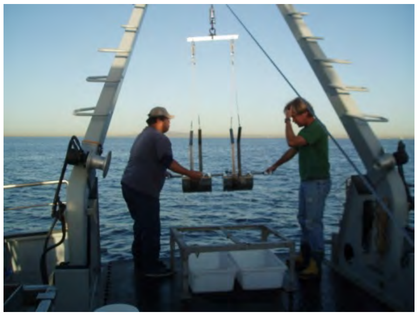
chapter 4

SEDIMENT GEOCHEMISTRY



Chapter 4
SEDIMENT GEOCHEMISTRY

INTRODUCTION

The Orange County Sanitation District's (District) Ocean Monitoring Program (OMP) requires assessments of sediment quality, including the distribution and concentration of chemical contaminants in bottom sediments within the monitoring area. The objectives are to determine the presence, magnitude, and spatial extent of wastewater-related changes to sediment characteristics and their possible relation to the health of biological communities. This information is then used to determine compliance with the District's NPDES ocean discharge permit (see box).

Both natural and anthropogenic processes affect the physical and chemical properties of sediments. Large-scale, regional, and local currents, combined with naturally occurring inputs (e.g., atmospheric, terrestrial, biogenic) provide and distribute organic and inorganic constituents to sediments. These patterns are then influenced by anthropogenic alterations to the system, for example the wastewater outfall. The outfall is a 10 ft. diameter pipe with associated ballast rock that alters current flow, which can affect sediment characteristics, such as grain size and geochemistry, near the structure. Discharged effluent contains a variety of organic and inorganic contaminants that can affect sediment quality (Anderson et al. 1993; OCSD 1985, 2003). Also, changes in effluent characteristics (e.g., flow, concentrations, particle size) may be reflected in sediments near to as well as some distance from the outfall. Therefore, periodic measurements of the physical, chemical, and toxicological characteristics of sediments are used to assess these changes and can identify temporal and spatial trends due to natural and anthropogenic sources.

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

Criteria		Description
C.3.d	Inert Solids	The deposition of inert solids in marine sediments shall not degrade benthic communities.
C.4.c	Dissolved Sulfides	Dissolved sulfide concentrations shall not be elevated to concentrations resulting in degradation to biota.
C.4.d	COP Table B Substances	Substances found in California Ocean Plan Table B shall not cause degradation to biota.
C.4.e	Organics in Sediments	The concentration of organic material in sediments shall not be increased to levels resulting in degradation of marine life.

The District has undertaken three projects in the last 8 years that have the potential to significantly affect effluent characteristics. The first was the initiation of effluent disinfection by chlorination with hypochlorite bleach followed by de-chlorination with sodium bisulfate, which began in August 2002. The second was the Ground Water Replenishment System (GWRS) wastewater reclamation project that was initiated in January 2008. This has decreased the volume of effluent discharged into the ocean from 237 million gallons per day (MGD) in 2006-07 to 212 MGD in 2007-08 and to 149 MGD in 2010-11. While the effluent volume has decreased, the mass balance of contaminants being discharged is approximately the same, which means that the contaminants are more concentrated than before GWRS. Third, the District has been under a consent decree to achieve secondary treatment standards by 2012. This effort was initiated in 2002 with the utilization of existing secondary treatment capacity. What affect, if any, these treatment changes will have on sediment characteristics and biota are currently being assessed.

METHODS

The District collects sediment samples for physical, chemical, and toxicity analyses. The District's NPDES ocean discharge permit requires that samples be collected quarterly at 10 stations along the 60-meter (m) contour (outfall depth) and annually in summer at an additional 39 stations that range in depth from 40 to 303 m (Figure 4-1). The purpose of the quarterly surveys is to assess outfall influence along the 60 m (outfall depth) contour and to determine long-term trends, while the annual survey is to assess the spatial extent of the influence of the effluent discharge throughout the monitoring area. The annual survey assessment included data from the quarterly stations and the 39 annual stations (n=49 stations). Single samples were collected at all stations. The annual survey data are reported as the means of stations located within six zones based on station depth or proximity to the outfall. The depth zones are Shallow-shelf (40–46 m), Mid-shelf within-ZID (56–60 m), Mid-shelf non-ZID (56–60 m), Outer-shelf (91–100 m), Slope (187–241 m), and Basin (296–300 m). The four stations comprising the Mid-shelf within-ZID station group are located with the ZID and considered to be directly under the influence of the wastewater discharge, while the other stations are intended to monitor the influence of the discharge beyond the zone of initial dilution. Individual station differences or trends within or across zones are discussed where appropriate.

In July 2010, the District also collected single samples from an additional 59 stations as part of a special sediment-mapping project. The goal of this project is to optimize the placement of stations to improve detection of potential environmental effects due to the wastewater discharge. For this effort, only sediment grain size, total linear alkylbenzenes (tLAB), cadmium, and zinc were analyzed. These analyses added little new information so they were excluded from this chapter. The concurrent sampling of infaunal invertebrates added significant information and that discussion is included in Chapters 5 and 7.

Sediments were collected using paired, stainless steel, 0.1 m^2 Van Veen grab samplers. The top 2 cm of the sediment was sampled with a stainless steel scoop and placed into specific containers for chemical and toxicity analyses. All samples (metals. organics, TOC, grain size, and dissolved sulfides) were placed in coolers on wet ice and then transferred to the District's Environmental Laboratory and Ocean Monitoring Division for analysis.

Concentrations of metals, chlorinated pesticides, polychlorinated biphenyls (PCB), polycyclic aromatic hydrocarbons (PAH), total organic carbon (TOC), and dissolved sulfides were measured in each sediment sample. Total dichlorodipheynltrichloroethane (tDDT) represents the summed concentrations of o,p'- and p,p'- [2,4- and 4,4'-] isomers of DDD, DDE, and DDT, and p,p'-DDMU, total polychlorinated biphenyls (tPCB) represents the summed concentrations of 45 congeners, and total chlorinated pesticides (tPest) represents the sum of alpha- and cis-chlordane, cis- and trans-nonachlor, hexachlorobenzene, aldrin, dieldrin, endrin, gamma-BHC, heptachlor, heptachlor epoxide, and mirex. Linear alkylbenzenes

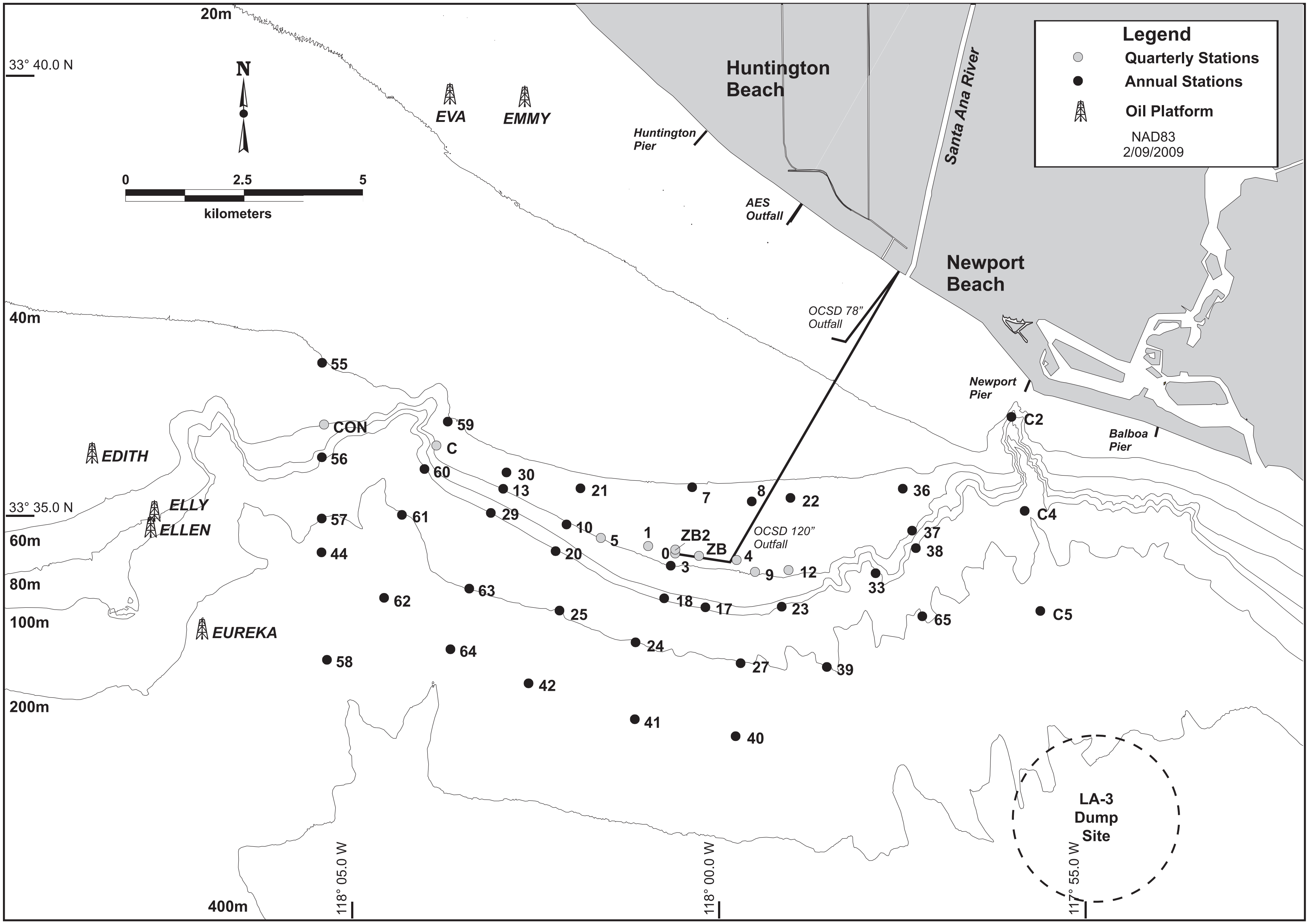


Figure 4-1. Sediment geochemistry sampling stations for annual and quarterly surveys, 2010-11.

Orange County Sanitation District, California.

(LABs) are commonly found in detergents and serve as sewage markers. LABs were measured in the July 2010 survey to better distinguish changes in sediment quality attributable to the wastewater discharge. For summed concentrations such as tDDT, any undetected components (i.e., concentrations below the analytical detection limits) were treated as zero. When all component concentrations were undetected, the corresponding total concentrations were assumed to be zero. Single analytes (e.g., metals) not detected during analysis were given the value of one-half the detection limit for statistical analysis. Sediment chemistry and grain size samples were processed and analyzed using performance-based and EPA-recommended methods. Samples for dissolved sulfide were analyzed in accordance with procedures outlined in Schnitker and Green (1974) and Standard Methods 20th Edition (1998). Due to the number of additional samples (59) collected for the Sediment Mapping Study, the legacy contaminants DDT and PCB and the suite of chlorinated pesticides were not collected in the July 2010 survey, but were included in the other three quarterly surveys.

The District's NPDES ocean discharge permit states that the concentrations of substances contained in Table B of the California Ocean Plan (COP) and the concentration of organic substances shall not be increased to levels that would degrade marine life. The COP does not contain numeric sediment quality criteria and there are no numeric sediment contaminant limits in the District's NPDES discharge permit. Sediment contaminant concentrations were evaluated against sediment quality guidelines known as Effects Range-Low (ERL) and Effects Range-Median (ERM) (Long et al. 1995) and the mean ERM quotient (mERMq) method (Long et al. 1998). The ERL/ERM guidelines were developed for the National Oceanic and Atmospheric Administration (NOAA) National Status and Trends Program as non-regulatory benchmarks to aid in the interpretation of sediment chemistry data and to compliment toxicity, bioaccumulation, and benthic community assessments (Long and MacDonald 1998). The ERL is defined as the 10th percentile sediment concentration of a chemical below which a toxic effect is unlikely. An ERM is the 50th percentile sediment concentration above which a toxic effect frequently occurs (Long et al. 1995).

In addition to the direct measurement of chemical contaminants in the sediments, the District also conducted laboratory sediment toxicity tests as a measure of sediment quality. Sediment toxicity was tested in October 2010 and April 2011 using whole sediments for the 10-day *Eohaustorius estuarius* amphipod survival test. Amphipods were exposed to test and control sediments and the percent survival in each were determined. Toxicity threshold criteria were selected to be consistent with the State of California Sediment Quality Objectives (SQO) for bays and estuaries (Bay et al. 2009). The SQO categorizes toxicity into four categories: 1) non-toxic, 2) low toxicity, 3) moderate toxicity, and 4) high toxicity. This is based on the percent difference from a control and whether or not the difference is statistically significant based on a t-test ($p \leq 0.05$). This scheme is discussed in more detail in the Methods Appendix (Appendix A).

Because chemical contaminants tend to co-occur in sediments and toxicity can be related to exposures to multiple contaminants, Long et al. (1998) developed the mean ERM quotient (mERMq) to improve the ability to use contaminant concentrations to predict toxicity. The mERMq is the average of specific compound concentrations divided by their corresponding ERM. Based on the recommendations in Long et al. (1998), the minimum level of significance for mERMq analysis was set at 0.11. A mERMq of 0.1 to 1.0 corresponds to a 32% probability of high sediment toxicity and 16.5% of marginal sediment toxicity, or a 48% likelihood of the sediment exhibiting some degree of toxicity. A mERMq of greater than 1.0 corresponds to a 71% probability of high sediment toxicity and 6% of marginal sediment toxicity, or a 77% likelihood of some degree of sediment toxicity. The mERMq was also employed as an assessment benchmark in this analysis.

Spatial trends for the July 2010 annual station data were assessed graphically by sediment character or analyte using data maps and statistically by correlation-based principal components analysis (PCA) using the PRIMER v6 statistical software package (PRIMER 2001). Depth related gradients and relationships between chemical compounds and physical sediment characteristics were assessed using Pearson Product Moment Correlation using the Minitab® Statistical Software package. Data was transformed where appropriate. Statistical significance was set at $p \leq 0.05$. Temporal trends were assessed graphically using constituent annual means from monitoring years 1999-00 through 2010-11.

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

RESULTS AND DISCUSSION

The following is a summary of the July 2010 annual survey and the four quarterly surveys.

Correlation Analysis

Relationships of sediment physicochemical characteristics to tLAB sediment concentration was performed using Pearson correlation analysis since LABs and wastewater are strongly associated (SAIC 2003). Significant correlations between tLAB and sediment measures suggest, but do not prove, cause-effect relationships with the outfall discharge of treated wastewater. When there is a significant correlation of a sediment measure to tLAB, but not station depth it suggests a discharge-related influence. When there is a correlation with station depth, but not tLAB it indicates a depositional influence likely associated with sediment grain size.

In July 2010, similar to previous years, station depth was highly correlated with percent fines ($R = 0.80$) due to the depositional pattern associated with sediment grain size. Correlations to percent fines will be reported as a surrogate for station depth in spatial analyses.

Spatial Analysis

<u>Linear Alkylbenzenes (LAB)</u>

The highest rate of effluent particle deposition occurred near the outfall (Table 4-1; Figure 4-2). In July 2010, mean concentration of tLAB was 2 to 12 times greater stations within the ZID (184.8 ug/kg) than the other shelf, slope, or basin stations (16.8 to 87.5 ug/kg). Outside of the ZID, concentrations of tLAB >100 ug/kg were found in upcoast slope and San Gabriel Canyon Stations (44, 57, 58, and 62) and Newport Canyon Station C5. This suggests a potential for measurable discharge impacts away from the nearfield and upcoast effluent transport with deposition in the San Gabriel Canyon. This pattern is consistent with predominant sub-tidal currents below 30 m (SAIC, 2009). Unlike previous years, tLAB concentrations were not correlated with percent fines (see below).

Along the 60-m contour, tLABs were generally highest at the ZID stations and decreased with increasing distance from the outfall in both directions (Table 4-2; Figure 4-3). Within-ZID concentration means were approximately six times greater than non-ZID stations. The predominantly upcoast flowing bottom currents appeared to influence particulate deposition. For example, upcoast Stations 1 and 5 had three times the concentration of tLABs than downcoast Stations 9 and 12.

<u>Percent Fine Sediments</u>

Mean percent fines were lowest within the ZID (13.1%) compared to the other shelf strata (34.4 to 45.8%), increasing to greater than 80% in the slope, basin, and submarine canyons (Table 4-1; Figure 4-4). Station group means were comparable to Bight'08 area weighted means (AWM) by depth except for the within-ZID group, which was more than three-times lower. The lower percentage of fines found near the outfall is due in part to scouring by currents and contributions from coarse-grained shell hash (i.e., the calcareous tubes of worms and mollusk shells).

Unlike July 2009, tLAB concentrations were not significantly correlated with percent fines. One potential cause of this change may be that increased wastewater reclamation through GWRS is altering particle sizes and effluent velocity at the outfall discharge ports affecting grain size distributions in the monitoring area in 20010-11. This hypothesis is being examined as part of the investigation into changes in the benthos near the outfall.

Table 4-1. Annual concentrations of sediment organic contaminants (µg/kg) at the District's annual stations in 2010-11 compared to Effects Range–Low (ERL) and Effects Range–Median (ERM) values and regional measurements of sediment physical characteristics.

Orange County Sanitation District, California

Station	Depth	Total LAB (ųg/kg)	Median Phi	Fines (%)	TOC (%)	Sulfides (mg/kg)	Total PAH (ųg/kg)	Total DDT (ųg/kg)	Total Pest (ųg/kg)	Total PCB (ug/kg)
Shallow Shelf (40 – 46 meters)										
7	41	20.5	3.87	40.0	0.82	4.92	99.5	NS	NS	NS
8	44	28.0	3.89	41.2	1.10	7.55	99.1	NS	NS	NS
21	44	13.1	3.80	35.6	0.91	2.25	78.1	NS	NS	NS
22	45	15.5	4.04	51.3	1.07	6.20	108.5	NS	NS	NS
30	46	26.2	3.69	32.9	0.73	2.35	101.5	NS	NS	NS
36	45	11.9	4.01	50.3	1.18	3.41	149.7	NS	NS	NS
55	40	3.90	2.88	5.1	0.62	3.63	20.3	NS	NS	NS
59	40	15.0	3.39	21.4	0.71	4.82	50.7	NS	NS	NS
	Mean	16.8	3.75	34.7	0.89	4.39	88.4	NS	NS	NS
Mid-Shelf Within-ZID (56 – 60 meters)										
0 **	56	295.4	3.41	9.4	0.72	2.56	876.0	NS	NS	NS
4 **	56	77.1	3.41	13.8	0.48	10.20	66.6	NS	NS	NS
ZB **	56	112.9	3.57	19.3	0.52	4.83	172.6	NS	NS	NS
ZB2 **	56	253.6	3.42	9.9	0.69	3.42	164.1	NS	NS	NS
	Mean	184.8	3.45	13.1	0.60	5.25	319.8	NS	NS	NS
Mid-Shelf Non-ZID (56 – 60 meters)										
1 **	56	63.9	3.72	29.8	0.50	4.88	147.4	NS	NS	NS
3	60	62.7	3.60	19.3	0.77	5.69	156.0	NS	NS	NS
5 **	59	63.8	3.88	41.2	1.19	3.86	110.2	NS	NS	NS
9 **	59	23.2	3.40	16.5	0.53	6.56	47.0	NS	NS	NS
10	60	39.4	4.02	50.8	0.76	6.01	113.2	NS	NS	NS
12 **	58	18.6	3.36	18.5	0.52	11.20	124.2	NS	NS	NS
13	59	22.1	3.92	44.8	0.76	3.43	114.9	NS	NS	NS
37	56	10.4	2.64	12.6	0.65	5.76	40.3	NS	NS	NS
C **	56	10.9	3.66	26.7	0.49	2.45	58.6	NS	NS	NS
C2	56	19.3	5.34	91.6	2.56	66.50	640.0	NS	NS	NS
CON **	59	13.6	3.51	27.1	0.52	2.14	56.6	NS	NS	NS
	Mean	31.6	3.77	34.4	0.84	10.8	146.2	NS	NS	NS
Outer Shelf (91–-100 meters)										
17	91	21.3	3.61	24.9	3.93	5.60	92.2	NS	NS	NS
18	91	17.1	3.76	31.6	1.10	3.16	62.6	NS	NS	NS
20	100	35.1	4.28	63.8	0.90	3.89	130.7	NS	NS	NS
23	100	18.6	3.73	37.4	1.02	5.06	106.5	NS	NS	NS
29	100	44.7	4.34	68.5	1.04	4.10	185.0	NS	NS	NS
33	100	31.5	2.91	17.0	0.79	5.43	112.7	NS	NS	NS
38	100	25.8	4.00	50.0	1.43	11.50	165.1	NS	NS	NS
56	100	34.9	3.99	49.6	1.20	4.08	235.3	NS	NS	NS
60	100	80.3	4.36	69.0	1.51	4.76	221.4	NS	NS	NS
	Mean	34.4	3.91	45.8	1.44	5.29	145.7	NS	NS	NS

Table 4-1 Continues.

Table 4-1 Continues.

Station	Depth	Total LAB (ųg/kg)	Median Phi	Fines (%)	TOC (%)	Sulfides (mg/kg)	Total PAH (ųg/kg)	Total DDT (ųg/kg)	Total Pest (ųg/kg)	Total PCB (ug/kg)
					Slope (187 – 241 meters)					
24	200	40.7	4.76	84.6	1.80	11.80	198.0	NS	NS	NS
25	200	74.1	4.97	86.7	1.63	14.20	386.8	NS	NS	NS
27	200	28.1	4.42	68.2	0.99	3.55	88.5	NS	NS	NS
39	200	19.0	3.65	30.9	1.15	3.73	61.6	NS	NS	NS
44	241	215.9	6.22	96.6	0.82	28.60	478.5	NS	NS	NS
57	200	263.3	5.74	94.2	2.59	28.60	471.4	NS	NS	NS
61	200	80.3	4.81	84.9	2.21	13.10	228.4	NS	NS	NS
63	200	61.8	4.73	86.0	1.04	5.28	277.5	NS	NS	NS
65	200	46.8	4.61	74.2	1.54	7.42	262.6	NS	NS	NS
C4	187	45.3	5.76	95.0	2.66	32.10	522.9	NS	NS	NS
	Mean	87.5	4.97	80.2	1.64	14.8	297.6	NS	NS	NS
					Basin (296 – 300 meters)					
40	303	47.1	4.83	85.5	2.00	3.94	164.1	NS	NS	NS
41	303	47.7	4.82	80.3	1.99	4.17	176.3	NS	NS	NS
42	303	92.5	5.45	92.2	1.85	9.97	297.1	NS	NS	NS
58	300	131.2	6.04	98.1	3.35	16.10	382.2	NS	NS	NS
62	300	123.4	5.81	96.8	1.97	28.00	334.4	NS	NS	NS
64	300	44.1	5.01	85.9	1.60	4.19	156.1	NS	NS	NS
C5	296	115.9	6.13	96.2	3.13	36.00	400.4	NS	NS	NS
	Mean	86.0	5.44	90.7	2.27	14.6	272.9	NS	NS	NS
[1] ERL		NA	NA	NA	NA	NA	4,022	1.58	NA	22.7
[1] ERM		NA	NA	NA	NA	NA	44,792	46.1	NA	180
[2] Bight'08 Mid-shelf AWM		NA	NA	46.8	1.0	NA	179.0	16.0	NA	13.0
[2] Bight'08 Outer-shelf AWM		NA	NA	60.0	1.5	NA	231.0	56.0	NA	19.0
[2] Bight'08 Upper Slope/Basin AWM		NA	NA	81.3	2.6	NA	234.0	238.0	NA	36.0

AWM = Area Weighted Mean, NS = Not Sampled, NA = Not Applicable

All stations n=1

** Quarterly Station

[1] Long et al. 1995

[2] Schiff et al. (2011)

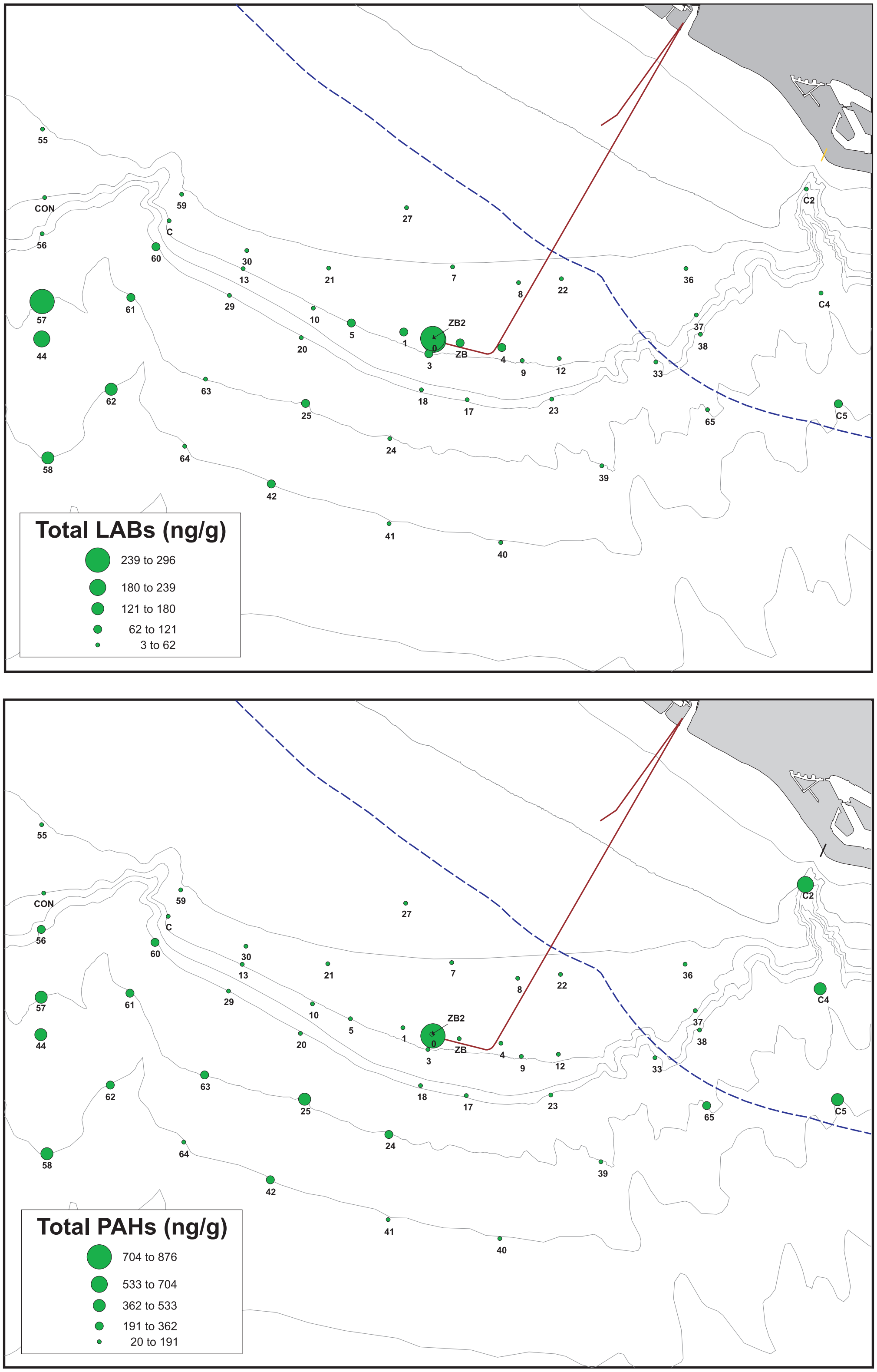


Figure 4-2. **Spatial trend bubble plots of tLABs and tPAHs.**

Orange County Sanitation District, California.

Table 4-2. Mean annual concentrations of sediment organic contaminants at the District's quarterly stations in 2010-11, compared to Effects Range–Low (ERL) and Effects Range–Median (ERM) values and regional measurements of sediment physical characteristics.

Orange County Sanitation District, California

Station	Depth	tLAB (ųg/kg)	Median Phi	Fines (%)	TOC (%)	Sulfides (mg/kg)	Total PAH (ųg/kg)	Total DDT (ųg/kg)	Total Pest (ųg/kg)	Total PCB (ųg/kg)
Within-ZID Stations										
0	56	295.4	3.39	8.23	0.50	2.50	376.0	**3.57**	0	**23.9**
4	56	77.1	3.46	17.2	0.34	4.39	54.9	**1.84**	0	2.85
ZB	56	112.9	3.54	18.3	0.34	7.07	91.8	1.49	0	3.11
ZB2	56	253.6	3.46	11.4	0.60	7.62	214.7	**3.02**	0	**27.1**
	Mean	184.8	3.46	13.8	0.45	5.40	184.4	**2.48**	0	14.24
Non-ZID Stations										
1	56	63.9	3.68	26.3	0.37	4.39	102.7	**3.14**	0	10.6
5	59	63.8	3.88	40.4	0.62	3.17	61.4	**4.13**	0	4.14
9	59	23.2	3.42	17.5	0.35	5.23	66.8	**1.85**	0	1.61
12	58	18.6	3.35	17.9	0.35	6.20	43.8	**2.06**	0	0.87
C	56	10.9	3.62	27.6	0.41	2.25	59.3	**4.96**	0.10	2.45
CON	59	13.6	3.59	25.3	0.38	1.45	43.4	**4.34**	0	1.94
	Mean	32.3	3.59	25.8	0.41	3.78	62.9	**3.41**	0.017	3.60
Sediment Quality Guideline and Reference Values										
[1] ERL		NA	NA	NA	NA	NA	4,022	1.58	NA	22.7
[1] ERM		NA	NA	NA	NA	NA	44,792	46.1	NA	180.0
[2] Bight'08 Mid-shelf AWM		NA	NA	46.8	1.0	NA	179.0	16.0	NA	13.0
[2] Bight'08 Outer-shelf AWM		NA	NA	60.0	1.5	NA	231.0	56.0	NA	19.0
[2] Bight'08 Upper Slope/Basin AWM		NA	NA	81.3	2.6	NA	234.0	238.0	NA	36.0

AWM = Area Weighted Mean, NA = Not Applicable

Values greater than the ERL are bolded.

Quarterly stations n = 4, except tLAB: n = 1 (July 2010)

[1] Long et al. (1995)

[2] Schiff et al. (2011)

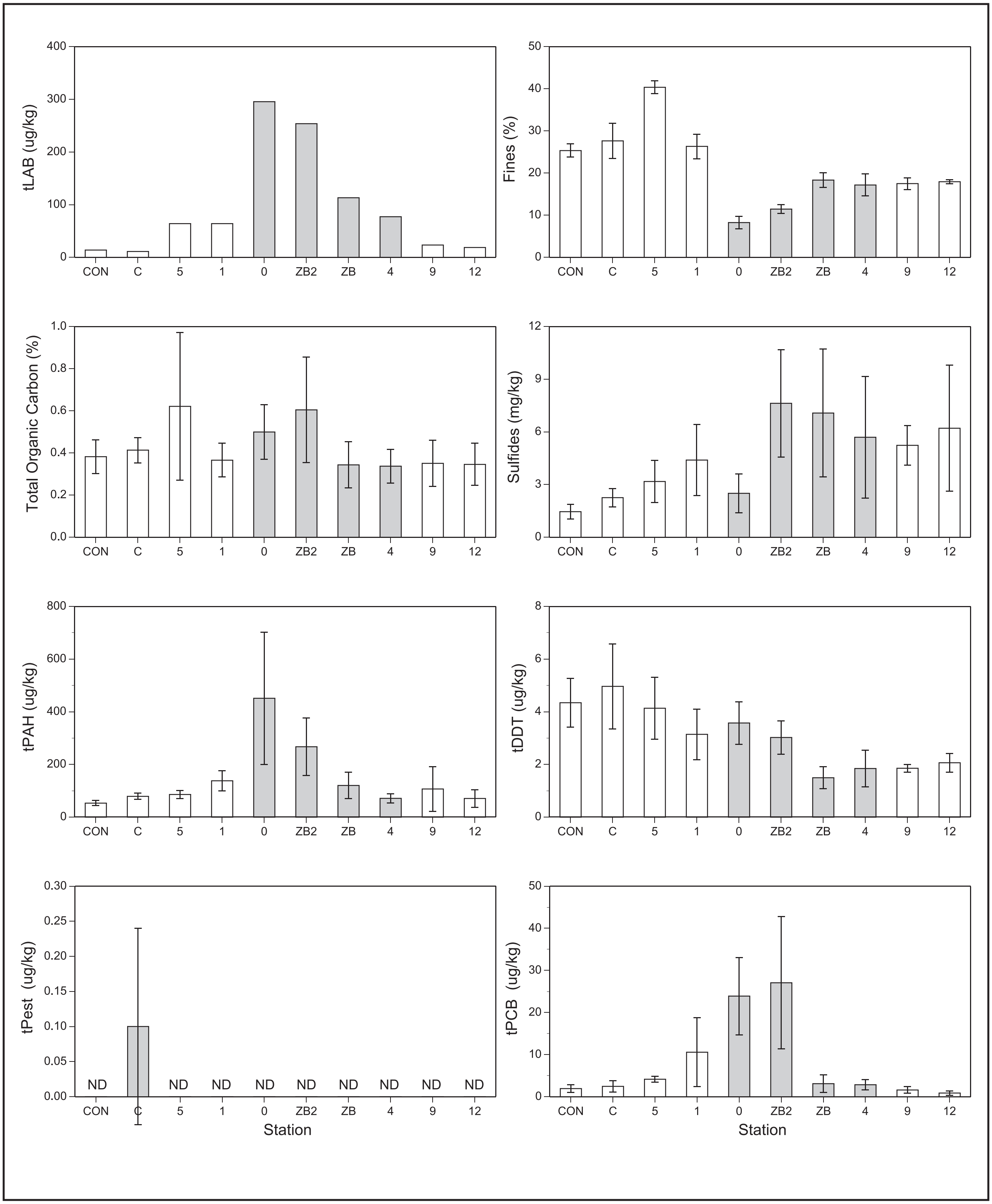


Figure 4-3. **Distribution of mean and standard deviation values for total LAB (ųg/kg), fines (%), total organic carbon (%), dissolved sulfides (mg/kg), total PAH (ųg/kg), total DDT (ųg/kg), total pesticides (ųg/kg), and total PCB (ųg/kg) in sediments at the 60 m shelf stations during 2010-11.**
Stations plotted from north to south (left to right). ZID stations indicated in grey.

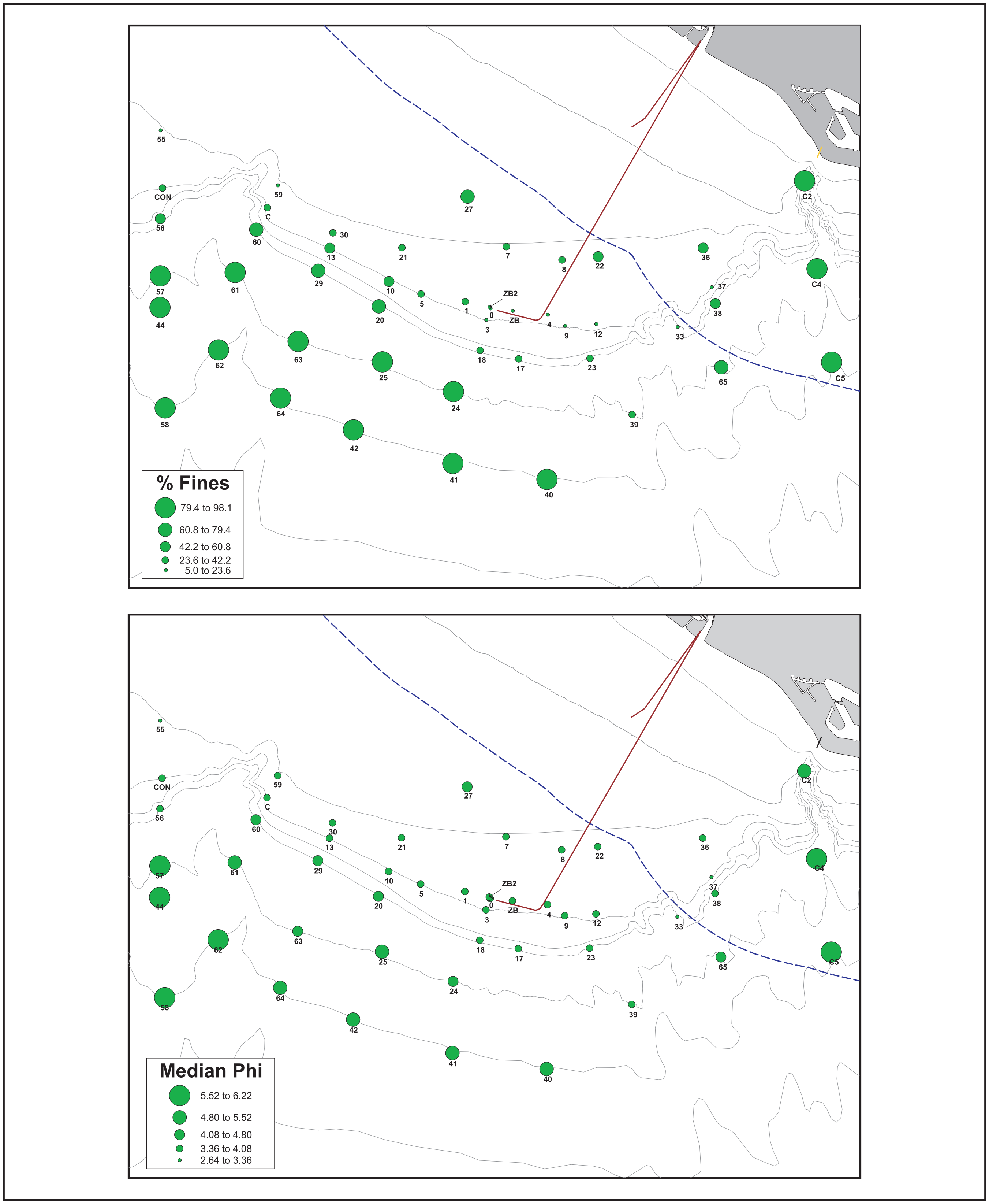


Figure 4-4. **Spatial trend bubble plots of % fines and median phi.**

Orange County Sanitation District, California.

At the 60-m quarterly stations, mean for percent fines were 13.8% within the ZID and 25.8% beyond the ZID (Table 4-2); however, percent fines were significantly higher upcoast of the outfall (Figure 4-3). Values at within-ZID Stations 0 and ZB2 decreased 3.4% and 5.2%, respectively, from 2009-10, while values at all other stations either stayed within 1% or increased from the 2009-10 values. Mean values at Stations 0 and ZB2 (8.23% and 11.4%, respectively) were below their long-term (1985–2010) low values for those stations (10.7% and 13.1%, respectively). The mean percent fines for all quarterly stations were below Bight'08 mid-shelf area-weighted means.

<u>Sediment Organic Content</u>

Total Organic Carbon (TOC)
In July 2010, mean percent TOC by station depth ranged from 0.60 to 2.27%, generally increasing with depth (Table 4-1; Figure 4-5). Values were generally comparable to Bight'08 means by depth strata. Mean TOC was lowest within the ZID. Correlation analysis found significant relationships of TOC to percent fines (R = 0.65), but not tLAB, indicating that sediment grain size is the primary factor determining sediment TOC concentrations and the outfall discharge is not a significant factor.

Quarterly station means for sediment TOC were comparable for most stations with a range of 0.34 to 0.62% (Table 4-2; Figure 4-3). Only outfall Stations 0 and ZB2 and nearfield upcoast Station 5 averaged values of 0.50% or above. Station 5 also had the highest percent fines, which might suggest an outfall influence; however, Station 5 had low tLAB levels indicating minimal outfall influence. Further, Station 1 had TOC levels comparable to other non-ZID stations indicating no evidence of an upcoast gradient. Station means were below Bight'08 mid-shelf AWMs.

Dissolved Sulfides
In the annual survey, mean sediment sulfide concentrations remained low ranging from 4.39 mg/kg at shallow-shelf stations to 14.8 mg/kg at slope stations (Table 4-1; Figure 4-5). Compared to shelf stations, sulfide concentrations were elevated in the slope, basin, and submarine canyons, which is consistent with a depositional, deep-water environment. Consistent with previous years (OCSD 2010), correlation analysis showed a significant relationship of dissolved sulfides to percent fines (R = 0.55), but not to tLAB concentrations suggesting a non-discharge related influence.

There was little difference in quarterly station means for sediment sulfides. Within-ZID stations averaged 5.72 mg/kg, only slightly above the 3.78 mg/kg at the non-ZID stations (Table 4-2; Figure 4-3). The quarterly mean for within-ZID Station 0 was 2.50 mg/kg, which was less than half the concentration at the other within-ZID stations, and more comparable to the upcoast farfield stations. This is counterintuitive since Station 0 is generally among the highest concentrations of sediment chemistry measures. The reason for the low sediment sulfide concentration at Station 0 may be related to the low percent fine sediment.

<u>Organic Contaminants</u>

Total Polycyclic Aromatic Hydrocarbons (tPAH)
In July 2010, mean sediment tPAH concentrations were highest at within-ZID stations (319.8 ug/kg) followed by slope (297.6 ug/kg) and basin (272.9 ug/kg) station groups (Table 4-1; Figure 4-2). The concentrations at these station groups were approximately two to three times those in the shallow shelf (88.4 ug/kg), mid-shelf non-ZID (146.2 ug/kg), and outer shelf (145.7 ug/kg) station groups. The slope and basin group means exceeded the Bight'08 AWMs. The highest concentration (593 ug/kg) occurred at Station 0. Although above the regional mid-shelf mean of 179 ug/kg, this value was still well below the ERL of 4,022 ug/kg, indicating a low probability of sediment toxicity due to PAHs. Correlation analysis showed a significant relationship of tPAH with tLAB (R=0.62) and percent fines (R=0.48), suggesting an outfall influence.

Mean tPAH concentrations at the 60-m quarterly stations were highest near the outfall terminus (ZID Stations 0 and ZB, and nearfield Station 1), and then decreased with increasing distance from the outfall (Table 4-2; Figure 4-3). Non-ZID station means were below Bight'08 mid-shelf AWMs.

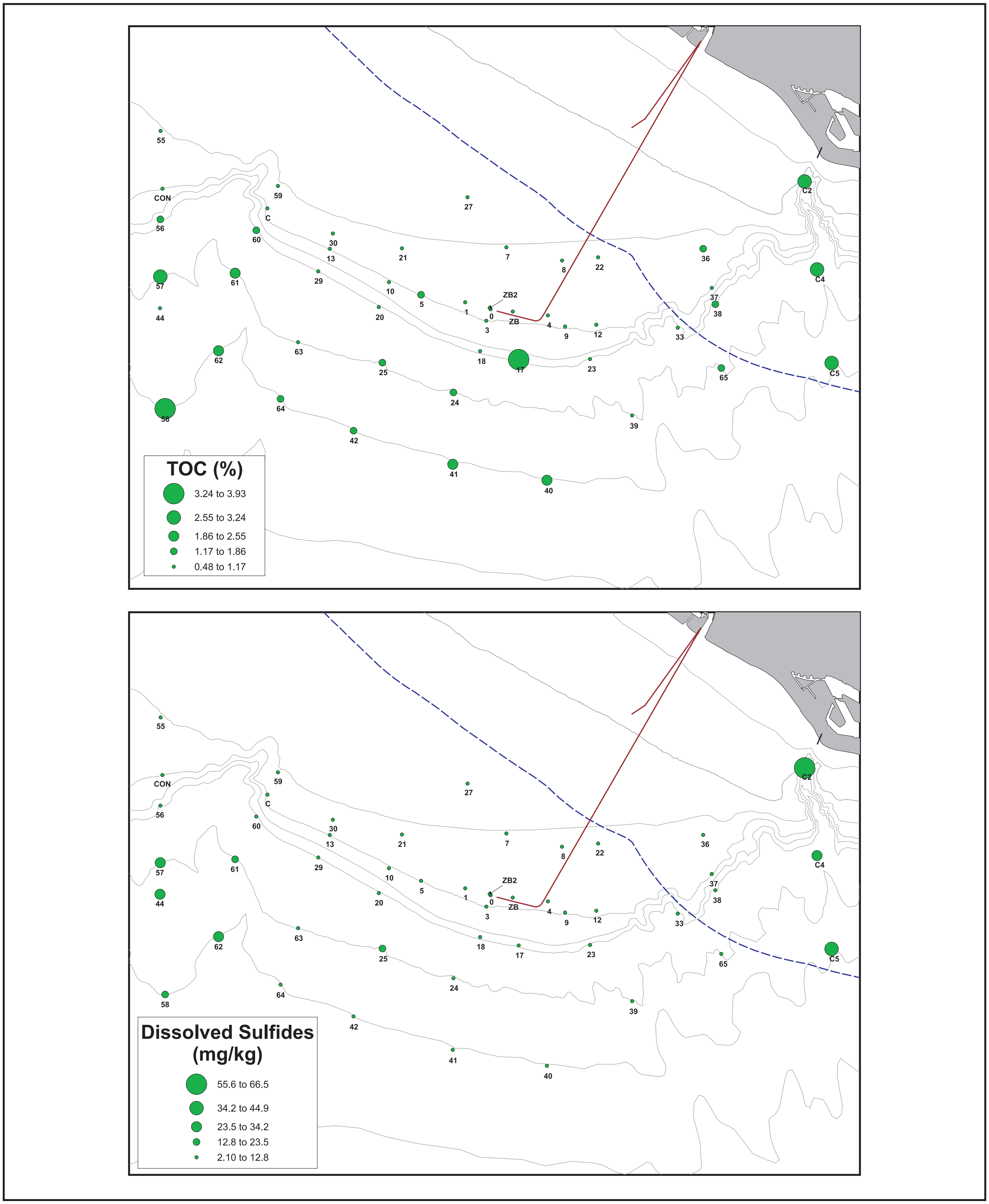


Figure 4-5. **Spatial trend bubble plots of % TOC and dissolved sulfides.**

Orange County Sanitation District, California.

Total Chlorinated Pesticides other than DDT (tPest)
The outfall is not a significant source of chlorinated pesticide compounds. They were not detected at any station during the three quarter surveys except for non-ZID Station C in October 2010 (0.10 ug/kg; Table 4-2; Figure 4-3).

Total dichlorodipheynltrichloroethanes (tDDT)
Mean tDDT concentration exceeded the ERL at all quarterly stations except within-ZID Station ZB, but all were below the Bight'08 mid-shelf AWM (Table 4-2). Mean sediment concentrations ranged from 2.48 ug/kg within the ZID to 3.41 ug/kg beyond the ZID. There was a gradient of increasing concentrations upcoast from the outfall (Figure 4-3). This pattern likely reflects the influence of the high tDDT concentrations in Palos Verdes Shelf sediments and the redistribution of tDDT-laden sediments in the SCB. All quarterly station means except for Station ZB exceeded the ERL. Historically, tDDT has been found to be highly variable between years and stations (OCSD 2003). The lack of outfall influence is consistent with results from previous years and the legacy contaminant properties of DDT. DDT is found ubiquitously in the Southern California Bight and its occurrence in sediments is due to historical discharges that ceased in the early 1970's.

Total Polychlorinated Biphenyls (tPCB)
Mean total PCB (tPCB) concentrations at quarterly within-ZID stations (14.24 ug/kg) were almost 4 times that of non-ZID stations (3.60 ug/kg; Table 4-2). Mean station concentrations were highest at ZID Stations 0 (23.90 ug/kg) and ZB2 (27.10 ug/kg) and decreased outside the ZID and with increasing distance from the outfall (Figure 4-3). All non-ZID stations had tPCB concentrations below the ERL and the Bight'08 mid-shelf AWM.

Metals
In July 2010, as in previous years, metals were grouped according to two basic sediment concentration patterns: 1) Group A metals show grain size/depth-related patterns with no clear outfall effect, and 2) Group B metals are those with some degree of outfall influence (Figure 4-6). Group A metals included arsenic, beryllium, chromium, lead, nickel, and selenium. Group B consisted of cadmium, copper, mercury, silver, and zinc. All metals showed significant correlations to tLABs and all but mercury were correlated with percent fines. Group A metals exhibited stronger correlations to percent fines (R>0.80) and Group B metals to tLAB (R>0.60). Some metals switch groups from year-to-year (e.g., copper), a result that may be due to variability in concentration and the effect of oceanographic conditions on deposition. Cadmium and mercury, both known to be related to wastewater discharges, showed the most obvious patterns of an outfall influence. The mean within-ZID station cadmium concentration of 0.56 mg/kg is greater than the Bight'08 mid-shelf mean of 0.32 mg/kg, but still below the ERL. The spatial distributions of all metals are presented in Appendix B, Figure B-27.

Of the 539 sediment metal analyses conducted (11 metals x 49 stations) only 13 (~3%) exceeded ERL values and none exceeded ERMs. Arsenic, cadmium, copper, mercury, and nickel exceeded their ERLs, predominately at slope and basin stations (Table 4-3). The mean mercury concentration in the Within-ZID station group was 4 to 8 times higher than other groups, but was slightly below the ERL. All metals except beryllium in the slope and basin depth groups had concentrations comparable to or below the Bight'08 upper slope and basin AWMs. Beryllium concentrations in the deeper groups were almost twice that of the Bight'08 AWMs.

Quarterly station mean sediment concentrations for most metals were comparable to or below Bight'08 mid-shelf AWMs and ERL values (Table 4-4). Mean sediment concentrations of mercury and cadmium exceeded ERL values at within-ZID Station 0. Both metals indicated an outfall influence with higher concentrations within the ZID and decreasing concentrations with increased distance from the outfall (Figures 4-7, B-11). The remaining metals showed no patterns related to the outfall.

Principal Components Analysis (PCA)
Principal Components Analysis (PCA) and non-metric multidimensional scaling (MDS) was performed using the July 2010 annual station data, including the 10 quarterly stations (n = 49 stations). The MDS analysis showed very low

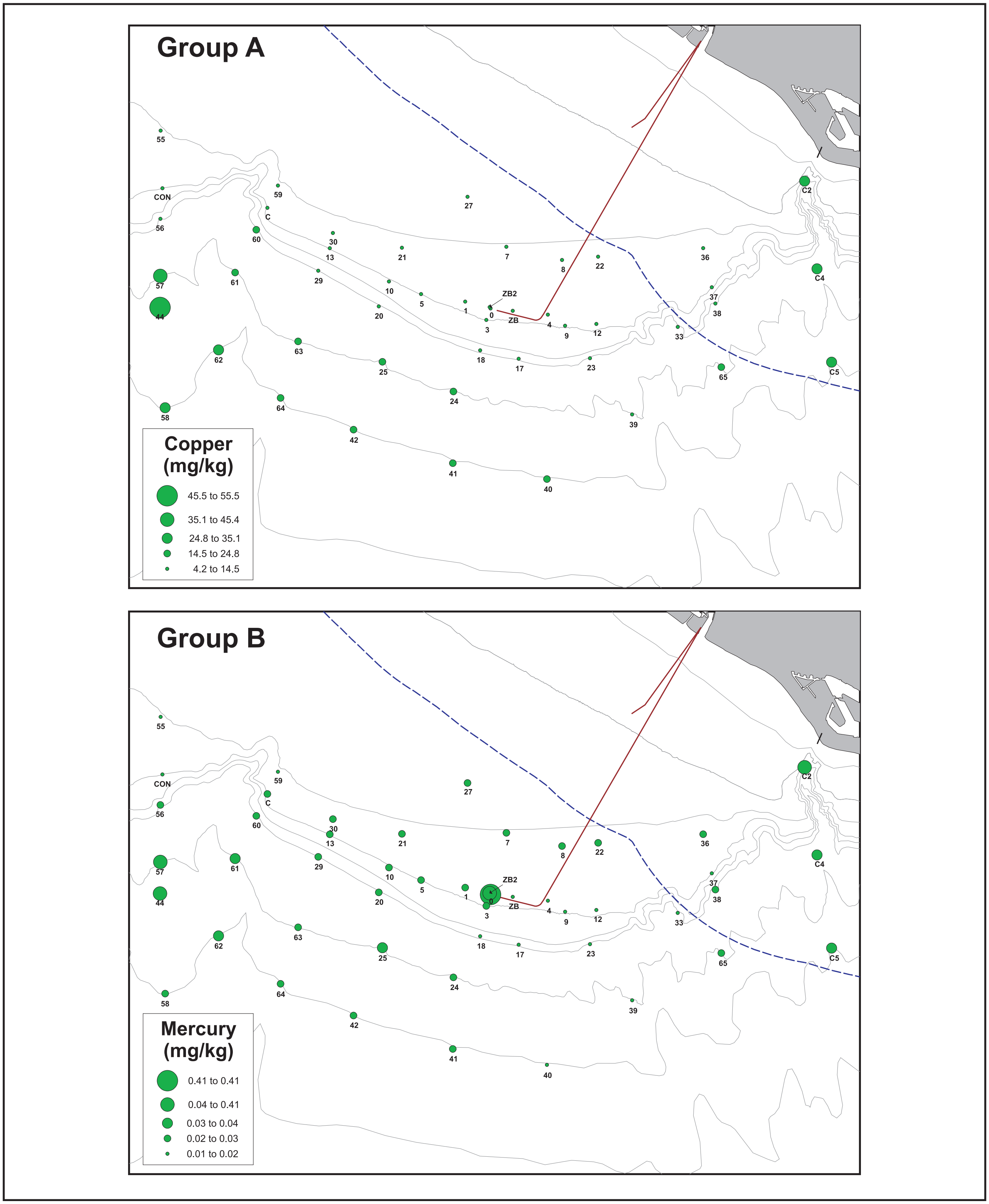


Figure 4-6. **Spatial trend bubble plots of representative Group A (copper) and Group B (mercury) metals.**

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Table 4-3. Annual concentrations of sediment metals (mg/kg) at the District's annual stations in 2010-11 compared with Effects Range–Low (ERL) and Effects Range–Median (ERM) values and regional measurements of sediment physical characteristics.

Orange County Sanitation District, California.

Station	Depth (m)	As	Be	Cd	Cr	Cu	Pb	Hg	Ni	Se	Ag	Zn
Shallow Shelf (40 – 46 meters)												
7	41	3.50	0.23	0.26	20.5	10.4	6.17	0.02	9.70	0.50	0.10	39.2
8	44	3.71	0.23	0.30	17.5	9.18	6.35	0.02	8.46	0.36	0.18	35.7
21	44	3.60	0.24	0.20	17.6	8.16	5.98	0.02	8.12	0.30	0.14	35.4
22	45	4.60	0.28	0.27	21.8	10.9	6.75	0.02	10.8	0.49	0.14	45.8
30	46	3.23	0.24	0.24	19.3	9.09	6.02	0.02	8.41	0.44	0.15	36.1
36	45	4.15	0.28	0.27	18.7	9.14	7.12	0.02	9.99	0.38	0.09	40.9
55	40	2.42	0.16	0.10	12.8	4.24	3.40	0.01	6.22	0.29	0.02	23.0
59	40	2.70	0.20	0.15	14.7	5.94	4.69	0.011	6.93	0.31	0.09	27.7
	Mean	3.49	0.23	0.22	17.9	8.38	5.81	0.02	8.58	0.38	0.12	35.5
Mid-Shelf Within-ZID (56 – 60 meters)												
0 **	56	3.38	0.23	0.74	22.1	14.3	5.05	**0.41**	9.10	0.46	0.20	45.8
4 **	56	2.71	0.23	0.29	19.5	8.80	4.09	0.01	10.6	0.38	0.13	39.4
ZB **	56	3.23	0.28	0.50	20.2	12.7	4.23	0.01	10.0	0.46	0.18	48.2
ZB2 **	56	3.23	0.22	0.72	19.3	12.4	4.87	0.05	7.94	0.37	0.20	43.4
	Mean	3.14	0.24	0.56	20.3	12.1	4.56	0.12	9.41	0.42	0.18	44.2
Mid-Shelf Non-ZID (56 – 60 meters)												
1 **	56	2.89	0.25	0.38	20.0	11.7	6.03	0.02	8.70	0.37	0.29	41.1
3	60	2.38	0.26	0.32	18.8	10.5	5.05	0.02	8.70	0.34	0.21	41.7
5 **	59	3.55	0.28	0.32	20.9	12.1	6.68	0.02	9.77	0.39	0.27	42.8
9 **	59	2.57	0.26	0.23	19.6	9.10	4.49	0.01	8.81	0.44	0.13	38.6
10	60	3.67	0.32	0.35	24.8	14.2	6.62	0.02	11.5	0.49	0.27	48.2
12 **	58	3.44	0.24	0.23	17.3	8.26	5.37	0.02	8.02	0.35	0.16	35.4
13	59	3.90	0.27	0.28	24.2	12.1	6.30	0.02	11.4	0.52	0.18	48.2
37	56	2.92	0.22	0.16	12.6	5.58	4.04	0.01	6.96	0.25	0.06	31.0
C **	56	3.60	0.24	0.19	18.3	7.63	6.36	0.02	7.93	0.36	0.12	34.3
C2	56	7.86	0.58	0.68	35.4	27.9	16.1	0.04	**23.5**	1.05	0.20	115
CON **	59	3.65	0.26	0.19	19.8	9.05	6.18	0.01	9.46	0.38	0.13	39.3
	Mean	3.68	0.29	0.30	21.1	11.6	6.66	0.02	10.4	0.45	0.18	46.9
Outer Shelf (91–-100 meters)												
17	91	3.28	0.31	0.25	21.5	9.77	5.14	0.01	11.3	0.47	0.10	47.6
18	91	3.32	0.31	0.23	22.7	10.1	5.70	0.01	11.6	0.47	0.10	46.7
20	100	3.42	0.31	0.31	23.2	12.9	7.30	0.02	11.4	0.47	0.25	47.7
23	100	3.49	0.28	0.24	20.0	8.77	5.30	0.01	10.5	0.44	0.08	43.5
29	100	3.48	0.30	0.33	26.2	14.4	6.90	0.02	12.6	0.56	0.24	50.9
33	100	3.56	0.28	0.26	17.4	8.13	5.13	0.01	9.44	0.30	0.11	38.7
38	100	4.12	0.35	0.46	25.0	13.2	6.90	0.02	14.1	0.62	0.15	55.1
56	100	3.50	0.31	0.31	24.1	13.0	7.64	0.02	12.0	0.39	0.22	47.1
60	100	3.53	0.34	0.43	27.3	16.2	8.71	0.02	13.3	0.51	0.31	53.4
	Mean	3.52	0.31	0.31	23.0	11.8	6.52	0.02	11.8	0.47	0.17	47.9

Table 4-3 Continues.

Table 4-3 Continued.

Station	Depth (m)	As	Be	Cd	Cr	Cu	Pb	Hg	Ni	Se	Ag	Zn
						Slope (187 – 241 meters)						
24	200	4.04	0.43	0.51	31.9	17.6	10.4	0.02	16.3	0.77	0.28	61.5
25	200	4.53	0.48	0.63	36.6	22.1	13.1	0.03	18.1	0.96	0.40	67.6
27	200	3.59	0.39	0.41	25.7	13.2	8.10	0.02	13.8	0.61	0.17	52.0
39	200	3.21	0.32	0.33	24.1	10.3	5.32	0.01	12.5	0.54	0.22	49.2
44	241	**8.43**	0.60	**1.25**	66.6	**55.5**	19.6	0.05	**27.7**	1.52	**1.15**	108
57	200	5.92	0.56	0.85	50.0	**36.3**	17.1	0.04	**22.7**	1.16	0.77	90.1
61	200	4.85	0.45	0.67	35.6	23.5	12.7	0.03	17.6	0.89	0.47	67.8
63	200	4.48	0.41	0.55	32.3	19.7	12.4	0.03	16.6	0.81	0.37	62.5
65	200	4.62	0.41	0.58	28.0	15.8	8.59	0.02	15.7	0.67	0.20	59.0
C4	187	7.50	0.58	0.79	39.1	24.8	16.2	0.03	**21.9**	1.10	0.31	95.2
	Mean	5.12	0.46	0.67	37.0	23.9	12.4	0.03	18.3	0.90	0.43	71.3
						Basin (296 – 300 meters)						
40	303	4.39	0.43	0.55	36.0	20.2	8.74	0.02	19.1	1.03	0.21	67.0
41	303	4.60	0.46	0.49	36.2	20.5	7.91	0.02	19.6	1.05	0.19	65.9
42	303	6.04	0.51	0.64	39.5	23.0	13.4	0.02	20.0	1.20	0.33	75.3
58	300	6.83	0.55	0.73	48.2	29.8	17.1	0.02	**23.1**	1.41	0.50	86.0
62	300	6.81	0.56	0.87	49.1	32.4	18.0	0.03	**23.0**	1.45	0.60	88.9
64	300	5.44	0.51	0.54	36.1	22.1	12.3	0.02	19.6	1.08	0.27	69.1
C5	296	7.47	0.62	0.93	48.4	30.4	16.6	0.03	**24.0**	1.29	0.46	94.1
	Mean	5.94	0.52	0.68	41.9	25.5	13.4	0.02	**21.2**	1.22	0.37	78.0
						SEDIMENT QUALITY GUIDELINES						
[1] ERL		8.20	NA	1.20	81.0	34.0	46.7	0.15	20.9	NA	1.00	150
[1] ERM		70.0	NA	9.60	370	270	218	0.70	51.6	NA	3.70	410
[2] Bight'08 Mid-shelf AWM		6.1	0.3	0.32	31.0	10.7	7.8	0.05	12.0	0.72	0.24	46.0
[2] Bight'08 Outer-shelf AWM		6.1	0.19	0.47	36.0	12.3	9.1	0.05	17.0	0.54	0.25	52.0
[2] Bight'08 Upper Slope/Basin AWM		8.8	0.29	1.4	68.0	22.8	15.0	0.09	29.0	1.60	1.60	79.0

NA = Not applicable.
Individual values greater than the ERL are bolded.
Annual stations n=1.
****** Quarterly Stations
[1] Long et al. (1995)
[2] Schiff et al. (2006)

Table 4-4. Mean concentrations of sediment metals (mg/kg) at the District's quarterly stations in 2010-11 compared to Effects Range–Low (ERL) and Effects Range–Median (ERM) values and regional measurements of sediment physical characteristics.

Orange County Sanitation District, California.

Station	Depth (m)	As	Be	Cd	Cr	Cu	Pb	Hg	Ni	Se	Ag	Zn
Within-ZID Stations												
0	56	3.42	0.23	**1.24**	20.85	14.3	4.9	**0.23**	8.6	0.37	0.20	46.65
4	56	2.75	0.24	0.25	17.85	8.1	4.1	0.02	8.6	0.31	0.12	37.63
ZB	56	2.92	0.26	0.44	18.12	10.4	4.1	0.02	9.1	0.32	0.14	44.30
ZB2	56	3.00	0.22	0.72	19.60	12.0	4.7	0.03	8.4	0.35	0.20	47.08
	Mean	3.02	0.24	0.66	19.12	11.2	4.4	0.07	8. 7	0.34	0.17	43.92
Non-ZID Stations												
1	56	2.65	0.24	0.35	19.03	11.4	5.6	0.02	8.6	0.32	0.24	40.65
5	59	3.21	0.26	0.31	20.80	12.4	6.1	0.02	10.0	0.35	0.25	43.63
9	59	2.78	0.25	0.20	18.43	8.6	4.5	0.01	8.5	0.33	0.12	37.70
12	58	2.97	0.23	0.20	17.05	7.6	4.7	0.01	8.1	0.30	0.24	35.60
C	56	3.33	0.25	0.23	20.15	9.2	6.2	0.02	9.6	0.36	0.13	40.67
CON	59	3.19	0.25	0.19	19.95	9.0	5.8	0.01	9. 8	0.35	0.12	40.38
	Mean	3.02	0.25	0.24	19.24	9.7	5.5	0.02	9.1	0.33	0.18	39.77
Sediment Quality Guideline and Reference Values												
[1] ERL		8.20	NA	1.20	81.0	34.0	46.7	0.15	20.9	NA	1.00	150
[1] ERM		70.0	NA	9.60	370	270	218	0.70	51.6	NA	3.70	410
[2] Bight'08 Mid-shelf AWM		6.1	0.3	0.32	31.0	10.7	7.8	0.05	12.0	0.72	0.24	46.0
[2] Bight'08 Outer-shelf AWM		6.1	0.19	0.47	36.0	12.3	9.1	0.05	17.0	0.54	0.25	52.0
[2] Bight'08 Upper Slope/Basin AWM		8.8	0.29	1.4	68.0	22.8	15.0	0.09	29.0	1.60	1.60	79.0

AWM = Area Weighted Mean, NA = Not Applicable

Values greater than the ERL are bolded.

Quarterly stations n = 4.

[1] Long et al. (1995)

[2] Schiff et al. (2011)

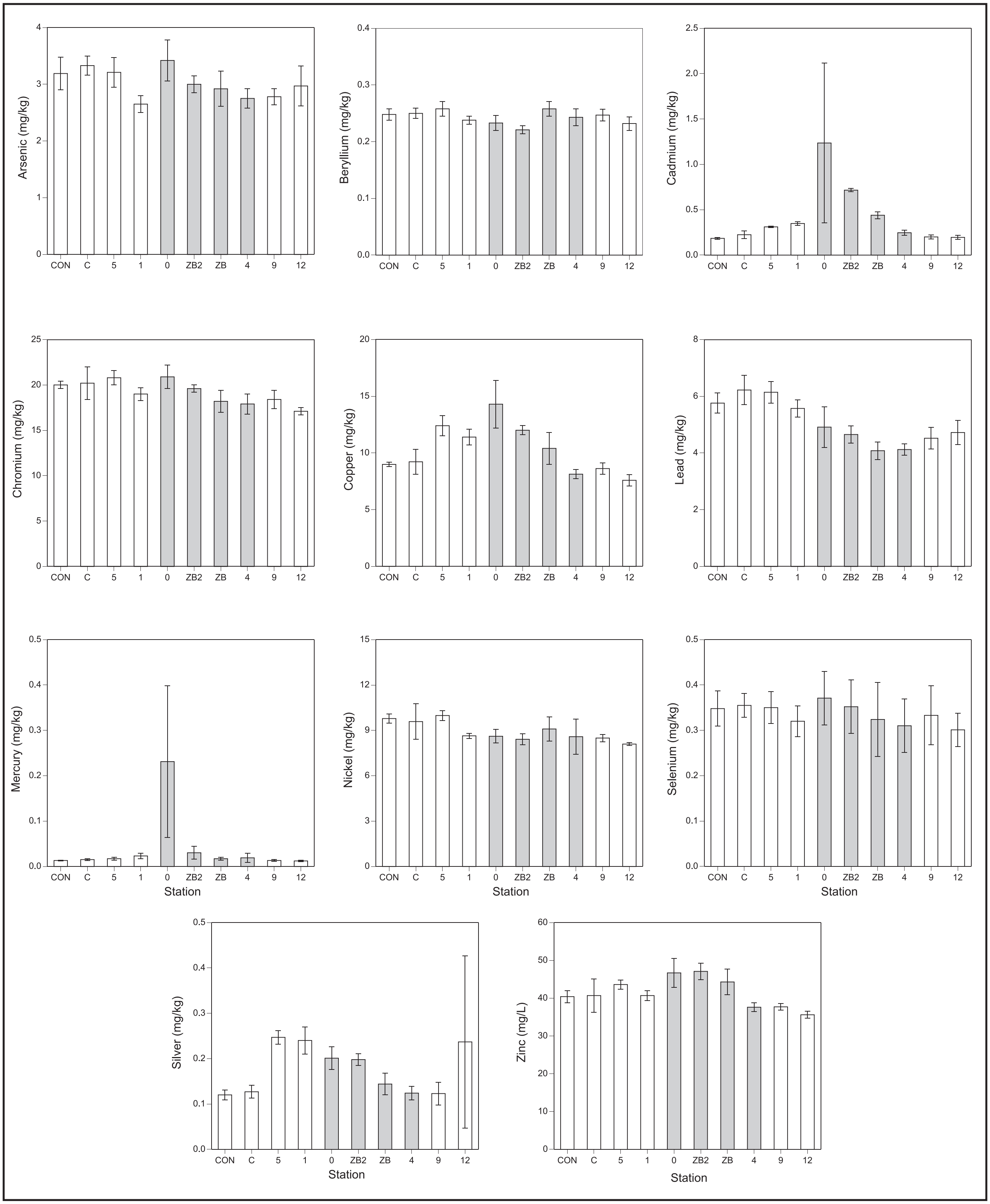

Figure 4-7. Distribution of mean and standard deviation values (mg/kg) for arsenic, beryllium, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver, and zinc in sediments at the 60 m shelf stations during 2010-11.

Stations plotted from north to south (left to right). ZID stations indicated in gray.

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2d stress (0.03) and produced similar results to the PCA.

These analyses identified five major station groups, and some subgroups within major groups, that generally correlated with grain size (percent fines) and the influence of the outfall discharge (Table 4-5, Figures 4-8).

For the following discussion, it should be noted that while cadmium and zinc were higher in some station groups than in others, all were below, concentrations that are considered harmful to marine life. The terms "high, moderate, and low concentrations" are used for comparison of station groups only.

Station Group 1 (SG1) consists of within-ZID Stations 0 and ZB2 and is characterized by the highest concentrations of tLAB, moderate concentrations of cadmium and zinc, and low percent fines. SG2 contains stations in high depositional areas including San Gabriel Canyon Stations 44, 57, 58, 62, and Newport Canyon Station C5. SG2 is characterized by high percent fines, tLAB, cadmium, and zinc. The elevated tLAB and cadmium concentrations suggest a strong outfall influence in the San Gabriel Canyon and is consistent with predominant upcoast-flowing sub-tidal currents below 30 m (SAIC, 2009). SG3 is comprised of 29 San Pedro Shelf stations. This group is characterized by low tLAB concentrations, moderate percent fines, and low to moderate Cd and Zn. An outfall influence is evident at within-ZID Stations 4 and ZB, and nearfield Stations 1 and 5 to form a sub-group of stations (SG3A), but not sufficiently to group with SG1 (Table 4-5). SG4 consists of 13 Newport Canyon, outer-shelf, slope, and basin stations. SG4 is characterized by low tLAB, high percent fines, and moderate cadmium and zinc concentrations. The low tLAB concentrations indicate minimal outfall influence even at these moderate to high depositional stations. SG5 has only shallow-shelf Station 55, located approximately 8 km upcoast from the outfall. This station is characterized by low percent fines and low tLAB, cadmium, and zinc concentrations.

Table 4-5. Station groups identified by principal components analysis (PCA) and non-metric multidimensional scaling (MDS) on the annual stations in July 2010.

Orange County Sanitation District, California.

Station Group	Stations	Subgroup A	Subgroup B	Subgroup C
1	0, ZB2			
2	44, 57, 58, 62, C5	44, 57	58, 62, C5	
3	1, 3, 4, 5, 7, 8, 9, 10, 12, 13, 17, 18, 20, 21, 22, 23, 27, 29, 30, 33, 36, 37, 38, 39, 56, 59, C, CON, ZB	1, 3, 4, 5, ZB	9, 12, 21, 33, 37, 59, C, CON	7, 8, 10, 13, 17, 18, 20, 22, 23, 27, 29, 30, 36, 38, 39, 56
4	24, 25, 40, 41, 42, 60, 61, 63, 64, 65, C2, C4	60	C2, C4	24, 25, 40, 41, 42, 61, 63, 64, 65
5	55			

n = 49

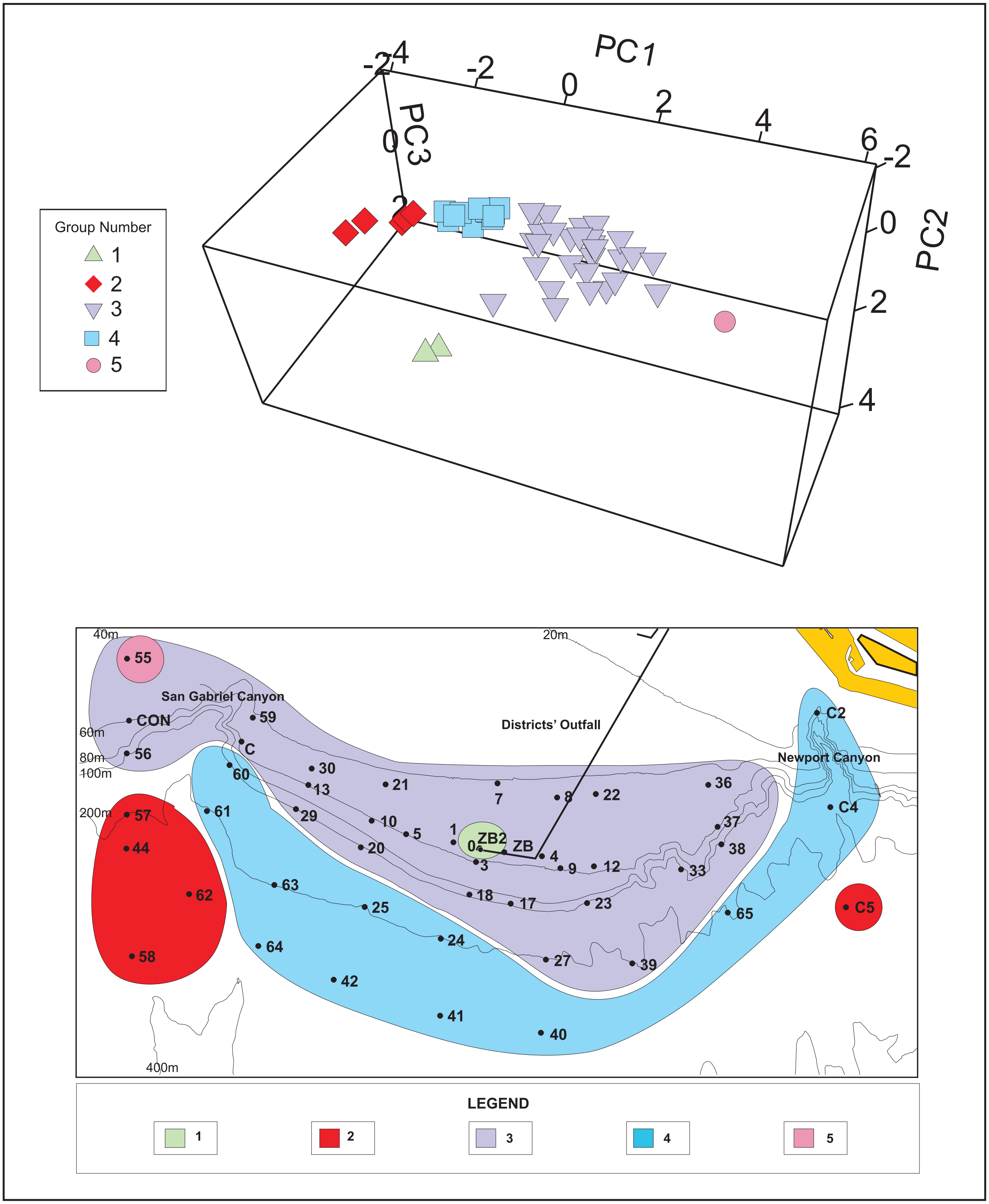

Figure 4-8. **Station plot (a) and map of station groups (b) of principal components analysis (PCA) for July 2010. Station symbols correspond to PCA station groupings (group numbers).**

Long-term (Temporal) Trend Analysis

Long-term trends at the quarterly stations for all sediment measures showed no noteworthy changes from those reported last year that are not attributable to previously observed station variability (OCSD 2010). All 2010-11 sediment measure values are within the range of long-term variability seen in the 60 m stations and are at concentrations that are not of biological concern (i.e., below ERL values) in non-ZID station groups with the exception of the legacy contaminant tDDT (Figure 4-9).

Most measures showed either no significant change or are decreasing over time at most 60-m stations. These include percent fines, dissolved sulfide, tDDT, tPCB, tPAH, arsenic, beryllium, cadmium, chromium, copper, lead, nickel, selenium, silver, and zinc. Since 1999-2000, percent TOC is increasing slightly at a comparable rate at all stations indicating an area-wide influence. However, since 2006-07, TOC levels have remained relatively constant, except for continued increases at within-ZID Stations 0 and ZB2, and non-ZID upcoast Station 5 (Figure 4-9). Mercury concentrations are higher and more variable over time at within-ZID Stations 0 and ZB2 than all other 60-m stations with concentrations eight times higher than at the other stations. However, mercury, cadmium, and arsenic showed dramatic increases in 2010-11 at ZID Station 0.

Several measures showed definite outfall-related patterns over time. Percent fines were consistently highest at Station 5 followed by Stations 1, C, and CON, then 9 and 12, and were lowest at the four within-ZID Stations. Silver showed a similar pattern to percent fines except that Stations 1 and 5 were approximately equal. Cadmium and copper at Stations 0 and ZB2 had concentrations that were several times greater than Station CON. Stations 4 and ZB were also high in cadmium and copper. The lowest values occurred at Stations 9, 12, C, and CON, which were all comparable through time.

Sediment Toxicity

Whole-sediment toxicity testing was conducted on sediments collected during the October 2010 and April 2011 surveys. No toxicity was indicated in any of the October 2010 samples. Low toxicity was found with the 10-day amphipod survival test at within-ZID Stations 0 and ZB2 in April 2011 (Table 4-6).

In 2010-11, all samples were below the mERMq threshold indicating low potential for toxicity (i.e., mERMq>0.11). The mERMq values ranged from 0.02 to 0.08 with station means ranging from 0.02 to 0.06 (Table 4-7). This is consistent with previous years, but is in contrast to the whole-sediment toxicity seen at within-ZID Stations 0 and ZB2 in April 2011, and the decline in invertebrate populations near the outfall that has occurred over the last few years (see Chapter 5). The mERMq is based on a suite of traditional wastewater contaminants and is not reflective of all potentially toxic compounds actually in the effluent (e.g., chlorination by-products).

The general lack of whole-sediment toxicity and low mERMq scores is inconsistent with the observed decline in invertebrate communities that has been occurring near the outfall over the last few years. These results suggest that whatever factor(s) is causing invertebrate communities to decline near the outfall it is not acutely toxic nor is it likely measured in the permit-required suite of chemicals monitored by the District. See Chapter 5 for a complete discussion of the decline in invertebrate communities in the monitoring area.

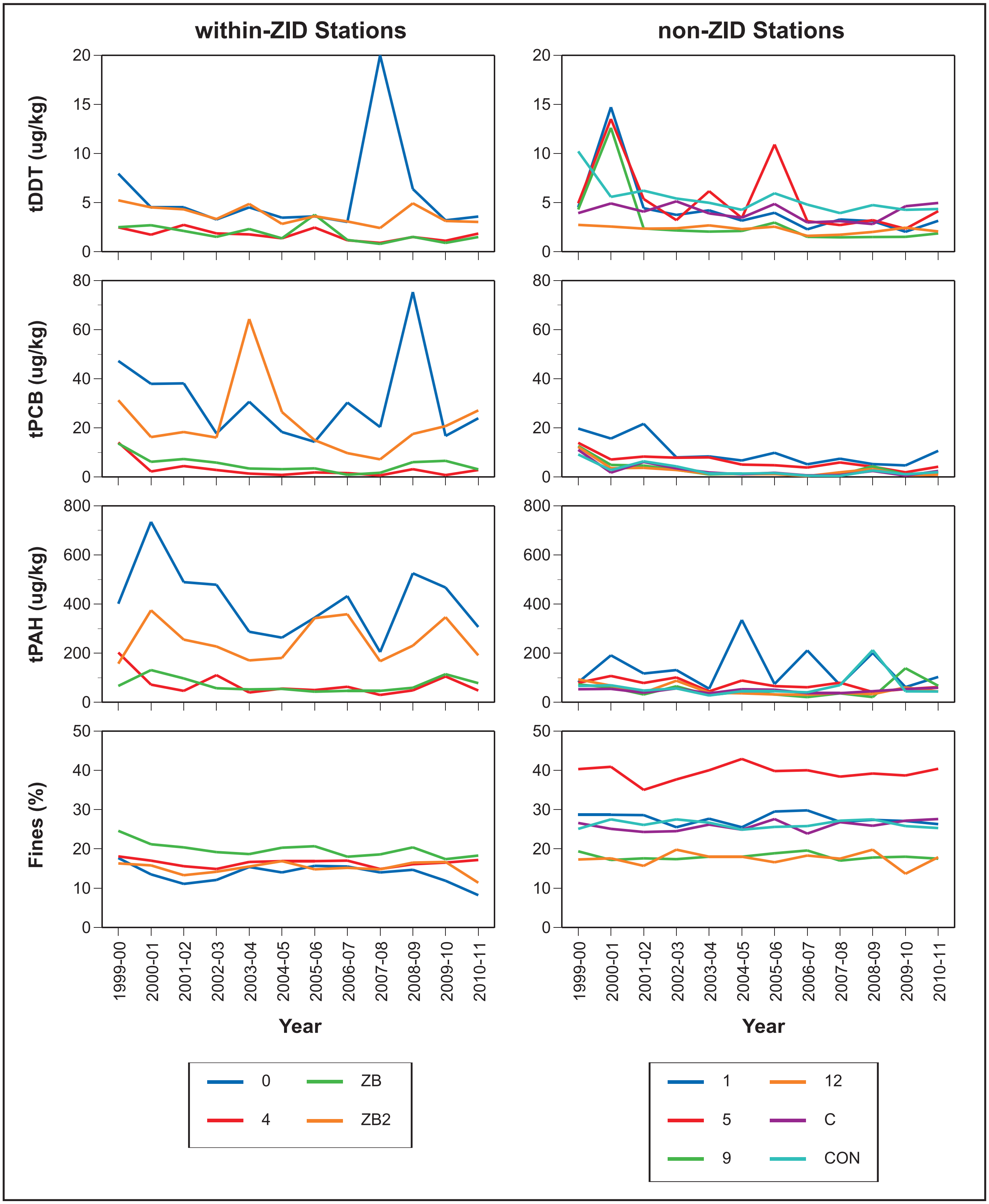

Figure 4-9. **Changes over time for total DDT, total PCB, total PAH, % fines, sulfides[1], total organic carbon, arsenic, beryllium, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver, and zinc in sediments at the 60 m shelf station groups during 1997–2011.**

[1] Sulfides analysis performed as acid volatile sulfides from 1997 through 2006 and as dissolved sulfides for 2007 and 2008.

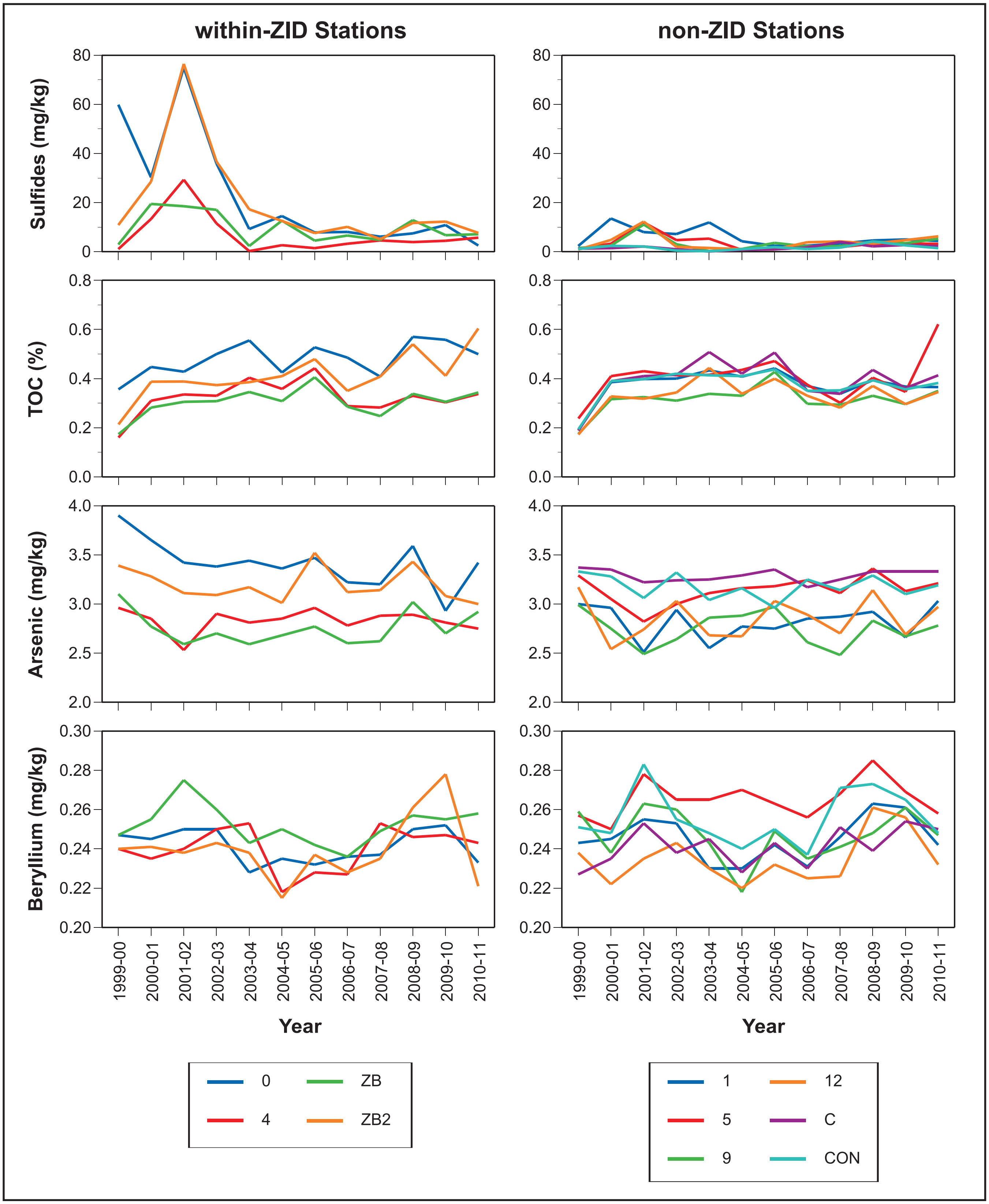

Figure 4-9 Continued.

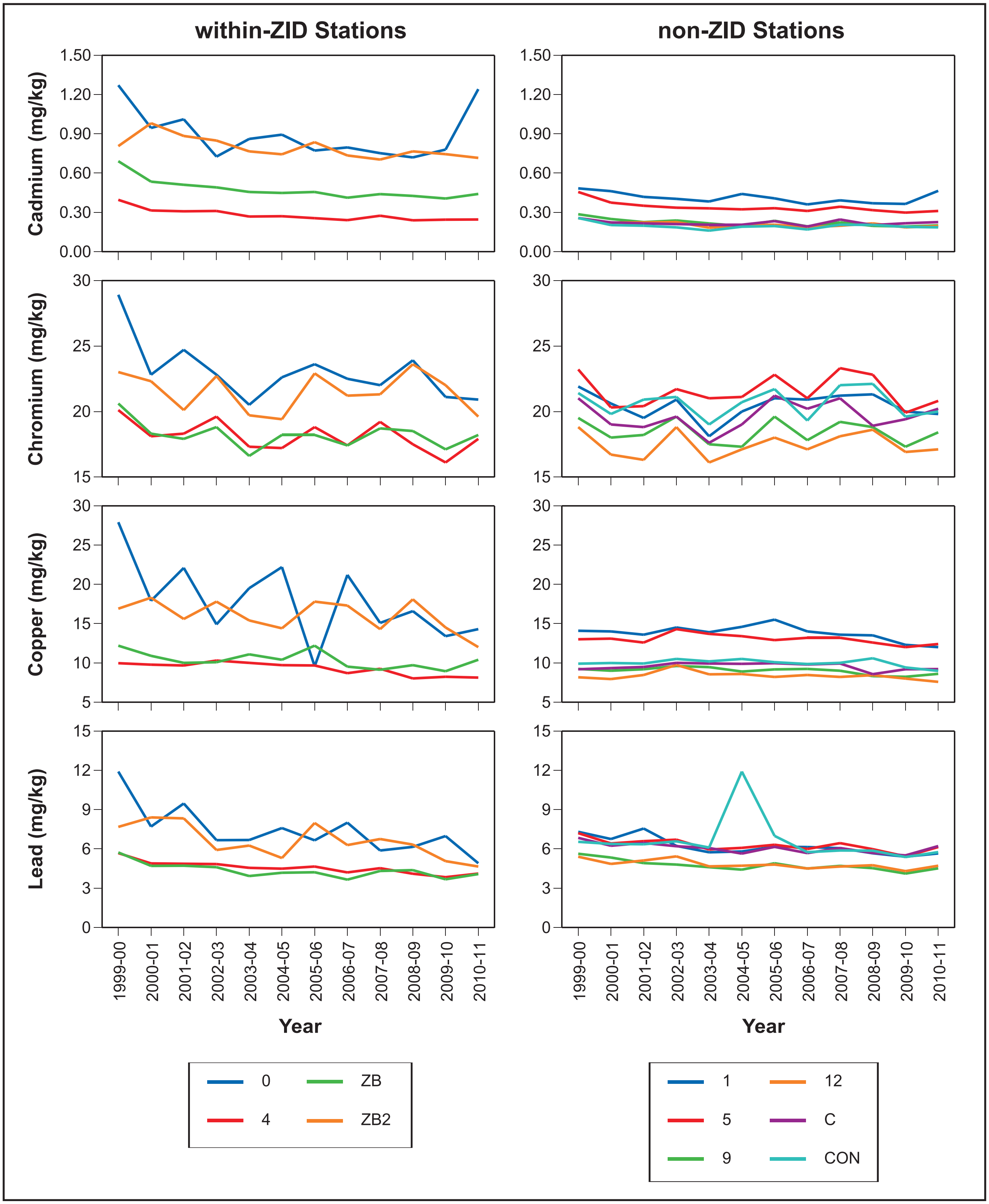

Figure 4-9 Continued.

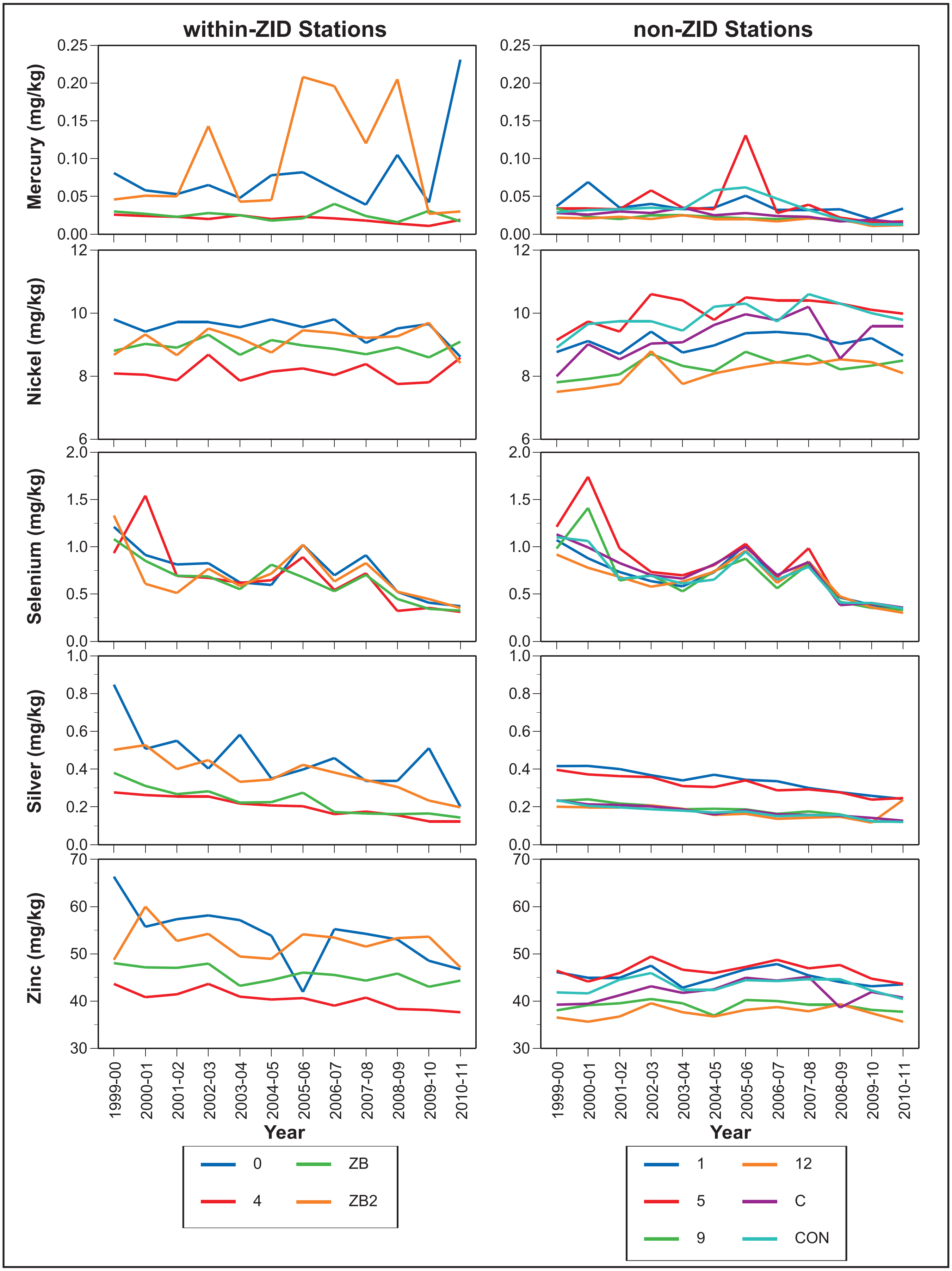

Figure 4-9 Continued.

Table 4-6. Sediment toxicity test results for October 2010 and April 2011. Whole-sediment (amphipod) test results given as test sediment percent difference from home sediment.

Orange County Sanitation District, California.

Date	Station									
	CON	C	5	1	ZB2	0	ZB	4	9	12
April 2011	1.0	0	1.0	6.0	**13.0**	**15.0**	7.0	4.0	4.0	7.0
October 2010	1.0	8.1	0	1.0	6.1	6.1	0	3.0	-1.0	-1.0
Historical Results										
2009-10 Mean**	2.6	-2.1	-2.1	2.6	1.0	**22.7**	1.1	1.0	1.0	3.1
January 2009	0	6.6	4.4	-2.2	5.5	2.2	4.4	4.4	-2.2	1.1
January 2008	0	9.0	3.0	3.0	3.0	3.0	-2.0	4.0	-1.0	-3.0
October 2006*	-5.8	5.8	1.2	-4.6	-4.6	-1.2	3.5	2.3	1.2	2.3
2005-06 Mean	1.5	0.5	0.5	-0.5	0.5	2.5	3.5	5.6	-0.5	1.5
2004-05 Mean	1.0	3.0	5.0	7.0	6.0	6.0	-1.0	5.0	1.0	1.0
2003-04 Mean	3.0	10.0	5.0	4.0	5.0	5.0	8.0	5.0	4.0	3.0
2002-03 Mean	2.7	10.3	5.0	3.7	5.3	5.3	8.0	5.0	4.0	3.3

Negative values represent values greater than 100% of home sediment. Bolded values represent significant toxicity.
Amphipod test results that are >20% different and $p<0.05$ from the control = toxic response (Bay et al. 2000).
* Results prior to July 2006 are means based on quarterly testing. Beginning in the 2006-07 monitoring year, only one quarter per year is tested. The quarter to be tested is chosen at random with the provision that a quarter will not be tested in consecutive years.
** Station 0, 4, 5, 12, and C: n = 1, all others: n = 2.

Table 4-7. Mean ERMq values for sediment contaminant concentrations, 2010-11.

Orange County Sanitation District, California.

Survey	Station									
	CON	C	5	1	ZB2	0	ZB	4	9	12
April 2011	0.03	0.02	0.03	0.04	0.05	0.05	0.03	0.03	0.02	0.02
January 2011	0.02	0.02	0.03	0.03	0.07	0.05	0.03	0.02	0.02	0.02
October 2010	0.03	0.03	0.03	0.03	0.04	0.08	0.03	0.02	0.02	0.03
July 2010	0.02	0.03	0.03	0.04	0.05	0.04	0.03	0.02	0.02	0.03
2010-11 Mean	0.03	0.03	0.03	0.04	0.05	0.06	0.03	0.02	0.02	0.03
Historical Results										
2009-10 Mean	0.03	0.03	0.03	0.03	0.06	0.06	0.03	0.03	0.02	0.02
2008-09 Mean	0.05	0.04	0.04	0.04	0.08	**0.11**	0.05	0.03	0.04	0.04
2007-08 Mean	0.03	0.03	0.04	0.04	0.05	0.06	0.03	0.3	0.03	0.02

Values less than or equal to 0.10 indicate a low potential for toxicity, between 0.11–1.0 indicate moderate potential for toxicity, and >1.00 indicates a high probability for toxicity (Long et al. 1998). Bolded values indicate potentially toxic sediment conditions.

CONCLUSIONS

Sediment geochemistry results from the 2010-11 monitoring year were generally consistent with those of previous years suggesting generally good sediment quality in the monitoring area as measured by core monitoring parameters. There are mostly decreasing trends over time in organic chemical constituents, with most concentrations below the ERL thresholds. Metal constituents outside the ZID are generally at concentrations below that of biological concern with no clear outfall-related temporal trends. Principal Components Analysis indicated that stations grouped primarily by station depth (percent fines) and outfall influence (e.g., San Gabriel Submarine Canyon). Mean ERMq analysis indicated a low probability of sediment toxicity in the monitoring area outside the ZID, which was consistent with whole-sediment toxicity test results. Overall, results suggested that there were some minor effects to sediment quality, but they are mainly localized near the outfall or in depositional areas, such as the slope, basin, and submarine canyons, but not of a magnitude that should cause adverse effects on marine communities. However, these results were in contrast to declining invertebrate communities near the outfall suggesting that the causative factor(s) are not measured in the core monitoring program.

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