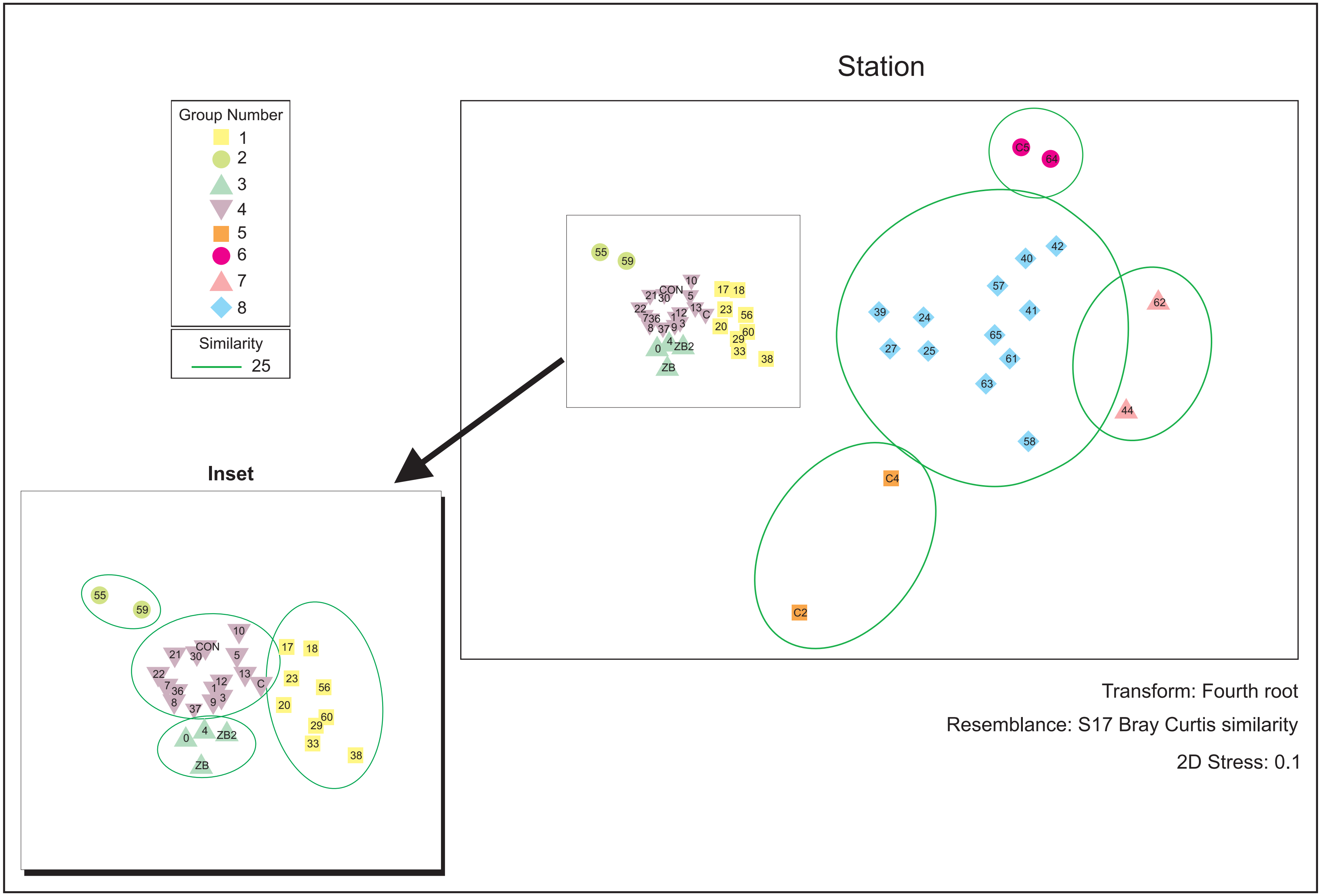

Figure 5-11. Non-metric multi-dimensional scaling (MDS) station plot with cluster analysis overlay. Station symbols correspond to cluster analysis station groupings (group numbers).

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Station Cluster 2 (SC2) consists of Stations 55 and 59, which are upcoast and inshore from the outfall at a depth of 40 m. SC2 is characterized by having the highest percentage of crustacean species of any cluster (Table 5-6), including the highest abundance of *Amphideutopus oculatus* and high abundances of *Ampelisca agassizi* and *Amelicsca pugetica*.

Station Cluster 3 (SC3) consists of the four ZID Stations (0, 4, ZB, and ZB2) and is characterized by the highest percentage of polychaetes (Table 5-6), specifically *Aricidia catherinae*, *C. capitata* complex, *Lumbrineris californiensis*, *Mediomastus* sp., and *Prionospio jubabta*. SC3 is the only cluster with the polychaete *Armandia brevis*. Within SC3, Station ZB is distinguished by having the largest abundance of *C. capitata* of any station.

Station Cluster 4 (SC4) consists of Stations 1, 3, 5, 7, 8, 9, 10, 12, 13, 21, 22, 30, 36, C, and CON. These are all San Pedro Shelf stations ranging in depths from 38 m to 60 m. SC4 is characterized by high abundance of the brittle star *Amphiodia urtica* and certain crustaceans including *Caegognathia crenulatifrons*, *E. carcharodonta*, and six species of Ampeliscid amphipods. This cluster also has high abundances of the polychaetes *A. catherinae*, *Chloeia pinnata*, *Euclymeninae* sp. *A*, *Mediomastus* sp., *Prionospio jubata*, *Spiophanes berkeleyorum*, and *S. duplex*, and the minor taxa Phoronida.

Station Cluster 5 (SC5) consists of Stations C2 and C4, 56 and 187 m deep, respectively. These stations encompass the upper slope area of Newport Canyon. SC5 is characterized by the crustacean *Pinnixa occidentalis*, the mollusks *Axinopsida serricata* and *Saxicavella pacifica*, and the polychaetes *C. capitata* and *Paraprionospio pinnata*. SC5 has the second highest percentage of polychaetes (Table 5-6) and the largest abundance of *C. capitata* outside the ZID, occurring primarily at Station C2.

Station Cluster 6 (SC6) also consists of two Stations (64 and C5), both of which are approximately 300 m depth. SG6 is characterized as having low overall abundances and is dominated by the mollusk *Nuculana conceptionis* and the polychaetes *Chloeia pinnata*, *Glycinde armigera*, and *Paraprionospio pinnata*.

Station Cluster 7 (SC7) consists of Stations 44 and 62, which are along the slope area of San Gabriel Canyon at 241 and 300 m depth, respectively. SG7 has low overall abundances and the highest percentage of mollusks (Table 5-6). SG7 is characterized by the presence of the mollusks *Compressidens stearnsii*, *Rhabdus rectius*, and *Yoldia seminuda*, and the polychaete *Aphelochaeta monilaris*.

Station Cluster 8 (SC8) consists of 12 Stations (24, 25, 27, 39, 40, 41, 42, 57, 58, 61, 63, 65), that range in depth from 197 to 303 m. SG8 is characterized by the crustaceans *A. unsocalae*, *Diastylis pellucida*, *Eudorella pacifica*, *Euphilomedes producta*, the echinoderm *Brisaster townsendi*, the molluscs *Compressidens stearnsii*, *Rhabdus rectius*, and *Tellina carpenteri*; and the polychaetes *Aphelochaeta monilaris*, *Maldane sarsi*, *Melinna heterodonta*, *Nephtys ferruginea*, *Onuphis iridescens*, *P. pinnata*, and *Spiophanes kimballi*.
Overall, depth and sediment-related factors appear to be most significant in determining infaunal distribution and abundance throughout the monitoring area. This analysis supports the general finding that the effects of the wastewater discharge are primarily localized near

the outfall (station cluster 3) and are causing only minimal effects to the infaunal community in the District's monitoring area.

CONCLUSIONS

There was an overall increase in the number of species and total abundance of individuals in 2007-08 compared to 2006-07, though both decreased at the annual stations. In general, invertebrate communities outside the ZID appeared normal and most could be characterized as being of reference condition. In fact, the BRI characterized 26% more annual survey stations as reference compared to 2006, even though there was a net decrease in the number of species and total abundance at these stations in 2007. Similar to previous years, the 2007-08 monitoring results showed some localized outfall effects within the ZID and at several stations close to the outfall. However, these stations show only marginal deviation from reference condition per the ITI and BRI. Overall, the infaunal community in the monitoring area appears healthy and permit criteria regarding sediment quality were met (See Chapter 2). These results support the conclusion that outfall impacts are limited to those stations closest to the discharge and the receiving environment is not being degraded as a result of District operations.

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