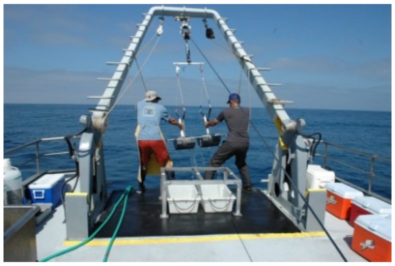
chapter 5

MACROBENTHIC INVERTEBRATE COMMUNITIES



Chapter 5
MACROBENTHIC INVERTEBRATE COMMUNITIES

INTRODUCTION

The Orange County Sanitation District's (District) 305-cm (120-in) diameter outfall pipe rests on the San Pedro Shelf between the Newport and San Gabriel submarine canyons (Figure 5-1). The release of final effluent from the outfall pipe contributes nutrients, wastewater contaminants, and particulates to the coastal zone, which in turn may affect the local infaunal invertebrates (e.g., worms, clams, and crustaceans) that live in the ocean sediments. The outfall pipe and its associated ballast rock also form 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 (OCSD 1995, 1996; Diener and Riley 1996; Diener *et al.* 1997). Nevertheless, natural features of the environment (e.g., sediment type and water depth) account for most of the variability in the distribution of infaunal species along the San Pedro Shelf, with depth-related factors being the most important (OCSD 1996, 2004).

The District is authorized to discharge treated wastewater into receiving waters per its NPDES ocean discharge permit with the proviso that it does not degrade the infaunal communities (see box below). In order to demonstrate compliance with this objective, the infaunal communities are monitored by the District to evaluate whether the wastewater discharge has degraded these communities beyond the zone of initial dilution (ZID) (>60 m in any direction of the outfall diffuser). 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). Since natural processes strongly influence infaunal assemblages, outfall effects are discerned from natural influences by comparing community measures of the invertebrate fauna near the outfall to those at farfield sites. This chapter provides the results of the 2012-13 monitoring year.

Compliance Criterion Pertaining to Benthic Infaunal Communities Contained in the District's NPDES Ocean Discharge Permit (Order No. R8-2012-0035, Permit No. CAO110604).

Criterion	Description
V.A.4.a. Biological Characteristics	Marine communities, including vertebrates, invertebrates, and plant species shall not be degraded.

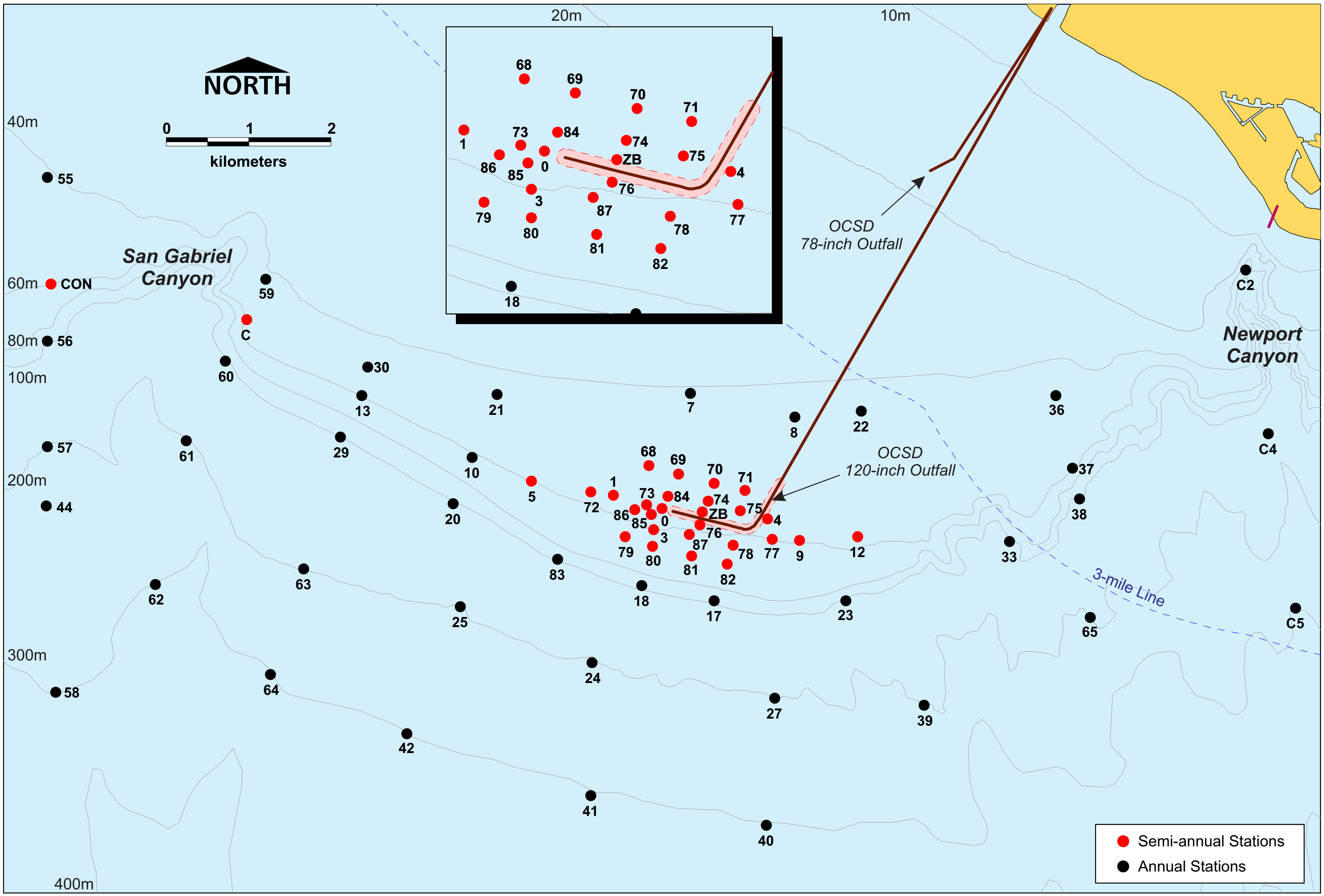


Figure 5-1. Benthic infaunal sampling stations for annual and semi-annual surveys, 2012-13.
Note: ZID boundary indicated by red dashed lines around the outfall terminus.

Past monitoring efforts (1985–2004) showed that outfall effects were minimal and that "normal" communities were present beyond the ZID (OCSD 1996, 2003–2006). The 2005–2010 monitoring surveys, on the other hand, revealed a general decline in community health at stations within the ZID since 2005 that resulted in degraded conditions within the ZID and changed conditions at several stations near the outfall diffuser (OCSD 2007–2012). As these changes coincided with the implementation of three wastewater treatment modifications beginning in 2002 (see Chapter 1), District staff conducted the following studies to determine the extent and cause(s) of the changes in benthic assemblages that began in 2005: (1) a redistribution and increased density of sampling sites near the discharge in July 2011 and January 2012 in order to assess the spatial extent of these changes; (2) statistical correlation analyses of treatment plant operations and environmental monitoring data to identify potential causes (e.g., polymer and bleach usage, final effluent flow rates); (3) the potential effect of wastewater reclamation (e.g., decreased final effluent volume and reverse osmosis reject stream constituents); and (4) the formation of chlorination by-products from effluent disinfection. Results to date are presented in Chapter 7. Despite the aforementioned changes, recent monitoring data (2011-12) indicated that the infaunal communities had improved (OCSD 2013).

METHODS

Field Methods

A 0.1 m^2 modified paired Van Veen sediment grab sampler was used to collect one infaunal sample each from 29 semi-annual stations at depths from 52–65 m in July 2012 (summer) and March 2013 (winter) and from 39 annual stations at depths from 40–303 m in July 2012 (Figure 5-1). The annual stations were not sampled in winter as in the previous survey, as this protocol was omitted from the new 2012 NPDES permit. The purpose of the semi-annual stations survey was to determine long-term trends and potential effects along the 60 m depth contour, while the annual stations survey was primarily to assess the spatial extent of the influence of the effluent discharge. Each station was assigned to one of six depth categories: (1) middle shelf Zone 1 (31–50 m); (2) middle shelf Zone 2, within-ZID (51–90 m); (3) middle shelf Zone 2, non-ZID (51–90 m); (4) middle shelf Zone 3 (91–120 m); (5) outer shelf (121–200 m); and (6) upper slope/canyon (201–500 m). In the following sections, the middle shelf Zone 2, within- and non-ZID stations are simply referred to as within-ZID and non-ZID stations, respectively. Each sample was gently washed with filtered seawater through a 1.0 mm sieve. Retained organisms were rinsed into one liter plastic containers and anesthetized with 7% magnesium sulfate for approximately 30 minutes. To preserve the animals, full strength buffered formaldehyde was then added to achieve a 10%, by volume, solution and returned to the laboratory.

Laboratory Methods

After 3–10 days in formalin, each sample was rinsed with water and transferred to 70% ethanol for long-term preservation. Samples were sent to Weston Solutions, Inc. and Marine Taxonomic Services, Inc. where they were sorted to five taxonomic groups: Polychaeta (worms), Mollusca (snails, clams, etc.), Crustacea (shrimps, crabs, etc.), Echinodermata (sea stars, sea urchins, etc.), and miscellaneous phyla (Cnidaria, Nemertea, etc.). Upon completion of sample sorting, the taxonomic groups were distributed for identification and enumeration according to the schedule in Table A-7. Species names used herein follow those given in the Southern California Association of Marine Invertebrate Taxonomists (SCAMIT) List, Edition 6 (Cadien and Lovell 2011).

Data Analyses

Infaunal organisms were classified into the five aforementioned taxonomic groups as appropriate to facilitate comparisons between stations and depth. Six measures were used to assess infaunal community health and function: (1) total number of species (richness); (2) total number of individuals (abundance); (3) Shannon-Wiener Diversity Index (H′); (4) Swartz's 75% Dominance Index (SDI); (5) Infaunal Trophic Index (ITI); and (6) Benthic Response Index (BRI). Margalef Species Richness and Species Evenness were not calculated as in the previous survey, as they were omitted from the new permit. H′ was calculated using $\log_e$ (Zar 1999). SDI was calculated as the minimum number of species with combined abundance equal to 75% of the individuals in the sample (Swartz 1978). SDI is inversely proportional to numerical dominance, thus a low index value indicates high dominance (i.e., a community dominated by a few species). The ITI was developed by Word (1978, 1990) to provide a measure of infaunal community "health" based on a species' mode of feeding (e.g., primarily suspension vs. deposit feeder). ITI values greater than 60 are considered indicative of a "normal" community, while 30–60 represent a "changed" community, and values less than 30 indicate a "degraded" community. The BRI measures the pollution tolerance of species on an abundance-weighted average basis (Smith *et al.* 2001). This measure is scaled inversely to ITI with low values (<25) representing reference conditions and high values (>72) representing defaunation or the exclusion of most species. The intermediate value range 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, as it is a commonly used southern California benchmark for infaunal community structure and was developed with the input of regulators (Ranasinghe *et al*. 2007, 2012).

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 outfall and some (e.g., *Capitella capitata* Complex) can dominate the calculation of community measures. The presence of the pollution sensitive species typically indicates 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 select crustacean species from the amphipod genera *Ampelisca* and *Rhepoxynius*. The pollution tolerant species include *C. capitata* Complex (polychaete) and *Euphilomedes carcharodonta* (ostracod crustacean). Patterns of these species were used to assess the spatial and temporal influence of the wastewater discharge in the receiving environment.

Spatial patterns of community measures and species for the Summer 2012 and Winter 2013 data sets were assessed qualitatively using geographic data maps created with MapInfo v11.5 (Mapinfo 2012). PRIMER v6 (2001) multivariate statistical software was used to examine the spatial patterns of infaunal invertebrate communities in the monitoring area for Summer 2012. 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). Only the middle shelf Zones 1–3 stations were used in the analyses since Clarke and Warwick (2001) warn that clustering 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 to incorporate the less common species (Clarke and Warwick 2001). The SIMPER ("similarity percentages") routine in PRIMER was also used to determine inter- and intra-group species differences.

For the Summer 2012 data set, relationships of community metrics and indicator species with physical (i.e. percent fine sediments) and chemical (i.e., the sewage marker total linear alkylbenzenes (tLAB), percent total organic carbon (TOC), and dissolved sulfides) sediment characteristics were assessed using the Pearson Product Moment Correlation function on the Minitab® Statistical Software package (MINITAB 2007). Correlation analyses were made only on middle shelf Zones 1 and 2 stations to eliminate depth-related factors. Regression analysis also was performed with Minitab to measure relationships of the occurrence of indicator species with depth. Statistical significance was set at $\alpha = 0.05$.

Long-term trends of community measures and indicator species were evaluated graphically (qualitatively) between two semi-annual station groups: the within-ZID group comprising Stations 0, 4, and ZB, and the non-ZID group consisting of Stations 1, 5, 9, 12, C, and CON. These 60 m within- and non-ZID stations represent those that have been sampled quarterly since 1985. A more complete summary of methods for the analyses and the indices used in this chapter are presented in Appendix A.

The following is a summary of primarily the Summer 2012 survey, with community measure results and spatial trends discussed either broadly in terms of the depth categories (e.g., middle shelf Zone 1, within-ZID, etc.) or at specific stations as appropriate. The Winter 2013 data are not discussed in detail except where the differences between the summer and winter data are noteworthy.

RESULTS AND DISCUSSION

Taxa and Abundance

A total of 676 invertebrate taxa comprising 36,313 individuals were collected in the 2012-13 monitoring year. Although the former value is higher than that of the previous year (n = 615), the latter is considerably lower than the 41,538 individuals collected in 2011-12. Indeed, the number of individuals collected this monitoring period is the lowest since 1985 (Table 5-1). This dramatic decline is likely attributed to the relatively low number of samples collected during the present monitoring period (n = 97) as compared to previous years (n = 138–313; Table 5-1).

As with the previous surveys, the mean number of species and individuals of the major taxonomic groups was generally higher at the shallower stations as compared to the deeper stations, and the Polychaeta was the dominant taxonomic group at all depth categories (Table 5-2). The mean number of species and individuals of each of the five

Table 5-1. Total number of samples, species, and individuals (abundance) of infauna collected from the 1985-1986 monitoring period to the present study period.

Orange County Sanitation District, California.

Monitoring period	Total Number of Samples	Total Number of Species	Total Abundance
1985-1986	300	647	209,882
1986-1987	300	661	172,787
1987-1988	300	643	166,475
1988-1989	300	662	214,802
1989-1990	300	658	174,454
1990-1991	300	665	160,734
1991-1992	300	651	161,525
1992-1993	300	663	135,083
1993-1994	300	678	172,403
1994-1995	196	698	135,739
1995-1996	300	730	186,408
1996-1997	300	688	130,597
1997-1998	313	715	136,268
1998-1999	159	637	68,879
1999-2000	159	621	71,195
2000-2001	159	627	71,760
2001-2002	159	639	75,401
2002-2003	159	593	60,174
2003-2004	159	708	58,682
2004-2005	159	593	61,466
2005-2006	159	688	107,451
2006-2007	159	597	60,832
2007-2008	159	602	67,883
2008-2009	159	688	58,212
2009-2010	159	710	58,773
2010-2011	159	618	58,800
2011-2012	138	615	41,538
2012-2013	97	676	36,313

Table 5-2. Species richness and abundance of major taxonomic groups by station depth categories in Summer 2012. Values represent the mean and range (in parentheses).

Orange County Sanitation District, California.

Community Measure	Depth (m)	Polychaeta	Crustacea	Mollusca	Misc. Phyla	Echinodermata
Number of Species	Middle shelf Zone 1 (31–50)	47 (38–58)	32 (24–38)	10 (6–13)	8 (6–15)	5 (3–6)
	Middle shelf Zone 2, within-ZID (51–90)	48 (43–52)	27 (25–28)	15 (11–18)	6 (2–8)	3 (2–4)
	Middle shelf Zone 2, non-ZID (51–90)	45 (21–60)	28 (3–35)	14 (6–21)	6 (2–11)	4 (1–7)
	Middle shelf Zone 3 (91–120)	56 (40–72)	16 (8–23)	17 (13–25)	5 (3–8)	3 (1–5)
	Outer shelf (121–200)	25 (16–35)	8 (2–23)	12 (9–15)	2 (0–3)	2 (0–4)
	Upper slope/ Canyon (201–500)	14 (9–22)	3 (1–6)	8 (5–12)	1 (0–1)	1 (0–3)
Abundance of Individuals	Middle shelf Zone 1 (31–50)	205 (120–283)	132 (70–169)	16 (6–24)	15 (9–23)	30 (4–64)
	Middle shelf Zone 2, within-ZID (51–90)	231 (191–304)	103 (61–139)	40 (14–60)	12 (7–14)	9 (7–16)
	Middle shelf Zone 2, non-ZID (51–90)	212 (72–390)	134 (18–228)	31 (18–65)	14 (4–31)	21 (2–75)
	Middle shelf Zone 3 (91–120)	271 (160–353)	57 (25–119)	52 (31–84)	11 (5–16)	64 (33–112)
	Outer shelf (121–200)	80 (29–153)	25 (2–112)	60 (22–88)	2 (0–5)	5 (0–10)
	Upper slope/ Canyon (201–500)	37 (18–58)	5 (1–9)	21 (9–42)	1 (0–1)	2 (0–5)

taxonomic groups in the present survey was similar between within- and non-ZID stations. The Winter 2013 data are presented in Table 5-3, but are not discussed.

The crustacean *E. carcharodonta* was the most abundant species, with 3,435 individuals in total, followed by the polychaetes *Chloeia pinnata* (n = 2,036), *Chaetozone columbiana* (n = 1,981), *Prionospio* (*Prionospio*) *jubata* (n = 1,167), *Sthenelanella uniformis* (n = 1,022) and *Mediomastus* sp. (n = 964), and the echinoderm *A. urtica* (n = 819). These taxa comprised 33% of the total individuals collected during this survey period.

Table 5-3. Species richness and abundance of major taxonomic groups by station depth categories in Winter 2013. Values represent the mean and range (in parentheses).

Orange County Sanitation District, California.

Community Measure	Depth (m)	Polychaeta	Crustacea	Mollusca	Misc. Phyla	Echinodermata
Number of Species	Middle shelf Zone 2, within-ZID (51–90)	51 (40–58)	31 (28–37)	14 (11–19)	7 (3–9)	3 (2–4)
	Middle shelf Zone 2, non-ZID (51–90)	48 (33–73)	30 (23–46)	10 (4–15)	6 (1–12)	4 (1–7)
Abundance of Individuals	Middle shelf Zone 2, within-ZID (51–90)	282 (188–353)	194 (87–322)	25 (21–38)	22 (13–40)	5 (4–7)
	Middle shelf Zone 2, non-ZID (51–90)	222 (102–358)	171 (76–329)	21 (6–41)	10 (1–26)	10 (1–36)

Community Measures

Number of species

The number of species collected in Summer 2012 generally decreased with increasing depth as in the two previous surveys (Table 5-4; Figure 5-2). However, the mean number of species at within-ZID stations was similar to, rather than lower than, that of non-ZID stations in the present survey (means of 99 and 97, respectively) as compared to the 2010 (means of 60 and 91, respectively) and 2011 (means of 76 and 94, respectively) surveys. The mean number of species at within- and non-ZID stations was higher than the two regional reference means (Table 5-4). All within-ZID stations and non-ZID stations (except C2) had species richness values within the OCSD historical ranges of 40–137 and 65–142 species, respectively. Station C2 is located at the head of the Newport Canyon and typically differs from other 60-m, non-ZID stations in sediment characteristics (e.g., percent fines) and contaminant concentrations (see Chapter 4), all of which affect species composition and distribution. Number of species was not significantly correlated with tLAB, percent fine sediments, dissolved sulfides, or TOC, indicating that the variations in species richness at middle shelf Zone 1 and 2 stations were not associated with the outfall discharge.

Table 5-4. Summary of infaunal community measures sorted by depth and stations sampled during the Summer 2012 survey, as well as regional and historical values.

Orange County Sanitation District, California.

Station	Depth (m)	Total Number of Species	Total Abundance	Shannon-Wiener Diversity Index (H')	Swartz's 75% Dominance Index	Infaunal Trophic Index (ITI)	Benthic Response Index (BRI)
				Middle shelf Zone 1 (31–50 m)			
7	41	110	389	4.25	40	86	18
8	44	121	381	4.20	44	78	19
21	44	106	438	3.95	31	80	21
22	45	95	271	4.08	38	95	17
30	46	104	412	4.00	33	80	17
36	45	111	404	4.00	39	85	18
55	40	89	405	3.80	27	75	18
59	40	86	488	3.63	24	75	19
	Mean	**103**	**399**	**3.99**	**35**	**82**	**18**
				Middle shelf Zone 2, within-ZID (51–90 m)			
0 *	56	88	433	3.49	21	46	25
4 *	56	98	424	3.75	31	76	19
76 *	58	101	328	3.90	34	72	24
ZB *	56	107	390	4.00	35	75	23
	Mean	**99**	**394**	**3.79**	**30**	**67**	**23**
				Middle shelf Zone 2, non-ZID (51–90 m)			
1*	56	100	489	3.68	26	77	20
3*	60	117	667	3.69	27	71	18
5*	59	109	618	3.72	27	74	15
9*	59	108	342	4.04	41	79	14
10	60	88	373	3.43	23	76	16
12*	58	98	298	3.83	35	83	15
13	59	93	369	3.78	28	84	16
37	56	114	403	4.23	45	78	18
68*	52	88	288	3.93	32	79	19
69*	52	98	367	3.81	32	86	13
70*	52	99	413	3.90	33	74	16
71*	52	93	361	3.74	30	75	21
72*	55	101	475	3.68	27	77	17
73*	55	119	532	3.93	29	70	24
74*	57	93	358	3.90	33	68	23
75*	60	80	366	3.84	27	72	22
77*	60	98	307	4.00	39	81	18
78*	63	86	269	3.69	29	79	17
79*	65	106	470	3.68	30	75	15
80*	65	118	564	4.05	35	83	14
81*	65	95	487	3.57	25	73	19
82*	65	103	360	3.90	36	76	19
84*	54	104	600	3.76	26	70	22
85*	57	73	276	3.50	22	67	27
86*	57	113	492	3.75	29	71	20
87*	60	113	554	3.84	31	77	16
88*	57	89	354	3.80	30	89	16
C*	56	37	145	3.11	15	88	45
C2	56	92	359	3.73	31	77	16
CON*	59	97	412	3.78	30	77	19
	Mean	**100**	**489**	**3.68**	**26**	**77**	**20**

Table 5-4 Continues.

Table 5-4 Continued.

Station	Depth (m)	Total Number of Species	Total Abundance	Shannon-Wiener Diversity Index (H')	Schwartz' 75% Dominance Index	Infaunal Trophic Index (ITI)	Benthic Response Index (BRI)
Middle shelf Zone 3 (91–120 m)							
17	91	107	495	3.84	28	78	15
18	91	100	465	3.82	32	83	14
20	100	97	546	3.70	26	85	17
23	100	99	489	3.85	26	83	17
29	100	74	303	3.67	24	88	19
33	100	121	531	4.20	42	67	22
38	100	89	543	3.71	25	78	25
56	100	97	422	3.98	32	83	18
60	100	91	377	3.81	27	84	21
83	100	98	373	3.98	36	81	17
	Mean	**97**	**454**	**3.86**	**30**	**81**	**19**
Outer shelf (121–200 m)							
24	200	57	182	3.32	21	76	18
25	200	43	137	3.16	15	77	24
27	200	58	216	3.51	22	74	22
39	200	78	367	3.61	22	77	18
44	241	36	69	3.37	19	60	22
57	200	34	97	2.86	12	43	27
61	200	46	170	2.99	12	70	26
63	200	50	186	3.30	18	70	24
65	200	40	129	3.07	13	65	27
C4	187	49	173	3.24	17	68	23
	Mean	**57**	**182**	**3.32**	**21**	**76**	**18**
Upper slope/canyon (201–500 m)							
40	303	33	72	3.18	16	50	26
41	303	31	90	2.98	11	38	30
42	303	28	66	2.98	13	53	22
58	300	20	49	2.59	8	–	25
62	300	27	70	2.81	13	57	25
64	300	17	29	2.58	10	67	18
C5	296	29	69	3.14	14	52	24
	Mean	31	74	2.89	13	100	24
Regional reference values (mean)							
Bight'03 LPOTW**		90	396	3.68	29	NC	17
Bight'03 MSN-POTW**		76	321	3.60	26	NC	14
OCSD historical values (range)							
OCSD within-ZID 1998–2010		40–137	184–2686	0.78–4.19	1-41	1-84	20–43
OCSD non-ZID 1998–2010		65–142	163–1055	2.99–4.31	11–46	42–94	9–30

*Semi-annual station.
**Source: Ranasinghe *et al*. (2007).
Abbreviations: ZID = Zone of Initial Dilution; LOPTW = Large POTW; MSN-POTW = Middle shelf non-POTW; NC = Not calculated.

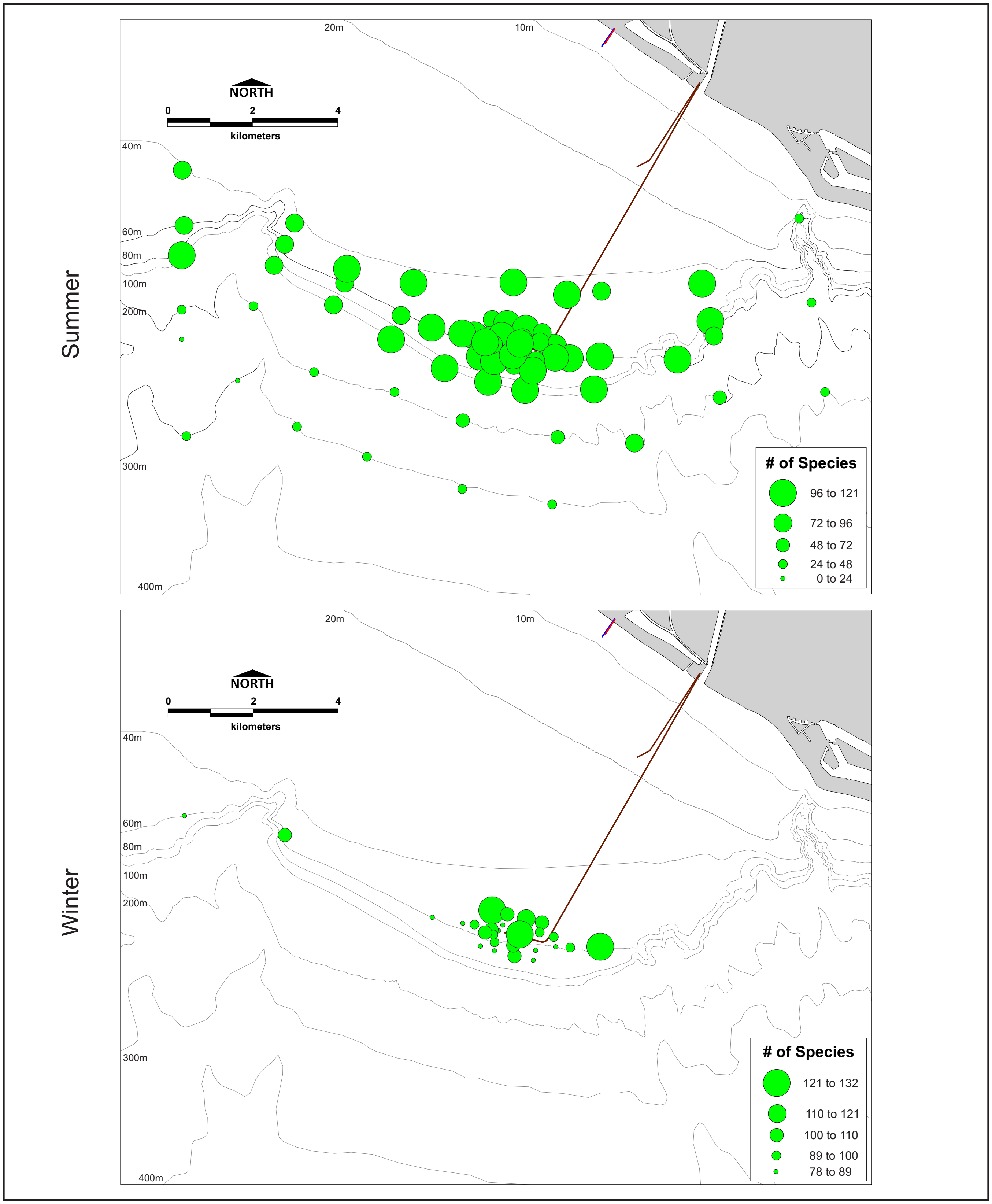


Figure 5-2. **Spatial trend bubble plots of number of species for Summer 2012 (top) and Winter 2013 (bottom).**

Orange County Sanitation District, California.

Abundance

Infauna abundances in the Summer 2012 survey followed the same general pattern as for number of species, with markedly lower abundances at the deeper stations (Table 5-4; Figure 5-3). As with the 2011 survey, mean abundance was similar between within- and non-ZID stations. The mean abundance at within- and non-ZID stations exceeded the middle shelf non-Publically Owned Treatment Works (MSN-POTW) regional reference value (Table 5-4). All within-ZID stations and non-ZID stations (except C2) had abundances within the respective OCSD historical ranges. Abundance was not significantly correlated with any of the sediment characters, indicating that variations in species abundances at middle shelf Zone 1 and 2 stations were not associated with discharged wastewater particulates.

Shannon-Wiener Diversity Index (H′)

Consistent with the Summer 2011 survey, the mean H′ values in the present survey generally decreased with increasing depth (Table 5-4; Figure 5-4). However, the mean H′ value at within-ZID stations was similar to, rather than lower than, that of non-ZID stations in the present survey (means of 3.79 and 3.78, respectively) as compared to the previous survey (means of 2.99 and 3.40, respectively). The mean H′ value at within- and non-ZID stations was higher than the two regional reference means (Table 5-4). H′ values at all within- and non-ZID stations were also within the respective OCSD historical ranges. H′ was weakly correlated with both tLAB (r = -0.385, p = 0.014) and percent fine sediments (r = 0.358, p = 0.023), indicating species diversity at middle shelf Zones 1 and 2 is to a certain extent influenced concomitantly by the effluent and sediment grain size.

Swartz's 75% Dominance Index (SDI)

As with the three aforementioned community measures, mean SDI values in the Summer 2012 survey were larger at the shallower stations than at the deeper stations (Table 5-4; Figure 5-5). The mean SDI value at within-ZID stations (mean of 30) was identical to that of non-ZID stations in the present survey as opposed to the 2010 (means of 12 and 32, respectively) and 2011 (means of 13 and 20, respectively) surveys. The mean SDI value at within- and non-ZID stations was marginally higher than the two regional reference means (Table 5-4). Furthermore, SDI values at all within- and non-ZID stations were within the respective OCSD historical ranges. SDI was moderately correlated with tLAB (r = -0.453, p = 0.003) and weakly correlated with percent fine sediments (r = 0.370, p = 0.019), indicating species equitability at middle shelf Zones 1 and 2 is influenced by the effluent and to a lesser extent by sediment grain size.

Infaunal Trophic Index (ITI)

For the Summer 2012 survey, the mean ITI score was lowest (60) at the deepest depth category (Table 5-4; Figure 5-6). All non-ZID stations had ITI scores above 60 (indicating a "normal" community) unlike the previous survey year when two non-ZID stations (73 and 87) had ITI scores within the 30–60 range (representing a "changed" community). More importantly, the ITI score at Station 0 was not only higher in Summer 2012 (46) than in Summer 2010 and 2011 (2 and 23, respectively), but was also higher in Winter 2013 than in Summer 2012 (Tables 5-4 and 5-5). This marked improvement of the infaunal

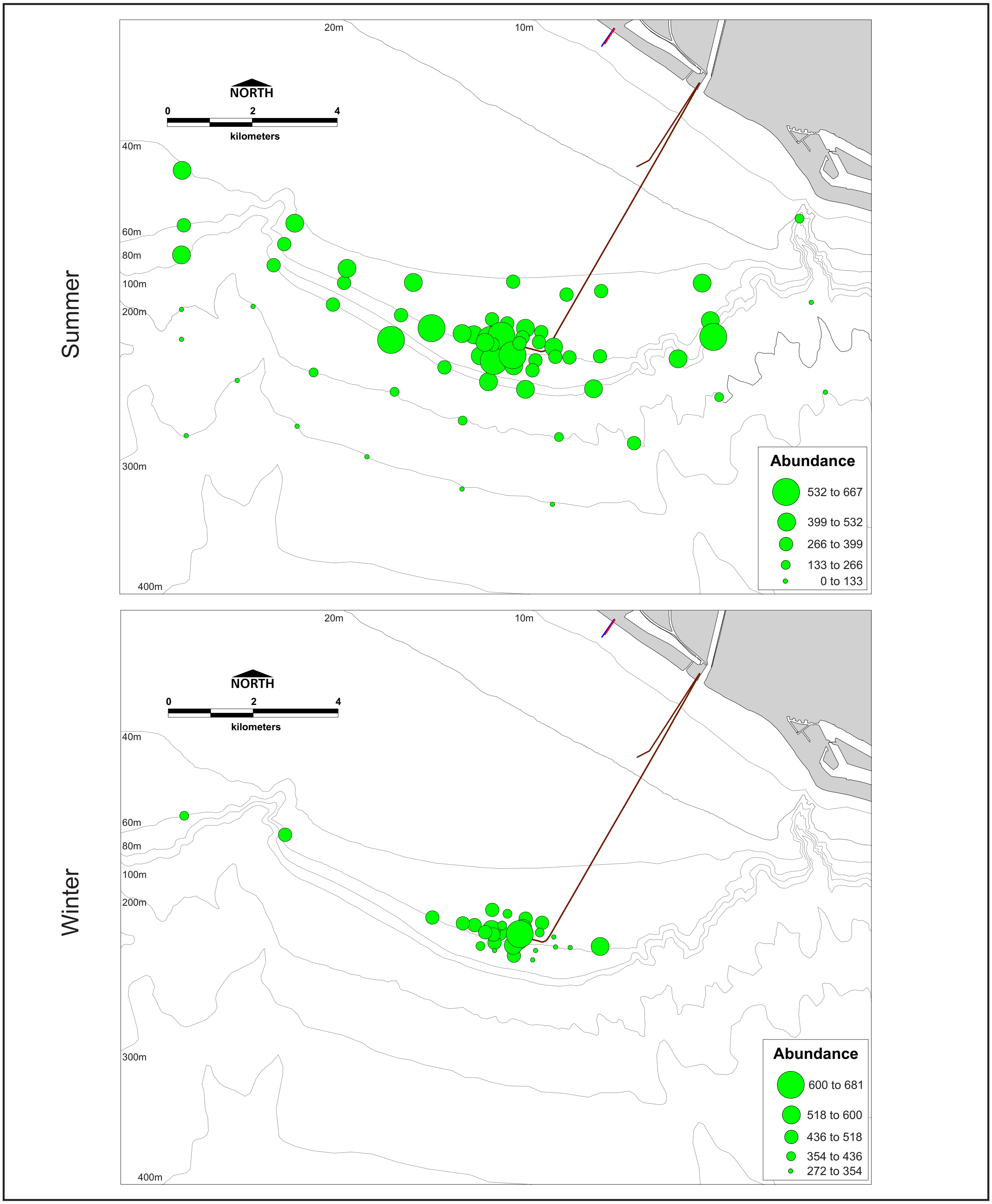


Figure 5-3. **Spatial trend bubble plots of abundance for Summer 2012 (top) and Winter 2013 (bottom).**

Orange County Sanitation District, California.

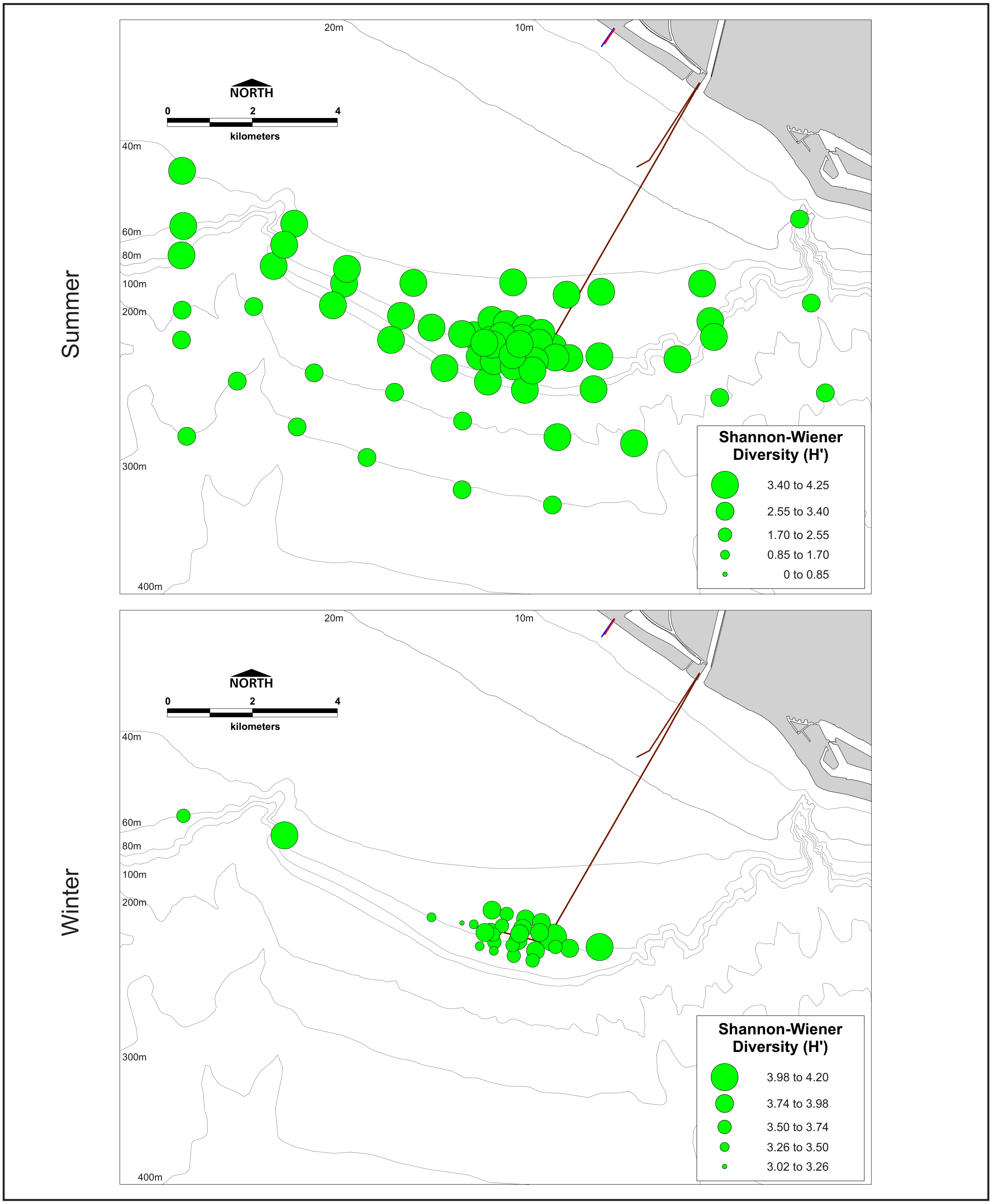


Figure 5-4. Spatial trend bubble plots of Shannon-Wiener Diversity Index (H') for Summer 2012 (top) and Winter 2013 (bottom).

Orange County Sanitation District, California.

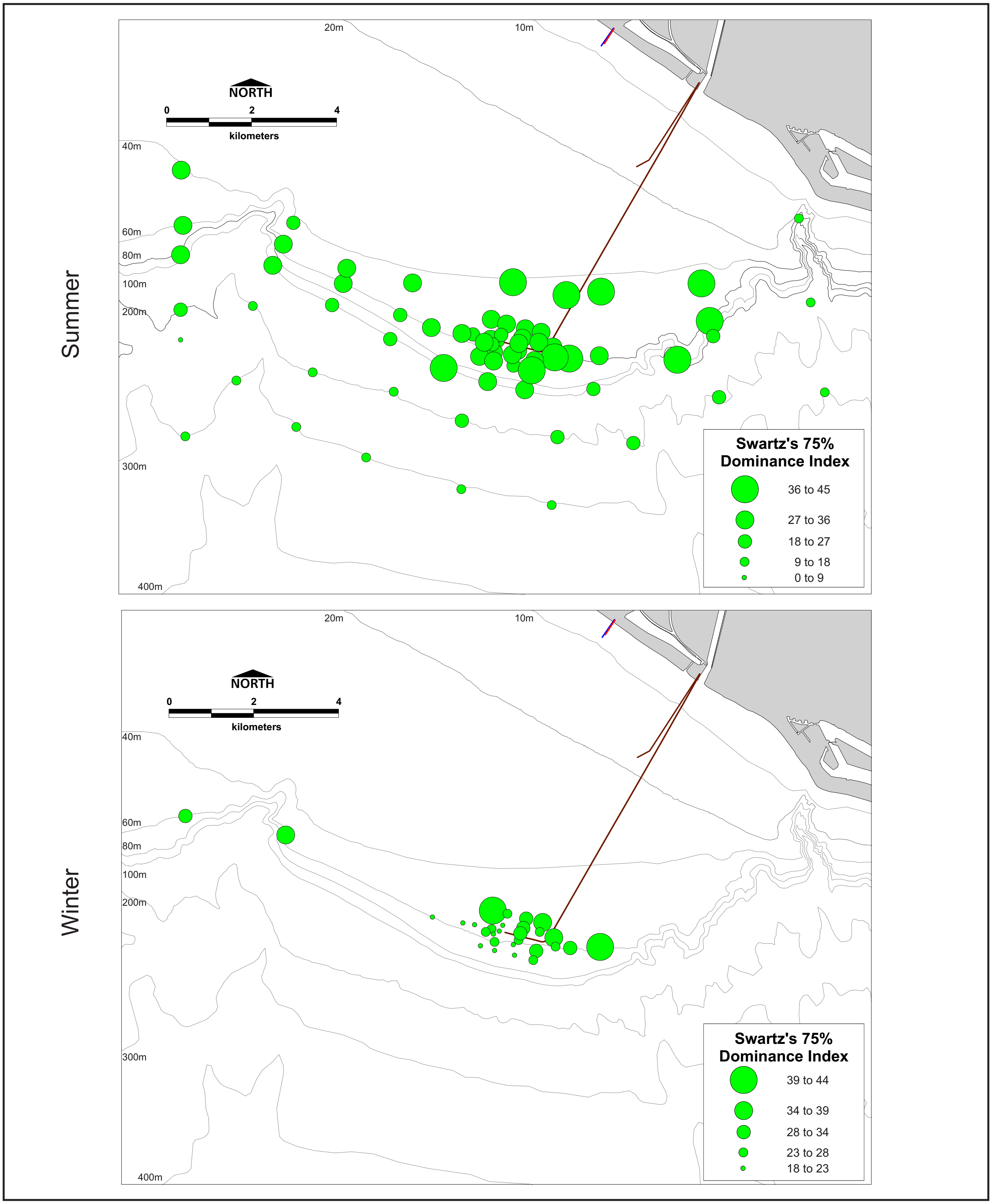


Figure 5-5. **Spatial trend bubble plots of Swartz's 75% Dominance Index (SDI) for Summer 2012 (top) and Winter 2013 (bottom).**

Orange County Sanitation District, California.

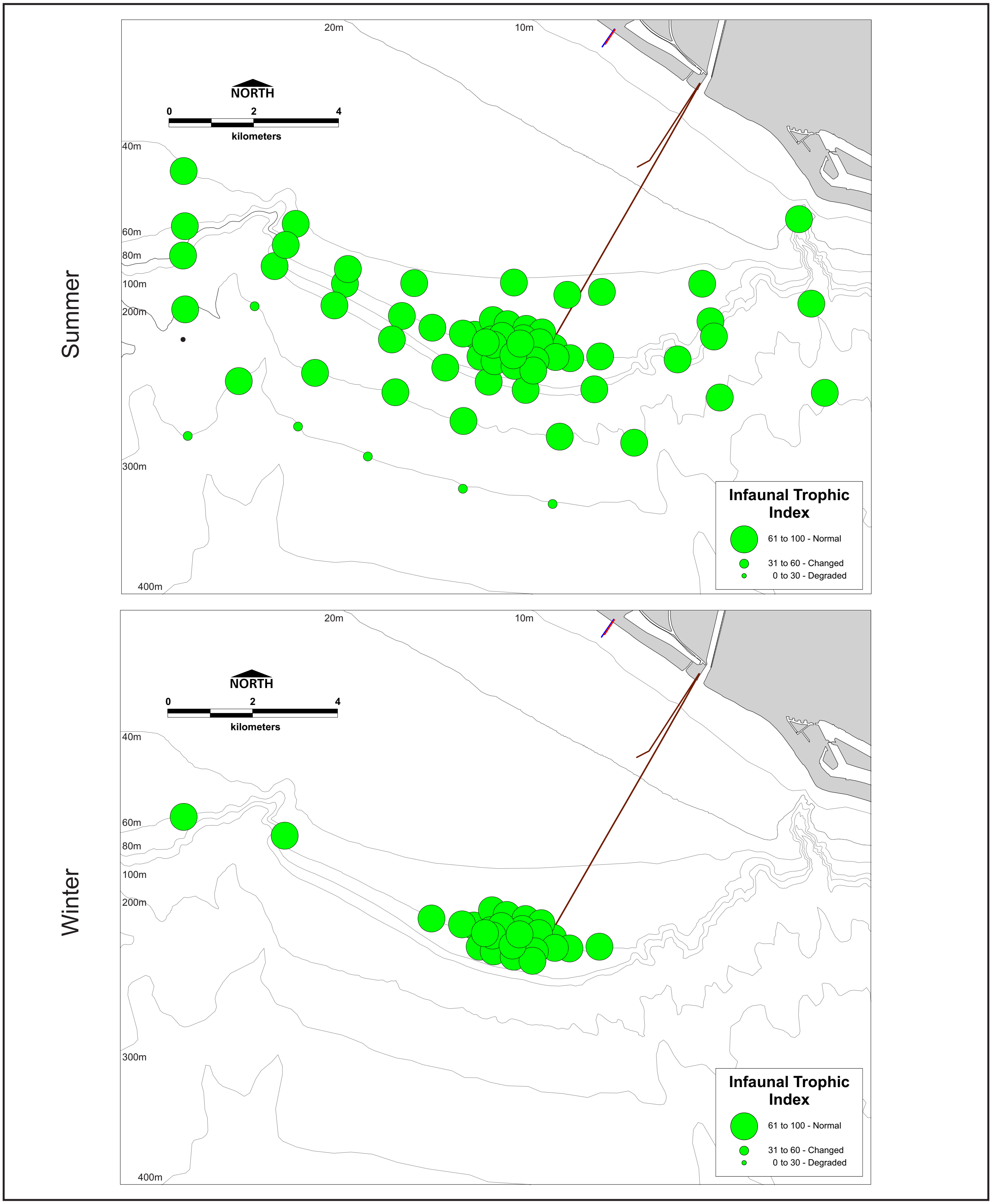


Figure 5-6. **Spatial trend bubble plots of Infaunal Trophic Index (ITI) for Summer 2012 (top) and Winter 2013 (bottom).**

Orange County Sanitation District, California.

Table 5-5. Summary of infaunal community measures sorted by depth and stations sampled during the Winter 2013 survey, as well as regional and historical values.

Orange County Sanitation District, California.

Station	Depth (m)	Total Number of Species	Total Abundance	Shannon-Wiener Diversity Index (H')	Swartz's 75% Dominance Index	Infaunal Trophic Index (ITI)	Benthic Response Index (BRI)
Middle shelf Zone 2, within-ZID (51–90 m)							
0	56	88	540	3.47	18	73	25
4	56	99	314	4.01	37	84	16
7	58	106	574	3.74	24	80	20
ZB	56	125	681	3.87	30	73	20
	Mean	**105**	**527**	**3.77**	**27**	**78**	**20**
Middle shelf Zone 2, non-ZID (51–90 m)							
1	56	95	469	3.30	19	69	21
3	60	96	461	3.51	24	70	19
5	59	87	440	3.38	23	74	16
9	59	92	315	3.91	31	85	19
12	58	132	538	4.19	44	85	15
68	52	129	474	3.79	40	76	13
69	52	102	373	3.57	28	77	16
70	52	115	479	3.92	33	84	17
71	52	109	440	3.95	34	82	18
72	55	81	512	3.02	19	74	16
73	55	108	579	3.73	26	76	22
74	57	108	525	3.82	29	76	19
75	60	93	427	3.85	28	83	21
77	60	78	289	3.72	25	74	19
78	63	84	301	3.74	29	74	18
79	65	79	398	3.35	20	77	16
80	65	79	331	3.48	23	81	13
81	65	100	505	3.53	22	77	16
82	65	81	272	3.70	28	79	20
84	54	84	414	3.56	21	75	21
85	57	93	462	3.63	23	68	21
86	57	101	485	3.74	28	76	19
87	60	104	536	3.55	22	72	19
C	56	109	459	4.04	37	87	13
CON	59	88	385	3.64	29	73	19
	Mean	**97**	**435**	**3.66**	**27**	**77**	**18**
Regional reference values (mean)							
Bight'03 LPOTW*		90	396	3.68	29	NC	17
Bight'03 MSN-POTW*		76	321	3.60	26	NC	14
OCSD historical values (range)							
OCSD within-ZID 1998–2010		40–137	184–2686	0.78–4.19	1-41	1-84	20–43
OCSD non-ZID 1998–2010		65–142	163–1055	2.99–4.31	11–46	42–94	9–30

*Source: Ranasinghe *et al*. (2007).

Abbreviations: ZID = Zone of Initial Dilution; LOPTW = Large POTW; MSN-POTW = Middle shelf non-POTW; NC = Not calculated.

communities in the monitoring area is likely due to the treatment plant operating at full secondary treatment levels coupled with the approximate 90% reduction in chlorine bleach usage for effluent disinfection. ITI was strongly correlated with tLAB (r = -0.785, p = 0.000) and weakly correlated with percent fine sediments (r = 0.353, p = 0.026), suggesting the health of the infaunal community within middle shelf Zones 1 and 2 is highly influenced by the effluent.

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

In the Summer 2012 survey, mean BRI scores were below 25 (indicating reference conditions) at all depth categories (Table 5-4; Figure 5-7). Among non-ZID stations, all but two (85 and C2) had scores ≤25. Station 85 had a score of 27, indicating a marginal deviation from reference conditions, while Station C2 had a score of 45, indicating a loss of biodiversity. However, in Summer 2011, four additional non-ZID stations (73, 75, 84, and 86) had BRI scores greater than 25 (range of 26–32). The infaunal community in the outfall area has further improved as evidenced by the decrease in BRI scores at Station 0 from 45 in Summer 2010 to 36 in Summer 2011 and 25 in Summer 2012. BRI scores were moderately correlated with tLAB (r = 0.585, p = 0.000) and weakly correlated with both percent fine sediments (r = -0.321, p = 0.044) and dissolved sulfides (r = 0.367, p = 0.020), suggesting the outfall discharge is an important factor in structuring the infaunal community within middle shelf Zones 1 and 2.

Temporal (long-term) Trend Analysis

Long-term trends in community measures for within- and non-ZID stations are presented in Figure 5-8. The infaunal communities at within-ZID stations exhibited a greater degree of interannual variability than those at non-ZID stations. There was no apparent trend over time for the annual mean number of species at non-ZID stations, while there was (until recently) a slight decline in the number of species at ZID stations, particularly Station 0. There was a general trend of declining abundances at within- and non-ZID stations, though this was much more pronounced at the former set of stations. H′ and SDI fluctuated similarly over time at all within-ZID stations. By contrast, H′ remained relatively constant and SDI showed a general increase over time at non-ZID stations. Until 2010, ITI scores at within-ZID stations were declining at Stations 0 and ZB, and to a lesser extent at Station 4. Conversely, ITI scores at non-ZID stations were relatively constant over time, however a dramatic decline in ITI was observed at Station C during 2011-12. BRI scores decreased slightly over time at within-ZID Station 4 and all non-ZID stations, indicating improving conditions. On the other hand, BRI scores at Stations 0 and ZB gradually decreased below 30 from 1985 to 2001, steadily increased above 35 thereafter until 2011, and have decreased precipitously to ≤25 this survey year.

Indicator Species

<u>Pollution Tolerant Species</u>

Euphilomedes carcharodonta

As with previous surveys, the abundance of *E. carcharodonta* during the Summer 2012 survey gradually increased in an upcoast direction from the outfall diffuser (Figure 5-9). *E.*

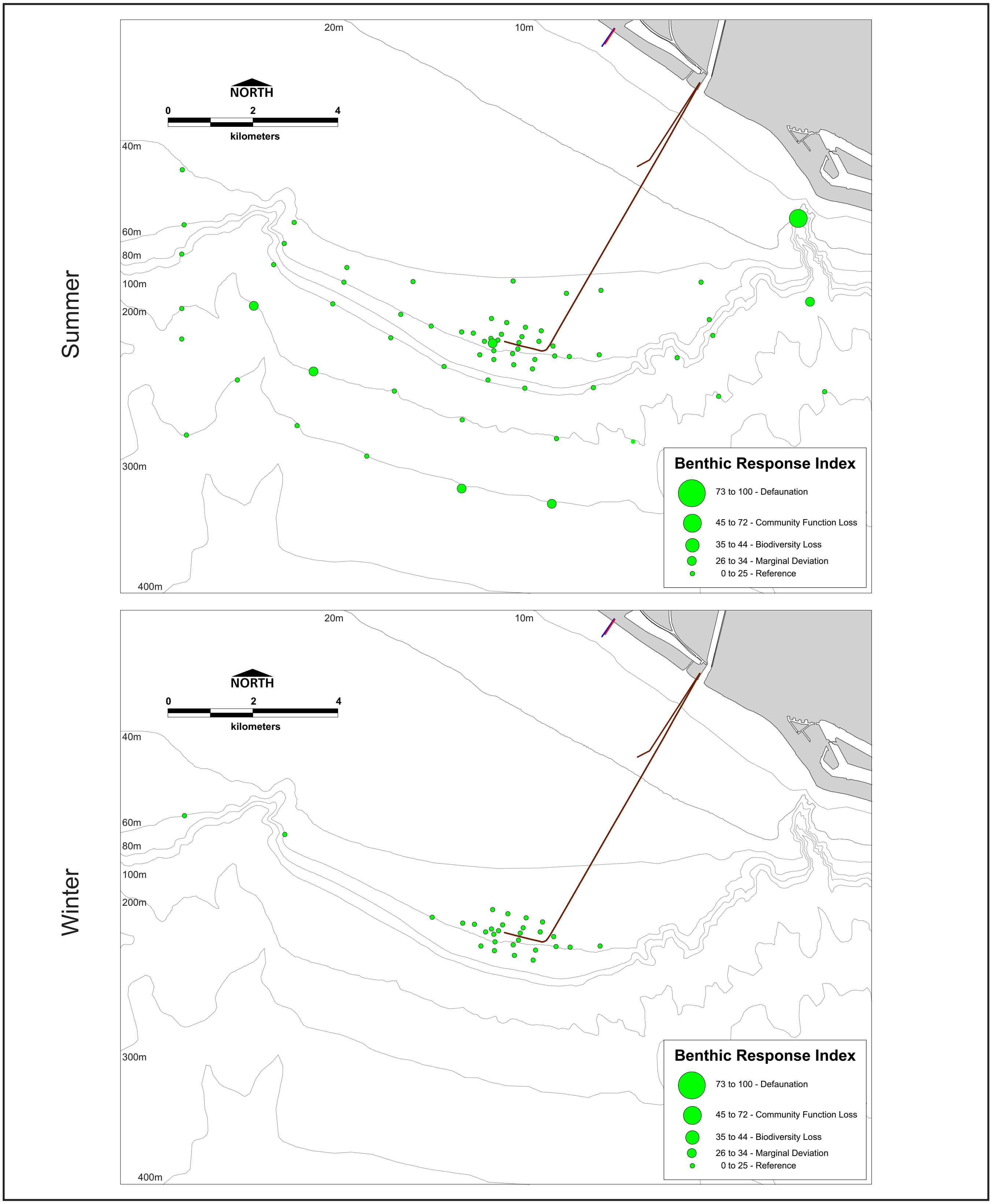


Figure 5-7. **Spatial trend bubble plots of Benthic Response Index (BRI) for Summer 2012 (top) and Winter 2013 (bottom).**

Orange County Sanitation District, California.

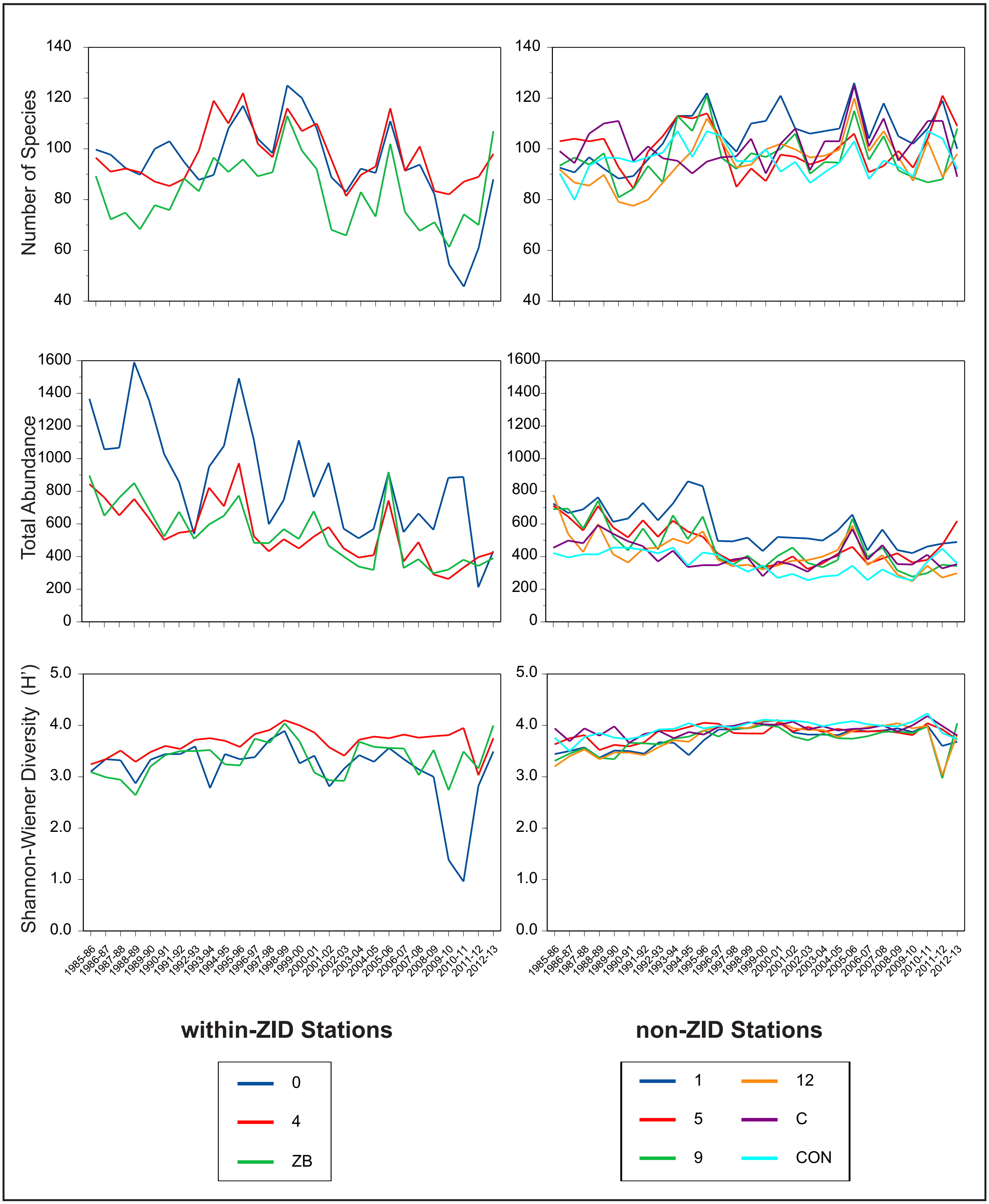


Figure 5-8. **Annual mean values for benthic infauna parameters at selected 60 meter stations for the period 1985–2013: No. of species, abundance, Shannon-Wiener Diversity (H'), Swartz's 75% Dominance, Infaunal Trophic Index (ITI), and Benthic Response Index (BRI).**

ZID = Zone of Initial Dilution

Orange County Sanitation District, California.

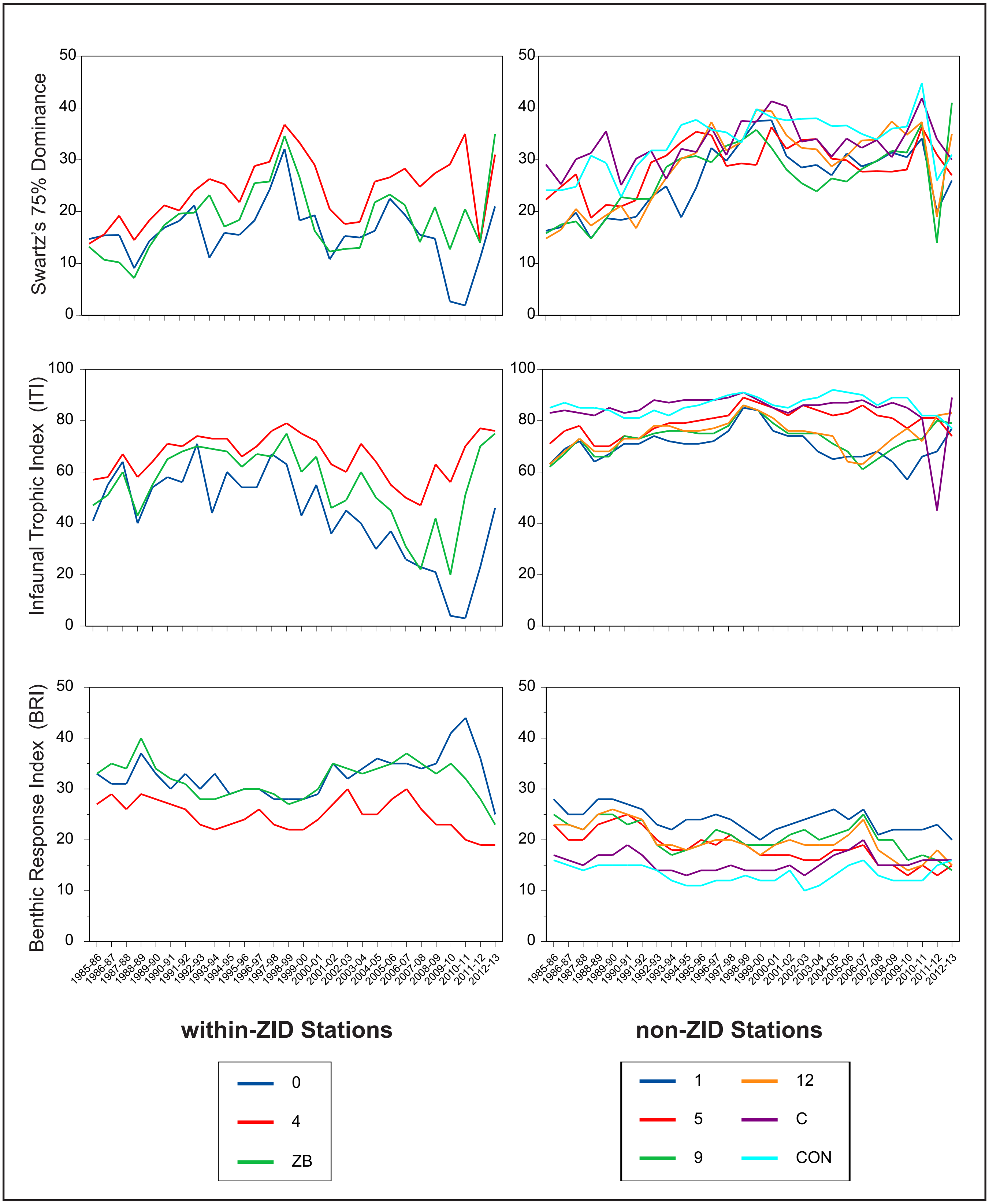


Figure 5-8 continued.

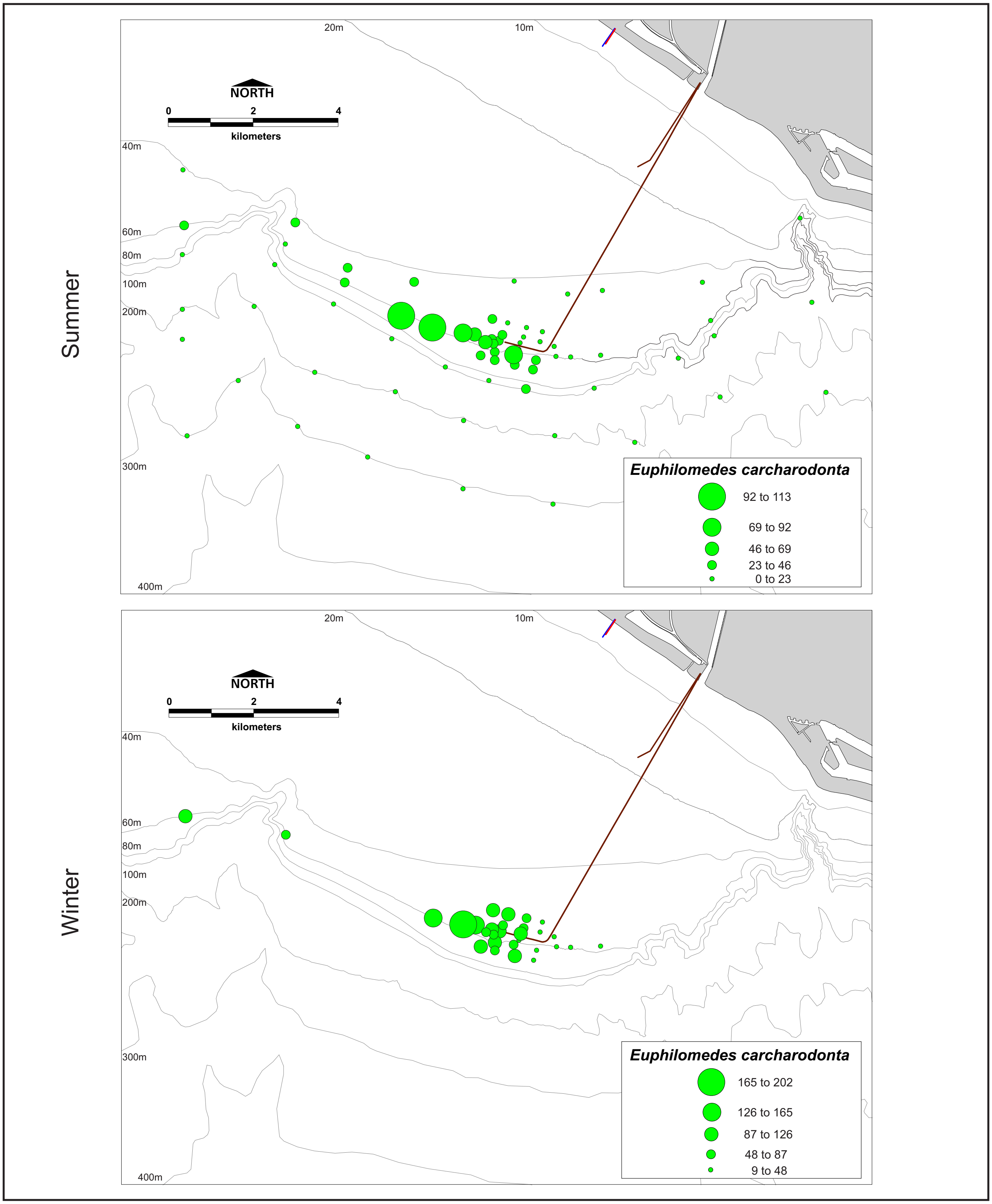


Figure 5-9. **Spatial trend bubble plots of *Euphilomedes carcharodonta* abundance for Summer 2012 (top) and Winter 2013 (bottom).**

Orange County Sanitation District, California.

carcharodonta was more abundant near the outfall, and to a lesser extent at upcoast farfield stations, in Winter 2013 than Summer 2012. Abundance of *E. carcharodonta* was related to depth (R^2 = 0.43, p = 0.000), but was not correlated with any sediment characters. Despite this, *E. carcharodonta* abundance was typically higher near the outfall and in the general direction of effluent plume movement (Figure 5-9). Since 2011, *E. carcharodonta* abundance has increased sharply at within-ZID Stations 0 and ZB, at non-ZID nearfield upcoast Stations 1, 3, and 5, and at non-ZID farfield upcoast Station CON (Figure 5-10), suggesting natural variation in the population dynamics of this species in the monitoring area.

Capitella capitata Complex

Similar to the previous survey year, abundance of *C. capitata* Complex remained low (<4 individuals) at all but one station in Summer 2012 and at all stations in Winter 2013, indicating that conditions continue to improve within the monitoring area (Figure 5-11). Abundance of *C. capitata* Complex was not related to depth, but was strongly correlated with tLAB (r = 0.820, p = 0.000) and moderately with TOC (r = 0.419, p = 0.007), indicating a strong outfall influence on the occurrence of *C. capitata* Complex in the monitoring area. *C. capitata* Complex increased from <100 individuals in 2005 to as many as 1,300 in 2010 at within-ZID Station 0, but declined considerably thereafter to below 100 (Figure 5-10). *C. capitata* Complex increased marginally in numbers from 2008 to 2011 at non-ZID nearfield Stations 1 and 3, but was absent at those stations this year.

<u>Pollution Sensitive Species</u>

Amphiodia urtica

In Summer 2012, *A. urtica* was more abundant at middle shelf Zone 3 stations, and to a lesser extent at upcoast non-ZID stations (Figure 5-12). Unlike the previous survey, *A. urtica* occurred in Summer 2012 at three outer shelf stations (24, 27, and 39), albeit in very low numbers (<5 individuals). Abundance of *A. urtica* was somewhat related to depth (R^2 = 0.16, p = 0.001), and was strongly correlated with percent fines (r = 0.681, p = 0.000) and weakly correlated with dissolved sulfides (r = -0.381, p = 0.015), indicating minimal outfall influence on the occurrence of *A. urtica* in the monitoring area. *A. urtica* abundance remained low (<10 individuals) over time at within-ZID stations and nearfield non-ZID stations (Figure 5-10). Conversely, *A. urtica* was typically more abundant and displayed higher interannual variability at upcoast non-ZID Stations 5, C, and CON.

Amphipods (*Rhepoxynius* spp. and *Ampelisca* spp.)

Similar to the 2011-12 survey, abundances of amphipod species in the genera *Rhepoxynius* and *Ampelisca* in July 2012 were highest at stations located upcoast and inshore of the outfall diffuser (Figure 5-13). Fewer than 10 individuals of these amphipods were collected at most stations deeper than 90 m. Amphipod abundances were related to depth (R^2 = 0.69, p = 0.000), but were not correlated with any sediment characters, indicating no outfall influence on the distribution of amphipods in the monitoring area. Amphipod abundances at within-ZID stations have, until recently, exhibited a decreasing trend over time. By contrast, non-ZID stations had slightly higher amphipod abundances, but no discernible temporal trend (Figure 5-10).

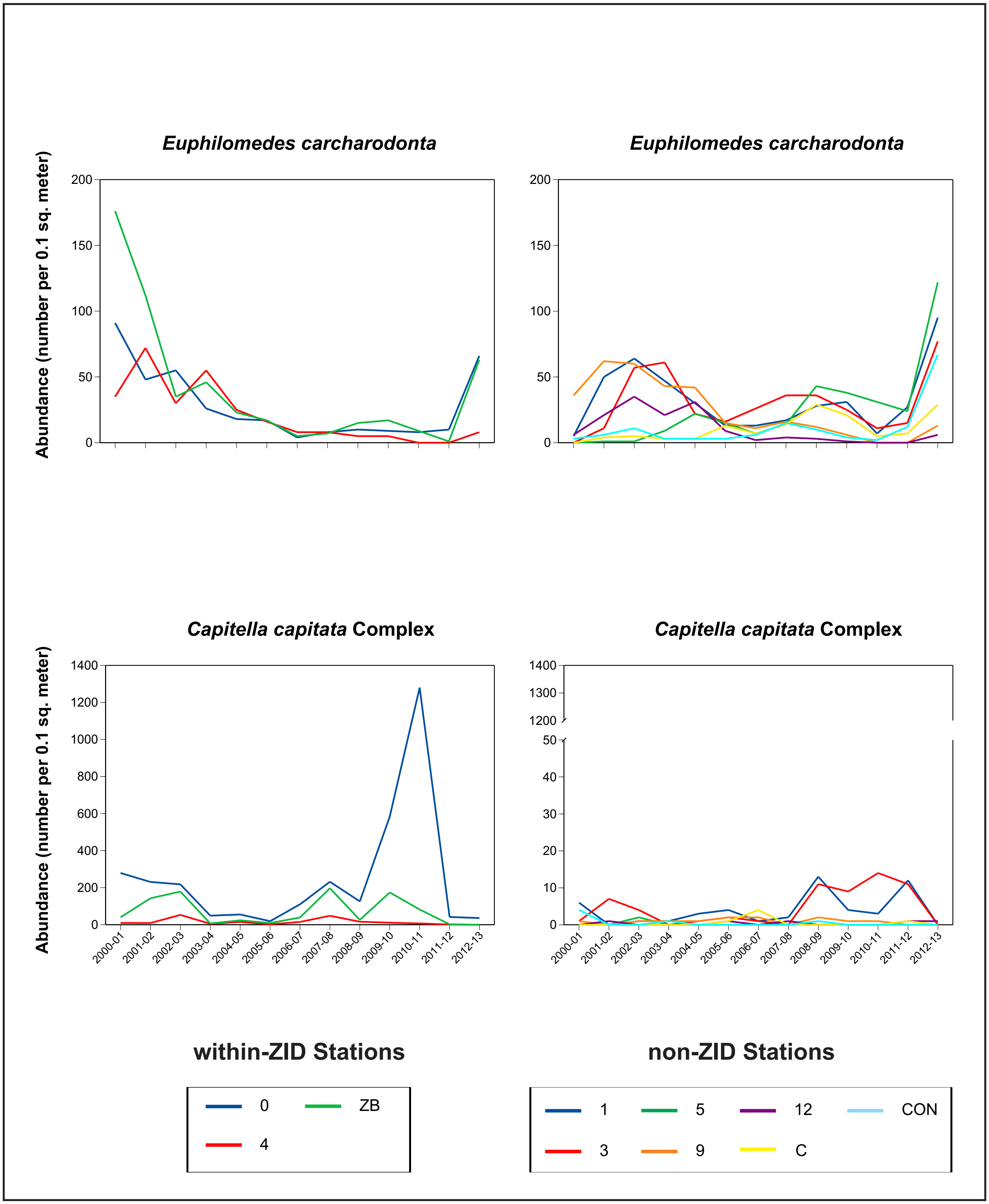


Figure 5-10. **Annual mean values of abundance for the period 2000–2012: *Euphilomedes carcharodonta*, *Capitella capitata* Complex, *Amphiodia urtica*, and amphipods.**

Orange County Sanitation District, California.

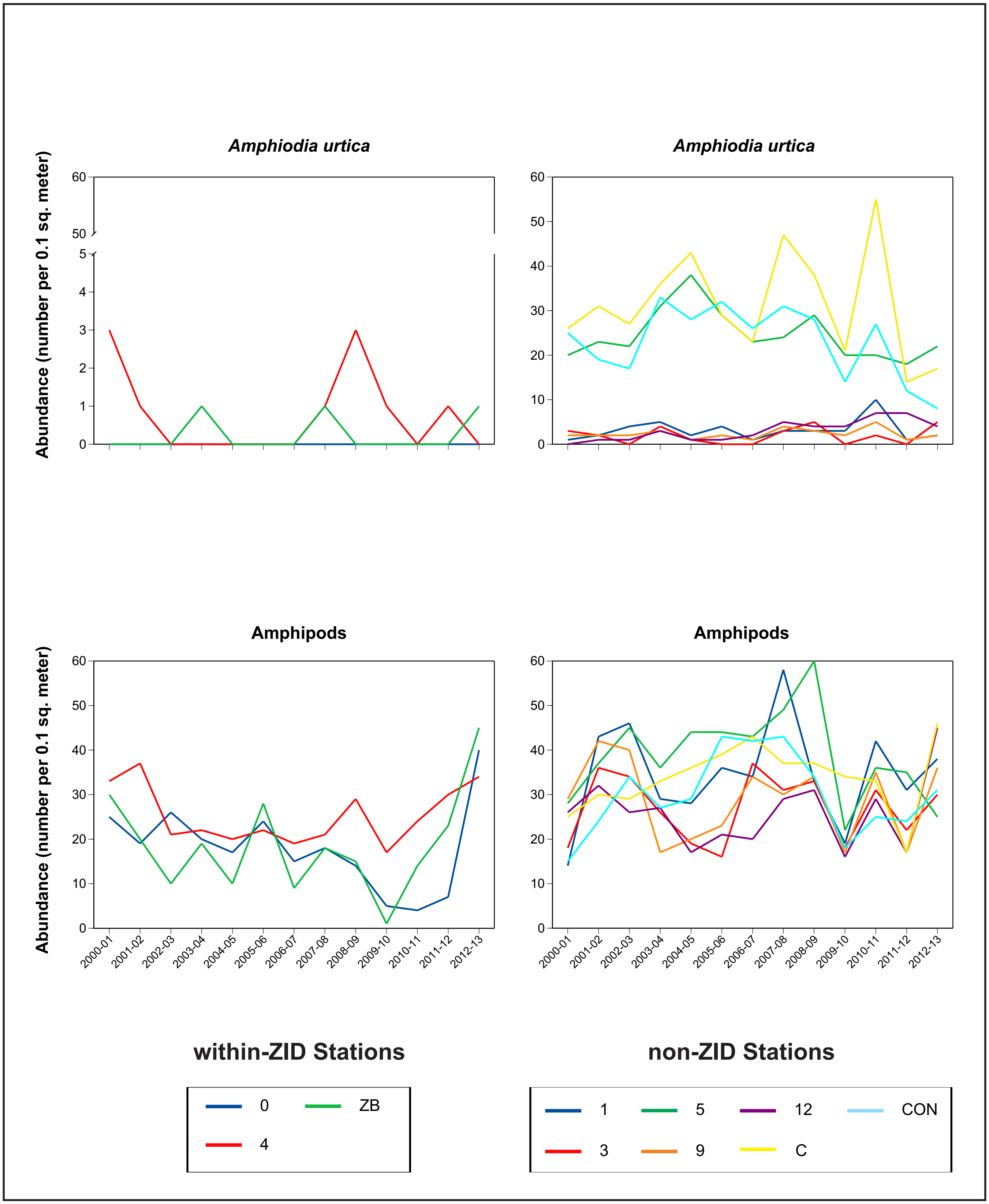


Figure 5-10 continued.

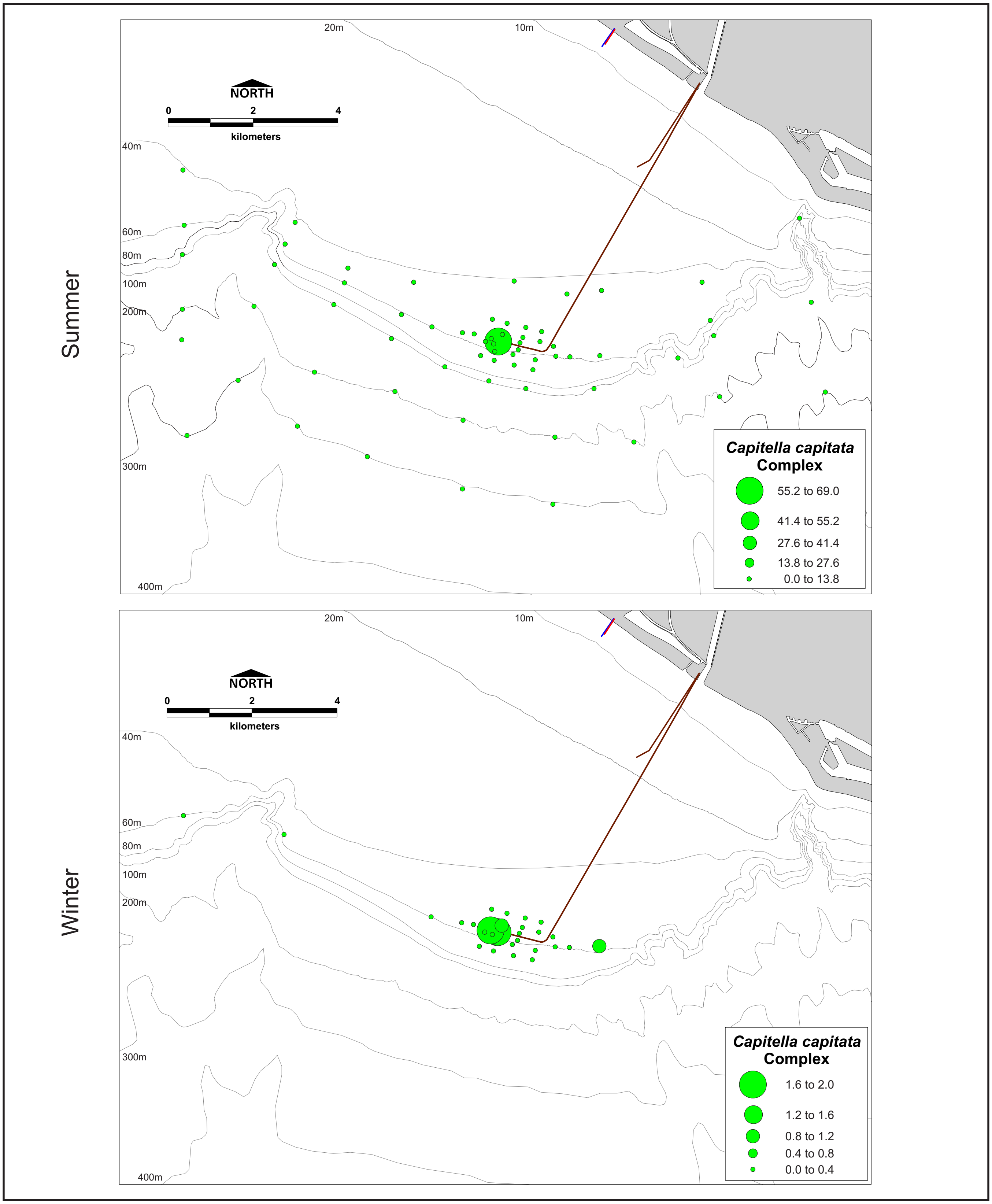


Figure 5-11. Spatial trend bubble plots of *Capitella capitata* Complex abundance for Summer 2012 (top) and Winter 2013 (bottom).

Orange County Sanitation District, California.

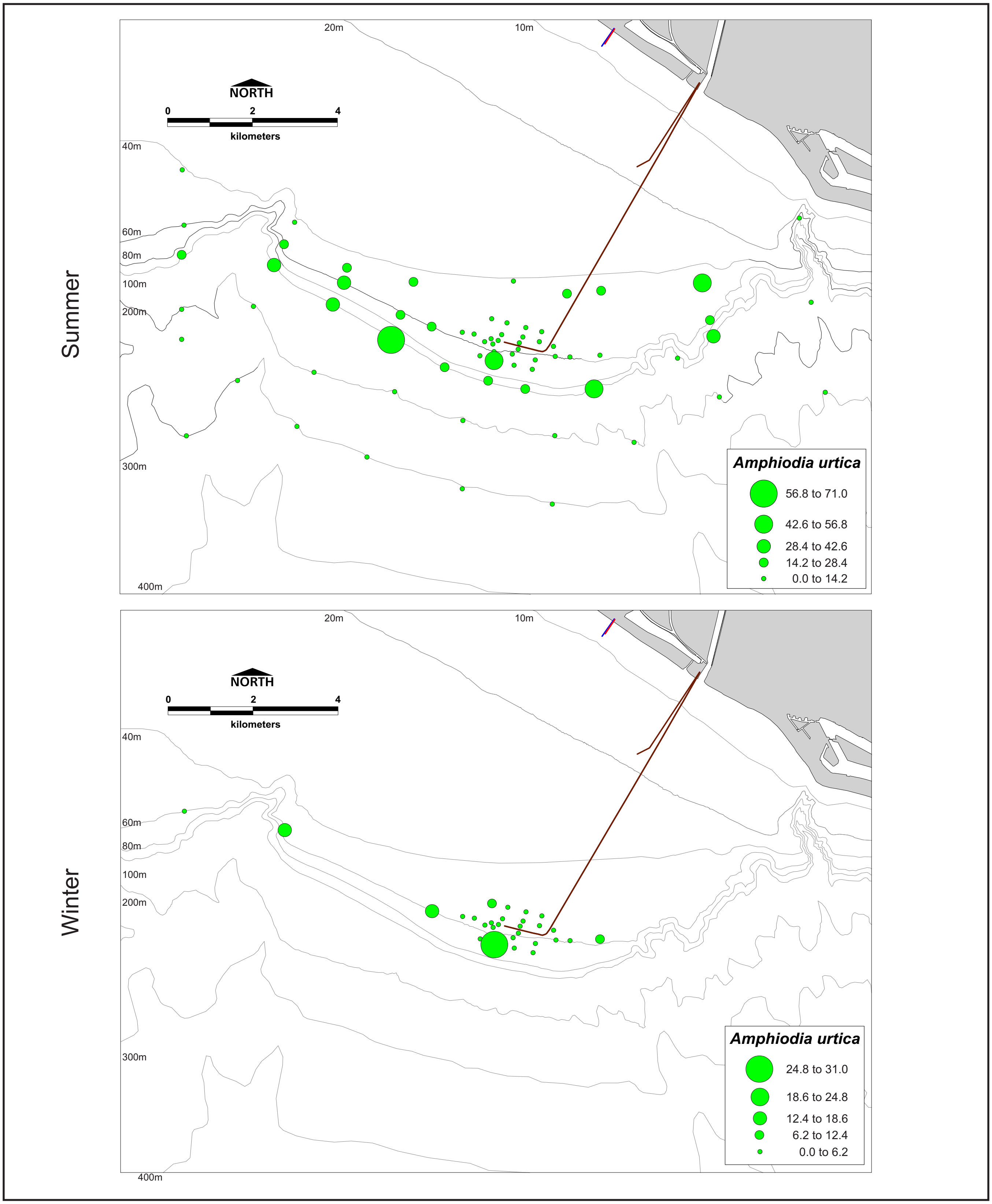


Figure 5-12. **Spatial trend bubble plots of *Amphiodia urtica* abundance for Summer 2012 (top) and Winter 2013 (bottom).**

Orange County Sanitation District, California.

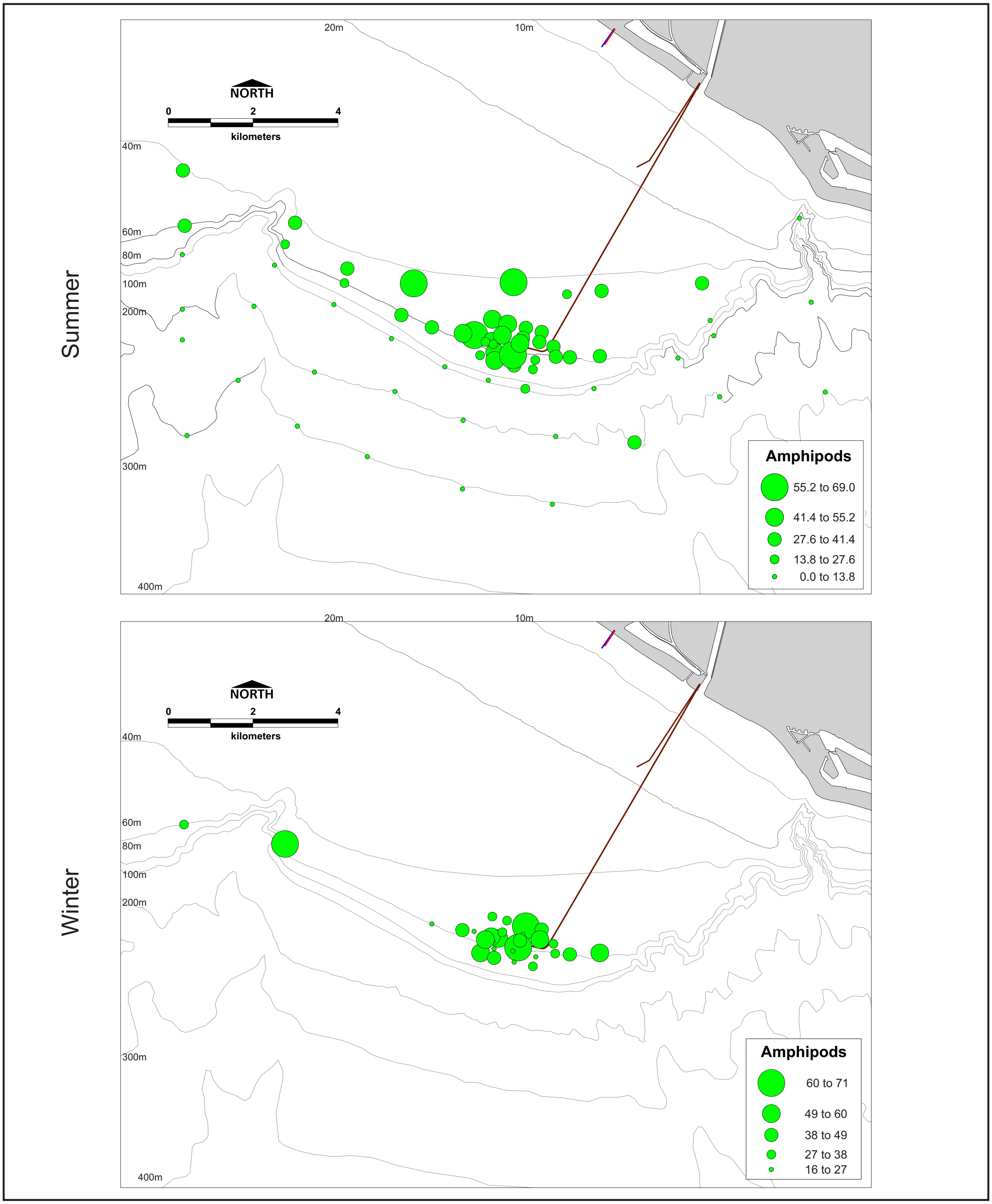


Figure 5-13. **Spatial trend bubble plots of amphipod abundance for Summer 2012 (top) and Winter 2013 (bottom).**

Orange County Sanitation District, California.

Spatial Analysis

Cluster Analysis

The cluster analysis on the Summer 2012 abundance data identified nine station groups with 49% similarity (Figures 5-14 and 5-15). The MDS ordination, with a 2-D stress of 0.14, likewise identified the same nine station groupings (Figure 5-16). The station clusters generally followed the depth contours. Station clusters SC1, SC2, SC4, and SC5 each consisted of a single station, therefore SIMPER analysis could not be applied to these clusters (Clarke and Warwick 2001).

Station Cluster 1 (SC1) included only Station C2, a non-ZID station located at the head of the Newport Submarine Canyon near the Newport Pier (Figure 5-15). Historically, station C2 clustered separately from other non-ZID stations (OCSD 2004–2013). Polychaeta was the most dominant group at this station, accounting for 55% of the abundance and 57% of the species (Table 5-6). SC1 also had the largest percent abundance and species of miscellaneous phyla (11 and 16%, respectively). The numerically dominant species were the mollusk *Rictaxis punctocaelatus*, the polychaetes *Cossura candida*, *Heteromastus filobranchus*, and *Paraprionospio alata*, the hemichordate *Schizocardium* sp., and the crustacean *Pinnixa schmitti* (Table 5-7). These taxa comprised 54% of the total individuals at this station.

Station Cluster 2 (SC2) included only Station 38, located the farthest downcoast from the outfall among the middle shelf Zone 3 stations (Figure 5-15). SC2 had the highest percent abundance and species of polychaetes, comprising 68% and 64%, respectively (Table 5-6). The numerically dominant species were the echinoderm *Amphiodia urtica*, the mollusk *Axinopsida serricata*, and the polychaetes *Aphelochaeta* sp. OC1, *Petaloclymene pacifica*, and *Spiophanes berkeleyorum* (Table 5-7). These taxa comprised 40% of the total individuals at this station.

Station Cluster 3 (SC3) consisted of all but one middle shelf Zone 3 stations (Figure 5-15). Polychaeta was the most dominant group at SC3 with 61% of the abundance and 56% of the species (Table 5-6). The numerically dominant species were the echinoderm *A. urtica* and the polychaetes *Aphelochaeta glandaria* Complex, *Chloeia pinnata*, *Lumbrineris cruzensis*, *Mediomastus* sp., and *P. pacifica* (Table 5-7). SIMPER analysis showed that SC3 was characterized by the echinoderm *A. urtica*, the mollusks *Nuculana* sp. A and *Tellina carpenteri*, and the polychaetes *A. glandaria* Complex, *C. pinnata*, *Eclysippe trilobata*, Euclymeninae sp. A, *Glycera nana*, *L. cruzensis*, *Mediomastus* sp., *P. pacifica*, *Pholoe glabra*, *Prionospio* (*Prionospio*) *dubia*, *Prionospio* (*Prionospio*) *jubata*, and *Travisia brevis*. Furthermore, SC3 was not grouped with SC2 (station 38) due to the absence of the crustacean *Photis parvidons*, the mollusk *Macoma carlottensis*, and the polychaetes *Cossura candida* and *Lumbrineris limicola* among others.

Station Cluster 4 (SC4) included only Station 37, a non-ZID station located downcoast from the outfall (Figure 5-15). Polychaeta was the most dominant group at this station, accounting for 46% of the abundance and 44% of the species (Table 5-6). The numerically dominant species were the crustacean *Photis californica*, the echinoderm *A. urtica*, the mollusk *Amphissa undata*, and the polychaetes *A. glandaria* Complex, *Mediomastus* sp.,

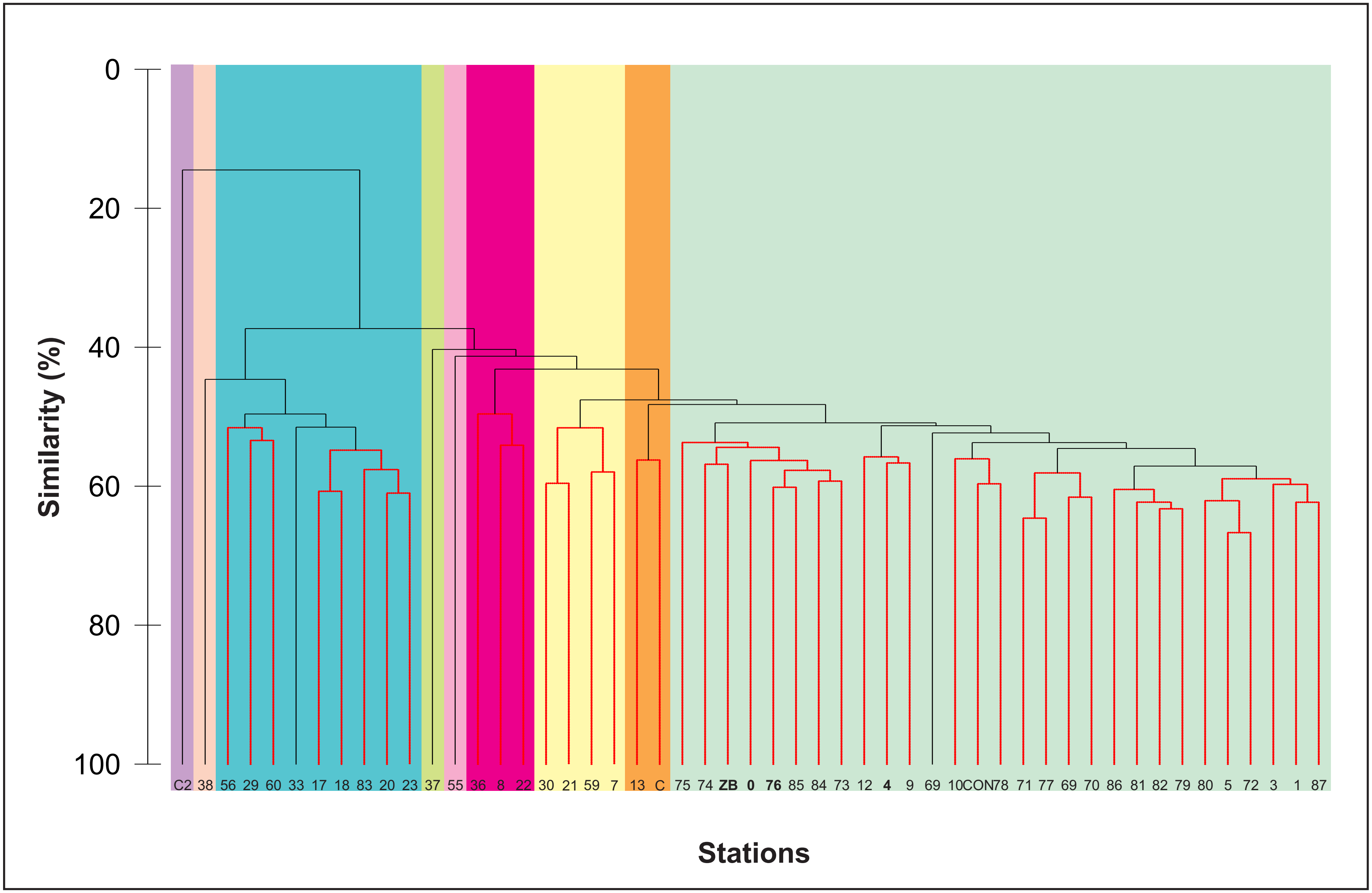


Figure 5-14. **Dendogram of infaunal cluster analysis results for July 2012.**
Note: Color coding identifies the nine distinct station clusters at the level of 49% similarity; ZID stations identified in bold.

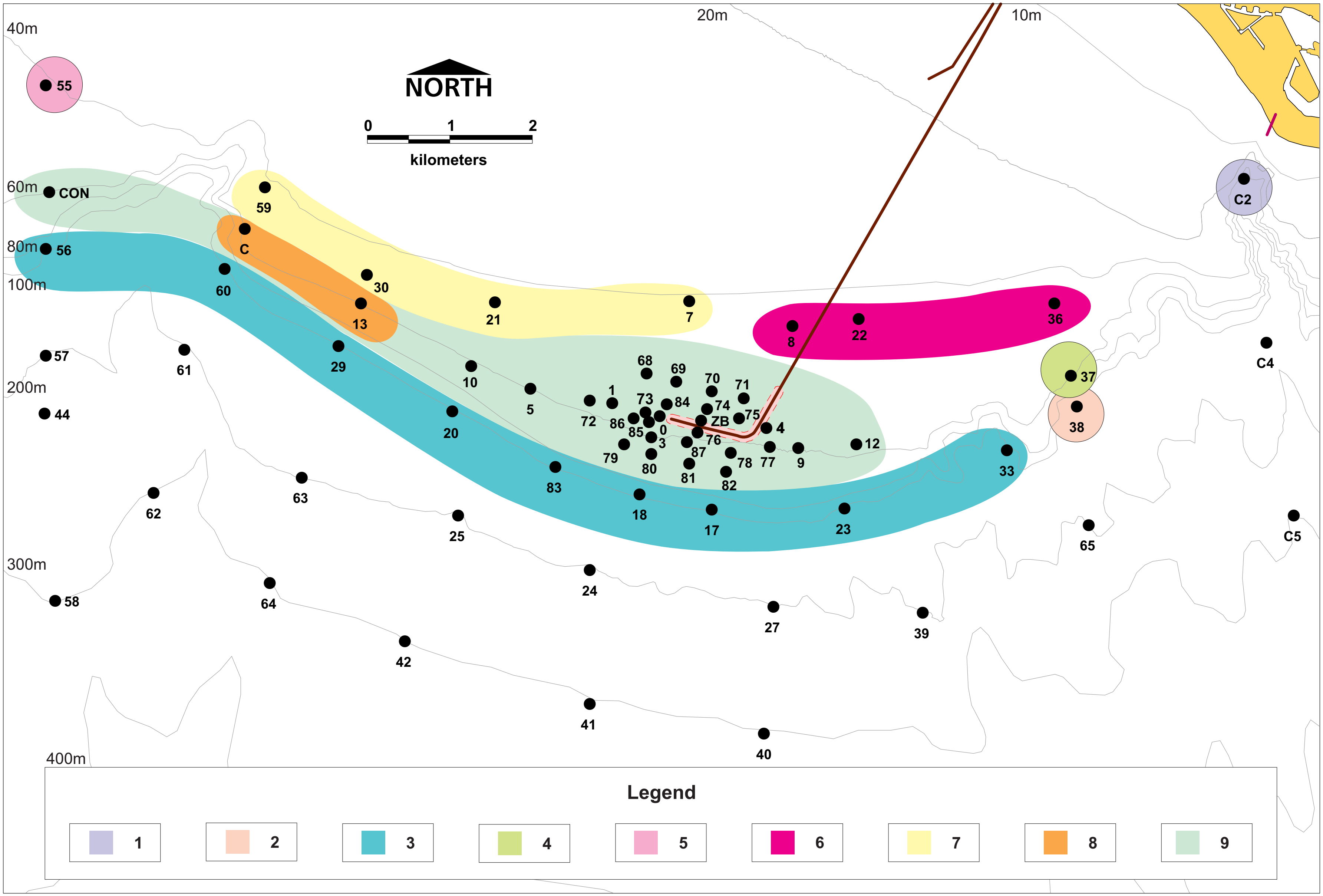


Figure 5-15. **Map of station groups from infaunal cluster analysis for July 2012.**
Note: ZID boundary indicated by red dashed lines around the outfall terminus.

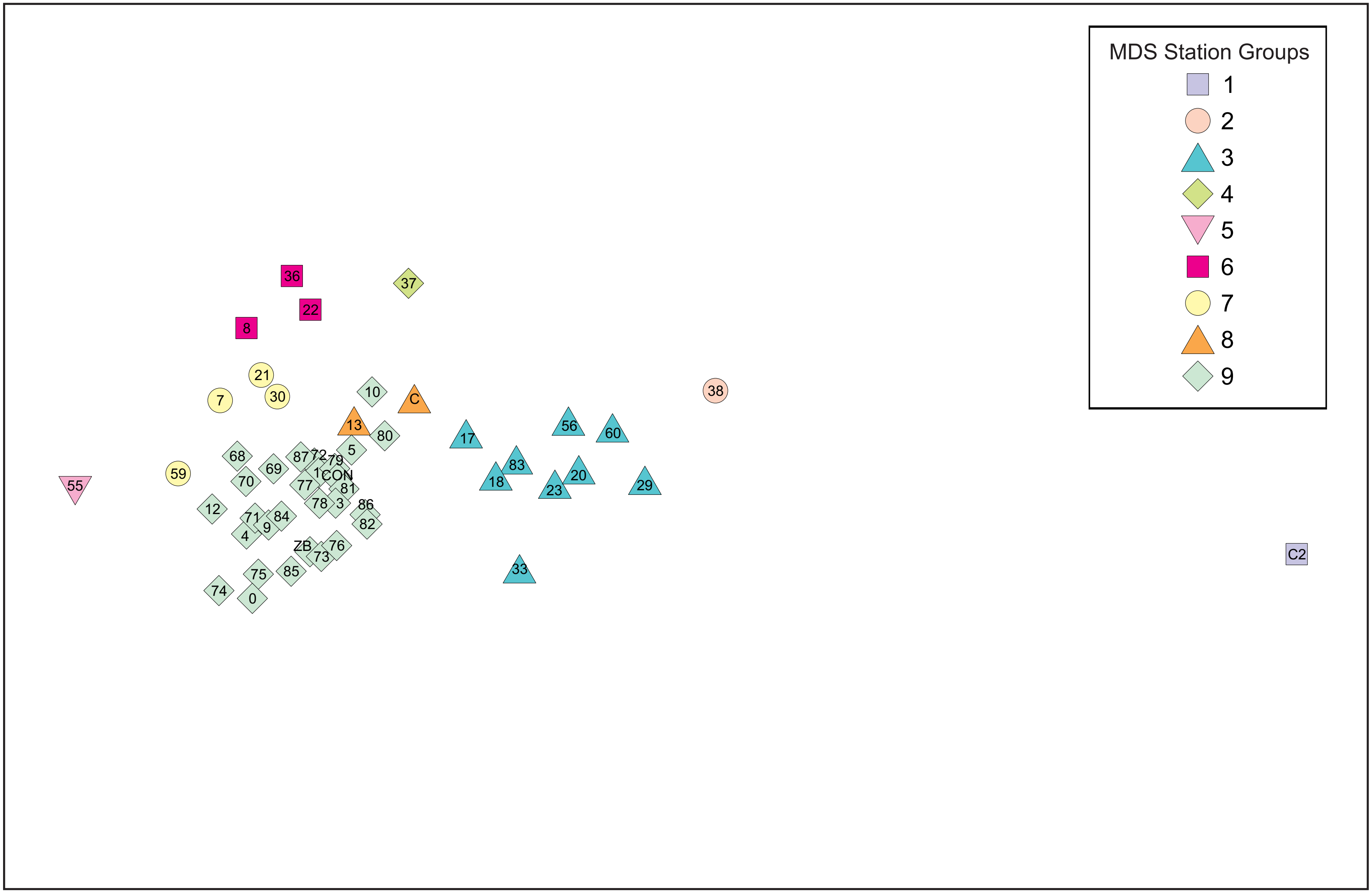


Figure 5-16. **Non-metric multidimensional scaling (MDS) plot of the sampling stations for July 2012. Station symbols and colors correspond to MDS station groupings (group numbers).**

Table 5-6. Percent abundance (top) and species (bottom) of the five major taxonomic groups per station cluster.

Orange County Sanitation District, California.

Station Cluster	Polychaeta	Crustacea	Mollusca	Misc. Phyla	Echinodermata
Percent Abundance					
1	55	7	26	11	1
2	68	4	16	3	9
3	61	15	12	3	9
4	46	24	14	5	11
5	53	35	6	2	3
6	54	26	4	4	12
7	51	37	4	3	4
8	54	25	8	3	10
9	53	33	8	3	3
Percent Species					
1	57	8	16	16	3
2	64	9	18	6	3
3	56	18	17	6	3
4	44	25	18	8	6
5	43	33	11	7	7
6	46	30	9	9	5
7	47	32	9	7	4
8	45	27	13	9	6
9	47	29	14	6	4

Table 5-7. Description of the nine station clusters (SC1 to SC9) defined in Figures 5-14 and 5-15, including the number of stations per cluster, mean number of species and abundance per station, and the five most abundant species per cluster.

Orange County Sanitation District, California

Parameter	SC1*	SC2*	SC3	SC4*	SC5*	SC6	SC7	SC8	SC9
Number of Stations	1	1	9	1	1	3	4	2	29
Mean Number of Species/Station	37	89	31	114	89	67	51	66	14
Mean Abundance/Station	125	464	404	386	387	342	417	339	410
Species	**Total Abundance per Station Cluster**								
Amphiodia urtica		40	**300**	27		95	50	50	
Amphissa undata				13					
Aphelochaeta glandaria Complex			**173**	12					
Aphelochaeta sp. OC1		28							
Aricidea (Acmira) catherinae						33			
Axinopsida serricata		22							
Chaetozone columbiana					18		110		**1009**
Chloeia pinnata			**337**					109	**1496**
Cossura candida	8								
Dialychone veleronis					25				
Euphilomedes carcharodonta							117	36	**986**
Heteromastus filobranchus	14								
Leptochelia dubia							**46**		
Lumbrineris cruzensis			**121**					35	**294**
Mediomastus sp.			**137**	18		81	50		**349**
Paraprionospio alata	7								
Petaloclymene pacifica		52	**137**						
Photis californica				32	24		50		
Pinnixa schmitti	6								
Pista estevanica					35				
Prionospio (Prionospio) jubata				13					
Rictaxis punctocaelatus	25								
Schizocardium sp.	7								
Spiophanes berkeleyorum		45				**45**			
Spiophanes norrisi					38	33	128		
Sthenelanella uniformis				12		31		20	

Bold values indicate species that were considered “characteristic” of a cluster by SIMPER analysis.
* = Groups comprised of a single station; therefore SIMPER analysis could not be applied.

P. (*Prionospio*) *jubata*, and *Sthenelanella uniformis* (Table 5-7). These taxa comprised 33% of the total individuals at this station.

Station Cluster 5 (SC5) included only Station 55, located the farthest upcoast among the middle shelf Zone 1 stations (Figure 5-15). This station typically clusters separately from other middle shelf Zone 1 stations (OCSD 2004–2013). Polychaeta was the most dominant group at this station, accounting for 53% of the abundance and 43% of the species (Table 5-6). SC5 also had the largest percent abundance and species of Crustacea (35 and 33%, respectively). The numerically dominant species were the crustacean *P*. *californica* and the polychaetes *Chaetozone columbiana*, *Dialychone veleronis*, *Pista estevanica*, and *Spiophanes norrisi* (Table 5-7). These taxa comprised 36% of the total individuals at this station.

Station Cluster 6 (SC6) consisted of Stations 8, 22, and 36, located inshore and successively downcoast from the outfall (Figure 5-15). Polychaeta was the most dominant group at SC6 with 54% of the abundance and 46% of the species (Table 5-6). The numerically dominant species were the echinoderm *A*. *urtica* and the polychaetes *Aricidea (Acmira) catherinae*, *Mediomastus* sp., *S*. *berkeleyorum*, *S*. *norrisi*, and *S*. *uniformis* (Table 5-7). SIMPER analysis revealed that SC6 is defined by the crustacean *Caecognathia crenulatifrons* and the polychaetes *Mooreonuphis nebulosa*, *P*. (*Prionospio*) *jubata*, and *S*. *berkeleyorum*.

Station Cluster 7 (SC7) consisted of Stations 7, 21, 30, and 59, located inshore and successively upcoast from the outfall (Figure 5-15). Polychaeta was the most dominant group at SC7 with 51% of the abundance and 47% of the species (Table 5-6). The numerically dominant species were the echinoderm *A*. *urtica*, the crustaceans *E*. *carcharodonta*, *Leptochelia dubia*, and *P*. *californica*, and the polychaetes *C*. *pinnata*, *Mediomastus* sp., and *S*. *norrisi* (Table 5-7). SIMPER analysis showed that SC7 was discriminated by the crustaceans *Ampelisca brevisimulata*, *Ampelisca hancocki*, *L*. *dubia*, *Rhepoxynius menziesi*, and *Rhepoxynius stenodes*, and the polychaetes *P*. *alata* and *Scalibregma californicum*. Moreover, SC7 was separated from SC6 by the presence of the crustacean *Metaphoxus frequens* and absence of the polychaete *Sternaspis affinis*.

Station Cluster 8 (SC8) consisted of Stations C and 13, located upcoast from the outfall diffuser (Figure 5-15). These stations also clustered separately from other middle shelf Zone 2 stations in the previous year. Polychaeta was the most dominant group at SC8 with 54% of the abundance and 45% of the species (Table 5-6). The numerically dominant species were the echinoderm *A*. *urtica*, the crustacean *E*. *carcharodonta*, and the polychaetes *C*. *pinnata*, *L*. *cruzensis*, and *S*. *uniformis* (Table 5-7). Characteristic species for SC8 could not be identified due to an anomaly in the SIMPER analysis.

Station Cluster 9 (SC9) consisted of all but three middle shelf Zone 2 stations (Figure 5-15). Polychaeta was the most dominant group at SC9 with 53% of the abundance and 47% of the species (Table 5-6). The numerically dominant species were the crustacean *E*. *carcharodonta* and the polychaetes *Chaetozone columbiana*, *C*. *pinnata*, *L*. *cruzensis*, and *Mediomastus* sp. (Table 5-7). Characteristic species identified by SIMPER were the crustaceans *Ampelisca pugetica*, *C*. *crenulatifrons*, *E*. *carcharodonta*, and *R*. *menziesi* and the polychaetes *C*. *columbiana* and *P*. (*Prionospio*) *jubata*. In addition, Stations C and 13 (SC8) were not grouped with SC9 due to the absence of the crustacean *P*. *californica* and the polychaete *A*. *glandaria* Complex coupled with the higher average abundances of the mollusk *Compsomyax subdiaphana* and the polychaete *Levinsenia gracilis*. SC9 was separated from Station 37 (SC4) due to the absence of the crustaceans *Deutella californica*, *Orthopagurus minimus*, *Pagurus spilocarpus*, and *Paguristes turgidus*, the mollusk *Pleurobranchaea californica*, and the polychaetes *Aphelochaeta monilaris*, *Brada pluribranchiata* and *Isocirrus longiceps*.

The main factor determining the station clusters described above was primarily the variation in the abundances of polychaete taxa. The within-ZID stations, particularly Stations 0 and ZB, historically form a separate station cluster from the surrounding non-ZID stations (OCSD 2009–2012). However in July 2011, Station ZB clustered with other non-ZID stations, including the farfield reference Station CON (OCSD 2013); in July 2012, Stations 0 and ZB were both nested within a large cluster (SC9) containing nearly all middle shelf Zone 2 stations (Figures 5-14 and 5-15). This suggests that the effluent discharge had an overall negligible effect on the benthic community structure along the 60-m depth contour.

CONCLUSIONS

Previous OCSD ocean monitoring reports documented a general decline in community health at middle shelf Zone 2 stations since 2005 that resulted in degraded conditions within the ZID and changed conditions at several stations near the outfall diffuser. However, the infaunal communities at within- and non-ZID stations have since recovered based on present data: the majority of the community measure values at these stations were consistent with regional and historical reference values; nearly all stations can be classified as reference condition based on BRI and ITI analyses; and the abundances of the pollution-tolerant polychaete species *C. capitata* Complex remained low, while the abundances of the pollution-sensitive amphipod species increased at within-ZID stations. Therefore, the biota outside the ZID was not degraded by the effluent discharge, and as such, permit criterion V.A.4.a. was met for 2012-13.

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