City of San Diego
PUBLIC UTILITIES
Water & Wastewater

Application For Renewal of NPDES CA0107409 and 301(h) Modified Secondary Treatment Requirements

POINT LOMA OCEAN OUTFALL

Volume V
Appendices C & D

January 2015

THE CITY OF SAN DIEGO PUBLIC UTILITIES DEPARTMENT

Application for Renewal of NPDES CA0107409

301(h) Modified Secondary Treatment Requirements for Biochemical Oxygen Demand and Total Suspended Solids

POINT LOMA OCEAN OUTFALL &
POINT LOMA WASTEWATER TREATMENT PLANT

Submitted pursuant to
Sections 301(h) and 301(j)(5) of the Clean Water Act

City of San Diego
Public Utilities Department
9192 Topaz Way
San Diego, CA 92123
(858) 292-6401

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APPLICATION FOR RENEWAL OF NPDES CA0107409
301(h) MODIFIED SECONDARY TREATMENT REQUIREMENTS

Point Loma Ocean Outfall
Point Loma Wastewater Treatment Plant

VOLUME V
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APPENDIX C.1

BENTHIC SEDIMENTS, INVERTEBRATES AND FISHES

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APPENDIX C.1

Benthic Sediments, Invertebrates and Fishes

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APPENDIX C.1

Benthic Sediments, Invertebrates and Fishes

SECTION C.1-1 | SUMMARY OF FINDINGS

The City of San Diego's discharge of municipal waste water into offshore marine waters maintains natural conditions in sediments and biota beyond the wastewater zone of initial dilution (ZID). Monitoring benthic sediment conditions and assessing the status of marine invertebrate and fish communities are conducted to assess outfall related impacts and is described in this Appendix. San Diego's offshore monitoring program has collected and analyzed more than 4,200 benthic samples (sediments and infauna) from different monitoring stations surrounding the Point Loma Ocean Outfall (PLOO) from July 1991 through 2013. In addition, nearly 650 otter trawls have been performed during this time to monitor demersal fish and megabenthic invertebrate communities in the region, while additional trawls and rig fishing activities have been conducted to monitor the bioaccumulation of contaminants in fish tissues (see Appendix D). Overall, 10 quarterly pre-discharge surveys (July 1991-October 1993) were conducted over a 2.5 year period to assess naturally occurring conditions and their temporal and spatial patterns of variability, while data from 59 post-discharge surveys over 20 years (January 1994-July 2013) have been analyzed to detect changes that may indicate outfall related effects.

After 20 years of wastewater discharge from the extended Point Loma outfall, monitoring results show only minor changes beyond the ZID boundary off Point Loma. Chemical and biological conditions of the sediments indicate no environmentally significant changes associated with the discharge. The only evidence of organic or contaminant loading of the sediments are slightly higher sulfide and BOD levels at a few sites located within about 300 m of the discharge zone. Although some changes have occurred that correspond to the initiation of discharge, benthic habitats outside the ZID boundary are characterized by infaunal communities composed of indigenous species populations representative of natural conditions. Key parameters such as infaunal abundance, species diversity, the Benthic Response Index (BRI), and patterns of key "indicator" species, are being maintained within the limits of variability that typify natural benthic communities of the Southern California Bight (SCB) continental shelf. Finally, analysis of trawl-caught fish and invertebrate communities show no evidence of outfall effects.

Sediments

Sediment conditions off Point Loma were analyzed based on a total of 540 0.1-m^2 grab samples collected at the 12 primary core stations located at outfall depths. Of the samples collected at these stations, 60 were collected prior to discharge and 480 during the post-discharge period. The latter includes 312 samples for the period covered in the City's previous 2007 waiver application (i.e., 1994-2006) and 168 samples for the period from 2007 through 2013.

Wastewater discharge is not significantly affecting sediment quality in the vicinity of the Point Loma outfall. Since the outfall began operation, there has been little evidence of organic and contaminant loading in the area. Most measured parameters continue to exist at levels within the range of natural variability for the San Diego region and other SCB reference areas. Higher levels of arsenic, chromium, copper, iron, nickel, and zinc observed in 1994 shortly after discharge began were not sustained. The only sustained effects were mostly restricted to a few sites located within about 120−300 m of the outfall discharge zone (i.e., within 200 m of the ZID). These three near-ZID sites include station E14 located near the ZID boundary just west of the center of the outfall wye, and stations E11 and E17 located off the ends of the southern and northern diffuser legs, respectively. Station E11 is located about 149 m from the southern ZID boundary, while E17 is located about 197 m from the northern ZID boundary. These effects included an increase in coarser sediments through time, measurable increases in sulfide concentrations, as well as smaller increases in BOD levels. Consequently, the PLOO discharge is not affecting sediment quality to the point that it will degrade the resident marine biota.

Benthic Infauna

The benthic infaunal communities off Point Loma were analyzed based on 1,064 0.1-m^2 grab samples collected at the 12 primary core stations located at outfall depths during January and July from 1991 through 2013. Of the samples collected at these sites over these 23 years, 120 were collected prior to discharge (1991−1993) and 944 afterwards (1994−2013).

Benthic communities around the PLOO continue to be dominated by ophiuroid-polychaete based assemblages, and have mirrored changes that have occurred throughout the SCB since monitoring began. For example, the brittle star *Amphiodia urtica* and several species of polychaetes (e.g. *Proclea* sp. A, *Spiophanes duplex, Phisidia sanctaemariae)* were dominant species during both the pre- and post-discharge periods. Polychaetes continue to account for the greatest number of species and individuals overall. Similar assemblages dominate much of the southern California benthos, including the San Diego region, although patches of other benthic assemblages occur in areas of different sediment types. The shifts in community composition that have occurred over time off Point Loma probably represent variation in southern California assemblages related to large-scale oceanographic events (e.g., El Niño), to natural population fluctuations, and habitat heterogeneity.

Although variable over the past 23 years, infaunal communities off Point Loma have remained characteristic of undisturbed habitats in terms of the number of species, number of individuals, and dominance. The values for these parameters off Point Loma are similar to other sites throughout the San Diego region and the entire SCB. In spite of this overall stability, comparisons of data from the pre- and post-discharge periods indicate a few trends. For example, there was a general increase in the total abundance and number of species of benthic infauna in the years after wastewater discharge began, although a similar pattern was already present prior to discharge. The increase in species richness was most pronounced nearest the outfall, contrary to what would be expected if environmental degradation were occurring. Increases in infaunal abundance were also generally accompanied by decreases in dominance, another pattern contrary to known pollution effects. Considering the nature of above changes, benthic communities around the Point Loma Ocean Outfall are not being dominated by a few pollution tolerant species.

Other changes in the benthos near the outfall also suggest moderate effects coincident with anthropogenic activities. For example, the increased variability in number of species and infaunal abundance at near-ZID station E14 since discharge began may be indicative of community destabilization or continuing disturbance. A similar increase in the benthic response index (BRI) at this station during the post discharge period may also be indicative of enrichment or disturbance events. However, BRI values at this and all other sites are still considered characteristic of undisturbed benthic habitats. Finally, the patchiness of sediments near the outfall and the corresponding shifts in assemblage structure suggest that changes in the area may be related to localized physical disturbance (e.g., shifting sediment types or freshwater input) as well as to organic enrichment.

Populations of some indicator organisms also revealed changes that correspond to minor organic enrichment near the outfall, while populations of others revealed no evidence of impact. For example, there was a significant change in the difference between ophiuroid (*Amphiodia* spp) populations that occur near the outfall (i.e., station E14) and those present at reference sites. The difference in *Amphiodia* populations was due to both a decrease in numbers of this brittle star near the outfall and corresponding increases at the “control” sites during the post-discharge period. Although changes in *Amphiodia* populations at station E14 may be related to organic enrichment, other factors such as increased predation pressure near the outfall pipe may be important. Whether or not these changes are related to organic enrichment, predation, or some other factor, abundances of *Amphiodia* off Point Loma are still within the range of those occurring naturally in the SCB. Patterns of change in populations of the polychaete *Capitella telata* (formerly referred to as *C. capitata* species complex off San Diego), the bivalve *Parvilucina tenuiscuplta*, and ostracods of the genus *Euphilomedes* also suggest a subtle enrichment effect near the outfall; however, densities of these organisms remain low and are within the range of natural variation for the SCB. Other benthic invertebrates that have been suggested as bioindicators such as several polychaete species in the genera *Mediomastus*, *Dorvillea* and *Armandia*, and amphipods in the genera *Rhepoxynius* and *Ampelisca* also revealed few changes that would indicate habitat degradation near the outfall.

Although some changes in benthic assemblages have appeared off Point Loma, these assemblages are still similar to those present prior to discharge and to natural indigenous communities of the southern California outer continental shelf. Thus, after 20 years of outfall operation, the discharge of wastewater through the PLOO has not caused any biological changes in benthic community structure that may be construed as degradation.

Demersal Fishes & Megabenthic Invertebrates

Demersal fish and megabenthic invertebrate communities were analyzed based on a total of 262 otter trawls taken at six stations off of Point Loma during January and July from 1991 through 2013. Of these trawls, 30 were performed prior to discharge (1991−1993) and 232 afterwards (1994−2013).

Analyses of temporal and spatial patterns did not reveal any effects on trawl-caught fish and invertebrate communities that could be attributed to the Point Loma outfall. Despite the high variability of these communities, patterns of change in species richness and abundance were similar at monitoring stations near the outfall and at those farther away. Although the abundance of some dominant fish, such as the Pacific sanddab, declined at the nearfield stations in proportion to the overall post-discharge population, sanddab abundances off Point Loma remain within the range of natural variability described for reference areas in the SCB. Furthermore, no changes in community structure were detected in the nearfield assemblages that corresponded to the initiation of wastewater discharge. Finally, the lack of physical abnormalities or indicators of disease such as fin rot, lesions and tumors suggest that fish populations have remained healthy off Point Loma since monitoring began.

SECTION C.1-2 | INTRODUCTION

The City of San Diego began pre-discharge monitoring for the extended deepwater Point Loma Ocean Outfall (PLOO) in July 1991. The design of the monitoring program was determined by members of the City's Ocean Monitoring Program through consultation with the United States Environmental Protection Agency (USEPA) and the San Diego Regional Water Quality Control Board (SDRWQCB). The aim of the program was to establish fixed stations at various distances and depths from the diffuser pipe, which would be monitored to evaluate the quality of sediments and their associated invertebrate and fish communities in order to determine whether or not changes in these communities might be attributed to discharge from the outfall.

The geographic coordinates and depths of the benthic and trawl monitoring stations for the PLOO region, along with details of changes or corrections, are available in a series of four Monitoring and Reporting Programs (MRPs) adopted by the SDRWQCB associated with NPDES Permit No. CA107409. These include the MRPs in Order No. 95-106 adopted in 1995, Order No. R9-2002-0025 adopted in 2002, Addendum No. 1 to Order No. R9-2002-0025 adopted in 2003, and present Order No. R9-2009-0001 adopted in 2009. A total of 23 benthic stations were originally established, including: (a) 12 stations located at the outfall discharge depth along the 98-m contour; (b) five shallower stations along the 88-m depth contour; and (c) six deeper stations in along the 116-m depth contour. Eight trawl stations were established parallel to the 100-m depth contour. A complicating factor of the overall site design is the presence of the U.S. Army Corps of Engineers dredge spoils disposal site (designated LA-5), located about 3300 m southwest of the outfall. Physical and chemical changes in sediments associated with the LA-5 disposal site have been previously documented (e.g., SAIC 1990).

Construction of the Point Loma outfall extension was completed in November 1993 at which time wastewater discharge was initiated at the deepwater location (~100 m). The results and findings presented in this application include analyses of monitoring data collected over about 23 years from July 1991 through the end of calendar year 2013 for sediment conditions (sediment grain size and chemistry), benthic infauna (macrofauna) communities, and demersal fish and megabenthic invertebrate trawl communities. This represents an update of the analyses presented in the City's 2007 301(h) waiver application (City of San Diego 2007c), which addressed monitoring data through calendar year 2006. Significant changes to the MRP requirements for the Point Loma region adopted in 2003 as part of Addendum No. 1 to Order No. R9-2002-0025 that affect comparisons between pre-discharge and post-discharge periods are described in detail in City of San Diego (2007c). However, all data were completely reanalyzed for this application in order to account for such factors.

Overall, a total of 69 quarterly or semiannual benthic or trawl surveys were conducted off Point Loma between July 1991 and December 2013. These include 2.5 years of pre-discharge conditions (1991−1993) and 20 years of post-discharge conditions (1994−2013). All data from these surveys have been analyzed and reported in annual receiving waters monitoring reports for the PLOO (City of San Diego 1995a, b, 1996, 1997a, 1998a, 1999a, 2000, 2001, 2002a, 2003a, 2004a, 2005a, 2006a, 2007a, 2008a, 2009a, 2010a, 2011a, 2012a, 2013a, 2014b).

SECTION C.1-3 | GENERAL METHODS

All sampling and analytical methodologies follow guidelines established by the Environmental Protection Agency (USEPA 1987a, 1987b) and as defined by the MRPs for NPDES Permit No. CA0107409. Additional details regarding monitoring for the Point Loma Ocean Outfall are available in the City of San Diego's Annual Quality Assurance and Receiving Waters Monitoring Reports (e.g., City of San Diego 2014a, b). Careful sample logging and custody procedures are followed throughout the program so that all samples and data are readily tracked and inventoried from the collection process through laboratory analysis and data reporting.

All benthic sediment and infauna samples were collected using a single or double 0.1 m^2 Van Veen grab. This type of grab is highly regarded for its sampling capabilities, including depth of penetration, lack of pressure wave upon impact, and ease of use. The criteria established by the USEPA to ensure consistency of grab samples were followed with regard to sample disturbance and depth of penetration (USEPA 1987a). Infaunal analyses are based on usually two replicate grab samples per station during each sampling period, while the corresponding sediment analyses are based on a single sample at each station. Demersal fish and megabenthic invertebrate communities were sampled using a 7.6 m Marinovich otter trawl net fitted with a 1.3 cm cod-end mesh (see Mearns and Allen 1978). Analyses of these trawl surveys are based on a single trawl per station during each sampling period.

Sediments & Infauna Database

Previous analyses of benthic sediments and infaunal communities in the vicinity of the Point Loma deepwater outfall have been based on the results of all surveys conducted from July 1991 through the end of 2013 and reported in City of San Diego (1995−2014). This includes a total of 10 pre-discharge surveys (July 1991−October 1993) and 59 post-discharge surveys (January 1994−July 2013). Overall, the subsequent sediment quality database consists of information from a total of 1,473 0.1-m^2 successfully collected samples, while the biological (infauna) database consists of data from 2,773 0.1-m^2 successful samples (Table C.1-1). These databases represent

TABLE C.1-1

Total number of benthic grab samples (sediments and infauna) and community trawls (demersal fishes and megabenthic invertebrates) for the deepwater Point Loma Ocean Outfall monitoring program from 1991 through 2013. Pre-discharge period = 1991-1993; Post-discharge period = 1994–2013. Data include: (a) total number of grabs and trawls over all surveys (2 or 4) per year for all benthic (n=23 max) and trawl (n=8 max) sites; and (b) number of grabs and trawls analyzed in this application for just the January and July surveys each year from the 12 primary core benthic stations and six current trawl stations.

	Sediment Grabs[a]		**Infauna Grabs**[ab]		**Fish Trawls**[ac]	
Year	**Total**	**Analyzed**	**Total**	**Analyzed**	**Total**	**Analyzed**
1991	46	12	84	24	32	6
1992	92	24	168	48	64	12
1993	92	24	168	48	64	12
1994	92	24	168	48	64	12
1995	92	24	167	47	64	12
1996	92	24	168	48	32	12
1997	69	24	168	48	32	12
1998	92	24	168	48	32	12
1999	92	24	165	47	32	12
2000	92	24	168	48	32	12
2001	92	24	168	48	32	12
2002	92	24	167	47	32	12
2003	58	24	107	47	22	12
2004	34	24	70	48	12	12
2005	34	24	68	48	12	12
2006	44	24	88	48	12	12
2007	44	24	88	48	12	12
2008	34	24	68	48	8	8
2009	34	24	68	48	8	8
2010	44	24	88	48	12	12
2011	44	24	88	48	12	12
2012	34	24	68	48	12	12
2013	34	24	46	36	12	12
Total	**1,473**	**540**	**2,774**	**1,064**	**646**	**262**
Pre-discharge	230	60	420	120	160	30
Post-discharge	1,243	480	2,354	944	486	232

[a] Reduced # of grabs and trawls in some years due to resource exchange agreements approved by SDRWQCB / USEPA.

[b] Six infauna grabs not analyzed due to poor preservation: (1) Stn. E23, Rep 2, Oct 1995; (2) Stn. B11, Rep 1, Jan 1999; (3) Stn. E7, Rep 2, Apr 1999; (4) Stn. E8, Rep 1, Jul 1999; (5) Stn. E20, Rep1, Oct 2002; (6) Stn. B9, Rep 2, Jan 2003.

[c] Trawls = 2 trawls/station 1991-1995 and 1 trawl/station 1996-2013.

about 147 m^2 and 277 m^2 of seafloor sediments, respectively. However, since sediment conditions and benthic community structure vary with depth in the SCB and elsewhere, the analyses presented in this application were limited to data collected at the 12 primary core stations located along the 98-m (320 ft) outfall discharge depth contour. From north to south, these stations are B12, B9, E26, E25, E23, E20, E17, E14, E11, E8, E5, and E2. Additionally, benthic sampling frequency was changed from a quarterly (January, April, July, October) to semiannual (January, July) schedule in late 2003 with the adoption of Addendum No. 1 to Order R9-2002-0025 as discussed previously. Thus, in order to allow for consistent spatial and temporal comparisons, data from the shallower 88-m sites and deeper 116-m sites (i.e., secondary core stations), as well as all April and October survey data, are not included in the analyses performed herein. Overall, the analytical benthic database for this appendix includes data from 540 sediment grabs and 1,064 infauna grabs collected at the primary core stations (Table C.1-1). However, data for all benthic samples collected for the PLOO monitoring program are included in the electronic files that are being submitted with this report. Detailed and analyses and assessments of these additional data have shown no significant evidence of habitat degradation due to wastewater discharge (e.g., see City of San Diego 2014b).

The City has also conducted annual region-wide surveys off the coast of San Diego since 1994 as part of regular receiving waters monitoring requirements for the South Bay Ocean Outfall (i.e., NPDES Permit Nos. CA0108928 and CA0109045) or as part of larger multi-agency surveys of the entire SCB (e.g., Bergen et al. 1998, 2001; Schiff and Gossett 1998; Noblet et al. 2002; Ranasinghe et al. 2003, 2007, 2012 Schiff et al. 2006, 2011). These surveys utilize the USEPA probability-based EMAP random sampling design and cover a geographic area ranging from Del Mar in northern San Diego County south to the USA/Mexico border. Preliminary results of a long-term assessment of the San Diego regional surveys conducted from 1994 to 2012 are considered herein in Appendix C.2. A total of 651 regional grabs (1grab/station/survey) were collected during this 19-year period at depths ranging from about 9 m to 1,023 m. Patterns of benthic community structure and various environmental parameters were assessed using a suite of univariate and multivariate statistics. Of the benthic samples collected at these sites, 265 comprised a single major cluster representing the mid-shelf region and encompassing the PLOO monitoring stations. Consequently, values for various community and sediment parameters associated with this cluster group of sites are used in part to estimate background conditions for the region that are most relevant to the Point Loma monitoring program. The results from this regional assessment were also used to calculate tolerance interval boundaries for a number of benthic community parameters for the San Diego region (see Appendix C.2). For calculation of reference and tolerance interval values, data from 12 grab samples collected at sites within 1.5 km of the PLOO discharge site were excluded from analysis. Additionally, data from these and subsequent surveys in 2004−2006 were used to create contour plots of various sediment parameters in order to compare regional sediment conditions during the 1994−2006 and

2007−2013 post-discharge periods (see Appendix C.3). Such regional data are not available for the pre-discharge period.

Trawl-Caught Fishes & Invertebrates Database

Prior analyses of demersal fish and megabenthic invertebrate communities surrounding the deepwater PLOO have been based on the results of all surveys conducted from July 1991 through the end of 2013 and reported in City of San Diego (1995−2014). This includes a total of 10 pre-discharge surveys (July 1991−October 1993) and 59 post-discharge surveys (January 1994−July 2013). The subsequent trawl database consists of information from a total of 646 trawls surrounding the deepwater discharge site (Table C.1-1). Although a second replicate trawl was taken at each station through 1995, only data from the first trawl are considered here for comparison to subsequent years. As discussed previously and described in the 2007 waiver application (City of San Diego 2007c), both the number of trawl stations and the sampling frequency were reduced in late 2003 due to a modification of the monitoring program. Specifically, sampling was discontinued at trawl stations SD9 and SD11, while sampling frequency was changed from a quarterly (January, April, July, October) to semiannual (January, July) schedule. Thus, in order to allow for consistent spatial and temporal comparisons, data from stations SD9 and SD11, as well as all April and October survey data, are not included in the analyses performed herein. Additionally, since measurements of invertebrate community biomass were discontinued after July 2003, an analysis of these data is not considered in this report. Overall, the analytical database for trawl-caught fishes and invertebrates database includes data from 262 trawls. However, data for all trawls collected for the Point Loma monitoring program are included in the electronic files that have been submitted with this report. Previous analyses of these additional data have shown no evidence of outfall-related impacts (e.g., see City of San Diego 2014b).

SECTION C.1-4 | SEDIMENT CONDITIONS

The City of San Diego has been monitoring marine sediment conditions in areas surrounding the extended PLOO since 1991. Benthic surveys were conducted quarterly (January, April, July, October) from July 1991 through July 2003, after which sampling was modified to semiannual surveys during January and July of each year. Locations for all benthic stations sampled during these periods are shown in Figure C.1-1. This section focuses on sediment grain size characteristics and the accumulation of organic solids and toxic contaminants during the pre- and

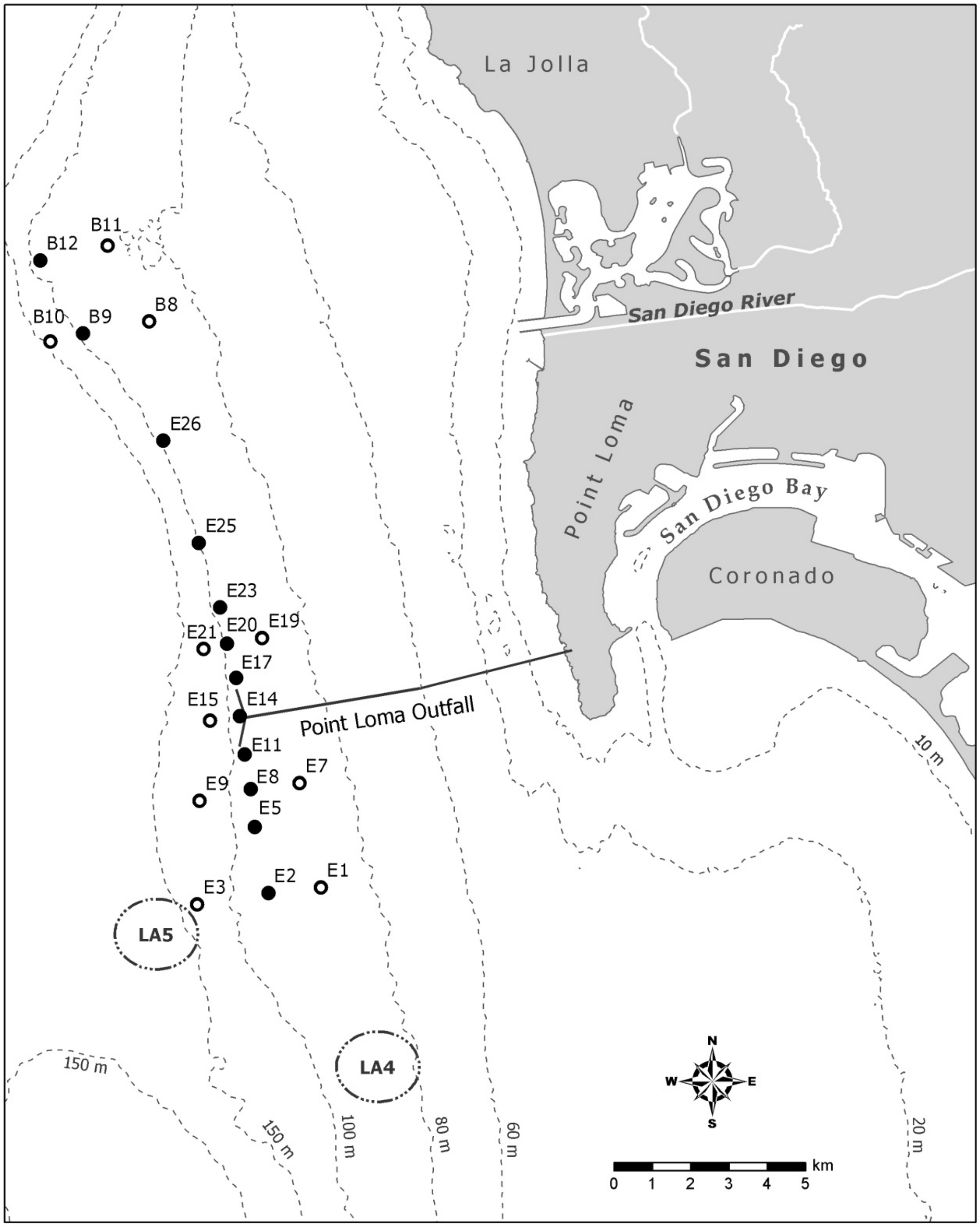

FIGURE C.1-1

Benthic station locations sampled around the Point Loma Ocean Outfall as part of the City of San Diego's Ocean Monitoring Program. Primary core stations (●) = 12 monitoring sites located along the 98-m outfall discharge depth contour that are the focus of the analyses presented in this 301(h) modified permit application. Secondary core stations (○) = five sites along the 88-m depth contour and five sites along the 116-m depth contour. LA-4 and LA-5 = USEPA designated dredged materials disposal sites.

post-discharge monitoring periods in order to evaluate the possible effects of wastewater discharge.

Data Sets & Analyses

Since sediment conditions often vary with depth, changes near the PLOO were evaluated by focusing on data collected at 12 primary core stations located at outfall discharge depths. From north to south, these stations are B12, B9, E26, E25, E23, E20, E17, E14, E11, E8, E5, and E2. Additionally, the following analyses are based on data from just the January and July surveys conducted at the above 12 sites from July 1991 through July 2013 (see Sections C.1-2 and C.1-3 for a complete description of dataset reduction). This includes five pre-discharge surveys (July 1991−July 1993) and 40 post-discharge surveys (January 1994−July 2006) with the subsequent database consisting of information from a total of 540 0.1-m^2 samples. These surveys included 60 grab samples from the pre-discharge period and 480 grabs for the post-discharge period. Additionally, the post-discharge period includes 312 samples from 1994−2006 that were analyzed during the last waiver application, and 168 samples from 2007−2013, which covers the current application period. Some comparisons are limited to data collected only during the summer (July) surveys in order to minimize differences due to natural seasonal fluctuations.

The primary core stations are located along the 98-m depth contour spanning the terminus of the PLOO (Figure C.1-1). Stations E14, E11 and E17 are located within about 100-300 m of the outfall diffuser legs (i.e., within 200 m of the ZID) and are considered nearfield or near-ZID sites. Station E14 is nearest the outfall, located adjacent to the ZID boundary about 103 m west of the center of the outfall wye. This station is the site most likely to be impacted by wastewater discharge. Stations E11 and E17 are located a little farther away off the ends of the southern and northern diffuser legs, respectively. Station E11 is located about 149 m from the southern ZID boundary, while E17 is located about 197 m from the northern ZID boundary. The remaining seven “E” stations are considered farfield sites. The two “B” stations are located >11 km north of the discharge area and were originally selected to represent reference or control sites.

The following parameters were evaluated in assessing impacts on the sediments. Grain size parameters included percent fines (silt and clay combined), percent sand, and percent coarser materials >2.0 mm in diameter). Measures of organic loading included total organic carbon (TOC), total volatile solids (TVS), total nitrogen (TN), biochemical oxygen demand (BOD), and sulfides. Trace metals examined and summarized herein include aluminum, arsenic, beryllium, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, selenium, silver and zinc. Data for additional metals such as antimony, barium, thallium and tin that occur sporadically off Point Loma and are generally present in very low concentrations are available in the electronic data submitted with this application and in the City’s annual monitoring reports (e.g., City of San

Diego 2014b, d). In addition, sediment concentrations of the pesticide DDT, polychlorinated biphenyl compounds (PCBs), and polycyclic aromatic hydrocarbons (PAHs) were evaluated. Discharge-related effects were evaluated in terms of (1) the range of natural variability under reference conditions, (2) the magnitude and spatial extent of any changes, and (3) an assessment of the potential for adverse effects. Estimates of natural variability pertaining to sediment conditions in the SCB have been extracted from various regional and bight-wide surveys conducted since 1985 (see Table C.1-2). These include the 1985 and 1990 SCCWRP reference surveys (Thompson et al. 1987, 1992), the 1994 Southern California Bight Pilot Project (see Schiff and Gossett 1998), the Southern California Bight Regional Monitoring Programs in 1998 (Bight′98), 2003 (Bight′03) and 2008 (Bight’08) (see Bergen et al. 2001, Noblet et al. 2002, Schiff et al. 2006, 2011), and annual surveys of the San Diego coastal region from Mexico to Del Mar that have been conducted since 1994 as part of NPDES monitoring requirements for the South Bay Ocean Outfall (e.g. see City of San Diego 1997b, 1998b, 1999a, 2002b, 2003b, 2004b, 2005b, 2006b, 2007b, 2008b, 2009b, 2010b, 2011b, 2012b, 2013b, 2014c).

The focus of most comparisons in this section is between conditions present during the 2.5 year pre-discharge period (July 1991−1993) and the entire 20 year post-discharge period (1994−2013). Exceptions are noted when data were not available for part of the pre-discharge period for specific parameters. Additionally, the post-discharge period is broken down into two periods (1994−2008 vs. 2009−2013) in some tables and figures in order to emphasize any patterns or trends during the past five years (2009−2013) since the last waiver application.

Results

Grain Size Distribution

Measurement of sediment grain or particle size allows for a better interpretation of the interaction of benthic animals with the environment. For example, differences in sediment composition (e.g., fine vs. coarse particles) and associated levels of organic loading can affect the burrowing, tube building and feeding preferences of infaunal invertebrates, thus leading to changes in benthic community structure. Parameters such as grain size and the proportion of silt and clay combined (percent fines), sand, and coarser particles (e.g., pebbles, gravel, shell hash) can be indicative of the hydrodynamic regime in the benthos, while physical properties of the sediments (size, shape, density, mineralogy) interact with deposited organic particles to create new conditions in sediment carbon coupling at the boundary layer.

Grain size characteristics of sediments around the Point Loma outfall are summarized in Table C.1-3 as percent fines, percent sand, and percent coarser particles, while trends for the percent fines and the percentage of coarse particles are presented in Figures C.1-2 and C.1-3, respectively. More detailed information is available in the electronic data submitted with this

TABLE C.1-2

Comparison of select sediment grain size and chemistry data for the Point Loma Ocean Outfall (PLOO) benthic stations with data from the SCCWRP 1985 and 1990 reference surveys, 1994 Southern California Bight Pilot Project (SCBPP), Bight'98, Bight'03 and Bight'08 Southern California Bight Regional Programs, and annual San Diego Regional Surveys (1994−2012). PLOO data are presented for 98-m outfall depth stations only sampled during January and July surveys with data expressed as means for all 12 stations combined during the pre-discharge (1991−1993) and post-discharge (1994−2013) periods. SCCWRP 60-m and 150-m reference survey data are expressed as approximate means for the 1985 and 1990 surveys combined. SCBPP, Bight'98, Bight'03 and Bight'08 data are expressed as mean values for the "mid-shelf" strata. San Diego regional survey values averaged over all depths (see Appendix C.2).

	SCCWRP Reference Surveys		SCB 1994, 1998, 2003, and 2008 Regional Surveys				San Diego Regional Surveys	PLOO Surveys (1991−2013)	
	60-m	150-m	SCBPP	Bight'98	Bight'03	Bight'08		Pre-Discharge	Post-discharge
Grain Size[a]									
%Fines	53	62	43	32	45	47	36	40	40
%Sand	47	38	—	—	—	—	62	58	57
%Coarse	—	—	—	—	—	—	2	0	1
Organic Indicators[c]									
TOC (%)	0.6	0.8	0.7	0.9	0.8	1.0	0.9	0.5	0.7
TN (%)	0.04	0.07	0.05	0.09	0.05	0.07	0.07	0.04	0.05
TVS (%)	0.72	0.85	—	—	—	—	2.65	2.15	2.41
BOD (ppm)	—	—	—	—	—	—	304	270	309
Sulfides (ppm)	—	—	—	—	—	—	7.5	1.2	5.4
Metals (ppm)									
Aluminum[b]	—	—	10,500	—	13,165	10,035	10,079	—	9,723
Antimony	—	—	0.21	0.50	0.10	0.18	0.49	0.00	0.76
Arsenic	—	—	5.1	5.6	4.1	6.1	3.4	2.4	3.2
Beryllium	—	—	0.2	—	0.6	0.3	0.2	0.4	0.2
Cadmium	0.2	0.3	0.3	0.4	0.4	0.3	0.1	1.3	0.2
Chromium	26	31	39	30	36	31	18	17	17
Copper	10	14	15	13	12	11	9	7	8
Iron[b]	17,963	21,311	18,600	—	19,511	20,724	13,023	12,408	13,184
Lead	6	7	11	12	7	8	5	2	3
Manganese[b]	133	156	—	—	—	—	106	—	105.9
Mercury	—	—	0.05	0.04	0.10	0.05	0.03	0.01	0.02
Nickel	12	14	18	23	14	12	8	7	7
Selenium	—	—	0.3	0.8	1.2	0.7	0.2	0.2	0.1
Silver	~0.1	<0.1	0.3	0.5	0.1	0.2	0.3	0.1	0.2
Zinc	47	54	59	58	47	46	31	28	29
Total DDT (ppt)	16,000	23,000	40,800	53,830	36,000	16,000	460	1,247	653
Total PCB (ppt)	Aro[d]	Aro[d]	Aro[d]	6460	2,400	13,000	545[d]	Aro[d]	129[d]
Total PAH (ppb)	23.3	47.8	<330	67.3	60.3	179.0	47.9	0.0	39.9

[a] Grain size not available before 1992 for PLOO surveys (i.e., 1991 data not comparable).

[b] TOC and TN not measured before Oct 1992, iron not measured before Jan 1993, aluminum and manganese not measured before 1994 for PLOO surveys.

[c] TOC, TN, TVS, BOD and sulfides missing SCBPP and Bight'98 values; TVS, BOD, sulfides also missing Bight'03 and Bight'08 values.

[d] PCBs neasured as Aroclors (Aro) through April 1998, so values are limited to PCB congeners measured afterwards.

TABLE C.1-3

Summary of sediment grain size and chemistry data for the Point Loma Ocean Outfall benthic stations; outfall depth stations only (n=12). Data are for January and July surveys only from 1991−2013; pre-discharge surveys = 1991−1993 (n=5); post-discharge surveys = 1994−2013 (n=40). See text for details of data reductions.

	Pre-Disharge Surveys (1991−1993)				1994−2008 Post-Disharge			2009−2013 Post-Disharge			All Post-Disharge Surveys			
	All Sites		Outfall Stn. E14	Ref. Stn. B9	All Sites	Outfall Stn. E14	Ref. Stn. B9	All Sites	Outfall Stn. E14	Ref. Stn. B9	All Sites		Outfall Stn. E14	Ref. Stn. B9
	Mean	Range	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Range	Mean	Mean
Grain Size[a]														
% Fines	40	28−52	39	42	39	31	43	44	34	50	40	11−55	32	45
% Sand	58	0−72	61	57	58	61	56	55	59	50	57	0−86	61	55
% Coarse	0	0−2	0	0	1	6	1	1	7	0	1	0−64	6	0
Organic Indicators														
TOC (%)[b]	0.53	0.41−1.04	0.47	0.58	0.65	0.45	0.67	0.83	0.54	0.82	0.69	0.25−4.85	0.48	0.71
TN (%)[b]	0.04	0.02−0.06	0.03	0.05	0.05	0.04	0.06	0.05	0.05	0.07	0.05	0−0.19	0.04	0.06
TVS (%)	2.15	1.0−3.3	2.07	2.37	2.46	1.94	3.01	2.29	1.73	3.12	2.41	1.02−5.42	1.88	3.04
BOD (ppm)	270	95−501	254	301	310	417	311	303	356	341	309	0−980	401	319
Sulfides (ppm)	1.2	0−5.4	1.7	0.5	4.8	18.2	1.4	6.9	29.1	4.9	5.4	0−89.5	21.0	2.2
Metals (ppm)														
Aluminum[a]	—	—	—	—	10,160	7,982	10,747	8,412	7,207	9,434	9,723	3131−22800	7,788	10,419
Antimony	0.0	0−0	0.0	0.0	0.9	0.3	0.8	0.3	0.3	0.3	0.8	0−13.0	0.3	0.6
Arsenic	2.4	1.4−4.0	2.2	2.1	3.3	3.6	3.5	3.0	3.2	3.6	3.2	1.3 7.8	3.5	3.5
Beryllium	0.4	0−2.0	0.2	0.5	0.2	0.2	0.1	0.2	0.1	0.2	0.2	0−3.1	0.2	0.1
Cadmium	1.3	0−5.7	1.1	1.3	0.3	0.2	0.3	0.1	0.2	0.1	0.2	0 5.7	0.2	0.2
Chromium	17.3	9.0−32.4	15.8	21.8	17.5	15.1	22.5	15.9	13.3	21.3	17.1	7.0−40.6	14.6	22.2
Copper	7.4	4.0−16.0	6.7	6.8	8.3	7.4	10.2	7.2	7.1	7.7	8.0	1.3−82.4	7.4	9.6
Iron[a]	12,408	9,700−20,300	10,250	14,450	13,731	10,840	17,760	11,542	9,081	15,570	13,184	4,840−27,200	10,400	17,213
Lead	1.8	0−12.0	1.0	1.2	2.7	1.4	3.0	5.5	5.0	6.6	3.4	0−15.5	2.3	3.9
Manganese[a]	—	—	—	—	109.4	95.5	120.6	96.8	90.6	106.5	105.9	31.5−317.0	94.1	116.6
Mercury	0.010	0−0.093	0.003	0.002	0.017	0.013	0.017	0.026	0.019	0.027	0.019	0−0.089	0.015	0.019
Nickel	6.6	0−10.0	5.7	7.3	7.2	7.5	7.7	7.2	6.9	8.6	7.2	0−29.0	7.4	7.9
Selenium	0.2	0−0.9	0.2	0.3	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0−0.8	0.1	0.1
Silver	0.12	0−4.0	0.00	0.60	0.22	0.10	0.25	0.22	0.24	0.11	0.22	0−5.84	0.13	0.21
Zinc	28.0	18.0−47.0	25.2	31.6	29.3	24.5	39.6	28.3	24.9	36.0	29.1	12.4−176.0	24.6	38.7
Pesticides, PCBs, PAHs														
Total DDT (ppt)	1247	0−7,300	970	1,640	685	311	2,402	557	463	2,411	653	0−44,830	349	2,404
Total PCB (ppt)[c]	—	—	—	—	69	0	0	257	40	56	129	0−7,638	13	18
Total PAH (ppb)	0.0	0-0	0.0	0.0	50.5	33.3	51.6	8.3	1.1	1.1	39.9	0−3,062.6	25.0	39.0

[a] Grain size not available before 1992.

[b] TOC and TN not measured before Oct 1992; iron not measured before Jan 1993; aluminum and manganese not measured prior to 1994.

[c] PCBs measured as Aroclors prior to April 1998 and as congeners thereafter; therefore PCB data reported herein are limited to congeners only for July 1998-2013.

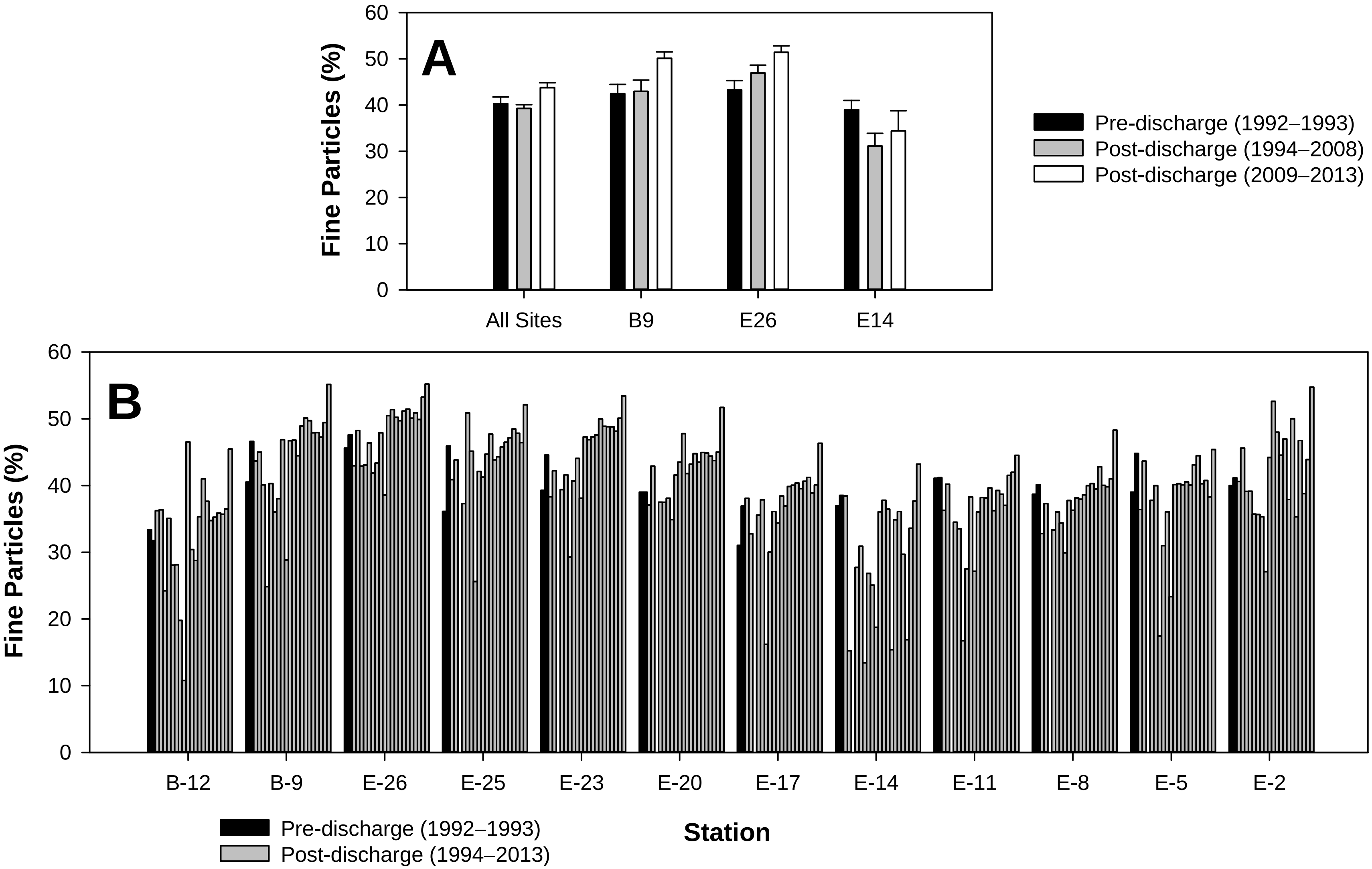

FIGURE C.1-2

Percent fines (silt and clay) in sediments at outfall discharge depths near the Point Loma Ocean Outfall from 1992 through 2013. (A) pre-discharge vs. post-discharge summary (means + 95% CI); (B) July surveys only.

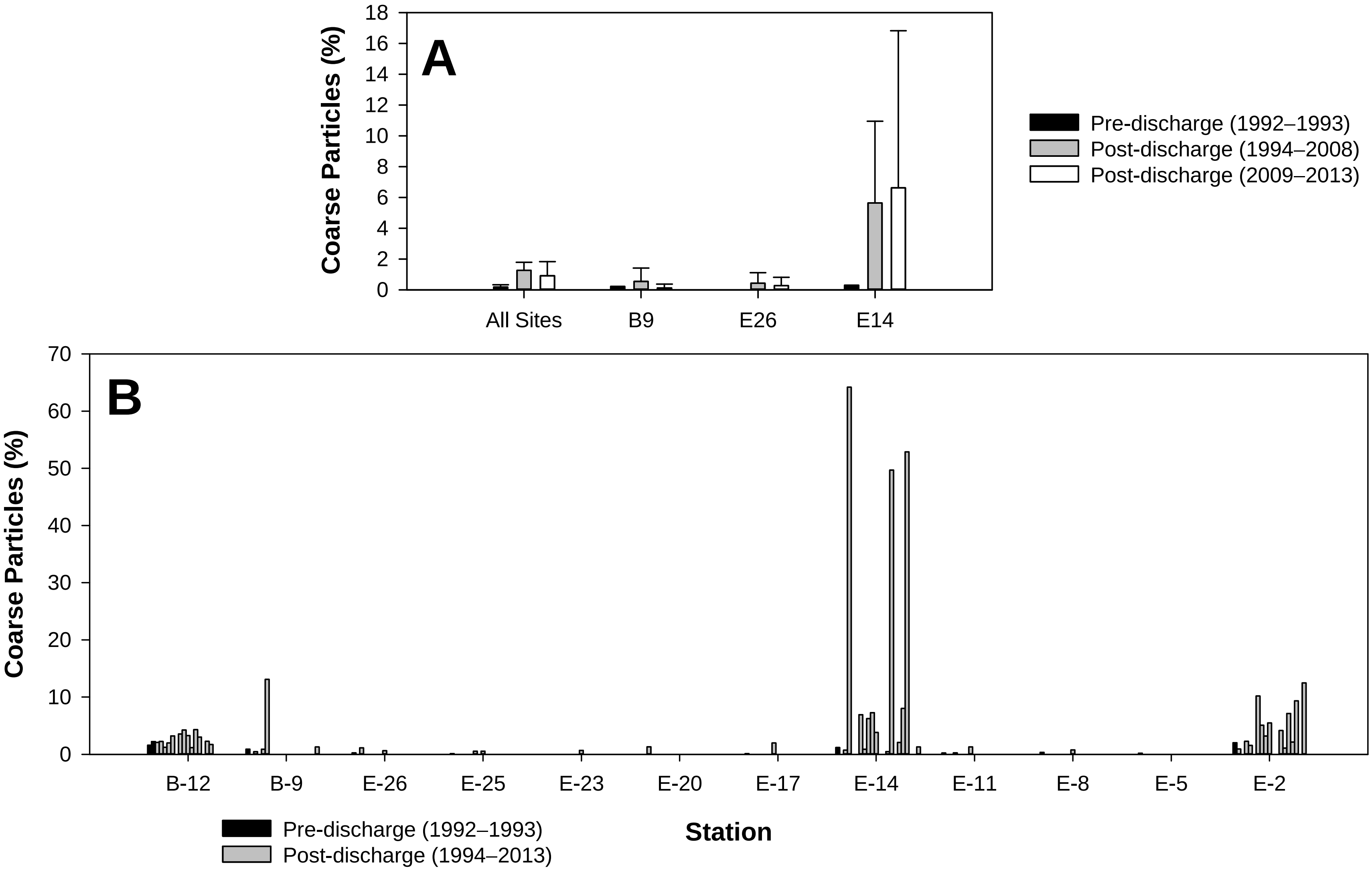

FIGURE C.1-3
Percent coarse particles in sediments at outfall discharge depths near the Point Loma Ocean Outfall from 1992 through 2013. (A) pre-discharge vs. post-discharge summary (means + 95% CI); (B) July surveys only.

application and in the City’s annual receiving waters monitoring reports (e.g., City of San Diego 2008a, 2009a, 2010a, 2011a, 2012a, 2013a and 2014b for calendar years 2007−2013). Overall, sediment composition has change very little off Point Loma over the past 23 years. For example, the percentage of fine sediments (silt and clay) averaged about 40% at the primary core stations during both the pre-discharge and post-discharge periods. Although differences between most sites were not significant in terms of the composition of sand, silt and clay, sediments at near-ZID station E14 have become slightly coarser since discharge began, averaging about 39% fines overall in 1991−1993 and only 32% fines since that time (Table C.1-3). This change is likely related to the movement of ballast materials used to support the outfall pipe and the presence of patchy sediments in the area. The latter is evident in Figure C.1-3 that shows the sporadic occurrence of very coarse sediments (>40%) at this near-ZID site. In addition, there has been little change in grain size distribution patterns since the previous waiver applications in 2001 and 2007. However, relic reef sediments at northern reference station B12 have frequently been characterized by the presence of very coarse materials such as shell hash and gravel that distinguish this station from most other sites along the outfall discharge depth contour. Relatively coarse materials have also been characteristic of the southernmost station E2 located near the LA-5 dredge materials disposal site. Overall, there appear to be no consistent changes over time that might correspond to effects caused by the discharge of wastewater.

Organic Loading Indicators

Indicators of organic loading in benthic sediments, including total organic carbon, total volatile solids, total nitrogen, biochemical oxygen demand, and sulfides have been detected in almost all (97−100%) of the sediment samples collected at the primary core stations since 1991 (see City of San Diego 2014b). Of these, total organic carbon and total volatile solids represent the more direct measurements of carbon imported as fine particulate matter.

Total Organic Carbon (TOC): TOC was not measured prior to October 1992, and therefore pre-discharge values represent data for only the January and July 1993 surveys. Operation of the Point Loma outfall has had no significant effect on TOC concentrations in local sediments, with TOC averaging ~0.5% at all sites during the pre-discharge period and ~0.7% during the post-discharge period (Table C.1-2). There was little difference in concentrations recorded near the outfall (e.g., station E14) and at reference sites farther away (e.g., station B9). Although TOC concentrations at northern station B12 have been highly variable, comparisons to summer survey data from the other outfall depth sites revealed no discharge related spatial or temporal patterns (Figure C.1-4). Finally, TOC values off Point Loma were generally similar to or slightly less than those from reference areas in the SCB as well as for other regional stations monitored off San Diego each year (Table C.1-2). The absence of TOC accumulation in the area indicates that

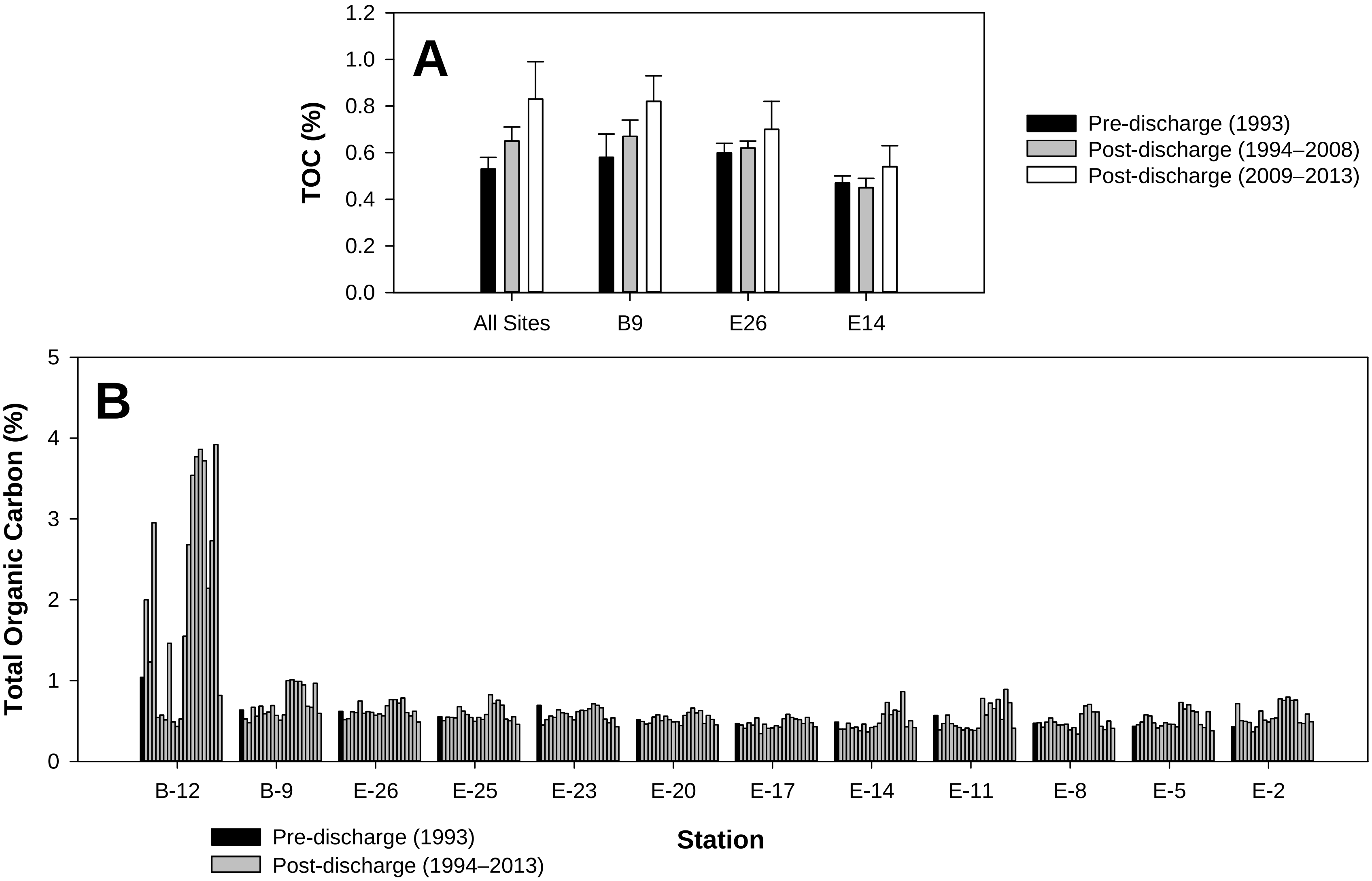

FIGURE C.1-4

Total organic carbon (%, TOC) in sediments at outfall discharge depths near the Point Loma Ocean Outfall from 1993 through 2013. (A) pre-discharge vs. post-discharge summary (means + 95% CI); (B) July surveys only.

sediment microbes and organisms off Point Loma are capable of maintaining oxidative metabolism at a rate exceeding carbon input.

<u>Total Volatile Solids (TVS)</u>: TVS is a measure of organic carbon and nitrogenous material that can be metabolized and solubilized in both receiving waters and sediments. There was little change in TVS concentrations in Point Loma sediments between the pre- and post-discharge periods (Figure C.1-5). TVS levels averaged ~2.2% at all sites prior to discharge and ~2.4% afterwards (Table C.1-3). These levels are typical of background conditions that occur in sediments up to 200 m depth in the SCB (see Bascom et al. 1979), which indicate that wastewater discharge via the outfall has not had any impact in terms of TVS. In fact, average TVS concentrations have decreased slightly nearest the outfall since discharge began, with values at near-ZID station E14 remaining lower or similar to sites located farther away since that time (Figure C.1-5b).

<u>Total Nitrogen</u>: Total nitrogen concentrations were not measured in Point Loma sediments prior to October 1992. Therefore, pre-discharge values represent data from only the January and July 1993 surveys. No apparent outfall effects were evident, although nitrogen levels appear slightly higher at almost all sites during the post-discharge period compared to values in 1993 (Figure C.1-6). Sediment nitrogen concentrations averaged 0.04% at all sites during the pre-discharge period and 0.05% during the post-discharge period (Table C.1-3). Comparison of data for the summer surveys only also indicated no pattern consistent with an outfall effect (Figure C.1-6b).

<u>Biochemical Oxygen Demand (BOD)</u>: BOD is a measure of the level of oxidative metabolism of discharged organic material by bacteria. There was a slight increase in BOD concentrations in sediments at sites off Point Loma between the pre- and post-discharge periods (Figure C.1-7). The greatest increase in BOD since wastewater discharge began has occurred at near-ZID station E14, although concentrations have decreased slightly at this site over the last five years (see Figure C.1-7a). The pattern of slightly higher BOD at station E14 is consistent with predictions that a light sprinkling of organic material from the outfall might occur within or near the ZID. Overall, BOD averaged 270 ppm at outfall depths during the pre-discharge surveys and 309 ppm afterwards (Table C.1-3). These values are well within the range of typical background concentrations of 250−1,000 ppm that have been reported for SCB sediments (e.g., Bascom 1979, Word and Mearns 1979).

<u>Sulfides</u>: Sediment sulfide concentrations showed a distinct outfall related pattern at discharge depths near the PLOO. Concentrations increased sharply immediately after discharge began at near-ZID station E14 located about 103 m west of the outfall wye at the edge of the ZID, and to a lesser extent at stations E11 and E17 located ~150−200 m from the edges of the southern and northern ZID boundaries, respectively (Figure C.1-8b). For example, sulfide levels at E14 increased from an average of 1.7 ppm prior to discharge to 21.0 ppm afterwards (Table C.1-3). Although sediment sulfides were not measured in the SCB reference surveys by means similar to

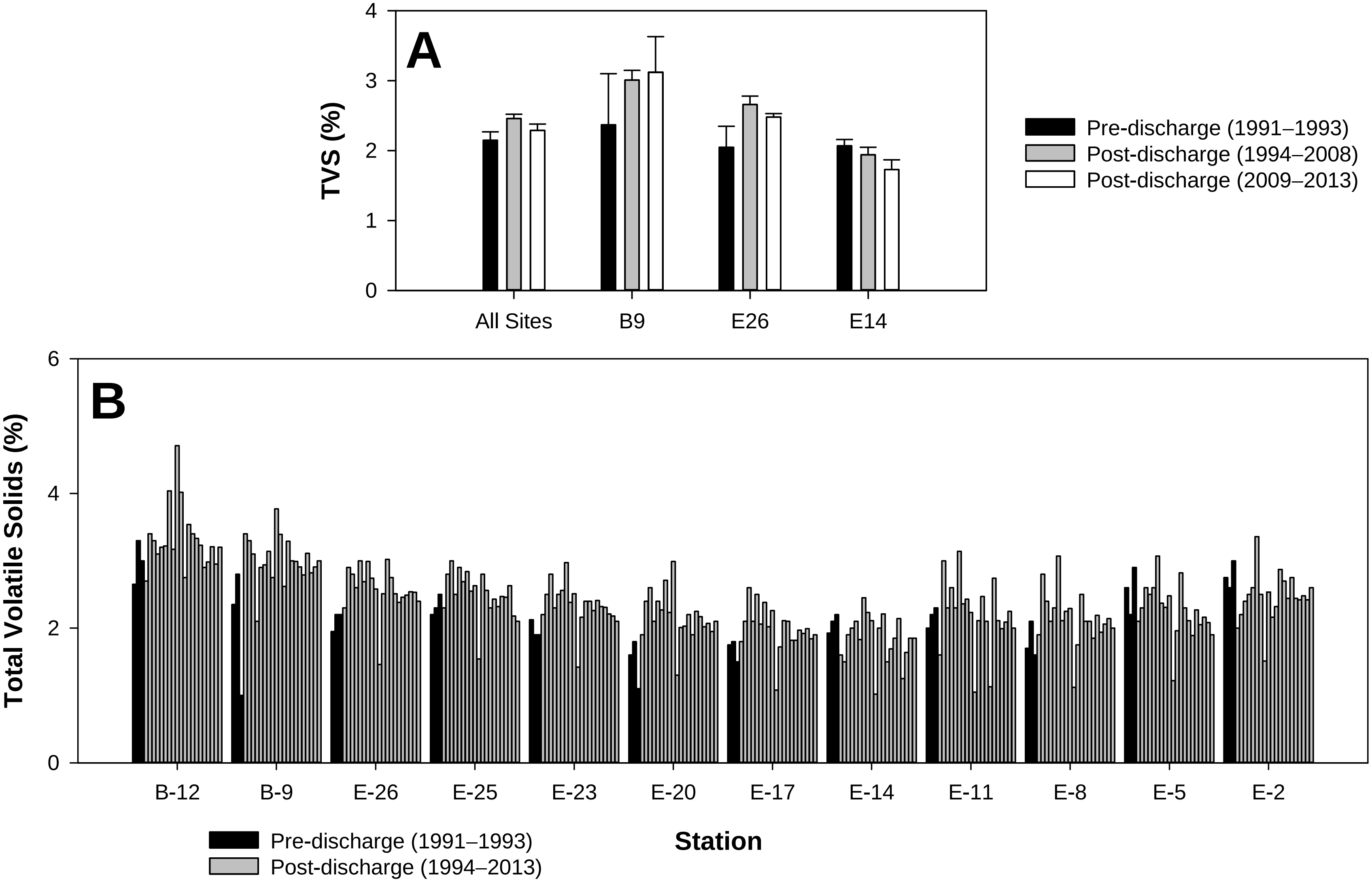

FIGURE C.1-5
Total volatile solids (%, TVS) in sediments at outfall discharge depths near the Point Loma Ocean Outfall from 1991 through 2013. (A) pre-discharge vs. post-discharge summary (means + 95% CI); (B) July surveys only.

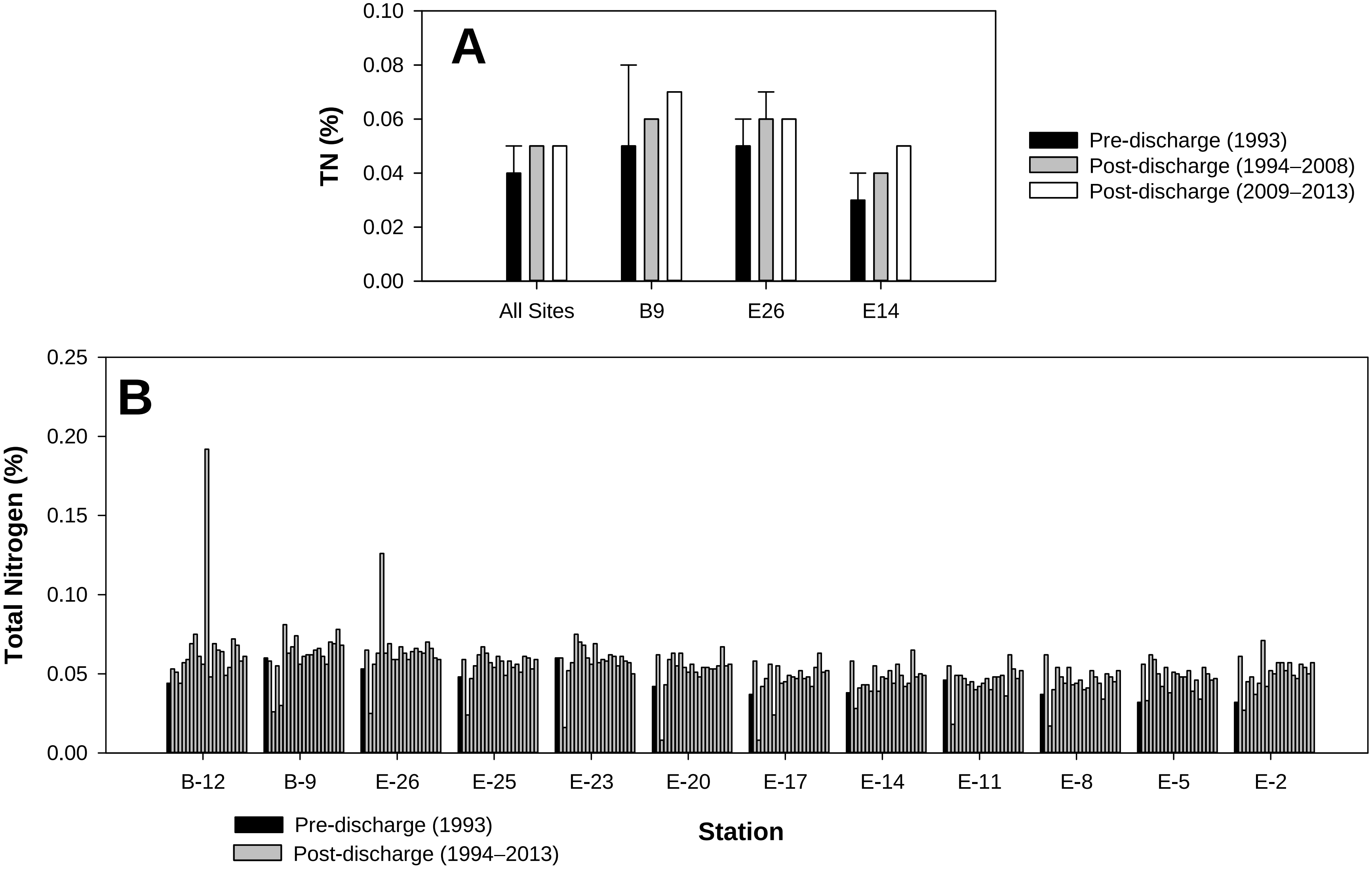

FIGURE C.1-6
Total nitrogen (%, TN) in sediments at outfall discharge depths near the Point Loma Ocean Outfall from 1993 through 2013. (A) pre-discharge vs. post-discharge summary (means + 95% CI); (B) July surveys only.

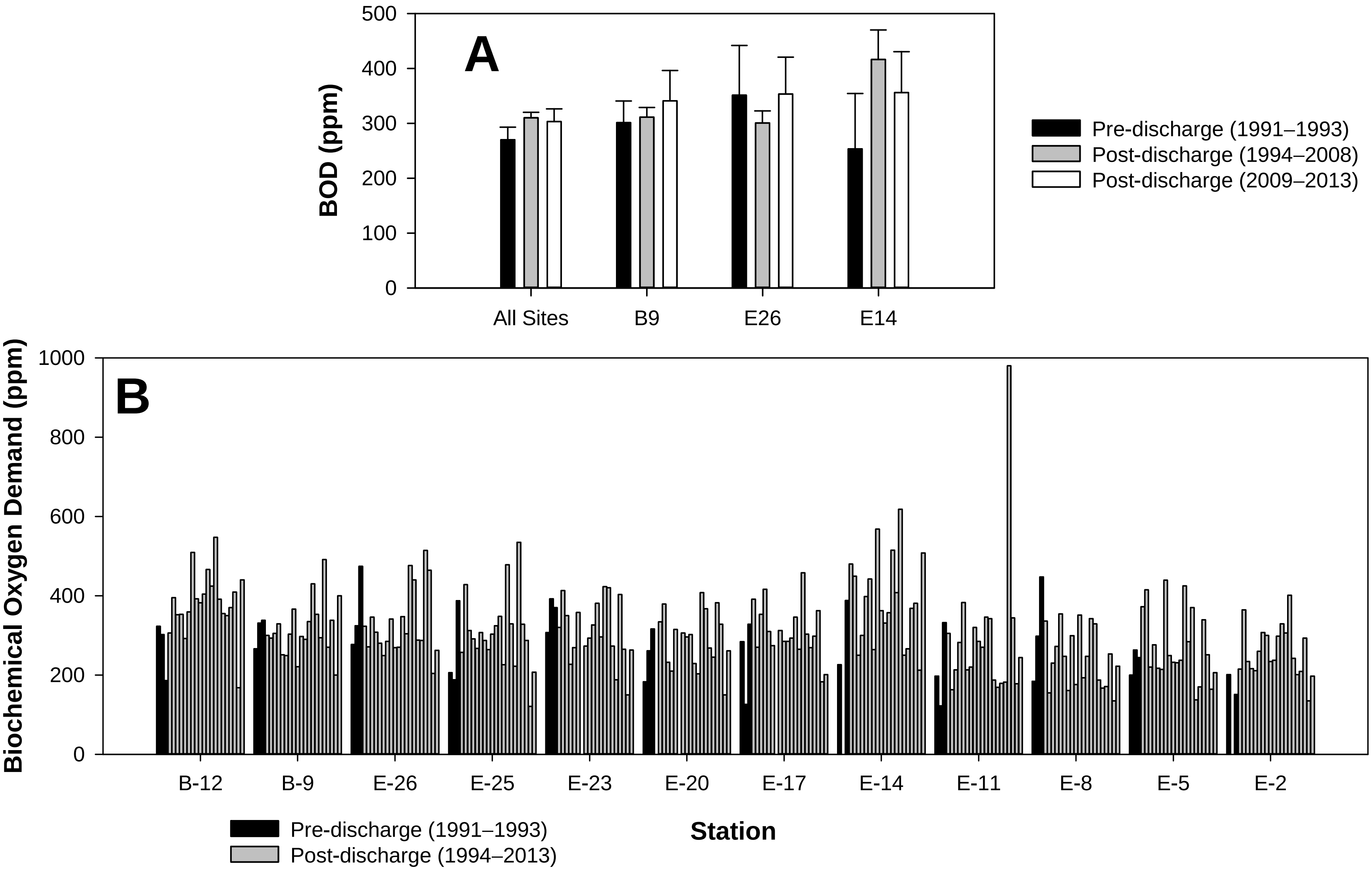

FIGURE C.1-7
Biochemical oxygen demand (ppm, BOD) in sediments at outfall discharge depths near the Point Loma Ocean Outfall from 1991 through 2013. (A) pre-discharge vs. post-discharge summary (means + 95% CI); (B) July surveys only.

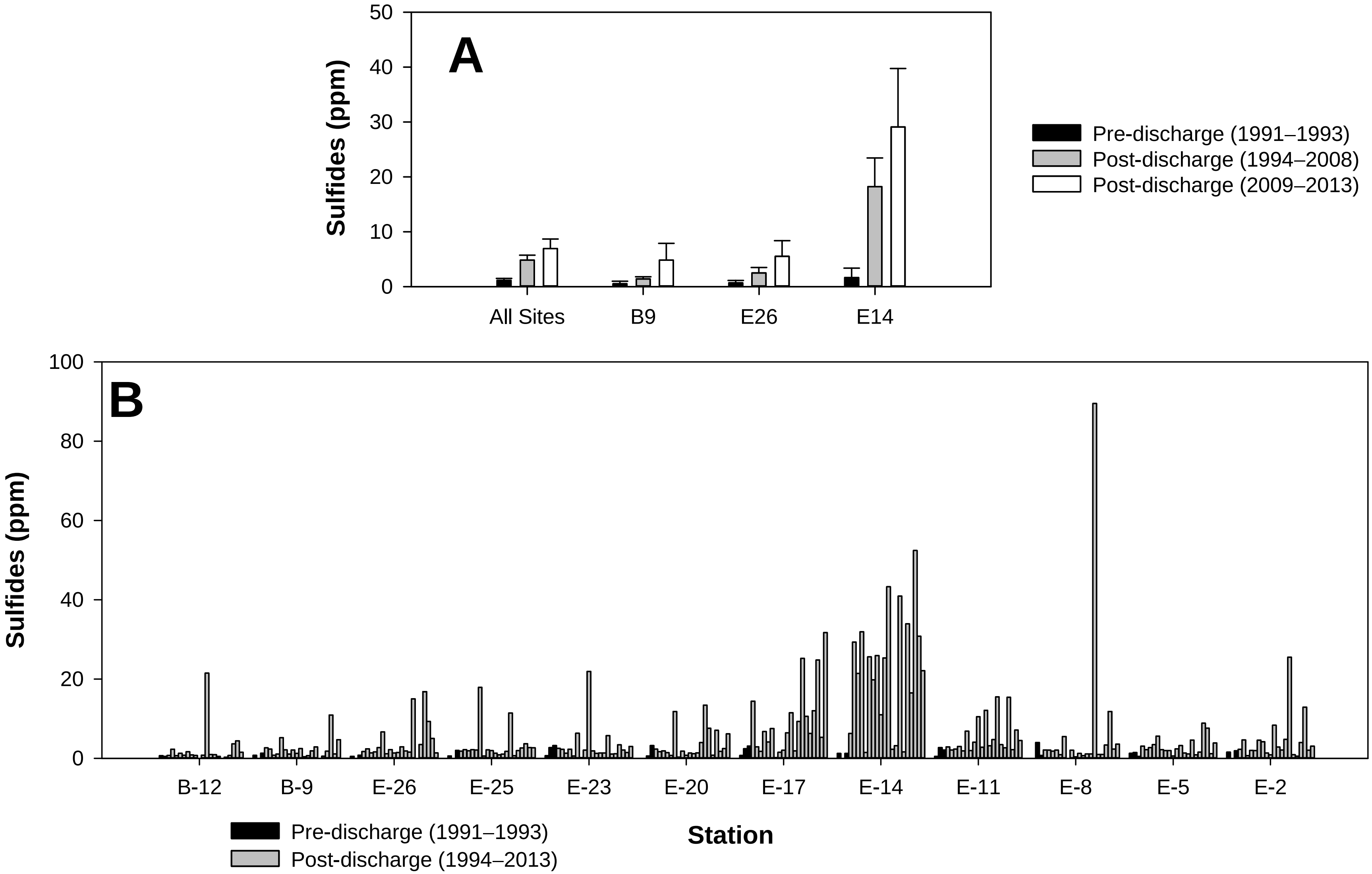

FIGURE C.1-8
Sediment sulfide concentrations (ppm) at outfall discharge depths near the Point Loma Ocean Outfall from 1991 through 2013. (A) pre-discharge vs. post-discharge summary (means + 95% CI); (B) July surveys only.

the City's ocean monitoring program, comparable measurements have shown sulfide levels exceeding 50 ppm off Newport Beach (e.g., CSDOC 1993) and greater than 500 ppm near the terminated 7-mile sludge outfall in Santa Monica Bay (City of Los Angeles 1990). There is no evidence that the relative small increase in sulfide concentrations near the PLOO discharge site is affecting sediment quality to the point that it will degrade the resident marine biota.

Trace Metals

Aluminum: Aluminum concentrations were not measured in Point Loma sediments prior to 1994, and therefore pre-discharge vs. post-discharge comparisons cannot be made for this trace metal. There was little difference in aluminum levels between the nearfield and farfield stations during the post-discharge period that could be attributed to wastewater discharge (Table C.1-3, Figure C.1-9). Concentrations averaged 9,723 ppm at the primary core stations over the entire post-discharge periods, although average values during the past five years were lower than between 1994−2008 (i.e., ~8,400 ppm vs. 10,160 ppm). Additionally, aluminum concentrations in sediments near the discharge zone were generally lower than at the more distant reference sites. For example, sediments at near-ZID station E14 averaged 7,788 ppm aluminum over all surveys, while reference site B9 averaged 10,419 ppm over the same period. The relatively high aluminum concentrations observed in 2004 and 2005 at many sites (e.g., see Figure C.1-9b) may have been related to increases in sediment deposition associated with higher rainfall during those years (see City of San Diego 2006a, b). Similar patterns were observed for iron and manganese, two other metals that may associated with terrestrial runoff (see below).

Arsenic: Arsenic concentrations averaged 2.4 ppm over all sites during the pre-discharge period and 3.2 ppm afterwards (Table C.1-3). Although this increase during the post-discharge period occurred at all sites, it was most pronounced at northern reference station B12 and secondarily at near-ZID station E14 (Figure C.1-10b). The lack of any clear spatial pattern makes it unlikely that changes in arsenic concentrations are related to wastewater discharge. Furthermore, arsenic levels at the outfall discharge depth stations are relatively low overall, averaging a little less than regional survey values off San Diego or the rest of the SCB (see Table C.1-2). Additionally, these values are below typical background concentrations of up to 10 ppm reported for southern California by Mearns et al. (1991), thus indicating that there has not been any significant accumulation of arsenic in the vicinity of the Point Loma outfall.

Beryllium: Beryllium concentrations were generally low throughout the region and revealed no patterns consistent with an outfall related effect (Figure C.1-11). Concentrations of this metal in PLOO sediments have been variable, ranging from below detection limits to a maximum of 3.1 ppm (Table C.1-3). Overall values averaged 0.4 ppm during the pre-discharge period and 0.2 ppm during the post-discharge period.

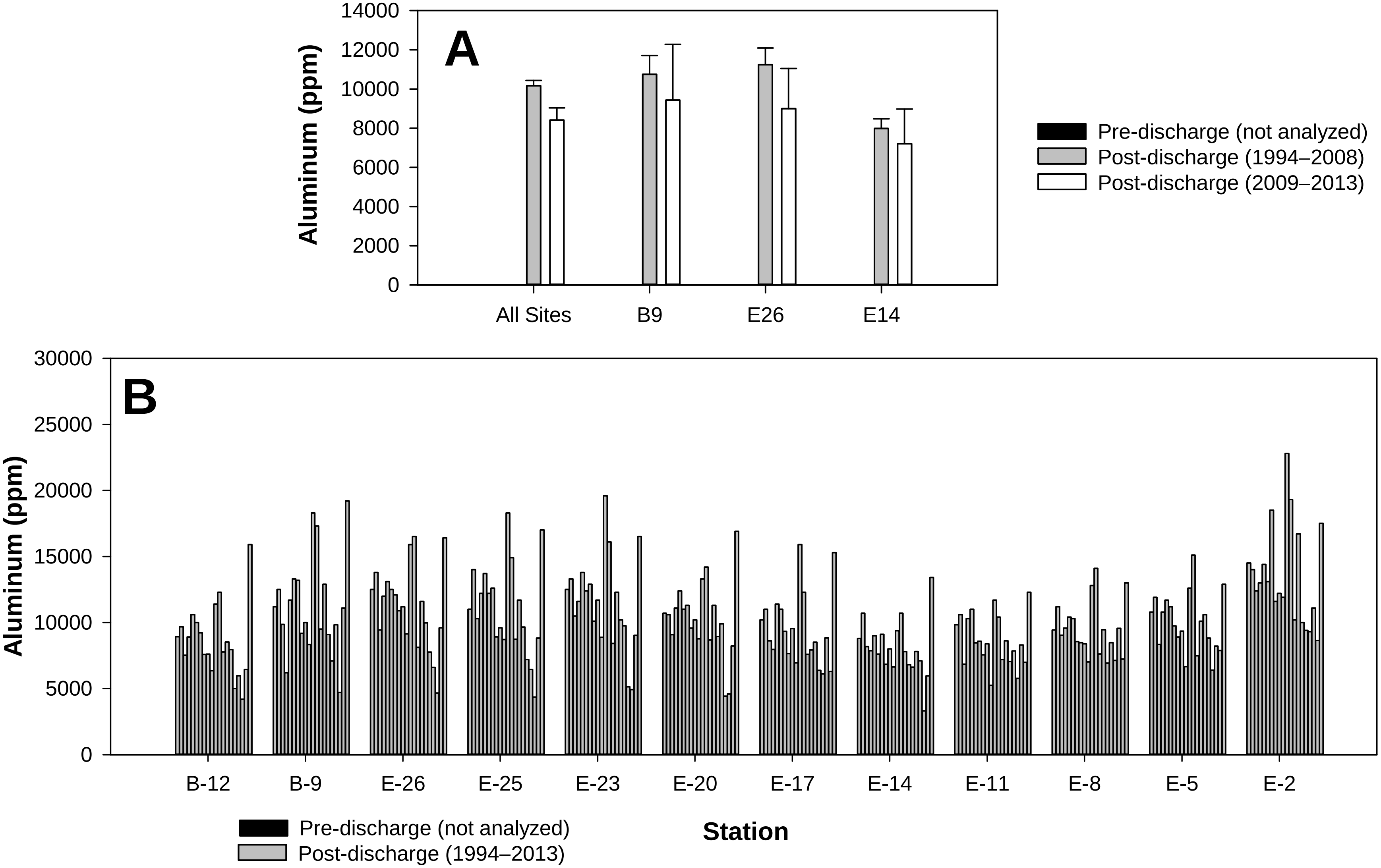

FIGURE C.1-9
Aluminum concentrations (ppm) in sediments at outfall discharge depths near the Point Loma Ocean Outfall from 1994 through 2013. (A) pre-discharge vs. post-discharge summary (means + 95% CI); (B) July surveys only.

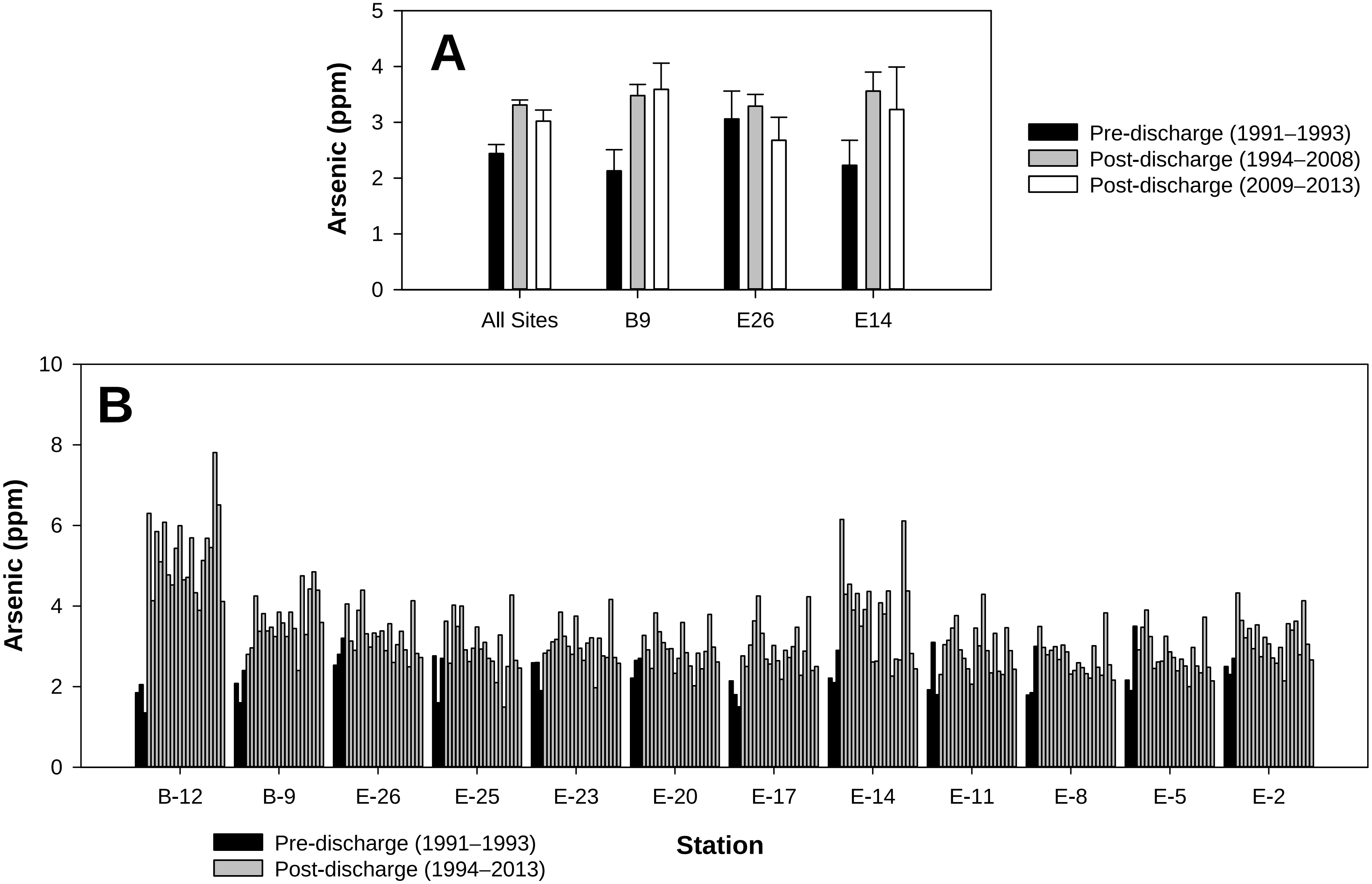

FIGURE C.1-10
Arsenic concentrations (ppm) in sediments at outfall discharge depths near the Point Loma Ocean Outfall from 1991 through 2013. (A) pre-discharge vs. post-discharge summary (means + 95% CI); (B) July surveys only.

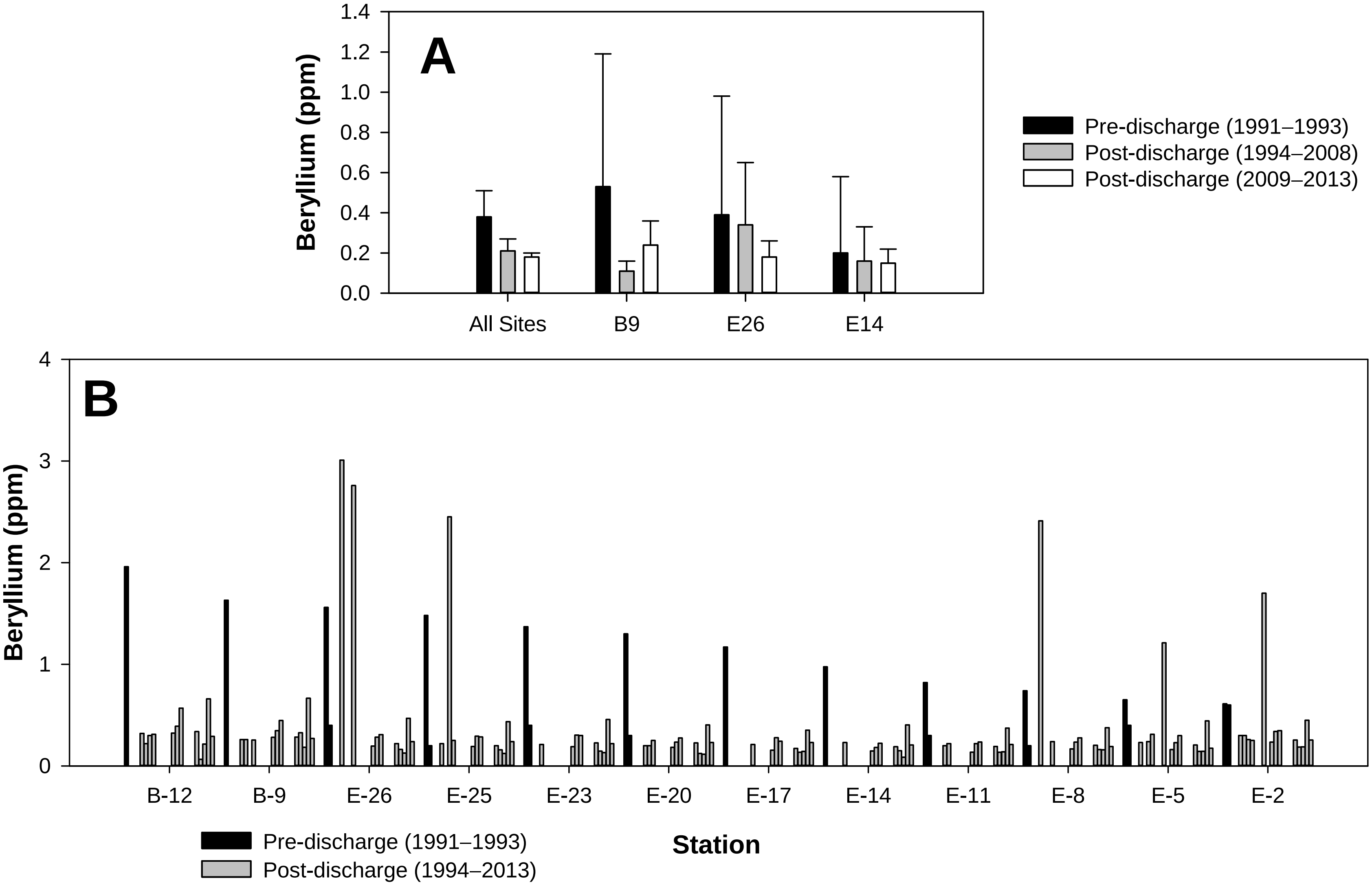

FIGURE C.1-11
Beryllium concentrations (ppm) in sediments at outfall discharge depths near the Point Loma Ocean Outfall from 1991 through 2013. (A) pre-discharge vs. post-discharge summary (means + 95% CI); (B) July surveys only.

Cadmium: Cadmium concentrations in sediments averaged 1.3 ppm over all sites during the pre-discharge period and 0.2 ppm afterwards (Table C.1-3). It is unclear what is responsible for the general decrease after wastewater discharge began since variation was very high at all sites (Figure C.1-12). Review of the data from the summer surveys only provided no additional clarification, with concentrations of cadmium being relatively high (~2−4.5 ppm) at all sites in 1993 and near or below detection limits at most other times (Figure C.1-12b). The apparent increase in the frequency of detected cadmium values beginning around 2003 represents an artifact of improved methodological abilities that resulted in lower MDLs for this metal.

Chromium: Chromium concentrations in sediments averaged 17.3 ppm at all sites prior to discharge and 17.1 ppm afterwards (Table C.1-3). These levels are similar to San Diego regional survey values but generally lower than typical background conditions in the SCB, the latter which range from 26−39 ppm (Table C.1-3). In addition, although temporal changes were similar across the region, chromium levels were generally higher at northern reference stations B9 and B12 than at the other 10 primary core stations (Figure C.1-13).

Copper: Copper concentrations averaged 7.4 ppm during the pre-discharge period and 8.0 ppm during the post-discharge period (Table C.1-3). Overall, values off Point Loma were slightly lower than regional values of ~10−15 ppm observed throughout the SCB (see Table C.1-2). Copper levels in PLOO sediments have generally been highest at southern station E2 located near the LA-5 dredged materials disposal site, although there was a single anomalous spike during the summer of 1997 at reference station B9 (see Figure C.1-14b). There does not appear to be any outfall-related trend in sediment copper concentrations off Point Loma.

Iron: Iron levels were not measured in 1991 and 1992, and therefore pre-discharge values are for 1993 only. No outfall effects have been evident in sediments along the PLOO discharge depth contour, with there being little difference between pre- and post-discharge iron concentrations (Table C.13, Figure C.1-15). In fact, the highest iron concentrations generally occurred in sediments at northern reference stations B12 and B9, as well as southernmost station E2 located near the LA-5 disposal site (Figure C.1-15b). Iron concentrations averaged 12,408 ppm at all primary core sites during 1993 compared to 13,184 ppm during the post-discharge period. The higher concentrations observed in 2004 and 2005 at many sites (see Figure C.1-15b) were likely related to increases in sediment deposition and/or fluxes in plankton populations associated with heavy storm activity. For example, extensive sediment plumes were observed during these years from aerial and satellite imagery (City of San Diego 2006a). Similar patterns were observed for aluminum and manganese, two other metals that may associated with terrestrial runoff. Additionally, sediment iron concentrations off Point Loma are generally lower than found elsewhere throughout the SCB (see Table C.1-2).

Lead: Lead concentrations in Point Loma sediments ranged from below detection limits to about 15.5 ppm (Table C.1-3). Generally, lead concentrations have been higher at southern station E2

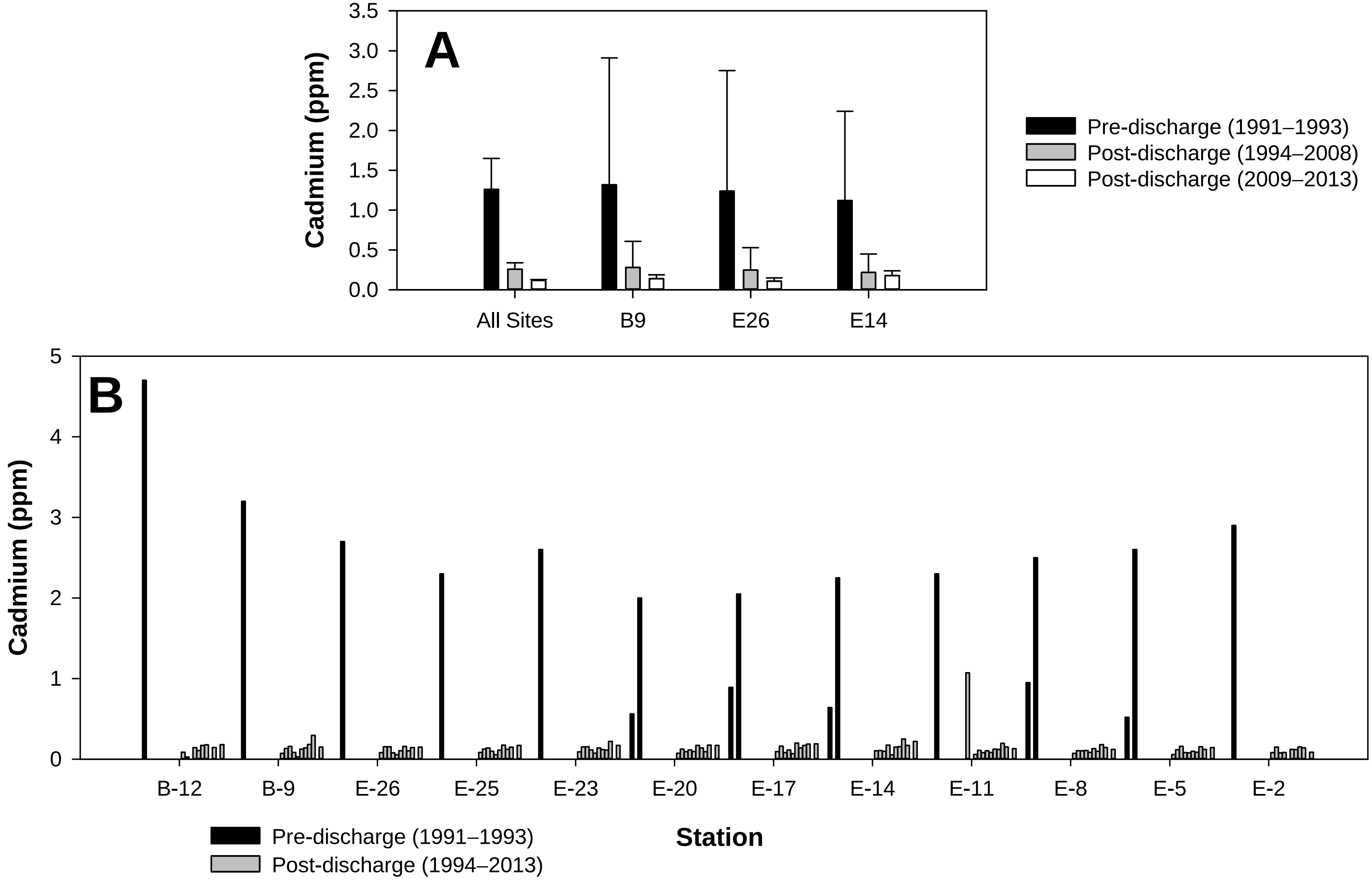

FIGURE C.1-12

Cadmium concentrations (ppm) in sediments at outfall discharge depths near the Point Loma Ocean Outfall from 1991 through 2013. (A) pre-discharge vs. post-discharge summary (means + 95% CI); (B) July surveys only.

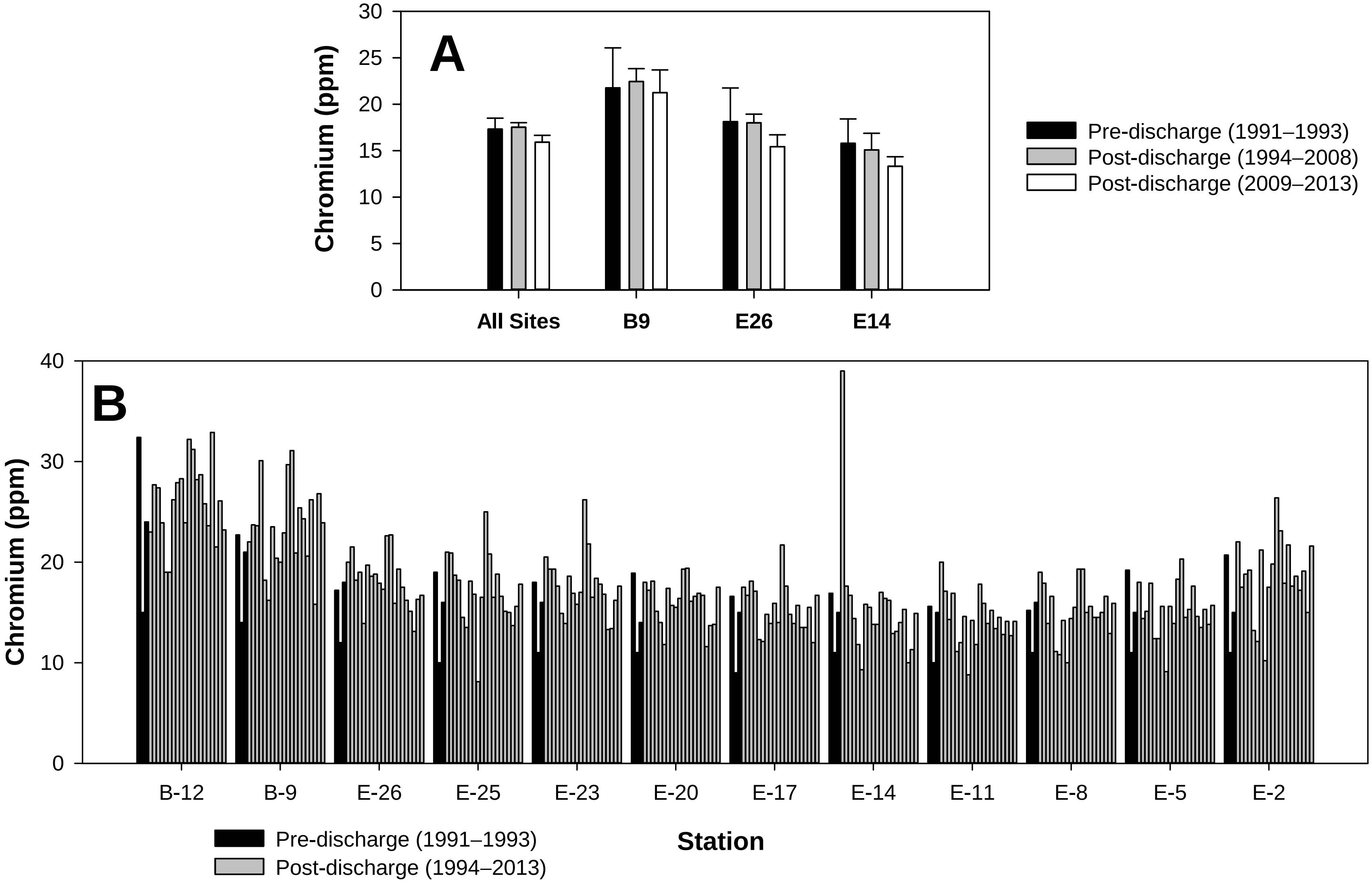

FIGURE C.1-13
Chromium concentrations (ppm) in sediments at outfall discharge depths near the Point Loma Ocean Outfall from 1991 through 2013. (A) pre-discharge vs. post-discharge summary (means + 95% CI); (B) July surveys only.

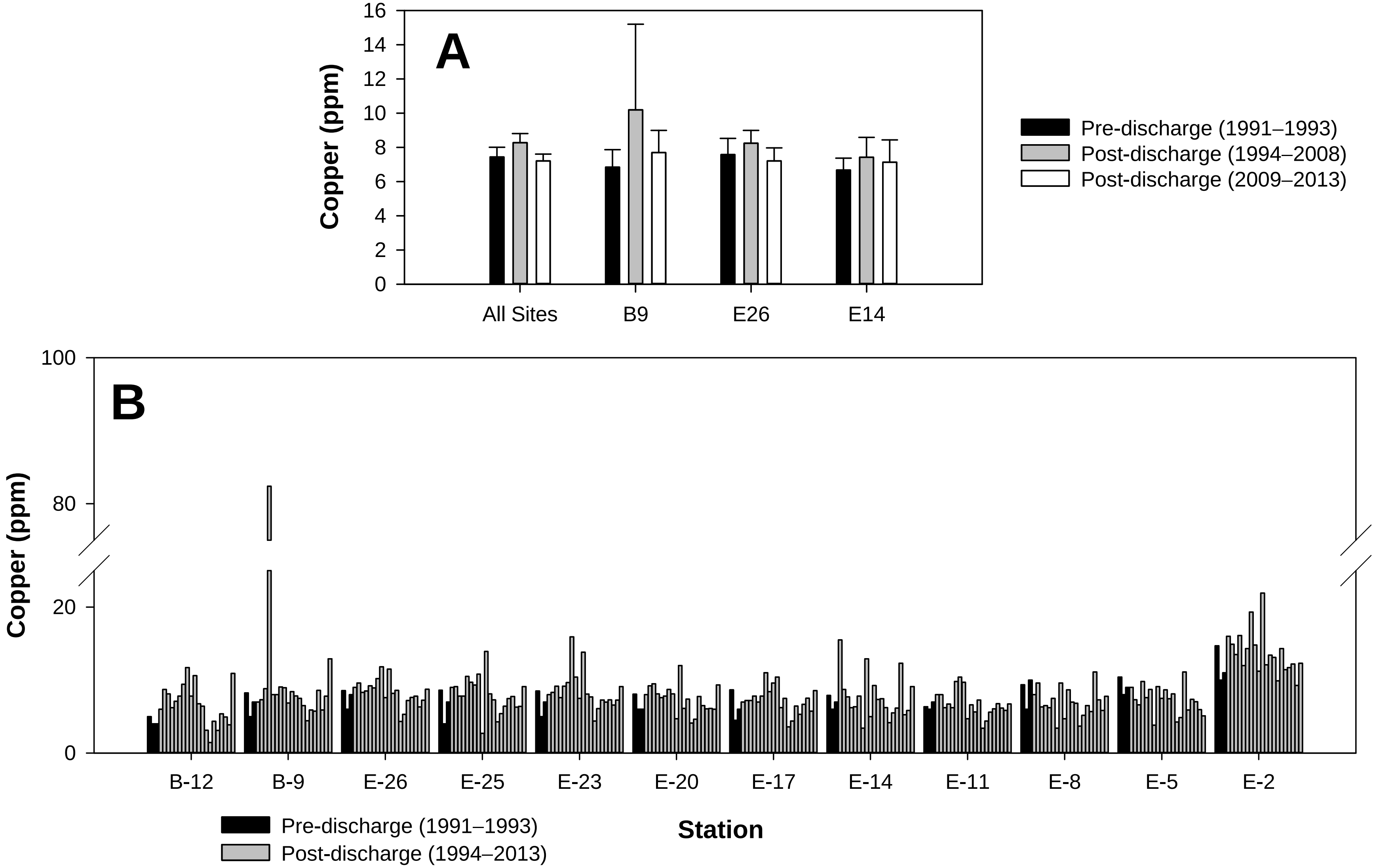

FIGURE C.1-14

Copper concentrations (ppm) in sediments at outfall discharge depths near the Point Loma Ocean Outfall from 1991 through 2013. (A) pre-discharge vs. post-discharge summary (means + 95% CI); (B) July surveys only.

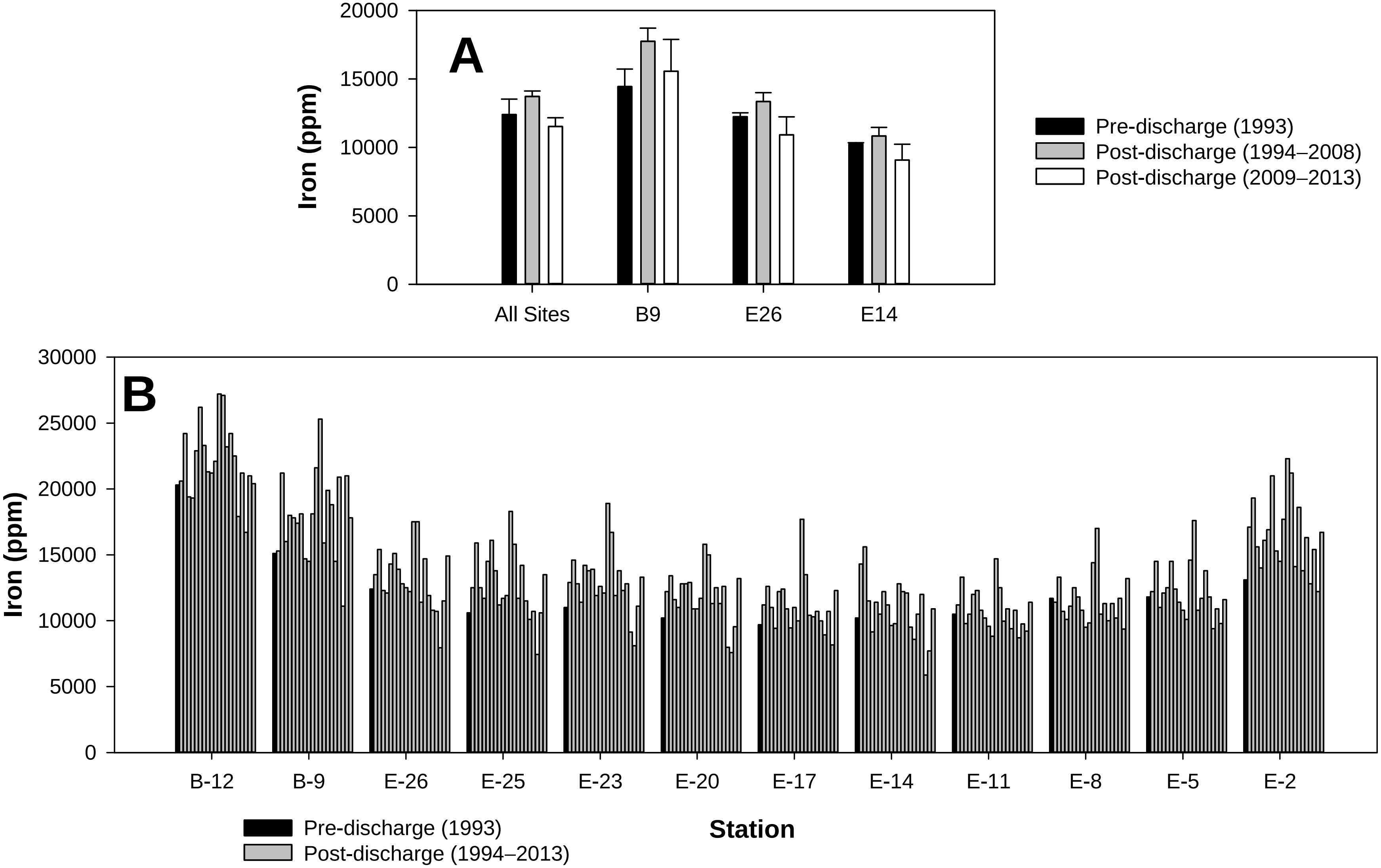

FIGURE C.1-15

Iron concentrations (ppm) in sediments at outfall discharge depths near the Point Loma Ocean Outfall from 1993 through 2013. (A) pre-discharge vs. post-discharge summary(means + 95% CI); (B) July surveys only.

located near the LA-5 dredge materials disposal site, although values at northern reference stations B9 and B12 have been similar over the past five years (Figure C.1-16b). There are no clear patterns relative to the outfall, with lead concentrations averaging 1.8 ppm in sediments over all primary core stations prior to discharge and 3.4 ppm during the post-discharge period. These values are lower than background concentrations for the SCB of around 6−12 ppm (Table C.1-2). A comparison of the July data was inconclusive since lead was detected only four times during the summer pre-discharge surveys, including once each at stations E2, E5, E8 and E25 (Figure C.1-16b).

Manganese: Manganese was not analyzed during the pre-discharge period, and therefore comparisons are limited to the post-discharge surveys. Overall, manganese levels were similar across the outfall depth stations with there being no patterns indicative of a discharge effect (Table C.1-3, Figure C.1-17). For example, manganese averaged about 106 ppm over all sites during the entire post-discharge period with mean values being a little lower at near-ZID station E14 (~94 ppm) than at reference station B9 (~117 ppm). The much higher manganese concentrations observed in 2004 and 2005 (Figure C.1-17b) may be related to increased sediment deposition associated with heavy storm activity during those years (see City of San Diego 2006a, b), although it's unknown what may have caused similar high values in July 2013. However, these temporary increases in manganese levels occurred throughout the region and did not show any patterns related to wastewater discharge,

Mercury: Mercury concentrations were low in sediments at all of primary core stations off Point Loma, averaging 0.01 ppm during the pre-discharge years and 0.019 ppm since discharge began (Table C.1-3). Maximum concentrations at all sites were less than 0.1 ppm. A review of data from the summer surveys only indicated no outfall-related patterns with the highest mercury concentrations typically occurring at station E2 near the LA-5 dredged materials disposal site (Figure C.1-18b).

Nickel: Nickel concentrations ranged from below detection limits to 29.0 ppm in Point Loma sediments, with an average of 6.6 ppm before outfall operation and 7.2 ppm afterwards (Table C.1-3). These values are generally below average background concentrations for the SCB (Table C.1-2), and are within the range of natural variability observed in various reference surveys. There is no evidence that discharge from the PLOO is resulting in any sustained accumulation of nickel in local sediments (see Figure C.1-19).

Selenium: Selenium concentrations provided no evidence of any outfall-related effects in sediments off Point Loma. Sediment concentrations averaged 0.2 ppm over all primary core stations during the pre-discharge period and 0.1 ppm afterwards, and no values exceeded 1.0 ppm (Table C.1-3). These values are similar to background shelf sediment conditions reported by Young (1975) and slightly less than SCB regional values reported herein (Table C.1-2). Comparison of data from the summer surveys revealed few changes other than unusually high

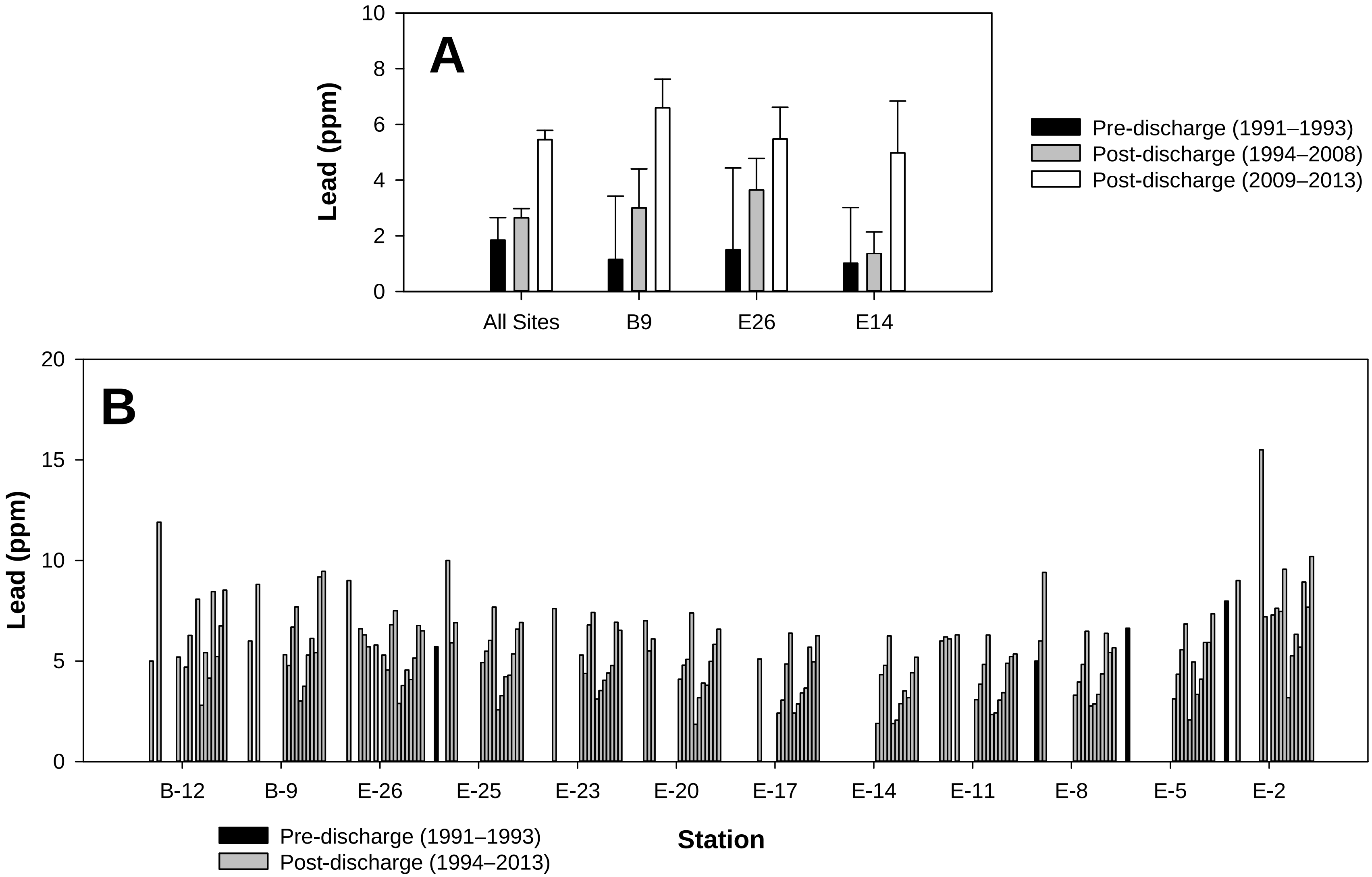

FIGURE C.1-16
Lead concentrations (ppm) in sediments at outfall discharge depths near the Point Loma Ocean Outfall from 1991 through 2013. (A) pre-discharge vs. post-discharge summary (means + 95% CI); (B) July surveys only.

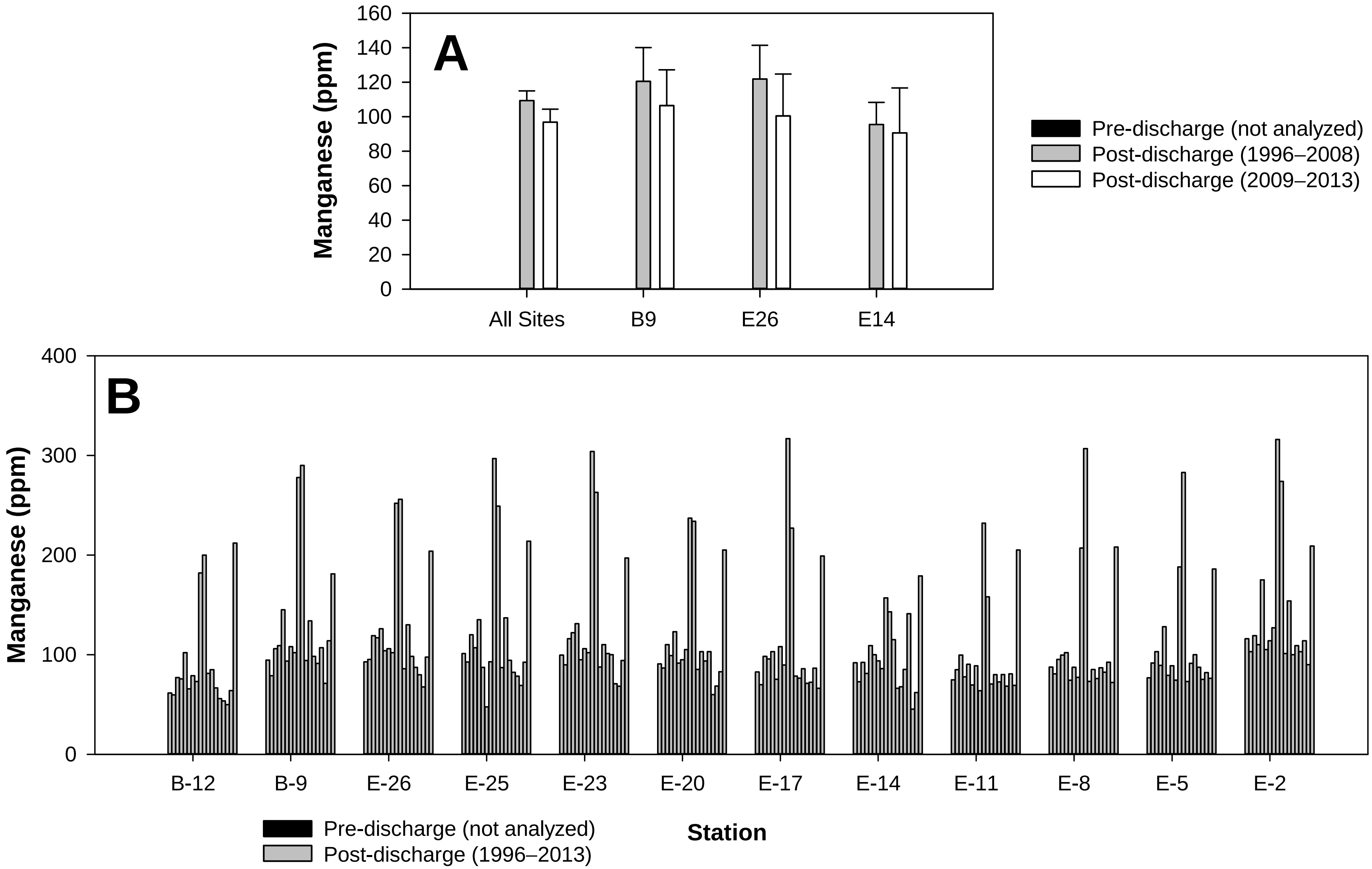

FIGURE C.1-17
Manganese concentrations (ppm) in sediments at outfall discharge depths near the Point Loma Ocean Outfall from 1996 through 2013. (A) pre-discharge vs. post-discharge summary (means + 95% CI); (B) July surveys only.

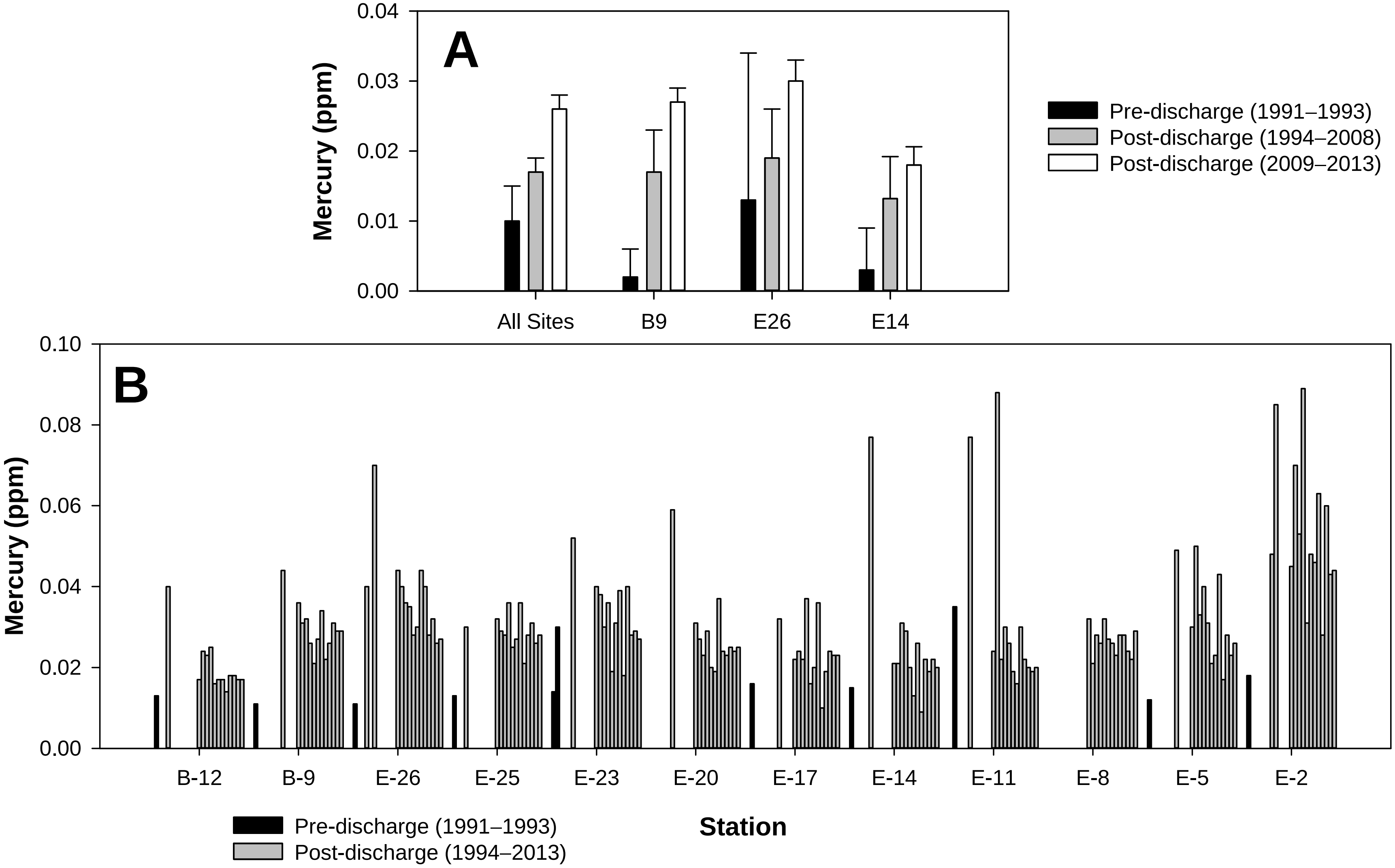

FIGURE C.1-18
Mercury concentrations (ppm) in sediments at outfall discharge depths near the Point Loma Ocean Outfall from 1991 through 2013. (A) pre-discharge vs. post-discharge summary (means + 95% CI); (B) July surveys only.

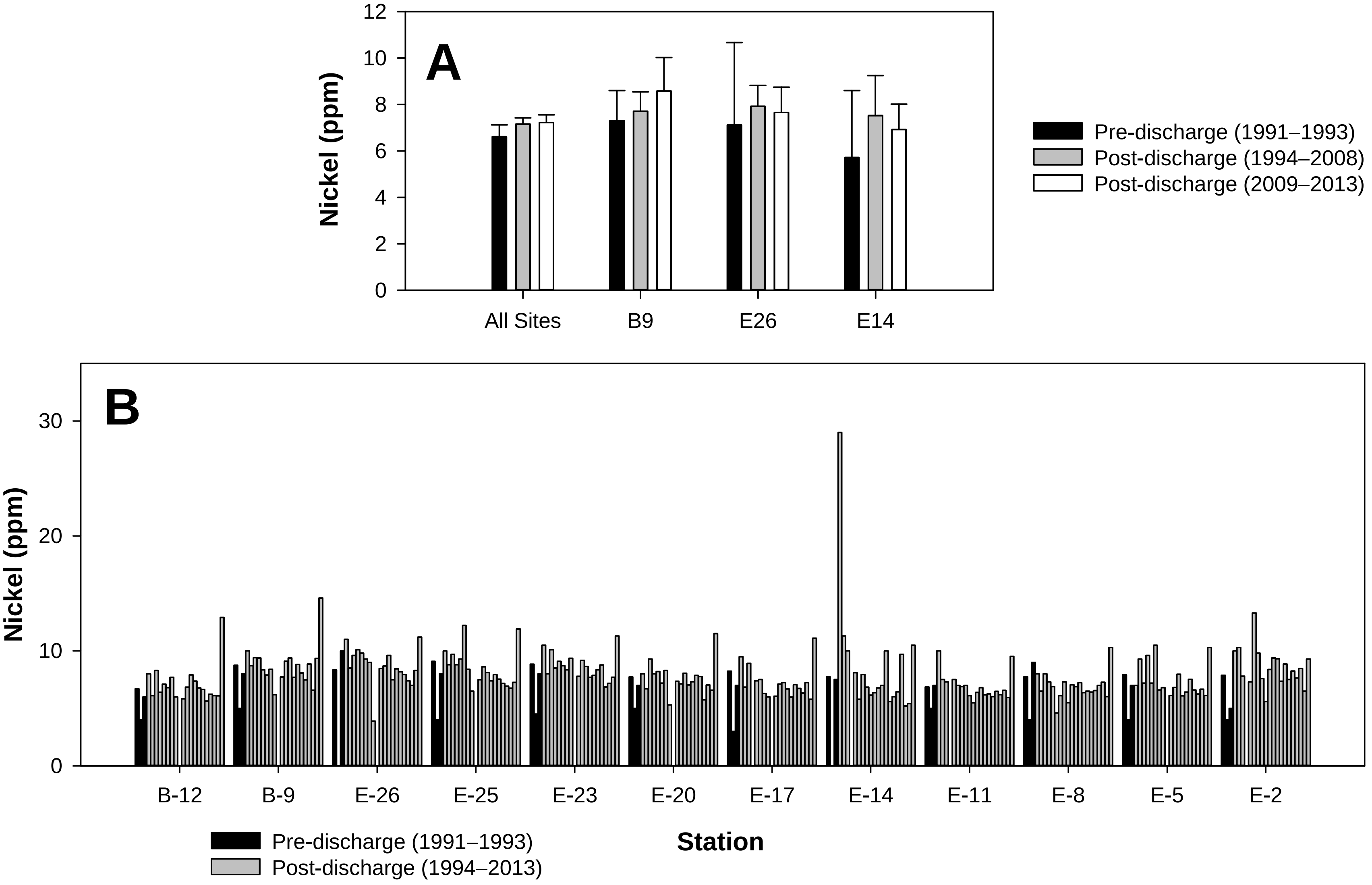

FIGURE C.1-19

Nickel concentrations (ppm) in sediments at outfall discharge depths near the Point Loma Ocean Outfall from 1991 through 2013. (A) pre-discharge vs. post-discharge summary (means + 95% CI); (B) July surveys only.

selenium levels during July 1993 prior to outfall operation, as well as some relatively high spikes that occurred at most sites over the past five years (Figure C.1-20b).

Silver: Silver has only rarely been detected in Point Loma sediments, usually occurring at concentrations near or below MDLs (Figure C.1-21b). Overall concentrations of silver averaged about 0.1 ppm during the pre-discharge period and 0.22 ppm thereafter (Table C.1-3).

Zinc: Zinc concentrations averaged 28.0 ppm in Point Loma sediments during the pre-discharge period and 29.1 ppm afterwards (Tables C.1-3). These levels are lower than average values reported for reference areas in the SCB (Table C.1-2). A comparison of zinc data over time revealed no evidence of any outfall-related changes (Figure C.1-22).

Pesticides, PCBs, and PAHs

Total DDT: DDT has been detected at all primary core stations off Point Loma, although there is no evidence of any effects related to the discharge of wastewater (Figure C.1-23). Sediment concentrations of total DDT were generally low, averaging 1,247 and 635 parts per trillion (ppt) during the pre- and post-discharge periods, respectively (Table C.1-3). These values are also considerably less than those measured during the various SCB reference surveys (Table C.1-2). However, exceptionally high DDT values have been reported on two occasions at outfall depths off Point Loma, including northern reference station B9 (44,830 ppt) in January 1999 and southern station E2 (40,900 ppt) located just east of the LA-5 disposal site in July 1995, indicating sources unrelated to the PLOO discharge. Additionally, region-wide total DDT concentrations peaked in 1993 during a 7-year period when 10 large dredging projects deposited contaminated San Diego Bay sediments at the LA-5 disposal site (Steinberger et al. 2003, City of San Diego 2006a). Similarly, discharges from Mission Bay and the San Diego River during periods of heavy rainfall may affect sediment conditions at the more northern sites (see City of San Diego 2007a).

Total PCB: PCBs were measured as Aroclors prior to April 1998 and as congeners since that time. Consequently, the data from these two periods are not comparable. No PCB Aroclors were detected in sediments at the primary core stations from 1991 through 1998. Since that time PCB congeners have been detected in sediment samples from only five stations along the 98-m discharge depth contour (i.e., stations E2, E5, E8, E17 and E25). The highest and most frequent occurrences of PCBs off Point Loma occurred at southern station E2 located near the LA-5 disposal site (Figure C.1-24). Overall, the most probable source of any PCB contamination in the benthos off Point Loma is the disposal of dredged sediments from San Diego Bay (see Parnell et al. 2008). There are no patterns in PCB distributions relative to outfall operation and the discharge of wastewater.

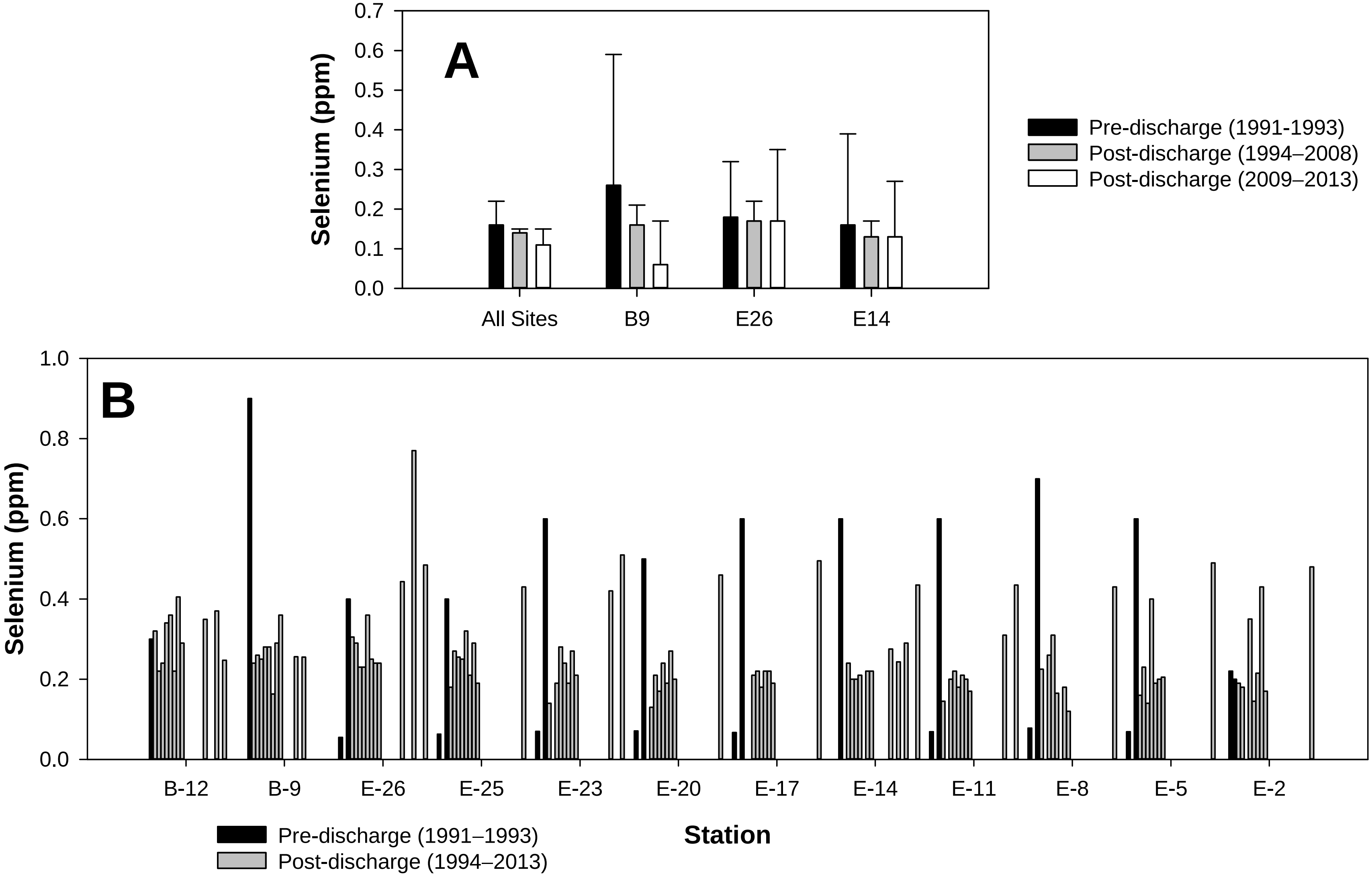

FIGURE C.1-20
Selenium concentrations (ppm) in sediments at outfall discharge depths near the Point Loma Ocean Outfall from 1991 through 2013. (A) pre-discharge vs. post-discharge summary (means + 95% CI); (B) July surveys only.

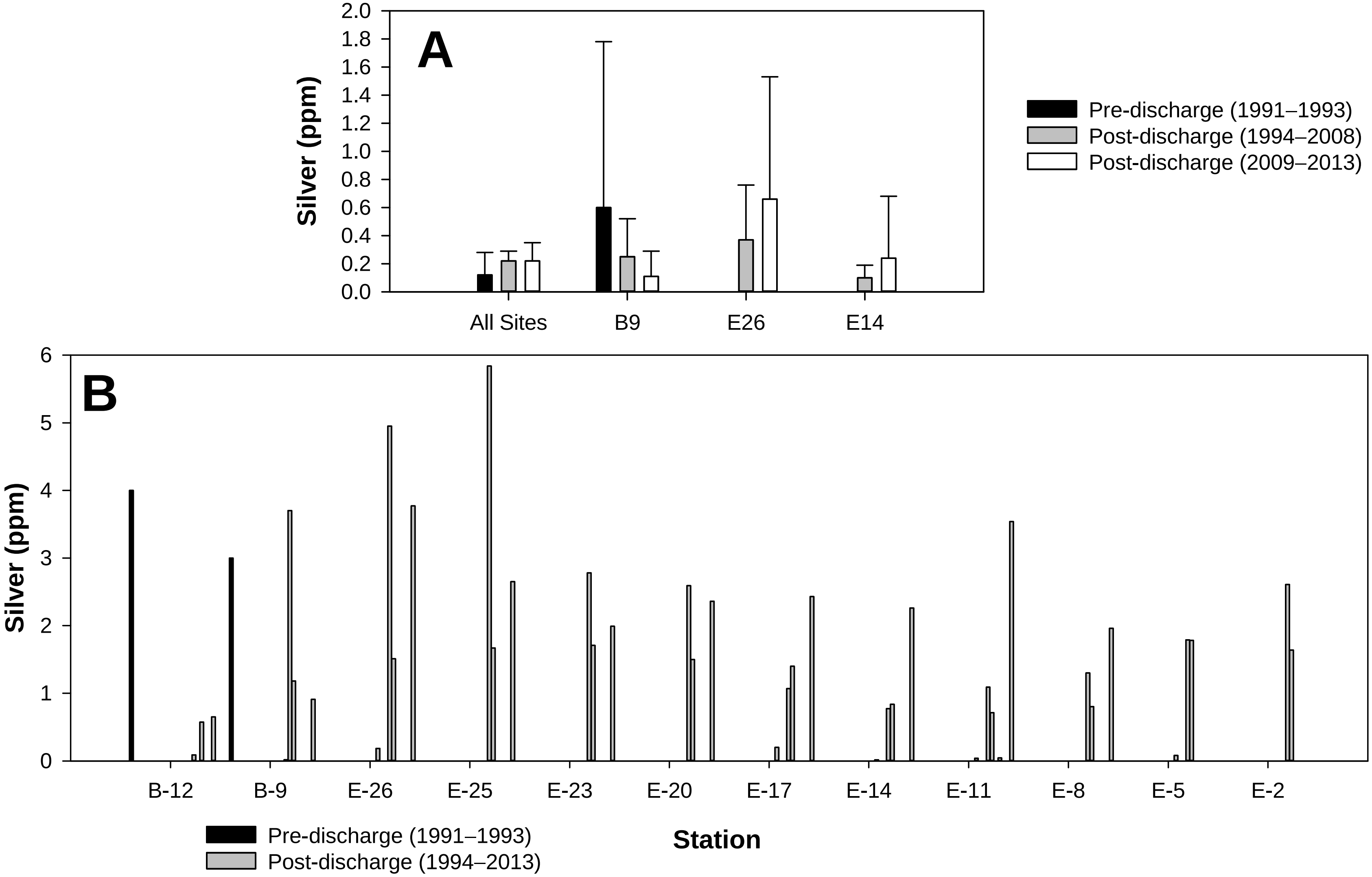

FIGURE C.1-21
Silver concentrations (ppm) in sediments at outfall discharge depths near the Point Loma Ocean Outfall from 1991 through 2013. (A) pre-discharge vs. post-discharge summary (means + 95% CI); (B) July surveys only.

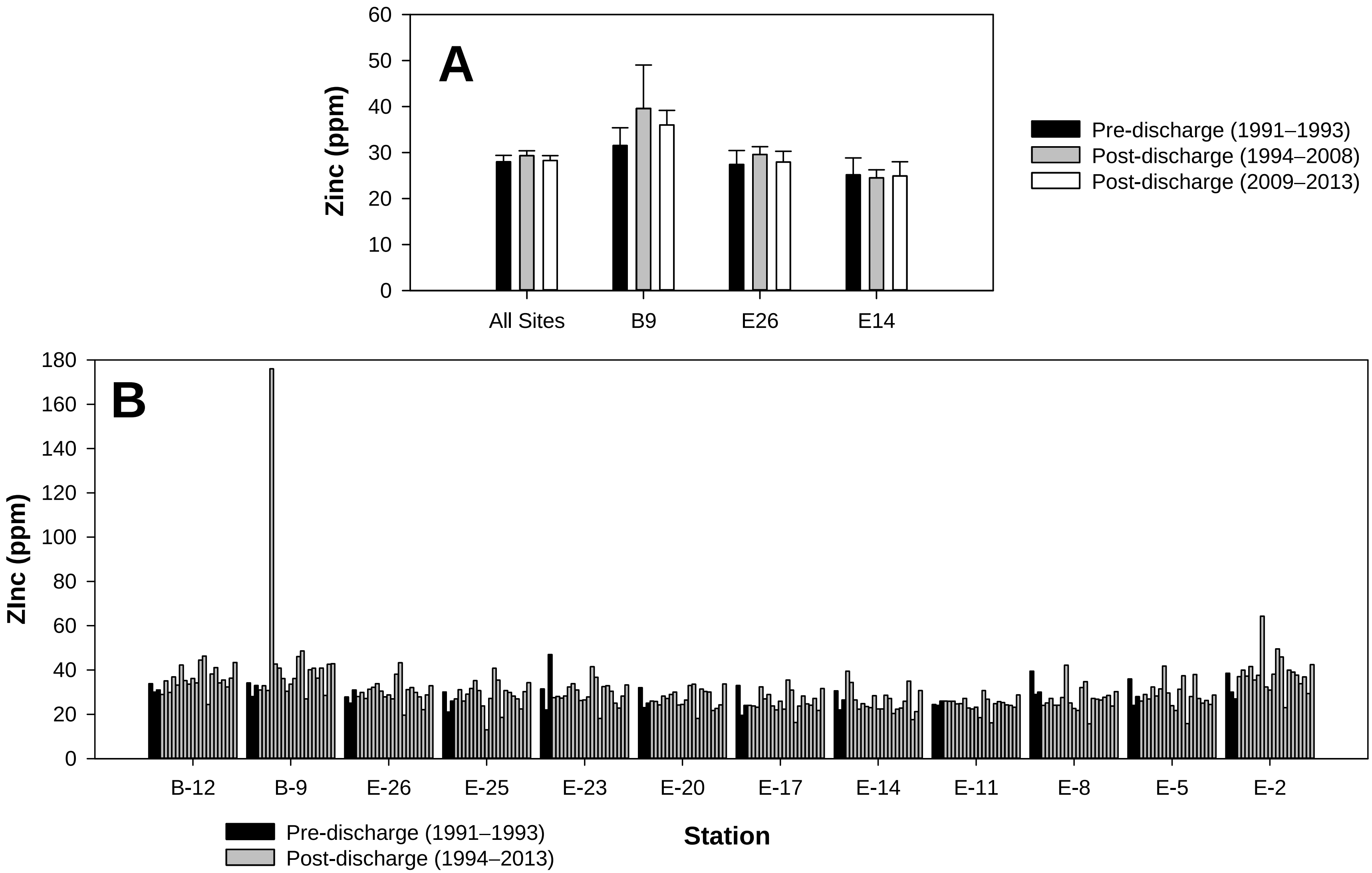

FIGURE C.1-22

Zinc concentrations (ppm) in sediments at outfall discharge depths near the Point Loma Ocean Outfall from 1991 through 2013. (A) pre-discharge vs. post-discharge summary (means + 95% CI); (B) July surveys only.

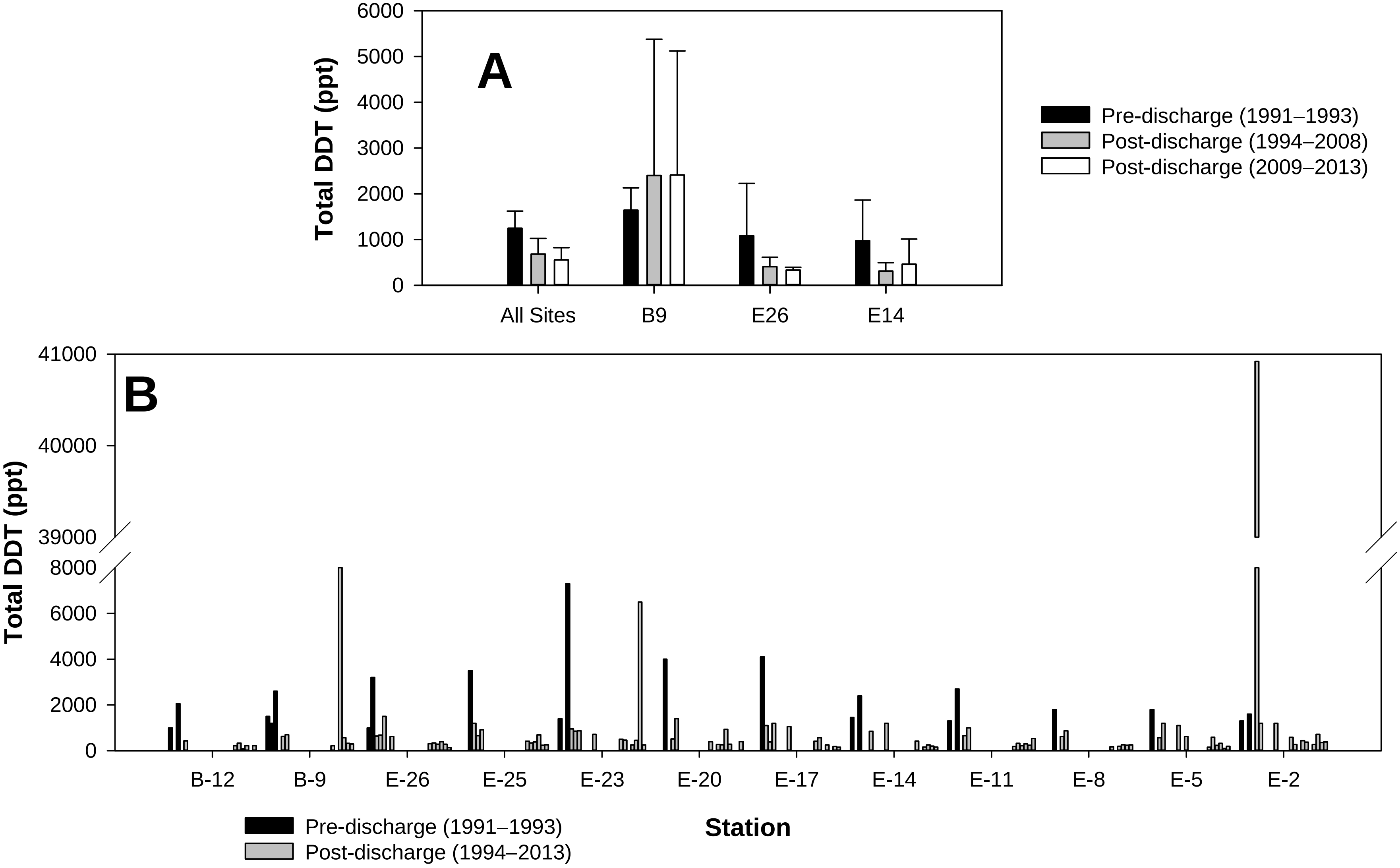

FIGURE C.1-23

Total DDT concentrations (ppt) in sediments at outfall discharge depths near the Point Loma Ocean Outfall from 1991 through 2013. (A) pre-discharge vs. post-discharge summary (means + 95% CI); (B) July surveys only.

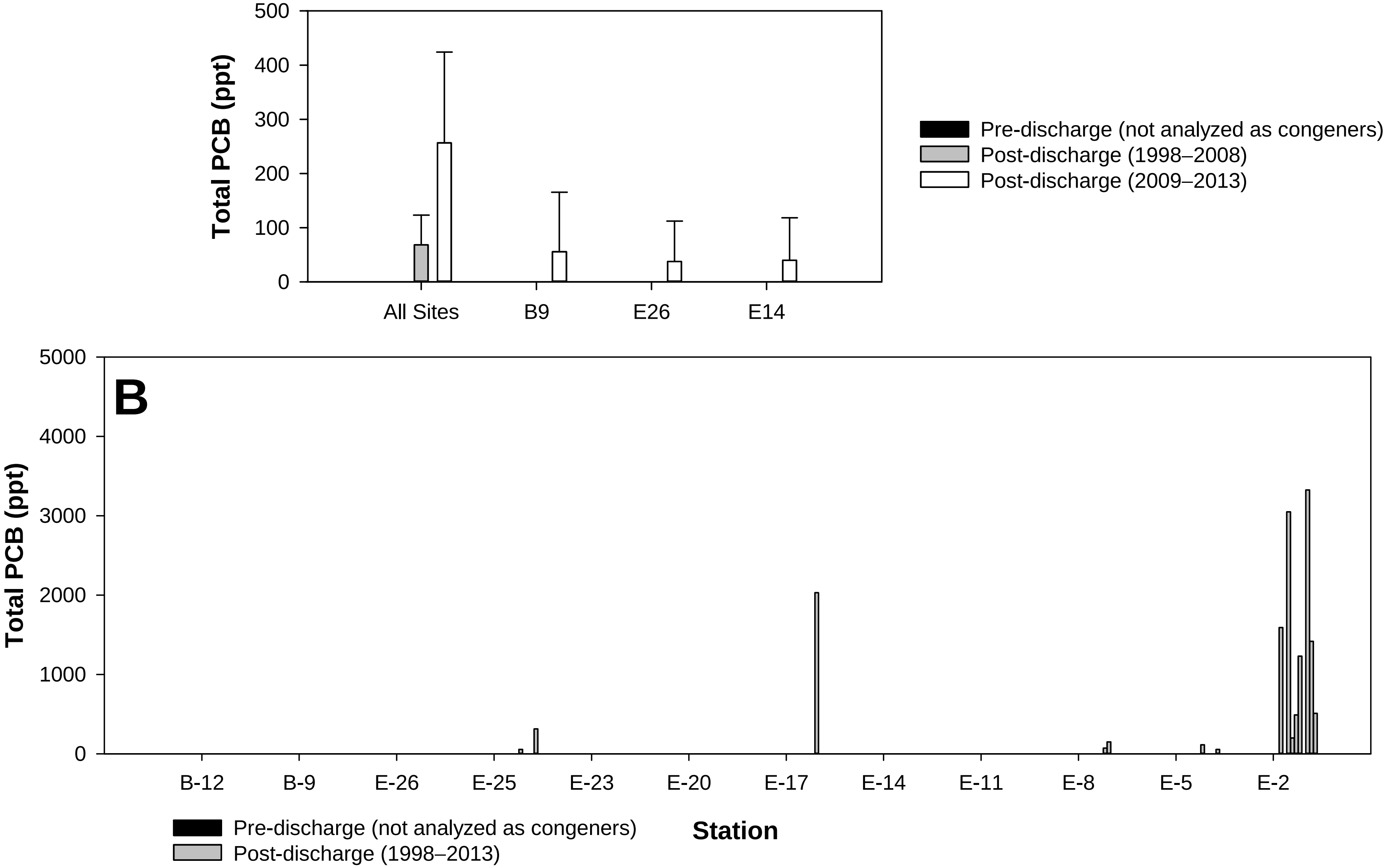

FIGURE C.1-24
Total PCB concentrations (ppt) measured as congeners in sediments at outfall discharge depths near the Point Loma Ocean Outfall from 1998 through 2013. (A) Post-discharge summary (means + 95% CI); (B) July surveys only. See text for discription of PCBs measured as arochlors and congeners.

Total PAH: PAHs have been detected sporadically in sediments off Point Loma and typically in low concentrations near or below method detection limits (Table C.1-3). For example, no PAHs were detected at outfall depths prior to wastewater discharge. PAH concentrations in Point Loma sediments during the post-discharge period have averaged about 40 ppb, which is less than average values reported for the four SCB regional surveys between 1994−2008 (Table C.1-2). Additionally, PAHs detected previously in sediments from sites located south of the PLOO have largely been attributed to short dumps intended for the LA-5 disposal site (see Anderson et al. 1993). Overall, there are no patterns in PAH distributions surrounding the Point Loma outfall that could be attributed to wastewater discharge (see Figure C.1-25).

Summary of Sediment Conditions

Wastewater discharge is not significantly affecting sediment quality in the vicinity of the Point Loma outfall. After 20 years of outfall operation, there is little to no evidence of organic and contaminant loading in the area, with measured parameters existing at levels within the range of natural variability for reference areas off San Diego and throughout the SCB. Although there were increases in levels of a few trace metals in 1994 shortly after discharge began, these increases were only temporary. The only sustained effects were restricted mostly to a few sites located within about 200 m of the ZID, including near-ZID station E14 just west of the center of the outfall wye, and near-ZID stations E11 and E17 located off the ends of the southern and northern diffuser legs, respectively. These effects included an increase in the percentage of coarse sediments (i.e., decrease in percent fines) through time, measurable increases in sulfide concentrations in near-outfall sediments, as well as smaller increases in sediment BOD levels. Consequently, there is no evidence that the discharge of wastewater via the PLOO is affecting the quality of benthic sediments to the point that it will degrade the resident marine biota.

SECTION C.1-5 | BENTHIC INFAUNA

The City of San Diego has been monitoring benthic infaunal communities around the extended Point Loma Ocean Outfall since 1991. Benthic surveys were conducted quarterly (January, April, July, October) from July 1991 through July 2003, after which sampling was modified to semiannual surveys during January and July of each year. The locations for all benthic stations sampled during these periods are shown in Figure C.1-1. The accumulation of organic indicators, trace metals, and other contaminants (e.g., pesticides, PCBs and PAHs) in sediments has already been discussed in the previous section. This section focuses on the results of the benthic infaunal

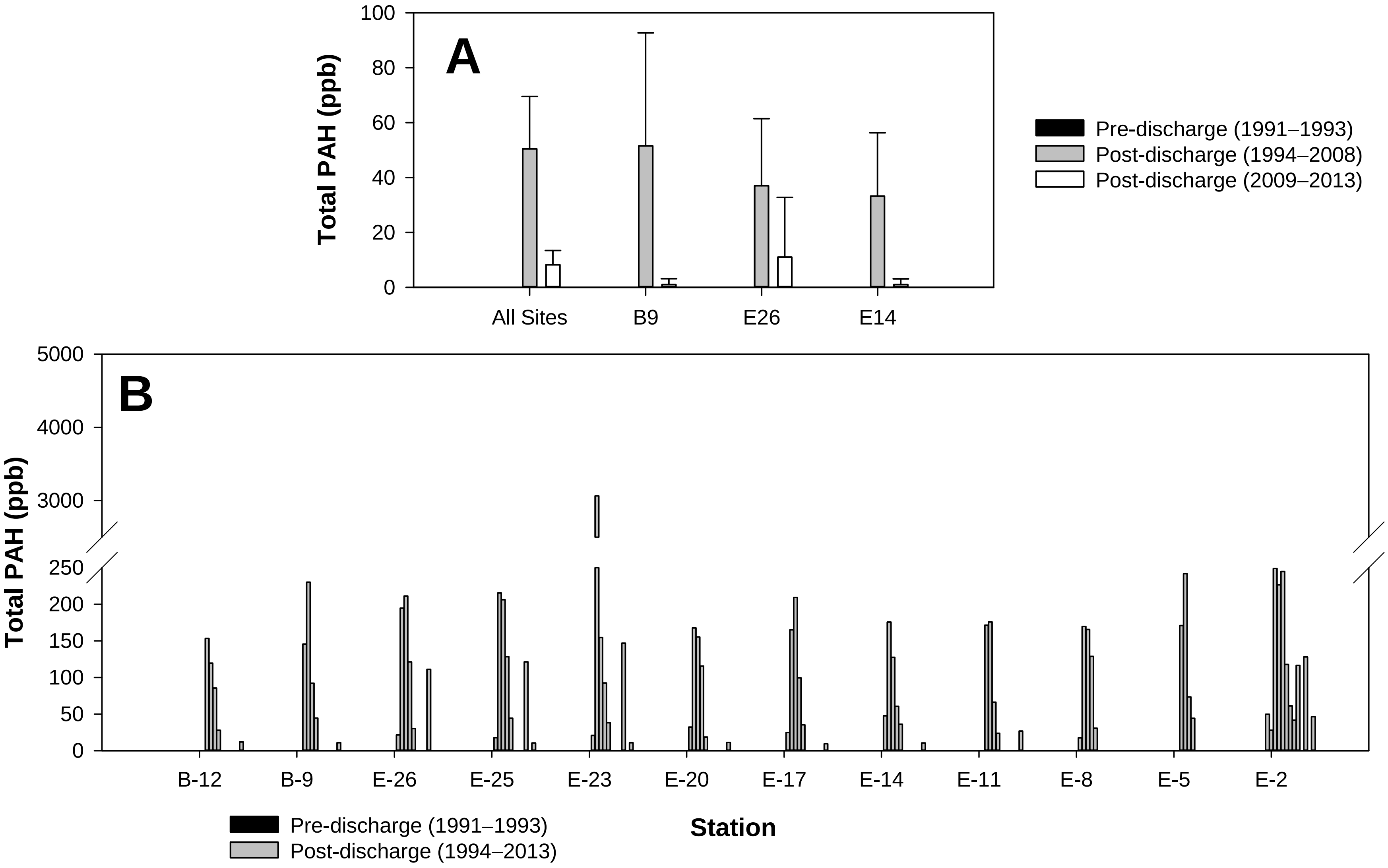

FIGURE C.1-25

Total PAH concentrations (ppb) in sediments at outfall discharge depths near the Point Loma Ocean Outfall from 1991 through 2013. (A) pre-discharge vs. post-discharge summary (means + 95% CI); (B) July surveys only.

analyses (i.e. macrobenthic communities) from the pre- and post-discharge monitoring periods to evaluate the possible effects of wastewater discharge.

Data Sets & Analyses

Since macrobenthic assemblages often vary with depth, changes near the Point Loma Ocean Outfall were evaluated by focusing on data collected at the 12 primary core stations located at outfall discharge depths. From north to south, these stations are B12, B9, E26, E25, E23, E20, E17, E14, E11, E8, E5 and E2. The following analyses of benthic communities in the region are based on a dataset consisting of the results from all January and July surveys conducted at the above stations from July 1991 through July 2013. This includes five pre-discharge surveys (July 1991−July1993), and 40 post-discharge surveys (January 1994−July 2013) with the subsequent biological database consisting of information from a total of 1,064 0.1-m^2 grab samples, representing about 107 m^2 of sea floor sediments; a few replicate samples were excluded from the analyses due to preservation problems (see Table C.1-1). Overall, the above surveys included 120 benthic grabs for the pre-discharge period and 944 grabs for the post-discharge period. Additionally, the post-discharge period includes 620 samples from 1994−2006 that were analyzed during the last waiver application, and 324 samples from 2007−2013 that cover the current application renewal period. Finally, since benthic community structure also varies considerably with season, some comparisons presented herein are limited to data collected only during the summer July surveys.

The primary core stations are located along the 98-m depth contour spanning the terminus of the PLOO (Figure C.1-1). Stations E14, E11 and E17 are located within about 100−300 m of the outfall diffuser legs (i.e., within 200 m of the ZID) and are considered nearfield or near-ZID sites. Station E14 is nearest the outfall, located adjacent to the ZID boundary about 103 m west of the center of the outfall wye. This station is the site most likely to be impacted by wastewater discharge. Stations E11 and E17 are located a little farther away off the ends of the southern and northern diffuser legs, respectively. Station E11 is located about 149 m from the southern ZID boundary, while E17 is located about 197 m from the northern ZID boundary. The remaining “E” stations are considered farfield sites. The “B” stations are located >11 km north of the outfall and were originally selected to represent reference or control sites. However, benthic communities differed between the “B” and “E” stations prior to operation of the outfall (Smith and Riege 1994; City of San Diego 1995a). Thus, farfield station E26 was chosen to represent an additional reference site. This station is located ~8 km north of the outfall and is considered the least likely “E” station to be impacted by wastewater discharge.

The following key community parameters were evaluated in assessing impacts on the benthos: (1) number of species per grab sample (i.e., species richness or species diversity), (2) number of individuals per sample (abundance), (3) dominance (Swartz dominance), (4) benthic response index (BRI), (5) abundances of major taxa groups (e.g., polychaetes, echinoderms, crustaceans, molluscs), (6) abundances of various pollution sensitive, pollution tolerant or opportunistic species (i.e., indicator species), and (7) abundances of numerically dominant taxa (i.e., top 10 species by abundance). Additional comparisons of changes in the benthos were made using the BACIP statistical design (see Box A). Outfall-related effects were evaluated in terms of (1) the range of natural variability under reference conditions, (2) the magnitude and spatial extent of any effect, and (3) an assessment of the potential for adverse effects. Estimates of natural variability for benthic community parameters in the SCB have been extracted from various regional and bight-wide surveys conducted since 1985 (see Table C.1-4). These studies include the 1985 and 1990 SCCWRP reference surveys (Thompson et al. 1987, 1992), the 1994 Southern California Bight Pilot Project (Bergen et al. 1998, 2001), the 1998, 2003 and 2008 Southern California Bight Regional Monitoring Programs (i.e., Bight’98, Bight’03, and Bight’08, respectively; Ranasinghe et al. 2003, 2007, 2012), annual region-wide surveys of the San Diego mainland shelf conducted as part of regular South Bay monitoring requirements, and tolerance intervals calculated from these latter annual surveys off San Diego (see Appendix C.2).

The focus of most comparisons in this section is between conditions present during the 2.5 year pre-discharge period (July 1991−1993) and the entire 20 year post-discharge period (1994−2013). Exceptions are noted when data were not available for part of the pre-discharge period for specific parameters. Additionally, the post-discharge period is broken down into two periods (1994−2008 vs. 2009−2013) in some tables and figures in order to emphasize any patterns or trends during the past five years (2009−2013) since the last waiver application.

Results

Major Community Parameters

Number of Species: One potential indicator of environmental degradation would be a reduction in benthic species diversity or the number of species near an outfall. The number of species off Point Loma averaged 67 and 90 species during the pre- and post-discharge periods, respectively (Table C.1-5). Although highly variable (e.g., 36−145 species per station), the number of species per grab was generally higher at all stations during the post-discharge period (Figure C.1-26). This post-discharge increase was perhaps more pronounced at near-ZID station E14, although a similar pattern is apparent at station E11 located within 149 m of the southern edge of the ZID, southern station E2 near the LA-5 dredged materials disposal site, and northern reference station B12. The results of BACIP analyses demonstrated a significant change in the difference in species diversity between impact station E14 and both the E26 and B9 control stations (Table C.1-6). However, species richness values for almost all stations and times were within the

Box A

BACIP Analysis Methods

A BACIP (Before-After-Control-Impact-Paired) statistical model was used to test the null hypothesis (H_0) that there were no changes in various benthic community parameters due to operation of the Point Loma Ocean Outfall (see Bernstein and Zalinski 1983; Stewart-Oaten et al. 1986, 1992; Osenberg et al. 1994). Briefly, the BACIP model tests differences between control (reference) and impact sites at times before and after a disturbance or 'impact' event (e.g., onset of wastewater discharge). Overall, the Point Loma outfall dataset includes 2.5 years (10 quarterly surveys) of 'Before Impact' data (1991–1993) and 20 years (59 quarterly or semiannual surveys) of 'After Impact' data (1994–2013). However, the data were limited to only winter (January) and summer (July) surveys conducted each year for the analyses presented herein (see Section C.1-3), which resulted in a reduced data set of five pre-discharge surveys and 40 post-discharge surveys. The 'E' benthic stations for the Pt Loma monitoring program, located within 8 km of the outfall, are the most likely to be affected by wastewater discharge. Near-ZID station E14 was selected as the impact site for all BACIP analyses since this station is located nearest the Zone of Initial Dilution (ZID) and is probably the site most susceptible to wastewater influence. In contrast, the 'B' stations are located at least 11 km north of the outfall and are the obvious candidates for reference or 'control' sites. However, benthic community structure already differed between the 'E' and 'B' stations prior to operation of the outfall (Smith and Riege 1994; City of San Diego 1995a). Consequently, two stations (E26 and B9) were selected to represent separate control sites in subsequent analyses. Farfield station E26 is located ~8 km from the outfall and is considered the least likely 'E' station to be impacted, while previous analyses suggested that reference station B9 was the most appropriate 'B' station for comparisons (Smith and Riege 1994; City of San Diego 1995a). Six dependent variables were analyzed, including three community parameters (number of species, infaunal abundance, and BRI) and abundances of three benthic invertebrate taxa (or species groups) known to be sensitive to organic enrichment. These indicators included ophiuroids in the genus *Amphiodia* (mostly *A. urtica*) and amphipods in the genera *Ampelisca* (Family Ampeliscidae) and *Rhepoxynius* (Family Phoxocephalidae).

All BACIP analyses were first interpreted using a Type I error rate of $\alpha = 0.05$. However, the substantial spatial and temporal variation inherent in many biological communities may often lead to an increased chance of Type II error and falsely conclude that no impact has occurred when it has happened (e.g., see Underwood 1990; Fairweather 1991; Otway 1995; Otway et al. 1996). One possible solution to this problem is to increase the probability of Type I error (i.e., falsely conclude an impact has occurred) by changing α from 0.05 to 0.10, and thereby increase the power of the t-tests to make the detection of any 'impact' less conservative (Otway 1995; Otway et al. 1996). Thus, all non-significant BACIP test results at $\alpha = 0.05$ were subsequently interpreted using the higher Type I error rate of $\alpha = 0.10$.

TABLE C.1-4

Comparison of benthic infauna species richness, abundance, and benthic response index (BRI) values for the PLOO benthic stations with data from the SCCWRP 1985 and 1990 reference surveys (60 and 150 m depths), 1994 Southern California Bight [SCB] Pilot ProJect (SCBPP), Bight'98, Bight'03, and Bight'08 SCB Regional Programs, and San Diego Regional Surveys (1994−2012). PLOO data are presented as means for the 12 outfall depth (~98 m) stations combined (January/July surveys only) during the pre-discharge (1991−1993) and post-discharge (1994−2013) periods. SCCWRP reference survey data are expressed as approximate averages for the 1985 and 1990 surveys combined. SCBPP, Bight'98, Bight'03 and Bight'08 data are expressed as mean values for the "mid-shelf" strata. San Diego regional survey values averaged over all depths (see Appendix C.2). Numbers in parentheses = ranges.

	SCCWRP Reference Surveys[a]		**SCB 1994, 1998, 2003, and 2008 Regional Surveys**[b]				**San Diego Regional Surveys**	**PLOO Surveys (1991−2013)**	
	60-m	**150-m**	**SCBPP**	**Bight'98**	**Bight'03**	**Bight'08**		**Pre-Discharge**	**Post-discharge**
Species Richness	63−83 (41−104)	47−62 (37−73)	84.5 (18−162)	61.5 (7−166)	62.4 (2−158)	98.5 (30−153)	76.2 (8−198)	67 (36−100)	90 (47−145)
Abundance	344−625 (208−1,200)	152−245 (110−288)	385.2 (3−1,696)	291.7 (11−1,830)	274.2 (5−2,298)	393.2 (79−1,159)	301.0 (10−1,467)	274 (79−551)	349 (94−966)
BRI[c]	—	—	—	16.6 (-15.8−47.3)	15.8 (-12.0−47.3)	14.8 (2.0−25.8)	12.7 (-11.0−34.3)	4.8 (-4.2−14.1)	9.2 (-4.8−28.5)

[a] Thompson et al. (1987) - 1985 Reference Site Survey; Thompson et al. (1993) - 1990 Reference site survey

[b] Bergen et al. (1998, 2001); Ranasinghe et al. (2003, 2007, 2012)

[c] BRI values not calculated for SCCWRP and SCBPP surveys

TABLE C.1-5

Summary of benthic infauna abundance, species richness (no. of species), Swartz dominance, diversity (H'), and benthic response index (BRI) values for the Point Loma Ocean Outfall benthic stations; outfall depth stations only (n=12). Data are for January and July surveys only from 1991−2013; pre-discharge surveys = 1991−1993 (n=5); post-discharge surveys = 1994−2013 (n=40). See text for details of data reductions.

	Pre-Discharge Surveys (1991−1993)				1994−2008 Post-Discharge			2009−2013 Post-Disharge			All Post-Disharge Surveys			
	All Sites		Outfall Stn. E14	Ref. Stn. B9	All Sites	Outfall Stn. E14	Ref. Stn. B9	All Sites	Outfall Stn. E14	Ref. Stn. B9	All Sites		Outfall Stn. E14	Ref. Stn. B9
	Mean	Range	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Range	Mean	Mean
Abundance														
All Invertebrates	274	79 – 551	262	237	356	444	323	325	441	285	349	94 − 966	443	313
Annelids[a]	156	44 – 424	154	132	210	297	190	186	294	163	204	35 − 827	296	183
Arthropods[b]	46	10 – 102	45	51	60	74	54	75	77	61	64	11 − 178	74	56
Molluscs	19	3 – 102	12	13	29	47	22	28	52	32	29	2 − 139	48	24
Echinoderms	50	9 – 92	48	36	51	19	53	31	7	24	46	0 − 179	16	46
Misc. Other Taxa	4	0 – 14	3	5	6	7	4	5	12	5	6	0 − 31	8	4
Species Richness	67	36 – 100	66	66	89	99	84	90	103	89	90	47 − 145	100	86
Swartz Dominance	19	8 – 31	20	20	28	29	27	32	30	34	29	3 − 50	30	29
Diversity (H')	3.3	2.7 – 3.9	3.4	3.4	3.8	3.8	3.7	3.9	3.9	4.0	3.8	1.9 − 4.4	3.8	3.7
BRI	4.8	-4.2 – 14.1	5.6	6.7	7.6	15.3	4.0	14.2	22.6	10.0	9.2	-4.8 − 28.5	17.1	5.4

[a] Annelids = mostly polychaetes

[b] Arthropods = mostly crustaceans

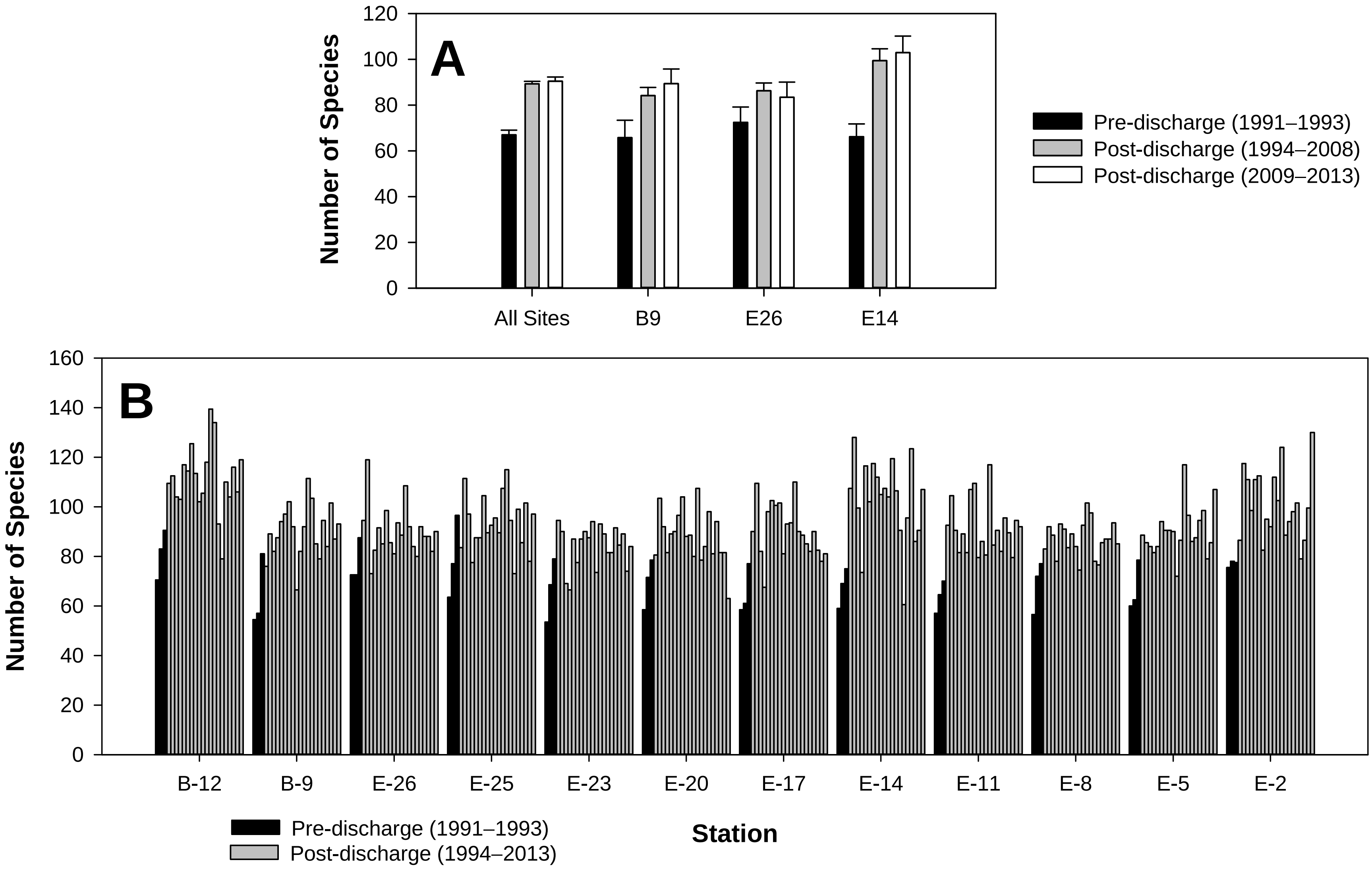

FIGURE C.1-26

Number of species of benthic infauna at outfall discharge depths near the Point Loma Ocean Outfall from 1991-2013. (A) Pre-discharge vs. post-discharge summary for all 12 primary core stations combined, near-ZID station E14, farfield station E26, and reference station B9. (B) Values for each station by year for July surveys only. Data are expressed as means per 0.1 m^2 plus the 95% CI for Figure A.

TABLE C.1-6

Results of BACIP t-tests for species richness, total infaunal abundance, benthic response index (BRI), and the abundance of several benthic indicator taxa around the Point Loma Ocean Outfall (1991−2013). Indicator taxa = ophiuroids *(Amphiodia* spp) and amphipods *(Ampelisca* spp and *Rhepoxynius* spp). Impact site = near-ZID station E14. Control sites = farfield station E26 and reference station B9. Before Impact period = July 1991 to July 1993 (n = 5 surveys); After Impact period = January 1994 to July 2013 (n= 40 surveys). NS = not significant at either the *alpha* = 0.05 or *alpha* = 0.1 levels.

	Comparison	**Before Impact**		**After Impact**			
	Control vs. Impact	**Mean ∆**	**Variance**	**Mean ∆**	**Variance**	**t**	**p-value**
Species Richness	E26 vs E14	7.3	5.5	17.7	3.8	-3.41	0.001
	B9 vs E14	7.8	3.4	18.2	5.1	-3.58	<0.001
Abundance	E26 vs E14	74.1	664.8	134.6	267.4	-1.98	0.027
	B9 vs E14	59.8	216.8	138.9	292.1	-3.51	0.001
BRI	E26 vs E14	2.2	0.4	9.4	0.2	-9.99	<0.001
	B9 vs E14	4.4	0.9	11.7	0.3	-6.85	<0.001
Amphiodia spp	E26 vs E14	9.0	8.7	35.0	14.0	-5.47	<0.001
	B9 vs E14	12.2	27.9	29.3	9.2	-2.81	0.004
Ampelisca spp	E26 vs E14	4.0	2.3	5.9	0.6	-1.11	NS
	B9 vs E14	4.6	1.1	5.9	0.4	-1.04	NS
Rhepoxynius spp	E26 vs E14	3.0	0.8	3.1	0.1	-0.05	NS
	B9 vs E14	2.1	0.3	3.0	0.1	-1.46	0.075

tolerance interval boundaries of 60−145 species per station calculated for the San Diego mainland shelf (see Appendix C.2).

The above increases in species richness may or may not be related to wastewater discharge. First, the increase could be part of a larger regional phenomenon as the number of species began to increase prior to wastewater discharge off Point Loma, and this increase has occurred at all stations regardless of proximity to the outfall. Second, the relatively large increase in number of species at near-ZID station E14 may be related to proximity to the outfall pipe and associated sediment heterogeneity (e.g., patchy sediments related to presence of ballast materials) in addition to organic enrichment. Additionally, two other stations characterized by relatively coarse and unstable sediments, stations E2 to the south and B12 to the north, also displayed relatively large increases in species diversity. Third, the numbers of infaunal species near the outfall are still generally within the range of natural variability seen at other SCB and San Diego reference areas (Table C.1-4; Appendix C.2). Whatever the reasons, wastewater discharge via the Point Loma outfall is not causing any reduction in the number of benthic species in the area.

Infaunal Abundance: Changes in total infaunal abundance are often used to demonstrate an effect of an ocean outfall discharge, although specific changes may vary depending upon the level of organic enrichment. For example, abundances of benthic invertebrates are generally predicted to increase in response to low to moderate levels of enrichment. This increase is generally not considered adverse unless it is accompanied by a reduction in the number of species present or a significant change in the feeding dynamics of the infaunal community. As organic input increases, the total number of species or diversity may begin to decline while populations of pollution tolerant species increase. Extremely high infaunal abundances associated with reduced numbers of species are often considered an indication of an adverse outfall effect. Benthic abundances would then be expected to decline when levels of organic enrichment reach the point of causing anoxic sediment conditions. Thus, evidence of high organic loadings coupled with reduced benthic abundances would be indicative of polluted or degraded conditions.

The number of infaunal animals at outfall depths off Point Loma averaged 274 per 0.1 m^2 grab sample over all pre-discharge surveys and 349 per grab during the post-discharge period (Table C.1-5). Overall, this represents about a 27% increase between the pre-discharge and post-discharge periods. In spite of this general increase, there were no clear spatial patterns in the region, and infaunal abundances at all stations were generally within the tolerance interval bounds of 223−603 animals per grab for the San Diego region (see Appendix C.2). Although highly variable (i.e., 79−966 animals/grab), abundances were generally higher at all stations in the post-discharge period (Figure C.1-27). For example, densities at near-ZID station E14 increased from an average of 262 animals per grab during the pre-discharge years to 443 per grab afterwards. Although the increase at station E14 could be an enhancement effect, infaunal

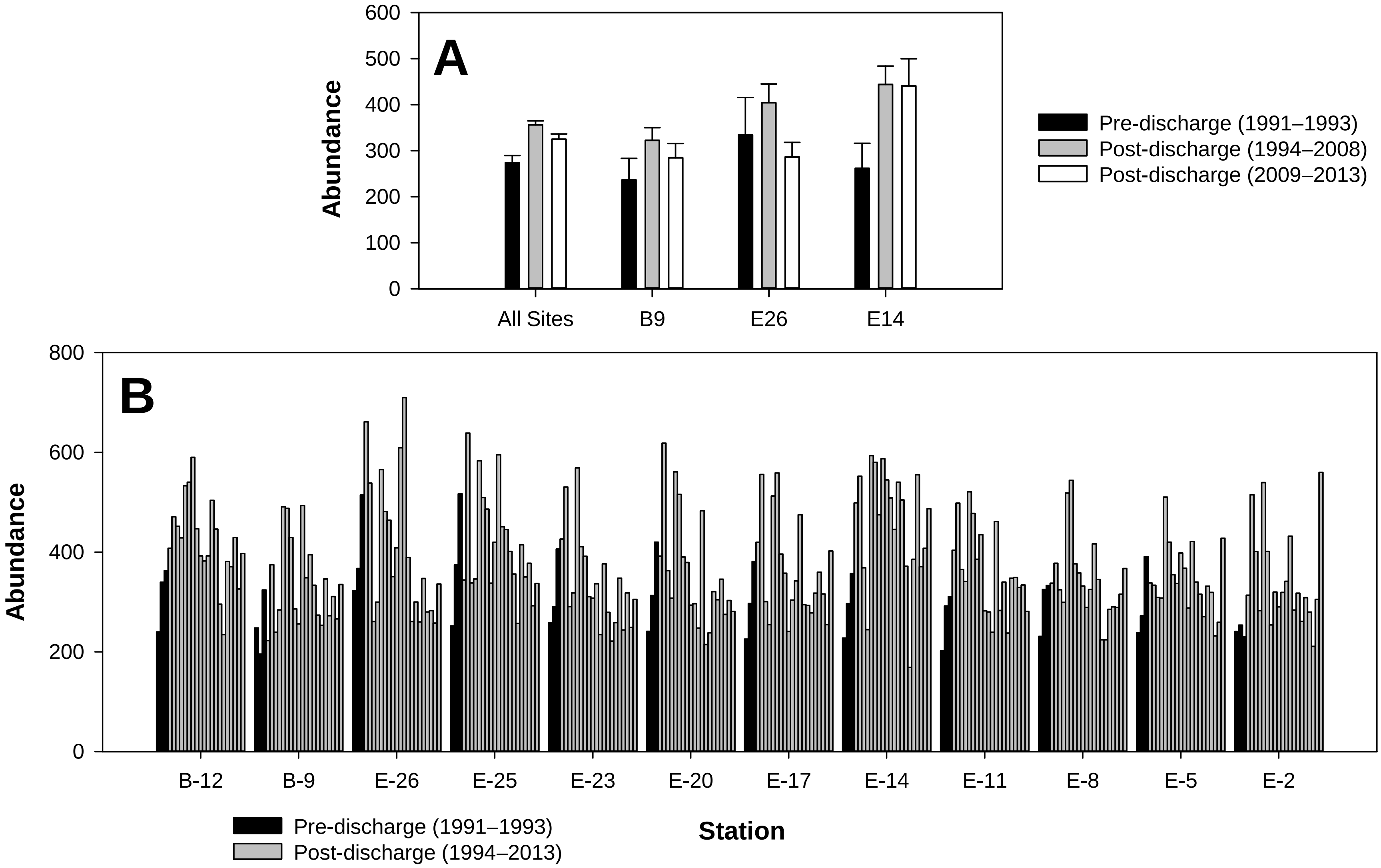

FIGURE C.1-27

Abundance of all benthic infauna at outfall discharge depths near the Point Loma Ocean Outfall from 1991-2013. (A) Pre-discharge vs. post-discharge summary for all 12 primary core stations combined, near-ZID station E14, farfield station E26, and reference station B9. (B) Values for each station by year for July surveys only. Data are expressed as means per 0.1 m^2 plus the 95% CI for Figure A.

abundances also increased at other sites considered beyond the outfall’s influence (e.g., stations E26 and B9). According to BACIP results, there was a significant change in the difference in abundance values between impact station E14 and both control sites (Table C.1-6). Although these results support an outfall enrichment pattern, the effect appears minor as infaunal abundances at all sites off Point Loma are generally similar to those reported from reference surveys conducted throughout San Diego and the entire SCB (Table C.1-4). This suggests that abundances near the Point Loma outfall are within the range of natural variability seen throughout mainland shelf benthic habitats of the SCB.

Dominance: Dominance is an indicator of benthic community structure which reflects shifts in the relative abundance of species (rather than the total number of species). Severely polluted or impacted habitats are typically dominated by a few pollution tolerant species, whereas more natural areas tend to have greater numbers of more evenly distributed species. One measure of dominance is the minimum number of species whose combined abundance accounts for 75% of the individuals in a sample (Swartz et al. 1986, Ferraro et al. 1994). Consequently, dominance as discussed herein is inversely proportional to numerical dominance, such that low index values indicate communities dominated by few species.

Dominance actually decreased (i.e., index values increased) off Point Loma after the initiation of wastewater discharge (Figure C.1-28). For example, the Swartz dominance values averaged 19 over all sites during the pre-discharge period and 29 afterwards (Table C.1-5). This pattern was apparent even at near-ZID station E14 where the number of species dominating the benthos also increased from about 20 to 30 between these periods. Thus, post-discharge benthic communities in the region were characterized by a more even distribution of species than prior to discharge. Overall, it is clear that benthic infaunal communities around the Point Loma outfall are not being numerically dominated by a few pollution tolerant species.

Benthic Response Index: The benthic response index (BRI) is an important tool for gauging anthropogenic impacts to coastal seafloor habitats throughout the SCB. BRI values below 25 are considered indicative of reference conditions, while values above 34 represent increasing levels of disturbance or environmental degradation (Smith et al. 2001). Because the BRI was developed from data collected within the SCB over several decades, the index is largely driven by the abundance of many of the species that are common off Point Loma.

Overall, BRI values have remained below 25 at all sites except near-ZID station E14 since 1991 (Figures C.1-29 and C.1-30). BRI values at the primary core stations averaged from -4.6 to 13.5 per station during the pre-discharge period and from -4.8 to 28.5 during the post-discharge period (Table C.1-5). The highest BRI occurred at station E14 nearest the outfall, where values have become elevated relative to other sites since 1994. BACIP t-test results indicated a net change in the difference of BRI values between this near-ZID station and both of the control sites (Table C.1-6). Although these data suggest an outfall related pattern, the effect is minor and is restricted

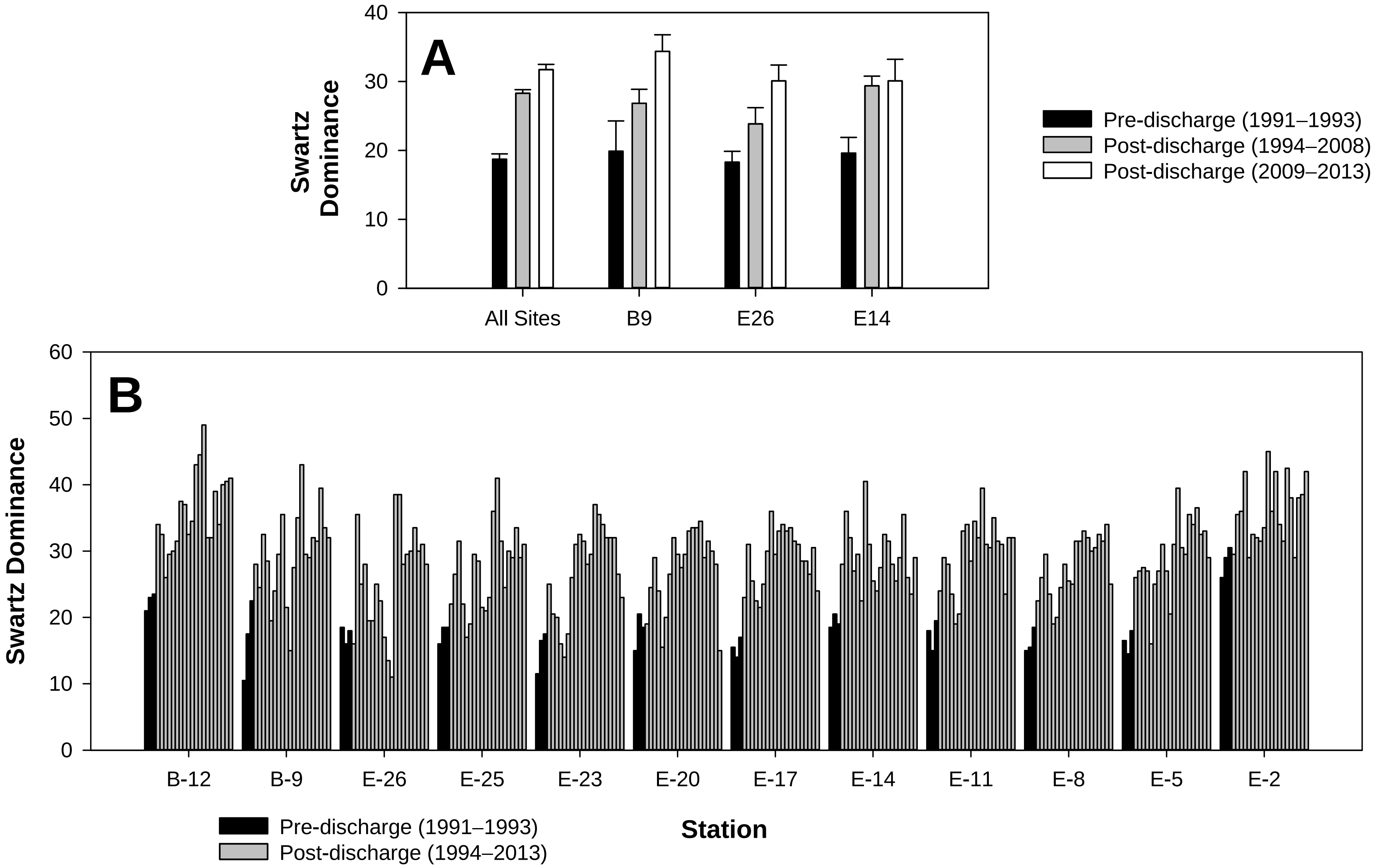

FIGURE C.1-28

Swartz dominance values for benthic infauna at outfall discharge depths near the Point Loma Ocean Outfall from 1991-2013. (A) Pre-discharge vs. post-discharge summary for all 12 primary core stations combined, near-ZID station E14, farfield station E26, and reference station B9. (B) Values for each station by year for July surveys only. Data are expressed as means per 0.1 m^2 plus the 95% CI for Figure A.

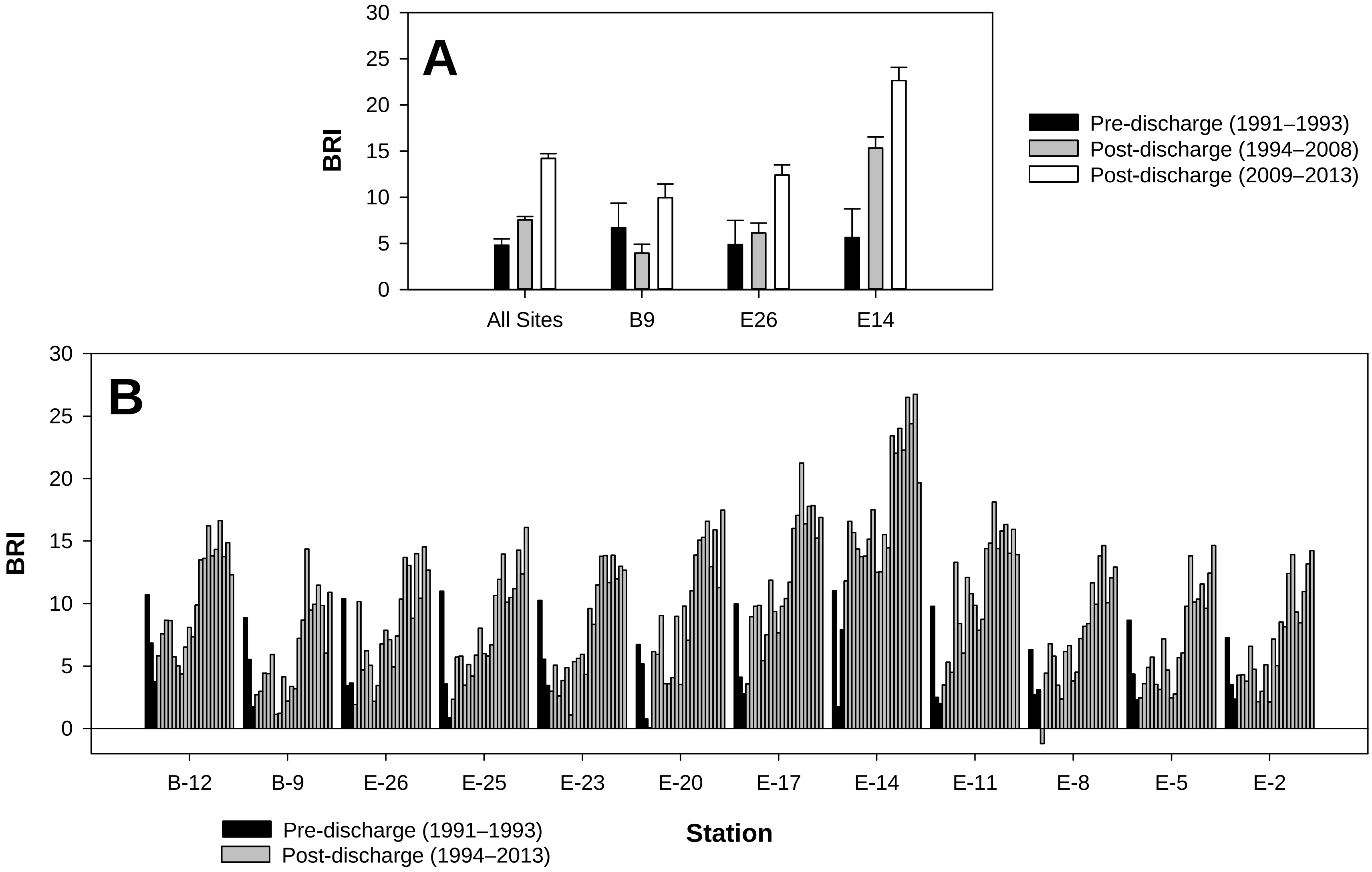

FIGURE C.1-29

Benthic response index (BRI) at outfall discharge depths near the Point Loma Ocean Outfall from 1991-2013. (A) Pre-discharge vs. post-discharge summary for all 12 primary core stations combined, near-ZID station E14, farfield station E26, and reference station B9. (B) Values for each station by year for July surveys only. Data are expressed as means per 0.1 m^2 plus the 95% CI for Figure A.

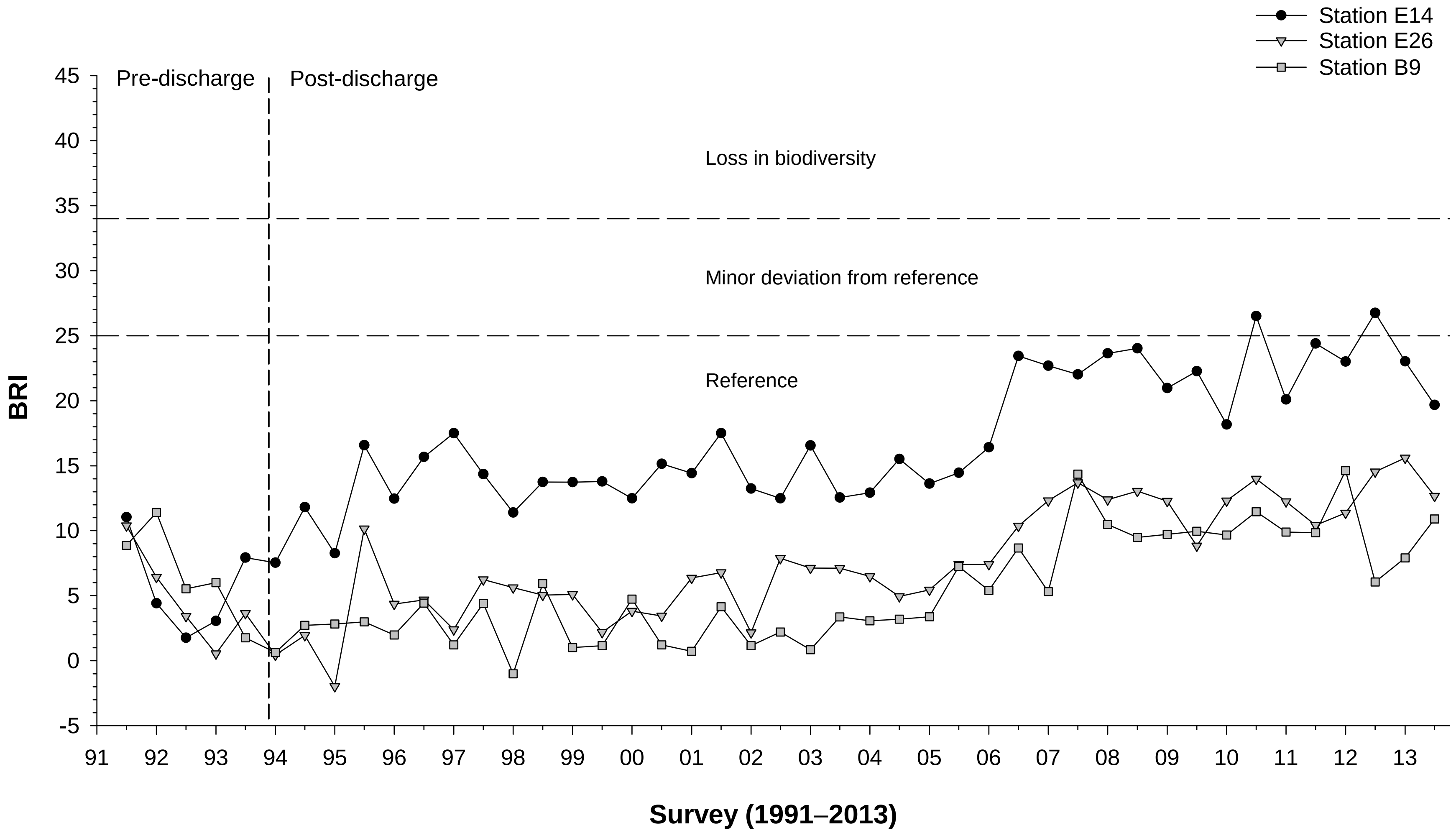

FIGURE C.1-30

BRI values at near-ZID station E14, farfield station E26, and reference station B9 along the Point Loma Ocean Outfall discharge depth contour from 1991-2013. Data are expressed as the mean BRI value for each station during the January and July surveys each year.

to this ZID boundary site. First, values at the nearest upcoast (E17) and downcoast (E11) stations were only minimally elevated, suggesting only a localized phenomenon (e.g., see City of San Diego, 2014b). Second, while BRI values at station E14 have risen above the upper tolerance interval in recent years (see Appendix C.2), most values have still been less than 25 and are considered characteristic of "reference" conditions for the SCB (see Figure C.1-30). The few higher BRI values between 25 and 28.5 that have been reported at this site over the past few years represent only a minor deviation from reference condition (i.e., BRI values >25<34) that is not indicative of degraded benthic habitats (see Smith et al., 2001).

Abundance of Major Taxa & Indicator Species

Annelida, Polychaeta: Polychaete worms (Phylum Annelida) represented the most abundant benthic invertebrates off Point Loma, composing 57–58% of the macrofauna at the primary core outfall depth stations during the pre- and post-charge periods, respectively (Table C.1-5). Although the proportion of polychaetes has remained relatively stable between these periods, actual densities increased approximately 31% from an average of 156 worms per 0.1 m^2 grab prior to outfall operation to 204 worms per grab during the post-discharge period.

A comparison of data collected during the summer surveys only suggested little evidence of any temporal or spatial trends related to the outfall (Figure C.1-31). Although the number of polychaetes increased sharply near the outfall (i.e., near-ZID station E14) immediately after discharge began in 1994 and 1995, this appeared to be a continuation of a general pattern at all stations that began prior to wastewater discharge. Polychaete populations then declined considerably during 1996 and 1997, after which they increased again between 1998 and 2000 at station E14. Similar alternating patterns of population increases and decreases have occurred throughout the region since that time, regardless of proximity to the Point Loma outfall, and are likely related to natural population responses to changing oceanographic conditions (e.g., El Niño/La Niña) or longer term climatic shifts or regime changes. For example, there was little difference in the changes that occurred near the outfall and at station E26 located to the north, beyond the outfall's influence. Much of the change in densities is in response to the cyclical nature of some numerically dominant polychaetes. For instance, populations of two such polychaetes, *Myriochele striolata* and *Proclea* sp A, have varied considerably over time (e.g., City of San Diego 2007a). Such variation can have significant effects on other community descriptive statistics (e.g., dominance, diversity, and abundance) or environmental indices (i.e., BRI) that use the abundance of indicator species in their equations.

Four species of polychaetes were among the 10 most abundant taxa over all primary core sites during both the pre-discharge and post-discharge periods (Table C.1-7). These included the spionid *Spiophanes duplex* (Figure C.1-32; previously reported as *S. missionensis*), the terebellids *Proclea* sp A (Figure C.1-33) and *Phisidia sanctaemariae* (Figure C.1-34; previously

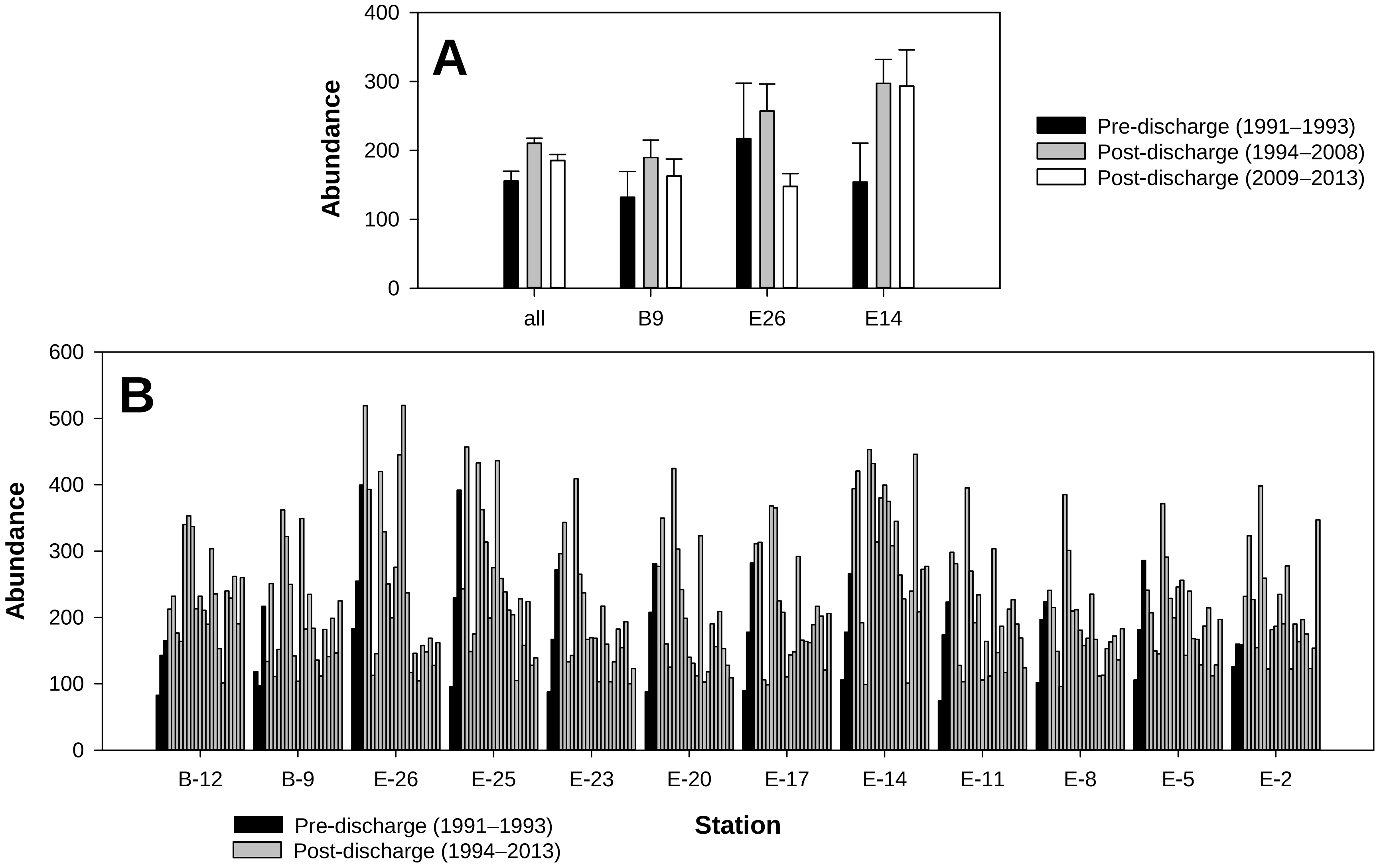

FIGURE C.1-31

Abundance of all annelids (mostly polychaetes) occurring at outfall discharge depths near the Point Loma Ocean Outfall from 1991-2013. (A) Pre-discharge vs. post-discharge summary for all 12 primary core stations combined, near-ZID station E14, farfield station E26, and reference station B9. (B) Values for each station by year for July surveys only. Data are expressed as means per 0.1 m^2 plus the 95% CI for Figure A.

TABLE C.1-7

Abundances of benthic infauna indicator taxa and dominant species at 12 primary core (discharge depth) monitoring sites for the Point Loma Ocean Outfall. Data are for January and July surveys only from 1991 through 2013 and are expressed as numbers per 0.1 m^2 grab sample. Pre-Discharge surveys = 1991−1993 (n=5); Post-Discharge surveys = 1994−2013 (n=40). See text for details of data reductions.

	Pre-Discharge (1991−1993)				1994−2008 Post-Disharge			2009−2013 Post-Discharge			All Post-Discharge (1994−2013)			
	All Sites		Outfall Stn. E14	Ref. Stn. B9	All Sites	Outfall Stn. E14	Ref. Stn. B9	All Sites	Outfall Stn. E14	Ref. Stn. B9	All Sites		Outfall Stn. E14	Ref. Stn. B9
	Mean	Range	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Range	Mean	Mean
SCB Representative Indicator Taxa														
Amphiodia spp (EO)	42.0	5 − 85	40.7	29.1	39.1	10.8	44.0	24.1	3.2	19.5	35.3	0 − 124	8.9	37.8
Ampelisca spp (CA)	6.9	0 − 21	7.8	6.6	10.7	8.6	12.5	12.6	7.2	13.6	11.1	0 − 33	8.2	12.8
Rhepoxynius spp (CA)	5.1	0 − 17	4.6	6.7	4.9	5.1	4.0	5.4	4.1	3.0	5.0	0 − 30	4.8	3.8
Euphilomedes spp (CO)	17.3	2 − 54	18.1	21.2	17.1	28.7	8.9	25.9	31.8	7.7	19.3	0 − 90	29.5	8.6
Parvilucina tenuisculpta (MB)	3.2	0 − 19	1.0	4.6	2.9	8.2	2.8	0.9	3.8	0.5	2.4	0 − 54	7.1	2.2
Solemya pervernicosa (MB)	0.0	0 − 0	0.0	0.0	0.0	0.3	0.0	0.5	5.1	0.0	0.1	0 − 21	1.5	0.0
Capitella teleta (P)	0.02	0 − 1	0.0	0.1	1.2	10.5	0.1	2.9	30.8	0.0	1.6	0 − 140	15.5	0.1
Mediomastus spp (P)	1.3	0 − 16	2.4	2.7	6.5	14.8	3.6	8.3	17.0	3.9	7.0	0 − 122	15.4	3.7
Dominant Taxa off Point Loma														
Amphiodia urtica (EO) ^{A,B,C}	37.8	0 − 85	36.6	24.6	26.3	6.2	32.8	19.7	2.3	17.2	24.6	0 − 78	5.2	28.9
Spiophanes duplex (P) ^{A,B}	33.8	2 − 139	38.2	27.6	11.5	5.3	12.7	0.9	0.2	0.2	8.8	0 − 123	4.0	9.5
Proclea sp A (P) ^{A,B,C}	15.0	0 − 78	11.6	7.8	16.9	11.4	11.2	1.7	0.5	3.9	13.1	0 − 111	8.7	9.3
Euphilomedes producta (CO) ^{A,B,C}	12.4	2 − 50	11.4	21.1	9.1	11.3	8.2	13.8	12.1	7.4	10.3	0 − 62	11.5	8.0
Pectinaria californiensis (P) ^{A}	10.8	0 − 43	6.5	14.4	6.8	5.8	6.6	1.1	0.9	1.2	5.3	0 − 76	4.6	5.2
Phisidia sanctaemariae (P) ^{A,B}	8.8	0 − 47	8.7	3.5	14.3	20.0	11.2	0.8	1.1	1.2	10.9	0 − 217	15.3	8.6
Polycirrus californicus (P) ^{A}	6.9	0 − 38	8.0	4.5	1.3	3.1	0.6	0.1	0.0	0.0	1.0	0 − 70	2.3	0.4
Maldanidae (P) ^{A}	6.8	0 − 22	7.4	6.7	2.7	3.4	3.0	1.0	1.3	1.2	2.3	0 − 14	2.9	2.5
Myriochele striolata (P) ^{A,B}	5.6	0 − 128	1.4	1.0	16.9	33.0	27.1	0.0	0.0	0.1	12.7	0 − 630	24.7	20.3
Euphilomedes carcharodonta (CO) ^{B,C}	4.9	0 − 37	6.7	0.1	7.9	17.4	0.7	12.1	19.7	0.3	9.0	0 − 70	18.0	0.6
Huxleyia munita (MB) ^{A}	5.1	0 − 43	4.6	0.0	3.0	2.6	0.0	0.4	0.4	0.0	2.3	0 − 48	2.0	0.0
Prionospio (Prionospio) jubata (P) ^{B}	3.1	0 − 17	3.4	3.0	7.1	12.6	2.9	10.8	14.2	7.1	8.1	0 − 114	13.0	4.0
Chaetozone hartmanae (P) ^{B}	0.8	0 − 12	0.5	0.3	9.1	16.8	10.4	9.7	11.9	20.5	9.3	0 − 65	15.6	13.0
Amphiodia sp (EO) ^{B,C}	0.5	0 − 10	0.4	0.2	10.6	3.8	8.3	3.5	0.8	2.0	8.8	0 − 60	3.0	6.7

Taxa Codes: EO=Echinodermata, Ophiuroidea; P=Polychaeta; CO=Crustacea, Ostracoda; CA=Crustacea, Amphipoda; MB=Mollusca, Bivalvia

[A] One of 10 most abundant taxa during the pre-discharge period

[B] One of 10 most abundant taxa during the post-discharge period

[C] Also an indicator species

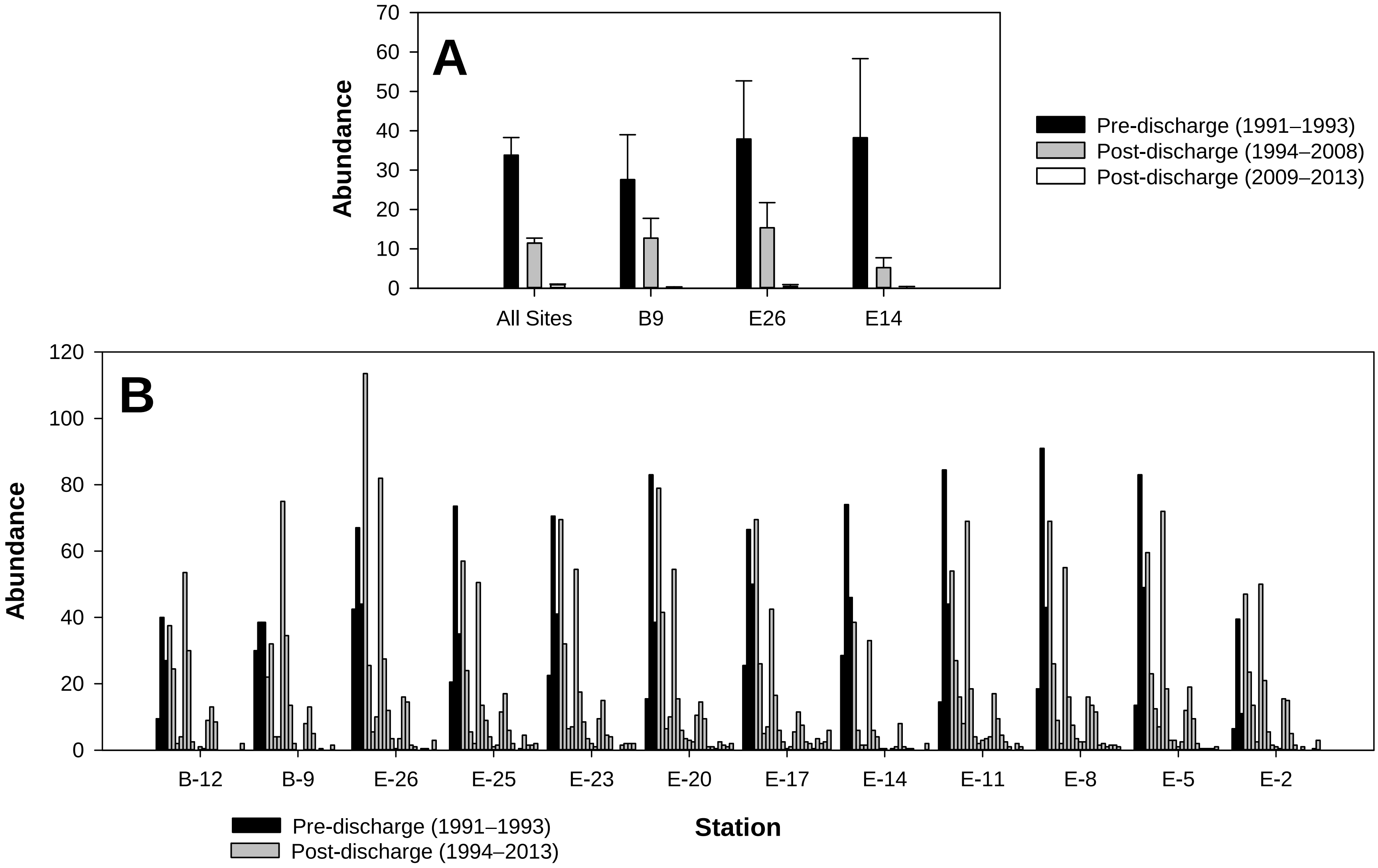

FIGURE C.1-32

Abundance of the spionid polychaete *Spiophanes duplex* at outfall discharge depths near the Point Loma Ocean Outfall from 1991-2013. (A) Pre-discharge vs. post-discharge summary for all 12 primary core stations combined, near-ZID station E14, farfield station E26, and reference station B9. (B) Values for each station by year for July surveys only. Data are expressed as means per 0.1 m^2 plus the 95% CI for Figure A.

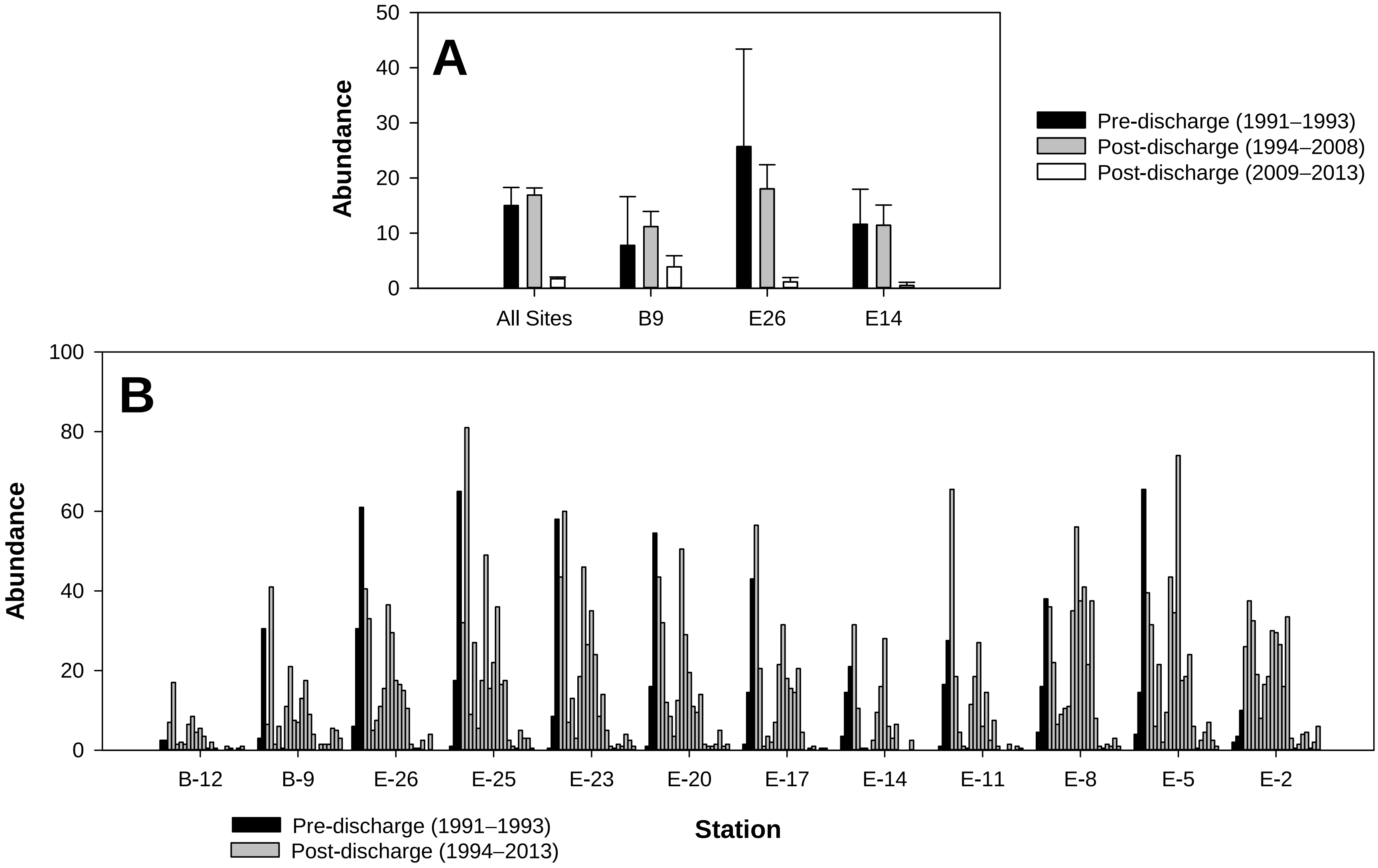

FIGURE C.1-33

Abundance of the terebellid polychaete *Proclea* sp A at outfall discharge depths near the Point Loma Ocean Outfall from 1991-2013. (A) Pre-discharge vs. post-discharge summary for all 12 primary core stations combined, near-ZID station E14, farfield station E26, and reference station B9. (B) Values for each station by year for July surveys only. Data are expressed as means per 0.1 m^2 plus the 95% CI for Figure A.

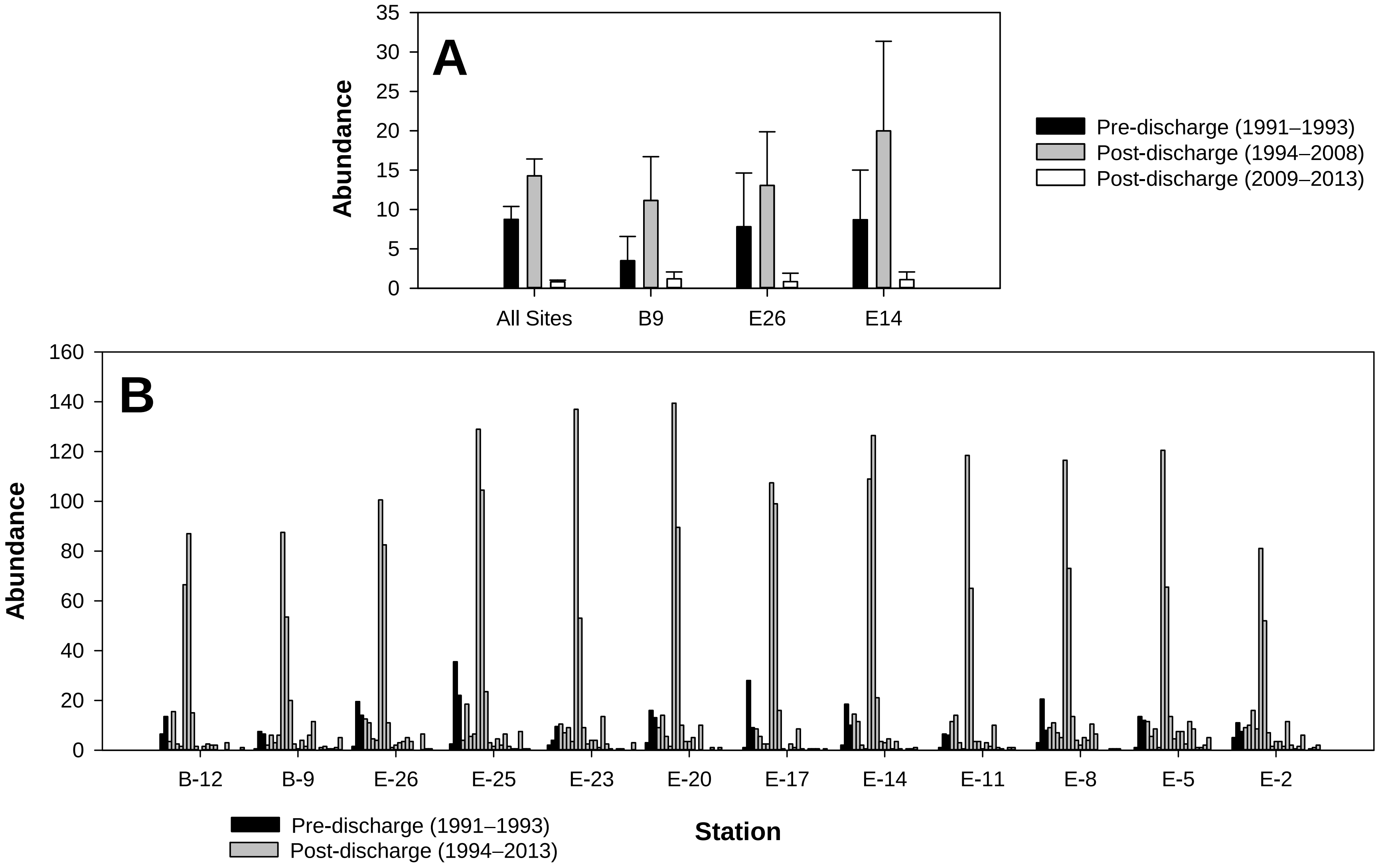

FIGURE C.1-34

Abundance of the terebellid polychaete *Phisidia sanctaemariae* at outfall discharge depths near the Point Loma Ocean Outfall from 1991–2013. (A) Pre-discharge vs. post-discharge summary for all 12 primary core stations combined, near-ZID station E14, farfield station E26, and reference station B9. (B) Values for each station by year for July surveys only. Data are expressed as means per 0.1 m^2 plus the 95% CI for Figure A.

reported as *Lanassa* sp D), and the oweniid *Myriochele striolata* (Figure C.1-35; previously reported as *Myriochele* sp M). Of these species, *S. duplex* showed the greatest change decreasing from an average of 34 animals per grab prior to discharge to about 9 animals per grab during the post-discharge period. In contrast, populations of the two terebellid species remained fairly stable when averaged over all sites, with *Proclea* sp A decreasing slightly from 15 to 13 animals per grab, and *Phisidia sanctaemariae* increasing slightly from 9 to 11 animals per grab. Populations of the fourth species, *M. striolata*, increased from an average of 6 individuals per grab during the pre-discharge period to 13 per grab during the post-discharge period.

Several species of polychaetes that occur in southern California waters are useful indicators of organic loading. These include the well known pollution indicator species in the genus *Capitella*, other capitellids in the genus *Mediomastus*, the dorvilleid *Dorvillea longicornis*, and the opheliid *Armandia brevis*. The *Capitella* species now recognized off Point Loma, *C. telata* (Blake et al. 2009) was previously considered part of a cosmopolitan species complex of several physiologically and genetically distinct sibling species (see Grassle and Grassle 1974, 1976, 1978). Overall, these worms are recognized for experiencing rapid population expansions in areas of organic loading or other disturbances (see Word et al. 1977; Grassle and Grassle 1976, 1978; Cuomo 1985; Tenore and Chesney 1985). Although background densities of *Capitella* spp are usually near zero, abundances may be higher where organic detritus accumulates naturally or where sediments are physically disturbed.

Capitella telata occurs rarely and typically in low abundances at outfall depths off Point Loma (Figure C.1-36), with populations averaging about 0.02 worms per 0.1 m^2 grab before discharge and 1.6 worms per grab during the post-discharge period (Table C.1-7). Populations of this species have shown a minor outfall related pattern with densities increasing from an average of zero to 15.5 worms per grab at near-ZID station E14 since discharge began. Although the highest number of *C. telata* reported since 1991 (140/grab) occurred at this near-ZID station in 2013 (see City of San Diego, 2014b), this abundance was still characteristic of undisturbed habitats. For example, *C. telata* commonly reaches densities as high as 500 individuals per 0.1 m^2 in polluted sediments (Reish 1957, Swartz et al. 1986). Overall, the relatively low abundance and sporadic occurrence of this polychaete off Point Loma suggests no substantial organic loading or habitat degradation is occurring near the outfall. Instead, population fluctuations of *C. telata* at station E14 located near the ZID boundary, and to a lesser extent at stations E11 and E17 located farther away but still within 200 m of the ZID, may be related to local physical disturbances associated with proximity to the outfall as well as to slight organic enrichment.

Capitellid polychaetes of the genus *Mediomastus* are also capable of population expansion in transitional areas of moderate organic enrichment, where they typically exceed densities of 10 worms per 0.1 m^2 (see Word et al. 1977). *Mediomastus* densities averaged about 1.3 animals per 0.1 m^2 at outfall depths off Point Loma during the pre-discharge period compared to about 7

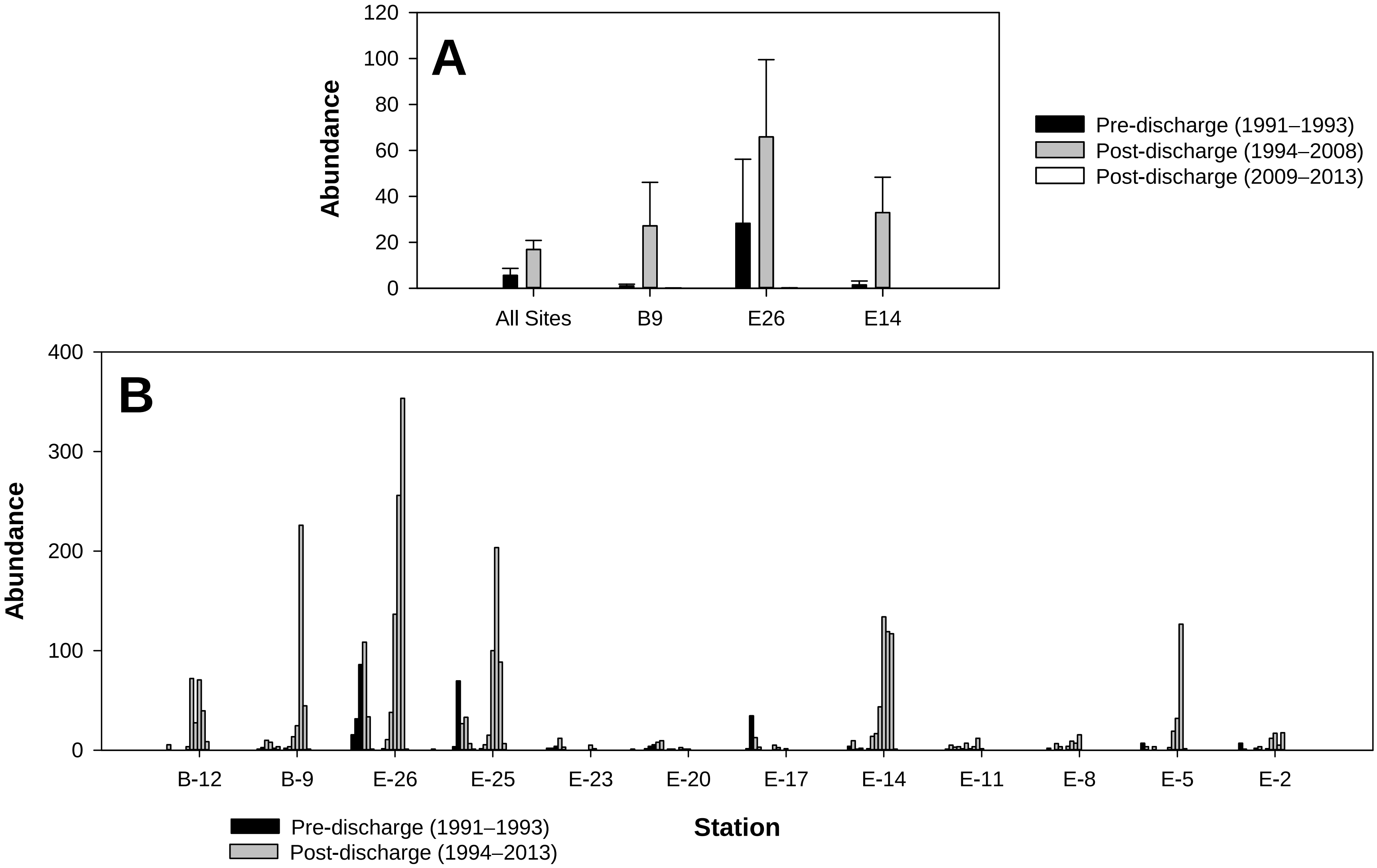

FIGURE C.1-35

Abundance of the oweniid polychaete *Myriochele striolata* at outfall discharge depths near the Point Loma Ocean Outfall from 1991-2013. (A) Pre-discharge vs. post-discharge summary for all 12 primary core stations combined, near-ZID station E14, farfield station E26, and reference station B9. (B) Values for each station by year for July surveys only. Data are expressed as means per 0.1 m^2 plus the 95% CI for Figure A.

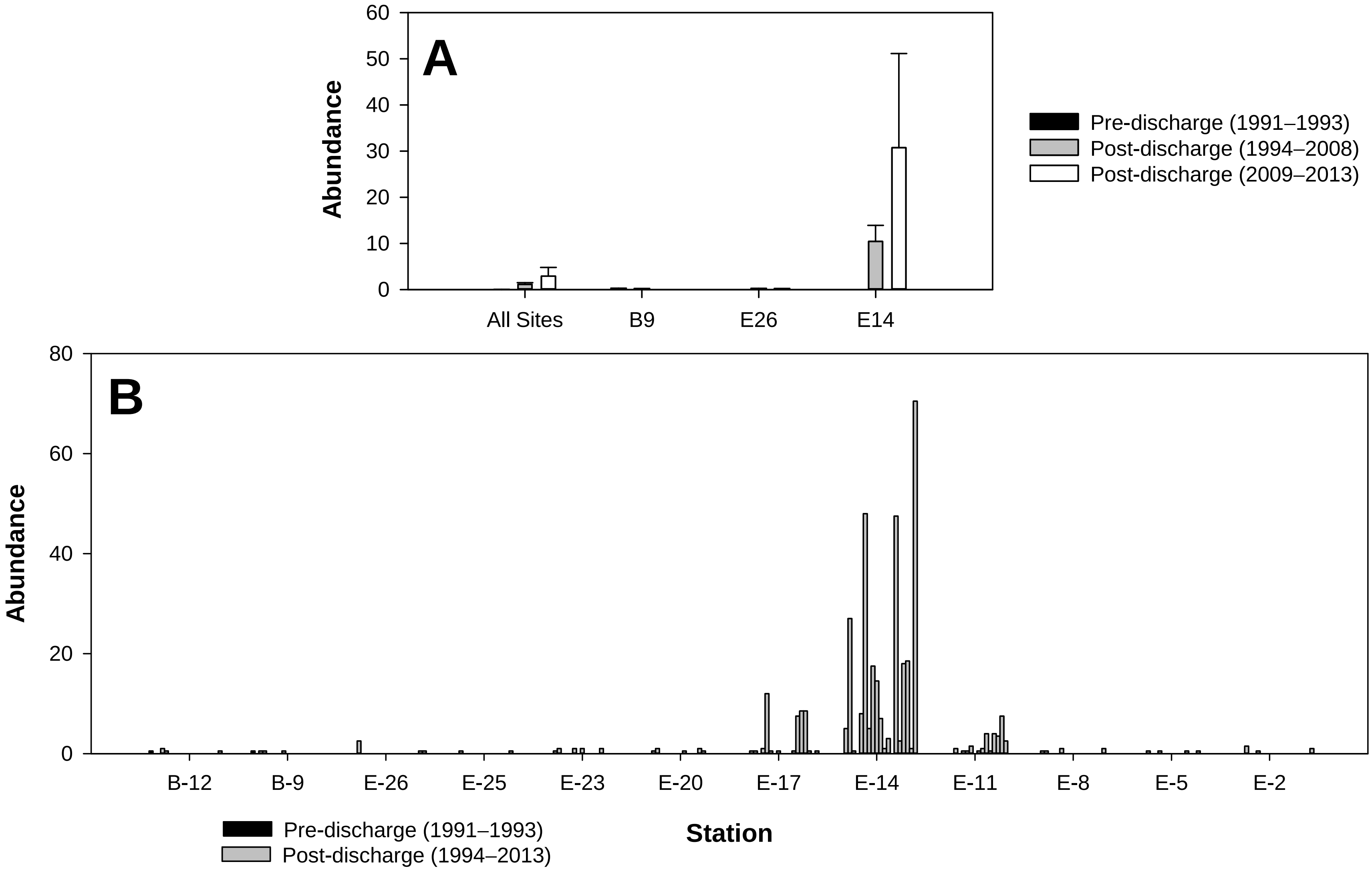

FIGURE C.1-36

Abundance of the capitellid polychaete *Capitella telata* at outfall discharge depths near the Point Loma Ocean Outfall from 1991-2013. (A) Pre-discharge vs. post-discharge summary for all 12 primary core stations combined, near-ZID station E14, farfield station E26, and reference station B9. (B) Values for each station by year for July surveys only. Data are expressed as means per 0.1 m^2 plus the 95% CI for Figure A.

animals per grab during the post-discharge period (Table C.1-7; Figure C.1-37). Although *Mediomastus* densities increased from about 2−15 worms/0.1 m^2 at near-ZID station E14 between these periods, these values are indicative of only moderate organic enrichment.

Other polychaetes that may be useful indicators of organic loading in SCB benthic sediments include the dorvilleid *Dorvillea (Schistomeringos)* sp (= complex of two species listed in SCAMIT 2014: *Dorvillea (S.) annulata* and *D. (S.) longicornis*) and the opheliid *Armandia brevis*. However, these polychaetes have occurred only rarely off Point Loma, with only a combined total of 50 specimens having occurred in the January and July surveys analyzed herein. These records include 29 specimens of *Dorvillea (S.)* sp collected during the post-discharge period between 1994 and 2010 at near-ZID station E14 and one specimen collected at station E5 in 2006. The *A. brevis* records include one specimen collected in 1992 prior to wastewater discharge at station E25 and 19 specimens collected during 2005−2008 in the post-discharge period at stations E11, E14, B9 and B12. Consequently, populations of these indicator species provide little evidence of organic loading in benthic sediments, which indicates habitat degradation is not occurring off Point Loma.

Echinodermata: Echinoderms accounted for about 18% of the total infaunal abundance at outfall depths off Point Loma prior to discharge and about 13% during the post-discharge period (Table C.1-5, Figure C.1-38). This small decrease, which represents about four individuals per grab, appears mostly driven by region-wide decreases in brittle stars of the genus *Amphiodia* (predominantly *A. urtica)*, especially over the past five years (see Figure C.1-39).

The ophiuroid *Amphiodia urtica* is considered a key bioindicator of the southern California benthos whose populations tend to decline in areas impacted by wastewater outfalls or other forms of disturbance (e.g., Barnard and Ziesenhenne 1961; Thompson, et al. 1993; Bergen 1995; Scanland 1995; Mauer and Nguyen 1996). *Amphiodia urtica* remains the most abundant echinoderm in the Point Loma region after 20 years of outfall operation, although it comprised at least 75% of all echinoderms sampled during the pre-discharge period compared to only about 53% during the post-discharge period (Table C.1-7). This species is also the most abundant invertebrate overall. Populations of *A. urtica* averaged about 38 animals per 0.1 m^2 grab during the pre-discharge period compared to about 25 per grab during the post-discharge period. Although these changes suggest an area-wide decrease after wastewater discharge began, the numbers may be slightly misleading. For example, juvenile *A. urtica* are difficult or impossible to identify reliably to species, and identifications of young animals therefore tend to be recorded either at the genus (i.e., *Amphiodia* sp) or family (Amphiuridae) level. Both of these taxa have also been recorded as dominants off Point Loma. Additionally, a congener of this species, *A. digitata*, also occurs in the region, although in much lower numbers and typically in coarser sediments; this species accounted for less than 6% of all *Amphiodia* off Point Loma. If we look at combined abundances of *Amphiodia* (i.e., *Amphiodia* spp), abundances averaged about 42 and

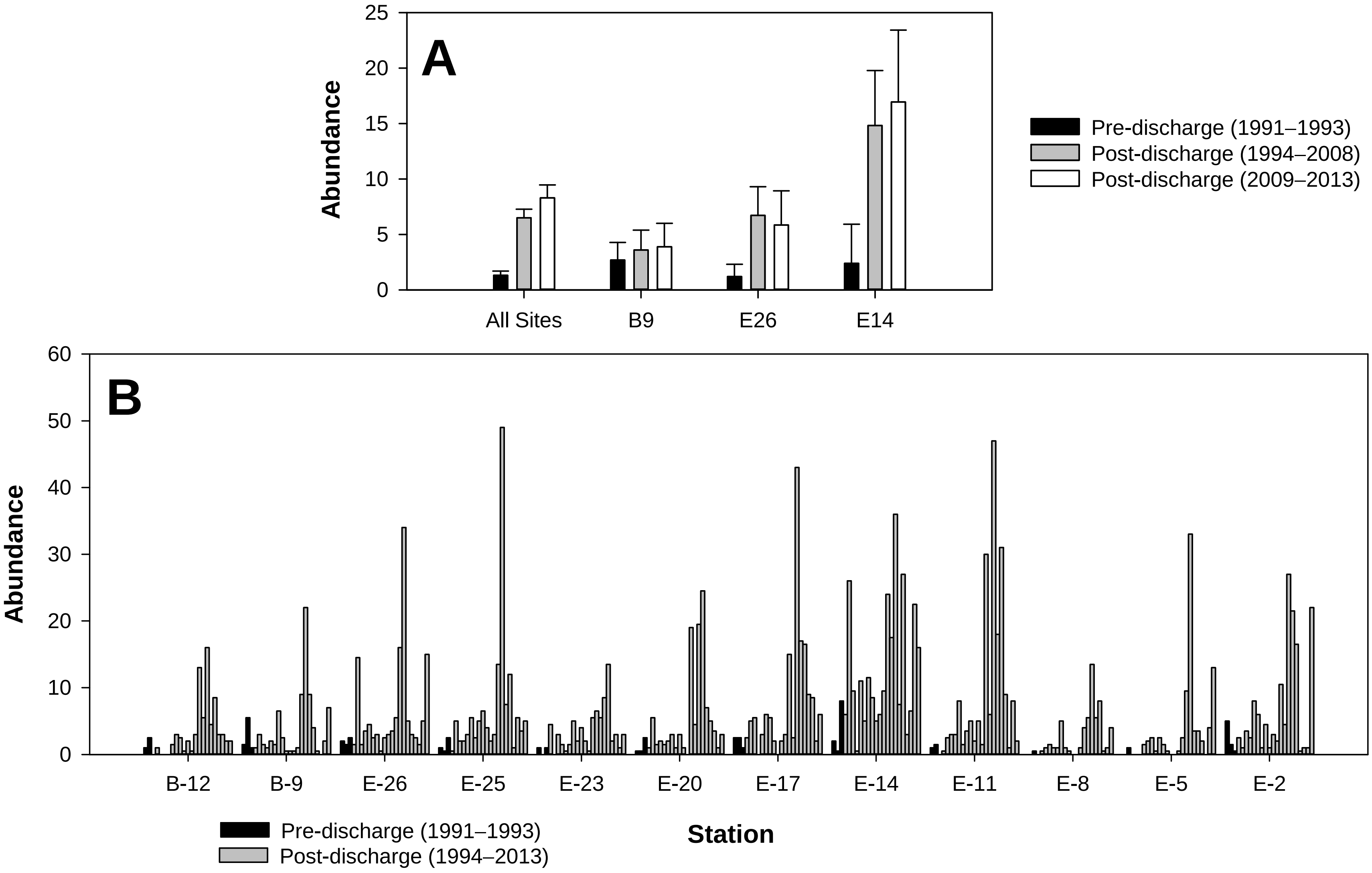

FIGURE C.1-37

Abundance of the capitellid polychaetes *Mediomastus* spp at outfall discharge depths near the Point Loma Ocean Outfall from 1991-2013. (A) Pre-discharge vs. post-discharge summary for all 12 primary core stations combined, near-ZID station E14, farfield station E26, and reference station B9. (B) Values for each station by year for July surveys only. Data are expressed as means per 0.1 m^2 plus the 95% CI for Figure A.

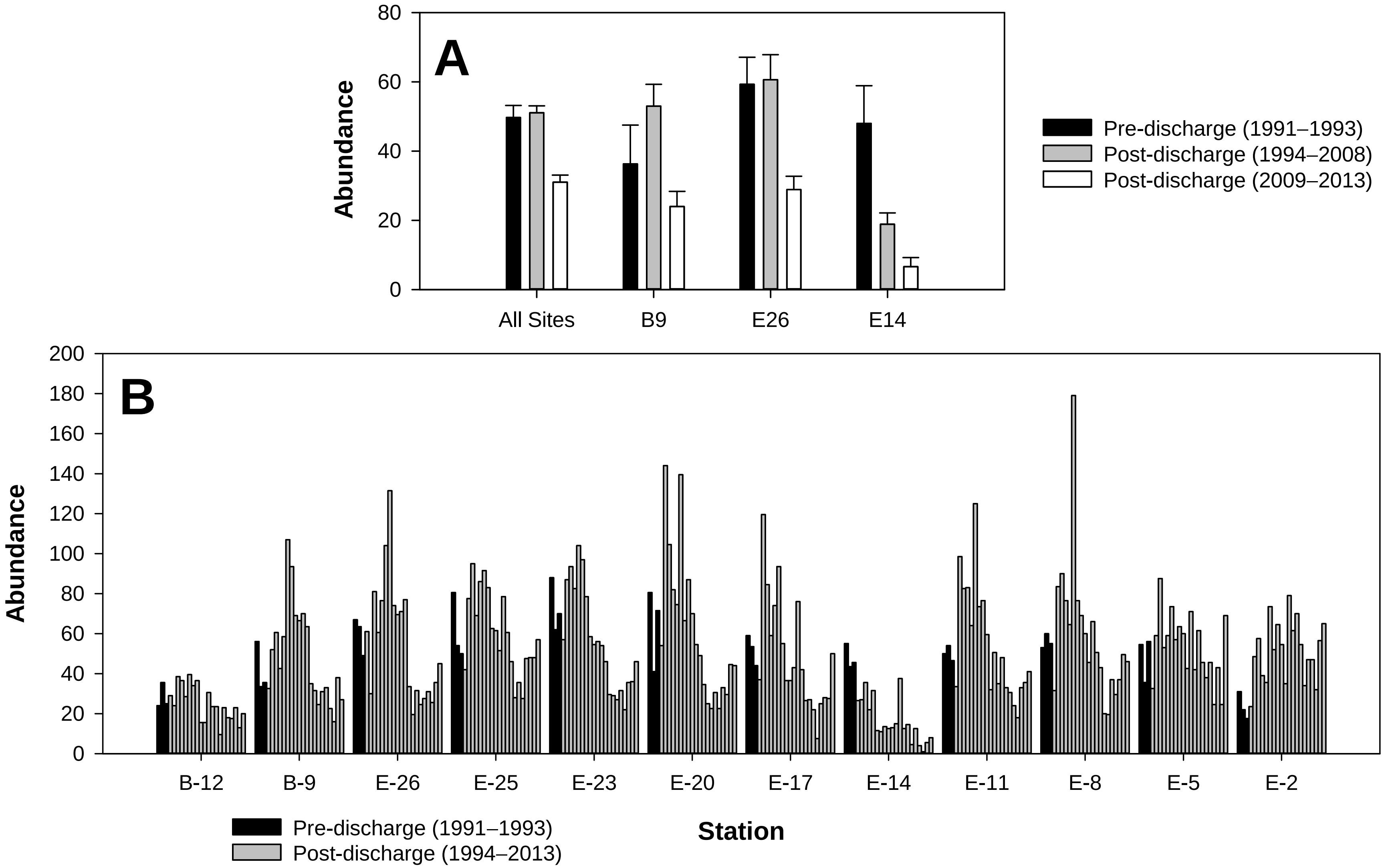

FIGURE C.1-38

Abundance of all echinoderms occurring at outfall discharge depths near the Point Loma Ocean Outfall from 1991-2013. (A) Pre-discharge vs. post-discharge summary for all 12 primary core stations combined, near-ZID station E14, farfield station E26, and reference station B9. (B) Values for each station by year for July surveys only. Data are expressed as means per 0.1 m^2 plus the 95% CI for Figure A.

35 animals per grab in the above two periods. Abundances did vary between stations, with near-ZID station E14 and northern reference station B12 having the lowest abundances during the post-discharge years (Figure C.1-39). However, all stations had *Amphiodia* abundances that were within tolerance interval boundaries for the region (see Appendix C.2). Results of BACIP t-tests indicated a significant change in the difference in abundances between impact station E14 and both of the “control” sites (stations E26 and B9) since the outfall began operation (Table C.1-6). For example, average *Amphiodia* abundances decreased about 78% at E14 compared to much smaller changes at E26 and B9 (see Figure C.1-39a). Although this pattern is consistent with the predicted effects of organic enrichment, predation by fish predators (e.g., basses and surfperch) attracted to the outfall pipe may also contribute to reduced *Amphiodia* numbers in nearby areas such as station E14 (see Davis et al. 1982, Ambrose and Anderson 1990, Posey and Ambrose 1994). For example, *Amphiodia* abundances at stations E11 and E17 located within 200 m of the ZID appear much less affected by the wastewater discharge (Figure C.1-39b). Whether or not these population changes are due to wastewater discharge, increased predation pressure, or some other factor, abundances of *Amphiodia* near the outfall and elsewhere are still within the range of natural variability seen at similar depths throughout the SCB (e.g., Bergen et al. 1998, 2001; Ranasinghe et al. 2003, 2007, 2012).

Arthropoda, Crustacea: As a group, crustaceans (Phylum Arthropoda) represented about 17% of the total infaunal abundance (Table C.1-5). Crustacean abundances tended to be higher during the post-discharge period than prior to discharge, although there was little change in the relative proportion of this taxon to most other groups (i.e., 17% pre-discharge versus 18% post-discharge over all sites). Overall, there does not appear to be any consistent outfall-related pattern in crustacean abundances (Figure C.1-40). Crustaceans also comprised about 17% of the total invertebrate abundance at near-ZID station E14 before discharge and about 18% afterwards.

The ostracod *Euphilomedes producta* was the most abundant crustacean inhabiting the benthos off Point Loma (Table C.1-7). This species and its congener, *E. carcharodonta*, are of interest as bioindicators since their abundances are generally considered to increase near outfalls. Although there appeared to be a slight enhancement near the outfall (e.g., at near-ZID stations E11, E14 and E17) in numbers of *Euphilomedes* through about 2006, there has been a more noticeable increase in populations of these ostracods over the past five years and peaking at most sites in 2013 (Figure C.1-41). For example, average abundances of these species combined (*Euphilomedes* spp) increased from about 18 per 0.1 m^2 grab at station E14 during the pre-discharge period to around 29 animals per grab afterwards. In contrast, abundances of these ostracods decreased from about 21 to 9 individuals per grab at reference station B9 over this same time period. *Euphilomedes* abundances above the upper tolerance interval of 35/grab for San Diego are wide spread at the E stations (see Appendix C.2), and may be indicative of region-wide effect associated with inputs from storm related discharges, plankton degradation, or other sources of enrichment.

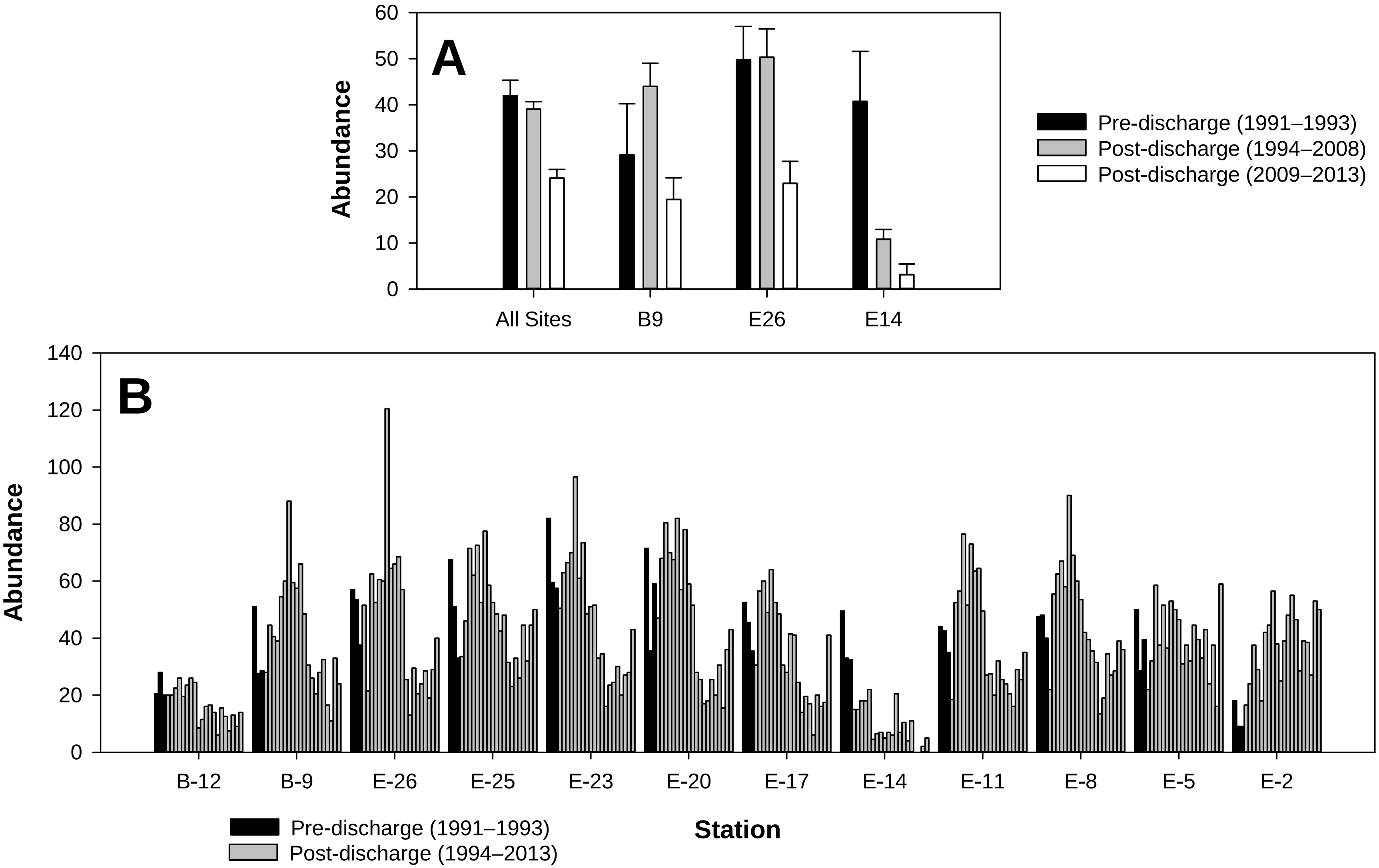

FIGURE C.1-39

Abundance of the ophiuroids *Amphiodia* spp at outfall discharge depths near the Point Loma Ocean Outfall from 1991-2013. (A) Pre-discharge vs. post-discharge summary for all 12 primary core stations combined, near-ZID station E14, farfield station E26, and reference station B9. (B) Values for each station by year for July surveys only. Data are expressed as means per 0.1 m^2 plus the 95% CI for Figure A.

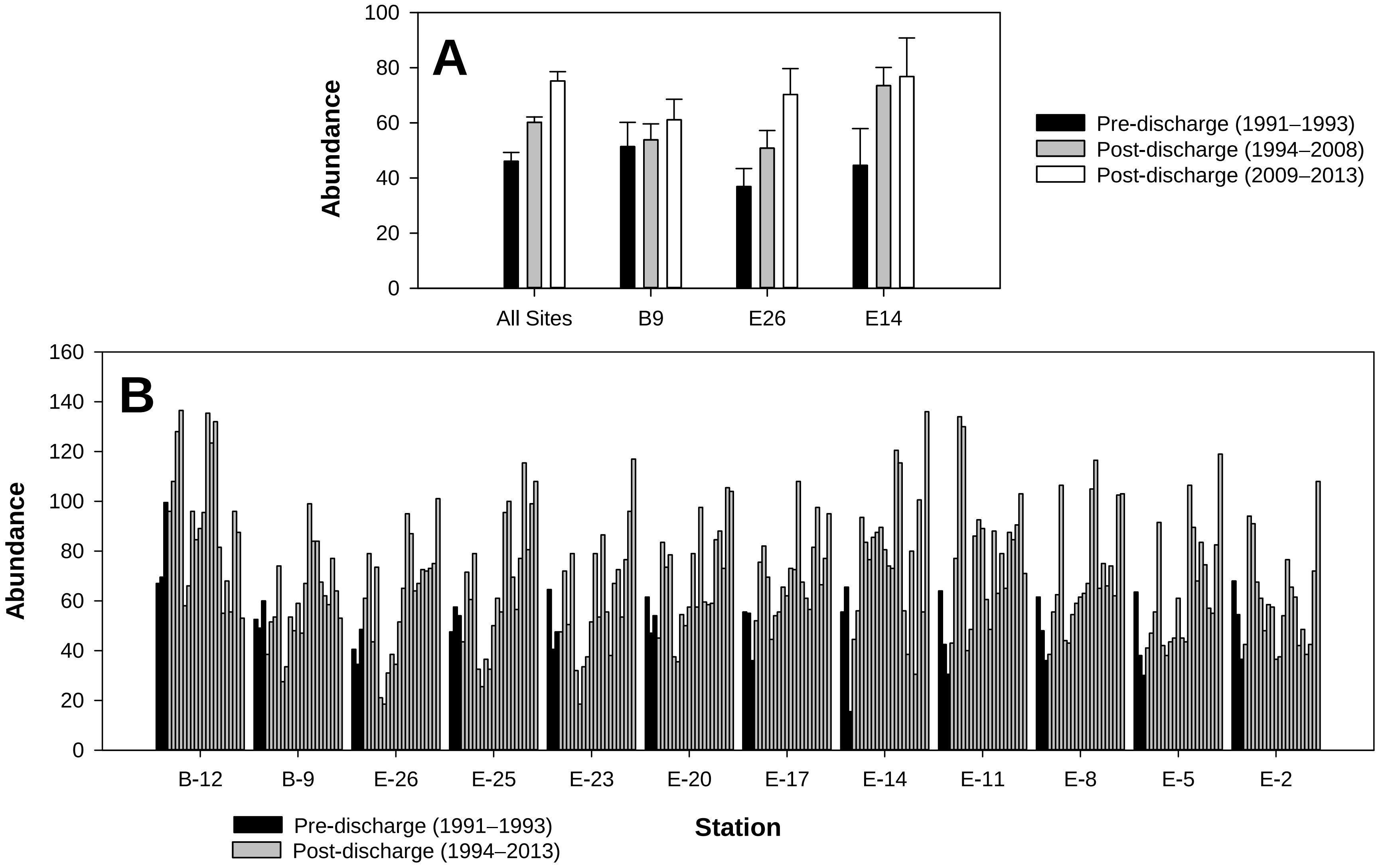

FIGURE C.1-40

Abundance of all arthropods (mostly crustaceans) at outfall discharge depths near the Point Loma Ocean Outfall from 1991-2013. (A) Pre-discharge vs. post-discharge summary for all 12 primary core stations combined, near-ZID station E14, farfield station E26, and reference station B9. (B) Values for each station by year for July surveys only. Data are expressed as means per 0.1 m^2 plus the 95% CI for Figure A.

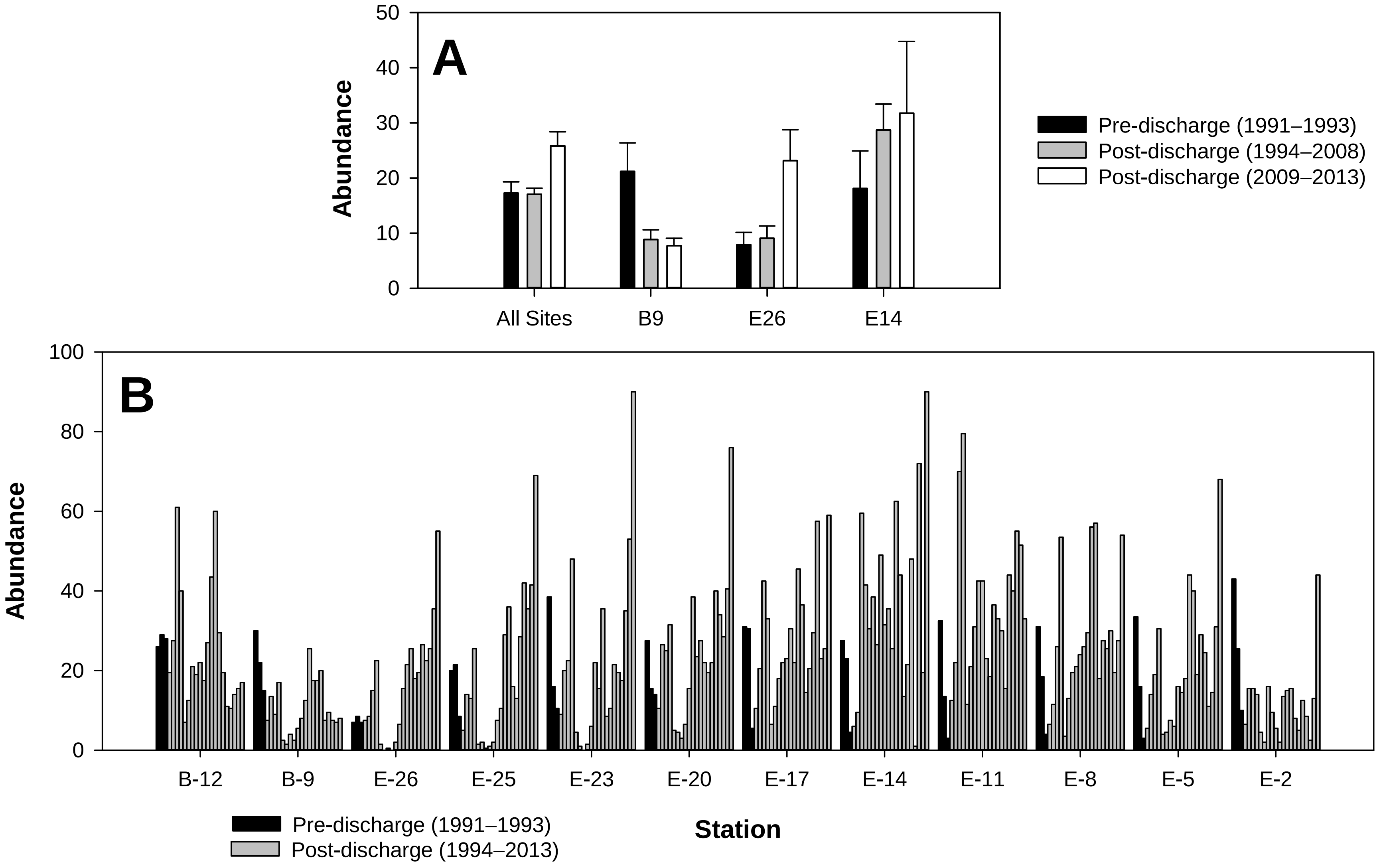

FIGURE C.1-41

Abundance of the ostracods *Euphilomedes* spp at outfall discharge depths near the Point Loma Ocean Outfall from 1991-2013. (A) Pre-discharge vs. post-discharge summary for all 12 primary core stations combined, near-ZID station E14, farfield station E26, and reference station B9. (B) Values for each station by year for July surveys only. Data are expressed as means per 0.1 m^2 plus the 95% CI for Figure A.

Abundances of other crustacean taxa known to be sensitive to organic enrichment were also examined. These included amphipods in the genera *Ampelisca* (Family Ampeliscidae) and *Rhepoxynius* (Family Phoxocephalidae). Although BACIP t-test results demonstrate no significant change in mean differences between E14 and either reference site for populations of *Ampelisca* spp, they show mixed results for populations of *Rhepoxynius* spp with populations at station E14 being significantly different from those at reference station B9 (i.e., at the $\alpha = 0.1$ significance level), but not station E26 (Table C.1-6). However, caution should be exercised in interpreting these results given the relatively low abundances and natural population fluctuations of these amphipods (see Figures C.1-42 and C.1-43). In fact, despite the differences indicated by the BACIP tests, overall average abundances of these amphipods have changed very little near the Point Loma outfall and were within the tolerance interval boundaries calculated for the region (Appendix C.2). This suggests that whatever changes were occurring had little to do with wastewater discharge. *Ampelisca* spp, for example, averaged 7.8 and 8.2 amphipods per grab at station E14 during the pre- and post-discharge periods, respectively, while *Rhepoxynius* averaged about 4.6 and 4.8 individuals per grab during these times. In contrast, abundances of *Ampelisca* at reference station B9 increased slightly from 6.6 to 12.8 individuals per grab, while abundances of *Rhepoxynius* declined from 6.7 to 3.8 individuals per grab.

Mollusca: Molluscs, mostly bivalves and gastropods, represented about 8% of the total infaunal abundance off Point Loma (Table C.1-5). Changes in molluscan populations suggest a possible outfall-related pattern, with densities increasing more near the outfall than at sites further away during much of the post-discharge period (Figure C.1-44). For example, the average number of molluscs increased from 12 to 48 animals per grab at near-ZID station E14 nearest the outfall between these periods. However, other notable increases in molluscan densities have been occurring at most of the northern E stations and B stations over the past five years, suggesting that factors unrelated to the outfall may be affecting these populations (see Figure C.1-44b).

The bivalve *Parvilucina tenuisculpta* has been suggested as an indicator species that may occur in high abundances in areas of moderate organic enrichment. However, populations of this species off Point Loma have actually decreased over time, averaging approximately 3.2 animals per 0.1 m^2 grab during the pre-discharge period to only 2.4 animals per grab afterwards (Table C.1-7). Comparison among sites did indicate that numbers of *P. tenuisculpta* increased somewhat at the nearfield stations and decreased at the farfield stations after the onset of discharge (Figure C.1-45), although this pattern has not been sustained, with values above the upper tolerance interval for this bivalve (see Appendix C.2) now occurring only occasionally and restricted to near-ZID station E14. Additionally, although these minor increases near the outfall are consistent with an enrichment effect, *Parvilucina* densities off Point Loma are still within the range of those that occur at similar depths throughout the SCB.

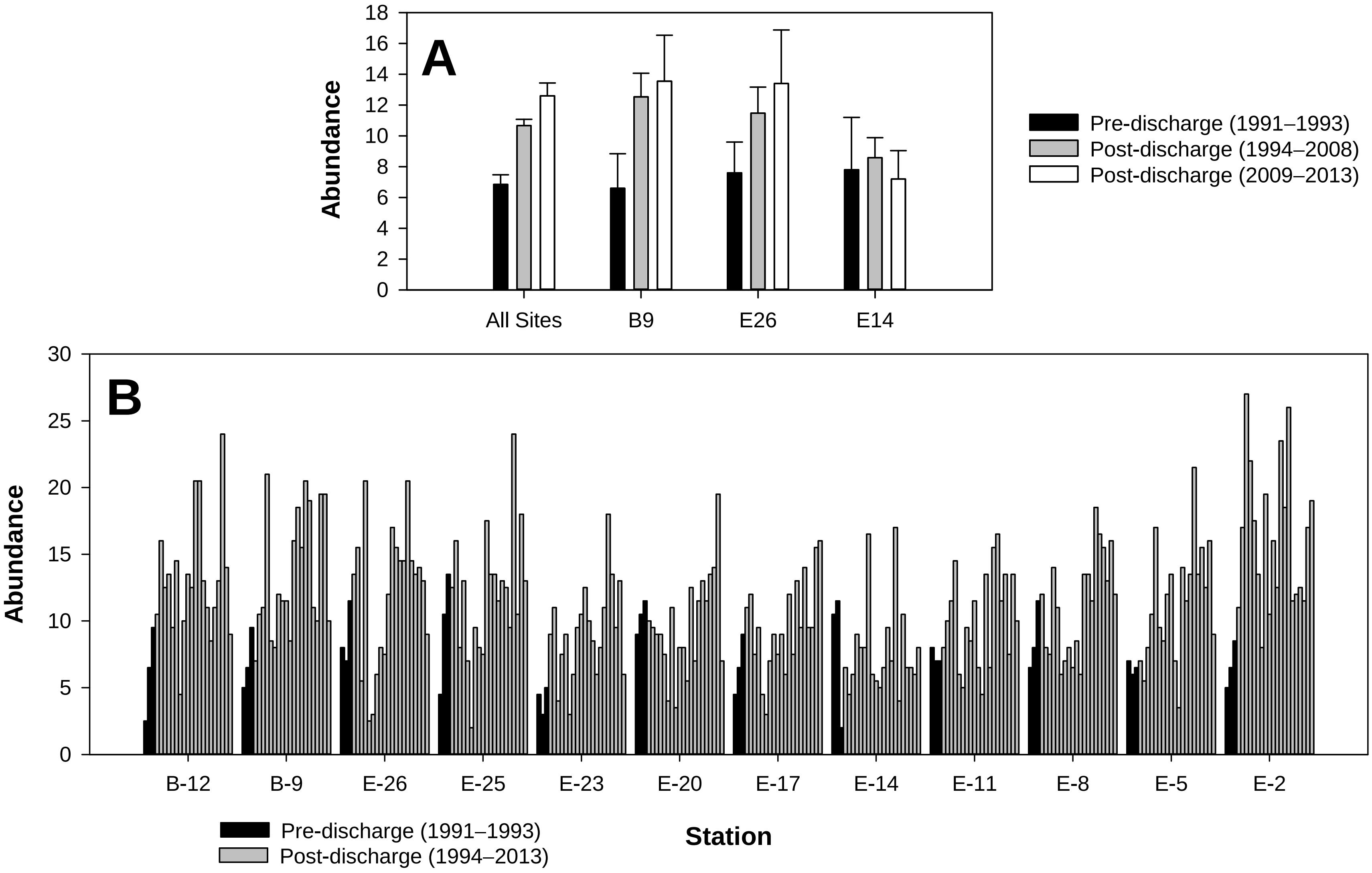

FIGURE C.1-42

Abundance of the ampeliscid amphipods *Ampelisca* spp at outfall discharge depths near the Point Loma Ocean Outfall from 1991-2013. (A) Pre-discharge vs. post-discharge summary for all 12 primary core stations combined, near-ZID station E14, farfield station E26, and reference station B9. (B) Values for each station by year for July surveys only. Data are expressed as means per 0.1 m^2 plus the 95% CI for Figure A.

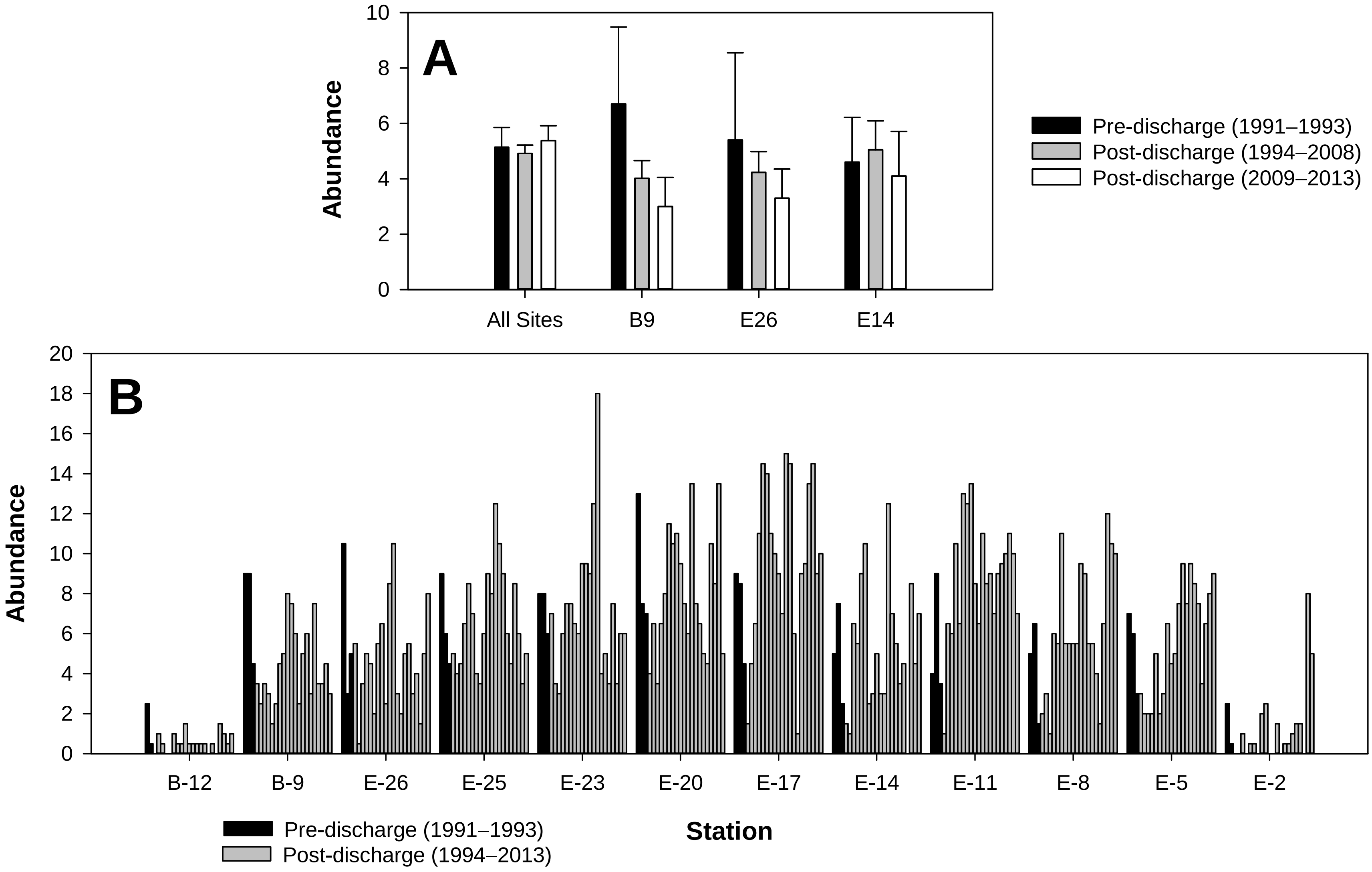

FIGURE C.1-43

Abundance of the phoxocephalid amphipods *Rhepoxynius* spp at outfall discharge depths near the Point Loma Ocean Outfall from 1991-2013. (A) Pre-discharge vs. post-discharge summary for all 12 primary core stations combined, near-ZID station E14, farfield station E26, and reference station B9. (B) Values for each station by year for July surveys only. Data are expressed as means per 0.1 m^2 plus the 95% CI for Figure A.

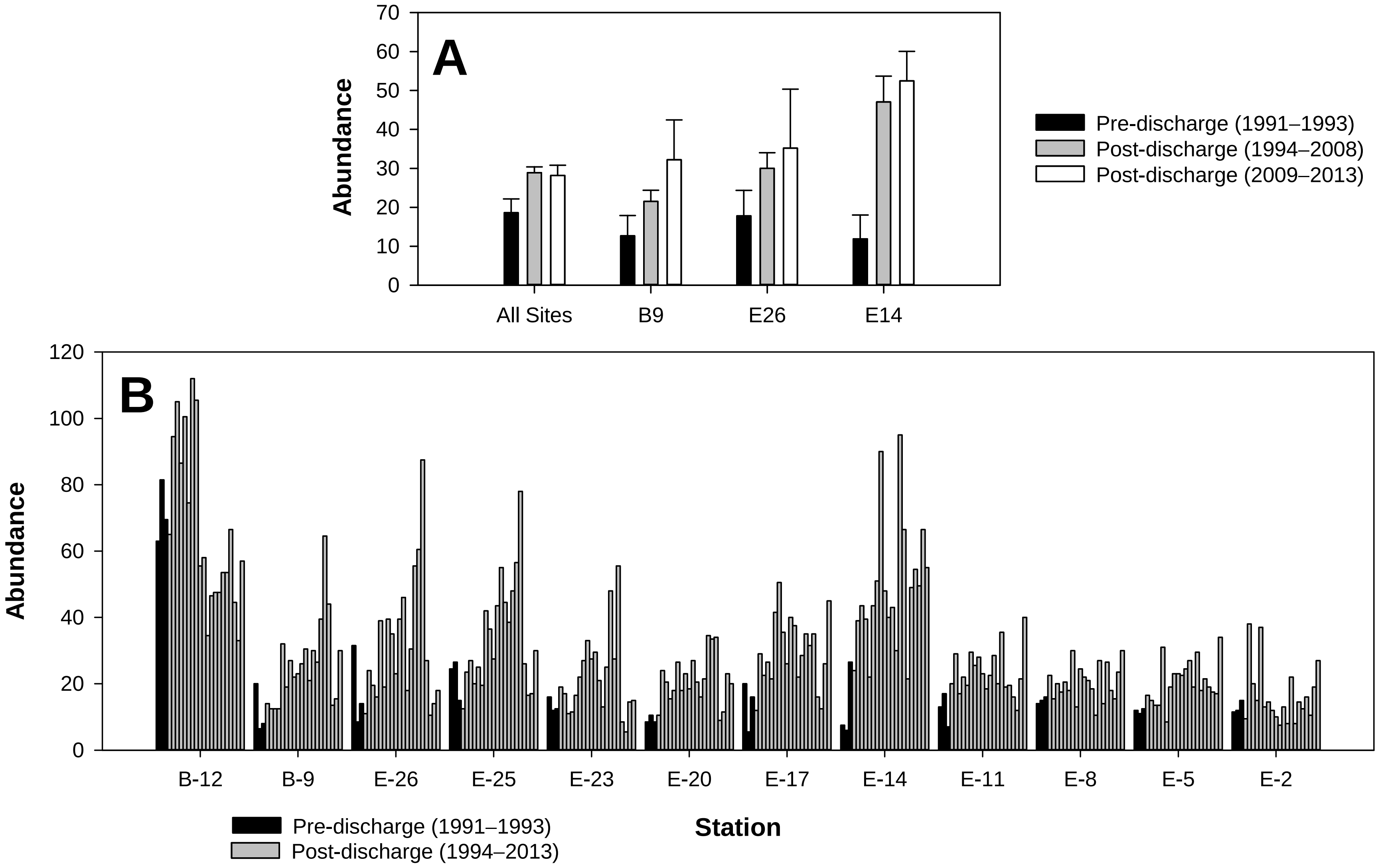

FIGURE C.1-44

Abundance of all molluscs at outfall discharge depths near the Point Loma Ocean Outfall from 1991-2013. (A) Pre-discharge vs. post-discharge summary for all 12 primary core stations combined, near-ZID station E14, farfield station E26, and reference station B9. (B) Values for each station by year for July surveys only. Data are expressed as means per 0.1 m^2 plus the 95% CI for Figure A.

Summary of Effects on Benthic Infauna Communities

Benthic communities around the Point Loma Ocean Outfall continue to be dominated by ophiuroid-polychaete based assemblages, with few major changes having occurred since monitoring began (see City of San Diego 1995a, b, 1996, 1997a, 1998a, 1999a, 2000, 2001, 2002a, 2003a, 2004a, 2005a, 2006a, 2007a, 2008a, 2009a, 2010a, 2011a, 2012a, 2013a, 2014b). The brittle star *Amphiodia urtica* and several species of polychaetes (e.g., *Spiophanes duplex*, *Proclea* sp A, *Phisidia sanctaemariae*) dominated assemblages during both the pre- and post-discharge periods. Polychaetes continue to account for the greatest number of species and individuals, while the *A. urtica* is the most abundant individual species in both periods. Similar assemblages have been described by Barnard and Ziesenhenne (1961), Jones (1969), Fauchald and Jones (1979), Thompson et al. (1987, 1992, 1993), EcoAnalysis et al. (1993), Zmarzly et al. (1994), Diener and Fuller (1995), Bergen et al. (1998, 2001), and Ranasinghe et al. (2003, 2007, 2012). This wide-spread assemblage dominates the southern California benthos, including mainland shelf depths throughout the entire San Diego coastal region (see City of San Diego 1997b, 1998b, 1999b, 2002b, 2003b, 2004b, 2005b, 2006b, 2007b, 2008b, 2010b, 2011b, 2012b, 2013b), although patches of other benthic assemblages occur where different sediment types are found (e.g., near river mouths and submarine canyons). The shifts in community composition that have occurred over time probably represent variation in southern California assemblages related to such things as large-scale oceanographic events (e.g., El Niño/La Niña conditions), stochastic natural events, or natural population fluctuations.

Although variable, benthic communities off Point Loma have remained similar between years in terms of the number of species, number of individuals, and dominance (e.g., see City of San Diego 2008-2013a, 2014b for recent years). In addition, values for these parameters are similar to those described for other sites throughout southern California (e.g., Thompson et al. 1987, 1993; EcoAnalysis et al. 1993; Bergen et al. 1998, 2001; Ranasinghe et al. 2003, 2007, 2012). In spite of this overall stability, a comparison of pre- and post-discharge data for the Point Loma region indicates some general trends. For example, there was an overall increase in the number of species and infaunal abundances after discharge began. However, the increase in species appeared most pronounced nearest the outfall, a pattern opposite that expected if environmental degradation were occurring. In addition, the increase in abundances was accompanied by a general decrease in dominance, a pattern also inconsistent with predicted pollution effects. There did appear to be a minor shift in the relative abundance of phyla at some sites that may be related to the outfall, with echinoderms decreasing and polychaetes and molluscs increasing after the onset of wastewater discharge. However, after evaluating the net effects it is clear that benthic communities surrounding the Point Loma outfall are not numerically dominated by a few pollution tolerant species as would be expected if there were an adverse environmental impact.

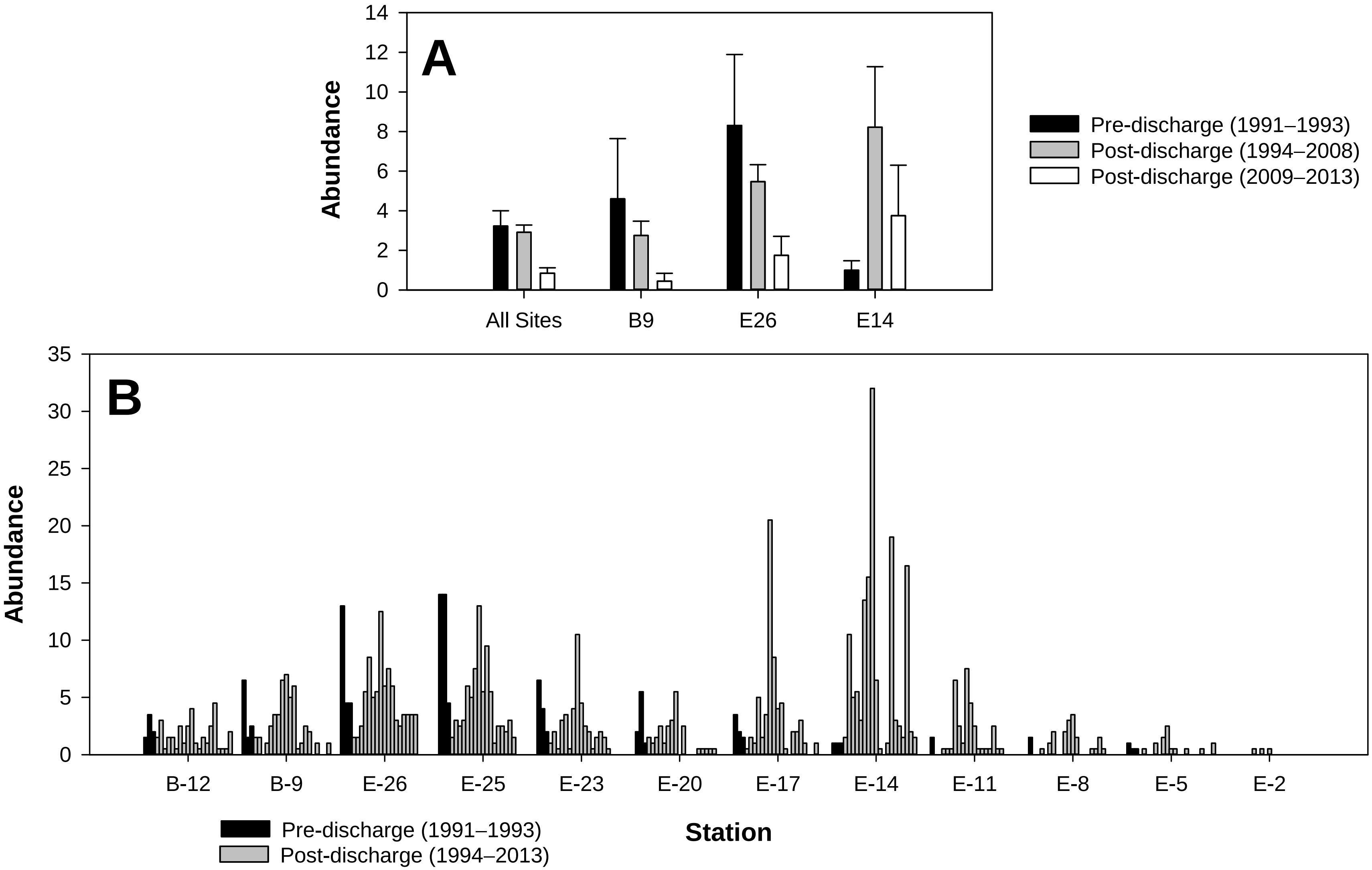

FIGURE C.1-45

Abundance of the bivalve *Parvilucina tenuisculpta* at outfall discharge depths near the Point Loma Ocean Outfall from 1991-2013. (A) Pre-discharge vs. post-discharge summary for all 12 primary core stations combined, near-ZID station E14, farfield station E26, and reference station B9. (B) Values for each station by year for July surveys only. Data are expressed as means per 0.1 m^2 plus the 95% CI for Figure A.

The results of BACIP t-tests revealed a few patterns in the difference between the likely impact site (near-ZID station E14) and the two "control" sites (stations E26 and B9) that could be attributed to the onset of discharge. The total number of species, infaunal abundance, abundance of ophiuroids (*Amphiodia* spp), and BRI values demonstrated a significant change between the impact site and both "control" sites since the outfall began operation. It is unclear what caused the difference in the number of infaunal species, since species richness has increased across all sampling sites. Higher species richness values near the outfall may be related to the greater variability at the impact site or to a decline in ophiuroid populations (see Ambrose 1993). Additionally, the difference in *Amphiodia* populations is due to both a decrease in numbers near the outfall and corresponding increases at the "control" sites during the post-discharge period. Although the decrease near the outfall is consistent with organic enrichment predictions, reduced *Amphiodia* numbers could also be an artifact of the outfall pipe attracting predators (e.g., Davis et al. 1982). In addition, populations of *Amphiodia* have declined at the farfield stations in recent years, an effect that may be related to natural population fluctuations. Whether or not these population changes are due to wastewater discharge, increased predation pressure, or some other factor, abundances of *Amphiodia* near the outfall and elsewhere are still within the range of natural variability seen at similar depths throughout the SCB (see Bergen et al. 1998, 2001; Ranasinghe et al. 2003, 2007, 2012). The difference in BRI values was due to an increase in this index at the impact site after discharge began and a corresponding decrease at the reference sites. Although this pattern is consistent with a disturbance event, BRI values at this and all other sites are still considered characteristic of reference conditions. The results were more ambiguous for abundances of amphipod crustaceans, in part because the indicator taxa considered occurred in fairly low abundances. There was no net change in the mean difference between sites for numbers of ampeliscid amphipods, while there has been a significant change in abundances of phoxocephalid amphipods between the impact site and "control" site B9, but not E26. Finally, although stations near the PLOO demonstrated some change in mean differences for several of these parameters, values for near-ZID station E14 were typically within tolerance limits calculated from the San Diego region (see Appendix C.2).

Patterns of change in populations of the polychaete *Capitella telata*, the bivalve *Parvilucina tenuiscuplta*, and ostracods of the genus *Euphilomedes* suggest a slight enrichment effect near the outfall; however densities of these organisms are still within the range of natural variation for the SCB. Other polychaetes that have been suggested as bioindicators also revealed little evidence of outfall related changes. For example, populations of worms in the genera *Mediomastus*, *Dorvillea* and *Armandia* underwent few changes that could indicate significant organic loading or habitat degradation in the vicinity of the outfall. A few other changes near the outfall may suggest some effects coincident with anthropogenic activities. For example, the increased variability in number of species and infaunal abundance at near-ZID station E14 since discharge began may be indicative of community destabilization (see Warwick and Clarke 1993;

Zmarzly et al. 1994). Sediment sulfide and BOD concentrations have also increased at this station since 1993 (see Section C.1-4). Finally, the occurrence of coarse sediments at station E14 at various times in the past and the corresponding shifts in assemblage structure suggest that some of these changes may be related to localized physical disturbances associated with the presence of the outfall pipe (e.g., shifting or patchy sediments, presence of construction debris), as well as to organic enrichment (e.g., see City of San Diego 1999b, 2000).

While it is difficult to detect specific or direct effects of the City of San Diego's ocean outfall on the offshore benthos, it is possible to see some changes occurring nearest the discharge site. Perhaps because of the minimal extent of these changes, it is not possible to determine whether these effects are due to the physical structure of the outfall or to organic enrichment associated with the discharge of effluent. Such impacts have spatial and temporal dimensions that vary depending on a range of biological and physical factors in this highly dynamic system. In addition, abundances of soft-bottom invertebrates exhibit substantial spatial and temporal variability that may mask the effects of any disturbance event (Morrisey et al. 1992a, 1992b; Otway 1995). The effects associated with the discharge of advanced primary (APT) and secondary treated sewage may also be negligible or difficult to detect in areas subjected to strong currents that facilitate the dispersion of the wastewater plume (see Diener and Fuller 1995). The minimal impact reported for San Diego's previous shallow water outfall (e.g., Zmarzly et al. 1994), combined with the high level of wastewater treatment (APT), an increased minimum dilution factor of 204:1 (vs. 113:1 at the old discharge site), and the deepwater location of the extended outfall decrease the chances that this discharge has or will impact the nearby benthos. Although some changes in benthic assemblages have occurred, assemblages near the outfall are still similar to those observed prior to discharge and to natural indigenous communities of the southern California outer continental shelf. Thus, after 20 years of operation, wastewater discharge through the Point Loma outfall has not caused degradation in benthic community structure.

SECTION C.1-6 | DEMERSAL FISHES & INVERTEBRATES

The City of San Diego has been monitoring demersal fish and megabenthic invertebrate communities in the offshore region surrounding the extended Point Loma Ocean Outfall (PLOO) since July 1991. Trawl surveys were conducted quarterly (January, April, July October) from July 1991 through July 2003, after which sampling was modified to semiannual surveys during January and July each year (see Figure C.1-46 for station locations). This section summarizes the results of the trawl surveys conducted during the pre-discharge and post-discharge monitoring periods to evaluate possible effects of wastewater discharge via the PLOO.

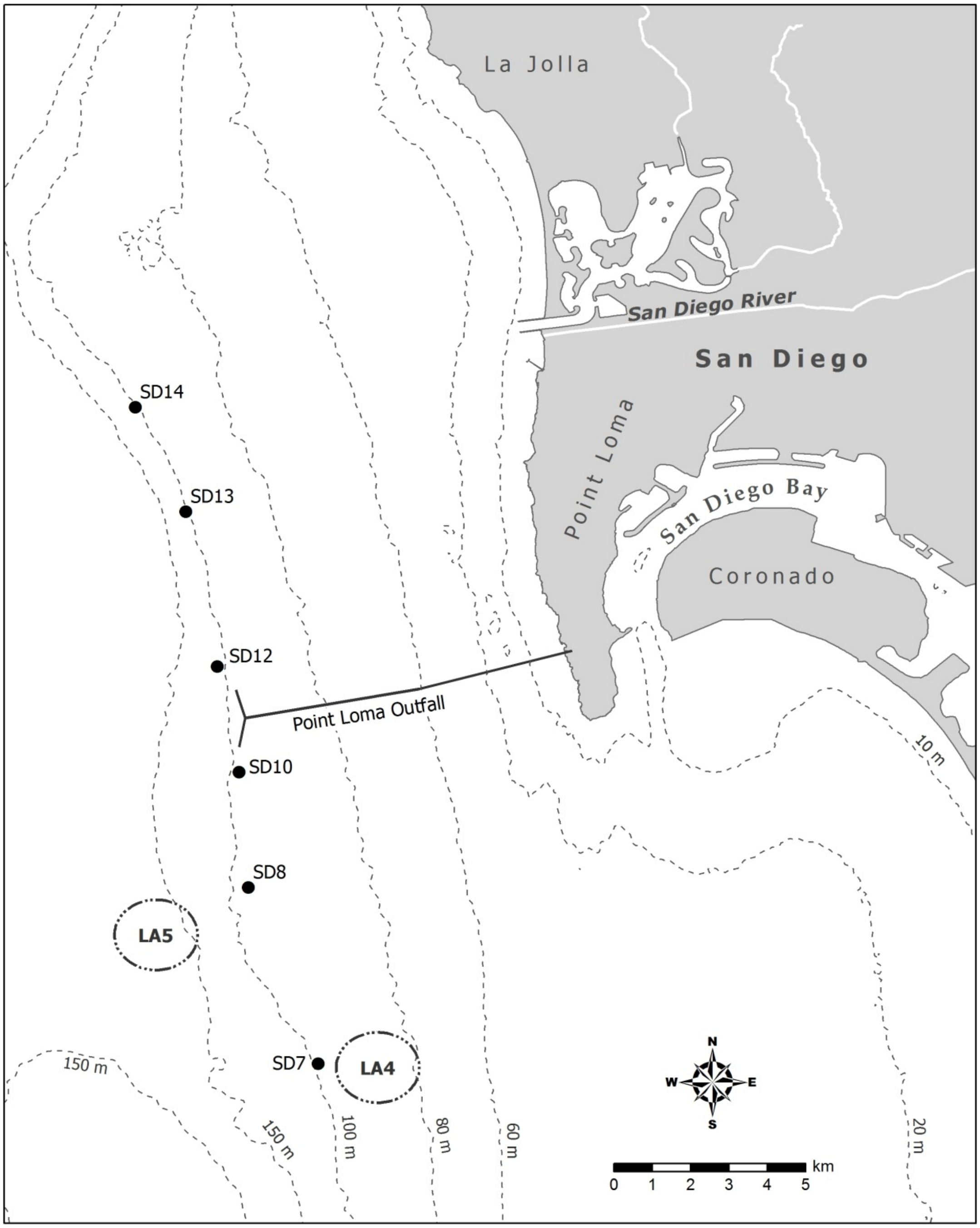

FIGURE C.1-46

Trawl station locations sampled around the Point Loma Ocean Outfall as part of the City of San Diego's Ocean Monitoring Program. Stations SD7, SD8, SD10, SD12, SD13 and SD14 = six monitoring sites that are the focus of the analyses presented in this 301(h) modified permit application. LA-4 and LA-5 = USEPA designated dredged materials disposal sites.

Data Sets & Analyses

The following analyses of demersal fish and megabenthic invertebrate communities at the PLOO monitoring stations are based on a dataset consisting of the results from all January and July trawl surveys conducted from July 1991 through July 2013 at six stations (see Sections C.1-2 and C.1-3 for a description of dataset reduction). This includes five pre-discharge surveys (July 1991−July 1993) and 40 post-discharge surveys (January 1994−July 2013) with the subsequent database consisting of information collected from a total of 262 trawls (Table C.1-1). Although a second replicate trawl was taken at each station through 1995, only data from the first trawl are considered here for comparison to subsequent years. Overall, the above surveys include 30 community trawls for the pre-discharge period and 232 community trawls for the post-discharge period. The post-discharge period includes 156 trawls from 1994−2006 that were analyzed for the previous November 2007 waiver application (City of San Diego 2007c), and 76 trawls from 2007−2013, which covers the current application period. In addition, since fish and invertebrate communities often vary with seasons, some comparisons are limited to data collected during the summer (July) surveys. This summary of fish and invertebrate populations off Point Loma focuses on community parameters such as the number of species (species richness), total abundances, and changes in the abundance of dominant or common species. Bottom-dwelling fish and invertebrate populations were sampled at each of the six trawl stations. These stations are located at depths of approximately 100 m (330 ft) and range from about 8 km north to 9 km south of the outfall (Figure C.1-46). For purposes of analysis and discussion, these stations are grouped into nearfield and farfield (or reference) sites. Stations SD10 and SD12 are located within 1.2 km of the outfall and are considered the nearfield stations. Stations SD7, SD8, SD13 and SD14 are located farther away and are considered the farfield stations; SD7 and SD8 are the southern farfield stations, and SD13 and SD14 are the northern farfield stations.

Demersal fishes and megabenthic invertebrates were collected using a 7.6 m Marinovich otter trawl net with a 1.3 cm cod-end mesh (see Mearns and Allen 1978). The net was towed for 10 minutes of bottom time at about 2.5 knots along a predetermined heading. All captured organisms were identified to species or to the lowest taxon possible in the field or returned to the laboratory for further identification. For fish, the total number of individuals and total biomass (wet weight, kg) were recorded for each species. Additionally, each individual fish was inspected for the presence of external parasites or physical anomalies (e.g., tumors, fin erosion, discoloration) and measured to the nearest centimeter size class (standard length). For invertebrates, the total number of individuals was recorded per species. For very abundant invertebrates such as sea urchins (e.g., *Lytechinus pictus* and *Strongylocentrotus fragilis*) and brittle stars (e.g., *Ophiura luetkenii*) in some trawl catches, abundance was estimated from the total species biomass based on the number of individuals per subsample (typically = 1.0 kg).

The focus of most comparisons in this section is between conditions present during the 2.5 year pre-discharge period (July 1991−1993) and the entire 20 year post-discharge period (1994−2013). Exceptions are noted when data were not available for part of the pre-discharge period for specific parameters. Additionally, the post-discharge period is broken down into two periods (1994−2008 vs. 2009−2013) in some tables and figures in order to emphasize any patterns or trends during the past five years (2009−2013).

Results

Demersal Fishes

A total of 87,452 demersal fishes were collected in 262 trawls conducted off Point Loma during January and July from 1991 through 2013 (Attachment C.1-A). These fishes comprised 88 taxa, including 84 distinct species. Overall, these communities were dominated by 13 different species that combined accounted for 95% of all fishes captured over this period (Table C.1-8). Pacific sanddab (C*itharichthys sordidus*) was by far the most abundant species across the entire region, accounting for approximately 55% of the total catch during the pre-discharge period and 48% during the post-discharge years. Two other species that represented at least 10% of the total fish catch during either the pre-discharge or post-discharge periods were plainfin midshipman (*Porichthys notatus*) and yellowchin sculpin (*Icelinus quadriseriatus*). For example, plainfin midshipman represented 10% of the pre-discharge catch but only about 2% of the catch since 1994. In contrast, yellowchin sculpin accounted for only 6% of the catch prior to discharge but has since increased to represent 11% of the catch between 1994 and 2013. Another two species represented at least 10% of the total catch restricted to the nearfield trawl stations during the post-discharge period. These included halfbanded rockfish (*Sebastes semicinctus*) and longspine combfish (*Zaniolepis latipinnis*), which respectively increased from 3−14% and 4−10% of the catch between the pre-discharge and post-discharge periods at these nearfield sites. The remaining dominant species accounted for only about 1−5% of the catch each. Most of these species are common in the types of soft-bottom habitats that characterize much of this region and the mainland shelf of the SCB. Overall, there appears to be only minor differences between the pre- and post-discharge periods at the nearfield and farfield sites.

Patterns of change in species richness (number of species) values for the demersal fish community were similar at the nearfield and farfield stations during the pre-discharge and post-discharge periods (Table C.1-9, Figure C.1-47). Overall, an average of 14−15 species was collected per haul during these two periods. However, individual hauls of fish were highly variable, ranging from 7 to 26 species each. Variation in the number of species at the nearfield trawl stations was within the range of that seen at the farfield stations over time (Figure C.1-47a). In addition, no changes in species richness were observed near the outfall that coincided with the

TABLE C.1-8

Summary of dominant fish species collected off Point Loma during January and July community trawls from 1991 through 2013 (n=45 surveys); these fishes represent 95% of the total abundance caught during this time. Data are presented for both pre-discharge (1991–1993) and post-discharge (1994−2013) periods and summarized for all six trawl stations combined and separately for the two nearfield stations (SD10, SD12) and four farfield stations (SD7, SD8, SD13, SD14). Data are expressed as the percent of the total abundance and as the mean abundance per trawl.

	All Stations (n=6)				**Nearfield Stations (n=2)**				**Farfield Stations (n=4)**			
	PRE	**POST**			**PRE**	**POST**			**PRE**	**POST**		
	1991–1993	**1994–2008**	**2009–2013**	**1994–2013**	**1991–1993**	**1994–2008**	**2009–2013**	**1994–2013**	**1991–1993**	**1994–2008**	**2009–2013**	**1994–2013**
Percent Abundance												
Pacific sanddab	55	50	46	48	57	41	40	41	55	54	50	53
Plainfin midshipman	10	4	1	2	8	2	1	2	11	3	1	3
Yellowchin sculpin	6	14	5	11	3	13	5	11	8	13	5	10
Stripetail rockfish	4	3	5	3	7	2	7	3	2	4	3	4
Dover sole	4	5	4	5	4	6	5	6	4	5	3	5
Longspine combfish	4	5	11	7	4	7	17	10	3	4	7	5
Longfin sanddab	3	4	<1	2	2	1	<1	1	3	3	<1	3
Pink seaperch	3	1	2	1	2	1	1	1	3	1	2	1
Halfbanded rockfish	2	5	7	8	3	17	6	14	1	3	8	4
Shortspine combfish	2	1	2	1	1	1	2	1	2	1	2	2
California lizardfish	1	<1	11	3	2	<1	10	3	1	<1	12	3
English sole	1	1	2	1	1	1	2	1	1	1	2	1
California tonguefish	1	1	1	1	1	1	<1	1	1	1	1	1
Mean Abundance												
Pacific sanddab	118	164	178	168	117	167	167	167	119	163	185	168
Plainfin midshipman	22	10	3	8	17	9	3	7	24	10	3	9
Yellowchin sculpin	13	44	19	38	7	54	22	46	17	38	17	33
Stripetail rockfish	8	10	18	12	15	8	27	13	4	11	13	11
Dover sole	9	20	14	19	9	26	22	25	9	17	10	15
Longspine combfish	8	19	42	24	9	30	70	40	8	13	27	16
Longfin sanddab	5	19	<1	7	4	6	<1	5	6	10	<1	8
Pink seaperch	6	19	7	5	5	5	5	5	6	3	8	5
Halfbanded rockfish	4	19	28	29	5	70	25	58	3	8	30	14
Shortspine combfish	3	4	9	5	2	5	9	6	4	4	9	5
California lizardfish	3	1	42	11	4	<1	41	11	3	1	43	11
English sole	2	3	7	4	1	3	9	5	2	3	6	4
California tonguefish	2	4	2	3	2	4	2	3	2	4	2	11

TABLE C.1-9

Summary of the number of fish species, fish abundance, and diversity (H') for the January and July Point Loma Ocean Outfall (PLOO) trawl surveys (n=45) compared to SCCWRP 1985 and 1990 reference surveys, 1994 Southern California Bight Pilot Project (SCBPP), and Bight'98, Bight'03, and Bight'08 SCB Regional Surveys. PLOO data are presented for both pre-discharge (1991−1993) and post-discharge (1994−2013) periods and summarized for all six trawl stations combined and separately for the two nearfield stations (SD10, SD12) and four farfield stations (SD7, SD8, SD13, SD14). All data are expressed as means with ranges in parentheses.

	SCCWRP Survey *		SCB 1994, 1998, 2003, and 2008 Regional Surveys †				PLOO Surveys (1991−2013)					
							Pre-discharge (1991−1993)			Post-discharge (1994−2013)		
	60-m	150-m	SCBPP	Bight '98	Bight '03	Bight '08	Nearfield	Farfield	All stations	Nearfield	Farfield	All stations
Species Richness	12 (5−16)	14 (8−22)	13 (7−23)	12 (1−26)	16 (8−22)	14 (4−22)	13 (8−19)	14 (9−22)	14 (8−22)	15 (7−21)	16 (9−26)	15 (7−26)
Abundance	201 (37−513)	334 (77−775)	157 (23−726)	168 (5−775)	415 (39−1,569)	293 (18−1,005)	208 (63−399)	217 (51−453)	214 (51−453)	410 (44−2,322)	317 (50−695)	349 (44−2,322)
Diversty	1.4 (0.6−2.0)	1.6 (0.9−2.2)	1.6 (0.6−2.6)	1.6 (0−2.4)	1.6 (0.3−2.3)	1.6 (0.9−2.3)	1.4 (0.1−2.3)	1.5 (1.1−2.0)	1.4 (0.7−2.3)	1.5 (0.8−2.2)	1.5 (0.8−2.2)	1.5 (0.8−2.2)

* Thompson et al. (1987) - 1985 Reference Site Survey; Thompson et al. (1993) - 1990 Reference site survey

† Allen, M.J. et al. (1998, 2002, 2007, 2011) Southern California Bight Regional Monitoring Program: Demersal Fishes and Megabenthic Invertebrates. Southern California Coastal Water Research Project, Costa Mesa, CA.

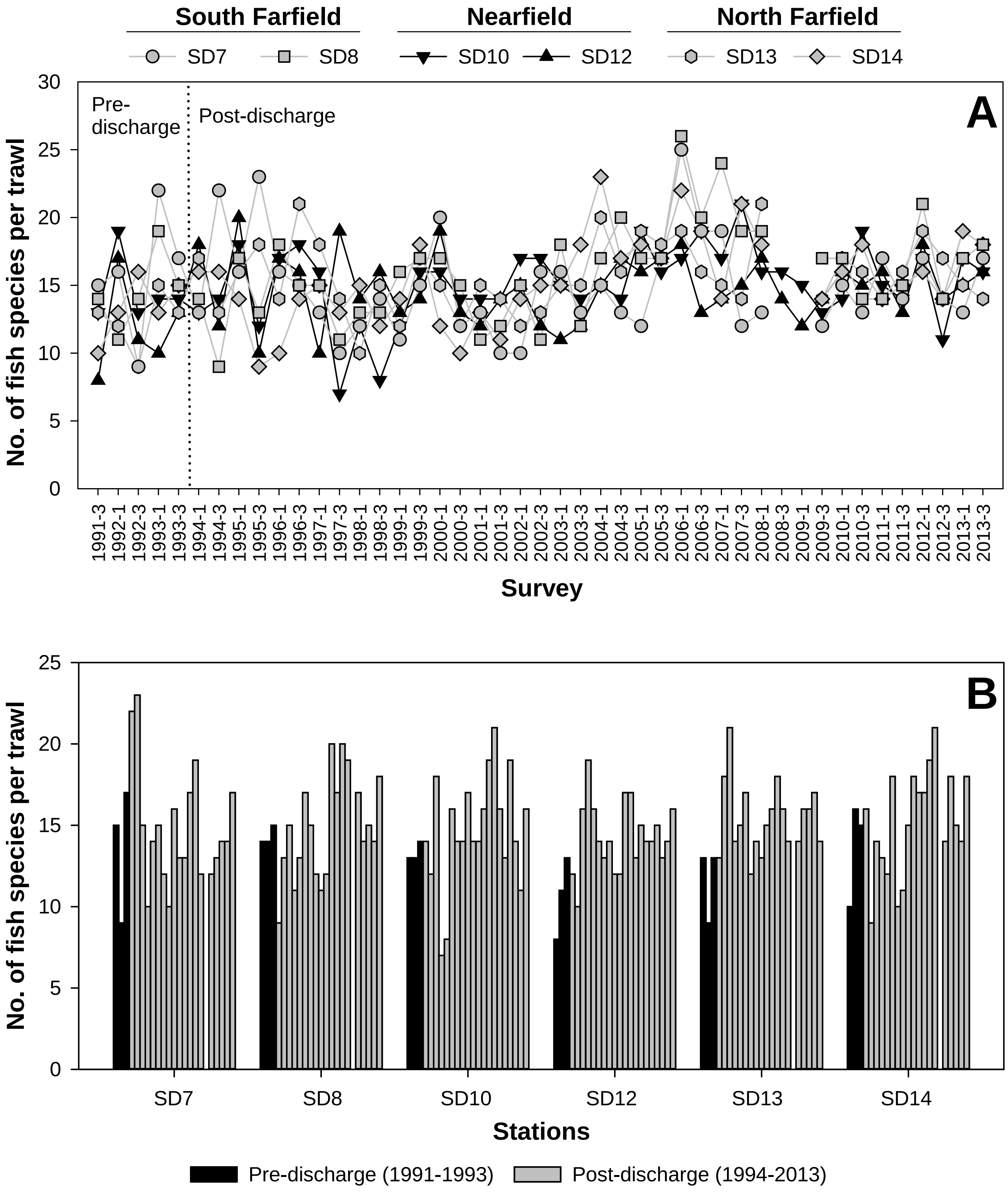

Figure C.1-47

Number of demersal fish species near the Point Loma Ocean Outfall (1991-2013). (A) no. species/trawl for south (SD7, SD8) and north (SD13, SD14) farfield stations versus nearfield stations (SD10, SD12); (B) no. species/trawl at each station, July surveys only.

onset of wastewater discharge at the end of 1993 (Figure C.1-47b). Consequently, there were no apparent temporal or spatial trends in the number of fish species that might suggest an outfall-related impact.

The total fish catch was also highly variable over time, ranging from 44 to 2,322 fishes per haul (Table C.1-9, Figure C.1-48). Average abundances were higher during the post-discharge period at both nearfield and farfield sites (Table C.1-9). The number of fish per haul increased about 97% (from 208 to 410 individuals) at the nearfield stations and about 46% (from 217 to 317 individuals) at the farfield stations between these periods. Most of this change, however, appears to have occurred between 2001 and 2006. As with species richness, variability in fish abundances over time at the nearfield stations was within the range of abundances seen at the farfield sites (Figure C.1-48a). The single exception occurred in January 2005 when large numbers of halfbanded rockfish were collected at stations SD10 and SD12 (see City of San Diego 2006a). In addition, there were no discernible changes at the two nearfield stations that coincided with the onset of wastewater discharge (Figure C.1-48b).

A large amount of the variability described above is due to fluctuations in populations of dominant species. For example, Pacific sanddabs consistently comprised the largest fraction of the trawl catches, accounting for 55% and 48% of the region’s fish communities during the pre- and post-discharge periods as previously discussed. However, numbers of this species varied greatly among all stations (Figure C.1-49a), and there was no indication of influence due to proximity of the outfall. The dramatic region-wide decrease in sanddab abundances between 1997 and 1998 was probably related to warmer waters associated with the 1997−1998 El Niño since this species tends to be associated with cooler waters (see Eschmeyer et al. 1983). However, it is unclear what may have caused similar, but less dramatic declines in Pacific sanddab populations around 2001−2002 and 2007−2008 when El Nino conditions were not present (see Figure C.1-49a).

Populations of several other dominant or occasionally abundant species also displayed considerable variability. For example, populations of yellowchin sculpin have undergone seasonal fluctuations in numbers since monitoring began, with especially large catches occurring occasionally during the post-discharge period (Figure C.1-49b). Dover sole also appear to undergo cyclic population fluctuations (Figure C.1-49e); however, these changes are probably associated with changes in oceanic temperatures (i.e., higher numbers during colder regimes). More sporadic were occurrences of large populations of species such as halfbanded rockfish (Figure C.1-49c) and longspine combfish (Figure C.1-49c). For example, longspine combfish were collected in large numbers at the nearfield stations in January 2002, January 2005, and from January 2012 through July 2013, while halfbanded rockfish were also collected in large numbers at these sites in January 2005 and July 2006. Otherwise these species occurred in much lower numbers. Overall, fluctuations in populations of these and other dominant fish near the outfall

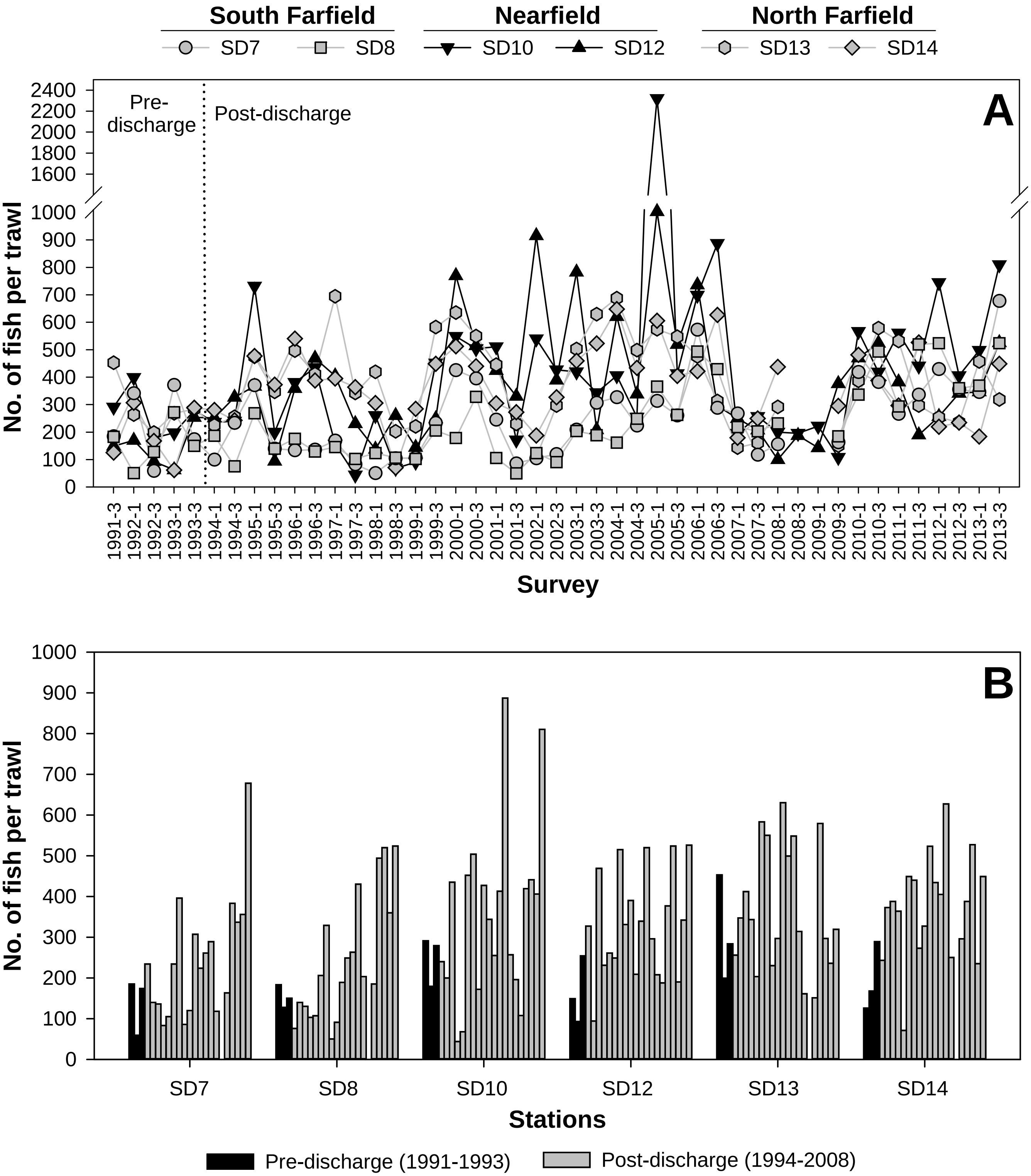

Figure C.1-48

Abundance of demersal fish species near the Point Loma Ocean Outfall (1991-2013). (A) abundance/trawl for south (SD7, SD8) and north (SD13, SD14) farfield stations versus nearfield stations (SD10, SD12); (B) abundance/trawl at each station, July surveys only.

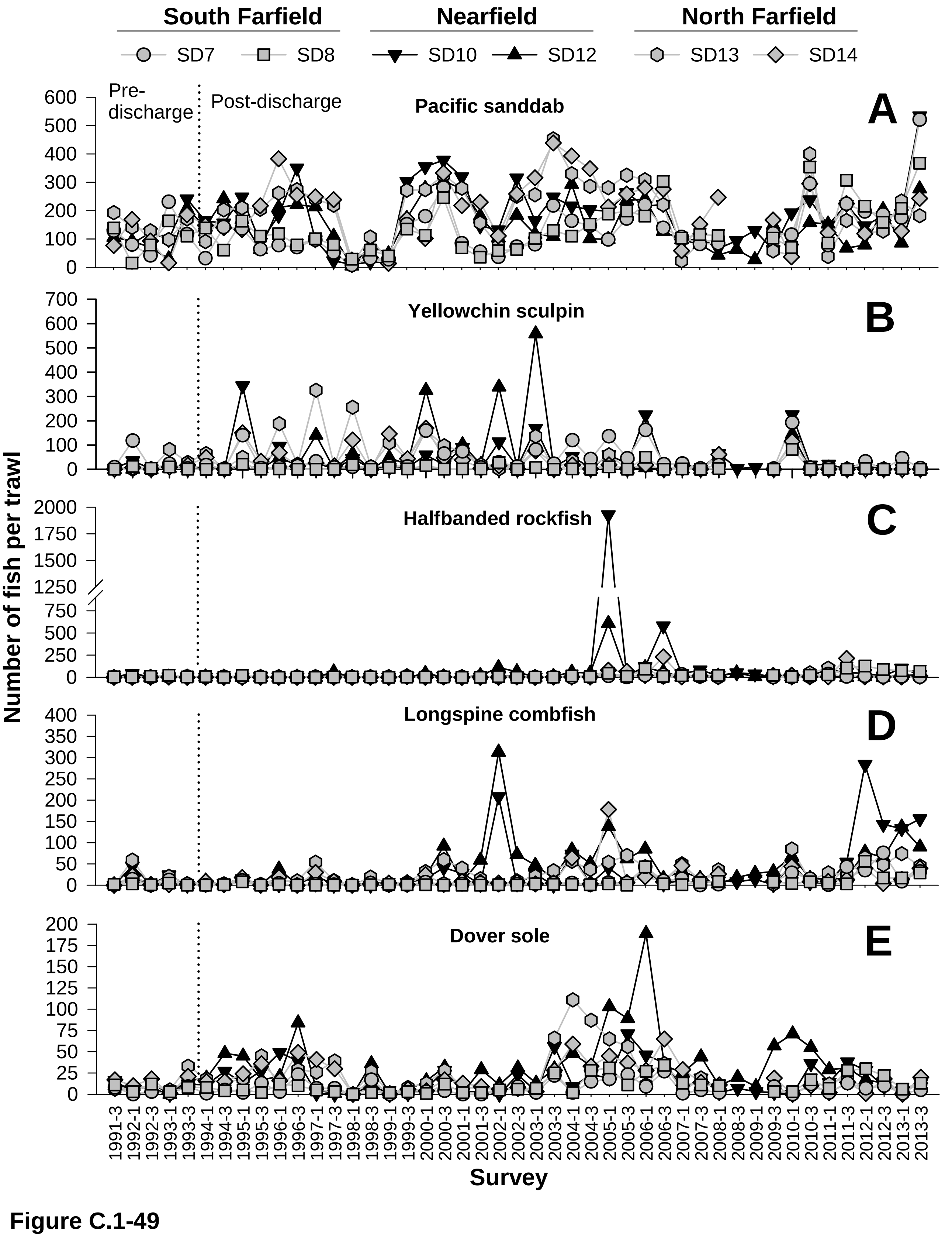

Figure C.1-49

Abundance of top 10 dominant fish species near the Point Loma Ocean Outfall (1991-2013) for south (SD7, SD8) and north (SD13, SD14) farfield stations versus nearfield stations (SD10, SD12); (A) Pacific sanddab; (B) Yellowchin sculpin; (C) Halfbanded rockfish; (D) Longspine combfish; (E) Dover sole; (F) Stripetail rockfish; (G) California lizardfish; (H) Plainfin midshipman; (I) Longfin sanddab; (J) Shortspine combfish.

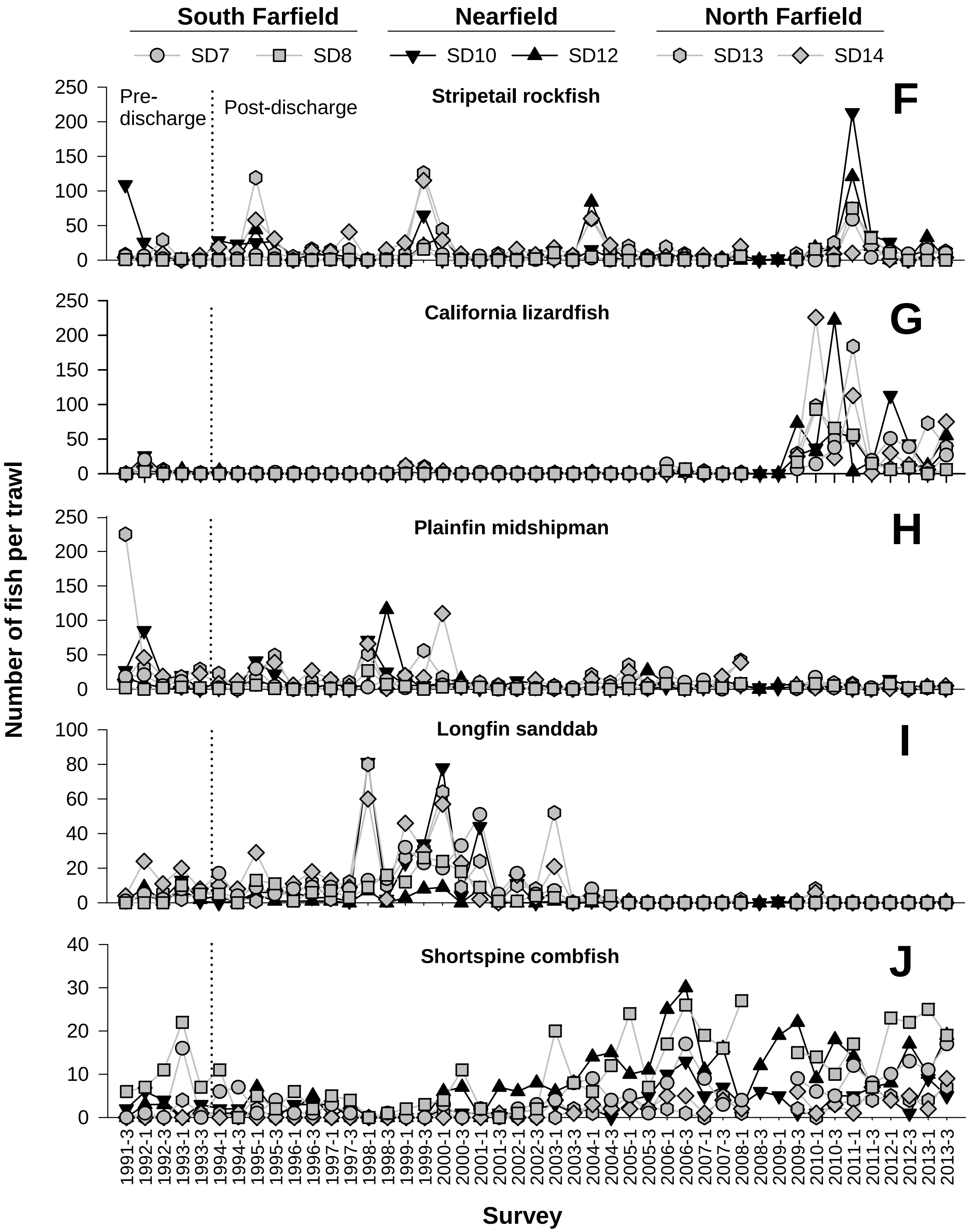

Figure C.1-49. *Continued*

were within the range of variability observed at farfield sites. Thus, wastewater discharge via the PLOO is not negatively impacting demersal fish communities in the region.

Megabenthic Invertebrates

A total of 469,595 megabenthic invertebrates were recorded in the 262 January and July trawls off Point Loma between 1991 and 2013 (Attachment C.1-B). These invertebrates comprised 149 taxa, including 125 distinct species. The sea urchin *Lytechinus pictus* dominated these trawl-caught assemblages, accounting for about 97% of the total catch during the pre-discharge period and 91% of the catch since then (Table C.1-10). Other occasionally abundant species included the sea pen *Acanthoptilum* sp, the sea urchin *Strongylocentrotus fragilis* (formerly = *Allocentrotus fragilis*), and the brittle star *Ophiura luetkenii*. Most of the remaining species were captured infrequently and/or in low numbers, with 93 taxa being represented by fewer than 10 individuals total since monitoring began.

The number of invertebrate species collected ranged from 3 to 29 per haul, with there being little difference in average numbers between the nearfield and farfield sites or between the pre-discharge and post-discharge periods (Figure C.1-50). Overall, species richness for trawl-caught invertebrate communities off Point Loma averaged about 11 species per haul during the pre-discharge period and 12 species per haul during the post-discharge period (Table C.1-11). Species richness at the nearfield sites was within the range of variability observed at the farfield stations over time (Figure C.1-50a). In addition, no clear spatial patterns were found that coincided with the onset of wastewater discharge (Figure C.1-50b). For example, higher species richness at the three stations south of the outfall (SD7, SD8, SD10) relative to those to the north (SD12, SD13, SD14) are likely due to differences in sediment composition and not proximity to the discharge zone. Moreover, although species richness increased in 1994 shortly after discharge began, the increase occurred at all stations and then returned to pre-discharge levels by July 1997. Overall, there are no temporal or spatial trends in the number of trawl-caught invertebrate species that might suggest an outfall-related impact.

The total invertebrate catch varied widely between trawls, ranging from 24 to 11,177 individuals per haul (Figure C.1-51). These numbers mostly reflect large fluctuations in abundances of the sea urchin *Lytechinus pictus* (see Table C.1-10). Invertebrate abundances were generally higher off Point Loma during the pre-discharge years when the number of individuals averaged 2,013 individuals per haul. In contrast, trawl-caught invertebrates averaged 1,764 individual per haul during the post-discharge period. Overall, total abundances were highly variable over time at all stations (Figure C.1-51), which again primarily reflected changes in *L. pictus* populations. Although abundances of some invertebrates varied between the pre- and post-discharge surveys, these changes did not appear to be outfall-related (see Figure C.1-52). For example, the tuna crab *Pleuroncodes planipes* was more abundant prior to discharge (Table C.1-10); however this was

TABLE C.1-10

Summary of dominant megabenthic invertebrates collected off Point Loma during January and July trawls from 1991 through 2013 (n=45 surveys); these invertebrates represent > 95% of the total abundance caught during this time. Data are presented for both pre-discharge (1991 −1993) and post-discharge (1994−2013) periods and summarized for all six trawl stations combined and separately for the two nearfield stations (SD10, SD12) and four farfield stations (SD7, SD8, SD13, SD14). Data are expressed as the percent of the total abundance and as the mean abundance per trawl.

	All Stations (n=6)				**Nearfield Stations (n=2)**				**Farfield Stations (n=4)**			
	PRE	**POST**			**PRE**	**POST**			**PRE**	**POST**		
	1991–1993	**1994–2008**	**2009–2013**	**1994–2013**	**1991–1993**	**1994–2008**	**2009–2013**	**1994–2013**	**1991–1993**	**1994–2008**	**2009–2013**	**1994–2013**
Percent Abundance												
Lytechinus pictus	97	93	83	91	99	94	96	94	97	93	76	89
Acanthoptilum sp	1	3	1	2	<1	4	3	4	<1	2	1	2
Strongylocentrotus fragilis	<1	1	4	3	<1	<1	1	<1	1	2	6	3
Ophiura luetkenii	<1	<1	10	2	<1	<1	2	<1	<1	<1	15	4
Mean Abundance												
Lytechinus pictus	1,959	1,690	1,346	1,607	2,421	2,264	1,718	2,128	1,728	1,393	1,140	1,334
Strongylocentrotus fragilis	16	22	60	32	5	8	16	10	22	30	85	43
Parastichopus californicus	6	5	2	4	1	2	2	2	6	6	3	5
Pleuroncodes planipes	6	<1	0	<1	4	<1	0	<1	8	<1	0	<1
Luidia foliolata	4	3	9	5	4	3	7	4	4	4	10	5
Astropecten californicus	3	5	3	4	4	7	3	6	3	4	2	3
Doryteuthis opalescens	2	1	<1	1	2	1	<1	1	2	2	2	1
Crangon alaskensis	2	1	<1	1	3	1	<1	1	1	1	<1	<1
Florometra serratissima	2	<1	2	1	<1	<1	<1	<1	3	1	3	1
Acanthoptilum sp	1	58	24	50	<1	102	47	88	1	36	11	30
Thesea sp B	1	1	1	1	1	2	1	1	1	1	<1	1
Ophiura luetkenii	1	2	157	39	1	1	30	8	2	2	228	55
Octopus rubescens	1	1	1	1	1	1	<1	1	2	1	2	1
Sicyonia ingentis	<1	8	1	6	<1	4	1	3	0	10	1	8
Platymera gaudichaudii	<1	2	<1	1	<1	<1	<1	<1	0	2	<1	2
Pleurobranchaea californica	<1	1	4	2	<1	1	3	2	<1	1	4	2

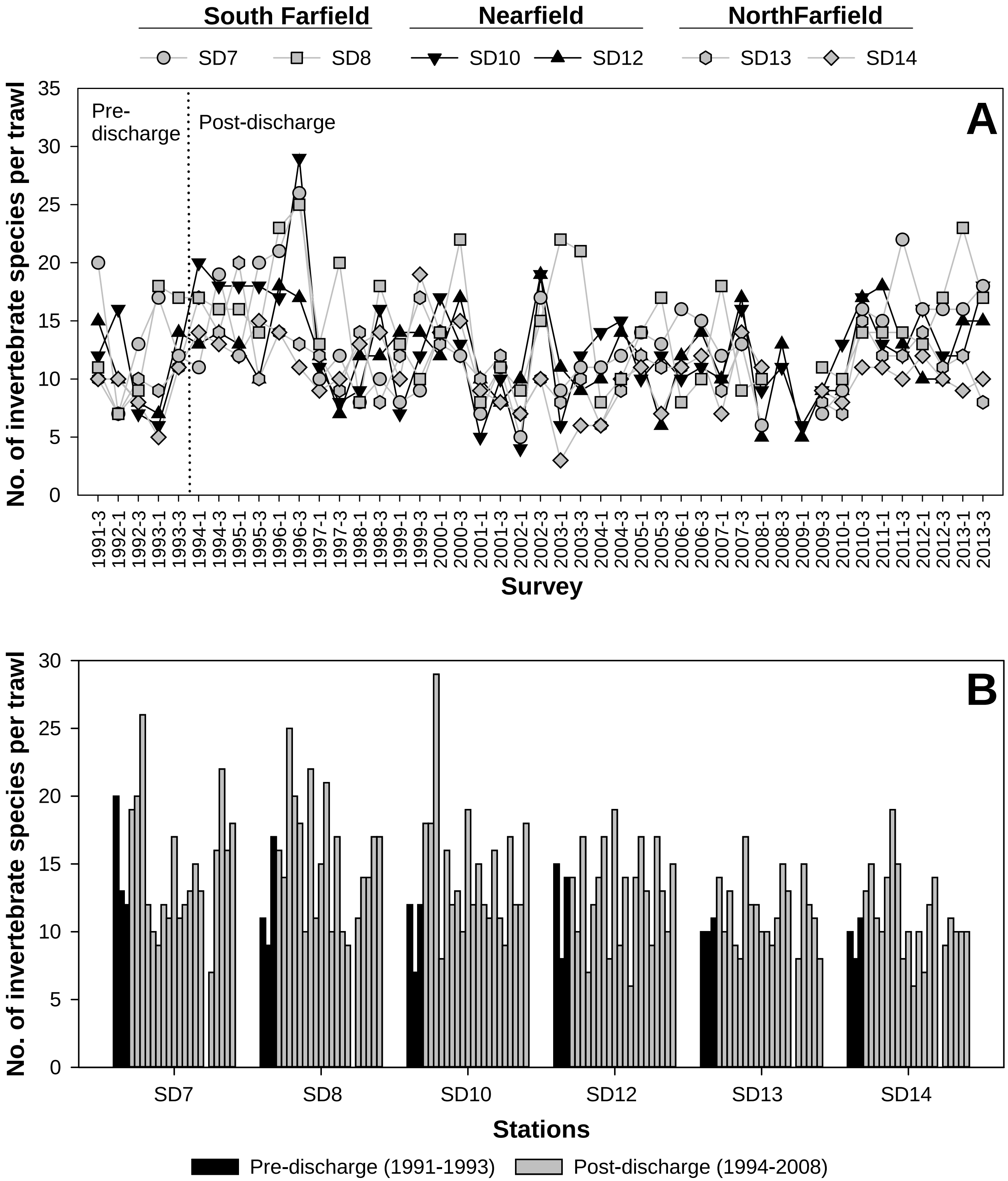

Figure C.1-50

Number of megabenthic invertebrate species near the Point Loma Ocean Outfall (1991-2013). (A) no. species/trawl for south (SD7, SD8) and north (SD13, SD14) farfield stations versus nearfield stations (SD10, SD12); (B) no. species/trawl at each station, July surveys only.

TABLE C.1-11

Summary of the number of invertebrate species, invertebrate abundance, and diversity (H') for the January and July Point Loma Ocean Outfall (PLOO) trawl surveys (n=45) compared to SCCWRP 1985 and 1990 reference surveys, 1994 Southern California Bight Pilot Project (SCBPP), and 1998, 2003, and 2008 Southen California Bight Regional Surveys (Bight '98, Bight '03, Bight '08). PLOO data are presented for both pre-discharge (1991–1993) and post-discharge (1994−2013) periods and summarized for all six trawl stations combined and separately for the two nearfield stations (SD10, SD12) and the four farfield stations (SD7, SD8, SD13, SD14). All data are expressed as means with ranges in parentheses.

	SCCWRP Survey *		**SCB 1994, 1998, 2003, and 2008 Regional Surveys[†]**				**PLOO Surveys (1991 - 2013)**					
							Pre-discharge (1991−93)			**Post-discharge (1994−2013)**		
	60-m	**150-m**	**SCBPP**	**Bight'98**	**Bight'03**	**Bight'08**	**Nearfield**	**Farfield**	**All stations**	**Nearfield**	**Farfield**	**All stations**
Species Richness	15.8 (5−37)	14.1 (5−37)	13.7 (6−41)	12 (1−25)	15 (3−37)	11 (3−21)	11 (6−16)	11 (5−20)	11 (5−20)	13 (4−29)	12 (3−26)	12 (3−29)
Abundance	182 (20−674)	994 (35−4,924)	805 (13−11,616)	620 (1−10,005)	681 (21−5,618)	1,061 (26−22,182)	2,458 (1,104−8,026)	1,791 (24−6,047)	2,013 (24−8,026)	2,265 (50−10,884)	1,500 (30−11,177)	1,764 (30−11,177)
Diversty	1.31 (0.43−2.19)	0.87 (0.04−2.00)	1.05 (0.03−2.42)	1.17 (0−2.43)	1.29 (0.07−2.77)	1.07 (0.04−2.30)	0.14 (0.03−0.29)	0.65 (0.03−1.92)	0.48 (0.03−1.92)	0.45 (0.01−2.02)	0.58 (0.04−2.06)	0.54 (0.01−2.06)

* Thompson et al. (1987) - 1985 Reference Site Survey; Thompson et al. (1993) - 1990 Reference site survey

[†] Allen, M.J. et al. (1998, 2002, 2007, 2011), Southern California Bight Regional Monitoring Program: Demersal Fishes and Megabenthic Invertebrates. Southern California Coastal Water Research Project, Costa Mesa, CA.

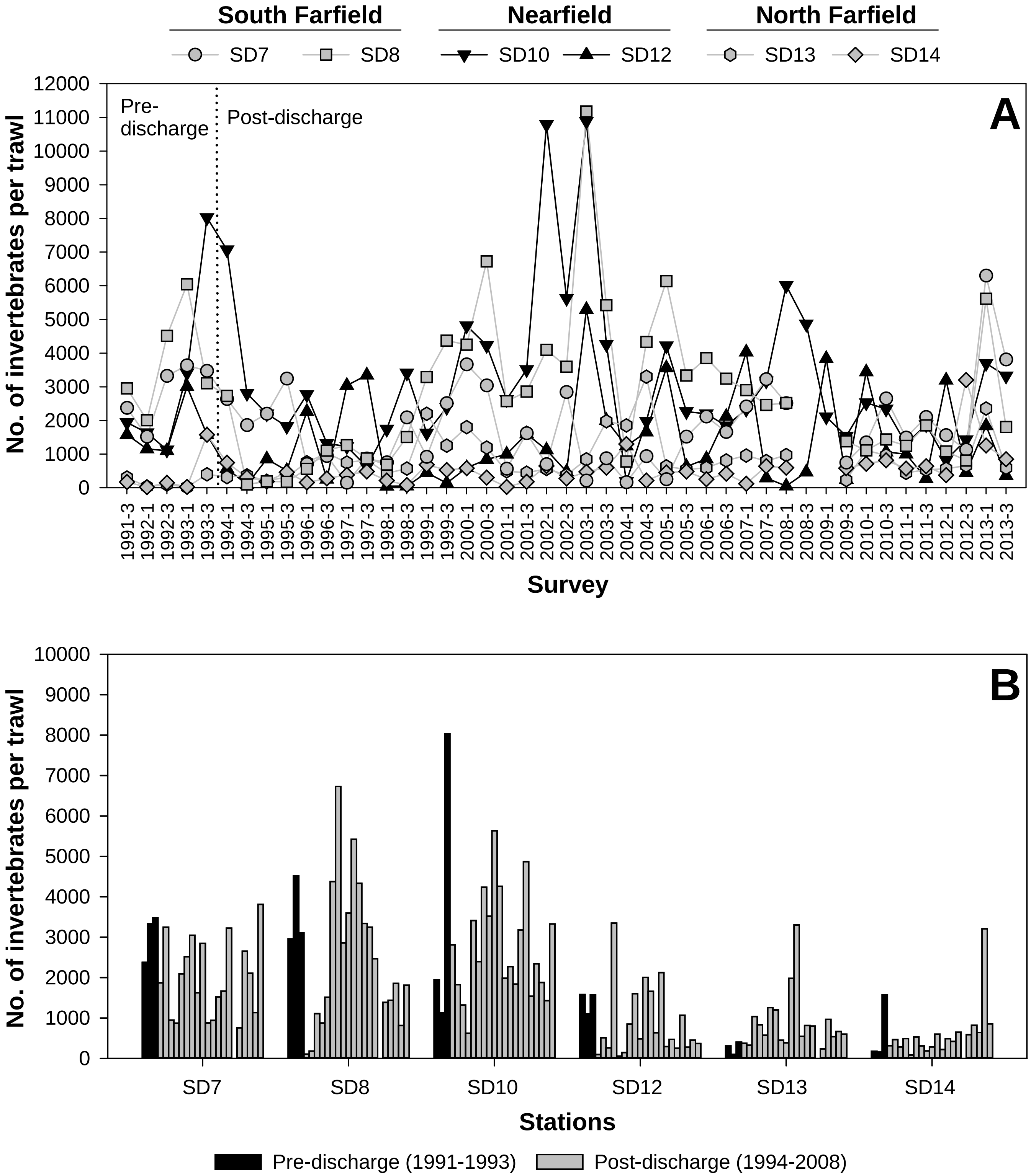

Figure C.1-51

Abundance of megabenthic invertebrates near the Point Loma Ocean Outfall (1991-2013). (A) abundance/trawl for south (SD7, SD8) and north (SD13, SD14) farfield stations versus nearfield stations (SD10, SD12); (B) abundance/trawl at each station, July surveys only.

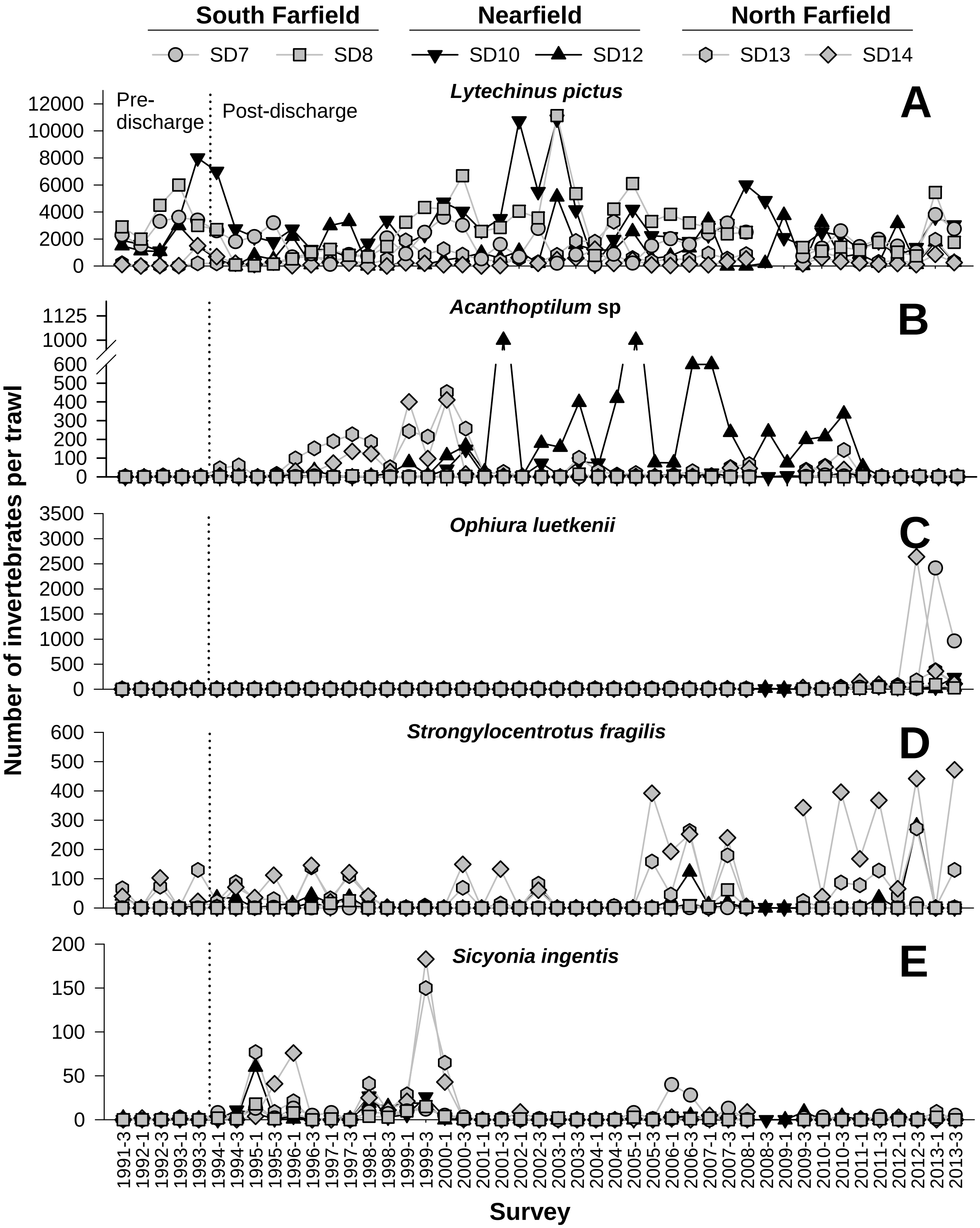

Figure C.1-52

Abundance of dominant megabenthic invertebrate species near the Point Loma Ocean Outfall (1991-2013) for south (SD7, SD8) and north (SD13, SD14) farfield stations versus nearfield stations (SD10, SD12); (A) *Lytechinus pictus*; (B) *Acanthoptilum* sp; (C) *Ophiura luetkenii*; (D) *Strongylocentrotus fragilis*; (E) *Sicyonia ingentis*; (F) *Luidia foliolata*; (G) *Parastichopus californicus;* (H) *Astropecten californicus*; (I) *Pleurobranchaea californica*; (J) *Octopus rubescens*.

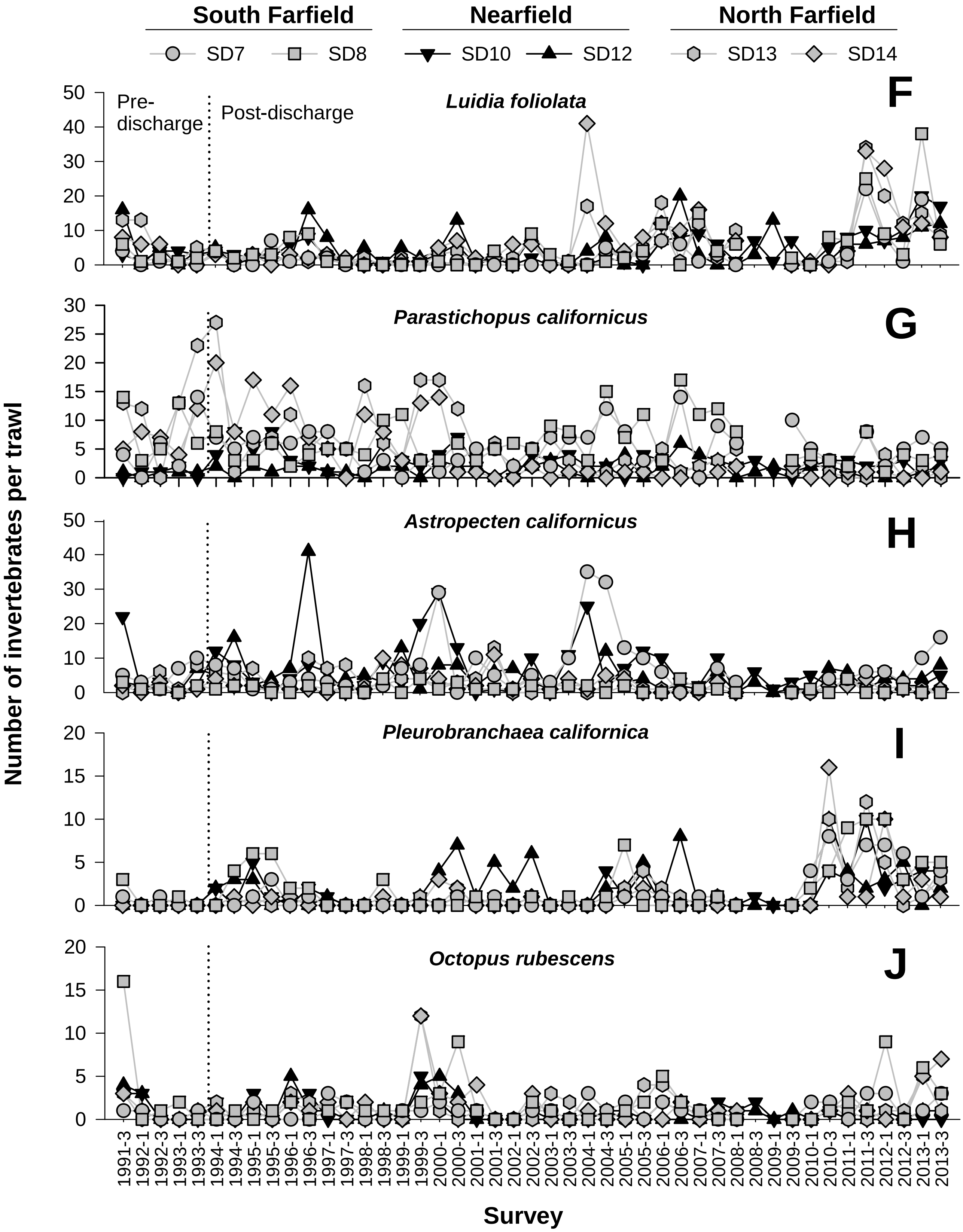

Figure C.1-52 *Continued*

due to large hauls of these crabs associated with El Niño conditions in 1992. Other species were considerably more abundant during the post-discharge period, including the urchin *Strongylocentrotus fragilis* (e.g., 16% pre-discharge vs. 32% post-discharge), the sea pen *Acanthoptilum* sp (e.g., 1% vs. 50%), the brittle star *Ophiura luetkenii* (e.g., 1% vs. 39%), and the shrimp *Sicyonia ingentis* (e.g., <1% vs. 6%) As with species richness, higher abundances at the southern stations relative to sites further north are likely due to differences in sediment composition. However, increases in these populations occurred at all stations, with no obvious patterns that could be attributed to outfall operation or wastewater discharge.

Summary of Effects on Fish & Invertebrate Communities

Analyses of temporal and spatial patterns did not reveal any effects on trawl-caught fish and invertebrate communities in the area that could be attributed to the discharge of waste water via the Point Loma outfall. Despite high variability in both types of communities, patterns of change in species richness and abundance were similar at stations near the outfall and farther away. Pacific sanddab abundances were within the range of natural variability described for reference areas in the SCB. In addition, no changes in demersal fish community structure were detected in nearfield assemblages that corresponded to the initiation of wastewater discharge at the end of 1993. Furthermore, although abundances of some dominant fish species (e.g., Pacific sanddabs) declined at the nearfield stations in greater proportion to the overall post-discharge populations, they remained within the range of natural variability described for reference areas in the SCB (e.g., Word and Mearns 1979; Thompson et al. 1987, 1992; Allen et al. 1998, 2002, 2007, 2011). Finally, the lack of physical abnormalities and indicators of disease such as fin rot, lesions or tumors also suggest that fish populations have remained healthy off Point Loma since monitoring began (e.g., City of San Diego 2014b).

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APPENDIX C.1

Benthic Sediments, Invertebrates and Fishes

ATTACHMENTS

Attachment C.1-A

Summary of demersal fish species captured at six trawl stations (SD7-SD8, SD10, SD12-SD14) around the Point Loma Ocean Outfall from the January and July surveys, 1991 through 2013. Data are number of fish collected (N), minimum (Min), maximum (Max), and mean standard length (cm). Taxonomic arrangement and scientific names are of Eschmeyer and Herald (1998) and Lawrence et al. (2013).

					Length (cm)		
Taxon/Species				**N**	**Min**	**Max**	**Mean**
MYXINIFORMES							
	Myxinidae	*Eptatretus stoutii*	Pacific hagfish	2	23	52	38
CHIMAERIFORMES							
	Chimaeridae	*Hydrolagus colliei*	Spotted ratfish	15	24	44	35
TORPEDIMIFORMES							
	Torpedinidae	*Torpedo californica*	Pacific electric ray	1	22	22	22
RAJIFORMES							
	Platyrhynidae	*Platyrhinoidis triseriata*	Thornback	1	17	17	17
	Rajidae	*Bathyraja interrupta*	Sandpaper skate	1	20	20	20
		Raja binoculata	Big skate	2	19	45	32
		Raja inornata	California skate	98	10	60	32
		Raja rhina	Longnose skate	1	19	19	19
		Raja stellulata	Starry skate	5	15	24	20
CLUPEIFORMES							
	Engraulidae	*Engraulis mordax*	Northern anchovy	1	13	13	13
ARGENTINIFOMESs							
	Argentinidae	*Argentina sialis*	Pacific argentine	462	3	13	7
AULOPIFORMES							
	Synodontidae	*Synodus lucioceps*	California lizardfish	2590	7	40	13
LAMPRIFORMES							
	Trachipteridae	*Trachipterus altivelis*	King-of-the-salmon	1	11	11	11
OPHIDIIFORMES							
	Ophidiidae	*Chilara taylori*	Spotted cusk-eel	87	10	24	16
		Ophidion scrippsae	Basketweave cusk-eel	4	15	17	16
	Bythitidae	*Brosmophycis marginata*	Red brotula	2	14	37	26
GADIFROMER							
	Merlucciidae	*Merluccius productus*	Pacific hake	5	20	38	27
BATRACHOIDIFORMES							
	Batrachoididae	*Porichthys myriaster*	Specklefin midshipman	4	10	29	18
		Porichthys notatus	Plainfin midshipman	2556	3	21	10
LOPHIIFORMES							
	Ogcocephalidae	*Zalieutes elater*	Roundel batfish	1	15	15	15

					Length (cm)		
Taxon/Species				**N**	**Min**	**Max**	**Mean**
GASTEROSTEIFORMES							
	Syngnathidae	*Syngnathus californiensis*	Kelp pipefish	2	13	17	15
	Macroramphosidae	*Macroramphosus gracilis*	Slender snipefish	1	10	10	10
SCORPAENIFORMES							
	Sebastidae	*Scorpaena guttata*	California scorpionfish	425	13	47	20
		Sebastes caurinus	Copper rockfish	1	28	28	28
		Sebastes chlorostictus	Greenspotted rockfish	105	4	26	11
		Sebastes constellatus	Starry rockfish	1	10	10	10
		Sebastes dallii	Calico rockfish	6	3	14	10
		Sebastes elongatus	Greenstriped rockfish	248	3	31	8
		Sebastes eos	Pink rockfish	26	5	15	9
		Sebastes goodei	Chilipepper	9	10	16	14
		Sebastes helvomaculatus	Rosethorn rockfish	1	7	7	7
		Sebastes hopkinsi	Squarespot rockfish	81	7	23	13
		Sebastes jordani	Shortbelly rockfish	2	12	16	14
		Sebastes levis	Cowcod	8	6	9	8
		Sebastes miniatus	Vermilion rockfish	6	27	36	30
		Sebastes nigrocinctus	Tiger rockfish	2	6	19	12
		Sebastes rosenblatti	Greenblotched rockfish	155	3	29	10
		Sebastes rubrivinctus	Flag rockfish	40	4	24	9
		Sebastes saxicola	Stripetail rockfish	2964	4	15	8
		Sebastes semicinctus	Halfbanded rockfish	6856	4	18	9
		Sebastes umbrosus	Honeycomb rockfish	1	14	14	14
		Sebastes zacentrus	Sharpchin rockfish	2	11	12	12
		Sebastes spp	Unidentified rockfish	76	2	13	6
	Triglidae	*Prionotus stephanophrys*	Lumptail searobin	4	7	15	10
	Hexagrammidae	*Ophiodon elongatus*	Lingcod	16	11	47	18
		Zaniolepis frenata	Shortspine combfish	1302	6	19	13
		Zaniolepis latipinnis	Longspine combfish	5851	5	17	11
	Cottidae	*Chitonotus pugetensis*	Roughback sculpin	304	1	17	8
		Icelinus fimbriatus	Fringed sculpin	5	14	16	15
		Icelinus quadriseriatus	Yellowchin sculpin	9124	3	11	6
		Icelinus tenuis	Spotfin sculpin	290	4	15	8
		Radulinus asprellus	Slim sculpin	1	8	8	8
	Agonidae	*Odontopyxis trispinosa*	Pygmy poacher	57	6	15	10
		Xeneretmus latifrons	Blacktip poacher	56	3	17	13
		Xeneretmus triacanthus	Bluespotted poacher	28	8	16	12
PERCIFORMES							
	Carangidae	*Trachurus symmetricus*	Jack mackerel	2	4	17	10
	Sciaenidae	*Genyonemus lineatus*	White croaker	27	17	27	22
	Embiotocidae	*Cymatogaster aggregata*	Shiner perch	1	12	12	12
		Zalembius rosaceus	Pink seaperch	1274	4	15	8
	Bathymasteridae	*Rathbunella alleni*	Stripefin ronquil	3	10	15	13
		Rathbunella hypoplecta	Bluebanded ronquil	19	8	17	13

					Length (cm)		
Taxon/Species				**N**	**Min**	**Max**	**Mean**
	Zoarcidae	*Lycodes cortezianus*	Bigfin eelpout	23	14	25	20
		Lycodes pacificus	Blackbelly eelpout	181	12	26	19
	Stichaeidae	*Plectobranchus evides*	Bluebarred prickleback	1	10	10	10
	Anarhichadidae	*Anarrhichthys ocellatus*	Wolf-eel	1	105	105	105
	Uranoscopidae	*Kathetostoma averruncus*	Smooth stargazer	3	8	19	12
	Callionymidae	*Synchiropus atrilabiatus*	Blacklip dragonet	1	9	9	9
	Gobiidae	*Lepidogobius lepidus*	Bay goby	240	4	8	6
		Rhinogobiops nicholsii	Blackeye goby	9	4	8	6
		Gobiidae	Gobiidae spp	1	3	3	3
	Scombridae	*Scomber japonicus*	Pacific chub mackerel	1	20	20	20
	Centrolophidae	*Icichthys lockingtoni*	Medusafish	3	6	7	7
	Stromateidae	*Peprilus simillimus*	Pacific pompano	1	8	8	8
PLEURONECTIFORMES							
	Paralichthyidae	*Citharichthys fragilis*	Gulf sanddab	72	6	15	11
		Citharichthys sordidus	Pacific sanddab	42,440	3	27	9
		Citharichthys stigmaeus	Speckled sanddab	7	4	11	6
		Citharichthys xanthostigma	Longfin sanddab	1748	3	20	12
		Hippoglossina stomata	Bigmouth sole	290	6	31	17
		Xystreurys liolepis	Fantail sole	1	18	18	18
		Paralichthyidae	Citharichthys spp	3	3	4	3
	Pleuronectidae	*Glyptocephalus zachirus*	Rex sole	3	11	15	13
		Lyopsetta exilis	Slender sole	495	4	18	13
		Microstomus pacificus	Dover sole	4577	4	25	11
		Parophrys vetulus	English sole	981	7	31	17
		Pleuronichthys decurrens	Curlfin sole	3	13	15	14
		Pleuronichthys verticalis	Hornyhead turbot	221	7	29	15
		Pleuronectidae	Unidentified flatfish	47	3	8	4
	Cynoglossidae	*Symphurus atricaudus*	California tonguefish	878	6	18	13

Attachment C.1-B

Summary of megabenthic invertebrate species captured at six trawl stations (SD7-SD, SD10, SD12-SD14) around the Point Loma Ocean Outfall, January and July surveys 1991 through 2013. Data include total number of individuals collected (N). Taxonomic arrangement according to SCAMIT (2013).

Taxon				Species	N
SILICEA/CALCAREA					
	UNKNOWN			Silicea/Calcarea	8
SILICEA					
	DEMOSPONGIAE			Demospongiae	1
		Hadromerida			
			Suberitidae	*Suberites latus*	17
CNIDARIA					
	ANTHOZOA			Anthozoa	2
		Stolonifera		Stolonifera	1
			Telestidae	*Telesto californica*	3
		Alcyonacea			
			Gorgoniidae	Gorgoniidae	3
				Adelogorgia phyllosclera	9
				Eugorgia rubens	1
				Leptogorgia chilensis	1
			Plexauridae	*Thesea* sp B	295
		Pennatulacea			
			Virgulariidae	Virgulariidae	10
				Acanthoptilum sp	11,585
				Stylatula elongata	4
				Virgularia agassizii	6
			Pennatulidae	*Ptilosarcus gurneyi*	1
		Actiniaria		Actiniaria	1
			Metridiidae	*Metridium farcimen*	127
MOLLUSCA					
	POLYPLACOPHORA			Polyplacophora	2
		Chitonida			
			Ischnochitonidae	*Lepidozona golischi*	1
	GASTROPODA			Gastropoda	1
			Calliostomatidae	*Calliostoma tricolor*	4
				Calliostoma turbinum	32
			Turbinidae	*Chlorostoma aureotincta*	1
		Hypsogastropoda			
			Ovulidae	*Simnia barbarensis*	83
				Simnia vidleri	3
			Naticidae	*Euspira draconis*	3
			Bursidae	*Crossata ventricosa*	2
			Velutinidae	*Lamellaria diegoensis*	3
			Fasciolariidae	*Barbarofusus barbarensis*	24
			Nassariidae	*Hinea insculpta*	15
			Muricidae	*Austrotrophon catalinensis*	2
				Pteropurpura macroptera	2
				Pteropurpura vokesae	1
				Pteropurpura sp	1

Taxon				Species	N
			Pseudomelatomidae	*Antiplanes catalinae*	12
				Megasurcula carpenteriana	107
			Cancellariidae	*Cancellaria cooperii*	17
				Cancellaria crawfordiana	27
		Opisthobranchia			
			Philinidae	*Philine alba*	41
				Philine auriformis	124
				Philine sp	2
			Pleurobranchidae	*Pleurobranchaea californica*	371
				Doridoidea	1
			Dorididae	*Doris montereyensis*	1
			Discodorididae	*Platydoris macfarlandi*	6
			Onchidorididae	*Acanthodoris brunnea*	23
			Goniodorididae	*Okenia vancouverensis*	1
			Arminidae	*Armina californica*	53
			Tritoniidae	*Tritonia tetraquetra*	37
			Dendronotidae	*Dendronotus iris*	1
				Dendronotus venustus	1
	BIVALVIA				
		Venerida			
			Chamidae	*Chama granti*	1
	CEPHALOPODA				
		Sepioidea			
			Sepiolidae	*Rossia pacifica*	140
		Teuthida			
			Loliginidae	*Doryteuthis opalescens*	309
		Octopoda			
			Octopodidae	*Octopus californicus*	2
				Octopus rubescens	311
				Octopus veligero	1
ANNELIDA					
	POLYCHAETA				
		Aciculata			
			Aphroditidae	*Aphrodita* sp	2
			Polynoidae	*Arctonoe pulchra*	79
				Hololepida magna	3
			Amphinomidae	*Chloeia pinnata*	29
		Canalipalpata			
			Serpulidae	*Protula superba*	7
ARTHROPODA					
	PYCNOGONIDA				
		Pegmata			
			Nymphonidae	*Nymphon pixellae*	141
	MAXILLOPODA				
		Pedunculata			
			Scalpellidae	*Hamatoscalpellum californicum*	55

Taxon			Species	N
MALACOSTRACA				
	Stomatopoda			
		Hemisquillidae	*Hemisquilla californiensis*	13
		Squillidae	*Schmittius politus*	7
	Isopoda			
		Aegidae	*Rocinela angustata*	1
		Corallanidae	*Excorallana truncata*	1
		Cymothoidae	*Elthusa vulgaris*	35
	Decapoda			
		Solenoceridae	*Solenocera mutator*	11
		Sicyoniidae	*Sicyonia ingentis*	1431
		Hippolytidae	*Eualus subtilis*	1
			Heptacarpus tenuissimus	1
		Pandalidae	*Pandalus platyceros*	9
			Pantomus affinis	8
		Crangonidae	*Crangon alaskensis*	216
			Crangon nigromaculata	1
			Metacrangon spinosissima	3
			Neocrangon resima	7
			Neocrangon zacae	48
		Axiidae	*Calocarides spinulicauda*	1
			Paguroidea	2
		Diogenidae	*Paguristes bakeri*	25
			Paguristes turgidus	45
			Paguristes ulreyi	1
		Paguridae	Paguridae	1
			Enallopaguropsis guatemoci	1
			Orthopagurus minimus	1
			Pagurus armatus	1
			Pagurus spilocarpus	2
			Parapagurodes laurentae	1
			Parapagurodes makarovi	1
		Munididae	*Pleuroncodes planipes*	206
		Lithodidae	*Paralithodes californiensis*	1
			Paralithodes rathbuni	7
		Homolidae	*Moloha faxoni*	3
		Calappidae	*Platymera gaudichaudii*	280
			Majoidea	1
		Epialtidae	*Loxorhynchus crispatus*	14
			Loxorhynchus grandis	8
		Inachidae	*Ericerodes hemphillii*	3
			Podochela lobifrons	37
		Inachoididae	*Pyromaia tuberculata*	8
		Parthenopidae	*Latulambrus occidentalis*	1
		Palicidae	*Palicus cortezi*	1

Taxon				Species	N
ECHINODERMATA					
	CRINOIDEA				
		Comatulida			
			Antedonidae	*Florometra serratissima*	237
	ASTEROIDEA			Asteroidea	3
		Paxillosida			
			Luidiidae	*Luidia armata*	94
				Luidia asthenosoma	165
				Luidia foliolata	1223
				Luidia sp	5
			Astropectinidae	*Astropecten californicus*	1063
				Astropecten ornatissimus	17
				Astropecten sp	4
		Valvatida			
			Odontasteridae	*Odontaster crassus*	2
			Goniasteridae	*Ceramaster patagonicus*	2
				Mediaster aequalis	17
			Asterinidae	*Patiria miniata*	1
		Spinulosida			
			Poraniidae	*Poraniopsis inflata*	1
			Echinasteridae	*Henricia* sp	2
		Forcipulatida			
			Asteriidae	*Pycnopodia helianthoides*	3
				Rathbunaster californicus	4
				Stylasterias forreri	1
	OPHIUROIDEA				
				Ophiuroidea	3
		Ophiurida			
			Ophiacanthidae	Ophiacanthidae	1
				Ophiacantha diplasia	5
			Ophiuridae	*Ophiura luetkenii*	9097
			Amphiuridae	Amphiuridae	16
				Amphichondrius granulatus	75
				Amphiodia urtica	11
				Amphiodia sp	7
				Amphipholis squamata	6
				Amphiura arcystata	2
			Ophiotricidae	*Ophiothrix spiculata*	49
			Ophiactidae	*Ophiopholis bakeri*	80
			Ophionereidae	*Ophionereis eurybrachiplax*	1
	ECHINOIDEA			Echinoidea	3
		Camarodonta			
			Toxopneustidae	*Lytechinus pictus*	431,694
			Strongylocentrotidae	*Strongylocentrotus fragilis*	7818
		Spatangoida			
			Brissidae	*Brissopsis pacifica*	17
			Spatangidae	*Spatangus californicus*	137

Taxon				**Species**	**N**
	HOLOTHUROIDEA				
		Aspidochirotida			
			Stichopodidae	*Parastichopus californicus*	1115
BRACHIOPODA					
	ARTICULATA				
		Terebratulida			
			Dallinidae	*Terebratalia occidentalis*	2
CHORDATA					
	ASCIDIACEA			Ascidiacea	1
		Phlebobranchiata			
			Cionidae	*Ciona intestinalis*	3
		Stolidobranchiata			
			Styelidae	*Styela* sp	1
			Pyuridae	*Halocynthia igaboja*	1
				Pyura sp	1

Appendix C.2
SAN DIEGO
BENTHIC TOLERANCE INTERVALS

Renewal of NPDES CA0107409

APPENDIX C.2

SAN DIEGO BENTHIC TOLERANCE INTERVALS

18-Year San Diego Regional Benthic Assessment and Reference Tolerance Intervals

THE CITY OF SAN DIEGO • STATE OF CALIFORNIA
SEMPER VIGILANS

January 2015

APPENDIX C.2

18-Year San Diego Regional Benthic Assessment and Reference Tolerance Intervals

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APPENDIX C.2

18-Year San Diego Regional Benthic Assessment and Reference Tolerance Intervals

SECTION C.2-1 | INTRODUCTION

An understanding of reference conditions is crucial to evaluating the results from environmental monitoring studies. Characterization of these background conditions using relevant indicators help to define what is natural (i.e., not anthropogenically impacted), allows for the establishment of baselines and the identification of appropriate reference sites. The City of San Diego has conducted regional benthic surveys of the continental shelf and slope off San Diego since 1994. The main objectives of these surveys are to characterize the benthic conditions for this diverse coastal region from the US/Mexico border to northern San Diego County and to identify areas impacted by anthropogenic or natural events. Several reference studies have been conducted previously in the Southern California Bight (e.g., Word and Mearns 1979, EcoAnalysis et al. 1993, Bergen et al. 1998, 2001, Smith et al. 2001, Ranasinghe et al. 2003, 2007, 2012) as well as two other studies that calculated tolerance intervals for important environmental indicators in the San Diego region (Smith and Riege 1998, Smith 2001).

For environmental data, the tolerance interval is a statistical tool used to define the putative natural range of values for reference variables. It is the confidence interval bound of a specific percentile of a data distribution. For example, it can describe with a desired degree of statistical certainty, the lower 10th and upper 90th percentile of infaunal abundance found among regional monitoring stations. Since the tolerance interval bound describes a range instead of a parameter (e.g. the mean), it compensates for the greater variability commonly found in environmental monitoring data. Also, since it incorporates confidence intervals, it allows for a more statistically rigorous comparison of reference versus impacted sites than means or ranges. For in-depth statistical descriptions of tolerance intervals used in environmental monitoring see Smith and Riege (1998), Smith (2002) and Smith et al. (2005).

The objectives of this appendix are to identify benthic sites or communities likely to provide the most appropriate reference values for environmental indicators within the Point Loma Ocean Outfall (PLOO) region and to quantify their tolerance intervals. Ordination and cluster analyses are used herein to identify the appropriate reference sites off San Diego for comparisons with regular PLOO monitoring stations (see Appendix C.1). Because these analyses are performed without *a-priori* consideration of depth or sample date, they represent an improvement over other studies where reference stations were selected solely based on comparable depth ranges, thus failing to account for temporal or spatial heterogeneity (e.g., varying sediment composition, organic loading) within different depth strata.

SECTION C.2-2 | DATASET AND METHODS

The benthic macrofauna samples used to identify reference sites were collected annually from 1994–2003 and 2005–2012 using the USEPA probability-based EMAP random sampling design. The surveys in 1995–1997 and 1999–2012 were performed as part of the NPDES monitoring program for the South Bay Ocean Outfall (see City of San Diego 2013 for details), while sampling in 1994, 1998, 2003, and 2008 was conducted as part of several large regional surveys of the entire Southern California Bight (see Bergen et al. 1998, Ranasinghe et a1. 2003, 2007, 2012). The study area ranged from off Carlsbad in northern San Diego County south to the US/Mexico border. Six-hundred and fifty-one samples were collected from sites ranging in depth from 9 to 1023 m over this 18 year period. Patterns of macrobenthic community structure and various environmental variables were assessed using univariate statistics and multivariate ordination and cluster analyses based on the Bray-Curtis measure of similarity.

Following the selection of appropriate reference sites, tolerance intervals were calculated for 15 environmental indicators: species richness (number of species), abundance (number of individuals), the benthic response index (BRI), Shannon diversity index (H'), Pielou's evenness index (J'), Swartz dominance index (minimum number of species accounting for 75% of the total abundance in each grab), the abundance of four pollution sensitive indicator taxa (*Amphiodia* spp, *Ampelisca* spp, *Proclea* sp A, *Rhepoxynius* spp), and the abundance of five pollution tolerant indicator taxa (*Euphilomedes* spp, *Mediomastus* spp, *Parvilucina tenisculpta, Solemya pervernicosa*, *Capitella teleata)*. Indicator data were tested for approximation to a normal distribution using the Shapiro-Wilk test for normality and transformed when appropriate. Where transformation did not improve normality, nonparametric tolerance intervals were computed from raw data. Parametric tolerance intervals were computed for the 10th and 90th percentiles with confidence intervals of 95% (α=0.05). Non parametric tolerance intervals were computed for the 5th and 95th percentiles with confidence intervals of 95% (α=0.05). Indicator variables from the PLOO primary core monitoring stations along the 98-m outfall depth contour sampled from 1991-2013 were plotted and compared to the calculated tolerance intervals.

SECTION C.2-3 | RESULTS

A total of 1534 taxa (mostly species) and 195,977 individuals were collected and identified during the 18 random sampling surveys. Region wide, infaunal abundances ranged from 10 to 1467 individuals per sample (mean=301 individuals) and the total number of species ranged from 8 to 198 per sample (mean=76 species). Although the results from univariate analyses varied, values for most community parameters were comparable to historical values recorded elsewhere for the Southern California Bight (Figure C.2-1, see also Appendix C.1, Table C.1-4).

Cluster analysis and ordination of sites discriminated between 10 habitat-related macrobenthic assemblages off San Diego (cluster groups A–J in Figure C.2-2) from 1994 through 2012. Benthic communities in the region remained dominated by ophiuroid-polychaete based assemblages throughout this period; with few major changes occurring since monitoring began. These groups were stratified along depth contours and sediment types associated with variations in seafloor topography, but displayed no spatial patterns relative to point source inputs (Figure C.2-3). Species composition differed among the 10 cluster groups and relative abundances of dominant taxa defined the assemblages (Table C.2-1). The stations comprising the largest cluster, group D (265 of the 651 samples), mirrored the PLOO 98-m primary core stations in terms of geographic location and depth. These similarities suggest that Group D represents a suitable reference assemblage and for comparisons of environmental variables to the PLOO stations. The group D stations were generally confined between the 60-m and 120-m depth contours ranging from near Carlsbad in the north to the Tijuana River region in the south. Sediment grain sizes at these stations were mixed, averaging about 46% fines and 53% sand with trace coarse particles. Total organic carbon (TOC) at the D group stations ranged from 0.3 to 3.3% (mean=0.7%). Finally, previous studies have suggested minor changes in the benthic community at a few sites located within about 0.5 km of the outfall discharge site. Consequently, we took a conservative approach and group D stations located within 1.5 km of the PLOO were eliminated from the tolerance interval calculations as their indicator values could be affected by discharge or the physical structure of the wye (Figure C.2-3).

Tolerance intervals for the group D reference data (excluding those closest to the PLOO) are shown in Table C.2-2. Both upper and lower bounds are reported with bolded values indicating thresholds for the direction of response expected from environmental impact. Tolerance intervals for the benthic response index (BRI) and abundance (after transformation) were computed parametrically. Parametric tolerance intervals were calculated for all other variables.

Scatter plots of indicator variables from the 98-m core monitoring stations sampled between 1991-2013 fit well, with some minor exceptions, within the upper and lower bounds calculated from the reference data (Figure C.2-4).

SECTION C.2-4 | DISCUSSION

Tolerance interval bounds computed from the group D assemblage sites provide an accurate assessment of reference conditions based on environmental variables. The use of tolerance interval bounds for benthic infaunal monitoring provides a level of statistical certainty when comparing impacted to reference sites. Further, tolerance interval bounds compliment other statistically rigorous methods of impact detection like BACIP analyses and can be used in conjunction to provide a broader context to the data. Tolerance interval bounds help to put assumed impacts into perspective. For example, if the value of an indicator variable from an impact site is near or within the interval bounds, impact can be deemed minimal or nonexistent. The further impact values deviate from the reference bound, the more serious the impact should be judged.

Previous studies have calculated tolerance interval bounds for the San Diego region between 1994-1996 (Smith and Riege 1998) and 1994-1999 (Smith 2001). This study builds on those works and is comparable to their findings. Data collected for this study covered 651 benthic samples from the coastal shelf surrounding the PLOO and spanned 18 years (1994–2003 and 2005–2012). This large sample size and longer temporal component increases sensitivity and effectiveness of detecting impacts as well as integrates changes to the indicator variables across time (Hunt et al. 2001). Further, the use of cluster analysis to identify an appropriate reference area is novel and avoids arbitrary site selection in favor of an ecological approach. Overall, these bounds provide a robust and appropriate reference for comparison to potential impacts to the region due to discharge from the PLOO. Lastly, tolerance intervals should be updated over time to incorporate spatio-temporal changes (e.g., ENSO events or shifts in sediment composition) which may affect tolerance interval bounds of reference conditions in the PLOO region.

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APPENDIX C.2

18-Year San Diego Regional Benthic Assessment and Reference Tolerance Intervals

TABLES

TABLE C.2-1

Mean abundance of species that account for ≤30% of intra-group similarity for cluster groups A–J according to SIMPER analysis.

	Cluster Group									
	A	**B**	**C**	**D**	**E**	**F**	**G**	**H***	**I**	**J**
Taxa	n=48	2	59	265	33	41	157	2	29	15
Aphelochaeta glandaria Cmplx	**19.8**		3.5	2.5	5.6	1.5	2.1		2.0	
Leptochelia dubia Cmplx	**8.2**		2.7	5.3	5.7	3.9	2.1			
Monticellina siblina	**7.9**	1.0	5.4	3.4	38.6	1.3	**12.2**		1.0	
Huxleyia munita	**7.8**			4.5						
Amphiodia digitata	**7.7**		2.6	2.7	2.5	1.0	1.8		2.2	
Ampelisca careyi	**5.2**		2.6	2.6	3.3		1.7			
Spiophanes duplex	4.2	**35.5**	3.2	**19.0**	**28.8**	2.4	**6.6**		2.0	
Phoronis sp	1.0	**11.5**	1.0	6.0	16.4	3.2	2.5		3.0	
Sabellides manriquei	3.0	**11.0**		3.8	7.7	1.6	1.0			
Spiophanes kimballi	2.4		**18.1**	6.9	1.0	1.0	1.0		4.5	
Mediomastus sp	4.8	3.0	**9.7**	4.4	**18.8**	3.9	**8.7**		2.9	
Paradiopatra parva	3.5		**8.0**	5.2	4.1	1.0	2.3		1.0	
Melinna heterodonta	1.0		**7.2**	1.3					2.0	1.0
Tellina carpenteri	5.4	1.0	**6.3**	2.7	4.7		4.0		9.1	
Paraprionospio alata	1.8	1.0	**5.4**	3.6	**5.5**	1.7	3.1		2.3	
Amphiodia urtica	1.5	1.0	3.5	**55.5**	2.6	1.5	2.2		1.0	
Amphiodia sp	2.6	4.0	1.9	**22.9**	3.5	1.9	1.8		2.0	
Amphiuridae	4.2		2.9	**11.5**	3.2	2.4	2.9		4.1	1.7
Pectinaria californiensis	5.6	14.0	3.6	**10.7**	4.0	1.7	4.0		1.3	
Sternaspis affinis	1.0		2.3	**5.6**	**5.9**	1.0	1.9		1.0	9.0
Rhepoxynius bicuspidatus	2.7		2.5	**4.7**	1.0		1.0			
Prionospio (Prionospio) dubia	2.3	1.0	2.4	**4.2**	3.1	2.0	1.3			1.0

TABLE C.2-1 (continued)

	Cluster Group									
	A	**B**	**C**	**D**	**E**	**F**	**G**	**H***	**I**	**J**
Taxa	n=48	2	59	265	33	41	157	2	29	15
Prionospio (Prionospio) jubata	4.3	9.0	2.0	5.0	**12.3**	3.6	5.8		1.0	
Spiophanes berkeleyorum	14.3	1.0	4.0	6.1	**12.3**	2.9	4.1		2.5	
Euclymeninae sp A	3.3	9.0	2.4	4.2	**9.7**	2.2	4.8		1.0	
Gadila aberrans	1.7	1.0	1.0	2.8	**9.4**	1.4	3.5			
Sthenelanella uniformis	1.5	4.0	1.0	3.7	**8.4**	1.7	2.1			
Typosyllis heterochaeta	1.8	1.0	1.5	2.2	**7.8**	10.7	3.5			
Maldanidae	1.6		3.9	4.0	**7.5**	2.2	3.2		5.3	2.5
Ampelisca pugetica	1.8			2.3	**5.3**	3.0	2.9		1.0	
Ampelisca cf *brevisimulata*	2.0		1.0	1.6	**1.3**	1.0	2.3		2.0	
Spiophanes norrisi	1.0	9.0	9.5	3.8	18.0	**27.6**	**28.4**		2.0	
Euchone arenae	1.4	2.0		1.4	1.3	**18.8**	1.7			
Spio maculata				1.3	2.0	**14.6**	2.0			
Micranellum crebricinctum	14.3	10.0		2.2	39.0	**12.2**	1.1			
Protodorvillea gracilis	1.4				1.0	**11.5**	2.3			
Ampelisca cristata cristata	1.0	1.0		1.4	3.3	**5.6**	4.1			
Eurydice caudata				2.0	1.0	**3.8**	1.0		1.0	
Tellina modesta				1.0	2.5	1.0	**6.0**			
Carinoma mutabilis	1.7	1.0	1.0	1.2	3.2	2.9	**3.8**			
Ampelisca unsocalae			4.0	2.0				**1.0**	2.2	1.5
Maldane sarsi	1.3	1.0	3.6	1.8	1.9		1.2	1.0	**12.2**	**2.8**
Nuculana conceptionis									**5.7**	
Monticellina cryptica	1.7		2.2	3.9	8.0	3.4	4.0		1.5	**1.9**

* *Ampelisca unsocalae* accounts for 33% of the similarity in Cluster Group H

TABLE C.2-2

Tolerance interval bounds for various environmental indicators calculated using benthic data from 253 randomly selected regional sites sampled from 1994-2003 and 2005-2012. P(norm) = the p value from a Shapiro-Wilk test for normality of the underlying data distribution. Parametric tolerance intervals computed for the 10th and 90th percentiles for indicators with p(norm) >0.15, Data were transformed when p(norm) for raw data were <0.15. Where transformation did not improve normality, non-parametric tolerance intervals for the 5th and 95th percentile were computed. Bolded values indicate thresholds for the direction of response predicted from environmental impact.

Indicator	p(norm)	Transformation	Lower Bound	Upper Bound
Species Richness	<0.001*	—	**60**	**145**
Abundance	0.387	ln	**223**	**603**
BRI	0.682	—	3	**16**
Diversity	<0.001*	—	**2.46**	**4.35**
Evenness	<0.001*	—	**0.58**	**0.92**
Swartz Dominance	0.009*	—	**7**	49
Amphiodia spp	<0.001*	—	**2**	195
Ampelisca spp	<0.001*	—	**2**	31
Proclea sp A	<0.001*	—	**0**	29
Rhepoxynius spp	<0.001*	—	**0**	12
Euphilomedes spp	<0.001*	—	0	**35**
Mediomastus spp	<0.001*	—	0	**13**
Parvilucina tenuisculpta	<0.001*	—	0	**9**
Solemya pervernicosa	<0.001*	—	0	**1**
Capitella teleta	<0.001*	—	0	**1**

* Non-parametric tolerance interval bounds computed

APPENDIX C.2

18-Year San Diego Regional Benthic Assessment and Reference Tolerance Intervals

FIGURES

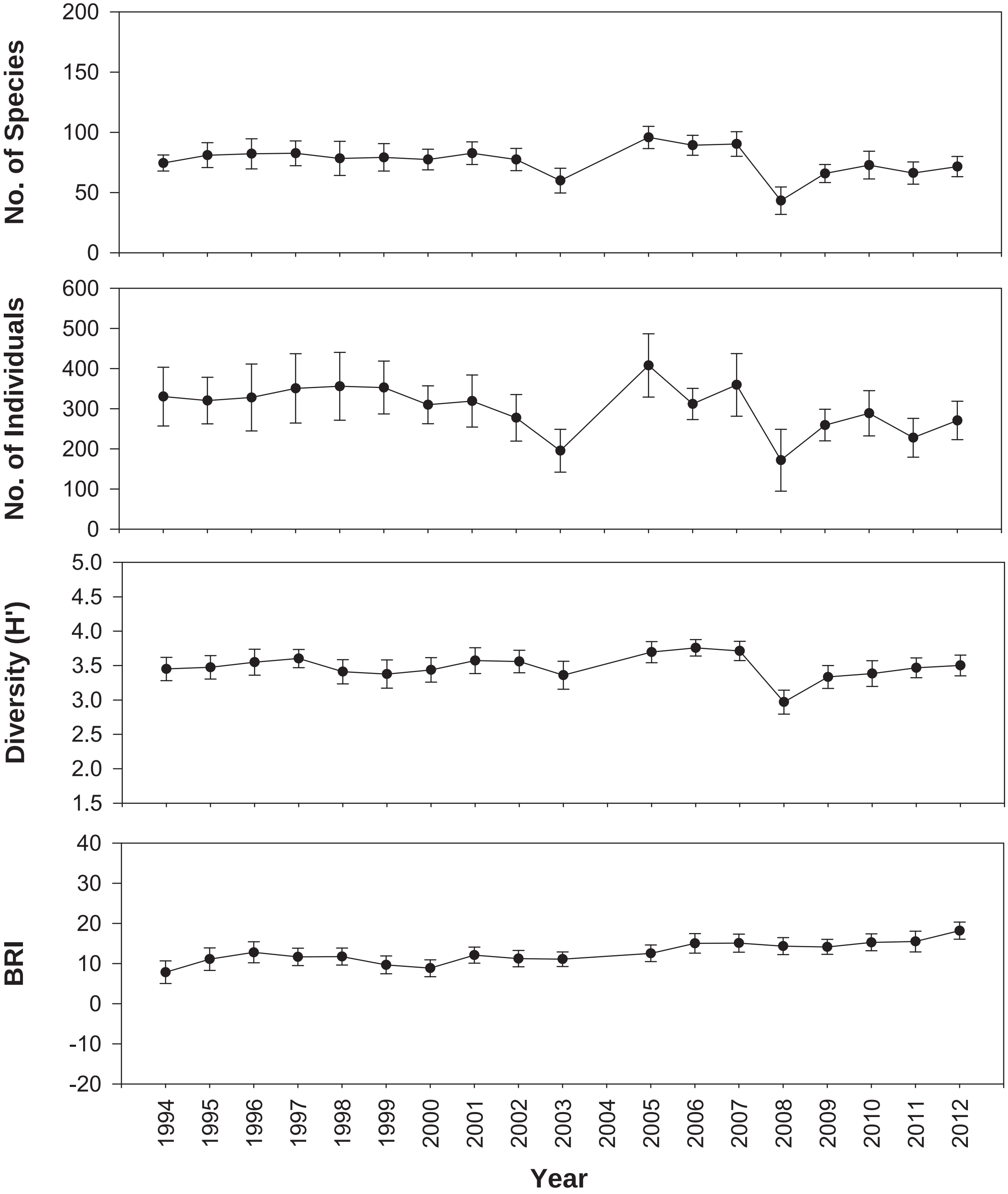
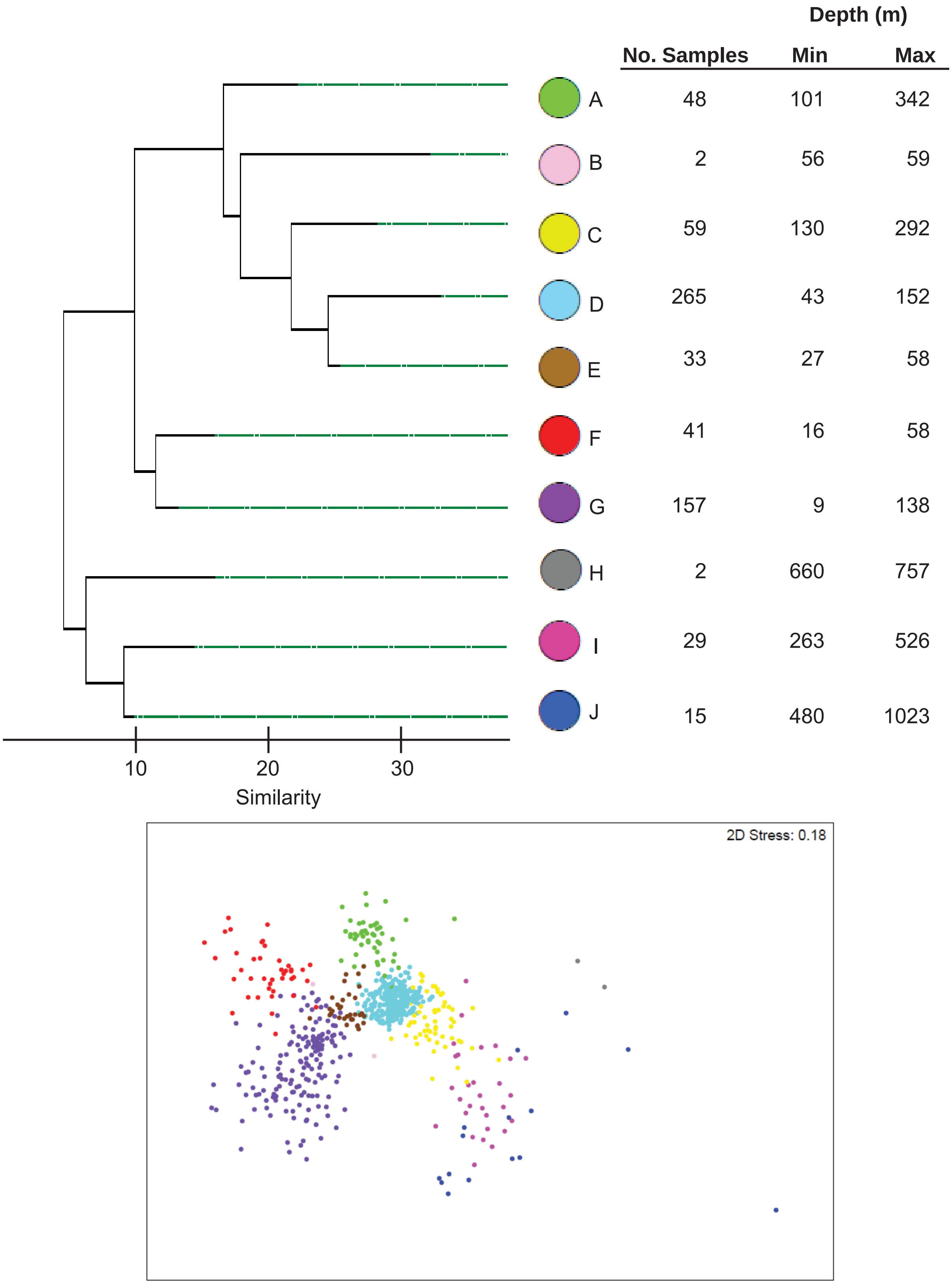


FIGURE C.2-1
Comparison of several macrofaunal community parameters at randomly selected regional stations sampled off the coast of San Diego from 1994-2003 and 2005-2012. Data are expressed as means per 0.1 m^2 ± 95% CI (n>24 per year).



		Depth (m)	
	No. Samples	Min	Max
A	48	101	342
B	2	56	59
C	59	130	292
D	265	43	152
E	33	27	58
F	41	16	58
G	157	9	138
H	2	660	757
I	29	263	526
J	15	480	1023

FIGURE C.2-2
Results of classification and nMDS ordination analyses of macrofaunal abundance data from randomly selected regional stations sampled off San Diego from 1994-2003 and 2005-2012.

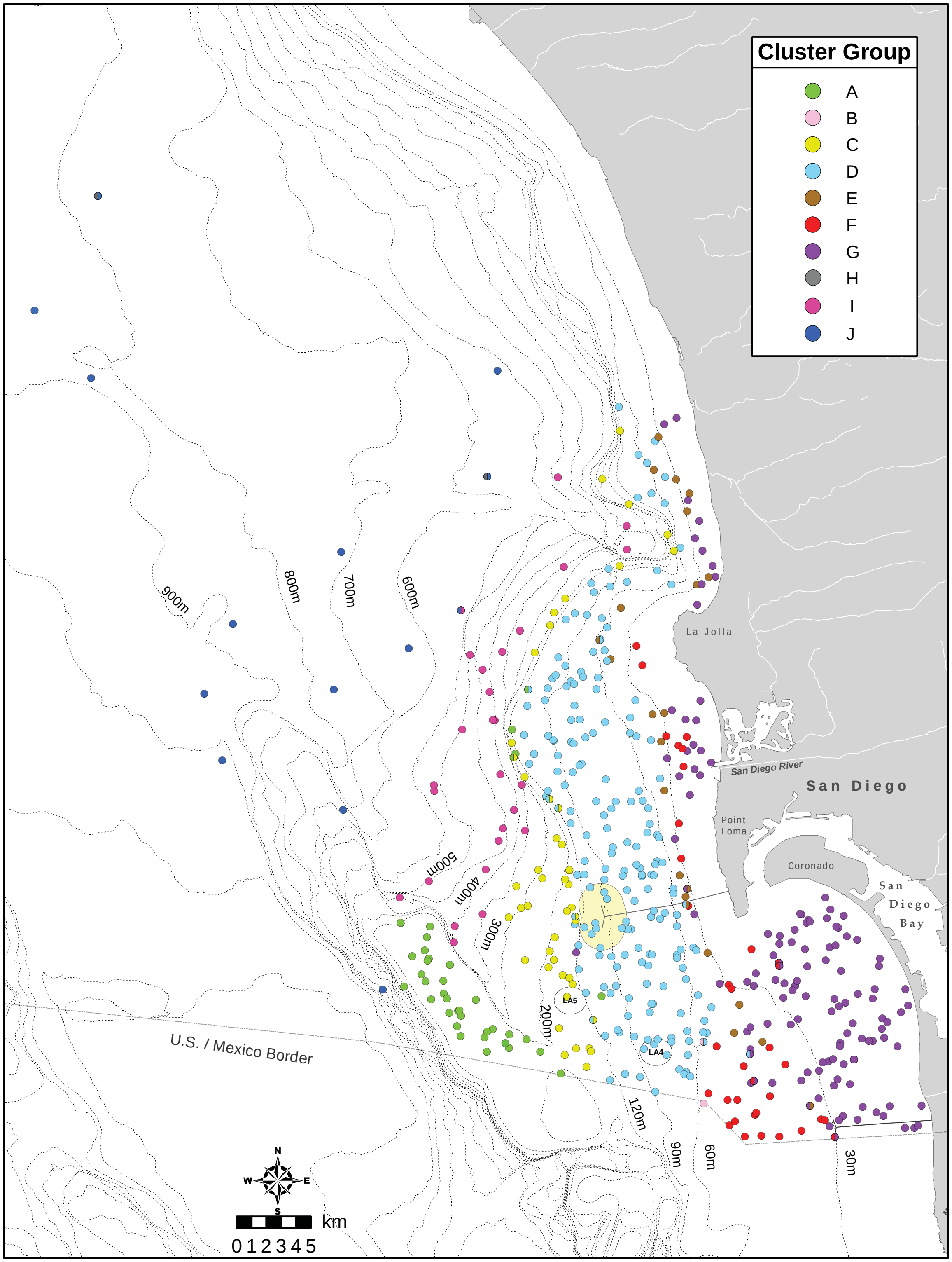


FIGURE C.2-3
Spatial distribution of cluster groups off San Diego. Colors correspond to colors in Figure C.2-2. Data from cluster group D (turquoise; excluding sites nearest the PLOO terminus) were used to calculate tolerance intervals.

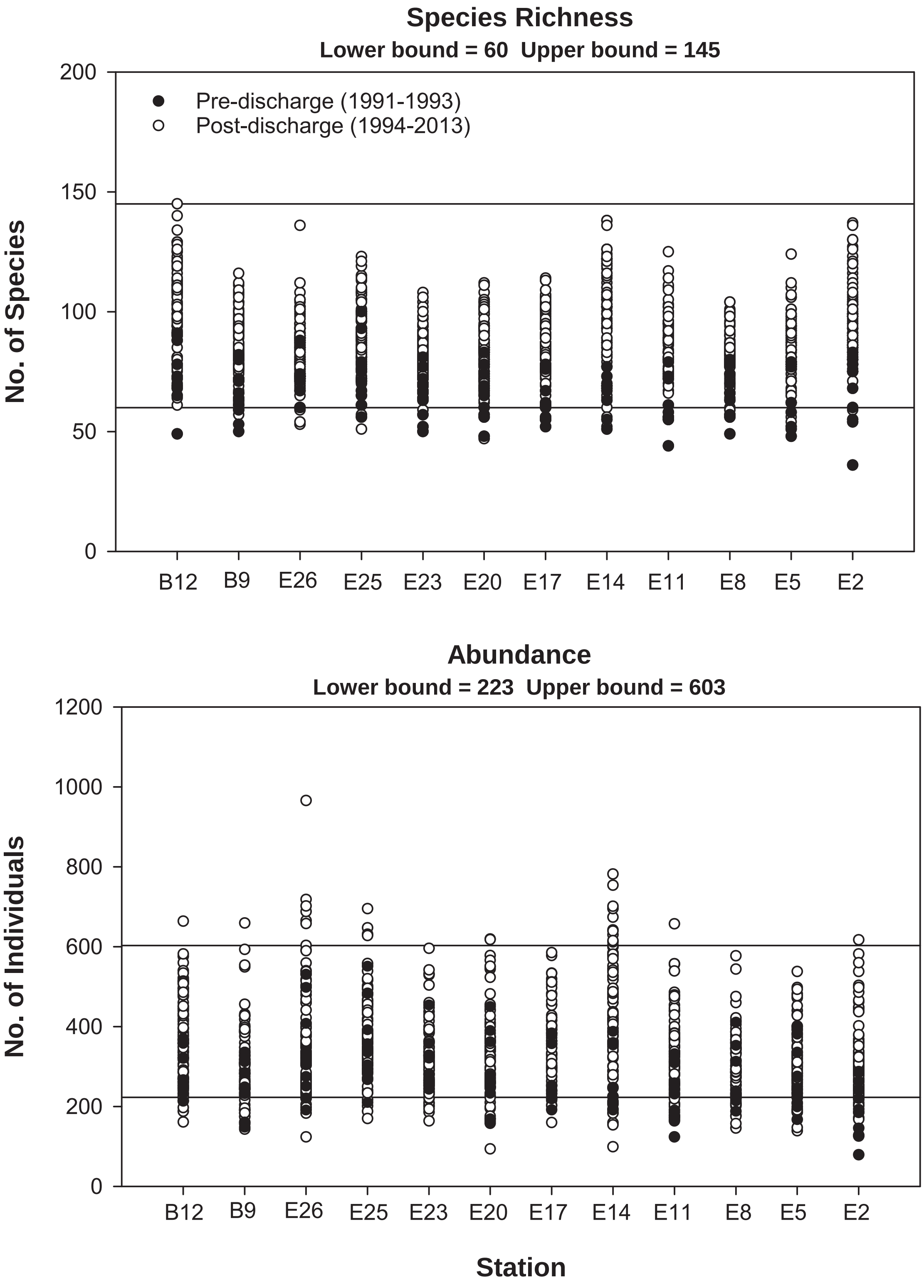
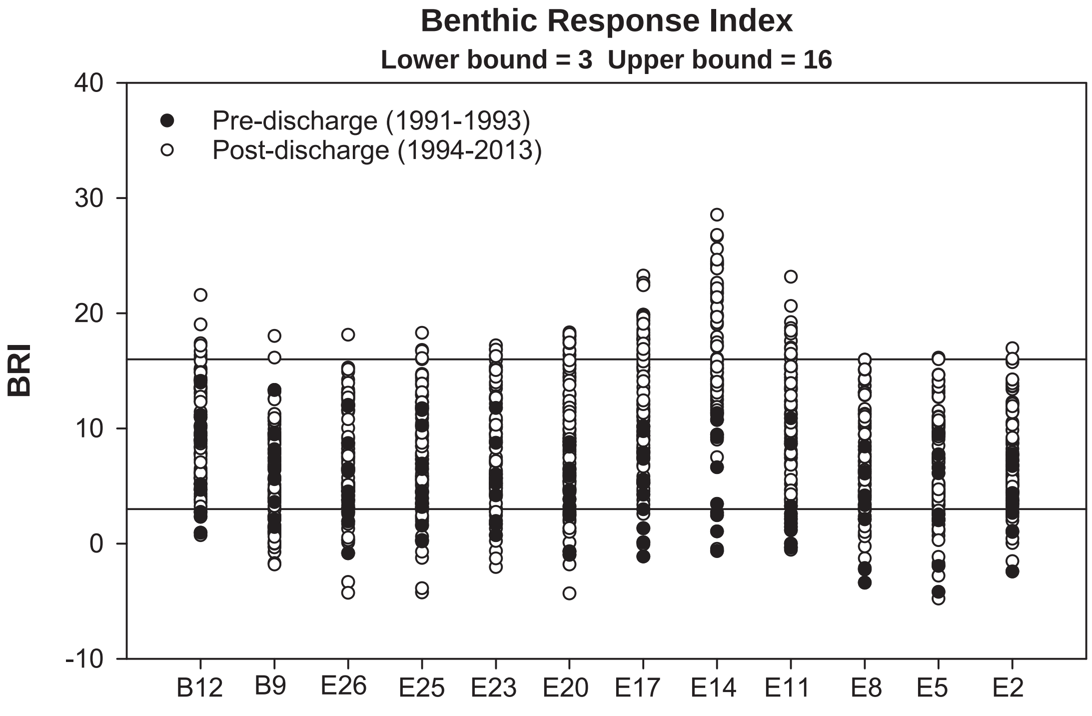


FIGURE C.2-4

Indicator values for the PLOO 98-m core monitoring stations sampled from 1991 through 2013. Horizontal lines indicate lower and upper tolerance intervals calculated from cluster group D sites for regional data collected from 1994 through 2012 (see text).



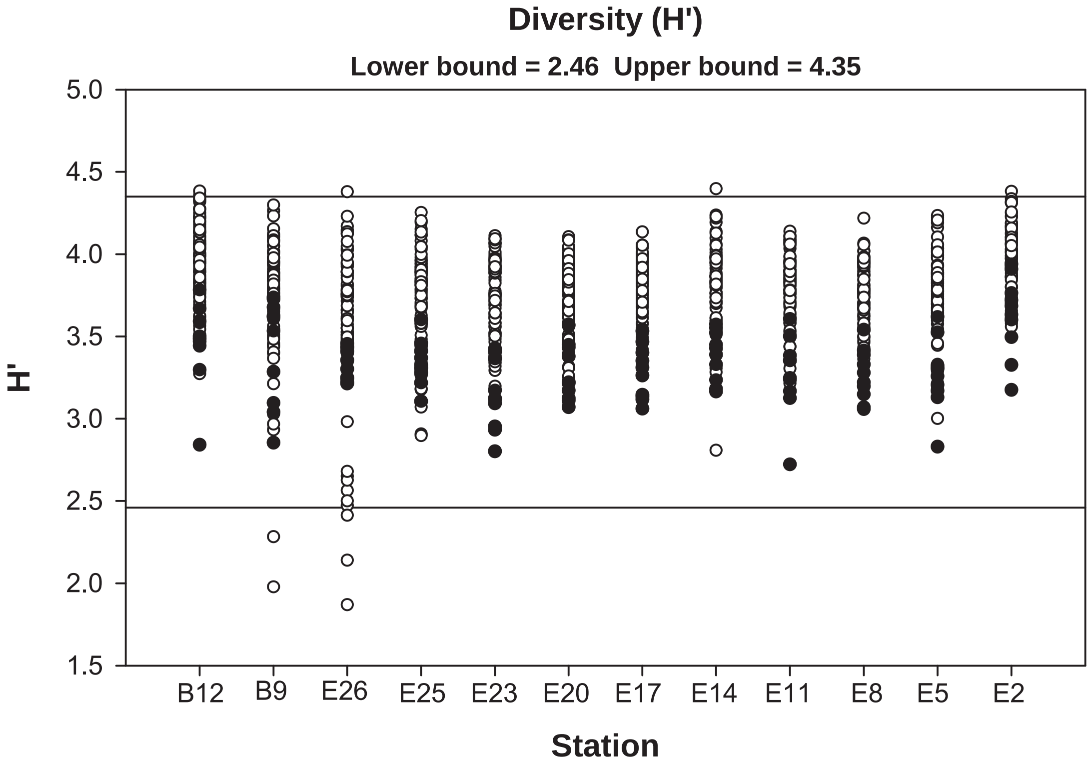
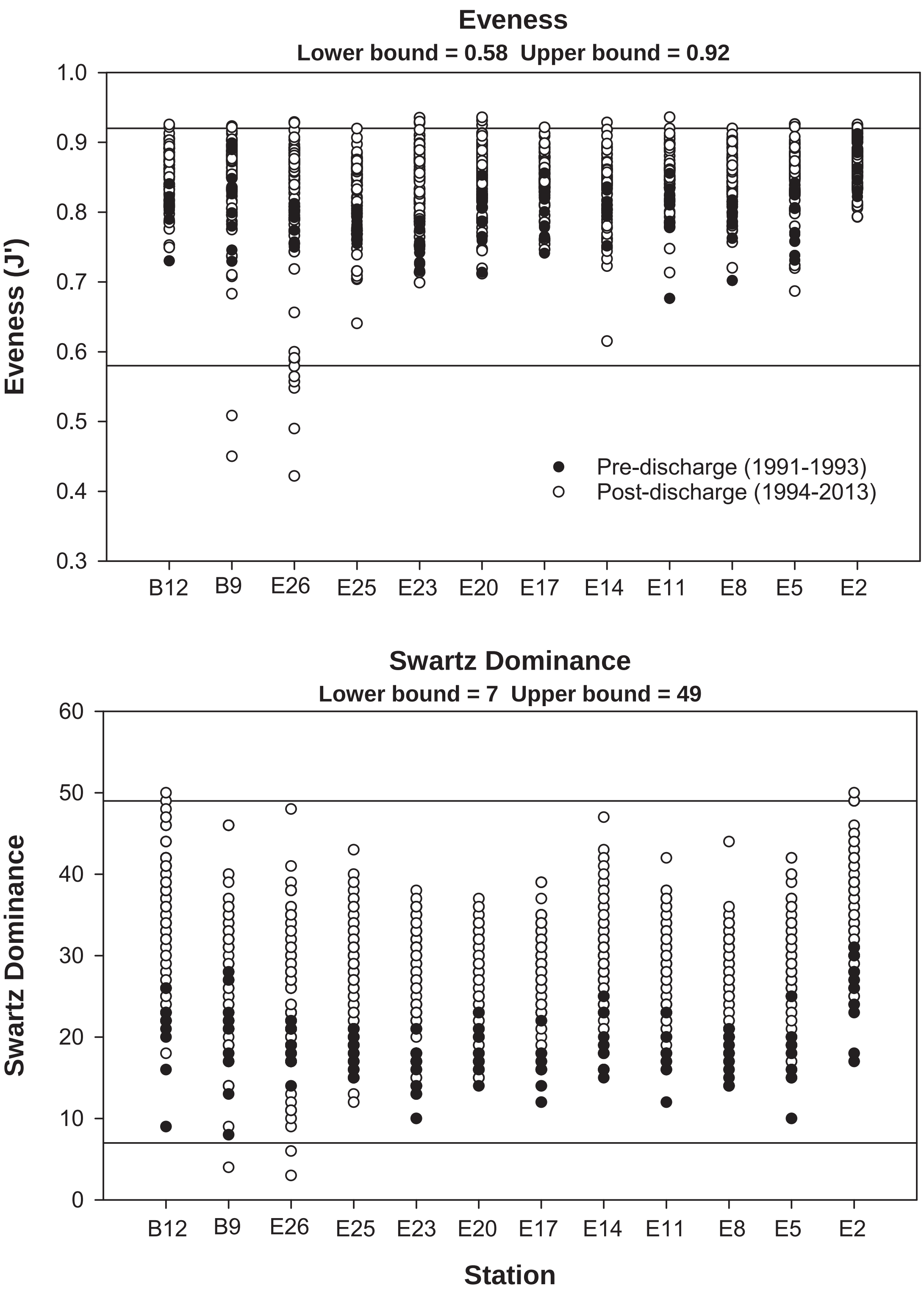


FIGURE C.2-4 (continued)



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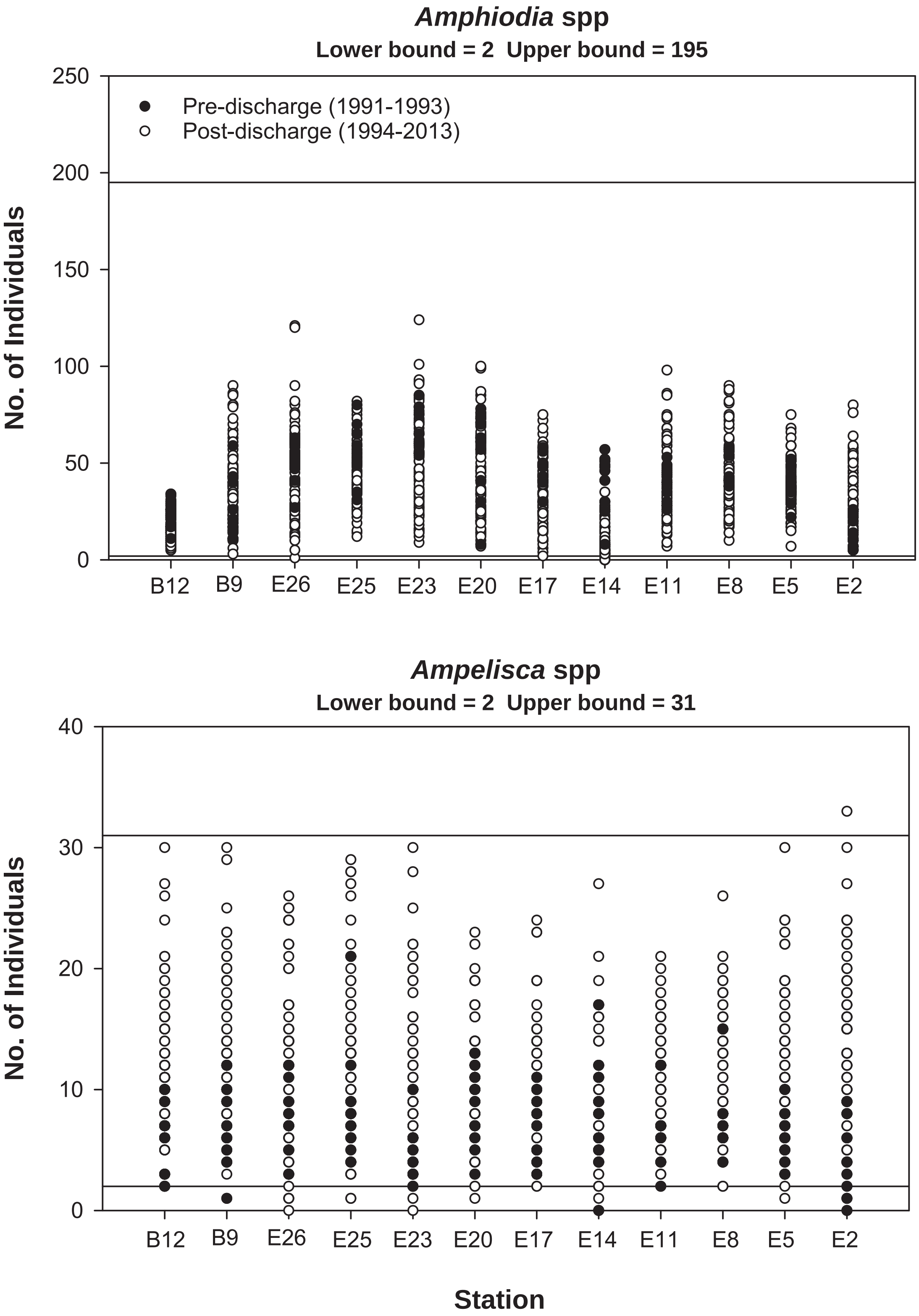

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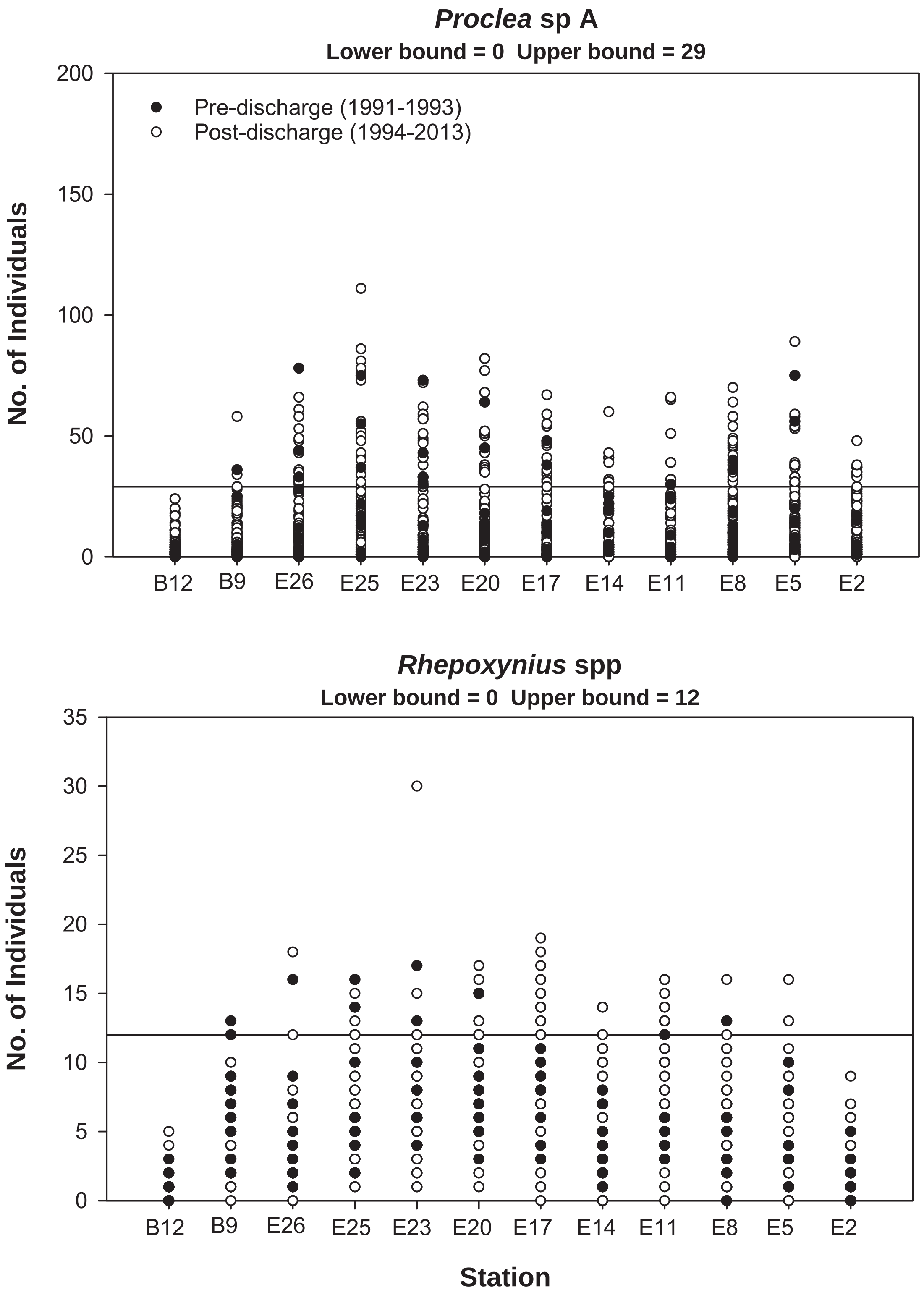


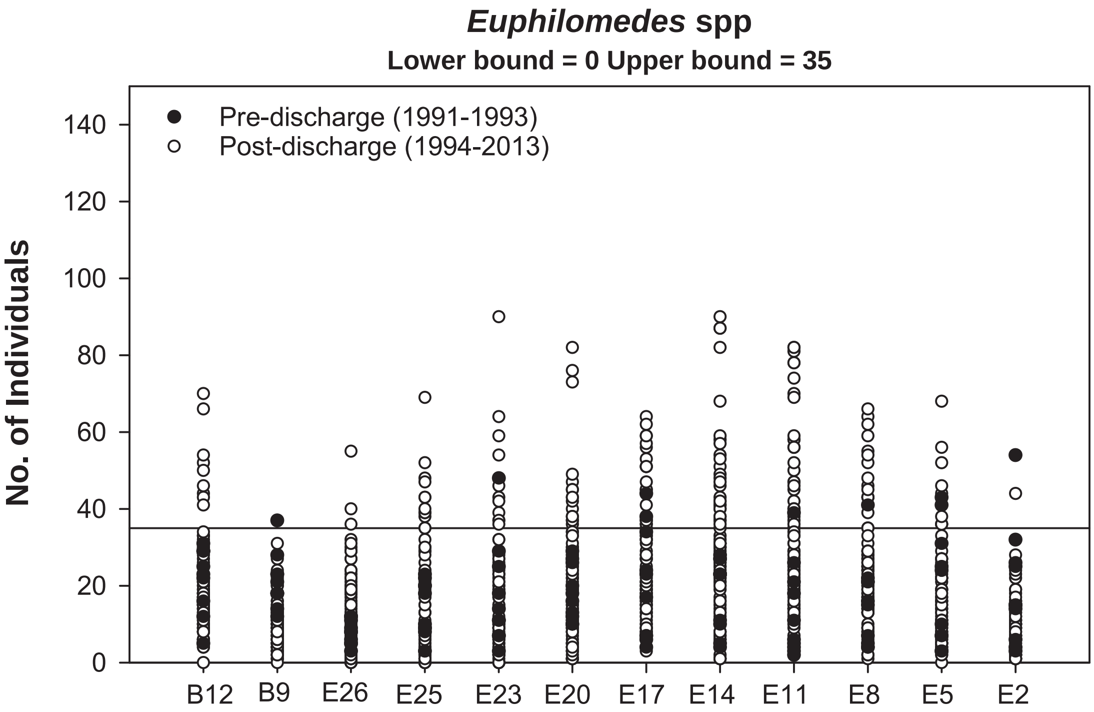
Proclea sp A

Lower bound = 0 Upper bound = 29

Rhepoxynius spp

Lower bound = 0 Upper bound = 12

FIGURE C.2-4 (continued)



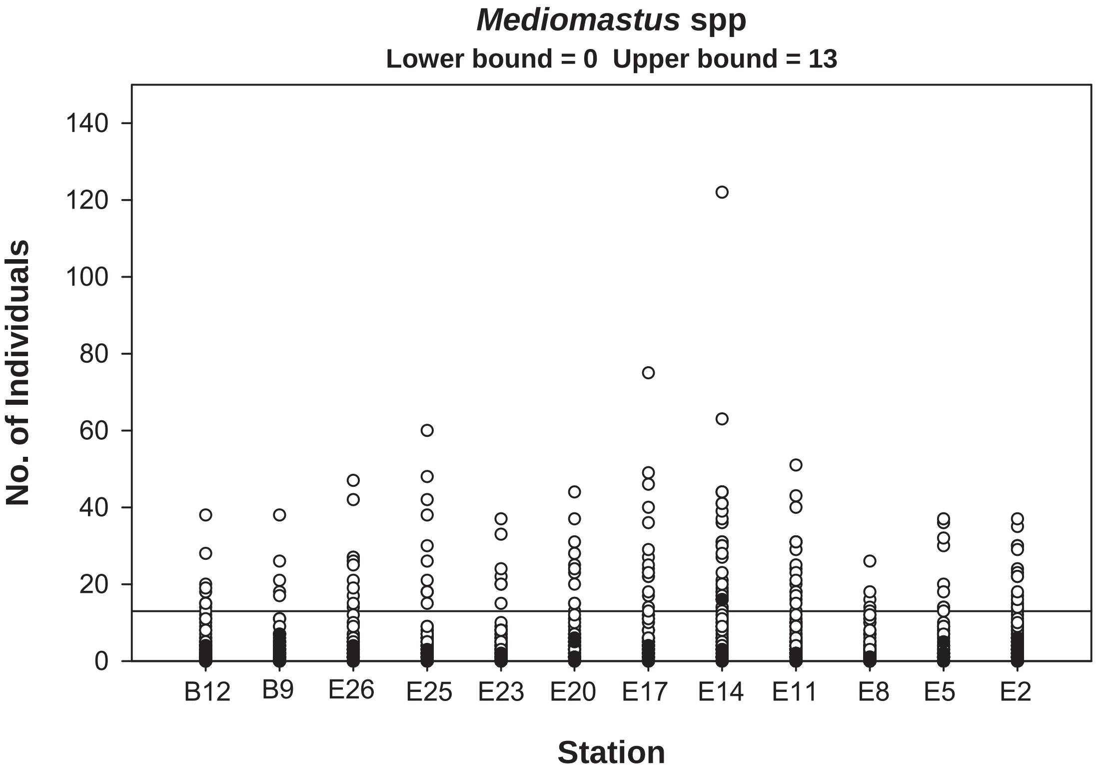
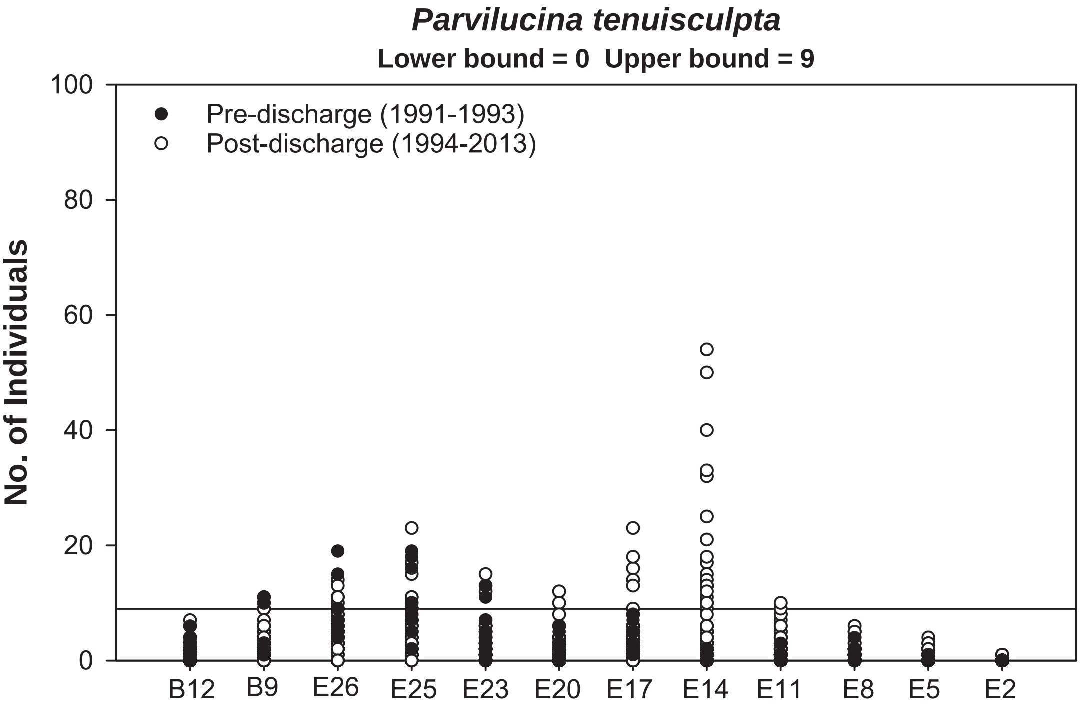


FIGURE C.2-4 (continued)



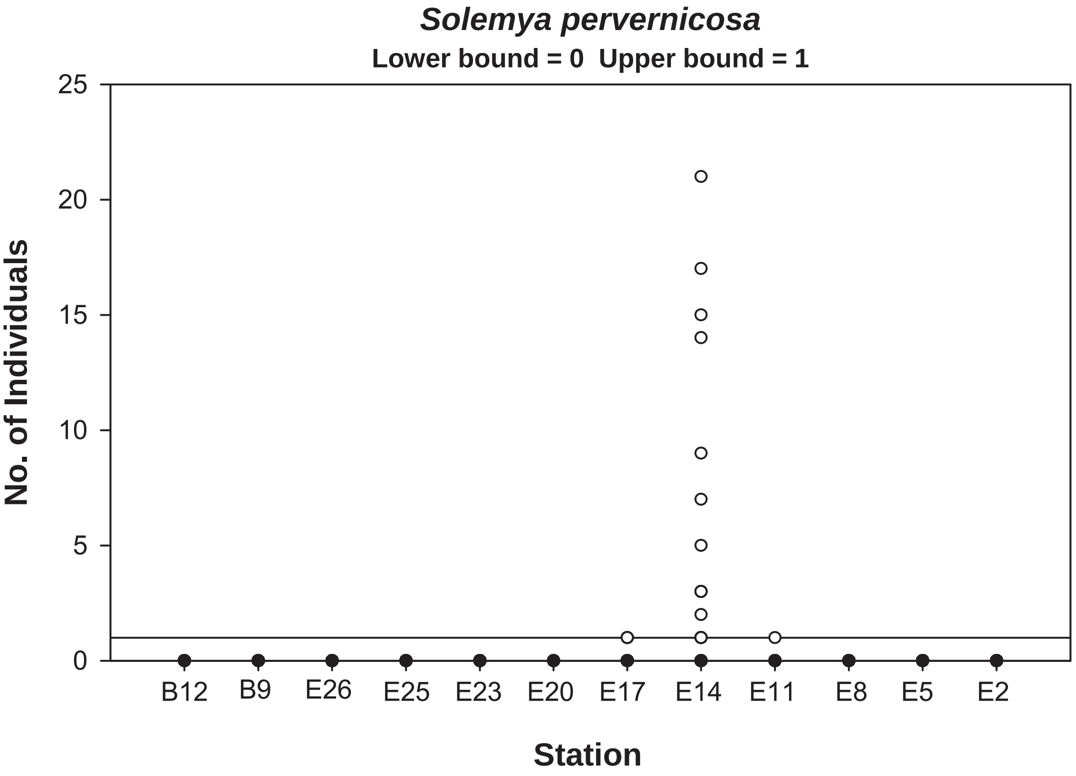


FIGURE C.2-4 (continued)

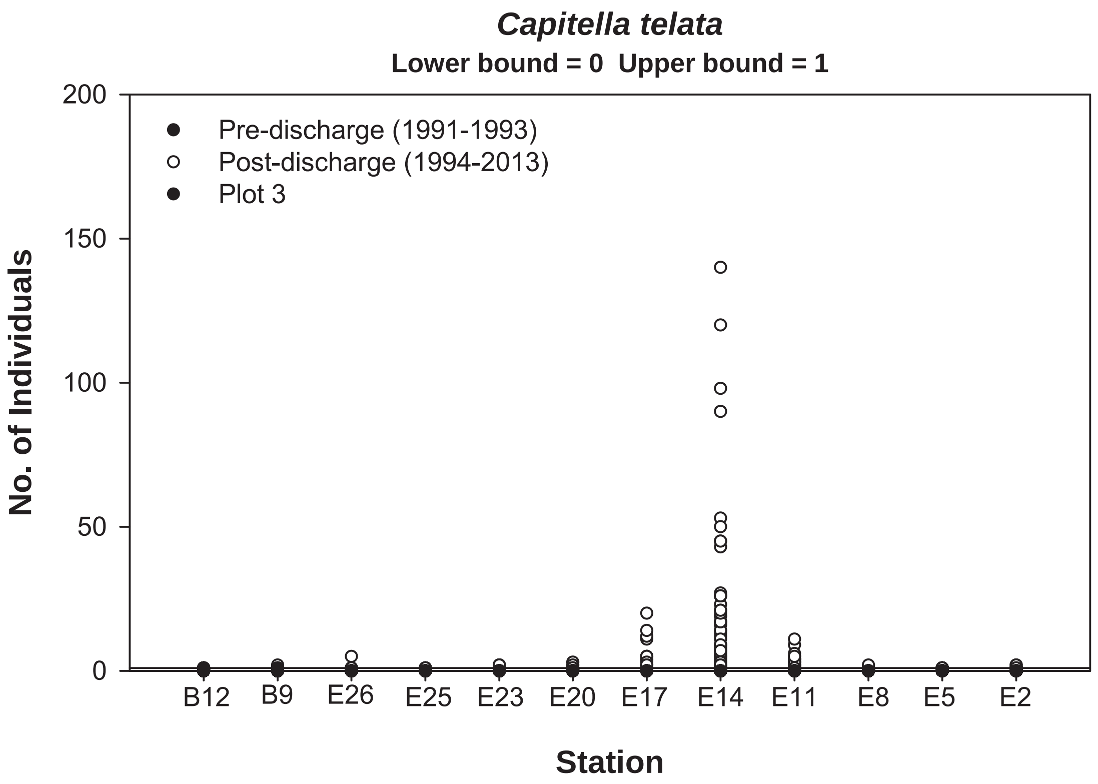


FIGURE C.2-4 (continued)

Appendix C.3

SAN DIEGO REGIONAL SEDIMENT QUALITY CONTOUR PLOTS

Renewal of NPDES CA0107409

APPENDIX C.3

SAN DIEGO REGIONAL SEDIMENT QUALITY CONTOUR PLOTS

January 2015

APPENDIX C.3

San Diego Regional Sediment Quality Contour Plots (1994 – 2012)

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APPENDIX C.3

San Diego Regional Sediment Quality Contour Plots (1994 – 2012)

SECTION C.3-1 | INTRODUCTION

In order to investigate temporal trends to the overall sediment quality conditions off San Diego over the past eighteen years, contour plots of most sediment quality parameters analyzed in Appendix C (see Section C.1-3) were constructed using data collected from a number of regional benthic surveys of the continental shelf and slope. These surveys have been conducted by the City of San Diego since 1994 in order to characterize benthic conditions for the large and diverse coastal region that ranges from the US/Mexico border to northern San Diego County (~Carlsbad), and to possibly identify areas impacted by anthropogenic or natural events. The main objective of this appendix is to provide side-by-side comparisons of regional sediment conditions off San Diego for two post-discharge periods: 1994-2006 versus the most recent waiver period from 2007-2012. These results can be compared to sediment data presented earlier in this application for the regular fixed-grid monitoring sites surrounding the Point Loma Ocean Outfall (PLOO). Such regional data are not available prior to 1994, so it was not possible to prepare similar contour plots for the 1991-1993 pre-discharge period.

SECTION C.3-2 | GENERAL METHODS

Sample Collection and Processing

The regional sediment samples analyzed herein were collected annually from 1994–2003 and 2005–2012 using the USEPA probability-based EMAP random sampling design. The surveys in 1995–1997 and 1999–2012 were performed as part of the NPDES monitoring program for the

South Bay Ocean Outfall (see City of San Diego 2013 for details), while sampling in 1994, 1998, 2003, and 2008 was conducted as part of several large regional surveys of the entire Southern California Bight (see Noblet et al. 2002, Schiff and Gossett 1998, Schiff et al. 2006, 2011). The study area ranged from off Carlsbad in northern San Diego County south to the US/Mexico border.

The contour plots (maps) presented herein were generated using the default settings in ESRI's ArcGIS Spatial Analyst inverse-distance weighted interpolation algorithm. The resulting grid layer provides estimated values for unsampled areas that fall between sampled locations. It should be noted that it is not possible to assess the level of accuracy for estimated values in unsampled areas using this deterministic interpolation method. Contour maps were created for the 1994-2006 post-discharge period (414 samples) and the 2007-2012 post-discharge period (237 samples) for each of the parameters listed below. Some stations were re-visited in subsequent surveys; the values from these stations were averaged. Zeros were substituted for non-detects.

Sediment grain size distributions were mapped using percent fines, which represents the silt and clay fractions combined (Figure C.3-1). Measures of organic loading that were mapped include total organic carbon (Figure C.3-2), total volatile solids (Figure C.3-3), total nitrogen (Figure C.3-4), and sulfides (Figure C.3-5). Biochemical oxygen demand (BOD), although included in fixed-site monitoring around the PLOO (see Section C.1-4, page C.1-9), has not been a target analyte for the regional surveys. Trace metals mapped include aluminum, arsenic, beryllium, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, selenium, silver, and zinc (Figures C.3-6 though C.3-19). Sediment concentrations of DDT were also mapped for the San Diego region (Figure C.3-20). Regional contour maps for PCBs are not included due to non-comparability of data between some years (i.e., Aroclors vs. congeners) and the rarity of detectable values. PAHs are also not included due to low concentrations near or below the MDL.

When comparing the spatial patterns apparent in the interpolated maps, it is important to note that areas of slightly elevated concentrations of certain organics and metals are restricted to very deep, lower slope stations far from the outfall. These elevated values at these very deep stations resulted in darker deep areas on the 2007-2012 plots when compared to the 1994-2006 plots, but this does not represent a temporal change or accumulation over time. The visual phenomenon in these maps is merely due to a sampling artifact since there were very few lower slope stations sampled prior to 2006. This becomes apparent when looking at the values in the upper northwest corner of the 1994-2006 plots where higher concentrations were recorded during the Bight'03 survey. Because lower slope stations were sampled more often during the more recent regional surveys, those interpolations have been strongly influenced by the slightly elevated concentrations found at the stations in those deeper areas.

SECTION C.3-3 | LITERATURE CITED

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APPENDIX C.3

San Diego Regional Sediment Quality Contour Plots (1994 – 2012)

FIGURES

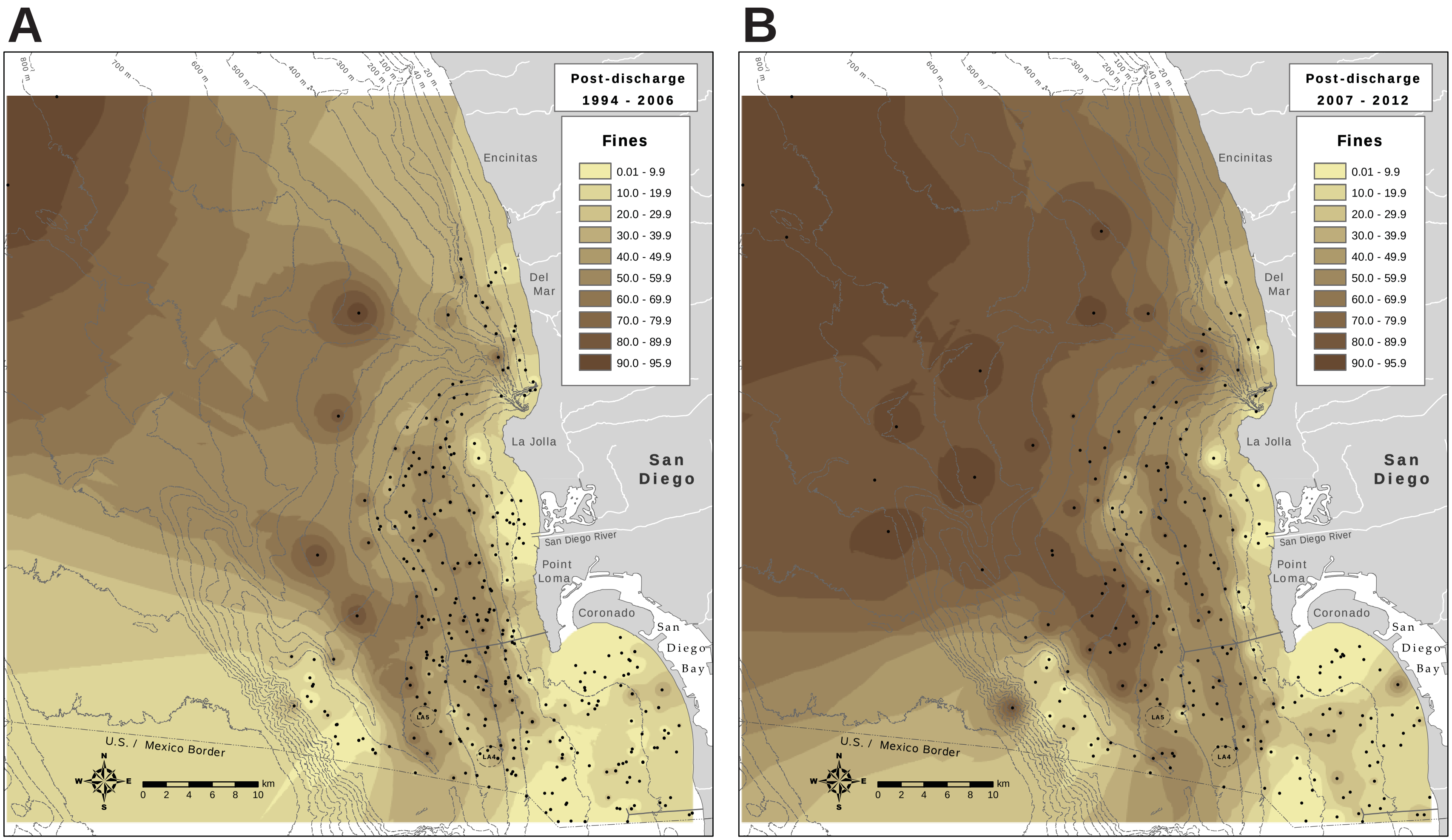

FIGURE C.3-1
Comparison of sediment particle size distribution for the San Diego coastal region during the 1994-2006 (A) and 2007-2012 (B) post-discharge periods. Data are expressed as %fines (silt + clay fractions combined) and were calculated using results from the San Diego annual regional surveys (1995-1997, 1999-2002, 2005-2007, 2009-2012), the Southern California Bight Pilot Project (1994), and the Bight'98, Bight'03, and Bight'08 regional monitoring programs (1998, 2003, 2008).

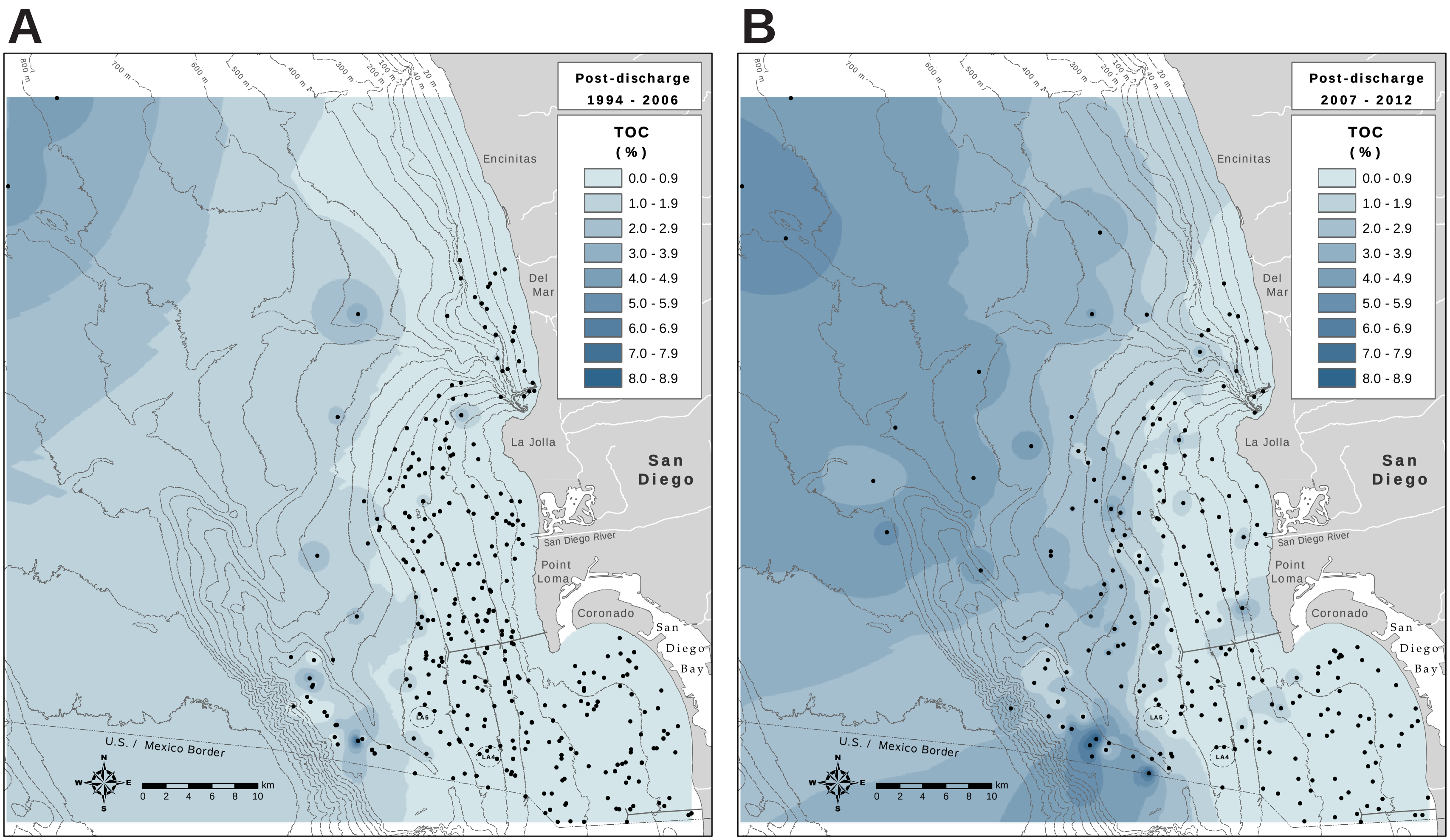

FIGURE C.3-2
Comparison of total organic carbon (TOC) in sediments for the San Diego coastal region during the 1994-2006 (A) and 2007-2012 (B) post-discharge periods. Data are expressed as %TOC and were calculated using results from the San Diego annual regional surveys (1995-1997, 1999-2002, 2005-2007, 2009-2012), the Southern California Bight Pilot Project (1994), and the Bight'98, Bight'03, and Bight'08 regional monitoring programs (1998, 2003, 2008).

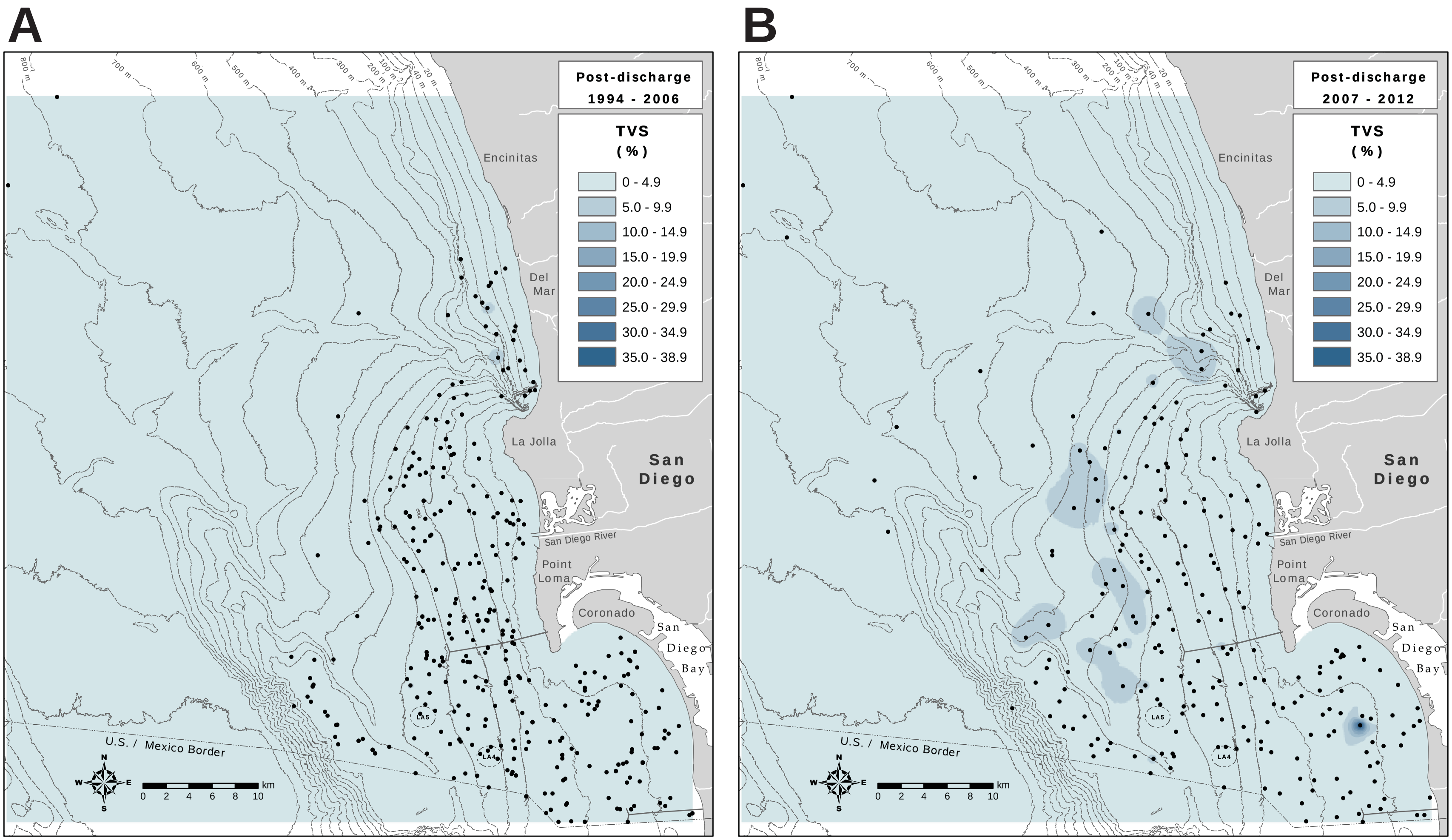

FIGURE C.3-3

Comparison of total volatile solids (TVS) in sediments for the San Diego coastal region during the 1994-2006 (A) and 2007-2012 (B) post-discharge periods. Data are expressed as %TVS and were calculated using results from the San Diego annual regional surveys (1995-1997, 1999-2002, 2005-2007, 2009-2012), the Southern California Bight Pilot Project (1994), and the Bight'98, Bight'03, and Bight'08 regional monitoring programs (1998, 2003, 2008).

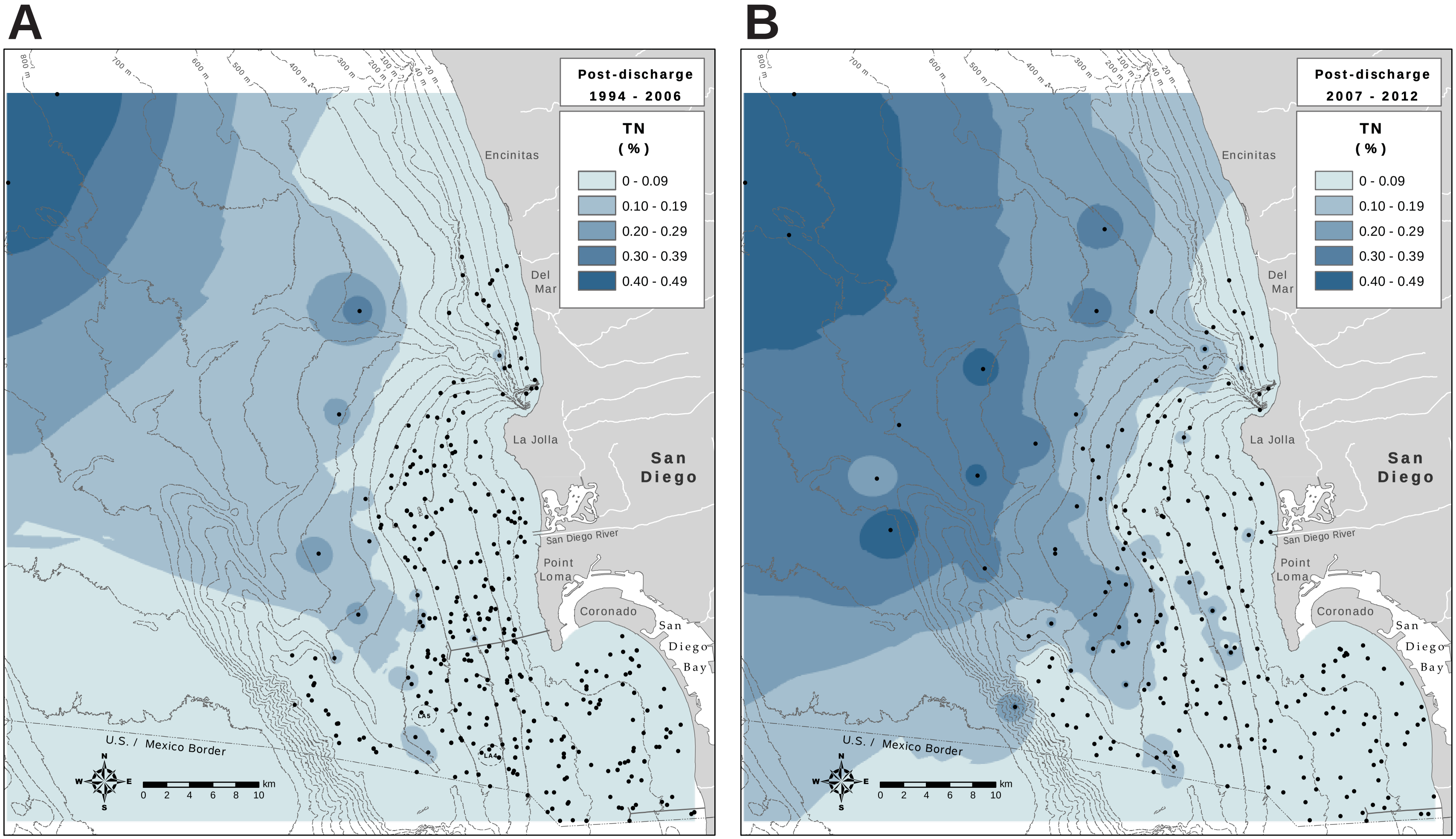

FIGURE C.3-4

Comparison of total nitrogen (TN) in sediments for the San Diego coastal region during the 1994-2006 (A) and 2007-2012 (B) post-discharge periods. Data are expressed as %TN and were calculated using results from the San Diego annual regional surveys (1995-1997, 1999-2002, 2005-2007, 2009-2012), the Southern California Bight Pilot Project (1994), and the Bight'98, Bight'03, and Bight'08 regional monitoring programs (1998, 2003, 2008).

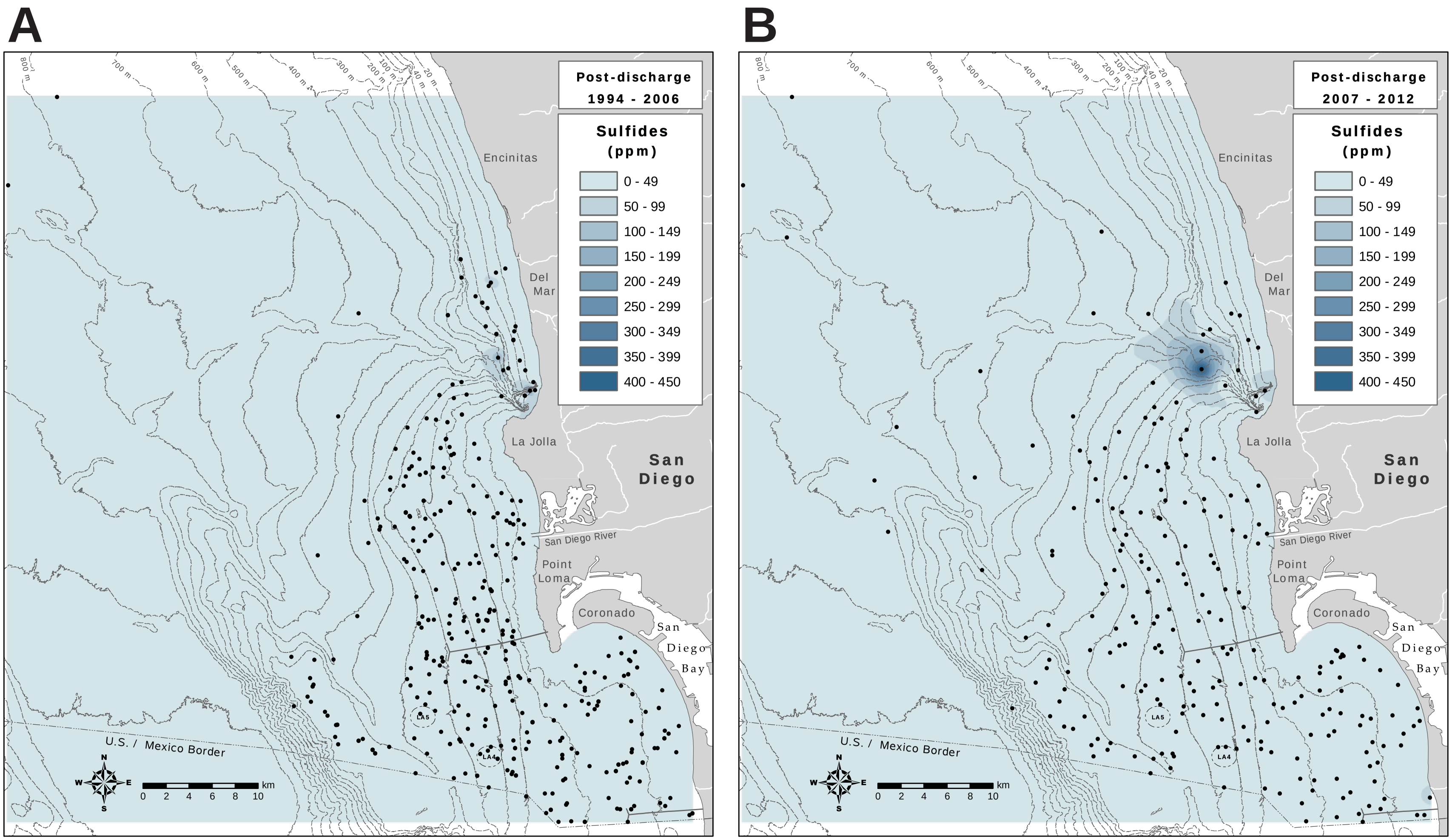

FIGURE C.3-5

Comparison of sulfide concentrations in sediments for the San Diego coastal region during the 1994-2006 (A) and 2007-2012 (B) post-discharge periods. Data are expressed as parts per million (ppm) and were calculated using results from the San Diego annual regional surveys (1995-1997, 1999-2002, 2005-2007, 2009-2012), the Southern California Bight Pilot Project (1994), and the Bight'98, Bight'03, and Bight'08 regional monitoring programs (1998, 2003, 2008).

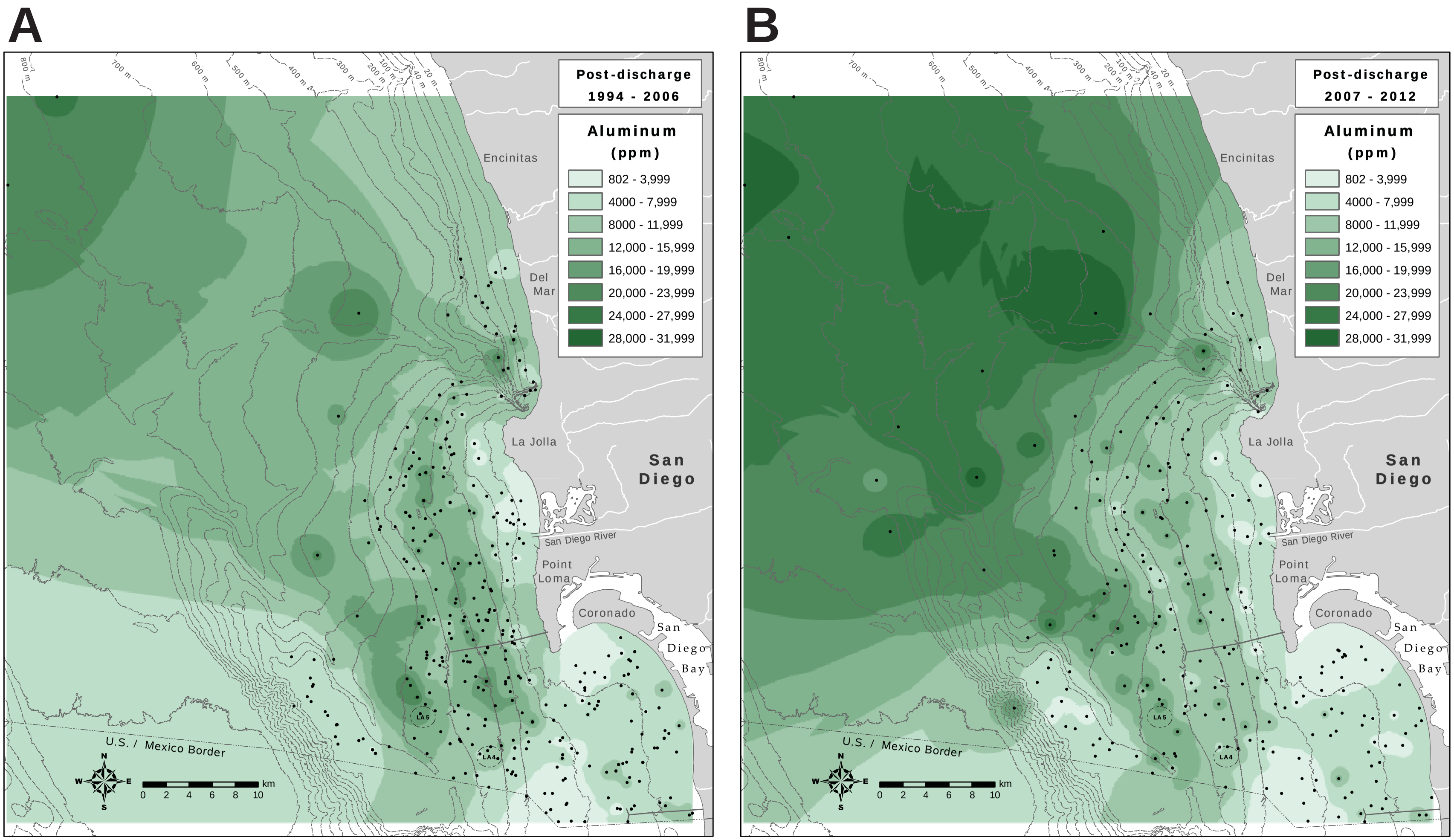

FIGURE C.3-6
Comparison of aluminum concentrations in sediments for the San Diego coastal region during the 1994-2006 (A) and 2007-2012 (B) post-discharge periods. Data are expressed as parts per million (ppm) and were calculated using results from the San Diego annual regional surveys (1995-1997, 1999-2002, 2005-2007, 2009-2012), the Southern California Bight Pilot Project (1994), and the Bight'98, Bight'03, and Bight'08 regional monitoring programs (1998, 2003, 2008).

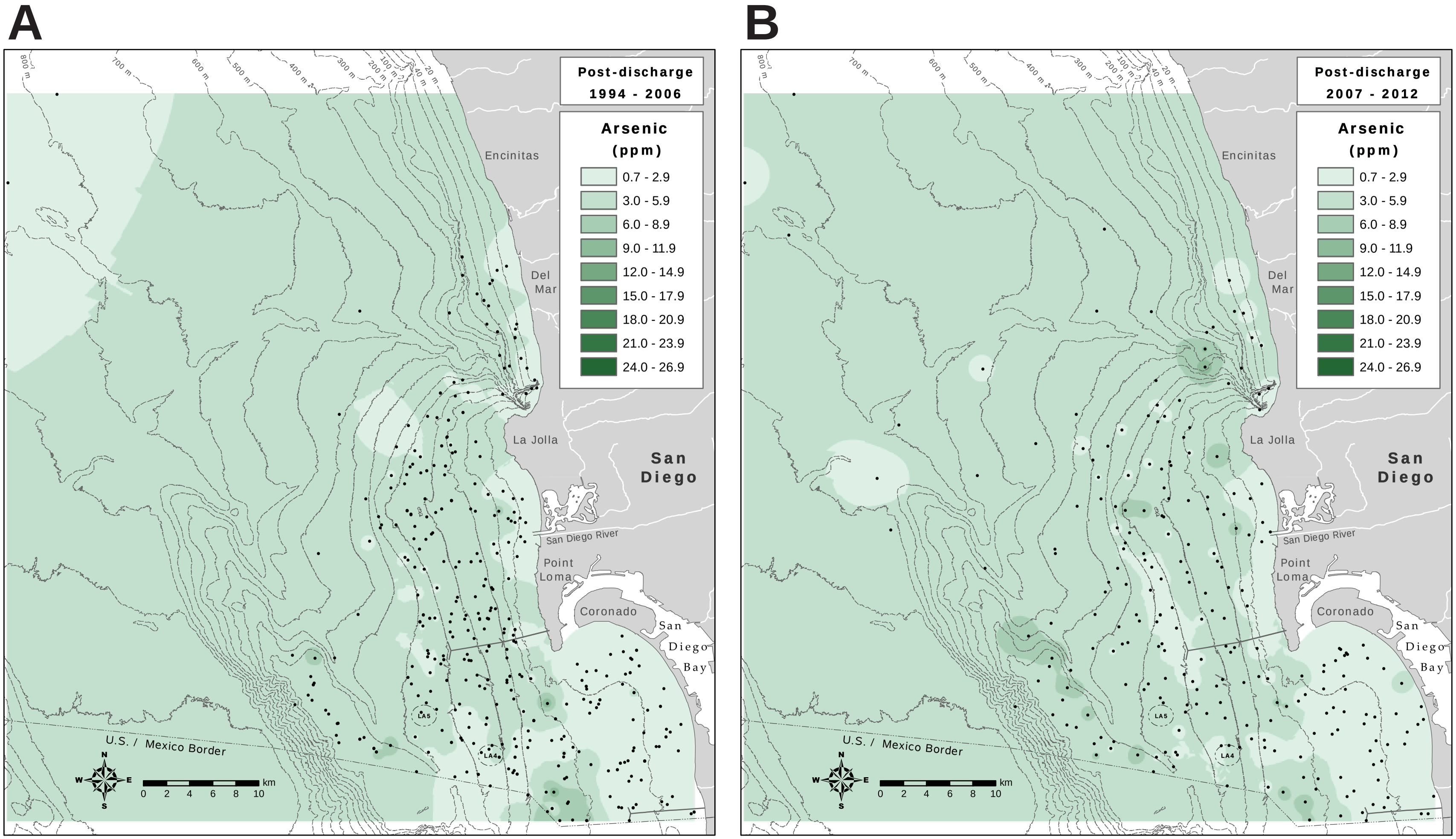

FIGURE C.3-7
Comparison of arsenic concentrations in sediments for the San Diego coastal region during the 1994-2006 (A) and 2007-2012 (B) post-discharge periods. Data are expressed as parts per million (ppm) and were calculated using results from the San Diego annual regional surveys (1995-1997, 1999-2002, 2005-2007, 2009-2012), the Southern California Bight Pilot Project (1994), and the Bight'98, Bight'03, and Bight'08 regional monitoring programs (1998, 2003, 2008).

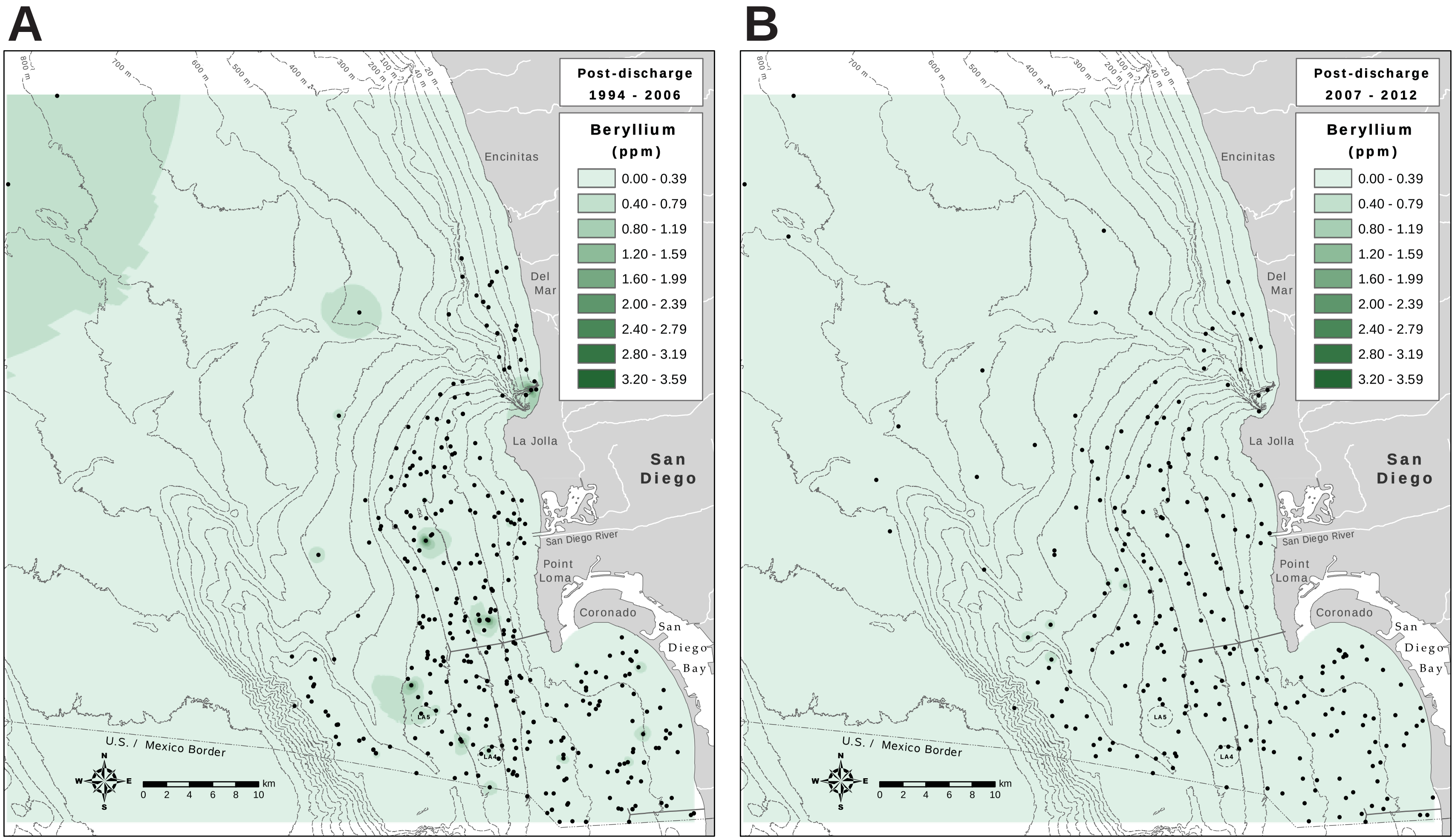

FIGURE C.3-8
Comparison of beryllium concentrations in sediments for the San Diego coastal region during the 1994-2006 (A) and 2007-2012 (B) post-discharge periods. Data are expressed as parts per million (ppm) and were calculated using results from the San Diego annual regional surveys (1995-1997, 1999-2002, 2005-2007, 2009-2012), the Southern California Bight Pilot Project (1994), and the Bight'98, Bight'03, and Bight'08 regional monitoring programs (1998, 2003, 2008).

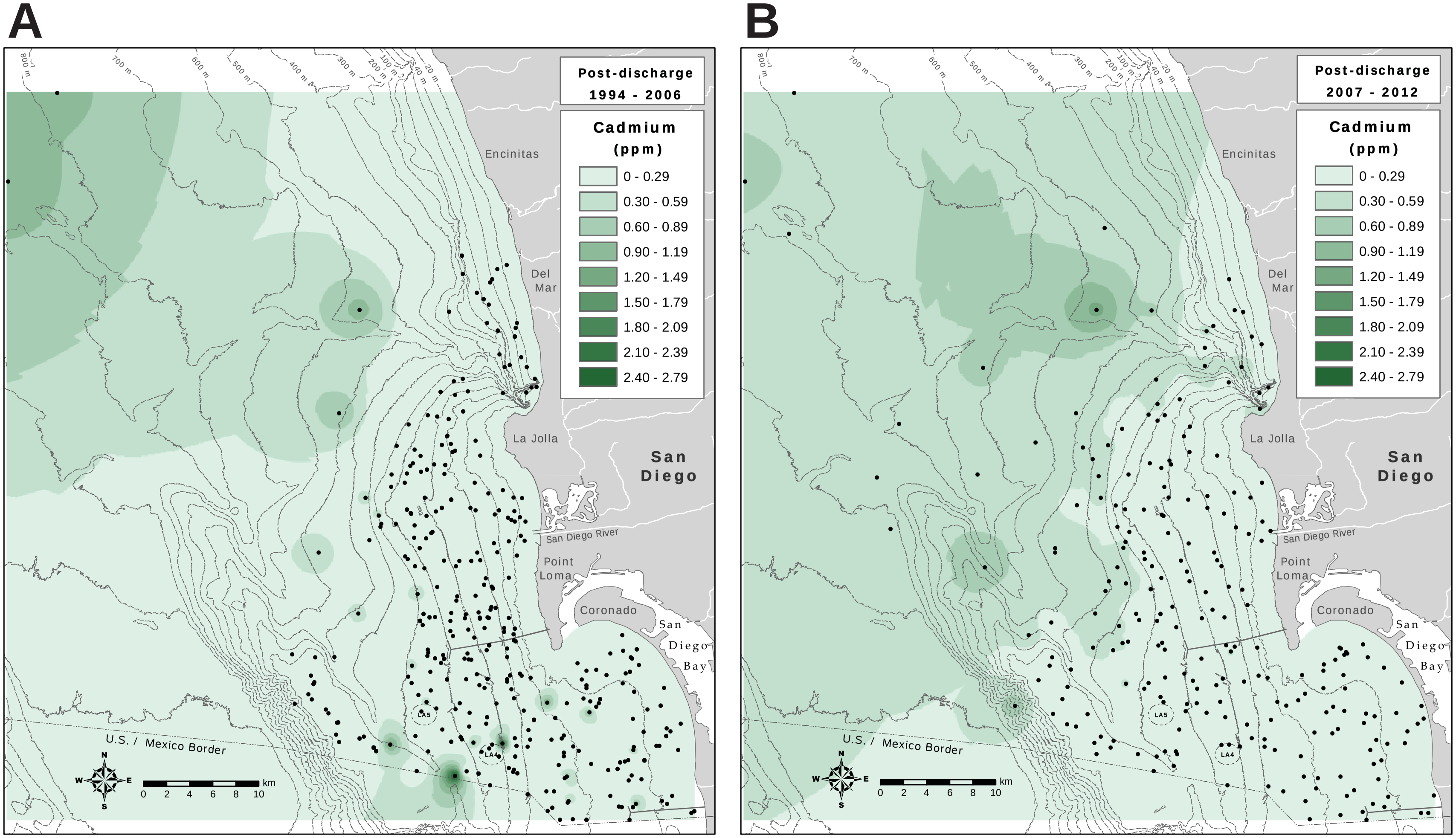

FIGURE C.3-9
Comparison of cadmium concentrations in sediments for the San Diego coastal region during the 1994-2006 (A) and 2007-2012 (B) post-discharge periods. Data are expressed as parts per million (ppm) and were calculated using results from the San Diego annual regional surveys (1995-1997, 1999-2002, 2005-2007, 2009-2012), the Southern California Bight Pilot Project (1994), and the Bight'98, Bight'03, and Bight'08 regional monitoring programs (1998, 2003, 2008).

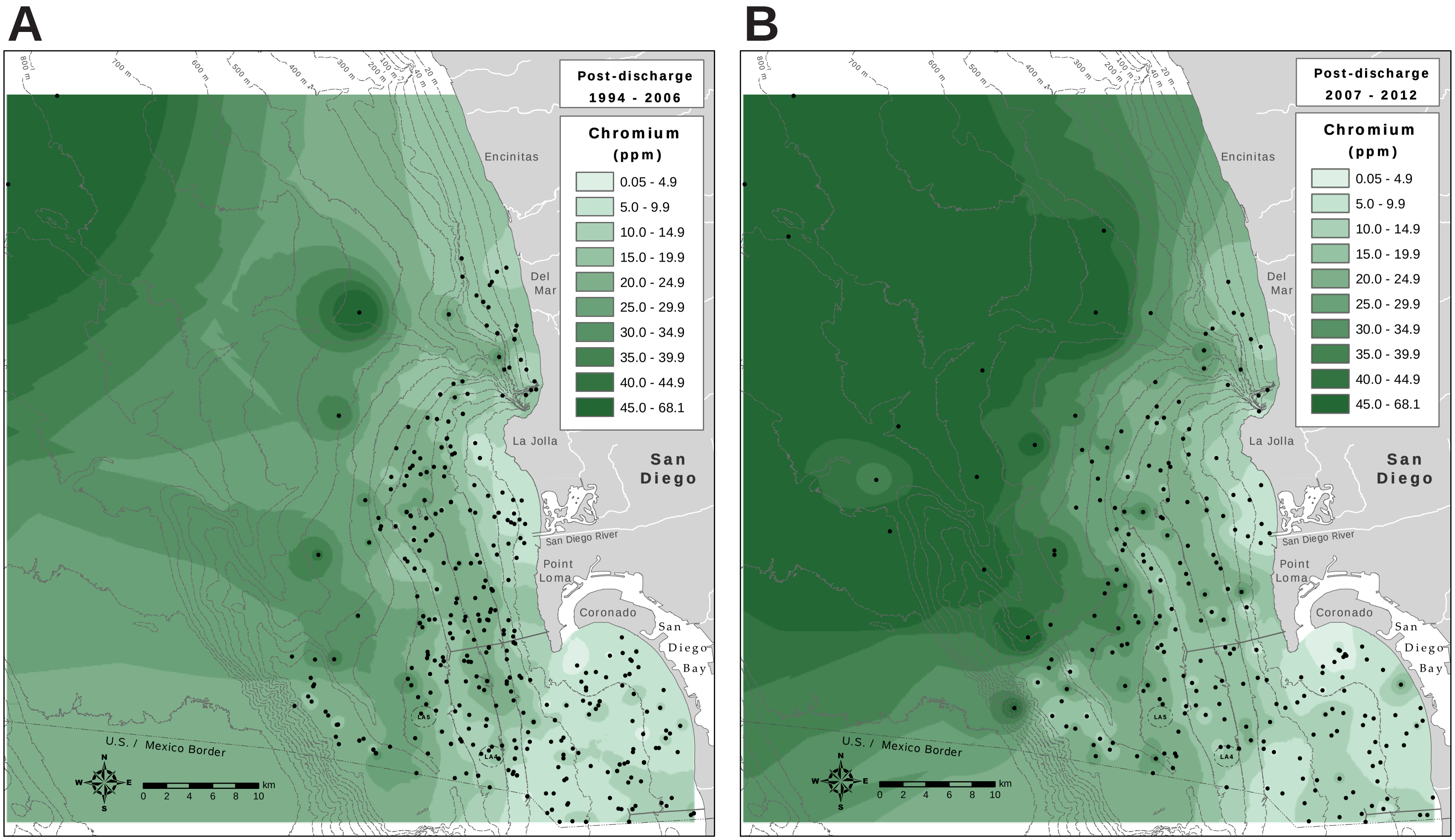

FIGURE C.3-10
Comparison of chromium concentrations in sediments for the San Diego coastal region during the 1994-2006 (A) and 2007-2012 (B) post-discharge periods. Data are expressed as parts per million (ppm) and were calculated using results from the San Diego annual regional surveys (1995-1997, 1999-2002, 2005-2007, 2009-2012), the Southern California Bight Pilot Project (1994), and the Bight'98, Bight'03, and Bight'08 regional monitoring programs (1998, 2003, 2008).

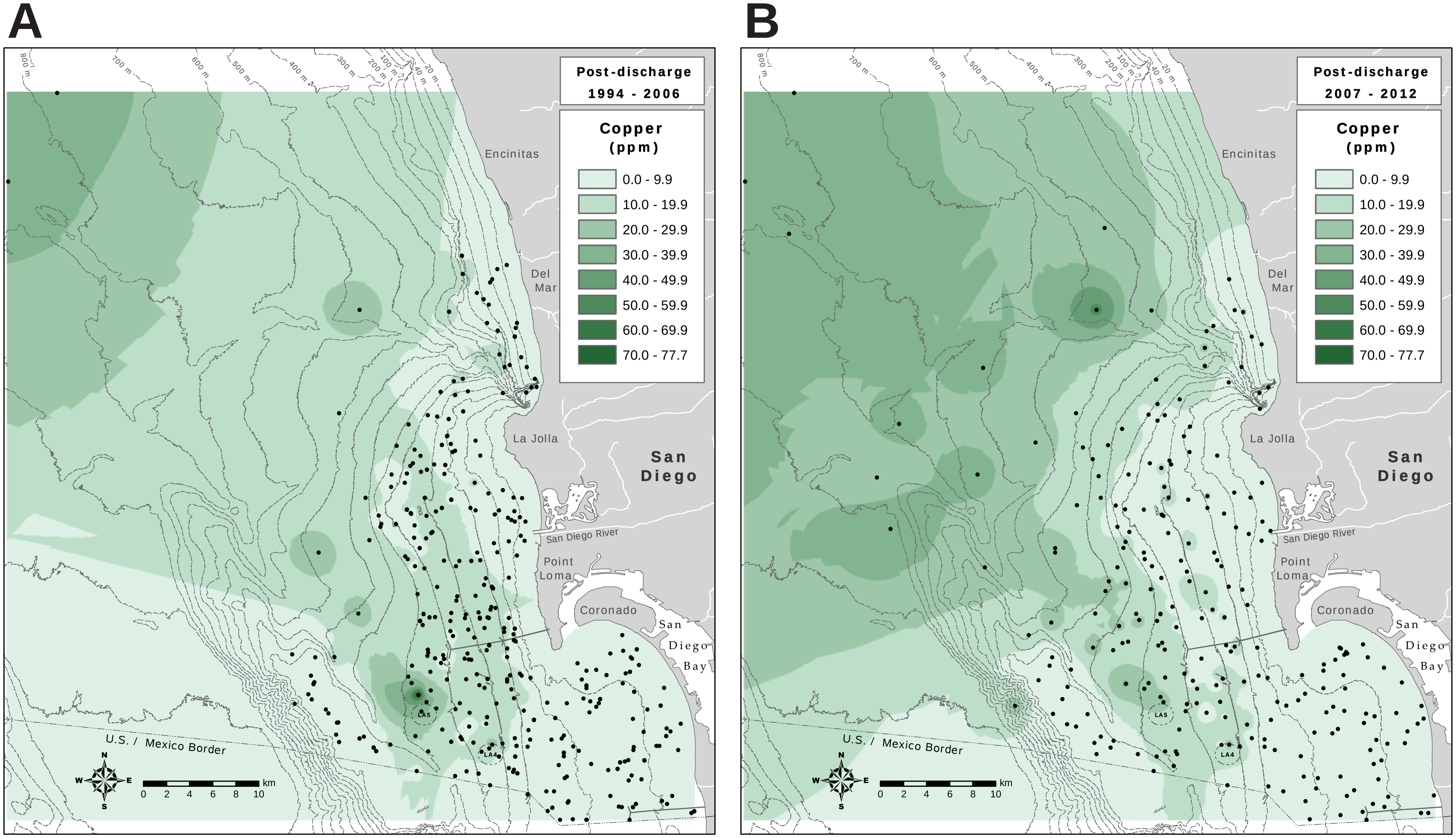

FIGURE C.3-11
Comparison of copper concentrations in sediments for the San Diego coastal region during the 1994-2006 (A) and 2007-2012 (B) post-discharge periods. Data are expressed as parts per million (ppm) and were calculated using results from the San Diego annual regional surveys (1995-1997, 1999-2002, 2005-2007, 2009-2012), the Southern California Bight Pilot Project (1994), and the Bight'98, Bight'03, and Bight'08 regional monitoring programs (1998, 2003, 2008).

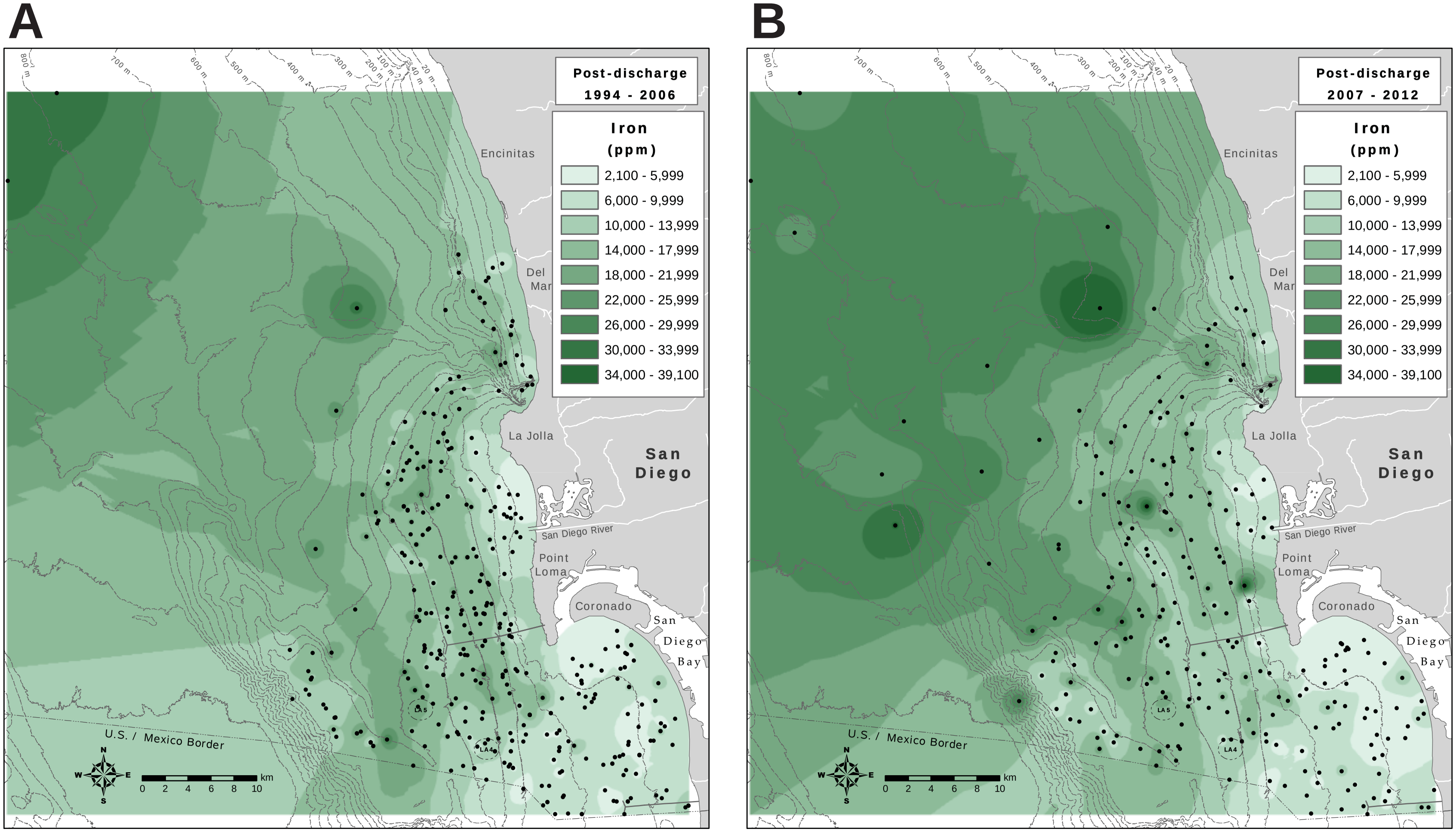

FIGURE C.3-12
Comparison of iron concentrations in sediments for the San Diego coastal region during the 1994-2006 (A) and 2007-2012 (B) post-discharge periods. Data are expressed as parts per million (ppm) and were calculated using results from the San Diego annual regional surveys (1995-1997, 1999-2002, 2005-2007, 2009-2012), the Southern California Bight Pilot Project (1994), and the Bight'98, Bight'03, and Bight'08 regional monitoring programs (1998, 2003, 2008).

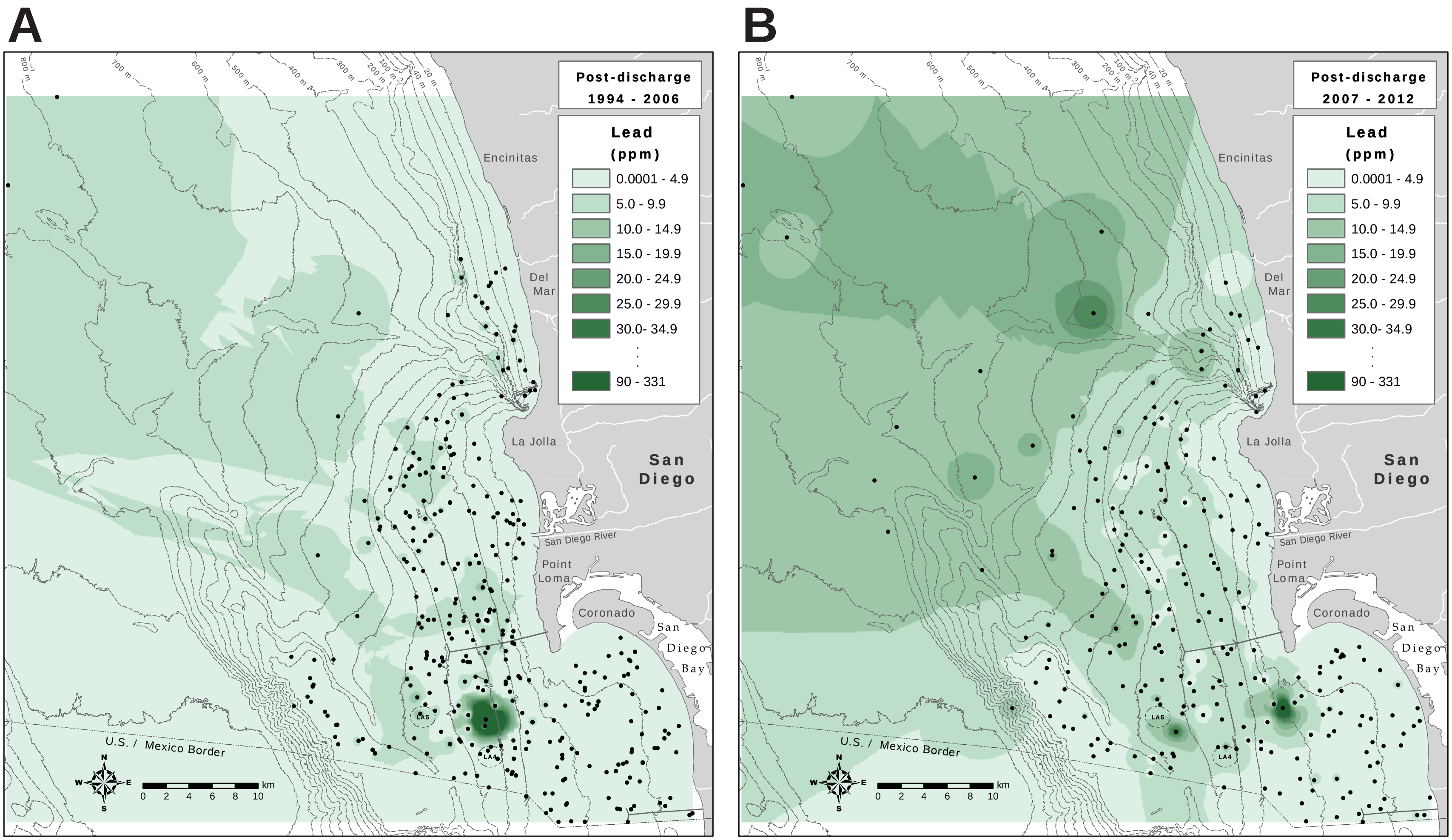

FIGURE C.3-13
Comparison of lead concentrations in sediments for the San Diego coastal region during the 1994-2006 (A) and 2007-2012 (B) post-discharge periods. Data are expressed as parts per million (ppm) and were calculated using results from the San Diego annual regional surveys (1995-1997, 1999-2002, 2005-2007, 2009-2012), the Southern California Bight Pilot Project (1994), and the Bight'98, Bight'03, and Bight'08 regional monitoring programs (1998, 2003, 2008).

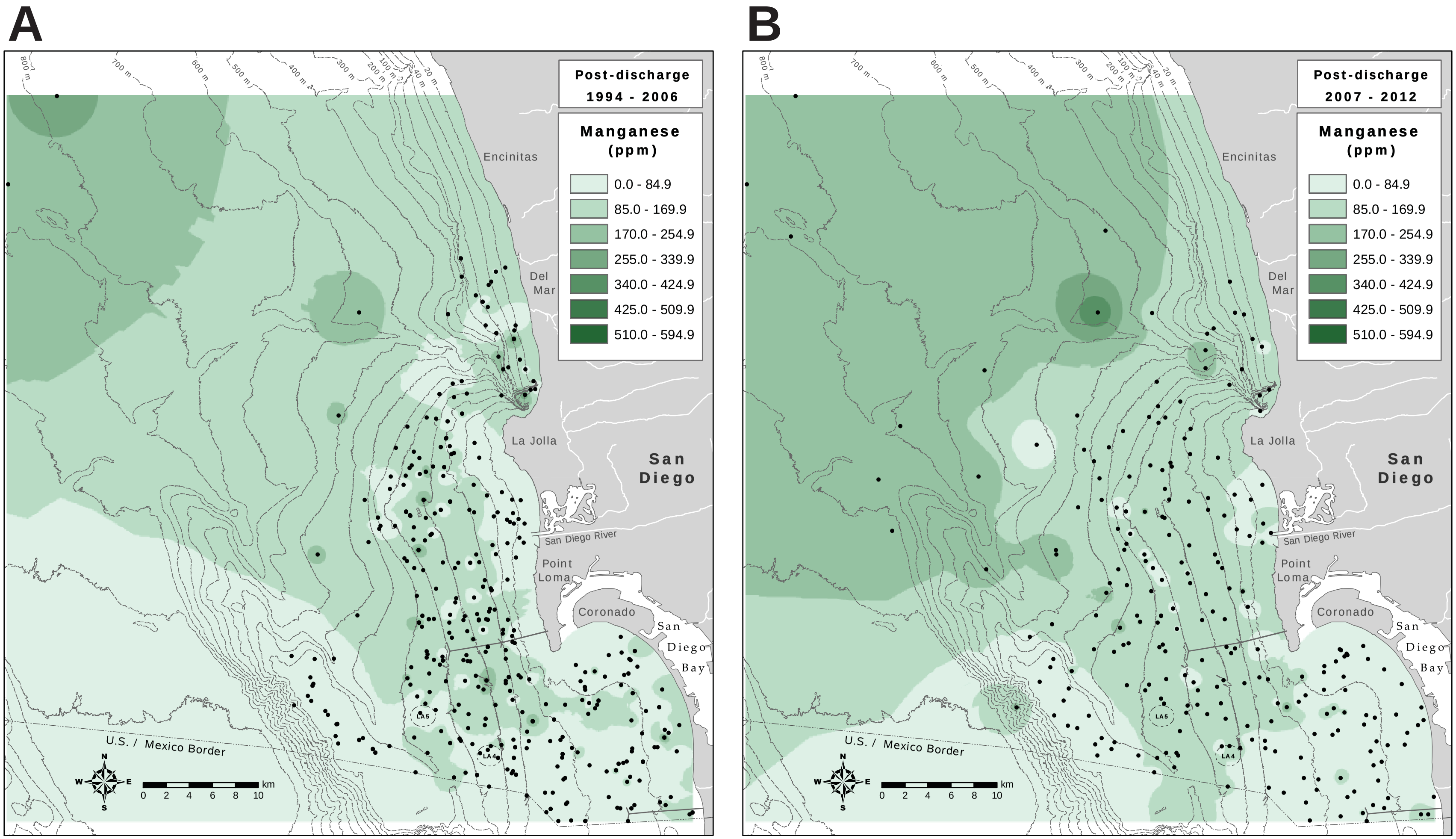

FIGURE C.3-14
Comparison of manganese concentrations in sediments for the San Diego coastal region during the 1994-2006 (A) and 2007-2012 (B) post-discharge periods. Data are expressed as parts per million (ppm) and were calculated using results from the San Diego annual regional surveys (1995-1997, 1999-2002, 2005-2007, 2009-2012), the Southern California Bight Pilot Project (1994), and the Bight'98, Bight'03, and Bight'08 regional monitoring programs (1998, 2003, 2008).

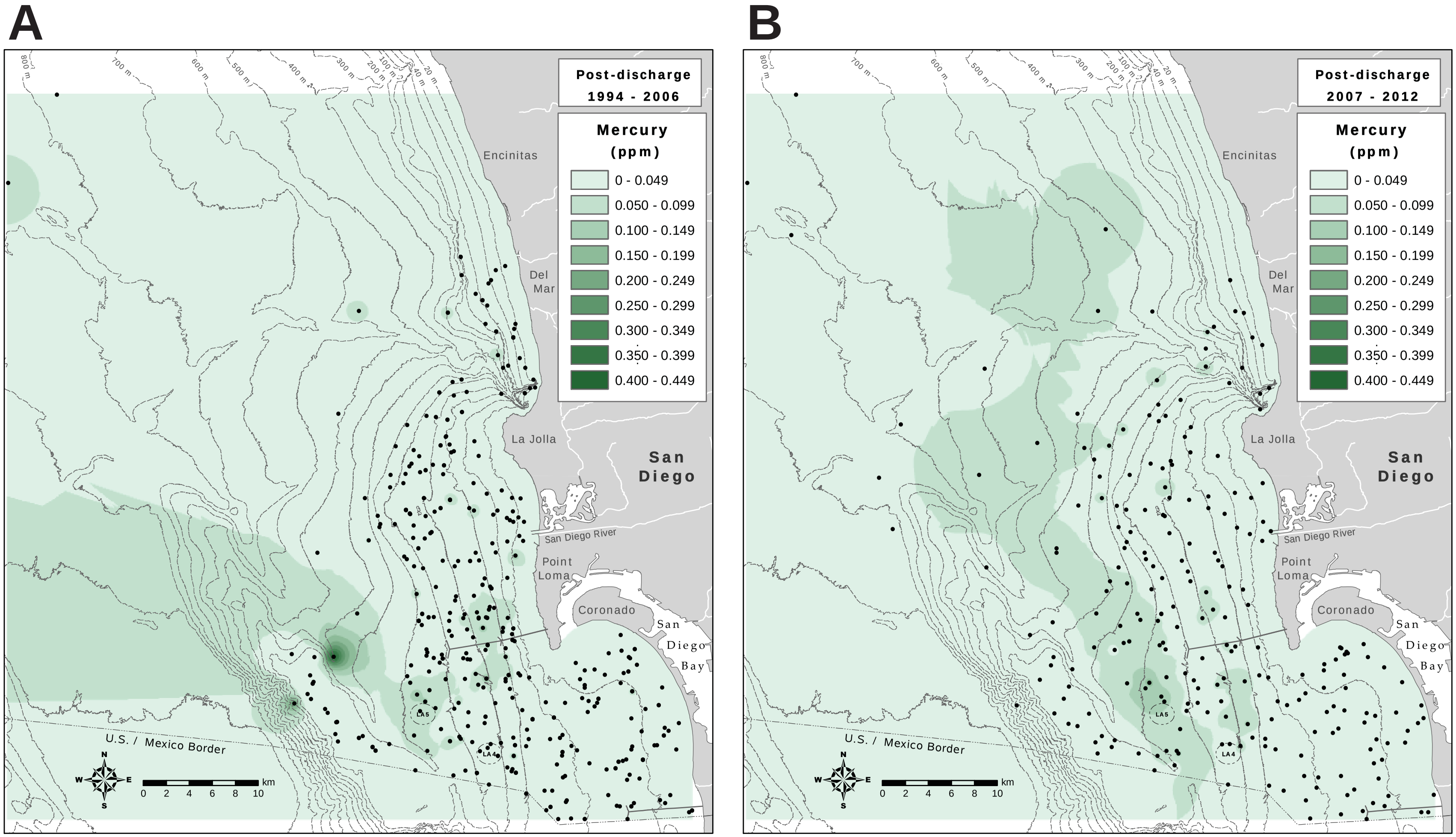

FIGURE C.3-15
Comparison of mercury concentrations in sediments for the San Diego coastal region during the 1994-2006 (A) and 2007-2012 (B) post-discharge periods. Data are expressed as parts per million (ppm) and were calculated using results from the San Diego annual regional surveys (1995-1997, 1999-2002, 2005-2007, 2009-2012), the Southern California Bight Pilot Project (1994), and the Bight'98, Bight'03, and Bight'08 regional monitoring programs (1998, 2003, 2008).

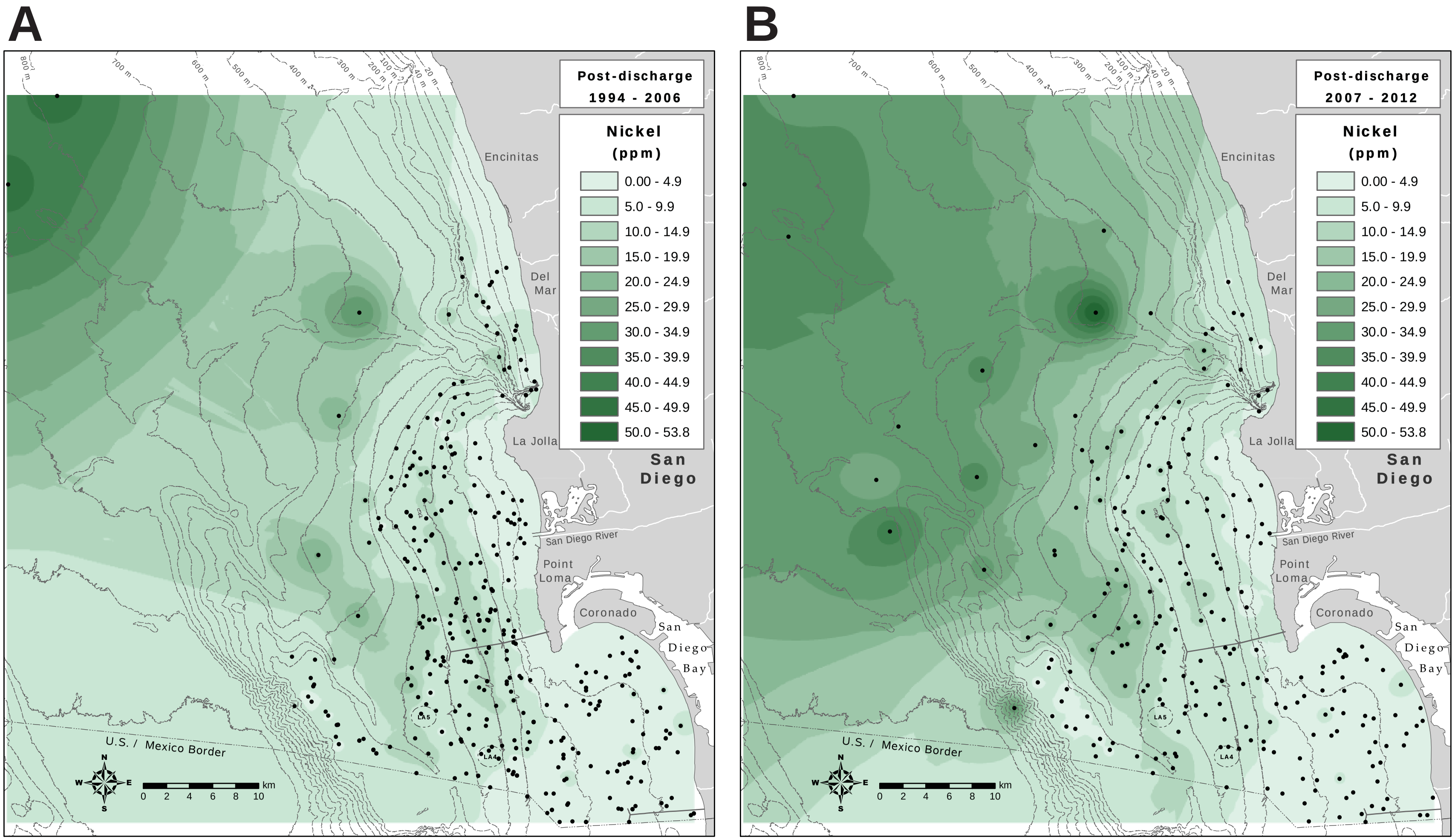

FIGURE C.3-16

Comparison of nickel concentrations in sediments for the San Diego coastal region during the 1994-2006 (A) and 2007-2012 (B) post-discharge periods. Data are expressed as parts per million (ppm) and were calculated using results from the San Diego annual regional surveys (1995-1997, 1999-2002, 2005-2007, 2009-2012), the Southern California Bight Pilot Project (1994), and the Bight'98, Bight'03, and Bight'08 regional monitoring programs (1998, 2003, 2008).

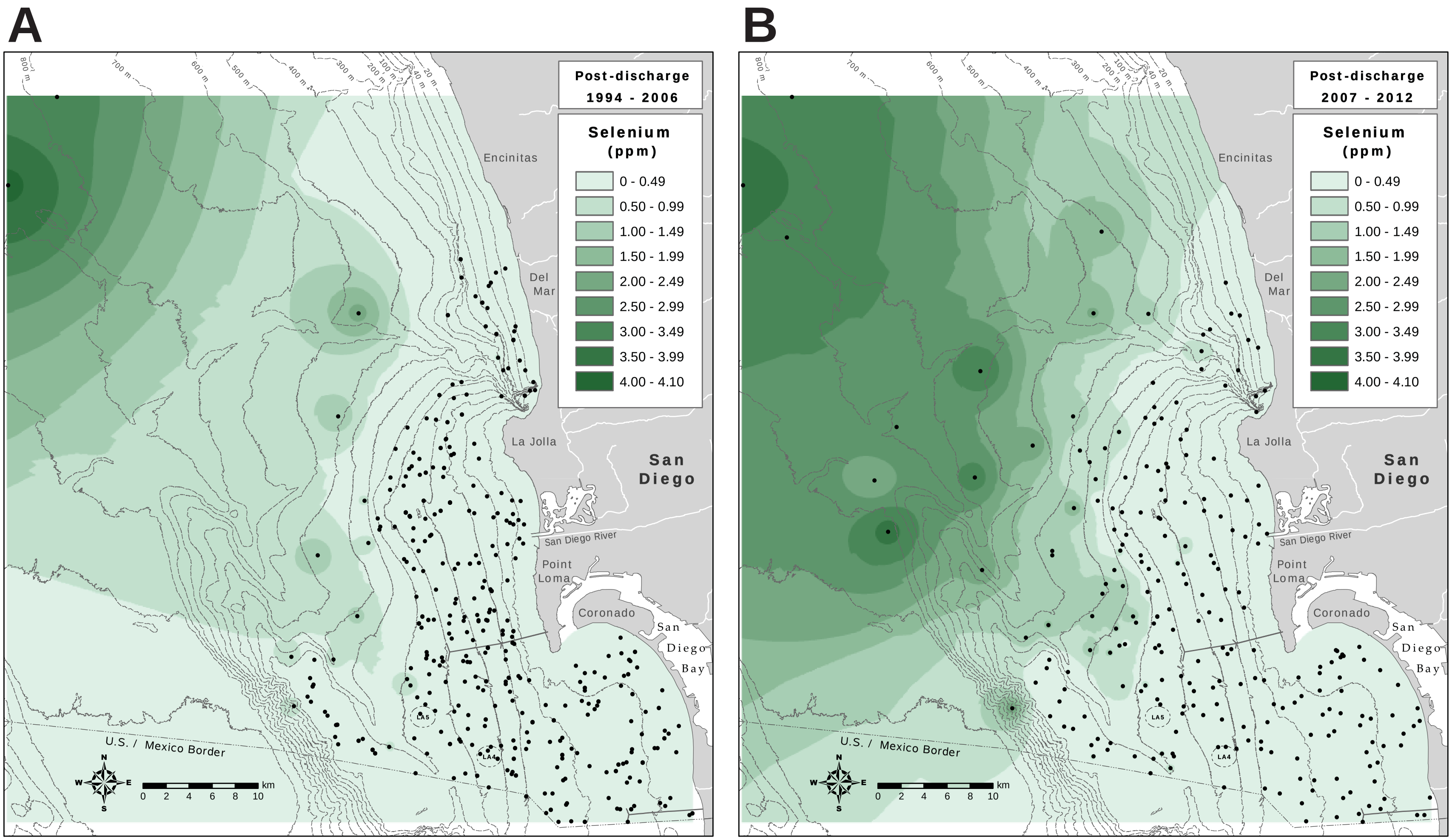

FIGURE C.3-17

Comparison of selenium concentrations in sediments for the San Diego coastal region during the 1994-2006 (A) and 2007-2012 (B) post-discharge periods. Data are expressed as parts per million (ppm) and were calculated using results from the San Diego annual regional surveys (1995-1997, 1999-2002, 2005-2007, 2009-2012), the Southern California Bight Pilot Project (1994), and the Bight'98, Bight'03, and Bight'08 regional monitoring programs (1998, 2003, 2008).

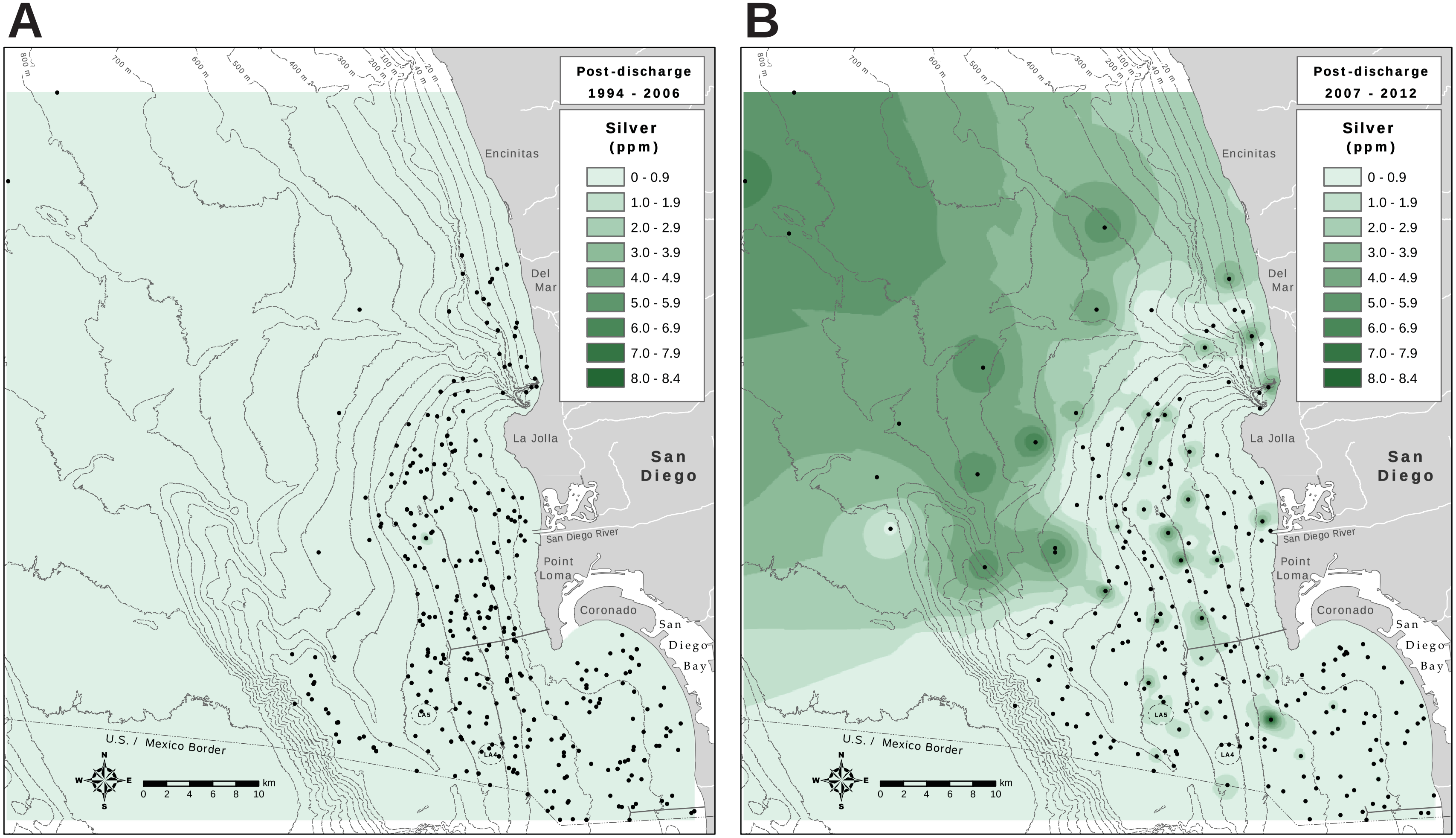

FIGURE C.3-18
Comparison of silver concentrations in sediments for the San Diego coastal region during the 1994-2006 (A) and 2007-2012 (B) post-discharge periods. Data are expressed as parts per million (ppm) and were calculated using results from the San Diego annual regional surveys (1995-1997, 1999-2002, 2005-2007, 2009-2012), the Southern California Bight Pilot Project (1994), and the Bight'98, Bight'03, and Bight'08 regional monitoring programs (1998, 2003, 2008).

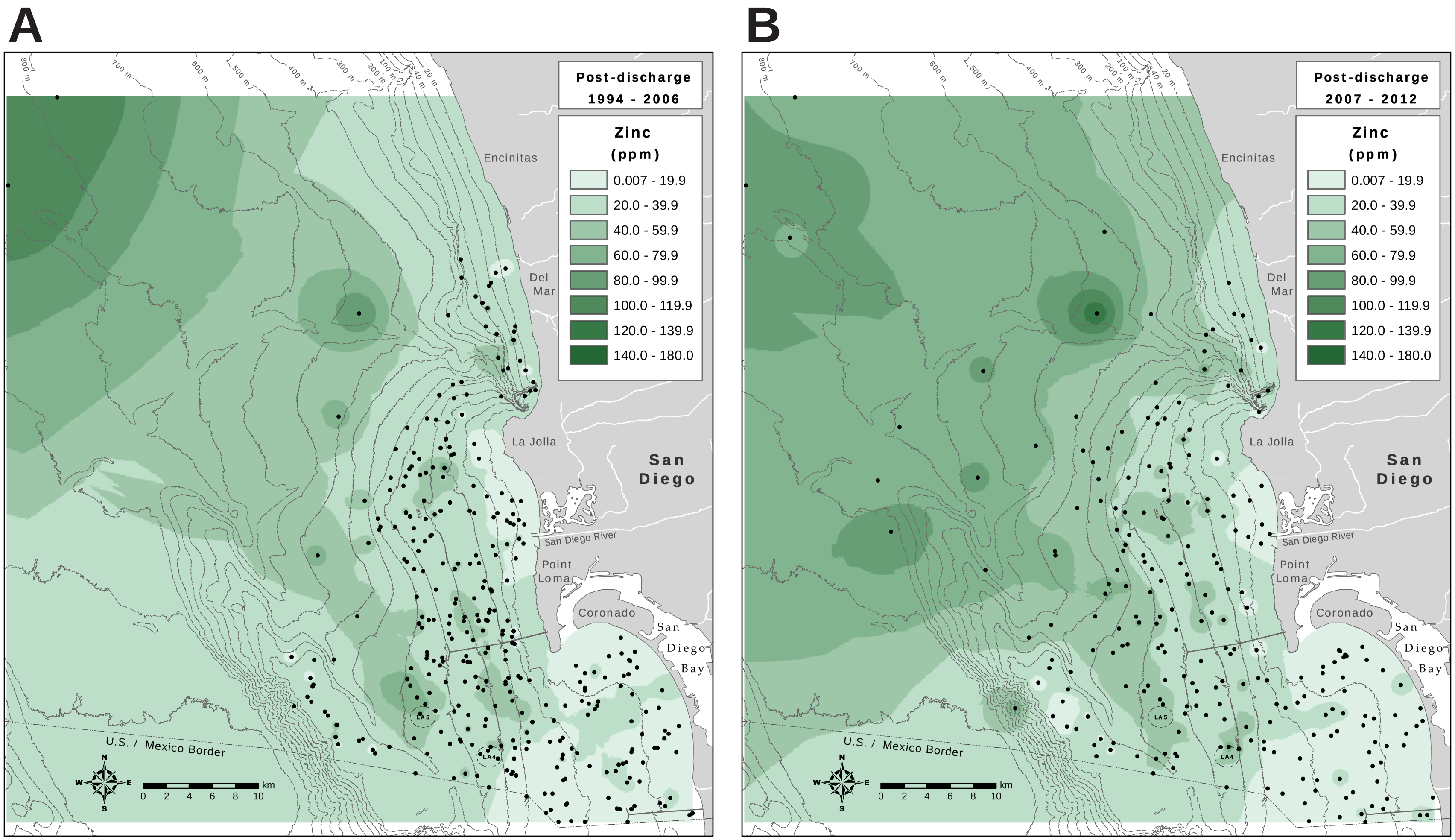

FIGURE C.3-19
Comparison of zinc concentrations in sediments for the San Diego coastal region during the 1994-2006 (A) and 2007-2012 (B) post-discharge periods. Data are expressed as parts per million (ppm) and were calculated using results from the San Diego annual regional surveys (1995-1997, 1999-2002, 2005-2007, 2009-2012), the Southern California Bight Pilot Project (1994), and the Bight'98, Bight'03, and Bight'08 regional monitoring programs (1998, 2003, 2008).

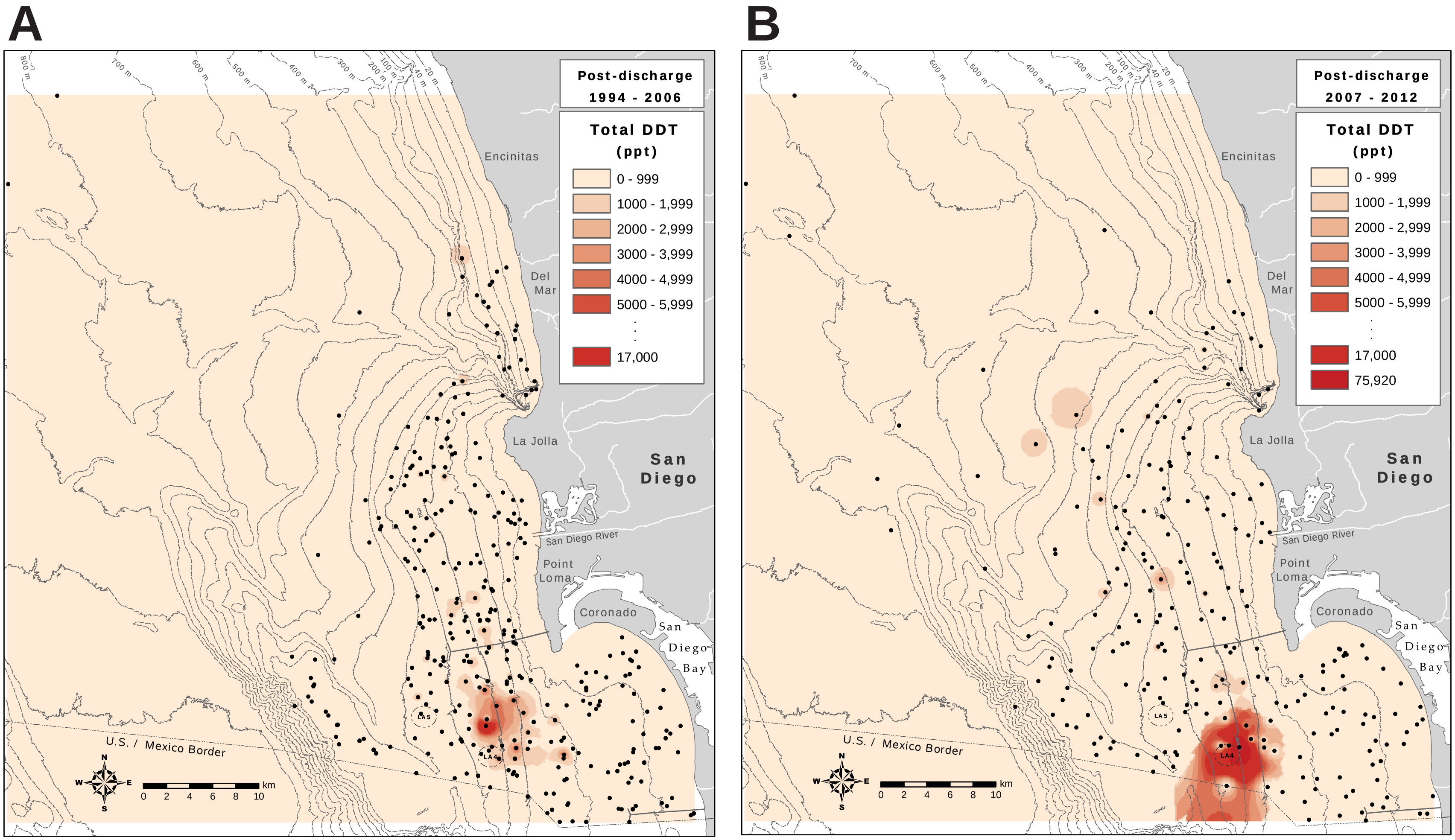

FIGURE C.3-20

Comparison of DDT concentrations in sediments for the San Diego coastal region during the 1994-2006 (A) and 2007-2012 (B) post-discharge periods. Data are expressed as parts per trillion (ppt) and were calculated using results from the San Diego annual regional surveys (1995-1997, 1999-2002, 2005-2007, 2009-2012), the Southern California Bight Pilot Project (1994), and the Bight'98, Bight'03, and Bight'08 regional monitoring programs (1998, 2003, 2008).

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Appendix C.4
SAN DIEGO
SEDIMENT MAPPING STUDY

Renewal of NPDES CA0107409

APPENDIX C.4

SAN DIEGO SEDIMENT MAPPING STUDY

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January 2015

APPENDIX C.4

San Diego Sediment Mapping Study

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APPENDIX C.4

San Diego Sediment Mapping Study

SECTION C.4-1 | INTRODUCTION

The Sediment Mapping Study was one of the first research projects approved by the San Diego Regional Water Quality Control Board (RWQCB) to meet the requirements of the "special studies" clause that was added to the NPDES permits and waiver for the first time in 2002 (NPDES Permit No. CA0107409, Order No. R9-2002-0025, Addendum No. 1). As such, the City was mandated to conduct this “special study” as part of the regulatory requirements governing the discharge of wastewater from the Point Loma Wastewater Treatment Plant (PLWTP) through the Point Loma outfall. The Model Monitoring Program for Large Ocean Discharges in Southern California (Schiff et al. 2001) defines special studies as unique mechanisms to focus monitoring efforts on specific questions. In the case of the City of San Diego's Ocean Monitoring Program, special studies are intended to address the need for enhanced environmental monitoring of the San Diego coastal region as recommended by the final finding of the Point Loma Outfall Project (PLOP) report (SIO 2004).

The goal of the Sediment Mapping Study was to investigate the potential of the kriging geostatistical interpolation technique for developing an accurate map of sediment and infauna conditions for the benthic marine environment off the coast of San Diego. Maps are easy to display, intuitively easy to understand, and since they give the viewer context over the entire area of interest, they are highly effective communication tools. Maps provide environmental managers with the ability to assess spatial patterns over a large spatial extent to detect any changes in sediment conditions (e.g., sediment quality, biotic communities) over time and distinguish impacted areas from reference areas. Despite their potential utility, however, most maps have traditionally been built using simple statistical tools to contour the data derived from relatively coarse sampling grids. As a result, most current maps of sediment condition (such as contaminant concentrations or grain size distributions) represent interpolations that do not include confidence estimates of their predictions. If the sample density is too low and combined with unsophisticated statistical tools, the accuracy of the resultant map can't be quantified, and the results should not be considered reliable.

To overcome this limitation and in partnership with the Southern California Coastal Water Research Program (SCCWRP), the City of San Diego proposed a resource-intensive study using a "multi-lag cluster design". This carefully constructed sampling scheme was designed to optimize the results obtained from the kriging method of spatial statistics, one of the more powerful statistical tools for mapping. Kriged maps are constructed using spatial variance among neighboring sampled locations to predict values in unsampled areas located between the sampled sites. Modeling spatial variance also enables calculation of confidence, which informs the process of determining optimal distances between sampling sites for mapping. If the spatial variance is high, then samples should be collected closer together to increase confidence at unsampled locations. If spatial variance is low, then samples can be spaced further apart to achieve the same confidence. Unless spatial variance is characterized, the sample locations will likely be placed inefficiently, suffering from imprecision if samples are spaced too far apart or wasted resources if samples are placed too close together. If the spatial variability for an area is known, on the other hand, then optimal sampling distances can be selected based on the level of confidence desired by the end-user.

The San Diego Sediment Mapping Study was conceptualized as a two-phased project to achieve two primary goals: 1) estimate spatial variance; and 2) create a map of sediment condition using kriging of samples from an optimized sampling grid. Phase 1 was expansive and extended over a large area (over 400 km^2). It was designed to estimate spatial variance for both sediment quality and benthic macrofaunal community condition in two distinct areas of interest off San Diego, the Point Loma Ocean Outfall (PLOO) and South Bay Ocean Outfall (SBOO) monitoring areas (Stebbins et al. 2004). The fieldwork for this phase was completed during the summer of 2004. The goal of Phase 2 was to utilize an optimal resolution (spacing) of sample sites to generate a completed map of sediment chemistry conditions within a 30 km^2 area surrounding the PLOO. The fieldwork for this phase was completed during the summer of 2012. A summary of findings for Phase 1 and preliminary results from Phase 2 are presented herein.

SECTION C.4-2 | GENERAL METHODS

Sample Collection and Processing

Samples for benthic community analyses were collected for Phase 1 at each station using a double 0.1-m^2 Van Veen grab. To ensure consistency of grab samples, protocols established by the USEPA were followed to standardize sample disturbance and depth of penetration (USEPA 1987). One macrofauna grab was collected at most sites, but at "field duplicate" sites, two macrofauna grabs were collected. Samples collected for benthic community assessment were sieved aboard ship through a 1.0 mm screen setup. The organisms retained on the screen were placed in separate containers, relaxed for 30 minutes in a magnesium sulfate solution, and then fixed in buffered formalin. After a minimum of 72 hours, each sample was rinsed with fresh water and transferred to 70% ethanol. All animals were sorted from the sediment into major taxonomic groups by a subcontracted laboratory, and identified to species (or the lowest taxon possible) following SCAMIT (2013) nomenclature and enumerated by City of San Diego marine biologists.

For both Phase 1 and Phase 2, one or two (i.e., "field duplicate") sediment grabs were taken at each station for the analysis of various physical and chemical sediment parameters. Sub-samples were taken from the top 2 cm of the sediment surface and handled according to standard guidelines available in USEPA (1987). All sediment chemistry and particle size analyses were performed at the City of San Diego's Environmental Chemistry Services Laboratory; a detailed description of analytical protocols can be found in City of San Diego (2005, 2013). A summary of parameters measured during each survey is listed in Attachment C.4-A with method detection limits (MDLs). Sediment chemistry data were generally limited to values above the MDL for each parameter. However, concentrations below MDLs were included as estimated values if the presence of a specific constituent was verified by mass-spectrometry.

Particle size analysis was performed using either a Horiba laser scattering particle analyzer or a set of nested sieves. The Horiba measures particles ranging in size from 0.5 to 2000 µm. Coarser sediments were removed and quantified prior to laser analysis by screening samples through a 2000 µm mesh sieve. These data were later combined with the Horiba results to obtain a complete distribution of particle sizes totaling 100%. When a sample contained substantial amounts of coarse sand, gravel, or shell hash that could damage the Horiba analyzer and/or where the general distribution of sediments would be poorly represented by laser analysis, a set of sieves with mesh sizes of 2000 µm, 1000 µm, 500 µm, 250 µm, 125 µm, and 63 µm was used to divide the samples into seven fractions. Sieve results and output from the Horiba were classified into size fractions (i.e., fine particles, fine sands, medium-coarse sands, coarse particles) based on the Wentworth scale (Folk 1980) for subsequent analyses.

Data Analyses

Benthic Infauna

The following community structure parameters were calculated per 0.1 m^2 grab: species richness (number of species), abundance (number of individuals), Shannon diversity index (H' per grab), Pielou's evenness index (J' per grab), Swartz dominance (minimum number of species accounting for 75% of the total abundance in each grab), and Benthic Response Index (mean BRI per grab, see Smith et al. 2001).

To examine spatial patterns in the benthic macrofaunal data, multivariate analyses were conducted using PRIMER (Clarke and Warwick 2001, Clarke and Gorley 2006). These analyses included classification (cluster analysis) by hierarchical agglomerative clustering with group-average linking and ordination by non-metric multidimensional scaling (MDS). The macrofaunal abundance data were square root transformed and the Bray-Curtis measure of similarity was used as the basis for both classification and ordination.

Sediments

Phase 1 and Phase 2 data summaries for the various sediment parameters included detection rates, minimum, median, maximum, and mean values for all stations combined. All means were calculated using detected values only; no substitutions were made for non-detects in the data to avoid underestimating sediment contaminant loads (see Helsel 2005). Total DDT (tDDT), total hexachlorocyclohexane (tHCH), total chlordane, and total PCB (tPCB) were calculated for each sample as the sum of all constituents with reported values. Sediment contaminant concentrations were compared to the Effects Range Low (ERL) and Effects Range Median (ERM) sediment quality guidelines of Long et al. (1995) when available. The ERLs represent chemical concentrations below which adverse biological effects are rarely observed, while values above the ERL but below the ERM represent levels at which effects occasionally occur. Concentrations above the ERM indicate likely biological effects, although these are not always validated by toxicity testing (Schiff and Gossett 1998).

Spearman rank correlations were calculated to assess if values for the various parameters co-varied in sediments. This non-parametric analysis accounts for non-detects in the data without the use of value substitutions (Helsel 2005). However, depending on the data distribution, the instability in rank-based analyses may intensify with increased censoring (Conover 1980). Therefore, a criterion of <50% non-detects was used to screen eligible constituents for this analysis.

SECTION C.4-3 | SUMMARY FOR PHASE 1

Sample Grid Design

Phase 1 focused on understanding spatial variability in the areas of interest. Once the spatial variability was determined, sampling distances (or lag distances) could then be optimized for the second phase (Phase 2). A variogram plot is used to model spatial variability in an area of interest and is the key to determining the optimal lag distances and other model parameters to be used when creating a map using kriging. The variogram (Figure C.4-1) plots one-half the variance (gamma) against a series of fixed distances and has three reference points known as the nugget, sill, and range.

The nugget indicates the variability between samples taken at very close proximities and represents both laboratory measurement error plus small-scale spatial variability. The sill is the variability achieved between samples spaced sufficiently far apart that a spatial relationship no longer exists. In this sense, the sill provides a measure of the variability among spatially independent samples. The range is the lag distance at which the sill is achieved and provides the limit to the extent of the spatial relationships between sample points.

The primary focus of Phase 1 was to generate sufficient information to create valid variograms for the target analytes in the areas of interest. This required sampling a large range of lag distances from the nugget, past the range, to the sill with a good number of samples collected at distances between the nugget and sill in order to best define the shape of the variogram curve. In order to generate these data, several clusters of sites were sampled at multiple locations throughout the mapping areas. Clusters were placed on top of existing regular monitoring grid sites to promote efficiency. S-shaped or more complex multi-lag clusters (i.e., overlapping S-clusters) can provide tremendous value since they cover a large range of lag distances (Ritter and Leecaster 2007).

To create variograms for sediment condition in the two main areas offshore of San Diego, several S-shaped multi-lag clusters were placed in each area of interest. Five clusters were centered around the PLOO, and another four clusters plus one half-cluster were centered around the SBOO. Additional spatial coverage was provided by sampling regular NPDES-mandated grid sites in both areas (Figures C.4-2 and C.4-3).

The clusters placed off Point Loma surrounded the existing outfall discharge/diffuser site (depth ~100 m). Sampling stations were located both north and south of the outfall, in shallower waters between the current wye and the old wye (depth ~60 m), and in an area bordering the LA-5 dredged materials disposal site located south-southwest of the outfall. Clusters in the South Bay outfall region were placed near the present outfall diffusers (depth ~30 m), in slightly deeper waters west and north-northwest of the discharge site, and at several other locations north and south of the outfall.

A total of 216 sediment chemistry and 227 infauna samples were collected on the continental shelf off San Diego and northern Baja California at depths from 17 to 224 m from a large area surrounding the PLOO and SBOO (Table C.4-1). For the Point Loma region, 13 of the sites are part of the existing PLOO monitoring grid; these include 12 primary core stations located along the 98-m depth contour and one secondary core station located along the 116-m depth contour. Additionally, eight other stations were included that correspond to the original PLOO discharge site; these are located along the 60-m depth contour. The remaining 80 sites were new locations allocated among five multi-lag clusters. For the South Bay outfall region, 27 of the sites are part of the existing SBOO monitoring grid while the remaining 69 sites were allocated to the multi-lag clusters. Duplicate sediment samples were taken at 11 of the PLOO area stations and 8 of the SBOO area stations (~10% of sites) to help derive the variogram nugget, thus reducing the total number of distinct sites sampled. Duplicate infauna samples were taken at 22 of the PLOO area stations and 8 of the SBOO area stations.

Benthic Infauna

Community Parameters

A total of 984 macrobenthic taxa were identified during the survey. Of these, 17% represented rare or unidentifiable taxa that were recorded only once. The number of taxa per station ranged from 28 to 206 (Table C.4-2). Macrofaunal abundance ranged from 67–955 individuals per grab. The greatest number of animals occurred at stations SM028 and SM019, both of which had over 900 individuals per grab. Three other stations had abundance values greater than 800 individuals per grab, while most sites had values between 200–500 individuals per grab.

Species diversity (H’) varied among stations, and ranged from 1.9 to 4.6 (Table C.4-2). Although most of the stations had values between 3.0 and 4.0, stations with the highest diversity (i.e., $\geq$4.0, n=38) were found mostly along the mid shelf as expected. The lowest value occurred at station

I15, a shallow water station located near the SBOO terminus. Species dominance was measured as the minimum number of species whose combined abundance accounts for 75% of the individuals in a sample (Swartz et al. 1986, Ferraro et al. 1994). Consequently, dominance as discussed herein is inversely proportional to numerical dominance, such that low index values indicate communities dominated by few species. These values varied widely throughout the region, ranging from 4 to 63 species per station.

Benthic Response Index (BRI) values at most stations were indicative of undisturbed communities or "reference conditions." Index values below 25 suggest undisturbed communities or "reference conditions," and those in the range of 25–33 represent "a minor deviation from reference condition," (Smith et al. 2001). Values greater than 44 indicate a loss of community function. BRI values throughout the San Diego region were generally indicative of reference conditions. Index values ≥25 were restricted to 10 grabs: I9, I9 dup, SM042, SM043, SM089, SM130, SM138, SM143, SM145, and SM146 (Attachment C.4-B).

Classification of Assemblages

Ordination and classification (cluster) analyses illustrate the biological patterns at the community level for benthic stations sampled during Phase 1 of the Sediment Mapping Study (Figure C.4-4). Cluster analysis discriminated seven groups (cluster groups A–G) that occurred at 1 to 114 sites each. Assemblages represented by each cluster group differed primarily by depth, location, and species composition (Table C.4-3, Figure C.4-4). The species composition and main descriptive characteristics of each cluster group are described below.

Cluster group A consisted of one station (I23, 21 m) with coarse sediments (11% fine particles) and contained 72 taxa and 830 individuals per grab. Total organic carbon (TOC) concentration at this station was 0.1%. Nematodes were the most abundant animals characterizing this assemblage, followed by *Saccocirrus* sp and *Hesionura coineaui difficilis*.

Cluster group B consisted of 47 nearshore stations located in the SBOO area that ranged in depth from 17 to 60 m. Sediments at stations within this group averaged 15% fines. Overall, the benthic assemblages represented by this group were typical of the shallow water sites in the region. Group B averaged 78 taxa and 284 individuals per grab. The dominant species included the polychaetes *Monticellina siblina*, *Spiophanes norrisi*, and *Spiophanes duplex*.

Cluster group C included 46 sites primarily located between 19 and 60 m, where sediments were coarse, containing only 4% fine particles. TOC at stations within this group averaged 0.1%. Assemblages represented by this group averaged 74 taxa and 354 individuals per grab. The polychaetes *Spiophanes norrisi*, and *Euchone arenae* and the crustacean *Ampelisca cristata cristata* were the numerically dominant species in this group.

Cluster group D represented the deepest eight outer shelf stations (mean depth=193 m). This group contained 64% fine sediments and averaged the highest concentration of TOC (1.1%). Group D had the lowest average number of species (55 taxa/grab and abundance (125 individuals/grab). The most abundant species were the polychaetes *Spiophanes kimballi* and *Paradiopatra parva*, and *Spiophanes berkeleyorum*.

Cluster group E consisted of two stations nearest the PLOO terminus (97 m). Sediments at these two stations were relatively coarse, averaging 12% fines. Species richness averaged 118 taxa and abundance averaged 818 individuals per grab. The dominant species included two polychaetes, *Mediomastus* sp and *Chloeia pinnata*, and the bivalve *Parvilucina tenisculpta*.

Cluster group F was composed of 9 transitional stations that were located at depths between 38 and 58 m. The sediments at these sites were generally mixed with about 27% fines and TOC concentrations were about 0.5%. Group F averaged 149 taxa and 485 individuals per grab. Dominate species included the polychaetes *Spiophanes duplex*, and *Sthenelanella uniformis* as well as the ostracod *Euphilomedes carcharodonta*.

Cluster group G comprised most (114) of the mid-shelf sites ranging in depth from 55 to 143 m. This cluster group, characterized by mixed sediments averaging 39% fines (23–58%), had an average species richness of 101 taxa and an average abundance of 388 individuals per grab. Assemblages represented by this group are typical of the ophiuroid dominated community that occurs along the mainland shelf off southern California. The most abundant species representing this mid-shelf group were the ophiuroid *Amphiodia urtica* and juvenile amphiurids, as well as the polychaetes *Myriochele striolata, Spiophanes duplex* and *Proclea* sp A.

Sediments

Sediment particle size and chemistry parameters are summarized across all stations and by region in Table C.4-4. Sediment composition was highly variable, with percent fines ranging from 0 to 76%, fine sands ranging from 3 to 82%, medium-coarse sands ranging from <1% to 86%, and coarse particles ranging from 0 to 58%. Detection rates were ≥77% for total nitrogen (TN), total organic carbon (TOC), total solids (TS), total volatile solids (TVS), and 15 out of 18 trace metals. In contrast, detection rates of selenium, silver, thallium, and total DDT ranged from 11 to 44%, while total PCB was found at ≤1% of the sites, and the pesticide chlordane was not detected. Overall, concentrations of the various parameters were variable with very few exceedances of available ERL and ERM thresholds (see Long et al. 1995). For example, arsenic, cadmium, chromium, lead, and silver never exceeded their ERL or ERM (for threshold values, see Table C.4-7), while exceedances for copper, mercury, nickel, and total DDT were rare (i.e., ≤1.4% of the Phase 1 sites). Zinc exceeded its ERL and its ERM at ~4% and <1% of all stations, respectively. None of the exceedances found during Phase 1 of this study occurred at PLOO or SBOO regular fixed-grid monitoring stations, or at the two Sediment Mapping stations located within close proximity to the PLOO (i.e., SMO42, SM043).

An initial investigation of an inverse distance weighting interpolation map for the percent fines results suggested that the PLOO region and the SBOO region represent distinctly different sediment regimes with substantial patchiness within each survey area (Figure C.4-5). This conclusion is supported by sediment composition found at PLOO stations, which averaged 46% fines, 45% fine sands, and <6% medium-coarse sands or coarse particles, versus the sediment composition found at SBOO stations, which averaged 15% fines, 45% fine sands, 37% medium-coarse sands, and ~3% coarse particles (Table C.4-4). These results are also consistent with historical findings for the PLOO and SBOO monitoring regions (City of San Diego 2014a, 2014b).

The Spearman rank correlation results for this study indicated that over half of the sediment chemistry analytes that were detected frequently enough (see methods) for correlation analysis co-varied with percent fines (10 analytes had high correlation, see Table C.4-5). This finding, combined with the well-established differences in the percent fines distribution for the PLOO versus SBOO regions (see Figure C.4-6), made it clear why attempts to krige across the entire Phase 1 sediment mapping region did not yield coherent models.

Instead, ordinary kriging was performed on Point Loma region samples separately from the South Bay outfall region samples. The results presented here are for the Point Loma sample grid only, and examples of the ordinary kriging results are provided in Figure C.4-7. Models were based on lognormal transformed values with a second order trend removal and anisotropic correction applied. Most analytes demonstrated an angle of anisotropy ~160 degrees. Variability showed strong spatial dependence for each parameter but range and nugget values varied widely among analytes. Major range results were as low as 2.5 km and as high as 24 km (which was the full distance of the North-South extent of the Phase 1 sampling grid for Point Loma).

Because the strength of the variance differences between the major and the minor directions was unanticipated, and since the sample design was strongly North-South oriented (especially with regard to closely-spaced samples) the kriging results were of limited use in capturing a usable standard error for the models. The extent of the sampling grid also caused difficulties for interpreting kriging results due to the presence of multiple sources of possible contaminant input (e.g., from tidal flushing of San Diego Bay and Mission Bay, as well as from the LA5 dredge disposal site). The kriging predictions exhibited especially large errors as the prediction surface approached the east and west edges of the sample grid. These model limitations seem to suggest that the trend removal method was not adequate. It may be that a localized trend removal method based on field knowledge would be more effective than the universal second order polynomial trend correction that was used.

With the major range values highly variable across analytes, the high standard errors occurring along the outer portions of the study area in the minor range direction, and the relationship with depth likely a further complicating factor (due to the coarse resolution of the bathymetric digital elevation model available at the time), it was determined that a cost-efficiency curve would be estimated using just the percent fines and BRI models since these parameters gave acceptable error values when manually-imposed effective range values were applied to the models. Evaluating the model at varying spatial grid resolutions showed that, according to this model, there are diminishing returns to sampling with a grid resolution below 1000 m. Quadrupling effort/costs and sample sizes from 1000 m between samples down to 500 m between samples only gains ~4% reduction in error.

These models were then used to construct Figure C.4-8, a cost efficiency model (curve) which illustrates the relationship between percent of total error (i.e., statistical confidence) and distance between samples for estimating grain size (% fines) and biological condition (benthic response index or BRI). This curve shows about a 5-10% increase in confidence for every 500 m reduction in spacing.

These findings were used to develop the sampling design for Phase 2 of the Sediment Mapping Study. With a finely-spaced grid spanning a more limited, localized area that was pre-rotated to best account for the strong degree of anisotropy (i.e., angle of greatest directional variability) exhibited by most analytes, it was anticipated that the Phase 2 dataset would better capture the small-scale variability in the region surrounding the PLOO. It was also anticipated that designing a tighter grid to keep the extent of the study area restricted to the immediate area surrounding the outfall would reduce the effects of other possible anthropogenic sources of contaminants. In short, the new sample design customized to the sediment conditions surrounding the PLOO was expected to provide accurate kriging models and make it possible to create a series of statistically defensible maps representing the concentrations of many of the analytes measured.

SECTION C.4-4 | SUMMARY FOR PHASE 2

Background

The second phase of the Sediment Mapping Study was intended to leverage the information captured by the first phase of the project regarding the spatial characterization of sediment chemistry conditions in the region immediately surrounding the PLOO.

The ultimate question to be answered by this survey was whether an accurate map of benthic conditions could be generated from an intensive sampling effort based on a spatially optimized sampling grid. Since the results from the first phase of the study covered a very large area, with a complex suite of contaminant inputs, it was determined that attempting to utilize kriging interpolation methods to characterize the area encompassing both the Point Loma and South Bay offshore regions was ineffective. The regions are distinctive in every regard, including depth ranges, contaminant load, distribution of sediments, and current regimes.

One useful finding that resulted from the first phase of the project was related to the fairly consistent angle of anisotropy for most analytes. This allowed the sampling grid for the second phase of the project to be rotated to match the angle of anisotropy. Aligning the grid with the dominant angle of anisotropy allowed the development of a sample grid that balanced variability between the major and minor ranges. These optimized asymmetrical distances allowed a reasonable number of sampling stations to cover a wider area. This carefully constructed sampling scheme was designed to optimize the results from the kriging method of modeling spatial autocorrelation.

The sampling design was subjected to iterative improvements in satellite station placement, most notably to balance areal coverage versus sampling density. The final design maximized the area covered while still providing enough closely-spaced point pairs (see Figure C.4-9) to establish confidence in the final spatial model.

Sample Grid Design

Using the estimates of spatial variance from Phase 1, as well as the directions of highest and lowest variance, and the subregions that were identified areas of interest, an optimized sample grid was designed to achieve the goal of Phase 2: to create a cost efficient and statistically defensible map of sediment quality for the Point Loma outfall region. There were 133 sample sites distributed in an optimized design that utilized two different sampling densities within different regions of the survey area. The base grid had sites spaced 800 m apart in the cross-shore (greatest variability) direction and 1200m apart in the along-shore (least variability) direction. The enhanced grid area, which immediately surrounds the outfall, had samples spaced 550 m x 800 m apart (in the cross-shore and along-shore directions, respectively). Additional “satellite” stations were placed short distances (either 250 m or 500 m) away from their anchor points, which were a selected subset of the grid stations intended to provide good spatial coverage of the full study area (Figure C.4-10 and Table C.4-6). The rotation (tilted placement) of the Phase 2 station grid was to account for the strong directionality to the spatial variability of the distribution of percent fines and some of the metals in the Point Loma region derived from Phase 1. Finally, duplicate samples were collected at a subset of the new grid stations in order to estimate measurement error and small scale variability.

Preliminary Results

Sediment particle size and chemistry parameters are summarized across all Phase 2 Sediment Mapping stations in Table C.4-7. Sediment composition averaged 54% fines, 44% fine sands, and only traces of medium-coarse sands or coarse particles. Detection rates were ≥70% for total nitrogen (TN), total organic carbon (TOC), total solids (TS), total volatile solids (TVS), total DDT, and 16 out of 18 trace metals. In contrast, detection rates of selenium, aldrin, hexachlorobenzene (HCB), total chlordane, and total PCB were found at ≤42% of the stations, and thallium, HCH, dieldrin, endosulfan, endrin, and Mirex were never detected. Overall, concentrations of various parameters were variable with very few exceedances of available ERL and ERM thresholds (see Long et al. 1995). For example, arsenic, cadmium, chromium, lead, and zinc never exceeded their ERL or ERM, while exceedances for copper, mercury, nickel, and total DDT were rare (i.e., ≤7.5% of the samples included in this study). Silver exceeded its ERL and its ERM at 50% and <1% of all stations, respectively.

Preliminary results suggest that, even with a limited study area and an optimized sampling grid, it is still challenging to develop robust kriged models of the spatial variability of sediment chemistry parameters in the region surrounding the PLOO. The variability seems to exhibit a strong, locally varying trend. Models will need to be developed that will effectively account for this trend that, for most of the studied analytes, appears correlated with percent fines and fines-associated metals (Table C.4-8, Figures C.4-11 and C.4-12). In contrast, the distance from outfall factor was not well correlated with any analyte studied (data not shown). Considering these complicated relationships will require a robust method of trend removal before accurate, reliable kriging models can be developed. The de-trending and modeling process is currently underway with results expected to be published in Fall 2015.

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APPENDIX C.4

San Diego Sediment Mapping Study

TABLES

TABLE C.4-1

Sampling effort for Phase 1 of the Sediment Mapping Study for both the Point Loma and South Bay Ocean Outfall regions.

Point Loma Ocean Outfall Region

	60-m PLOO		98-m PLOO*		Sed Map		Total
Sample Type	**Sites**	**Dups**	**Sites**	**Dups**	**Sites**	**Dups**	**Samples**
Sediment	8	4	13	6	80	1	112
Macrofauna	8	8	13	13	80	1	123

South Bay Ocean Outfall Region

			28-m SBOO		Sed Map		Total
			Sites	**Dups**	**Sites**	**Dups**	**Samples**
Sediment	—	—	27	8	69	0	104
Macrofauna	—	—	27	8	69	0	104

* Includes one Secondary core station currently monitored along the 116-m depth contour

TABLE C.4-2

Summary of macrofaunal community parameters for all samples (n) collected during Phase 1 of the Sediment Mapping Study in 2004. SR=species richness (no. taxa/0.1 m^2); Abun =abundance (no. individuals/0.1 m^2); H'=Shannon diversity index; J'=evenness; Dom=Swartz dominance; BRI=benthic response index.

Region	Depth (m)	SR	Abun	H'	J'	Dom	BRI
PLOO Region (n=123)							
Min	45	42	67	2.0	0.40	4	0
Max	224	160	955	4.6	1.00	63	35
Mean	97	98	378	3.7	0.80	30	8
95%CI	6	4	29	0.0	0.00	2	2
SBOO Region (n=104)							
Min	17	28	82	1.9	0.50	6	3
Max	64	206	830	4.5	0.90	57	28
Mean	34	83	339	3.4	0.80	23	17
95%CI	2	6	27	0.2	0.00	2	2
All Stations (n=227)							
Min	17	28	67	1.9	0.50	4	0
Max	224	206	955	4.6	1.00	63	35
Mean	68	91	360	3.6	0.80	27	12
95%CI	6	4	20	0.0	0.00	2	2

TABLE C.4-3

Summary of the most abundant taxa comprising cluster groups A–G (see Figure C.4-4). Data are expressed as mean abundance per cluster group; n=number of grabs per cluster group.

		Cluster Group						
		A	**B**	**C**	**D**	**E**	**F**	**G**
Species/Taxa	**Taxa**	**n=1**	**n=47**	**n=46**	**n=8**	**n=2**	**n=9**	**n=114**
Ampelisca cristata cristata	Crustacea	—	4.4	9.3	—	—	0.2	0.1
Amphiodia urtica	Echinodermata	—	—	0.5	0.5	—	6.2	37.4
Amphiuridae	Echinodermata	1.0	1.2	4.5	0.4	0.5	2.4	22.4
Aoroides inermis	Crustacea	—	0.1	0.5	—	28.0	1.9	0.3
Aricidea (Acmira) simplex	Polychaeta	—	—	0.3	0.4	4.5	12.2	2.3
Gadila aberrans	Mollusca	—	9.4	0.7	—	—	1.6	0.4
Chloeia pinnata	Polychaeta	—	1.5	1.1	2.3	53.0	9.8	11.6
Euchone arenae	Polychaeta	70.0	—	15.8	0.1	—	0.1	0.2
Euphilomedes carcharodonta	Crustacea	—	10.4	2.9	—	1.0	12.4	6.5
Hesionura coineaui difficilis	Polychaeta	71.0	—	0.9	—	—	—	—
Mediomastus sp	Polychaeta	—	2.3	1.0	3.6	182.5	4.1	4.1
Monticellina siblina	Polychaeta	—	39.0	1.1	0.3	9.5	6.1	1.2
Mooreonuphis sp	Polychaeta	—	—	7.9	—	—	—	—
Myriochele striolata	Polychaeta	—	1.8	0.9	—	—	—	53.5
Nematoda	Nematoda	199.0	1.0	7.1	—	35.0	7.3	0.4
Paradiopatra parva	Polychaeta	—	0.5	0.1	5.0	6.5	5.3	4.7
Parvilucina tenuisculpta	Mollusca	—	0.5	0.1	2.0	43.5	1.7	1.4
Phyllochaetopterus limicolus	Polychaeta	—	0.1	—	3.5	—	—	—
Pisione sp	Polychaeta	56.0	—	0.5	—	—	—	—
Proclea sp A	Polychaeta	—	—	—	0.1	—	1.0	12.7
Saccocirrus sp	Polychaeta	95.0	—	—	—	—	—	—
Spiophanes berkeleyorum	Polychaeta	—	2.6	1.5	4.4	8.0	2.1	2.5
Spiophanes norrisi	Polychaeta	7.0	31.5	108.7	—	—	8.7	0.2
Spiophanes duplex	Polychaeta	—	10.4	3.5	0.9	2.5	64.0	12.2
Spiophanes kimballi	Polychaeta	—	—	—	20.5	12.5	0.4	6.9
Sthenelanella uniformis	Polychaeta	—	0.3	0.1	—	3.0	17.4	1.1

TABLE C.4-4

Summary of particle sizes and chemistry concentrations for Phase 1 Sediment Mapping samples collected in 2004. Data include detection rate (DR), minimum, median, maximum, mean, and 95% confidence intervals (CI) for the entire survey area, as well as mean and 95%CI by region; n=number of samples.

	Phase 1 Survey Area (n=216) [b]						PLOO Region (n=112) [b]		SBOO REgion (n=104) [b]	
	DR	**Min**	**Median**	**Max**	**Mean**	**95%CI**	**Mean**	**95%CI**	**Mean**	**95%CI**
Particle Size (%)										
Coarse Particles	—	0.00	0.00	58.20	2.85	0.96	2.80	1.33	2.90	0.70
Med-Coarse Sands	—	0.23	5.55	86.43	20.69	3.75	5.47	5.21	37.07	6.31
Fine Sands	—	3.37	47.20	81.67	45.21	2.75	45.45	3.82	44.95	5.25
Fines	—	0.00	30.99	76.43	31.28	2.69	46.30	3.73	15.10	2.34
Organic Indicators (%)										
TN[a]	98	nd	0.04	0.16	0.04	0.00	0.06	0.00	0.02	0.00
TOC[a]	99	nd	0.36	1.55	0.40	0.04	0.58	0.05	0.18	0.03
TS	100	2.98	72.95	82.30	72.59	1.01	69.39	1.57	76.03	0.87
TVS	100	0.38	1.99	68.20	2.29	0.62	3.37	1.16	1.12	0.14
Metals (ppm)										
Aluminum	100	1750	14450	32300	13575	896	17762	828	9065	1106
Antimony	88	nd	0.95	4.37	1.52	0.13	1.77	0.16	1.21	0.20
Arsenic	100	0.68	3.05	7.85	3.17	0.17	3.58	0.15	2.73	0.30
Barium	100	2.86	43.40	230.00	45.24	3.86	60.80	4.97	28.48	3.96
Beryllium	96	nd	0.18	0.43	0.18	0.01	0.21	0.02	0.15	0.01
Cadmium	77	nd	0.06	0.47	0.10	0.01	0.13	0.01	0.06	0.01
Chromium	100	5.28	18.50	50.40	19.77	1.02	24.14	1.25	15.05	1.07
Copper	100	0.16	7.24	35.10	8.80	0.92	12.37	1.08	4.96	1.12
Iron	100	2260	16100	33100	15825	801	19560	766	11802	968
Lead	99	nd	2.95	9.55	3.36	0.23	3.42	0.34	3.28	0.32
Manganese	100	31.8	245.5	605.0	238.1	12.5	281.9	9.7	190.9	20.2
Mercury	84	nd	0.022	0.212	0.031	0.004	0.044	0.005	0.010	0.003
Nickel	100	0.63	6.78	33.00	6.73	0.57	9.47	0.69	3.77	0.50
Selenium	7	nd	nd	0.72	0.38	0.02	0.41	0.03	0.17	0.03
Silver	31	nd	nd	0.46	0.11	0.01	0.15	0.01	0.11	0.01
Thallium	44	nd	nd	2.89	1.15	0.10	0.92	0.10	1.75	0.19
Tin	80	nd	0.72	3.38	1.13	0.10	0.77	0.14	1.48	0.11
Zinc	100	3.61	29.60	908.00	42.99	10.55	43.42	8.52	42.52	19.97
Pesticides (ppt)										
Total DDT	11	nd	nd	17000	1695	473	2121	852	1141	268
Alpha Chlordane	0	nd	—	—	—	—	—	—	—	—
Oxychlordane	0	nd	—	—	—	—	—	—	—	—
Gamma Chlordane	0	nd	—	—	—	—	—	—	—	—
Total PCB (ppt)	<1	nd	nd	1590	1590	—	1590	—	—	—

[a] Only 210 samples were analyzed for TN and TOC; see Attachment C.4 for MDLs and abbreviations

[b] Minimum, median, and maximum values were calculated using all samples, whereas means and CIs were calculated on detected values only; nd = not detected

TABLE C.4-5

Results of Spearman rank correlation analyses of depth, percent fines and various sediment chemistry parameters from Phase 1 of the Sediment Mapping Study. Correlation coefficients of 0.70 – 0.80 are highlighted in blue; 0.80 – 0.90 in pink; >0.90 in yellow. For all analyses, n= the number of detected values. See Attachment C.4-A for abbreviations.

	Fines	*Organic Indicators (%)*				**Metals (ppm)**														
	(%)	**TN**	**TOC**	**TS**	**TVS**	**Al**	**Sb**	**As**	**Ba**	**Be**	**Cd**	**Cr**	**Cu**	**Fe**	**Pb**	**Mn**	**Hg**	**Ni**	**Sn**	**Zn**
n	216	206	208	216	216	216	190	216	216	207	167	216	216	216	213	216	181	216	173	216
Depth (m)	0.65	0.59	0.62	-0.31	0.67	0.52	0.24	0.43	0.43	0.06	0.45	0.43	0.47	0.59	-0.21	0.47	0.62	0.62	-0.71	0.26
Fines (%)		0.96	0.96	-0.84	0.93	0.88	0.46	0.34	0.76	0.52	0.64	0.82	0.71	0.81	-0.04	0.70	0.85	0.90	-0.61	0.44
Organic Indicators (%)																				
TN			0.99	-0.83	0.91	0.83	0.47	0.29	0.71	0.59	0.64	0.82	0.69	0.77	-0.02	0.65	0.82	0.89	-0.60	0.39
TOC				-0.82	0.91	0.84	0.46	0.30	0.72	0.59	0.65	0.82	0.69	0.77	-0.02	0.65	0.84	0.90	-0.60	0.39
TS					-0.78	-0.82	-0.47	-0.15	-0.70	-0.64	-0.58	-0.81	-0.66	-0.67	-0.05	-0.56	-0.62	-0.78	0.40	-0.41
TVS						0.87	0.50	0.39	0.78	0.50	0.64	0.86	0.75	0.86	0.00	0.73	0.86	0.94	-0.62	0.52
Metals (ppm)																				
Al							0.39	0.26	0.91	0.59	0.58	0.85	0.73	0.84	0.11	0.66	0.76	0.90	-0.47	0.55
Sb								0.34	0.35	0.49	0.73	0.68	0.72	0.45	0.01	0.24	0.42	0.52	-0.52	0.33
As									0.21	0.06	0.28	0.31	0.21	0.41	-0.04	0.26	0.56	0.39	-0.37	-0.06
Ba										0.61	0.61	0.82	0.73	0.79	0.25	0.62	0.68	0.85	-0.36	0.61
Be											0.69	0.72	0.53	0.44	0.27	0.27	0.43	0.61	-0.04	0.15
Cd												0.78	0.74	0.55	-0.14	0.38	0.56	0.73	-0.36	0.25
Cr													0.85	0.80	0.05	0.62	0.73	0.92	-0.49	0.53
Cu														0.70	0.08	0.45	0.68	0.78	-0.62	0.72
Fe															0.11	0.78	0.81	0.85	-0.49	0.55
Pb																-0.21	0.08	0.03	0.47	0.25
Mn																	0.62	0.69	-0.46	0.35
Hg																		0.84	-0.51	0.29
Ni																			-0.58	0.49
Sn																				-0.34

TABLE C.4-6

Sampling effort in the Point Loma Ocean Outfall region for Phase 2 of the Sediment Mapping Study in 2012. The "enhanced grid" stations were in the area of interest directly surrounding the outfall, whereas the "base grid" area was the region surrounding the enhanced grid area. The "outside grid area" stations were fixed-grid regular monitoring stations.

	No. of Stations by Area of Interest				
Station Type	**Enhanced Grid**	**Base Grid**	**Outside Grid Area**	**Total Stations**	**No. of Samples**
P2 Grid					
Regular (1 rep)	49	34	0	83	83
Duplicate (2 reps)	6	6	0	12	24
P2 satellite (1 rep)	11	15	0	26	26
PLOO Primary Core (1 rep)	7	1	4	12	12
TOTAL	73	56	4	133	145

TABLE C.4-7

Summary of particle sizes and chemistry concentrations for Phase 2 Sediment Mapping samples collected in 2012. Data include the detection rate (DR), minimum, median, maximum and mean values[a] for the entire survey area. ERL = Effects Range Low threshold; ERM = Effects Range Median threshold. See Attachment C.4-A for MDLs and other abbreviations.

	All Depths (n=133)						
	DR	**Min**	**Median**	**Max**	**Mean**	**ERL[b]**	**ERM [b]**
Particle Size (%)							
Coarse Particles	—	0.00	0.00	12.34	0.36	na	na
Med-Coarse Sands	—	0.19	0.78	16.46	1.24	na	na
Fine Sands	—	17.97	44.98	64.80	44.49	na	na
Fines	—	24.20	53.43	81.66	53.92	na	na
Organic Indicators (%)							
TN	100	0.027	0.069	0.182	0.076	na	na
TOC	100	0.253	0.644	2.330	0.776	na	na
TS	100	53.40	69.30	77.60	68.68	na	na
TVS	100	1.71	2.70	7.35	3.08	na	na
Metals (ppm)							
Aluminum	100	5170	15600	31700	16137	na	na
Antimony	79	nd	0.70	1.30	0.77	na	na
Arsenic	100	1.71	2.89	4.50	2.91	8.2	70
Barium	100	24.10	51.80	151.00	53.20	na	na
Beryllium	100	0.02	0.28	0.59	0.29	na	na
Cadmium	75	nd	0.14	0.35	0.17	1.2	9.6
Chromium	100	10.7	21.0	38.8	22.0	81	370
Copper	100	5.0	10.5	60.8	12.2	34	270
Iron	100	9240	15400	27000	15809	na	na
Lead	100	3.8	9.9	20.9	10.1	46.7	218
Manganese	100	75.1	172.0	257.0	172.6	na	na
Mercury	100	0.016	0.044	0.193	0.052	0.15	0.71
Nickel	100	4.2	9.8	23.7	10.8	20.9	51.6
Selenium	24	nd	nd	0.91	0.42	na	na
Silver	70	nd	0.99	5.54	1.38	1	3.7
Thallium	0	—	—	—	—	na	na
Tin	99	nd	2.40	6.95	3.37	na	na
Zinc	100	21.20	37.40	79.80	39.42	150	410
Pesticides (ppt)							
Aldrin	2	nd	nd	120	90	na	na
HCB	5	nd	nd	860	339	na	na
Total Chlordane	3	nd	nd	2800	1053	na	na
Total DDT	89	nd	390	18940	897	1580	46100
Total PCB (ppt)	42	nd	nd	3445240	64679	na	na

[a] Minimum, median, and maximum values were calculated based on all samples (n = 133), whereas means were calculated on detected values only (n ≤ 133); na = not available, nd = not detected

[b] From Long et al. 1995

TABLE C.4-8

Results of Spearman rank correlation analyses of depth, percent fines and various sediment chemistry parameters from Phase 2 of the Sediment Mapping Study. Correlation coefficients of 0.70 – 0.80 are highlighted in blue; 0.80 – 0.90 in pink; >0.90 in yellow. For all analyses, n= the number of detected values. See Attachment C.4-A for abbreviations.

	Fines	*Organic Indicators (%)*				Metals (ppm)																Total DDT
	(%)	TN	TOC	TS	TVS	Al	Sb	As	Ba	Be	Cd	Cr	Cu	Fe	Pb	Mn	Hg	Ni	Ag	Sn	Zn	(ppt)
n	133	133	133	133	133	133	105	133	133	133	100	133	133	133	133	133	133	133	93	132	133	119
Depth (m)	0.11	0.11	0.29	-0.10	0.31	0.05	0.17	-0.49	-0.03	0.21	-0.02	0.18	0.28	0.15	0.08	-0.08	0.20	0.15	0.02	0.07	0.16	0.06
Fines (%)		0.92	0.80	-0.92	0.87	0.91	0.25	0.60	0.79	0.65	0.64	0.89	0.73	0.81	0.81	0.52	0.68	0.93	0.19	0.24	0.81	0.74
Organic Indicators (%)																						
TN			0.85	-0.96	0.89	0.84	0.18	0.61	0.69	0.60	0.74	0.86	0.66	0.73	0.74	0.46	0.59	0.92	0.14	0.12	0.75	0.74
TOC				-0.85	0.92	0.77	0.23	0.47	0.57	0.67	0.64	0.87	0.64	0.76	0.66	0.44	0.55	0.85	0.12	0.30	0.75	0.64
TS					-0.89	-0.85	-0.22	-0.64	-0.72	-0.64	-0.75	-0.87	-0.67	-0.75	-0.77	-0.48	-0.61	-0.92	-0.12	-0.17	-0.77	-0.76
TVS						0.84	0.27	0.47	0.67	0.69	0.62	0.90	0.72	0.81	0.75	0.48	0.62	0.90	0.18	0.30	0.81	0.66
Metals (ppm)																						
Al							0.35	0.55	0.87	0.67	0.65	0.95	0.78	0.91	0.85	0.68	0.70	0.94	0.38	0.46	0.90	0.70
Sb								-0.14	0.27	0.23	-0.15	0.39	0.28	0.43	0.19	0.83	0.23	0.32	0.68	0.72	0.38	0.18
As									0.55	0.40	0.50	0.49	0.34	0.45	0.53	0.21	0.34	0.53	-0.15	-0.02	0.45	0.50
Ba										0.68	0.69	0.82	0.88	0.86	0.92	0.53	0.79	0.79	0.32	0.32	0.91	0.68
Be											0.75	0.74	0.74	0.69	0.86	0.28	0.57	0.69	0.07	0.24	0.74	0.61
Cd												0.68	0.71	0.63	0.75	0.13	0.45	0.70	0.00	-0.02	0.71	0.60
Cr													0.83	0.95	0.84	0.64	0.68	0.96	0.33	0.42	0.93	0.72
Cu														0.86	0.88	0.41	0.81	0.75	0.27	0.30	0.92	0.66
Fe															0.81	0.67	0.67	0.87	0.37	0.49	0.95	0.64
Pb																0.42	0.77	0.81	0.22	0.23	0.89	0.73
Mn																	0.38	0.60	0.78	0.71	0.60	0.34
Hg																		0.64	0.29	0.29	0.76	0.57
Ni																			0.25	0.33	0.87	0.73
Ag																				0.53	0.37	0.10
Sn																					0.43	0.09
Zn																						0.69

APPENDIX C.4

San Diego Sediment Mapping Study

FIGURES

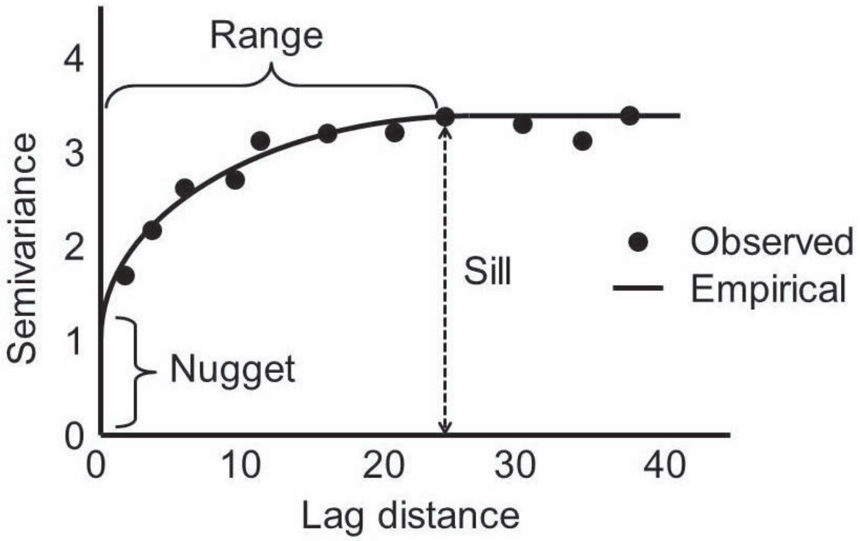


FIGURE C.4-1
Example variogram.

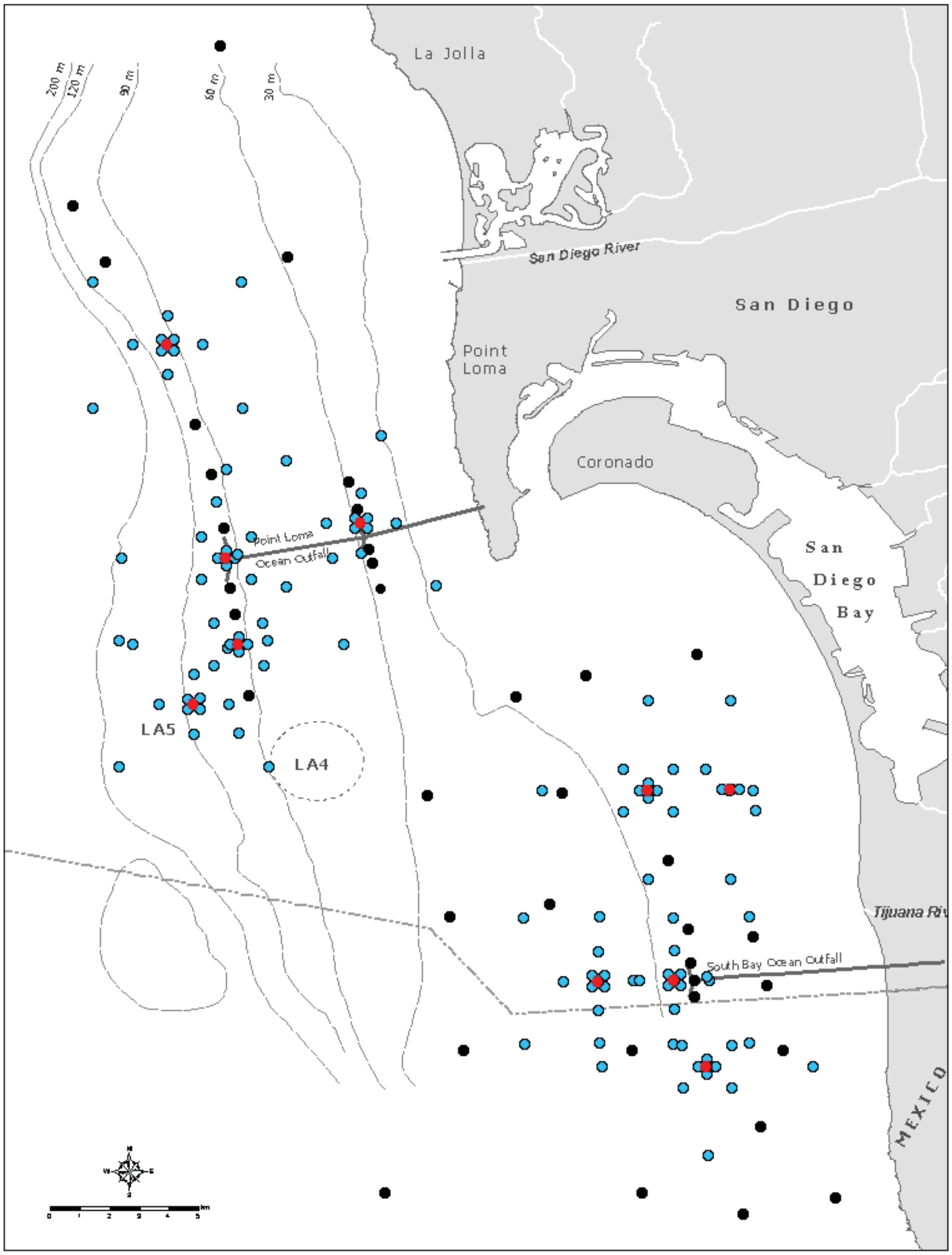


FIGURE C.4-2
Overview of the site distribution for Phase 1 of the Sediment Mapping Study. Blue circles = new mapping sites, black circles = current or old NPDES grid stations, red circles = cluster enhancement areas representing 3-5 sites, 50-m lag distances apart. See Figure C.4-3 for a magnified view of the site distribution for just the Point Loma Ocean Outfall region.

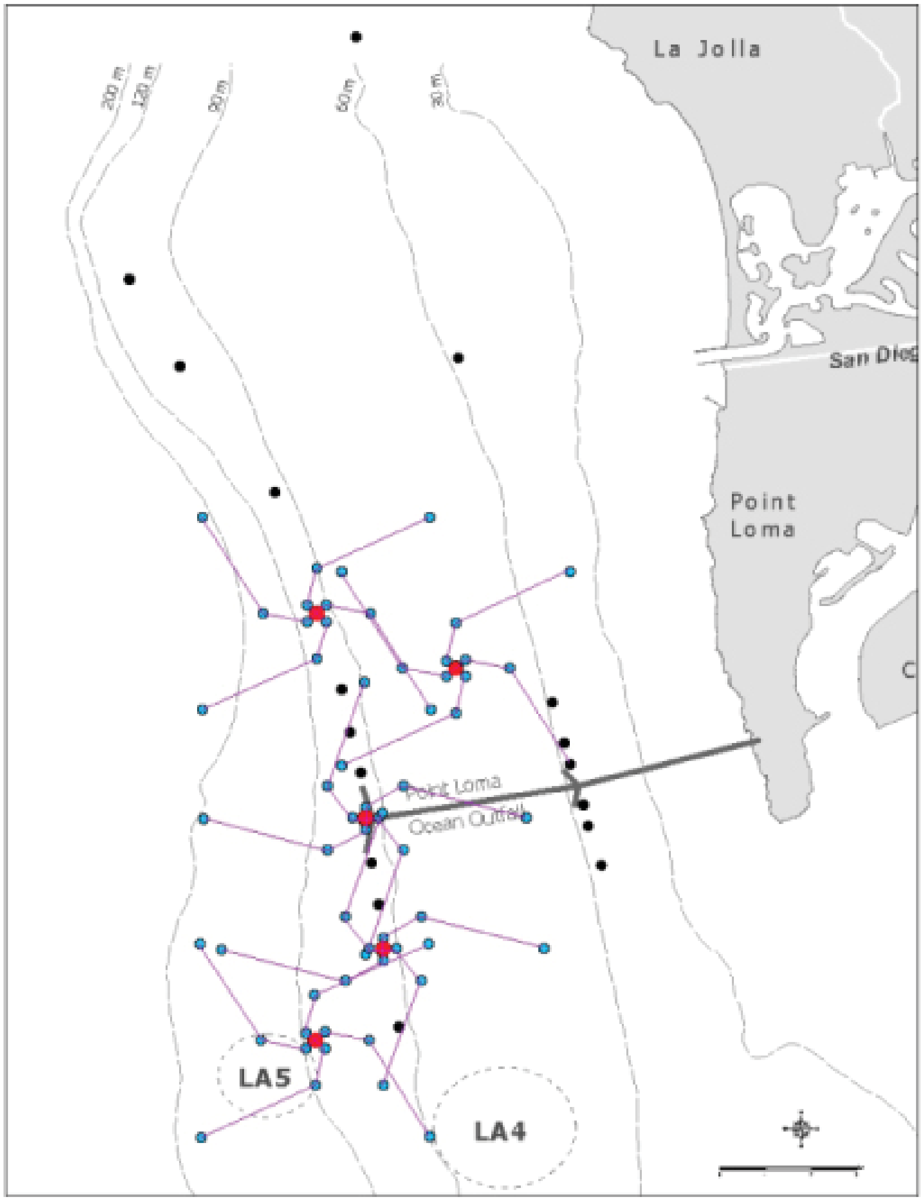
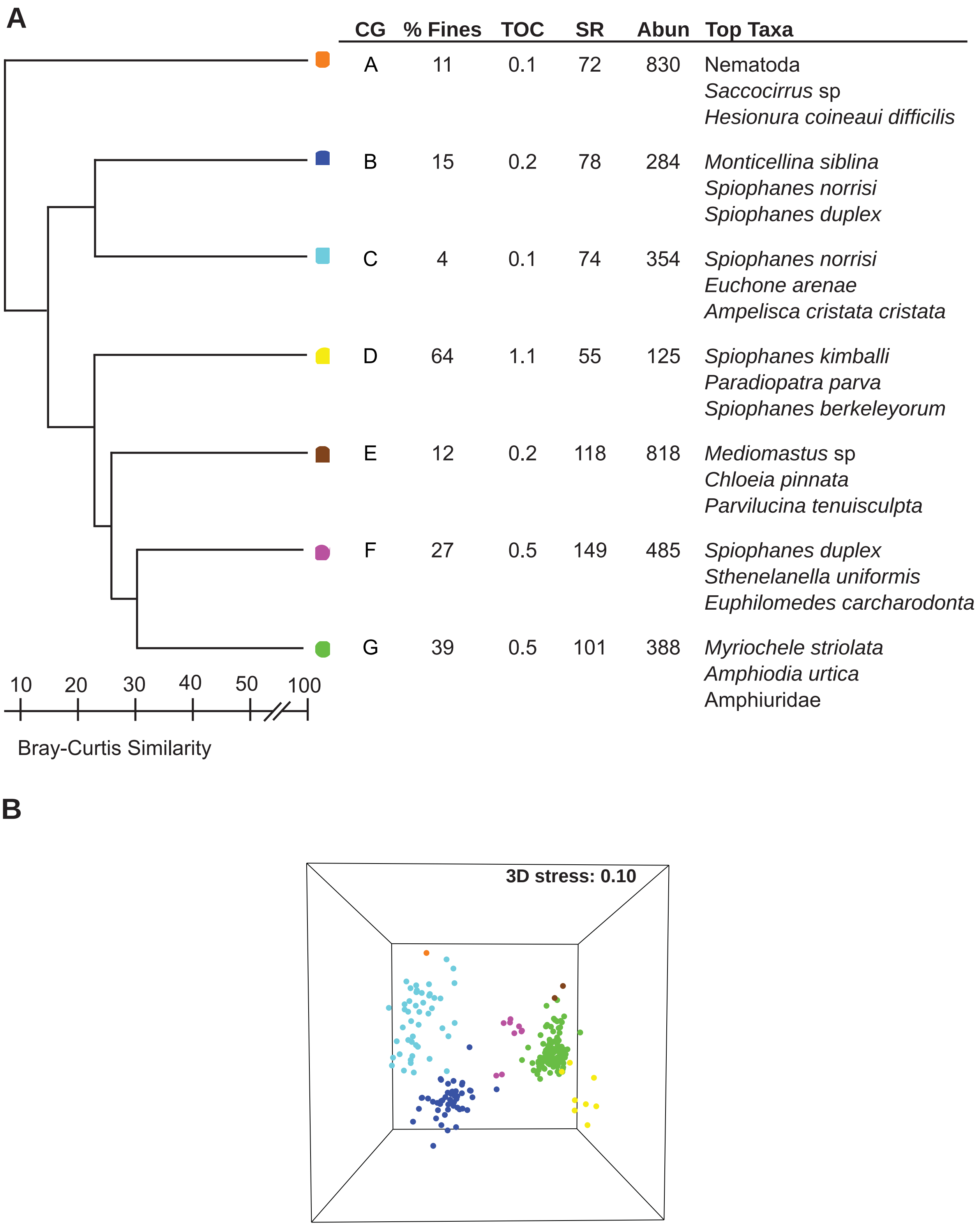


FIGURE C.4-3
Expanded view of the Phase 1 Sediment Mapping sites located within the Point Loma Ocean Outfall region showing location of multi-lag clusters: blue circles = new mapping sites; black circles = current NPDES 98-m grid stations or old NPDES stations along inshore 60-m depth contour; red circles = cluster enhancement areas representing five sites in close proximity only 50-m lag distances apart (1 grid or new station in center surrounded by 4 new sites).



CG	% Fines	TOC	SR	Abun	Top Taxa
A	11	0.1	72	830	Nematoda *Saccocirrus* sp *Hesionura coineaui difficilis*
B	15	0.2	78	284	*Monticellina siblina* *Spiophanes norrisi* *Spiophanes duplex*
C	4	0.1	74	354	*Spiophanes norrisi* *Euchone arenae* *Ampelisca cristata cristata*
D	64	1.1	55	125	*Spiophanes kimballi* *Paradiopatra parva* *Spiophanes berkeleyorum*
E	12	0.2	118	818	*Mediomastus* sp *Chloeia pinnata* *Parvilucina tenuisculpta*
F	27	0.5	149	485	*Spiophanes duplex* *Sthenelanella uniformis* *Euphilomedes carcharodonta*
G	39	0.5	101	388	*Myriochele striolata* *Amphiodia urtica* Amphiuridae

FIGURE C.4-4
Results of (A) classification and (B) nMDS ordination analyses of macrofaunal abundance data from Phase 1 of the Sediment Mapping Study in 2004. Data are expressed as mean values per 0.1 m^2 grab for each group.

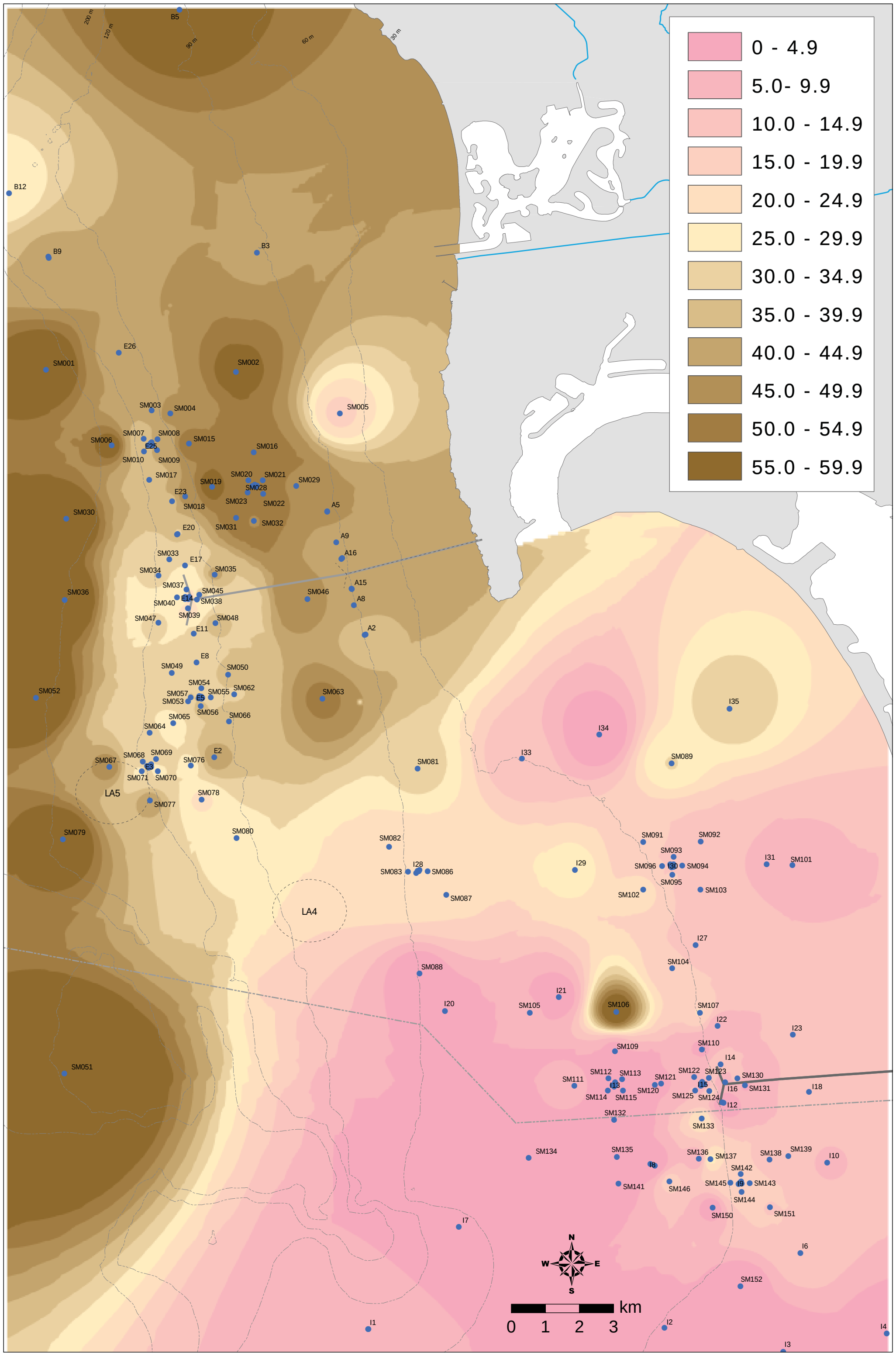


FIGURE C.4-5

An inverse distance weighted interpolation (which does not provide a measure of uncertainty) for percent fines across the full Phase 1 survey area of the Sediment Mapping Study in 2004.

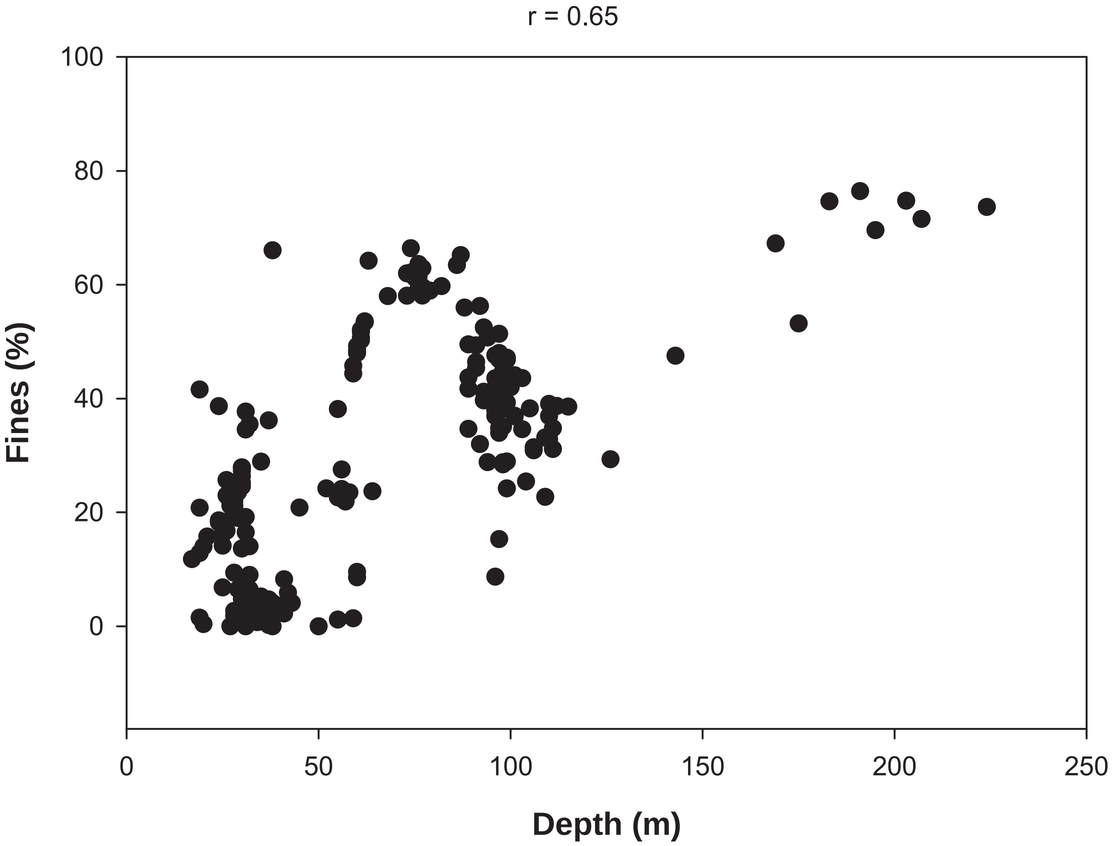


FIGURE C.4-6a

Scatterplot of depth versus percent fines from Phase 1 of the Sediment Mapping Study in 2004.

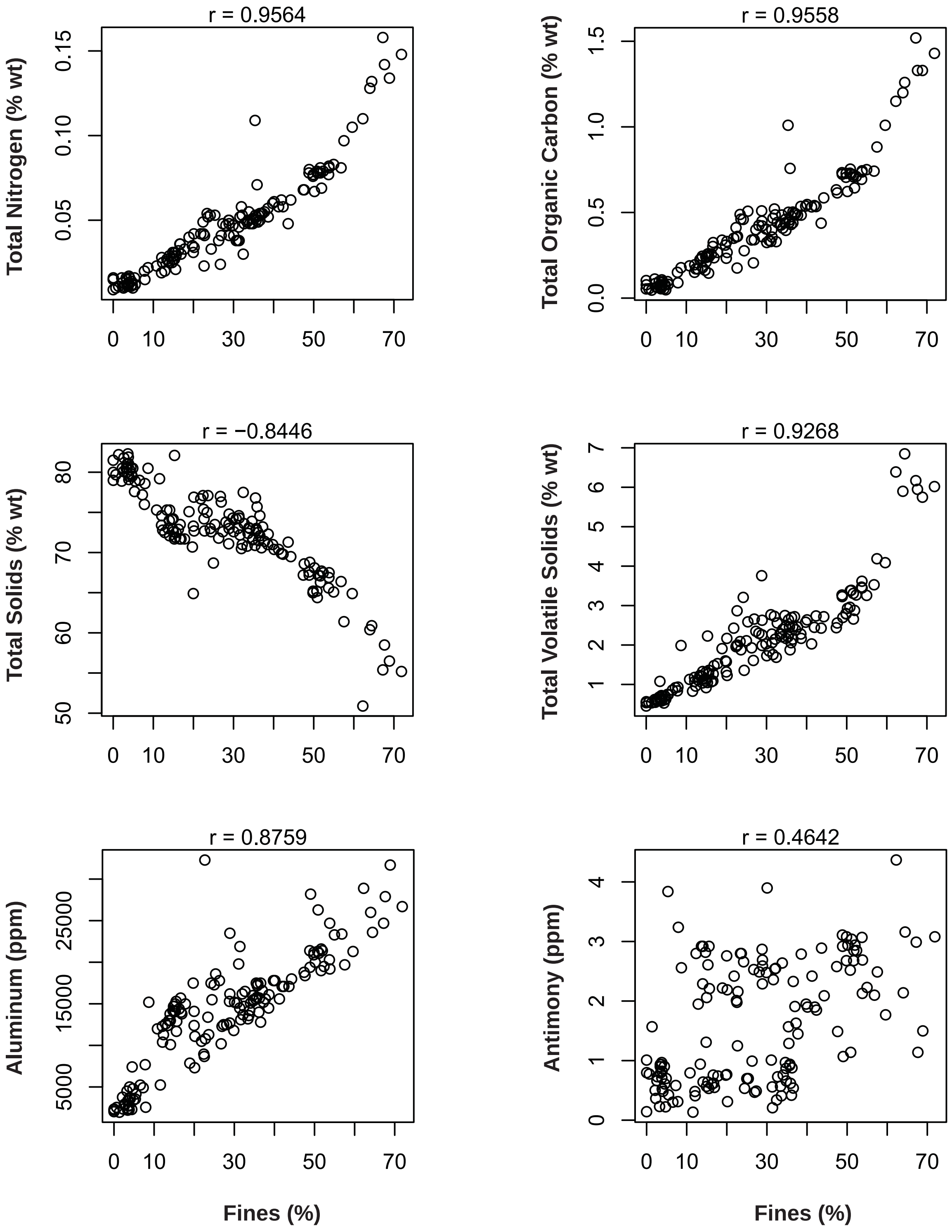


FIGURE C.4-6b

Scatterplots of percent fines versus various sediment chemistry parameters from Phase 1 of the Sediment Mapping Study in 2004.

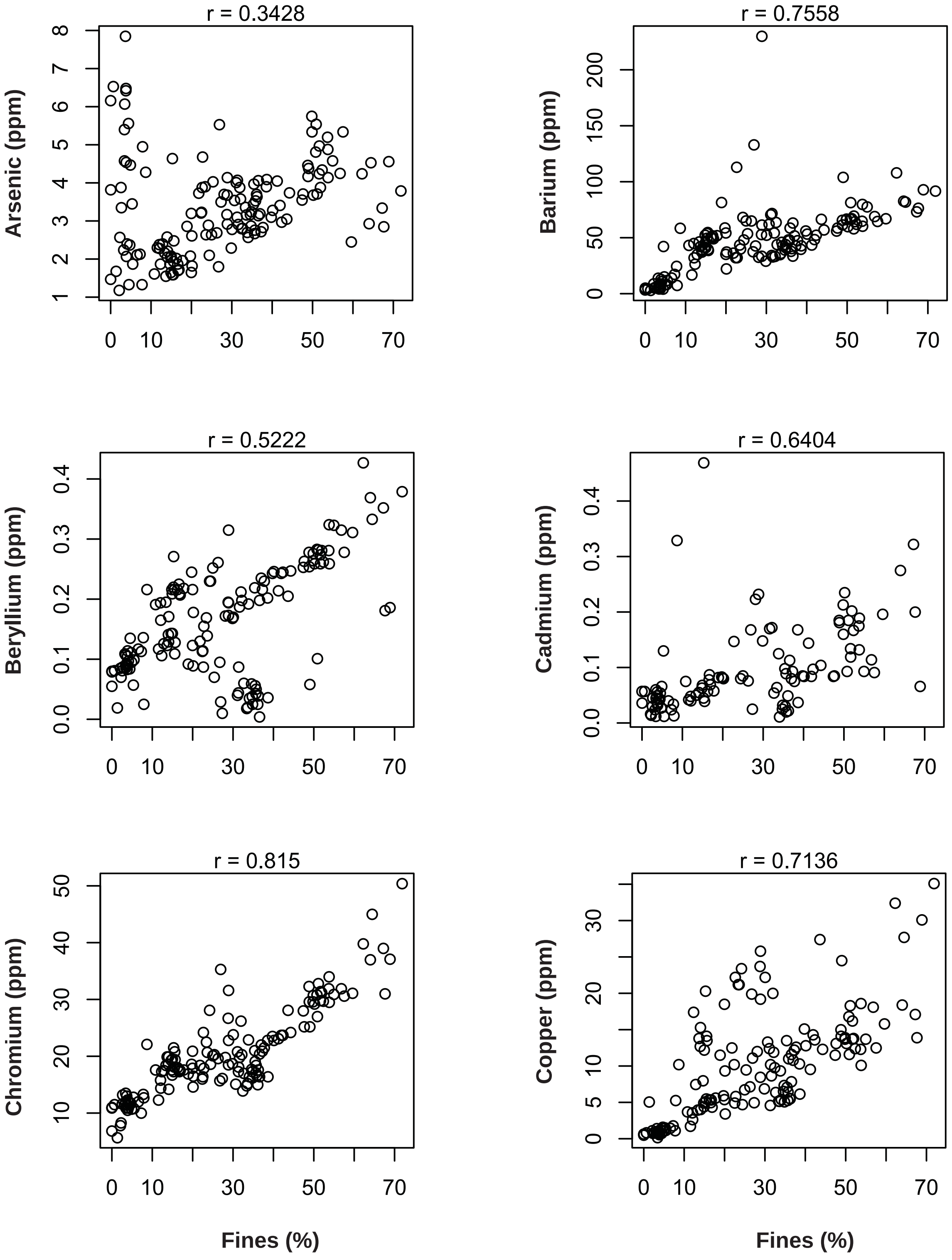


FIGURE C.4-6b (continued)

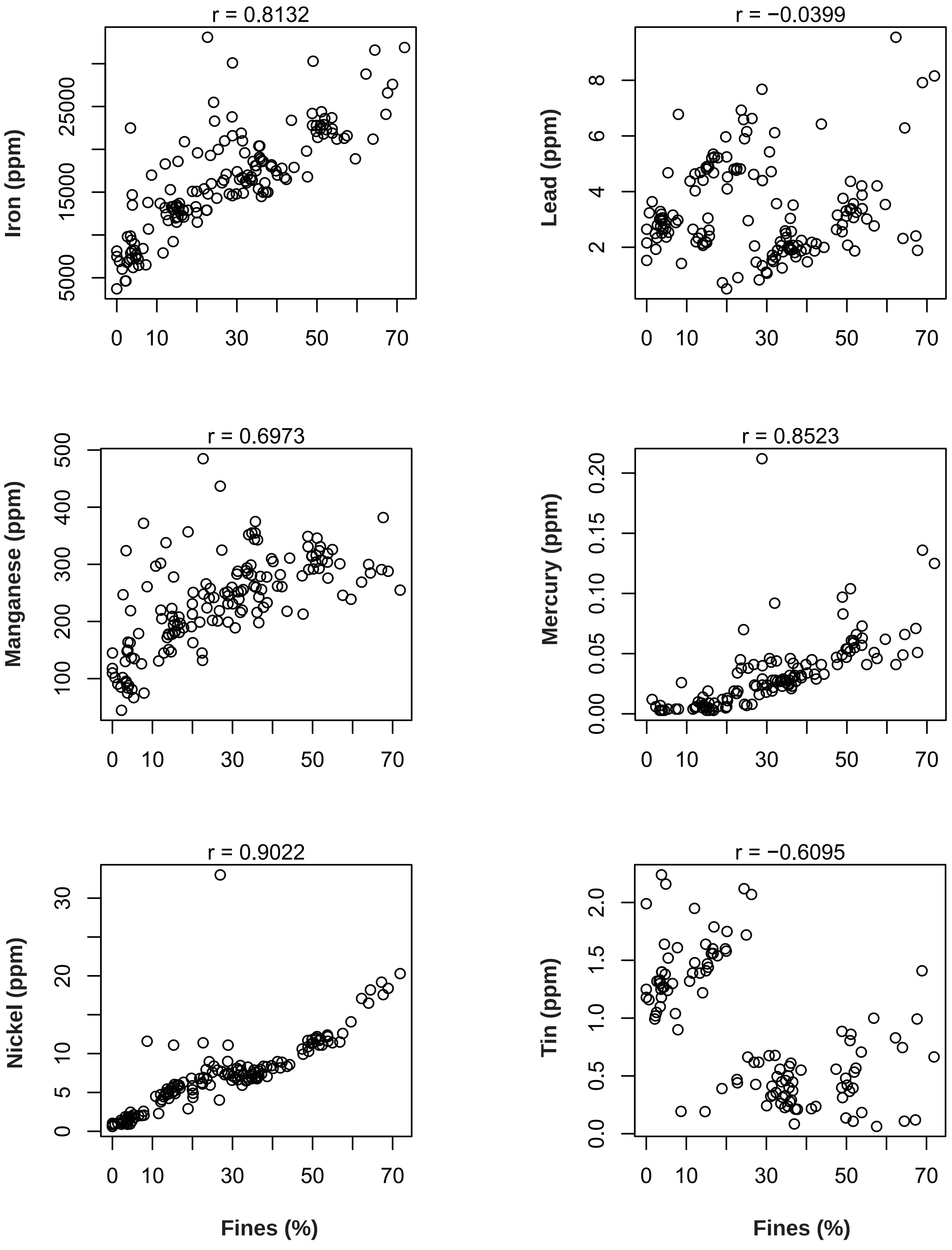


FIGURE C.4-6b (continued)

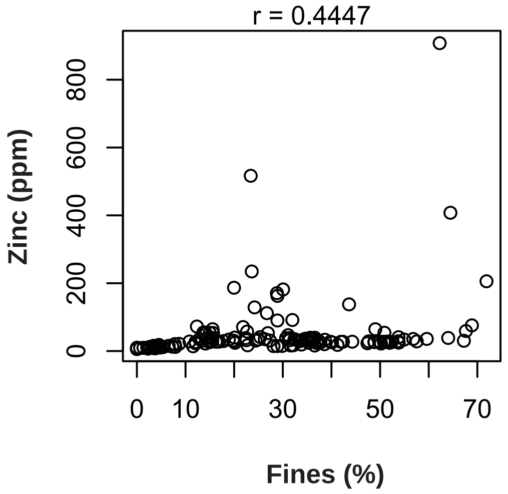


FIGURE C.4-6b (continued)

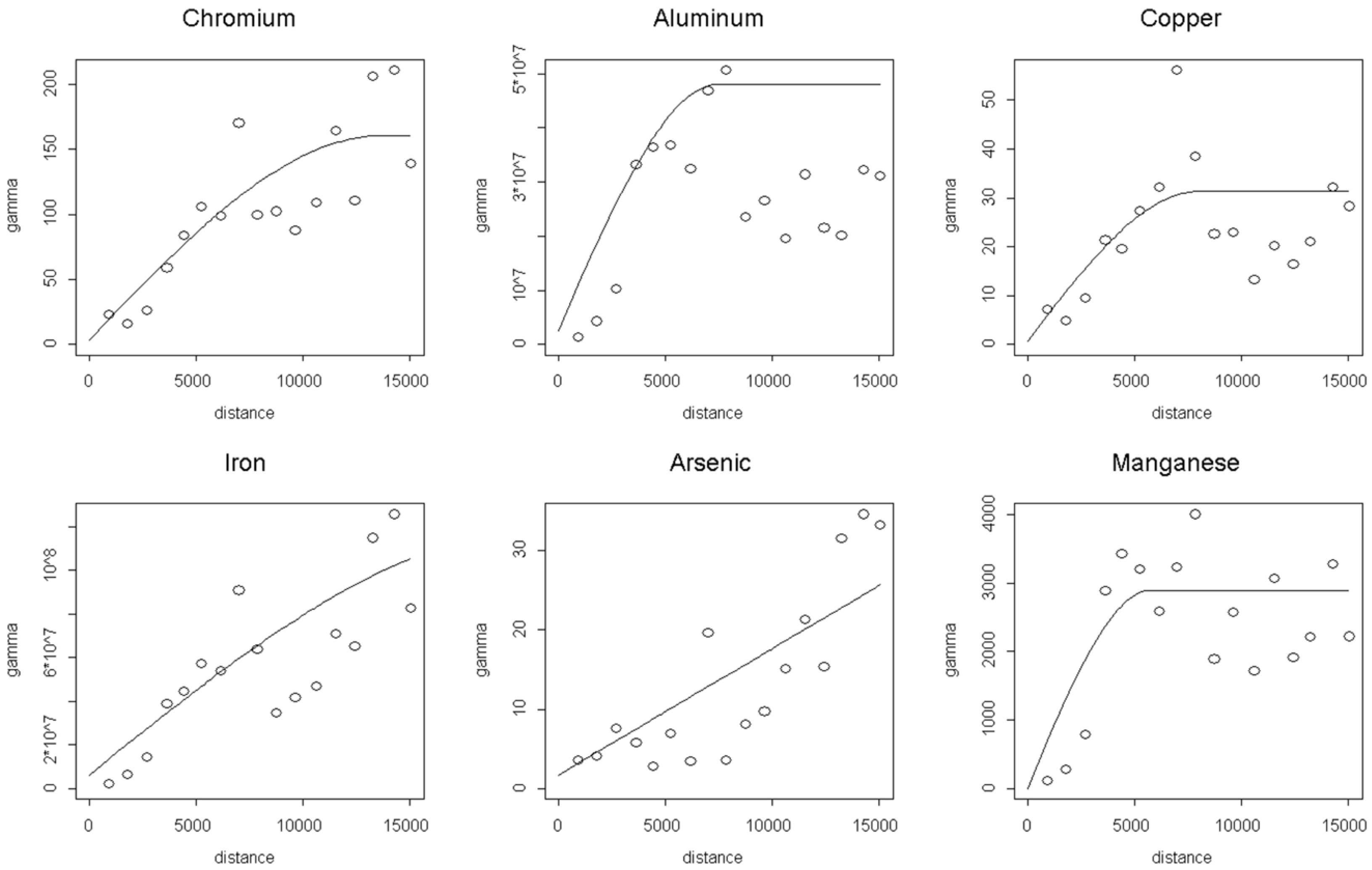


FIGURE C.4-7
Results of ordinary kriging for six metals from the Point Loma Ocean Outfall region sampled during Phase 1 of the Sediment Mapping Study in 2004.

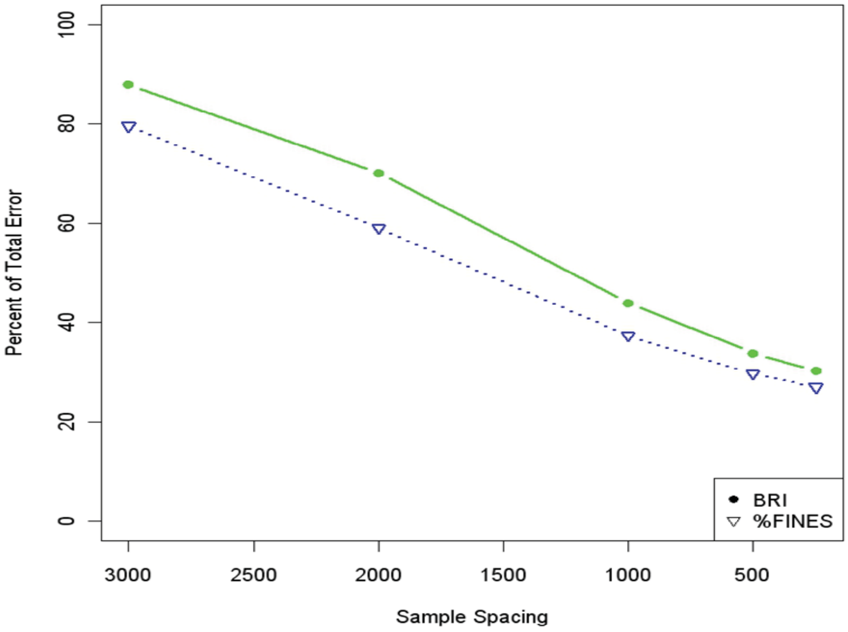


FIGURE C.4-8

Relationship of sample spacing and statistical confidence for the Point Loma Ocean Outfall region based on cost efficiency model results. Sample spacing in meters; %fines = grain size fraction ≤ 62.5 µm; BRI = benthic response index.

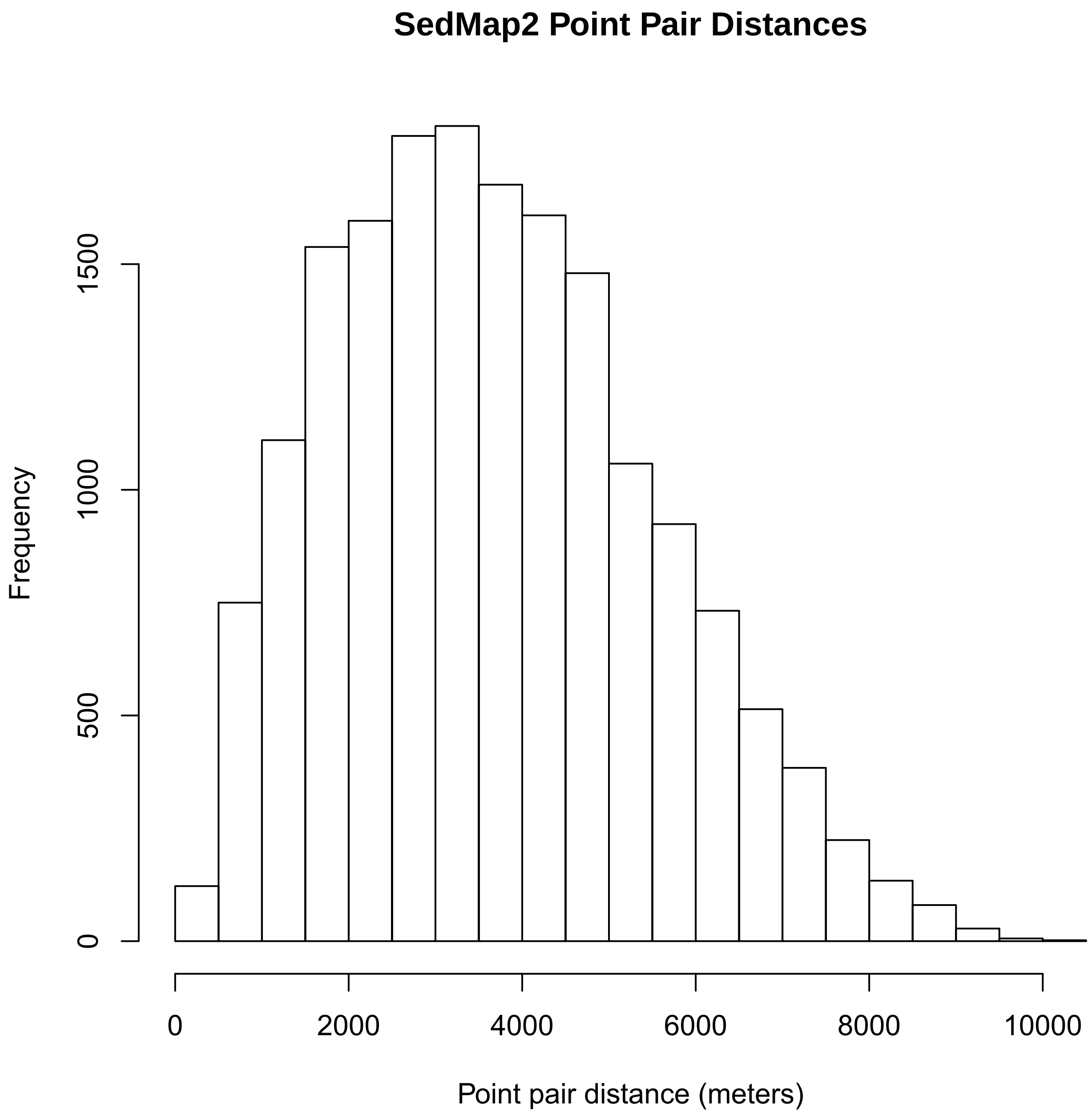


FIGURE C.4-9

Lag distribution (station-to-station distances) for Phase 2 Sediment Mapping Study sampling locations in 2012.

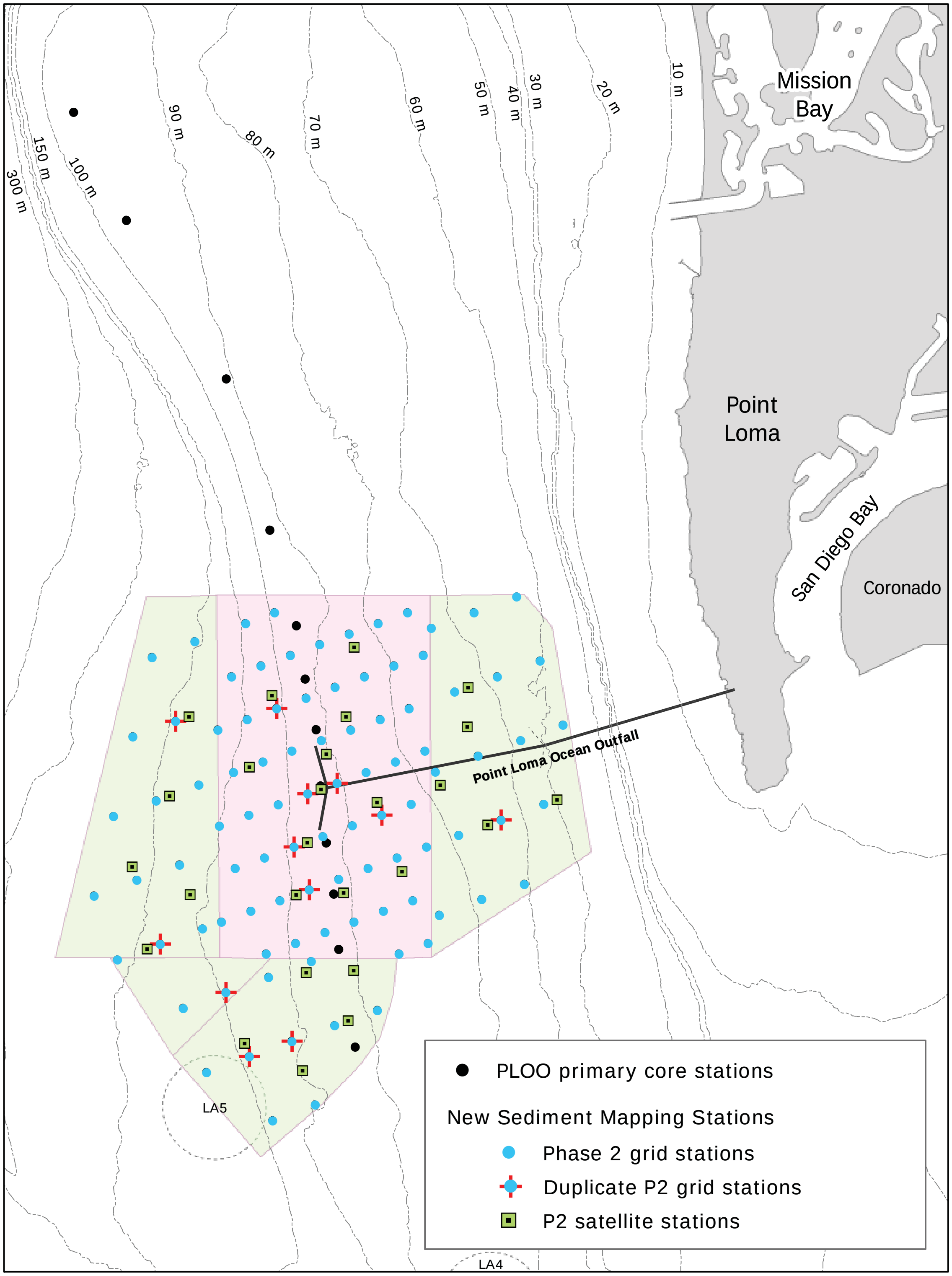


FIGURE C.4-10
Detailed sample design for Phase 2 of the Sediment Mapping Study in 2012. The optimized grid of sample locations was rotated to account for anisotropy, used closely spaced satellite stations to allow improved estimation of the nugget, and used two resolutions for the different areas of interest. Green area = base grid (800m x 1200m spacing). Pink area = enhanced grid (550m x 800m spacing).

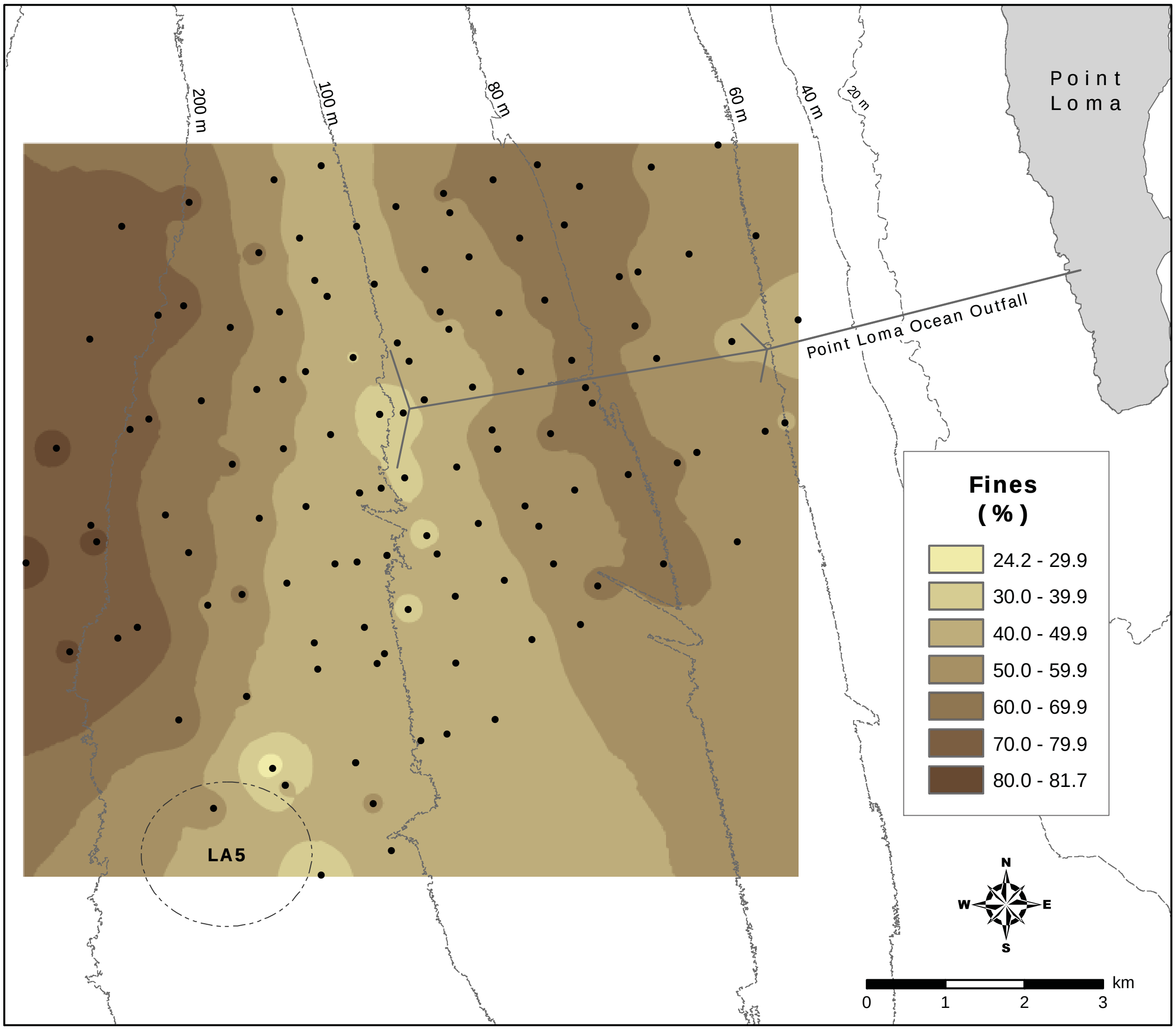


FIGURE C.4-11
An inverse distance weighted interpolation (which does not provide a measure of uncertainty) for percent fines across the full Phase 2 survey area of the Sediment Mapping Study in 2012.

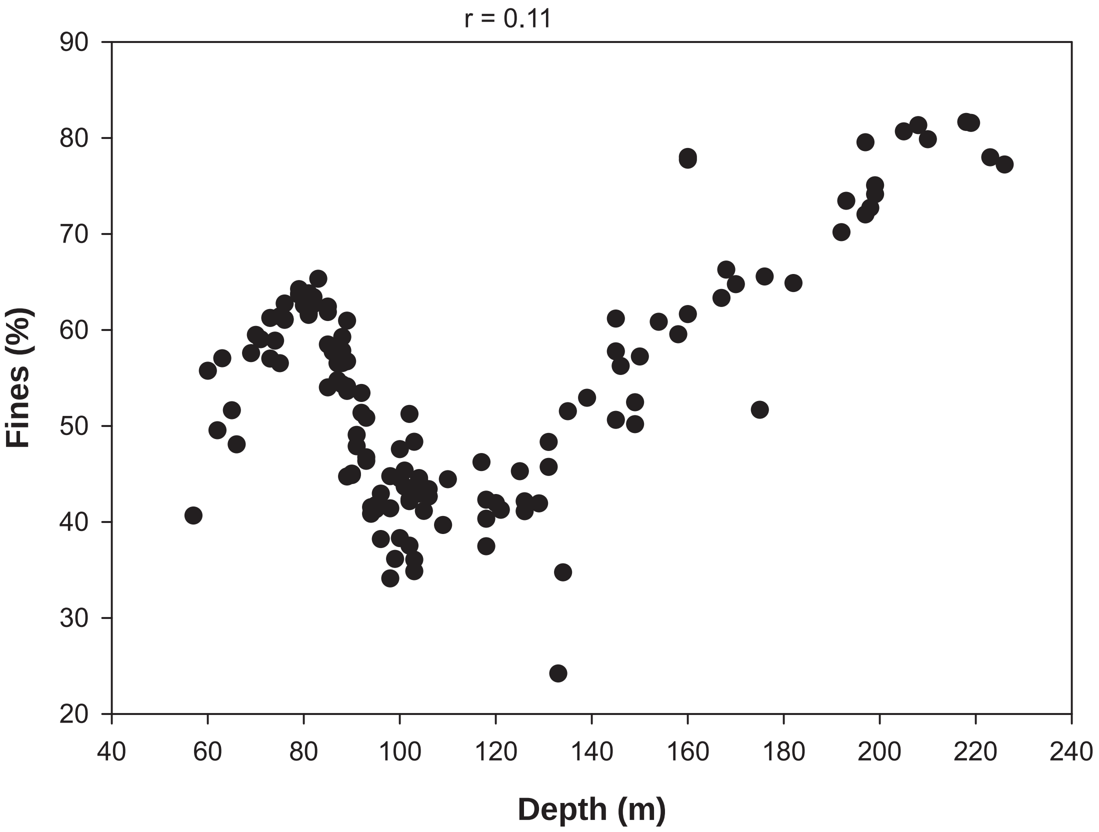


FIGURE C.4-12a

Scatterplot of depth versus percent fines from Phase 2 of the Sediment Mapping Study in 2012.

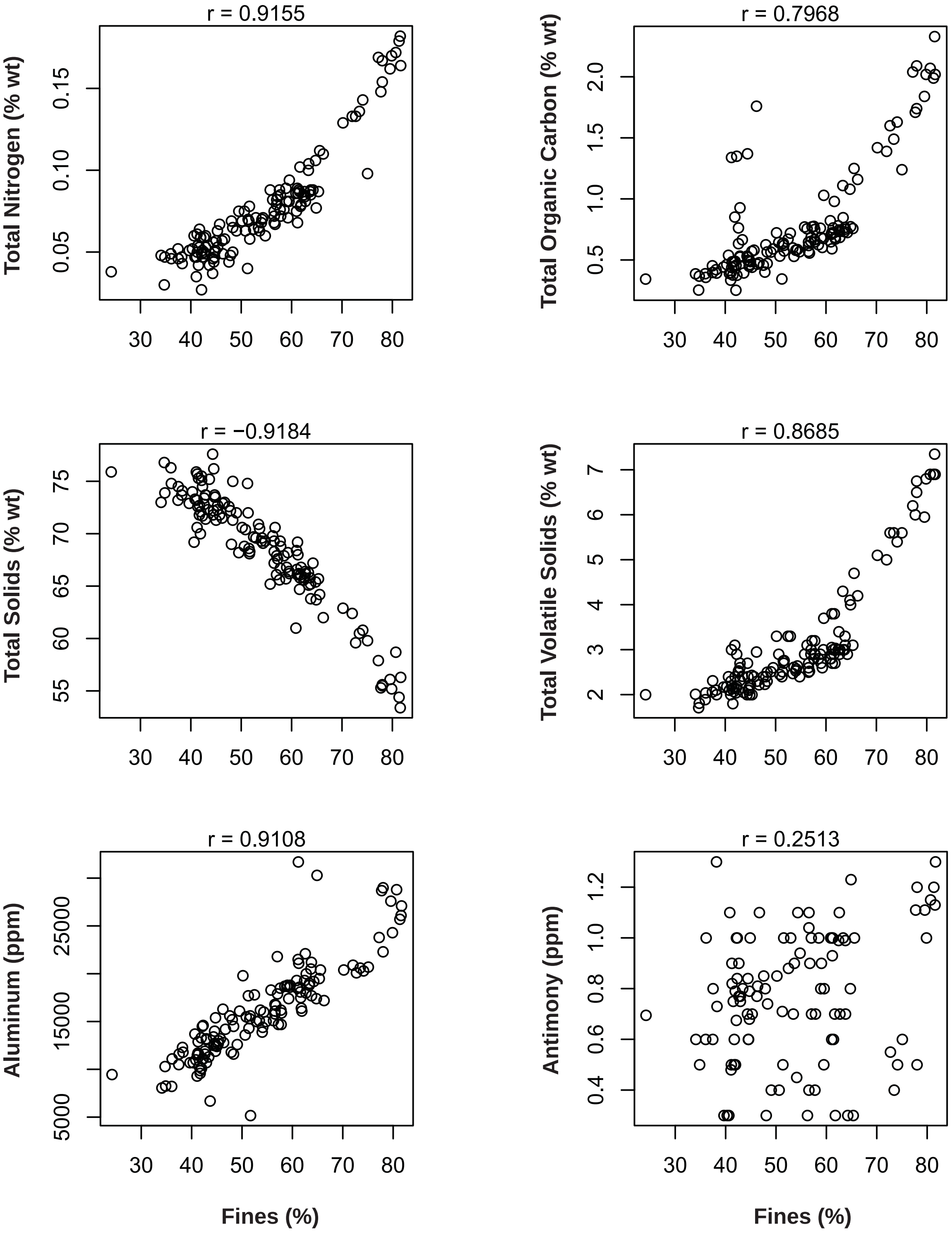


FIGURE C.4-12b

Scatterplots of percent fines versus various sediment chemistry parameters from Phase 2 of the Sediment Mapping Study in 2012.

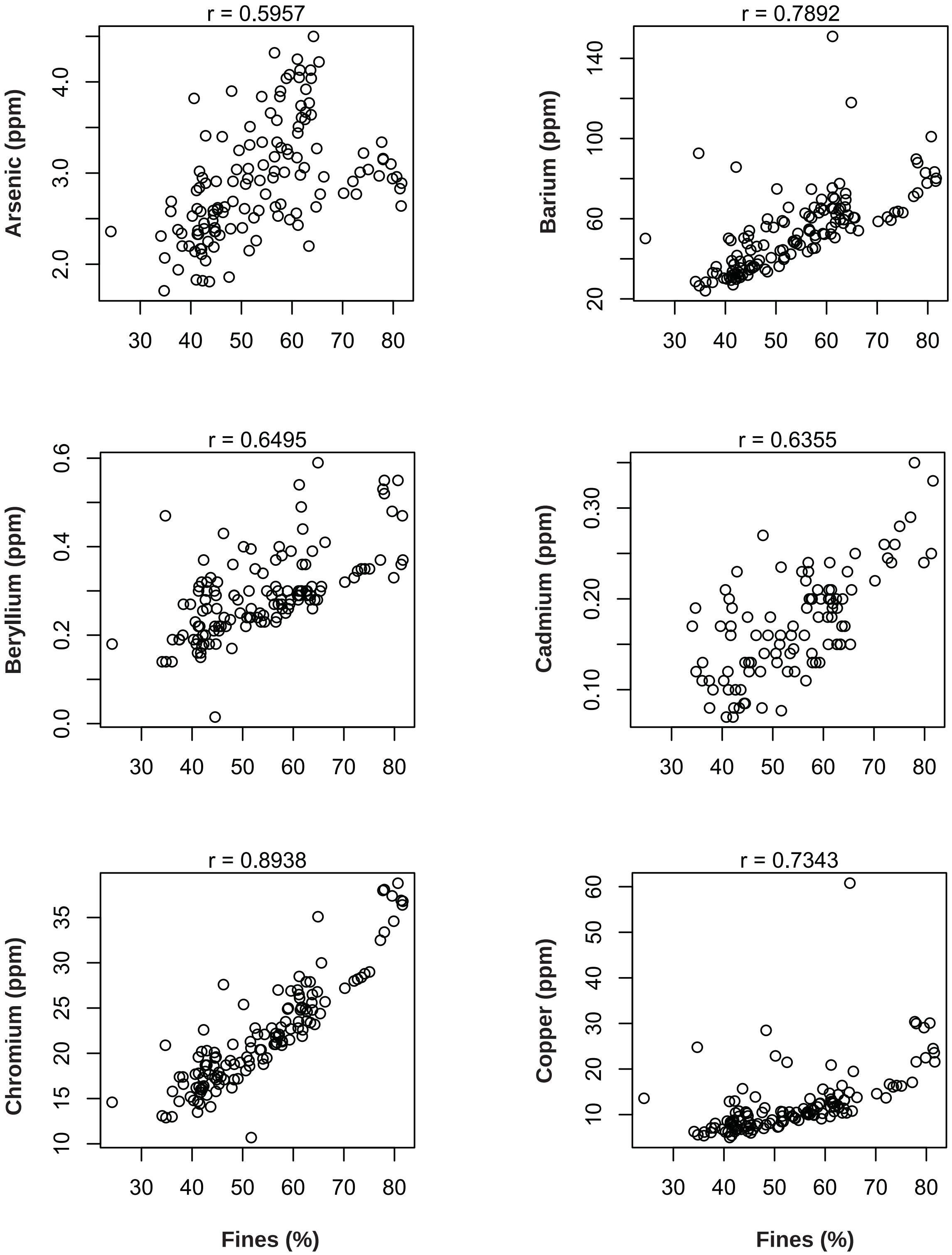


FIGURE C.4-12b (continued)

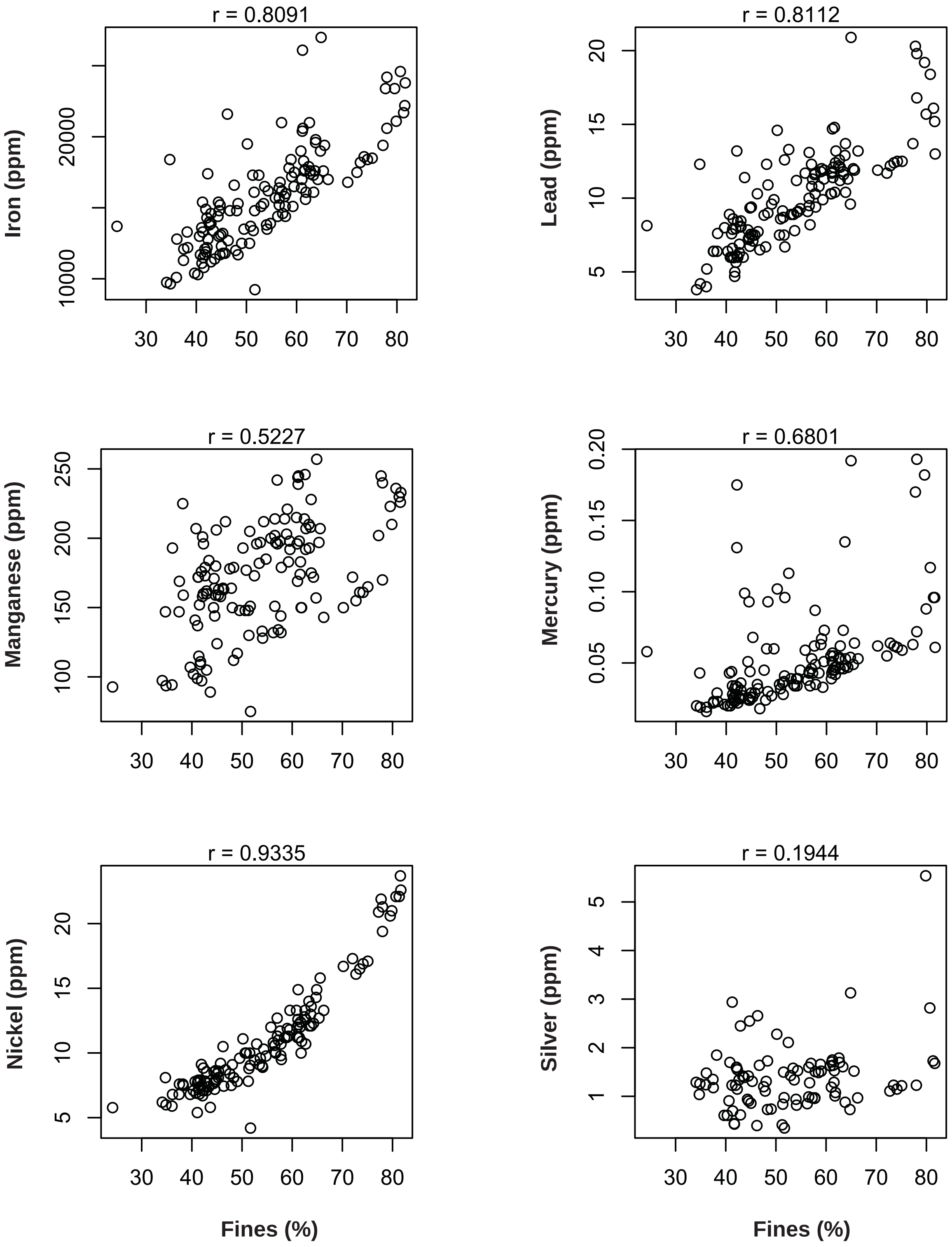


FIGURE C.4-12b (continued)

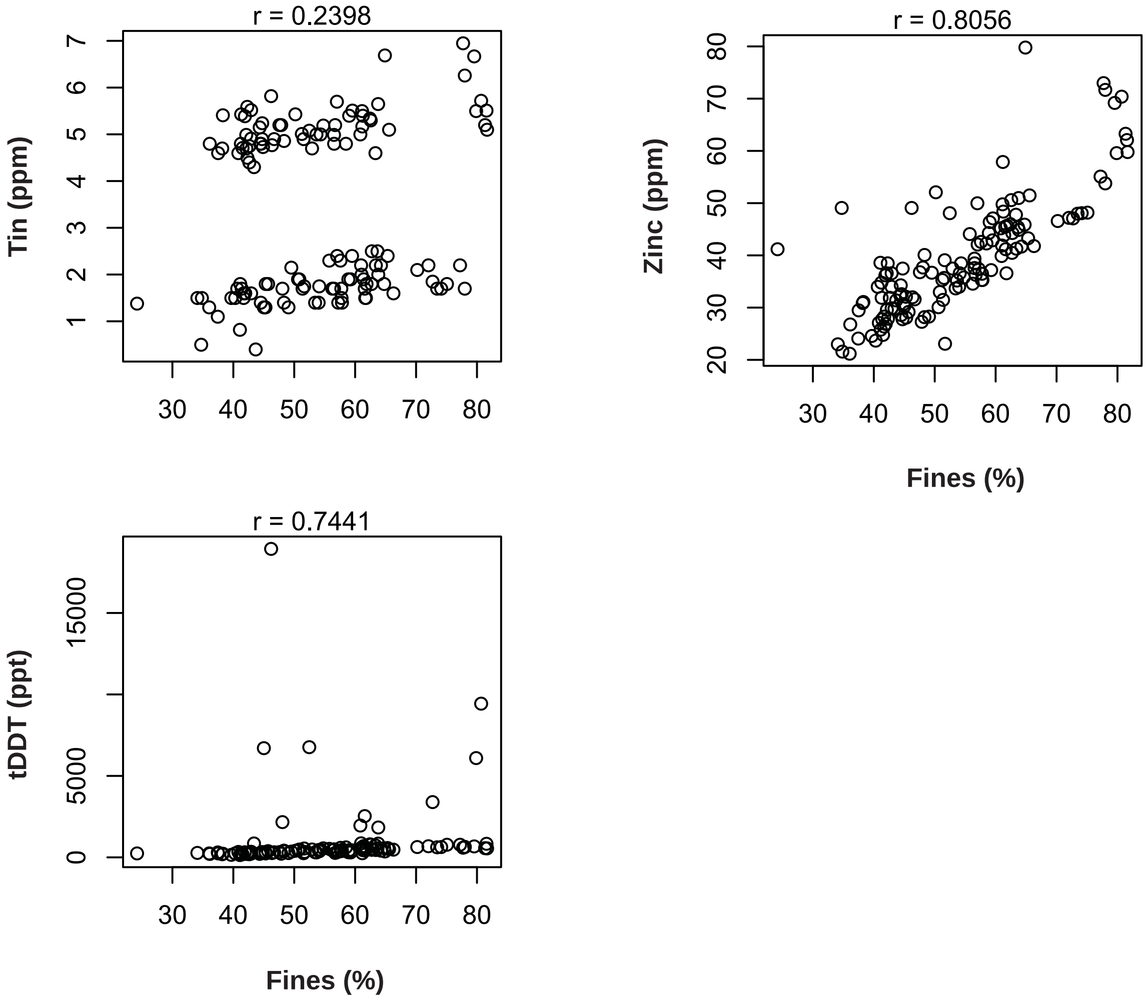


FIGURE C.4-12b (continued)

APPENDIX C.4

San Diego Sediment Mapping Study

ATTACHMENTS

ATTACHMENT C.4-A

Constituents and method detection limits (MDLs) used for the analysis of sediments collected during Phase 1 (2004) and Phase 2 (2012) of the Sediment Mapping Study.

Parameter	Phase 1	Phase 2	Parameter	Phase 1	Phase 2
Organic Indicators					
Total Nitrogen (TN, %wt)	0.005	0.005	Total Volatile Solids (TVS, %wt)	0.11	0.11
Total Organic Carbon (TOC, %wt)	0.01	0.01	Total Solids (TS, %wt)	0.24	0.24
Metals (ppm)					
Aluminum (Al)	1.15	2	Lead (Pb)	0.142	0.8
Antimony (Sb)	0.13	0.3	Manganese (Mn)	0.00367	0.08
Arsenic (As)	0.33	0.33	Mercury (Hg)	0.003	0.004
Barium (Ba)	0.00182	0.02	Nickel (Ni)	0.0364	0.1
Beryllium (Be)	0.00119	0.01	Selenium (Se)	0.24	0.24
Cadmium (Cd)	0.0104	0.06	Silver (Ag)	0.0129	0.04
Chromium (Cr)	0.016	0.1	Thallium (Tl)	0.221	0.5
Copper (Cu)	0.0278	0.2	Tin (Sn)	0.0586	0.3
Iron (Fe)	0.76	9	Zinc (Zn)	0.0521	0.25
Chlorinated Pesticides (ppt)					
Hexachlorocyclohexane (HCH)					
HCH, Alpha isomer	na	150	HCH, Delta isomer	na	700
HCH, Beta isomer	na	310	HCH, Gamma isomer	na	260
Total Chlordane					
Alpha (cis) Chlordane	5700	240	Heptachlor epoxide	na	120
Cis Nonachlor	na	240	Methoxychlor	na	1100
Gamma (trans) Chlordane	3800	350	Oxychlordane	5700	240
Heptachlor	na	1200	Trans Nonachlor	na	250
Total Dichlorodiphenyltrichloroethane (DDT)					
o,p-DDD	5700	830	p,p-DDE	3800	260
o,p-DDE	5700	720	p,p-DDMU[a]	—	—
o,p-DDT	3800	800	p,p-DDT	11000	800
p,p-DDD	3800	470			
Miscellaneous Pesticides					
Aldrin	na	430	Endrin	na	830
Alpha Endosulfan	na	240	Endrin aldehyde	na	830
Beta Endosulfan	na	350	Hexachlorobenzene (HCB)	na	470
Dieldrin	na	310	Mirex	na	500
Endosulfan Sulfate	na	260			

[a] No MDL available for this parameter

ATTACHMENT C.4-A (continued)

Parameter	Phase 1	Phase 2	Parameter	Phase 1	Phase 2
Polychlorinated Biphenyl Congeners (PCBs) (ppt)					
PCB 18	2600	540	PCB 126	3000	720
PCB 28	3000	660	PCB 128	2700	570
PCB 37	2100	340	PCB 138	3000	590
PCB 44	2600	890	PCB 149	2500	500
PCB 49	2700	850	PCB 151	2500	640
PCB 52	3100	1000	PCB 153/168	1200	600
PCB 66	2100	920	PCB 156	2900	620
PCB 70	2700	1100	PCB 157	2700	700
PCB 74	2700	900	PCB 158	2600	510
PCB 77	2100	790	PCB 167	3000	620
PCB 81	2500	590	PCB 169	2300	610
PCB 87	2800	600	PCB 170	3100	570
PCB 99	2500	660	PCB 177	3000	650
PCB 101	2600	430	PCB 180	2600	530
PCB 105	2600	720	PCB 183	2700	530
PCB 110	2900	640	PCB 187	2700	470
PCB 114	3000	700	PCB 189	2300	620
PCB 118	2700	830	PCB 194	2300	420
PCB 119	2400	560	PCB 201	2900	530
PCB 123	2800	660	PCB 206	1900	510

ATTACHMENT C.4-B

Macrofaunal community parameters at all stations sampled as part of the Phase 1 Sediment Mapping survey in 2004. SR=species richness (no. taxa/0.1 m2); Abun =abundance (no. individuals/0.1 m2); H'=Shannon diversity index; J'=evenness; Dom=Swartz dominance; BRI=benthic response index.

Region	Station	Depth (m)	SR	Abun	H'	J'	Dom	BRI
PLOO	A02	59	88	288	3.8	0.90	30	16
PLOO	A02 DUP	59	114	355	4.1	0.90	42	16
PLOO	A05	62	101	466	3.5	0.80	22	13
PLOO	A05 DUP	62	94	325	3.8	0.80	28	11
PLOO	A08	60	110	360	4.0	0.80	36	15
PLOO	A08 DUP	60	91	272	3.8	0.80	33	12
PLOO	A09	61	109	330	3.9	0.80	39	13
PLOO	A09 DUP	62	94	362	3.7	0.80	28	12
PLOO	A15	60	102	309	4.0	0.90	37	8
PLOO	A15 DUP	60	92	257	3.9	0.90	37	12
PLOO	A16	61	110	373	4.0	0.80	39	12
PLOO	A16 DUP	61	101	282	3.9	0.90	40	9
PLOO	B03	61	85	291	3.5	0.80	26	8
PLOO	B03 DUP	61	68	245	3.3	0.80	18	11
PLOO	B05	63	131	733	3.6	0.70	30	4
PLOO	B05 DUP	61	136	719	3.4	0.70	26	5
PLOO	B09	99	132	387	3.6	0.70	24	0
PLOO	B09 DUP	99	91	310	3.9	0.90	31	2
PLOO	B12	98	160	428	4.4	0.90	44	8
PLOO	B12 DUP	98	114	367	4.2	0.90	42	7
PLOO	E02	97	145	316	4.1	0.80	35	2
PLOO	E02 DUP	97	107	369	4.0	0.90	37	2
PLOO	E03	110	107	276	4.2	0.90	43	4
PLOO	E03 DUP	110	134	347	4.6	0.90	61	2
PLOO	E05	97	119	308	3.8	0.80	27	4
PLOO	E05 DUP	97	89	268	4.0	0.90	35	6
PLOO	E08	96	130	301	4.0	0.80	34	5
PLOO	E08 DUP	96	90	349	3.7	0.80	29	5
PLOO	E11	96	113	201	3.9	0.80	31	7
PLOO	E11 DUP	96	89	282	3.9	0.90	34	11
PLOO	E14	97	150	497	3.8	0.80	31	14
PLOO	E14 DUP	97	89	396	3.3	0.70	24	14
PLOO	E17	96	126	364	3.8	0.80	33	9
PLOO	E17 DUP	96	95	321	4.1	0.90	35	8
PLOO	E20	98	113	271	3.8	0.80	29	5
PLOO	E20 DUP	98	79	224	3.9	0.90	30	4
PLOO	E23	97	103	209	3.8	0.80	27	5
PLOO	E23 DUP	97	78	260	3.7	0.90	28	8
PLOO	E25	97	125	419	3.6	0.70	23	4

ATTACHMENT C.4-B (continued)

Region	Station	Depth (m)	SR	Abun	H’	J’	Dom	BRI
PLOO	E25 DUP	97	91	483	3.6	0.80	23	6
PLOO	E26	97	131	718	2.5	0.50	11	1
PLOO	E26 DUP	97	93	702	2.7	0.60	11	5
PLOO	SM001	207	46	96	3.4	0.90	22	20
PLOO	SM002	74	96	695	2.7	0.60	9	5
PLOO	SM003	91	94	337	3.9	0.90	31	5
PLOO	SM004	88	90	490	3.3	0.70	18	4
PLOO	SM005	45	118	357	4.3	0.90	45	16
PLOO	SM006	169	59	182	3.4	0.80	22	13
PLOO	SM007	100	101	424	4.1	0.90	34	10
PLOO	SM008	93	113	586	3.6	0.80	28	6
PLOO	SM009	94	102	441	3.9	0.80	29	6
PLOO	SM010	101	105	399	4.1	0.90	33	9
PLOO	SM011	98	99	357	4.0	0.90	34	7
PLOO	SM012	96	108	528	3.7	0.80	28	8
PLOO	SM013	97	96	355	4.0	0.90	33	4
PLOO	SM014	99	111	460	3.9	0.80	29	5
PLOO	SM015	86	102	654	3.1	0.70	17	5
PLOO	SM016	73	80	410	3.2	0.70	16	0
PLOO	SM017	103	88	294	4.0	0.90	32	7
PLOO	SM018	92	88	342	3.8	0.80	28	8
PLOO	SM019	87	120	955	2.4	0.50	10	4
PLOO	SM020	76	93	793	2.5	0.50	6	5
PLOO	SM021	74	80	416	3.0	0.70	11	4
PLOO	SM022	75	85	464	3.2	0.70	15	8
PLOO	SM023	77	84	374	3.4	0.80	19	5
PLOO	SM024	76	58	302	2.8	0.70	10	6
PLOO	SM025	77	78	383	3.1	0.70	14	5
PLOO	SM026	77	81	468	3.2	0.70	17	6
PLOO	SM027	76	75	338	3.2	0.70	16	5
PLOO	SM028	76	92	568	2.9	0.60	10	1
PLOO	SM028 DUP	76	81	909	2.0	0.50	4	8
PLOO	SM029	68	89	311	3.5	0.80	26	7
PLOO	SM030	224	42	67	3.6	1.00	26	14
PLOO	SM031	82	89	539	3.0	0.70	13	5
PLOO	SM032	79	82	829	2.2	0.50	5	8
PLOO	SM033	105	81	262	4.0	0.90	30	7
PLOO	SM034	115	74	203	3.9	0.90	30	9
PLOO	SM035	89	82	281	3.6	0.80	25	7

ATTACHMENT C.4-B (continued)

Region	Station	Depth (m)	SR	Abun	H’	J’	Dom	BRI
PLOO	SM036	203	49	128	3.2	0.80	19	16
PLOO	SM037	97	70	404	2.8	0.70	14	15
PLOO	SM038	92	91	490	3.5	0.80	23	19
PLOO	SM039	98	91	381	3.9	0.90	31	19
PLOO	SM040	101	96	348	4.0	0.90	34	9
PLOO	SM041	89	111	587	3.5	0.80	28	14
PLOO	SM042	96	102	782	3.5	0.70	21	35
PLOO	SM043	97	133	853	3.8	0.80	25	26
PLOO	SM044	98	104	405	4.0	0.90	34	13
PLOO	SM045	93	82	309	3.8	0.90	27	11
PLOO	SM046	73	74	319	3.2	0.70	17	8
PLOO	SM047	101	118	446	4.3	0.90	41	6
PLOO	SM048	91	78	371	3.6	0.80	21	10
PLOO	SM049	103	103	283	4.2	0.90	42	4
PLOO	SM050	89	100	301	3.9	0.80	35	4
PLOO	SM051	191	47	110	3.3	0.80	20	13
PLOO	SM052	183	53	137	3.3	0.80	20	13
PLOO	SM053	99	85	320	3.8	0.80	26	1
PLOO	SM054	96	91	280	3.9	0.90	30	4
PLOO	SM055	93	95	314	3.9	0.90	33	2
PLOO	SM056	96	98	332	3.9	0.80	31	3
PLOO	SM057	99	78	206	3.8	0.90	28	4
PLOO	SM058	96	86	251	4.0	0.90	32	3
PLOO	SM059	96	90	322	3.9	0.90	31	5
PLOO	SM060	96	80	281	3.7	0.90	25	2
PLOO	SM061	97	74	233	3.7	0.90	25	5
PLOO	SM062	89	72	240	3.5	0.80	23	4
PLOO	SM063	76	94	415	3.3	0.70	21	11
PLOO	SM064	111	137	417	4.5	0.90	55	9
PLOO	SM065	104	100	329	4.0	0.90	37	6
PLOO	SM066	91	88	303	3.8	0.80	30	5
PLOO	SM067	175	76	158	4.0	0.90	37	16
PLOO	SM068	112	126	351	4.3	0.90	51	7
PLOO	SM069	106	127	302	4.5	0.90	58	5
PLOO	SM070	106	126	278	4.5	0.90	57	6
PLOO	SM071	126	83	261	3.9	0.90	32	6
PLOO	SM072	109	89	245	4.0	0.90	33	7
PLOO	SM073	109	153	580	4.2	0.80	50	5
PLOO	SM074	110	139	339	4.6	0.90	63	5

ATTACHMENT C.4-B (continued)

Region	Station	Depth (m)	SR	Abun	H’	J’	Dom	BRI
PLOO	SM075	111	132	312	4.5	0.90	56	3
PLOO	SM076	99	100	229	4.3	0.90	44	6
PLOO	SM077	143	96	224	4.2	0.90	40	11
PLOO	SM078	99	156	549	4.4	0.90	54	3
PLOO	SM079	195	69	124	4.0	0.90	38	9
PLOO	SM080	94	139	374	4.4	0.90	56	8
SBOO	I01	60	80	222	3.0	0.70	11	15
SBOO	I01 DUP	60	51	149	3.3	0.80	19	10
SBOO	I02	34	54	239	2.5	0.60	12	14
SBOO	I03	27	67	359	3.4	0.80	17	10
SBOO	I04	19	36	112	3.1	0.90	13	7
SBOO	I06	25	45	193	2.8	0.70	12	10
SBOO	I07	50	98	407	4.1	0.90	34	13
SBOO	I08	35	91	335	2.8	0.60	14	15
SBOO	I08 DUP	35	54	201	3.1	0.80	14	16
SBOO	I09	30	121	381	3.2	0.70	20	28
SBOO	I09 DUP	30	86	339	3.3	0.70	21	26
SBOO	I10	20	54	168	3.4	0.80	20	13
SBOO	I12	28	99	221	2.5	0.50	9	15
SBOO	I12 DUP	28	74	223	3.6	0.80	29	24
SBOO	I13	38	85	266	3.1	0.70	15	9
SBOO	I13 DUP	38	48	139	3.2	0.80	17	14
SBOO	I14	28	73	241	3.5	0.80	23	22
SBOO	I15	31	73	249	2.0	0.50	6	11
SBOO	I15 DUP	31	54	297	1.9	0.50	7	15
SBOO	I16	29	107	329	3.7	0.80	36	20
SBOO	I18	19	43	113	3.2	0.80	16	4
SBOO	I20	55	79	375	3.4	0.80	19	9
SBOO	I21	41	48	184	3.2	0.80	15	7
SBOO	I22	28	60	217	3.2	0.80	17	24
SBOO	I23	21	72	830	3.0	0.70	10	17
SBOO	I27	29	75	210	3.9	0.90	31	23
SBOO	I28	56	206	532	4.2	0.80	49	10
SBOO	I28 DUP	56	138	532	4.1	0.80	42	8
SBOO	I29	37	95	766	3.1	0.70	13	14
SBOO	I30	28	78	134	3.6	0.80	23	21
SBOO	I30 DUP	28	46	119	3.3	0.90	17	24
SBOO	I31	19	57	252	3.0	0.70	16	16
SBOO	I33	30	90	320	3.9	0.90	31	19

ATTACHMENT C.4-B (continued)

Region	Station	Depth (m)	SR	Abun	H’	J’	Dom	BRI
SBOO	I34	20	61	427	2.8	0.70	10	7
SBOO	I35	19	69	170	3.9	0.90	32	22
SBOO	SM081	55	116	377	4.0	0.80	41	14
SBOO	SM082	64	149	440	4.4	0.90	52	11
SBOO	SM083	58	153	462	4.5	0.90	57	9
SBOO	SM084	57	141	411	4.5	0.90	55	8
SBOO	SM085	56	169	650	4.4	0.90	50	10
SBOO	SM086	55	149	492	4.2	0.80	47	10
SBOO	SM087	52	143	541	4.2	0.80	41	9
SBOO	SM088	59	49	101	3.6	0.90	24	16
SBOO	SM089	24	81	274	3.7	0.80	30	25
SBOO	SM091	30	93	335	3.9	0.90	28	21
SBOO	SM092	24	89	456	3.4	0.80	24	19
SBOO	SM093	27	67	311	2.7	0.70	12	20
SBOO	SM094	28	57	199	3.3	0.80	17	24
SBOO	SM095	28	76	229	3.8	0.90	29	24
SBOO	SM096	28	60	214	3.1	0.70	18	22
SBOO	SM097	28	63	222	3.6	0.90	21	21
SBOO	SM098	28	75	222	3.4	0.80	25	23
SBOO	SM099	27	28	82	3.0	0.90	13	20
SBOO	SM100	28	66	188	3.6	0.90	24	23
SBOO	SM101	17	72	305	3.1	0.70	18	16
SBOO	SM102	31	82	228	3.9	0.90	33	20
SBOO	SM103	25	82	286	3.7	0.90	27	24
SBOO	SM104	30	88	325	3.9	0.90	30	23
SBOO	SM105	42	106	578	3.6	0.80	24	16
SBOO	SM106	38	122	387	4.1	0.80	42	19
SBOO	SM107	30	87	246	3.9	0.90	34	20
SBOO	SM109	38	89	439	3.5	0.80	25	16
SBOO	SM110	30	80	416	2.7	0.60	15	20
SBOO	SM111	41	96	437	3.6	0.80	25	8
SBOO	SM112	39	97	459	3.5	0.80	23	10
SBOO	SM113	38	70	304	3.4	0.80	22	12
SBOO	SM114	37	70	338	3.3	0.80	17	8
SBOO	SM115	38	86	493	3.6	0.80	23	12
SBOO	SM116	38	104	540	3.5	0.80	25	16
SBOO	SM117	35	66	255	3.6	0.90	23	9
SBOO	SM118	38	64	291	3.3	0.80	18	3
SBOO	SM119	38	69	351	3.4	0.80	19	10

ATTACHMENT C.4-B (continued)

Region	Station	Depth (m)	SR	Abun	H’	J’	Dom	BRI
SBOO	SM120	35	78	342	3.5	0.80	22	12
SBOO	SM121	34	86	506	3.3	0.70	21	12
SBOO	SM122	32	72	347	2.8	0.60	18	17
SBOO	SM123	31	84	257	3.6	0.80	29	23
SBOO	SM124	30	110	403	4.0	0.80	38	22
SBOO	SM125	32	97	394	3.7	0.80	32	24
SBOO	SM126	31	70	302	2.9	0.70	17	18
SBOO	SM127	30	78	504	2.5	0.60	10	15
SBOO	SM128	32	72	558	2.1	0.50	6	18
SBOO	SM129	31	65	436	2.1	0.50	9	17
SBOO	SM130	26	91	301	3.6	0.80	30	26
SBOO	SM131	25	66	297	2.7	0.60	15	16
SBOO	SM132	37	45	325	2.4	0.60	8	5
SBOO	SM133	32	89	344	3.6	0.80	26	23
SBOO	SM134	43	87	344	3.8	0.80	27	15
SBOO	SM135	36	43	294	2.4	0.60	7	9
SBOO	SM136	32	53	247	2.8	0.70	14	23
SBOO	SM137	31	104	383	3.8	0.80	34	23
SBOO	SM138	25	110	570	3.4	0.70	22	25
SBOO	SM139	24	76	197	3.9	0.90	32	18
SBOO	SM141	37	96	462	3.8	0.80	27	11
SBOO	SM142	28	90	301	3.7	0.80	32	24
SBOO	SM143	26	97	391	3.6	0.80	29	25
SBOO	SM144	29	75	317	3.5	0.80	24	24
SBOO	SM145	35	92	409	3.6	0.80	28	25
SBOO	SM146	29	77	378	3.2	0.70	15	25
SBOO	SM147	29	100	508	3.8	0.80	29	23
SBOO	SM148	29	107	600	2.9	0.60	20	24
SBOO	SM149	29	84	298	3.8	0.90	28	24
SBOO	SM150	31	78	473	2.6	0.60	12	9
SBOO	SM151	26	77	334	3.2	0.70	17	23
SBOO	SM152	31	63	343	2.5	0.60	11	12

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Appendix C.5
DEEP BENTHIC HABITAT ASSESSMENT STUDY

Renewal of NPDES CA0107409

APPENDIX C.5

DEEP BENTHIC HABITAT ASSESSMENT STUDY

January 2015

APPENDIX C.5

Deep Benthic Habitat Assessment Study

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APPENDIX C.5

Deep Benthic Habitat Assessment Study Summary Report

SECTION C.5-1 | INTRODUCTION

The Scripps Institution of Oceanography (SIO) was hired by the City of San Diego (City) to assess the adequacy of the City's Ocean Monitoring Program in providing the data and scientific understanding necessary to answer relevant questions about the effects of the Point Loma Ocean Outfall on the marine environment off San Diego. This work, the Point Loma Outfall Project (PLOP), was performed by a team of SIO scientists who reviewed the City's existing monitoring efforts and capabilities and compared these to programs conducted elsewhere for similar ocean outfalls. The results of this scientific review were summarized in a peer-reviewed report (SIO 2004), which was submitted to the City in September 2004. This information was also conveyed to state and federal regulators and to other interested stakeholders, including the San Diego Regional Water Quality Control Board (RWQCB), the United States Environmental Protection Agency (USEPA), and local environmental organizations (i.e., Bay Council). The final PLOP report included a summary of major findings and a subsequent list of prioritized recommendations for enhanced environmental monitoring of the San Diego coastal region.

A primary recommendation of the PLOP report was that a special studies program should be developed and implemented to examine the need to extend the City's benthic monitoring program to additional areas where sediments may accumulate. It was also recommended that new target areas include deeper slope and submarine canyon habitats located further offshore of the Point Loma outfall, as well as the nearby LA-5 dredged materials disposal site (see Gardner et al. 1998). The Deep Benthic Pilot Study was designed to begin assessing the quality of deep benthic habitats that occur off Point Loma, San Diego, California. Specifically, the pilot study targeted sediment quality at depths greater than 200 m in the Loma Sea Valley located offshore of the regular Point Loma monitoring region. The general scope, direction and level of effort of the pilot study (e.g., sampling area, distribution and number of sites, biotic and abiotic parameters) were agreed upon during negotiations between the City, SIO, RWQCB, USEPA and Bay Council. The final study design, including the rationale for the specific location and selection of sampling sites, was developed collaboratively by representatives of the City and SIO (Stebbins and Parnell 2005) and a Phase 1 Summary Report for the San Diego Deep Benthic Pilot Study was included in the previous 301(h) waiver application in 2007 (City of San Diego 2007).

The objective of the Deep Benthic Habitat Assessment Study is to build on the findings of the Deep Benthic Pilot Study by summarizing results from all stations sampled in deeper habitats along the upper slope (200–500 m) and lower slope (500-1000 m) as part of various surveys conducted from 2003 to 2005 and from 2007 to 2013 (see Table C.5-1 and Attachment C.5-A). The area for this expanded study ranged from off Carlsbad in northern San Diego County to just south of the US/Mexico border. One hundred and ten samples were collected from sites ranging in depth from 199 to 1023 m during these 10 surveys. The majority of data come from the original pilot study conducted during 2005 (City of San Diego 2007) and three larger, multi-agency surveys of the entire Southern California Bight (SCB) conducted in 2003, 2008, and 2013 (Bight'13 CIA 2013, Ranasinghe et al. 2007, 2012). Additional data are from stations sampled during five San Diego Regional surveys conducted in 2007 and 2009–2012 (City of San Diego 2008, 2013), and the first phase of a special sediment mapping project conducted during 2004 (Stebbins et al. 2004). No data are included from the 2006 San Diego Regional survey as all stations were restricted to continental shelf depths (<200 m).

SECTION C.5-2 | MATERIALS AND METHODS

Sample Collection and Processing

Samples for benthic community analyses were collected at each station using a single or double 0.1-m^2 Van Veen grab. To ensure consistency of grab samples, protocols established by the USEPA were followed to standardize sample disturbance and depth of penetration (USEPA 1987). All samples were sieved aboard ship through a 1.0-mm mesh screen, and all debris and organisms retained on the screen were collected and relaxed for 30 minutes in a magnesium sulfate solution before fixing in buffered formalin. After a minimum of 72 hours, each sample was rinsed with fresh water and transferred to 70% ethanol. All animals were sorted from the sediment into major taxonomic groups by a subcontracted laboratory, and identified to species (or the lowest taxon possible) following SCAMIT (2013) nomenclature and enumerated.

An additional grab was taken at each station for the analysis of various physical and chemical sediment parameters. Sub-samples were taken from the top 2 cm of the sediment surface and handled according to standard guidelines available in USEPA (1987). All sediment chemistry and particle size analyses were performed at the City of San Diego's Environmental Chemistry Services Laboratory; a detailed description of current analytical protocols can be found in City of San Diego (2014). A summary of parameters measured during each survey is listed in Attachment C.5-B with method detection limits (MDLs). Sediment chemistry data were generally limited to values above the MDL for each parameter. However, concentrations below MDLs were included as estimated values if the presence of a specific constituent was verified by mass-spectrometry.

Particle size analysis was performed using a Horiba laser scattering particle analyzer which measures particles ranging in size from 0.5 to 2000 µm. Coarser sediments were removed and quantified prior to laser analysis by screening samples through a 2000 µm mesh sieve. These data were later combined with the Horiba results to obtain a complete distribution of particle sizes totaling 100%. Particle sizes were classified into size fractions (i.e., fine particles, fine sands, medium-coarse sands, coarse particles) based on the Wentworth scale (Folk 1980).

Data Analyses

Data summaries for the various sediment parameters included detection rates, minimum, median, maximum and mean values for all samples combined. All means were calculated using detected values only; no substitutions were made for non-detects in the data to avoid underestimating sediment contaminant loads (see Helsel 2005). Total DDT (tDDT), total hexachlorocyclohexane (tHCH), total chlordane, total PCB (tPCB), and total PAH (tPAH) were calculated for each sample as the sum of all constituents with reported values. Sediment contaminant concentrations were compared to the Effects Range Low (ERL) and Effects Range Median (ERM) sediment quality guidelines of Long et al. (1995) when available. The ERLs represent chemical concentrations below which adverse biological effects are rarely observed, while values above the ERL but below the ERM represent levels at which effects occasionally occur. Concentrations above the ERM indicate likely biological effects, although these are not always validated by toxicity testing (Schiff and Gossett 1998).

To examine spatial and temporal patterns in the benthic macrofaunal data, multivariate analyses were conducted using PRIMER (Clarke and Warwick 2001, Clarke and Gorley 2006). These analyses included ordination by non-metric multidimensional scaling (nMDS), hierarchical agglomerative clustering (cluster analysis) with group-average linking, and similarity profile analysis (SIMPROF) to confirm the non-random structure of the resultant cluster dendrogram (Clarke et al. 2008). The Bray-Curtis measure of similarity was used as the basis for the ordination and cluster analyses, and abundance data were square-root transformed to lessen the influence of the most abundant species and increase the importance of rare species. Major ecologically-relevant clusters supported by SIMPROF were retained, and similarity percentages analysis (SIMPER) was used to determine which organisms were responsible for the greatest contributions to within-group similarity (i.e., characteristic species) and between-group dissimilarity for retained clusters. Additionally, the following community structure parameters were calculated for each 0.1m^2-grab: species richness (number of species), abundance (number of individuals), Shannon diversity index (H'; Shannon and Weaver 1949), Pielou's evenness index (J'; Pielou 1977), and Swartz dominance (see Swartz et al. 1986, Ferraro et al. 1994). These parameters were then summarized by cluster group.

SECTION C.5-3 | SUMMARY

Sediments

An in-depth analysis of sediment and benthic infauna data for the Deep Benthic Habitat Assessment Study will be forthcoming in a comprehensive final report. Sediment particle size and chemistry parameters are summarized across all deep benthic (slope) samples in Table C.5-2, by depth range in Tables C.5-3, C.5-4, and C.5-5, compared to shelf values in Figure C.5-1, and mapped in Figure C.5-2. Sediment composition averaged 78% fines, 20% fine sands, and only traces of medium-coarse sands or coarse particles. Detection rates were ≥70% for sulfides, total nitrogen (TN), total organic carbon (TOC), total volatile solids (TVS), and 16 out of 18 trace metals (Table C.5-2). In contrast, detection rates of silver, total DDT, and total PAH ranged from 26 to 49%, while thallium, dieldrin, hexachlorobenzene, HCH, chlordane, and total PCB were found in ≤15% of the samples, and the pesticides aldrin, endosulfan, endrin, and Mirex were not detected. Overall, concentrations of the various parameters were variable with very few exceedances of available ERL and ERM thresholds (see Long et al. 1995). For example, lead, zinc and total PAH never exceeded their ERL or ERM, while exceedances for arsenic, cadmium, chromium, mercury, and total DDT were rare (i.e., ≤3% of the samples included in this study). Copper exceeded its ERL in 8% of the slope samples, all from sites located at depths greater than 500 m (Figure C.5-2m). Silver exceeded its ERL and its ERM in about 19% and 14% of all samples, respectively (Figure C.5-2t). Nickel exceeded its ERL in 66 samples, all but two of which were from sites located deeper than 450 m (Figure C.5-2r). Nickel only exceeded its ERM once.

In this study, median percent fines was higher on the slope than the shelf, and increased with increasing depth (Figure C.5-1). This trend was mirrored by sediment concentrations total nitrogen, total organic carbon, total volatile solids, aluminum, barium, beryllium, cadmium, chromium, copper, iron, manganese, nickel, and selenium, but not sulfides, antimony, arsenic, lead, mercury, silver, thallium, tin, zinc, total DDT, total PCB, or total PAH. The association between sediment particle size and the concentration of organics and trace metals is expected (see Eganhouse and Venkatesan 1993) and has been observed regionally off San Diego previously (City of San Diego 2013). No clear patterns relative to proximity to the Point Loma Ocean Outfall were observed (Figure C.5-2).

Benthic Infauna

Ordination and classification (cluster) analyses illustrate the biological patterns at the community level for benthic slope stations sampled from 2003 to 2005 and from 2007 to 2013 (Figures C.5-3 and C.5-4). Cluster analysis discriminated eight ecologically-relevant SIMPROF-supported groups (cluster groups A–H) that occurred at 1 to 51 sites each, with very little temporal partitioning evident. Instead, assemblages represented by each cluster group differed primarily by depth, location, and species composition (Tables C.5-6 and C.5-7, Figure C.5-5). The species composition and main descriptive characteristics of each cluster group are described below.

Cluster group A represented assemblages from two sites located at 252 and 342 m along the edge of the Coronado Bank. This group averaged the second highest species richness of 40 species/grab, the second highest abundance of 97 individuals/grab, and the highest diversity of 3.29 units/grab. Characteristic taxa that contributed to ~50% of intra-group similarity according to SIMPER for group A included *Amphiodia digitata*, *Mediomastus* sp, *Polycirrus* sp, *Parvilucina tenuisculpta*, Scaphopoda, and Ophiuroidea.

Cluster group B was the largest cluster, comprising 51 grabs collected along the upper slope from off of Carlsbad to just south of the US/Mexico border at depths between 199 and 430 m. Assemblages represented by this group had the highest species richness (48 species/grab), abundance (131 individuals/grab), Swartz dominance (20 taxa/grab), and the second highest diversity (3.28 units/grab). Assemblages represented by this group also had the most characteristic species, including *Mediomastus* sp, *Macoma carlottensis*, *Spiophanes kimballi*, *Maldane sarsi*, *Compressidens stearnsii*, *Melinna heterodonta*, *Paraprionospio alata*, Amphiuridae, *Aphelochaeta monilaris*, *Adontorhina cyclia*, and *Onuphis iridescens*.

Cluster group C comprised four sites located in the La Jolla Canyon at depths between 244 and 427 m. Compared to other upper slope clusters (i.e., groups A, B and F), these assemblages had lower species richness (23 species/grab), abundance (68 individuals/grab), diversity (2.57 units/grab), and Swartz dominance (10 taxa/grab). Characteristic species were limited to *Macoma carlottensis* and *Prionospio (Prionospio) ehlersi*. Cluster group C had the highest average abundance of *P (P) ehlersi* of all the groups.

Cluster group D represented the assemblage present in a single grab collected within the La Jolla canyon at 529 m. This assemblage had the lowest species richness (14 species), abundance (21 individuals), diversity (2.46 units), and Swartz dominance (9 taxa) of any cluster group. The species or taxa present included five *Maldane sarsi*, two *Fauveliopsis* sp, two *Monticellina cryptica*, two *Ypsilothuria bitentaculata*, and single specimens of *Cephalophoxoides homilis*, Lineidae, *Ophelina pallida*, *Aphelochaeta* sp SD18, *Saxicavella pacifica*, *Aphelochaeta phillipsi*, *Sternaspis williamsae*, Lasaeidae, *Listriolobus hexamyotus*, and *Sternaspis* cf *princeps*. Several of these taxa were unique to this station.

Cluster group E comprised four Deep Benthic Pilot Study sites sampled during 2005 at depths between 502 and 542 m. Assemblages represented by this group averaged 24 species and 50 individuals per grab, with diversity and Swartz dominance values of 2.70 units and 13 taxa per grab, respectively. Characteristic species included *Maldane sarsi*, *Eclysippe trilobata*, Yoldiidae, and *Kinbergonuphis vexillaria*.

Cluster group F represented assemblages from 16 grabs collected along the middle slope from off of Carlsbad south to the Coronado Bank at depths between 355 and 484 m. These assemblages averaged 27 species and 79 individuals per grab, with diversity and Swartz dominance values of 2.78 units and 11 taxa per grab, respectively. Characteristic species included *Maldane sarsi, Eclysippe trilobata,* and *Yoldiella nana.*

Cluster group G represented assemblages from 9 grabs collected at middle and lower slope depths between 480 and 790 m. Average species richness (21 species/grab), abundance (37 individuals/grab), diversity (2.80 units/grab), and Swartz dominance (13 taxa/grab) for these assemblages were very similar to those for cluster group H (see below) and lower than for the main upper slope assemblages represented by group B. Characteristic species included *Maldane sarsi, Monticellina cryptica, Yoldiella nana,* and *Fauveliopsis glabra.*

Cluster group H was the second largest cluster, comprising 23 grabs collected along the lower slope from off of Carlsbad to just south of the US/Mexico border at depths between 562 and

1023 m. As with group G, assemblages represented by group H had lower species richness (21 species/grab), abundance (38 individuals/grab), diversity (2.78 units/grab), and Swartz dominance (13 taxa/grab) than upper slope group B. Characteristic taxa included Ophiuroidea, *Maldane sarsi, Monticellina cryptica, Falcidens hartmanae, Sonatsa carinata, Harpiniopsis epistomata, Leiochrides hemipodus,* and Lineidae. While Ophiuroidea, *M. sarsi*, and *M. cryptica* were also characteristic of other cluster groups, the rest were only characteristic of group H.

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APPENDIX C.5

Deep Benthic Habitat Assessment Study

TABLES

TABLE C.5-1

Summary by project for slope stations included in the Deep Benthic Habitat Assessment Study. No slope stations were sampled during 2006. See Attachment C.5-A for station map.

			Depth (m)	
Year	**Project**	**No. of Stations**	**Min**	**Max**
2003	Southern California Bight Survey (BIGHT'03)	11	252	850
2004	Sediment Mapping Study Phase 1	3	203	224
2005	Deep Benthic Pilot Study	16	199	542
2007	San Diego Regional Survey	1	216	216
2008	Southern California Bight Survey (BIGHT'08)	23	203	1023
2009	San Diego Regional Survey	6	257	413
2010	San Diego Regional Survey	7	203	433
2011	San Diego Regional Survey	6	249	427
2012	San Diego Regional Survey	6	247	448
2013	Southern California Bight Survey (BIGHT'13)	31	244	942

TABLE C.5-2

Summary of particle sizes and chemistry concentrations in sediments from slope stations included in the Deep Benthic Habitat Assessment Study. Data include total number of samples (n), detection rate (DR), minimum, median, maximum, and mean values[a] for all stations combined. ERL = Effects Range Low threshold; ERM = Effects Range median threshold.

Parameter	n	DR	Min	Median	Max	Mean	ERL[b]	ERM [b]
Depth (m)	110	—	199	402	1023	448	—	—
Particle size (%)								
Fine Particles	110	—	24.94	83.22	96.12	78.27	—	—
Fine Sands	110	—	3.95	16.43	71.90	20.13	—	—
Med-Coarse sands	110	—	0.00	0.38	33.90	1.60	—	—
Coarse Particles	110	—	0.00	0.00	0.53	0.01	—	—
Organic Indicators								
Sulfides (ppm)	42	98	nd	10.75	444.00	28.85	na	na
TN (% weight)	110	100	0.05	0.21	0.50	0.22	na	na
TOC (% weight)	110	100	0.44	2.46	5.30	2.54	na	na
TVS (% weight)	76	100	3.06	7.41	14.10	7.63	na	na
Trace Metals (ppm)								
Aluminum	110	100	4540	24850	53700	24759	na	na
Antimony	110	70	nd	0.58	3.10	1.29	na	na
Arsenic	110	100	0.57	3.29	10.50	3.58	8.2	70
Barium	110	100	18.10	104.50	503.00	137.85	na	na
Beryllium	110	74	nd	0.33	1.66	0.41	na	na
Cadmium	110	99	nd	0.42	2.13	0.47	1.2	9.6
Chromium	110	100	12.50	38.85	92.80	40.67	81	370
Copper	110	100	5.03	21.30	51.30	21.99	34	270
Iron	110	100	9310	23450	49900	23745	na	na
Lead	110	100	1.41	8.98	30.10	10.13	46.7	218
Manganese	109	100	28.10	202.00	394.00	210.56	na	na
Mercury	109	100	0.015	0.054	0.425	0.063	0.150	0.710
Nickel	110	100	5.04	23.60	53.80	24.29	20.9	51.6
Selenium	110	85	nd	0.90	4.07	1.26	na	na
Silver	110	26	nd	nd	6.95	3.35	1	3.7
Thallium	110	5	nd	nd	0.93	0.60	na	na
Tin	109	100	0.12	1.50	5.14	1.63	na	na
Zinc	110	100	16.90	59.50	138.00	62.55	150	410
Pesticides (ppt)								
Dieldrin	107	1	nd	nd	800	800	na	na
Hexachlorobenzene	107	5	nd	nd	620	347	na	na
Total HCH	107	3	nd	nd	18200	9433	na	na
Total chlordane	110	4	nd	nd	3650	1731	na	na
Total DDT	110	43	nd	nd	1670	606	1580	46100
Total PCB (ppt)	110	15	nd	nd	7335	1224	na	na
Total PAH (ppb)	91	49	nd	nd	518	133	4022	44792

[a] Minimum, median, and maximum values were calculated using all samples, whereas means were calculated on detected values only; na=not available, nd=not detected

[b] From Long et al. 1995

TABLE C.5-3

Particle sizes and organic indicators summarized by depth range for slope stations included in the Deep Benthic Habitat Assessment study. Data include the total number of samples, detection rates, minimum, median, maximum, and mean[a] values.

		Particle size (%)				*Organic Indicators*[a]				
Parameter	***Depth (m)***	**Fine Particles**	**Fine Sands**	**Med-Coarse Sands**	**Coarse Particles**	**Sulfides (ppm)**	**TN (%wt)**	**TOC (%wt)**	**TS (%wt)**	**TVS (%wt)**
Depth Range = 199-299 m										
No. of Samples	29	29	29	29	29	15	29	29	28	24
Detect. Rate	—	—	—	—	—	100	100	100	100	100
Minimum	199	24.94	14.03	0.00	0.00	0.97	0.08	0.62	48.60	3.28
Median	247	71.30	28.28	0.54	0.00	10.70	0.15	1.73	56.40	6.17
Maximum	294	85.64	71.90	17.48	0.00	28.30	0.32	3.20	66.90	7.97
Mean	240	68.02	30.35	1.65	0.00	11.19	0.15	1.94	56.53	6.09
Depth Range = 300-399 m										
No. of Samples	24	24	24	24	24	13	24	24	21	17
Detect. Rate	—	—	—	—	—	100	100	100	100	100
Minimum	302	39.05	11.34	0.00	0.00	2.17	0.09	0.83	40.90	3.06
Median	337	78.14	21.59	0.42	0.00	11.60	0.19	2.22	50.90	7.72
Maximum	394	88.55	46.16	25.36	0.00	254.00	0.25	3.41	72.90	9.19
Mean	339	74.00	23.65	2.36	0.00	36.04	0.18	2.19	52.59	7.31
Depth Range = 400-499 m										
No. of Samples	21	21	21	21	21	10	21	21	20	16
Detect. Rate	—	—	—	—	—	90	100	100	100	100
Minimum	400	47.58	3.95	0.00	0.00	nd	0.10	1.21	41.40	4.22
Median	427	86.77	12.95	0.21	0.00	9.99	0.22	2.40	45.45	8.25
Maximum	484	96.12	44.73	11.44	0.40	444.00	0.31	3.30	84.40	9.28
Mean	434	81.01	17.55	1.43	0.02	57.02	0.21	2.43	50.74	7.59
Depth Range = 500+ m										
No. of Samples	36	36	36	36	36	4	36	36	36	19
Detect. Rate	—	—	—	—	—	100	100	100	100	100
Minimum	502	34.77	4.10	0.00	0.00	3.18	0.05	0.44	29.90	3.51
Median	667	89.92	10.01	0.14	0.00	5.91	0.32	3.32	39.70	9.88
Maximum	1023	95.92	30.70	33.90	0.53	18.20	0.50	5.30	67.30	14.10
Mean	698	87.78	11.07	1.15	0.01	8.30	0.31	3.32	40.37	9.92

[a] Minimum, median, and maximum values were calculated using all samples, whereas means were calculated on detected values only; nd=not detected

TABLE C.5-4

Metals (ppm) summarized by depth range for slope stations included in the Deep Benthic Habitat Assessment Study. Data include the total number of samples, detection rates, minimum, median, maximum, and mean[a] values. See Attachment C.5-B for translation of periodic table symbols.

Parameter	Al	Sb	As	Ba	Be	Cd	Cr	Cu	Fe	Pb	Mn	Hg	Ni	Se	Ag	Tl	Sn	Zn
Depth Range = 199-299																		
No. of Samples	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29
Detect. Rate	100	90	100	100	83	100	100	100	100	100	100	100	100	83	17	10	100	100
Minimum	4540	nd	1.69	18.10	nd	0.07	21.10	5.91	12600	1.41	28.10	0.02	5.47	nd	nd	nd	0.12	18.90
Median	19100	0.78	3.00	73.20	0.26	0.30	31.10	17.50	20000	8.60	177.00	0.06	17.60	0.60	nd	nd	1.64	48.20
Maximum	39400	2.99	5.75	121.00	0.46	0.51	43.20	31.20	30400	18.50	382.00	0.15	27.30	1.31	2.79	0.93	3.04	90.00
Mean	20720	1.20	3.42	71.67	0.32	0.29	31.49	16.78	20383	8.51	193.87	0.06	17.42	0.69	1.59	0.68	1.56	48.31
Depth Range = 300-399																		
No. of Samples	24	24	24	24	24	24	24	24	24	24	24	23	24	24	24	24	24	24
Detect. Rate	100	58	100	100	96	96	100	100	100	100	100	100	100	96	13	0	100	100
Minimum	4780	nd	2.58	51.20	nd	nd	12.50	5.03	9310	3.18	35.30	0.02	5.04	nd	nd	—	0.67	21.40
Median	18050	0.47	3.54	88.35	0.36	0.33	34.70	19.10	20200	7.17	158.00	0.06	19.70	0.86	nd	—	1.26	52.00
Maximum	43700	2.85	9.31	148.00	0.61	0.57	50.50	29.10	32500	25.80	313.00	0.43	29.30	1.56	3.83	—	5.14	85.10
Mean	20272	1.31	4.03	89.65	0.37	0.34	34.36	18.52	20746	8.77	172.78	0.08	19.10	0.86	1.89	—	1.49	51.15
Depth Range = 400-499																		
No. of Samples	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21
Detect. Rate	100	71	100	100	76	100	100	100	100	100	100	100	100	90	24	5	100	100
Minimum	11200	nd	1.01	72.10	nd	0.17	29.80	6.40	17100	2.16	77.60	0.02	10.40	nd	nd	nd	0.75	16.90
Median	21800	0.83	3.38	116.00	0.38	0.46	40.20	21.30	22900	8.03	186.00	0.05	24.10	1.22	nd	nd	1.36	64.00
Maximum	41300	3.10	10.50	200.00	1.66	2.13	68.20	27.10	32100	17.80	325.00	0.11	34.20	1.86	6.04	0.72	2.96	114.00
Mean	23957	1.55	3.86	114.74	0.47	0.54	41.49	19.78	23367	9.12	205.20	0.06	22.69	1.11	3.46	0.72	1.62	60.32
Depth Range = 500+																		
No. of Samples	36	36	36	36	36	36	36	36	36	36	35	36	36	36	36	36	35	36
Detect. Rate	100	61	100	100	50	100	100	100	100	100	100	100	100	75	44	3	100	100
Minimum	14600	nd	0.57	84.50	nd	0.09	28.90	8.74	19400	1.74	126.00	0.02	12.70	nd	nd	nd	0.63	33.70
Median	30600	0.36	3.15	220.00	nd	0.59	50.95	29.90	28350	12.90	251.00	0.05	33.55	1.66	nd	nd	1.94	82.10
Maximum	53700	2.88	7.47	503.00	0.67	1.25	92.80	51.30	49900	30.10	394.00	0.10	53.80	4.07	6.95	0.25	3.47	138.00
Mean	31472	1.20	3.24	236.79	0.53	0.65	51.80	29.80	28672	12.93	253.51	0.06	34.21	2.21	4.14	0.25	1.79	82.94

[a] Minimum, median, and maximum values were calculated using all samples, whereas means were calculated on detected values only; nd=not detected

TABLE C.5-5

Chlorinated pesticides, total PCB, and total PAH summarized by depth range for slope stations included in the Deep Benthic Habitat Assessment Study. Data include the total number of samples, detection rates, minimum, median, maximum, and mean values[a].

	Pesticides (ppt)					Total PCB	Total PAH
Parameter	**Dieldrin**	**HCB**	**tHCH**	**tChlordane**	**tDDT**	**(ppt)**	**(ppb)**
Depth Range = 199-299							
No. of Samples	26	26	26	29	29	29	22
Detect. Rate	0	0	0	0	59	17	41
Minimum	—	—	—	—	nd	nd	nd
Median	—	—	—	—	215	nd	nd
Maximum	—	—	—	—	1200	7335	308
Mean	—	—	—	—	524	1839	80
Depth Range = 300-399							
No. of Samples	24	24	24	24	24	24	20
Detect. Rate	0	4	4	4	33	21	55
Minimum	—	nd	nd	nd	nd	nd	nd
Median	—	nd	nd	nd	nd	nd	29
Maximum	—	210	6700	1760	1500	2250	518
Mean	—	210	6700	1760	766	768	206
Depth Range = 400-499							
No. of Samples	21	21	21	21	21	21	17
Detect. Rate	0	5	5	5	48	5	53
Minimum	—	nd	nd	nd	nd	nd	nd
Median	—	nd	nd	nd	nd	nd	20
Maximum	—	460	3400	1330	1500	330	457
Mean	—	460	3400	1330	526	330	123
Depth Range = 500+							
No. of Samples	36	36	36	36	36	36	32
Detect. Rate	3	8	3	6	33	14	50
Minimum	nd	nd	nd	nd	nd	nd	nd
Median	nd	nd	nd	nd	nd	nd	nd
Maximum	800	620	18200	3650	1670	4170	464
Mean	800	355	18200	1918	681	1244	118

[a] Minimum, median, and maximum values were calculated using all samples, whereas means were calculated on detected values only; nd=not detected

TABLE C.5-6

Community parameters summarized by cluster group (see Figure C.5-2). Data are minimum, median, maximum and mean values per grab.

	Cluster Group							
Parameter	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**
Number of Samples	2	51	4	1	4	16	9	23
Depth (m)								
Minimum	252	199	244	529	502	355	480	562
Median	297	286	317	529	514	429	527	757
Maximum	342	430	427	529	542	484	790	1023
Mean	297	293	326	529	518	429	603	764
Species Richness								
Minimum	30	22	18	14	15	20	12	8
Median	40	44	19	14	25	28	19	21
Maximum	49	126	34	14	30	37	33	38
Mean	40	48	23	14	24	27	21	21
Abundance								
Minimum	59	40	40	21	41	52	14	10
Median	97	106	66	21	49	76	40	31
Maximum	135	421	99	21	60	135	72	146
Mean	97	131	68	21	50	79	37	38
Diversity (H')								
Minimum	3.17	2.49	2.02	2.46	1.69	2.34	2.39	1.91
Median	3.29	3.32	2.53	2.46	2.95	2.79	2.71	2.85
Maximum	3.41	4.29	3.20	2.46	3.19	3.19	3.28	3.47
Mean	3.29	3.28	2.57	2.46	2.70	2.78	2.80	2.78
Evenness (J')								
Minimum	0.87	0.71	0.70	0.93	0.62	0.71	0.88	0.80
Median	0.90	0.87	0.86	0.93	0.91	0.86	0.94	0.94
Maximum	0.93	0.97	0.91	0.93	0.95	0.93	0.98	0.99
Mean	0.90	0.86	0.83	0.93	0.85	0.84	0.94	0.93
Swartz Dominance								
Minimum	16	8	4	9	4	7	8	6
Median	19	19	9	9	14	10	11	12
Maximum	21	45	17	9	18	16	19	24
Mean	19	20	10	9	13	11	13	13

TABLE C.5-7

Mean abundances for species that accounted for ≤50% of intra-group similarity for cluster groups A–H according to SIMPER analysis. SIMPER analysis is only conducted on cluster groups that contain more than one benthic grab, therefore highlighted values for Cluster Group D are the top four most abundant species.

	Cluster Group							
Taxa	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**
Amphiodia digitata	**7.5**	2.4				2.0		
Mediomastus sp	**5.5**	**10.1**				2.0		
Polycirrus sp	**3.5**	1.3	2.0			1.0		
Parvilucina tenuisculpta	**2.5**	2.0	1.3					
Scaphopoda	**2.5**	1.6	1.0		1.0	1.8		
Ophiuroidea	**1.0**	1.6	1.5			2.6	2.0	**4.5**
Macoma carlottensis		**10.9**	**7.0**			1.0		
Spiophanes kimballi		**10.0**						
Maldane sarsi		**8.5**		5.0	**13.0**	**9.5**	**4.6**	**1.3**
Compressidens stearnsii	2.0	**5.0**	1.3			2.0		1.0
Melinna heterodonta		**5.0**			1.0	1.0		2.0
Paraprionospio alata		**4.9**	9.0			1.3		
Amphiuridae	3.0	**3.4**				4.4		6.0
Aphelochaeta monilaris	1.0	**3.0**	4.0			1.0	1.0	2.2
Adontorhina cyclia		**2.9**				1.0	2.0	1.0
Onuphis iridescens		**1.8**	2.5		2.0	1.4		
Prionospio (Prionospio) ehlersi		2.1	**6.3**			1.8		1.0
Monticellina cryptica	1.0	1.8		2.0	1.0	1.7	**1.9**	**2.3**
Fauveliopsis sp	1.0	3.3		2.0		4.7	1.0	
Ypsilothuria bitentaculata				2.0			1.0	1.0
Eclysippe trilobata	1.0	3.8			**4.0**	**8.1**	1.4	1.0
Yoldiidae		1.0			**3.5**			1.0
Kinbergonuphis vexillaria					**1.3**	1.0	1.5	
Yoldiella nana		14.0	16.0			**9.3**	**3.4**	1.6
Fauveliopsis glabra		10.7			2.0	4.7	**3.2**	7.7
Falcidens hartmanae		1.0				2.0	2.5	**1.9**
Sonatsa carinata								**1.9**
Harpiniopsis epistomata					2.0	1.5	2.4	**1.7**
Leiochrides hemipodus						1.0	1.5	**1.5**
Lineidae	1.0	1.6	1.0	1.0	1.0	1.0		**1.3**

APPENDIX C.5

Deep Benthic Habitat Assessment Study

FIGURES

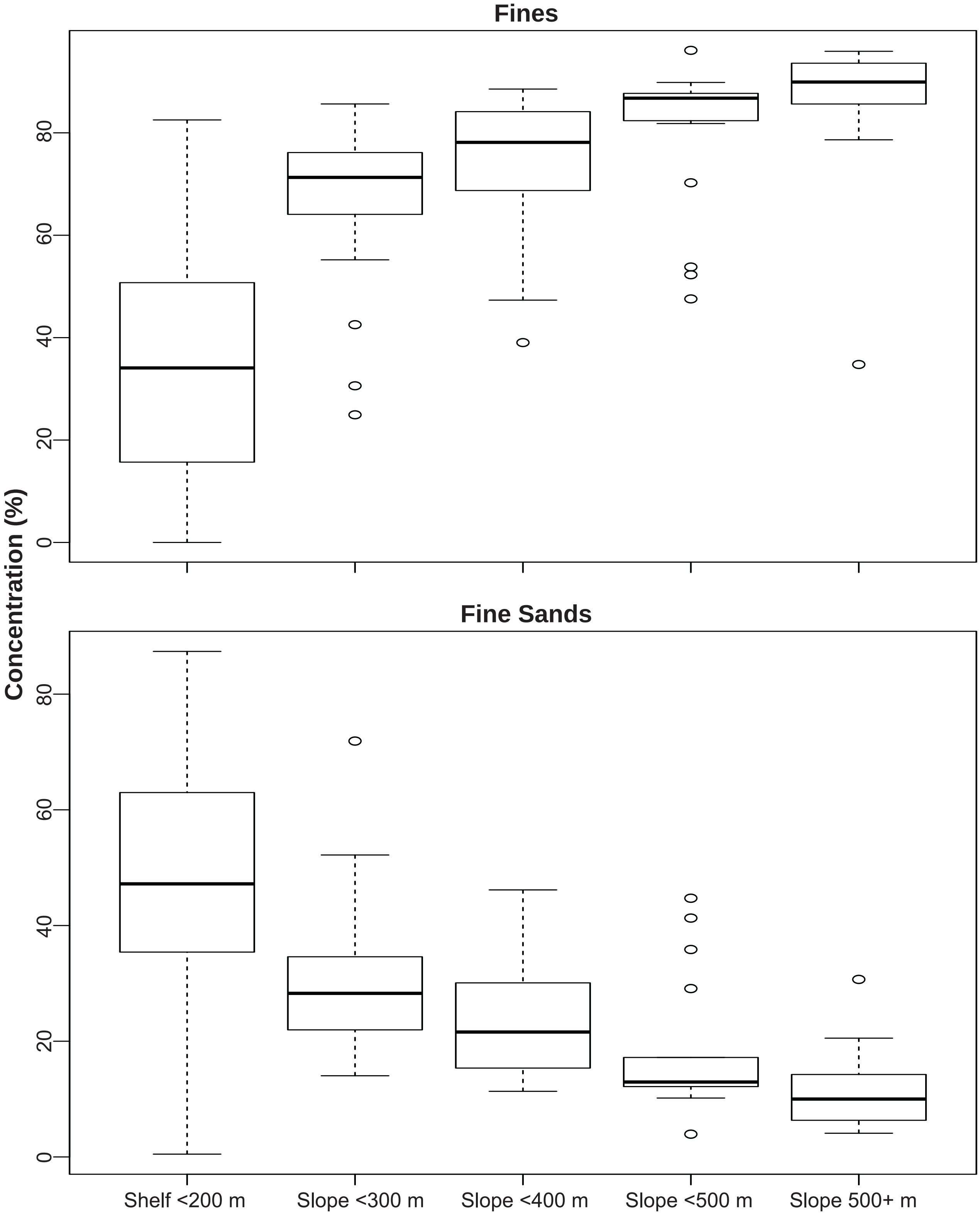


FIGURE C.5-1

Comparison of particle sizes and chemistry concentrations in sediments by depth range for all stations sampled during each project listed in Table C.5-1. Data include detected values only, and are presented as median, upper and lower quartiles, 1.5 times the interquartile range (whiskers), and outliers (open circles).

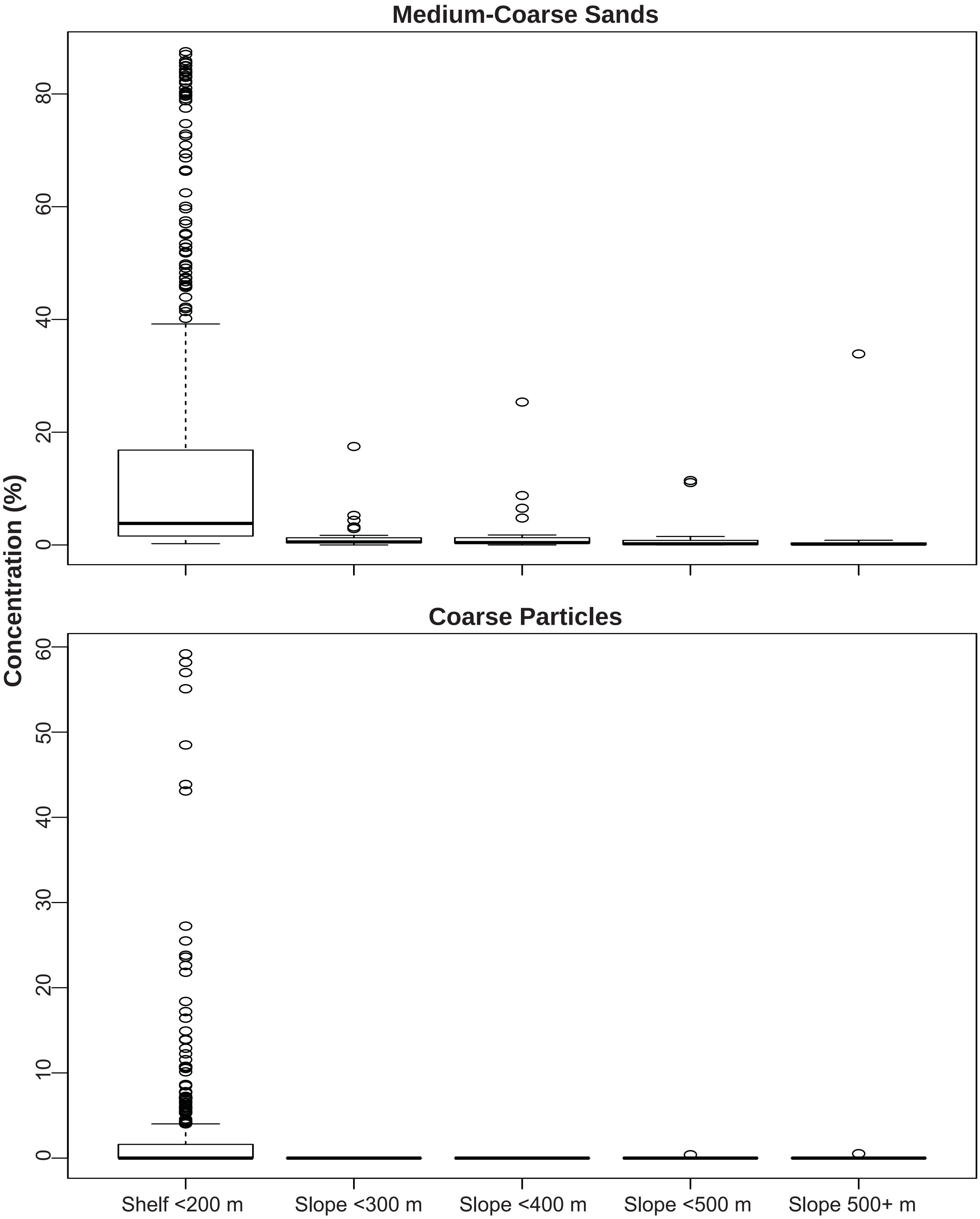


FIGURE C.5-1 (continued)

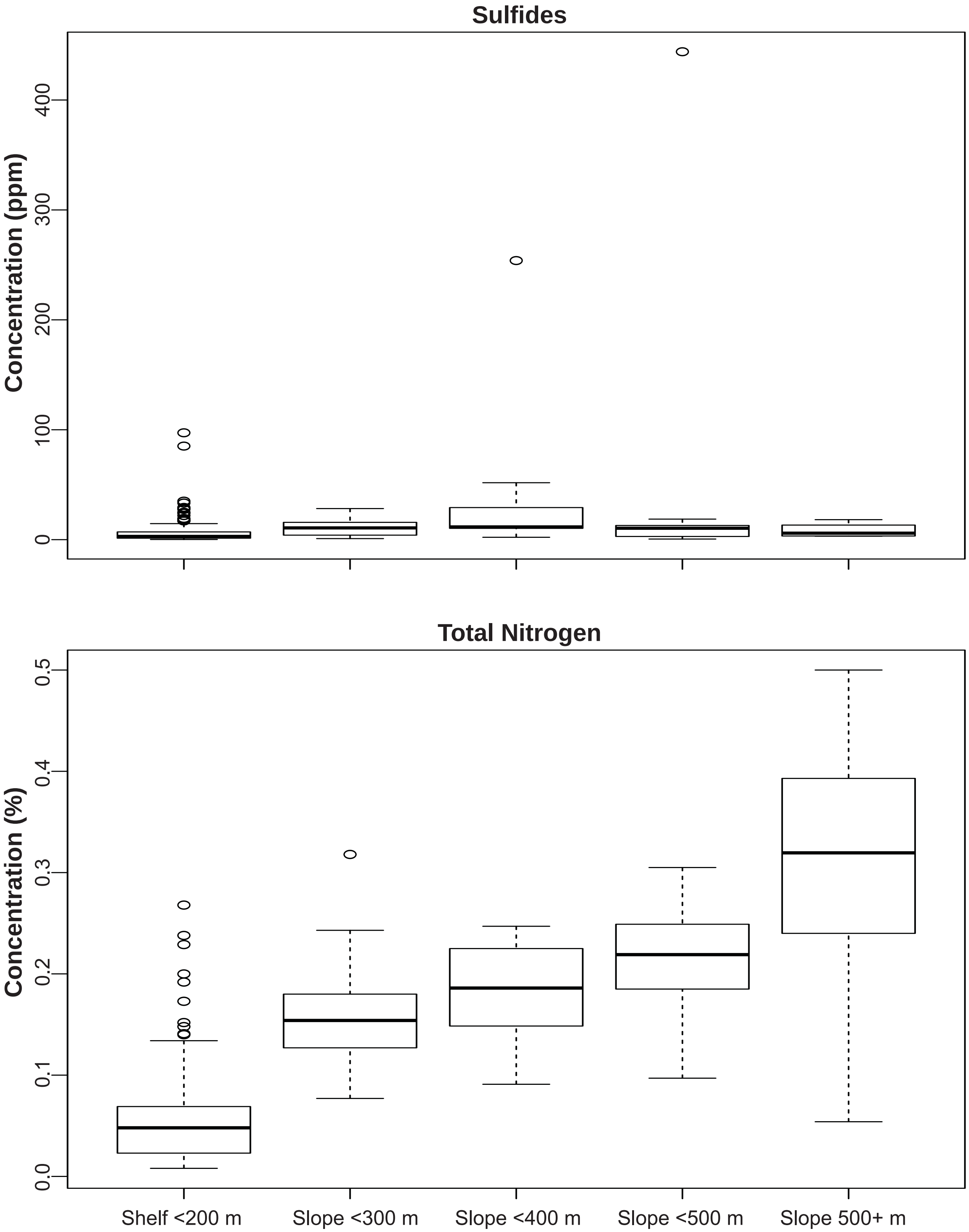


FIGURE C.5-1 (continued)

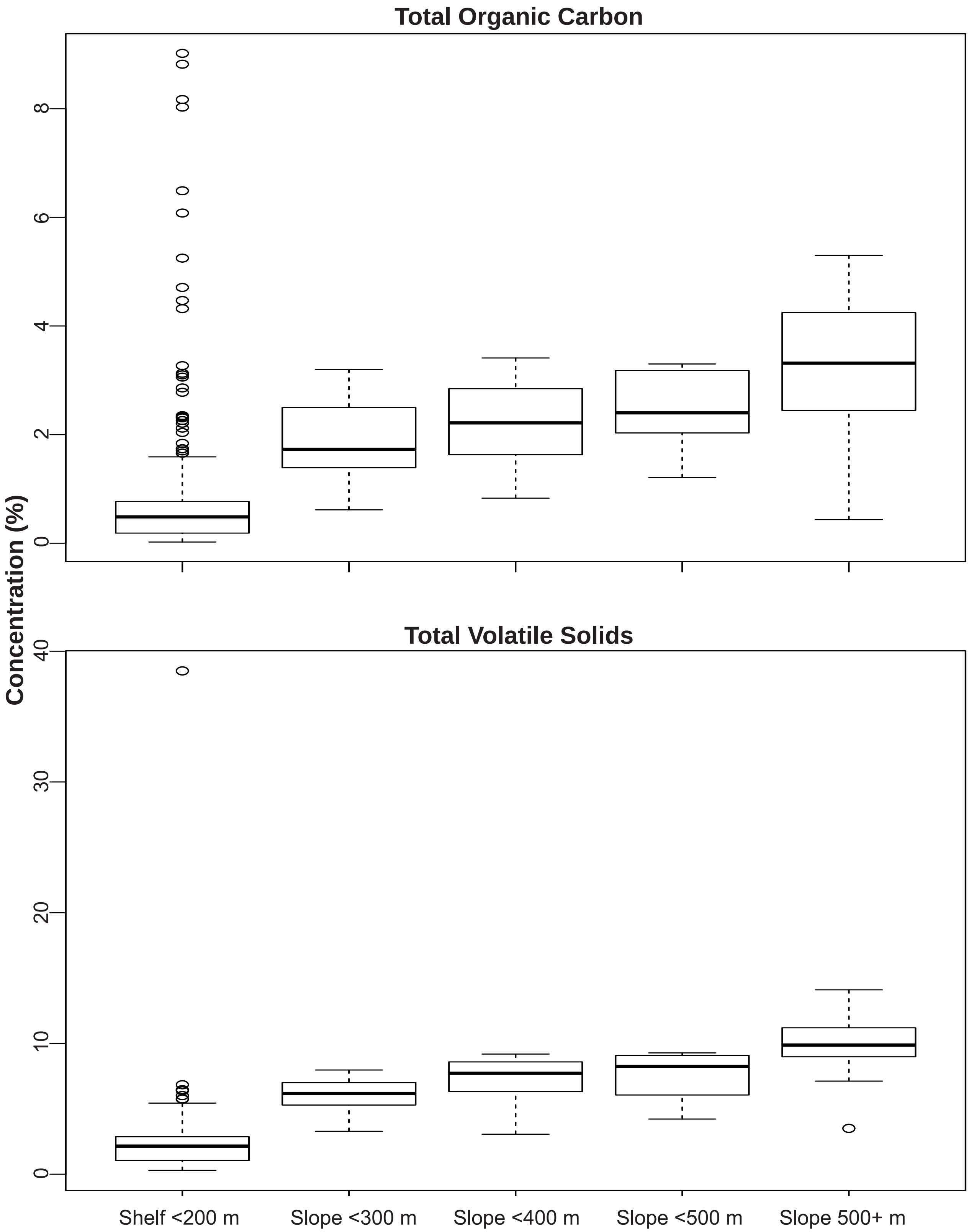


FIGURE C.5-1 (continued)

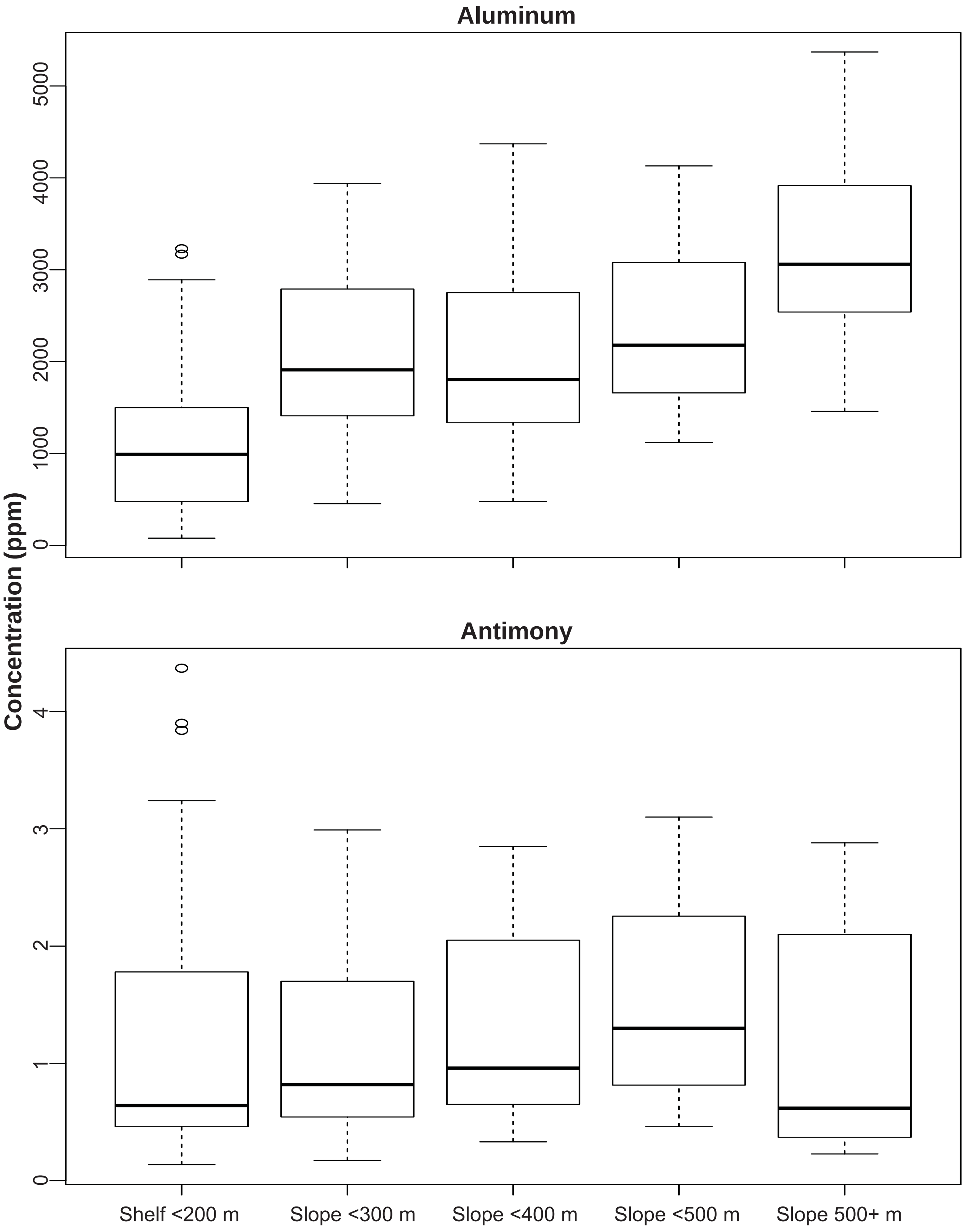


FIGURE C.5-1 (continued)

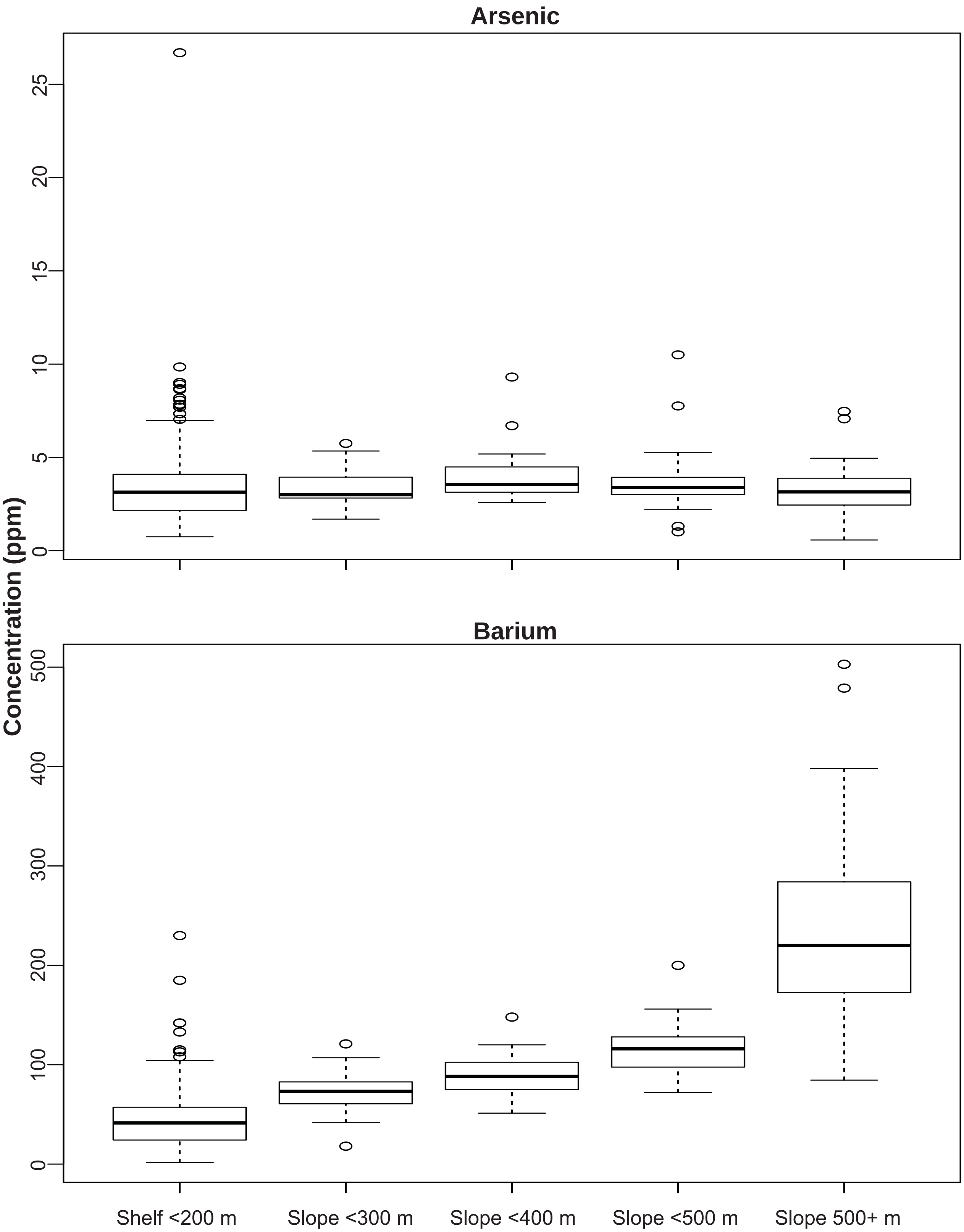


FIGURE C.5-1 (continued)

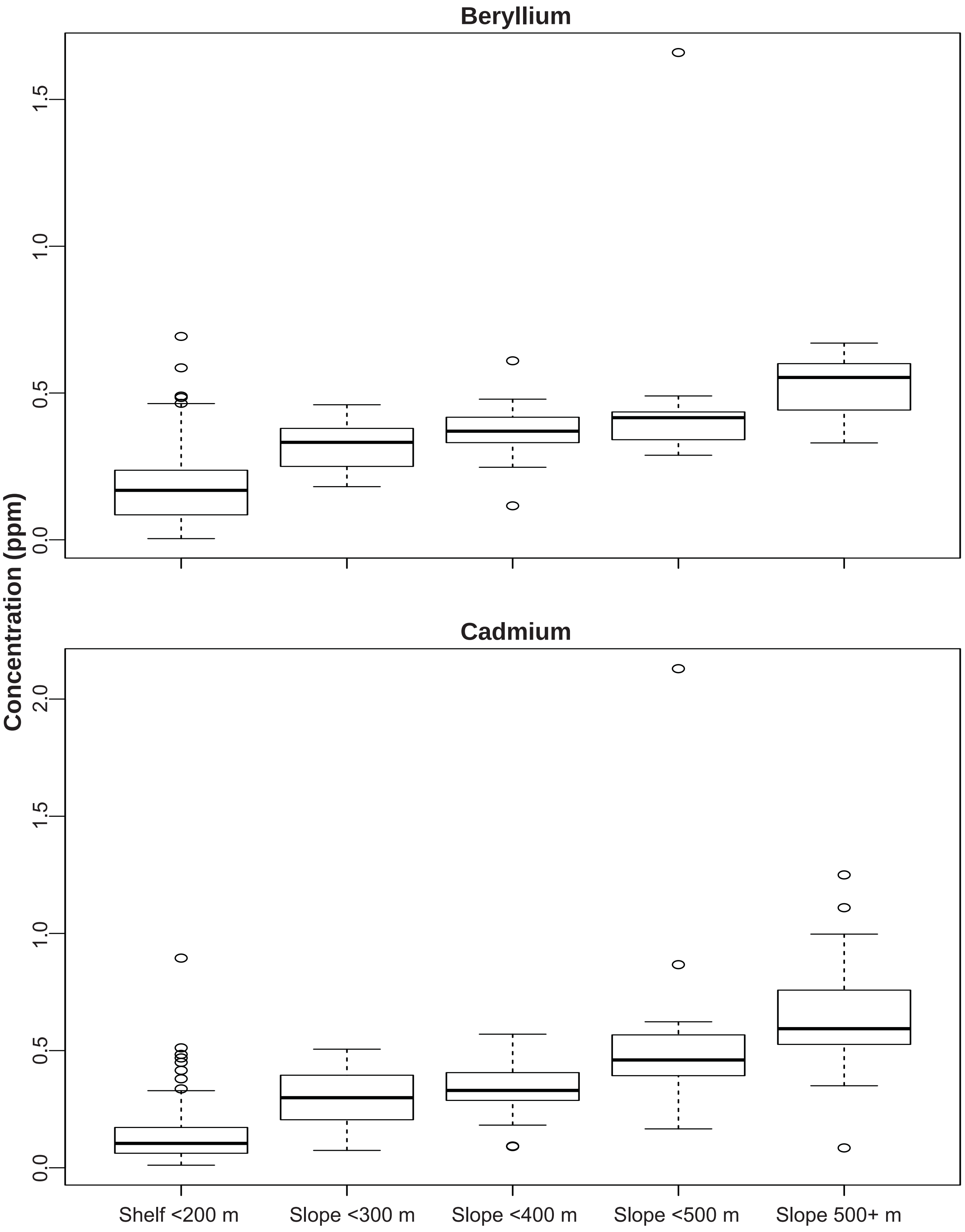


FIGURE C.5-1 (continued)

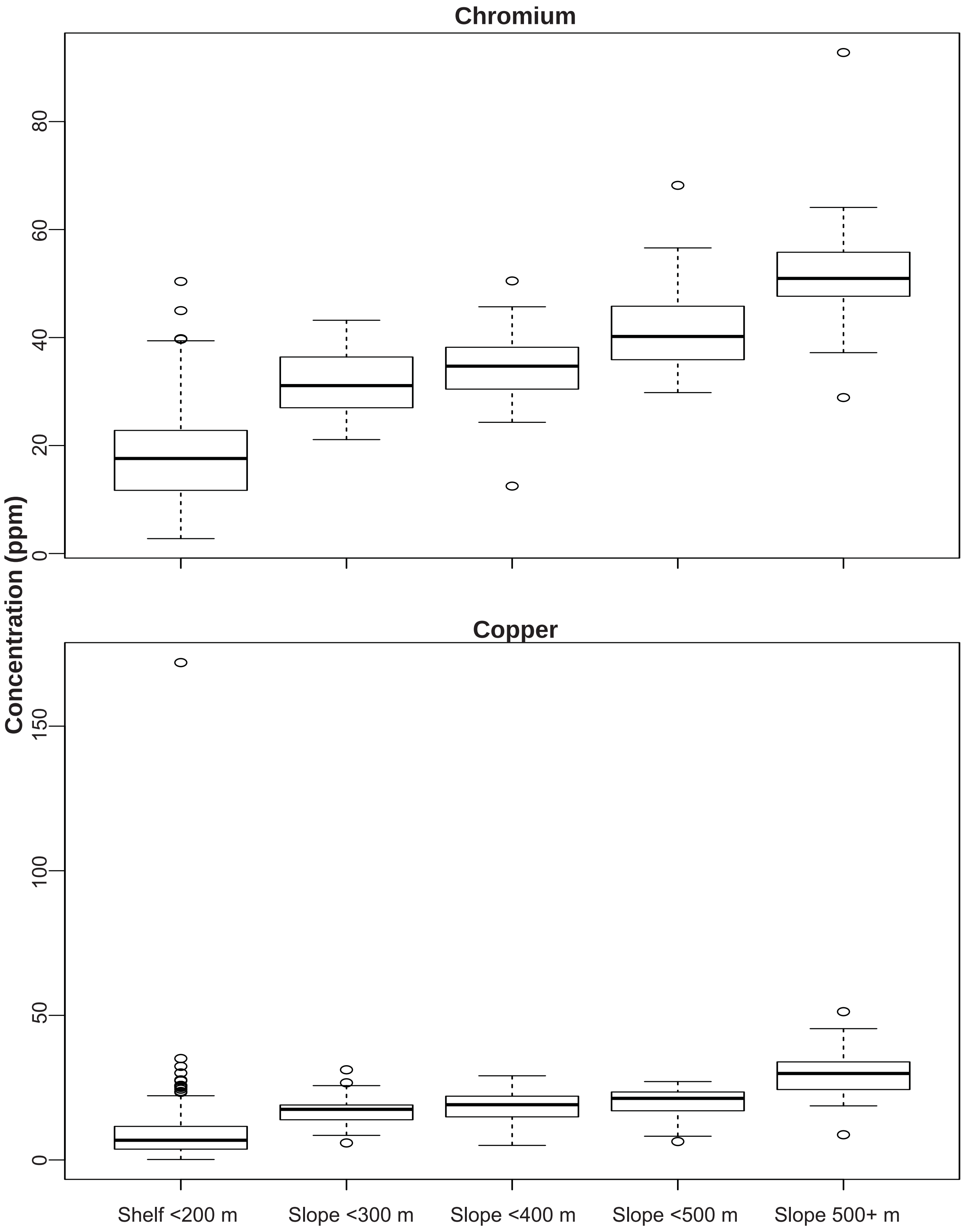


FIGURE C.5-1 (continued)

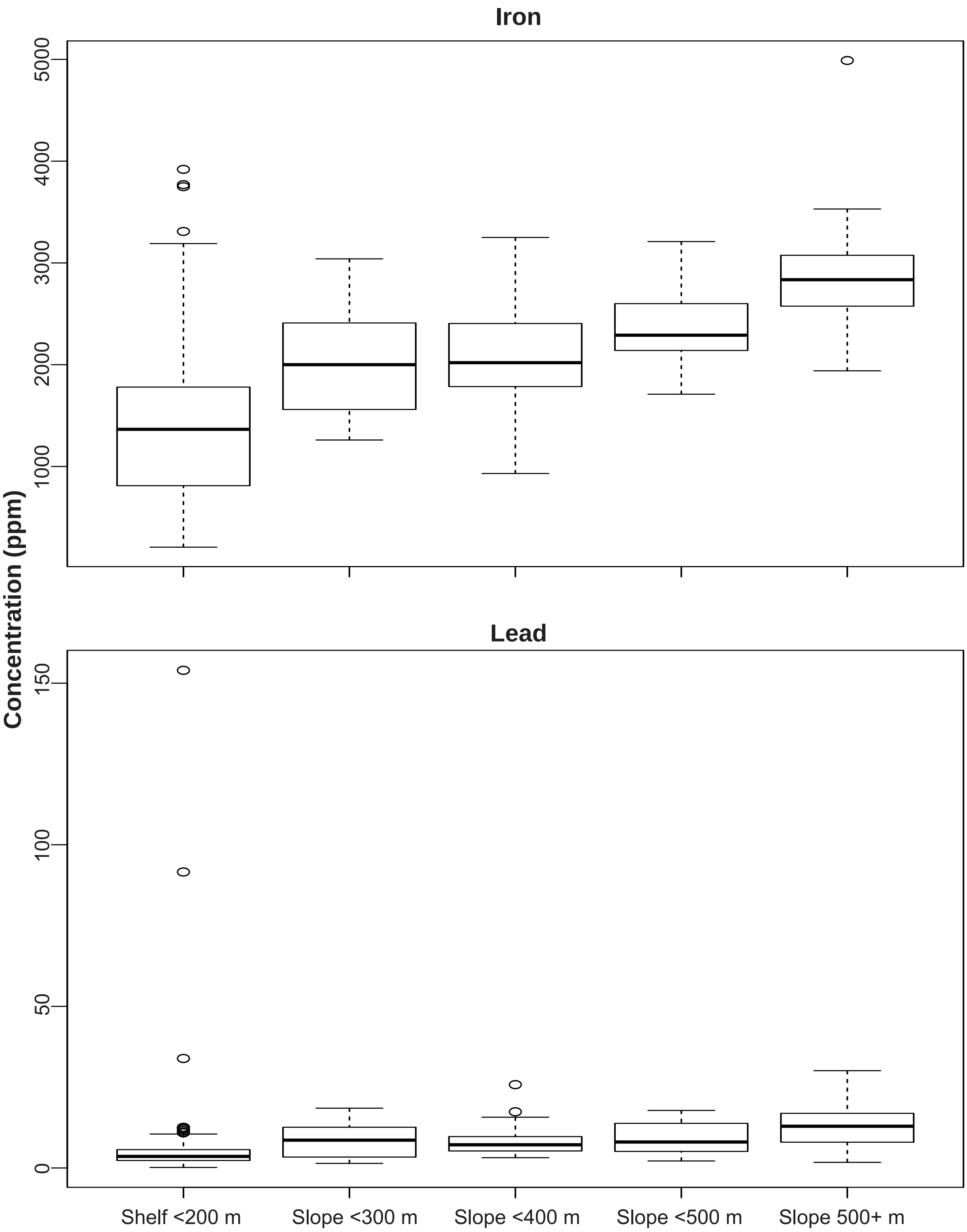


FIGURE C.5-1 (continued)

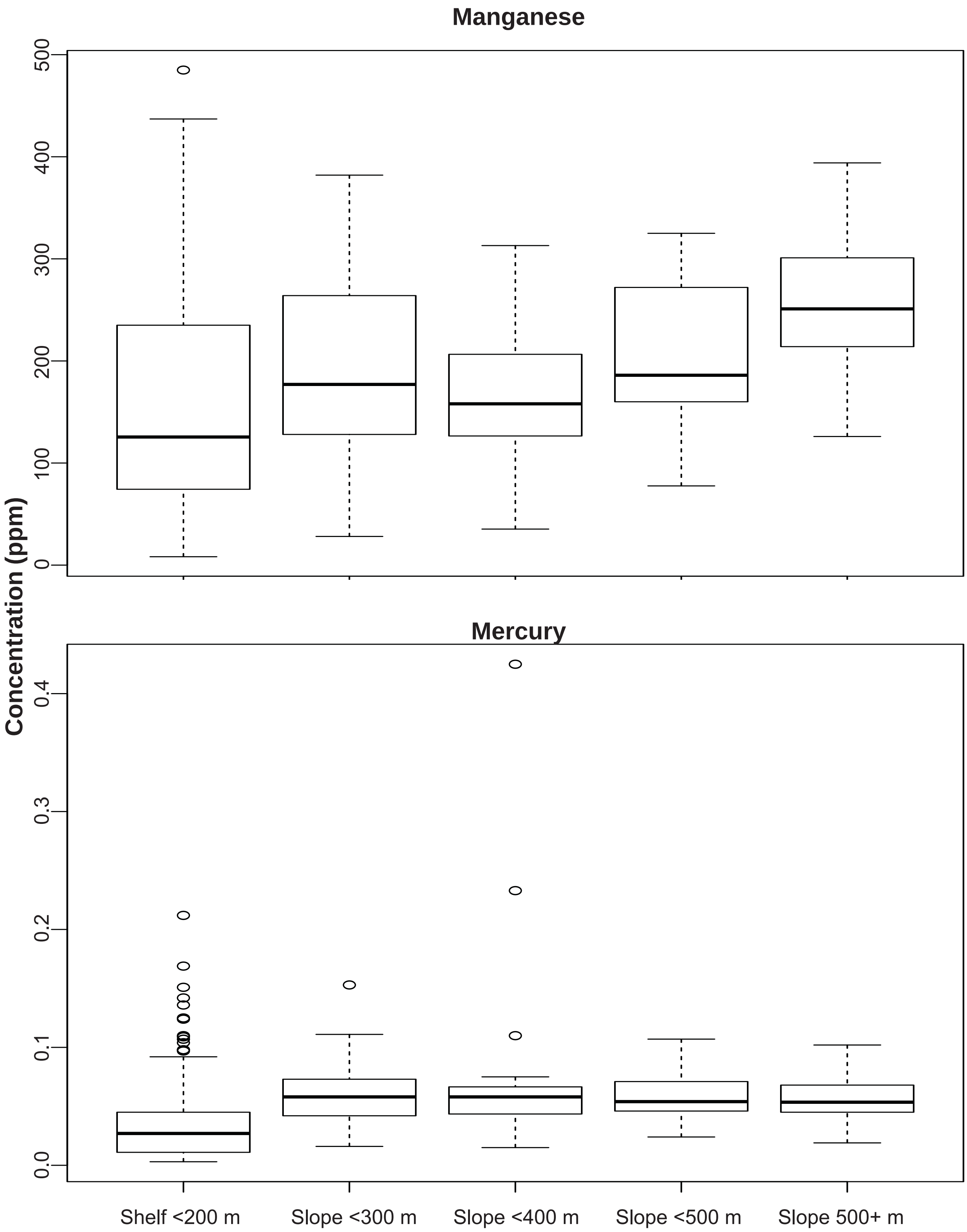


FIGURE C.5-1 (continued)

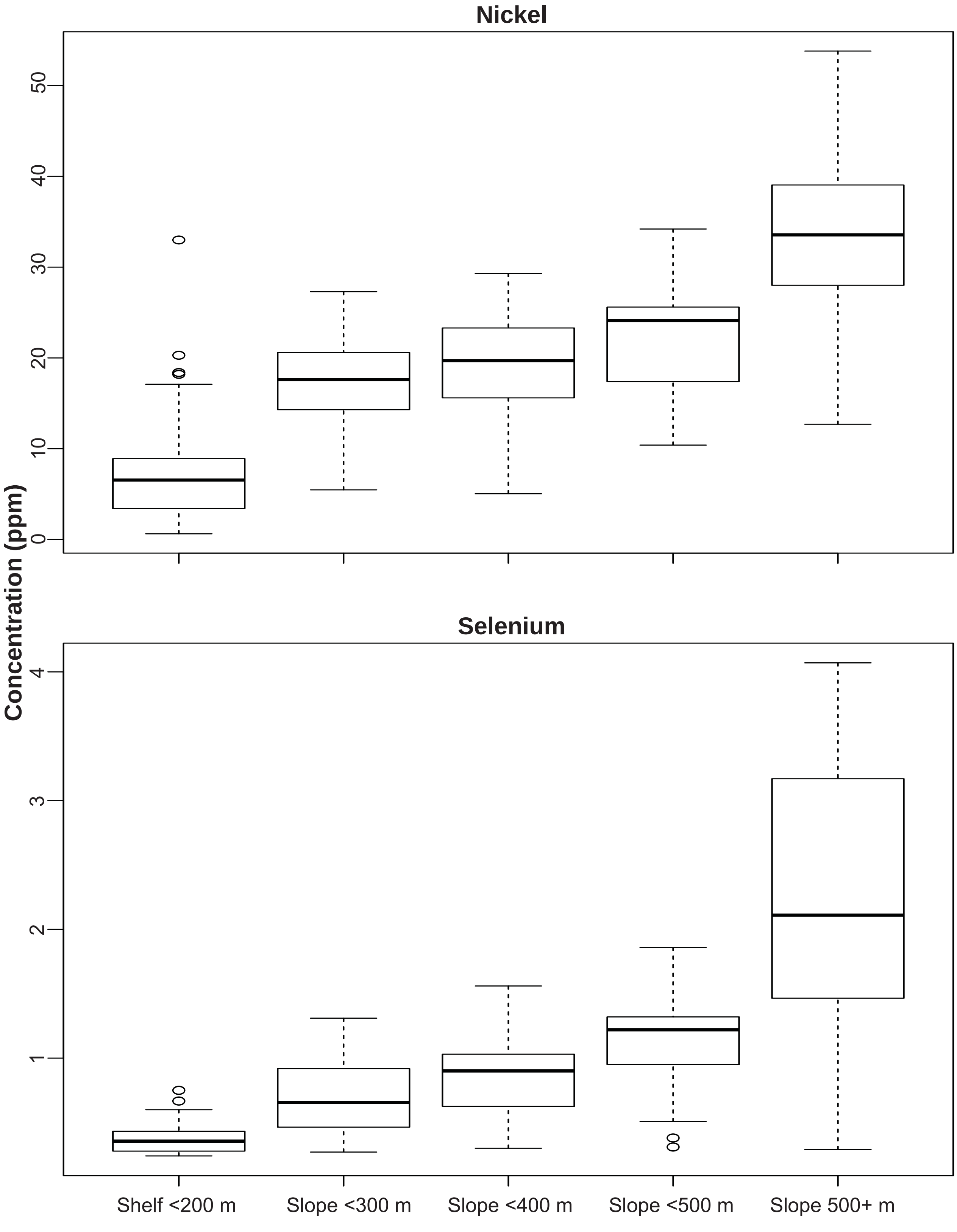


FIGURE C.5-1 (continued)

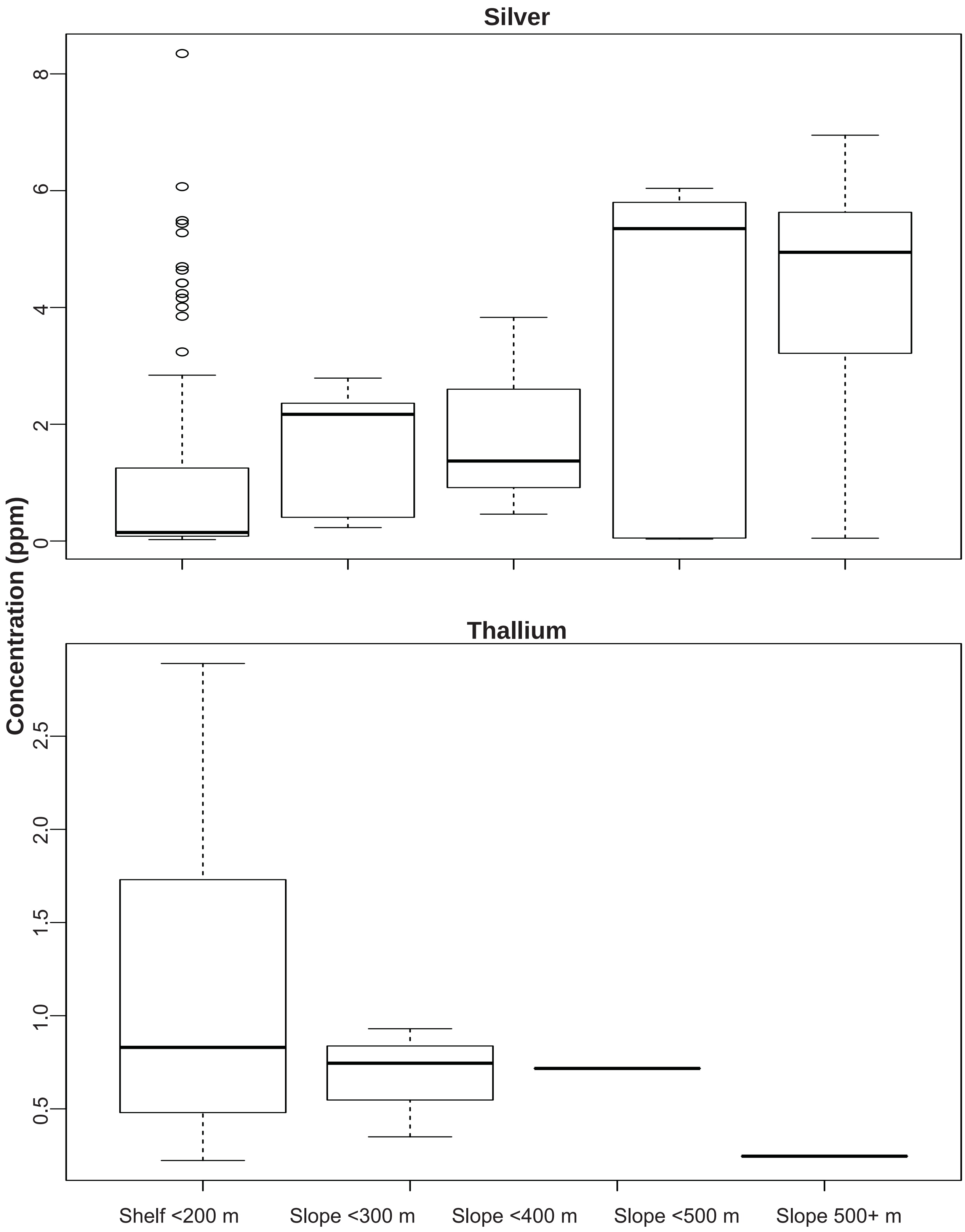


FIGURE C.5-1 (continued)

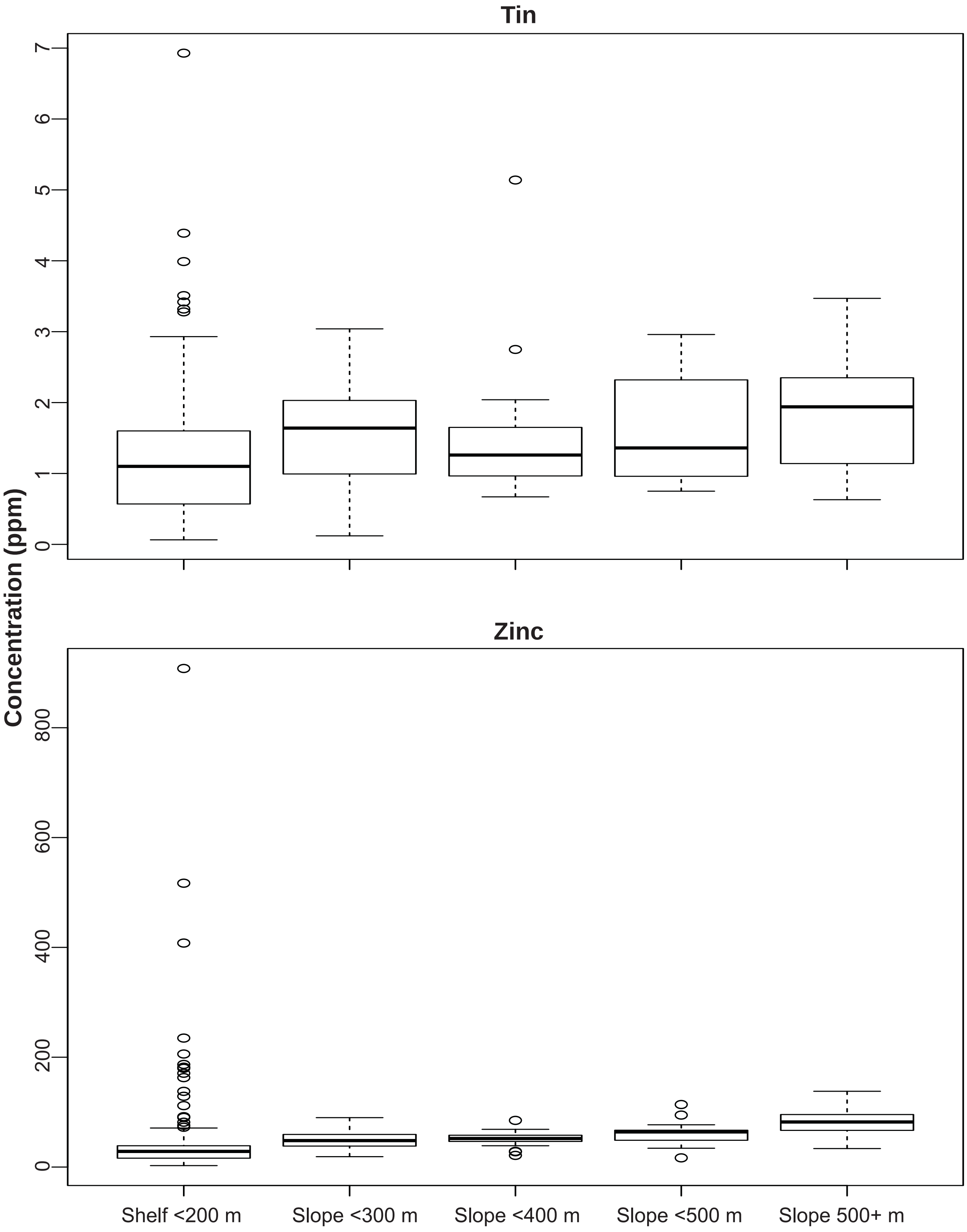


FIGURE C.5-1 (continued)

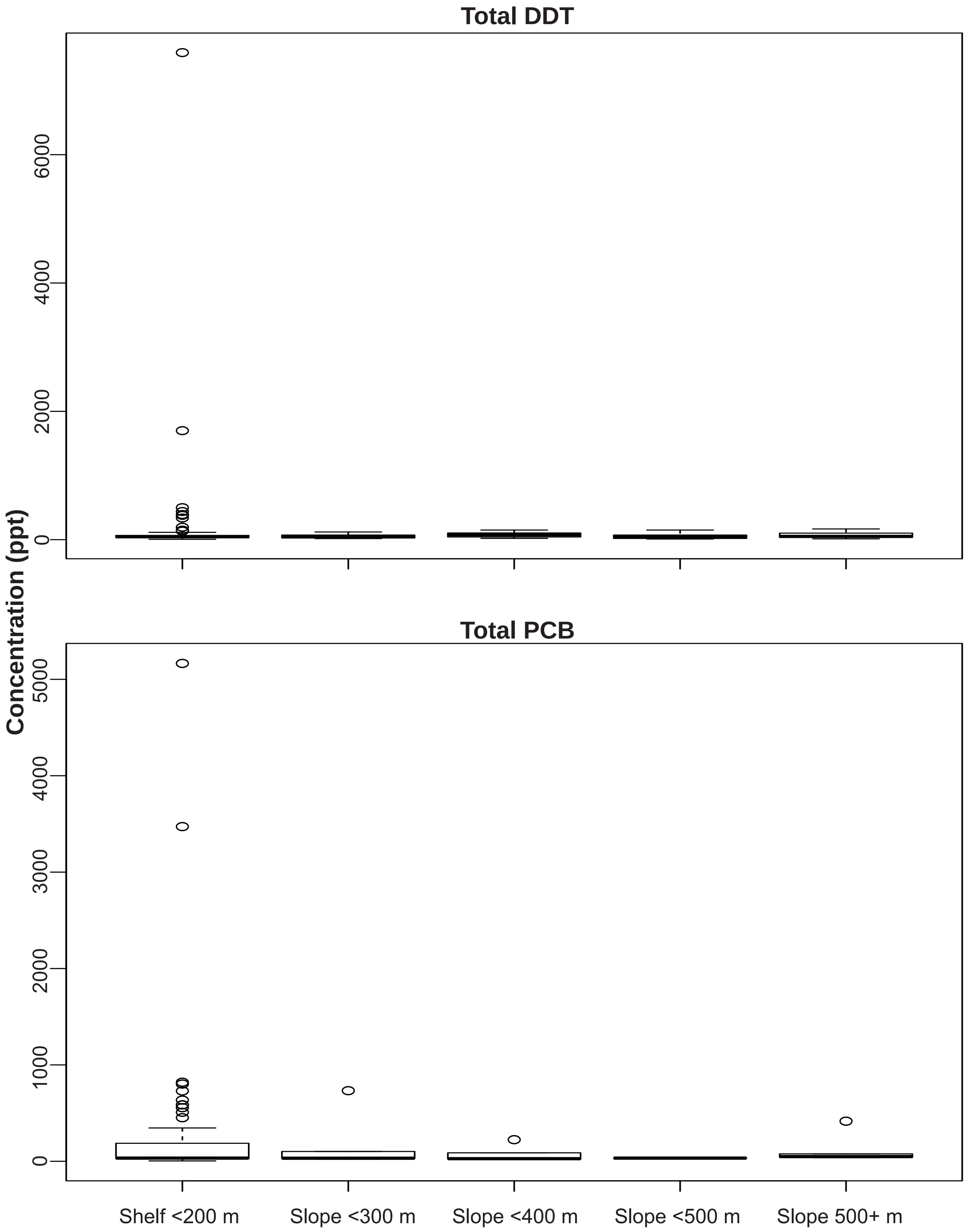


FIGURE C.5-1 (continued)

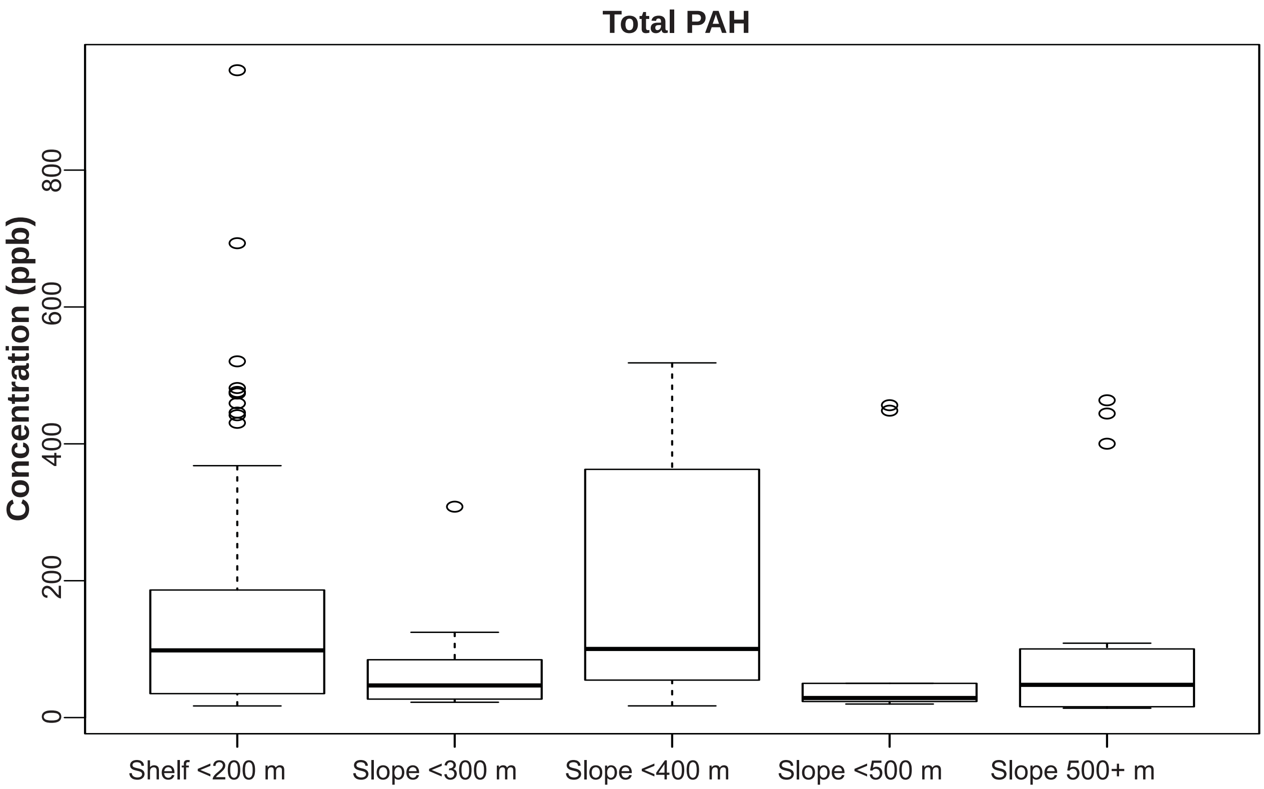


FIGURE C.5-1 (continued)

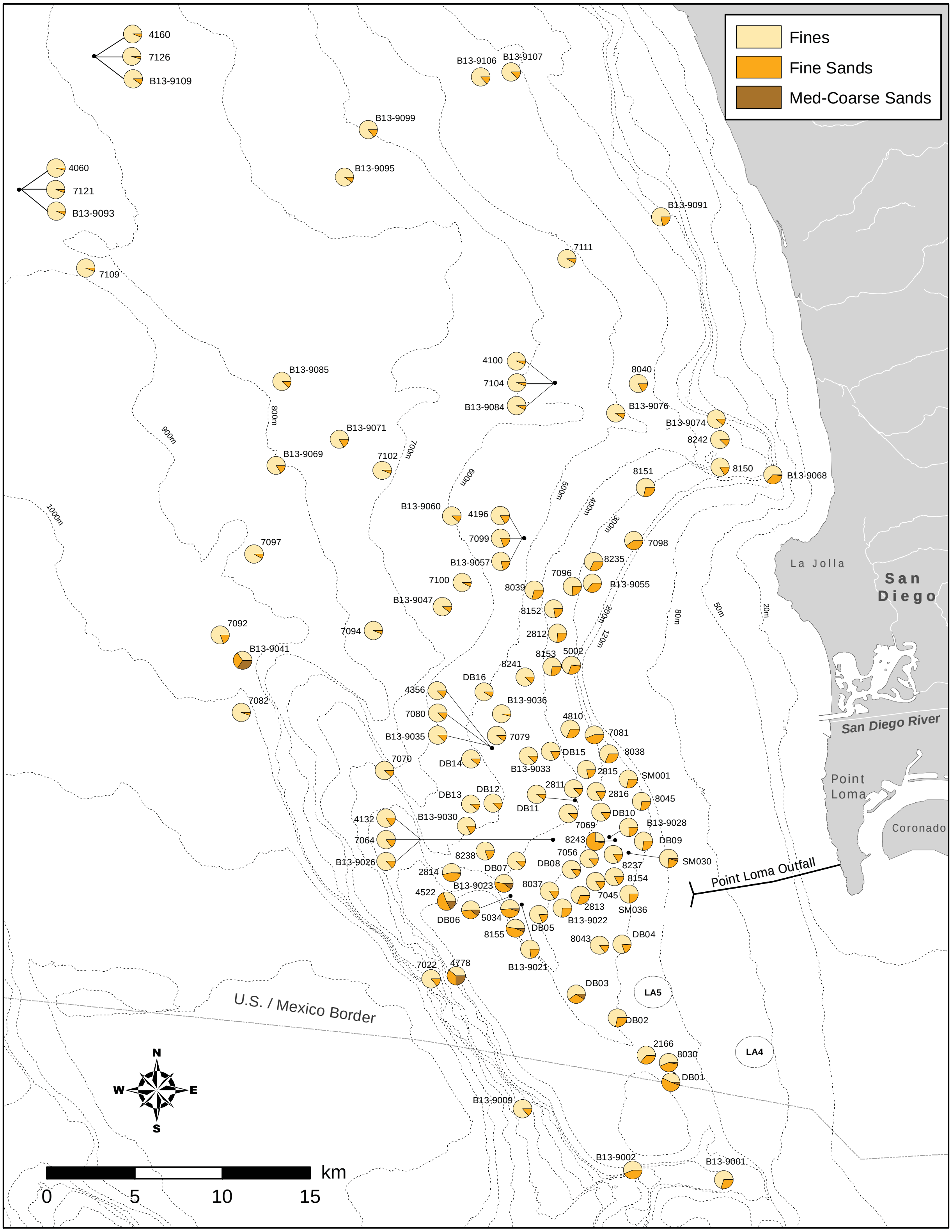


FIGURE C.5-2a

Distribution of particle sizes (%) across slope stations included in the Deep Benthic Habitat Assessment Study.

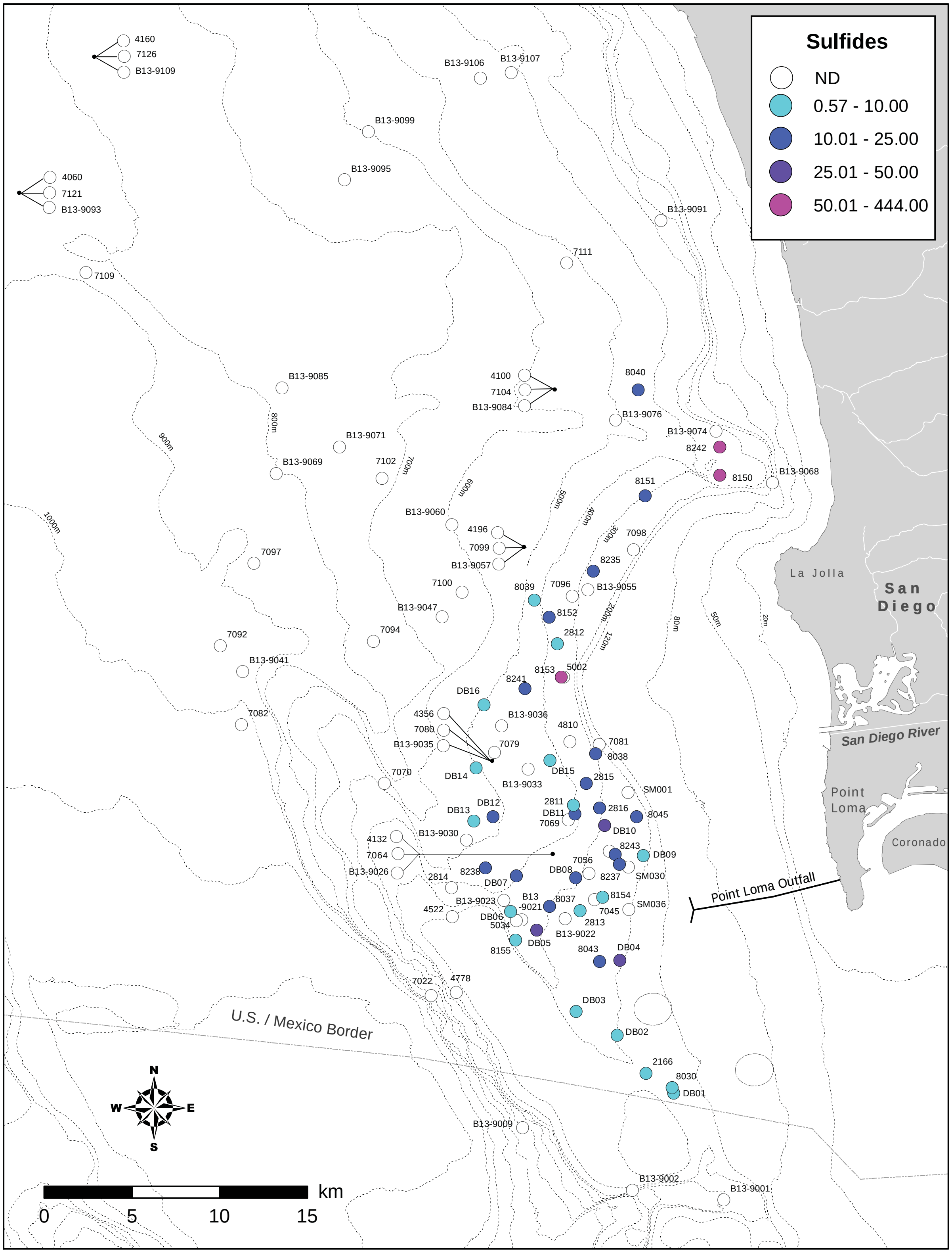


FIGURE C.5-2b
Distribution of sulfides (ppm) across slope stations included in the Deep Benthic Habitat Assessment Study.

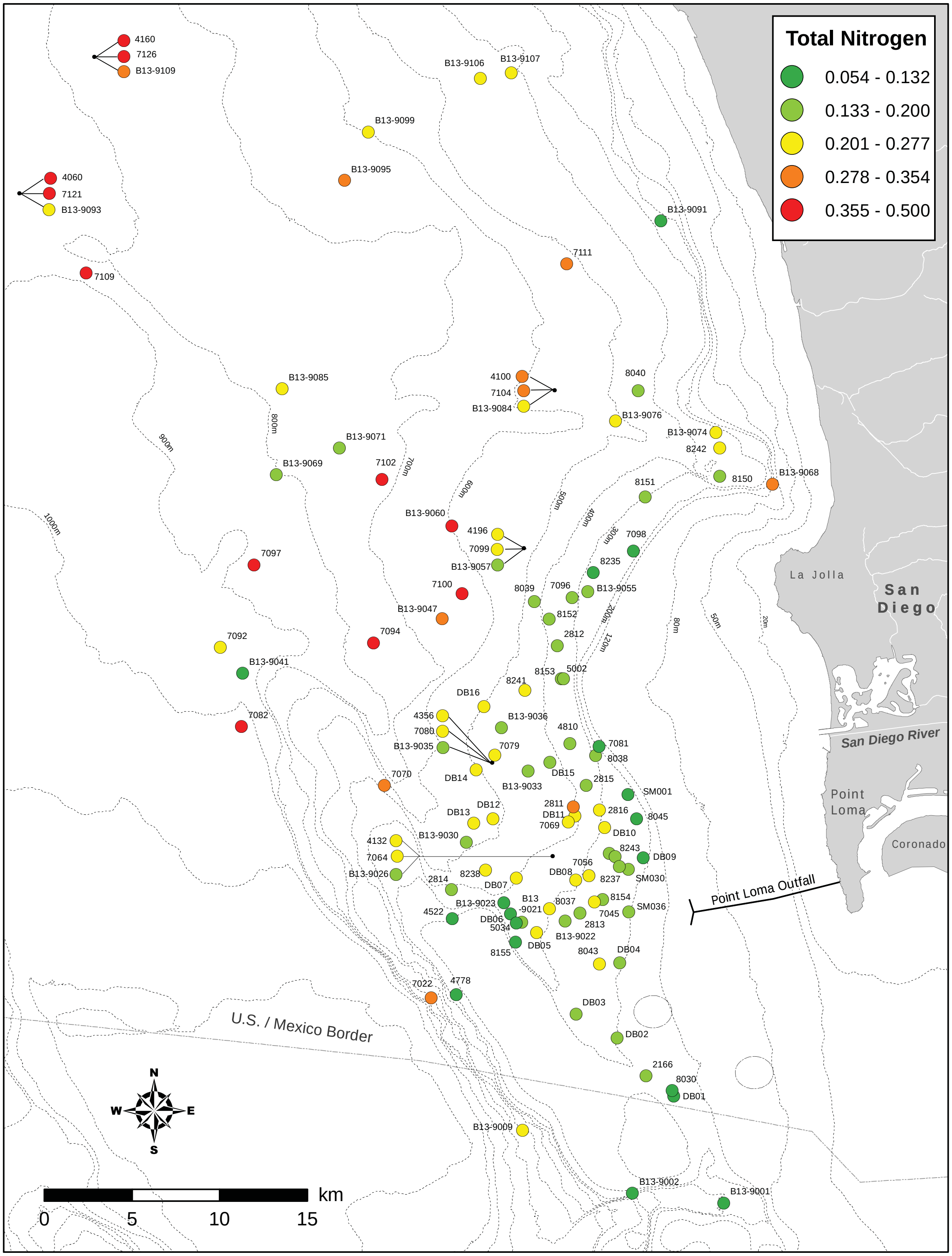


FIGURE C.5-2c
Distribution of total nitrogen (% weight) across slope stations included in the Deep Benthic Habitat Assessment Study.

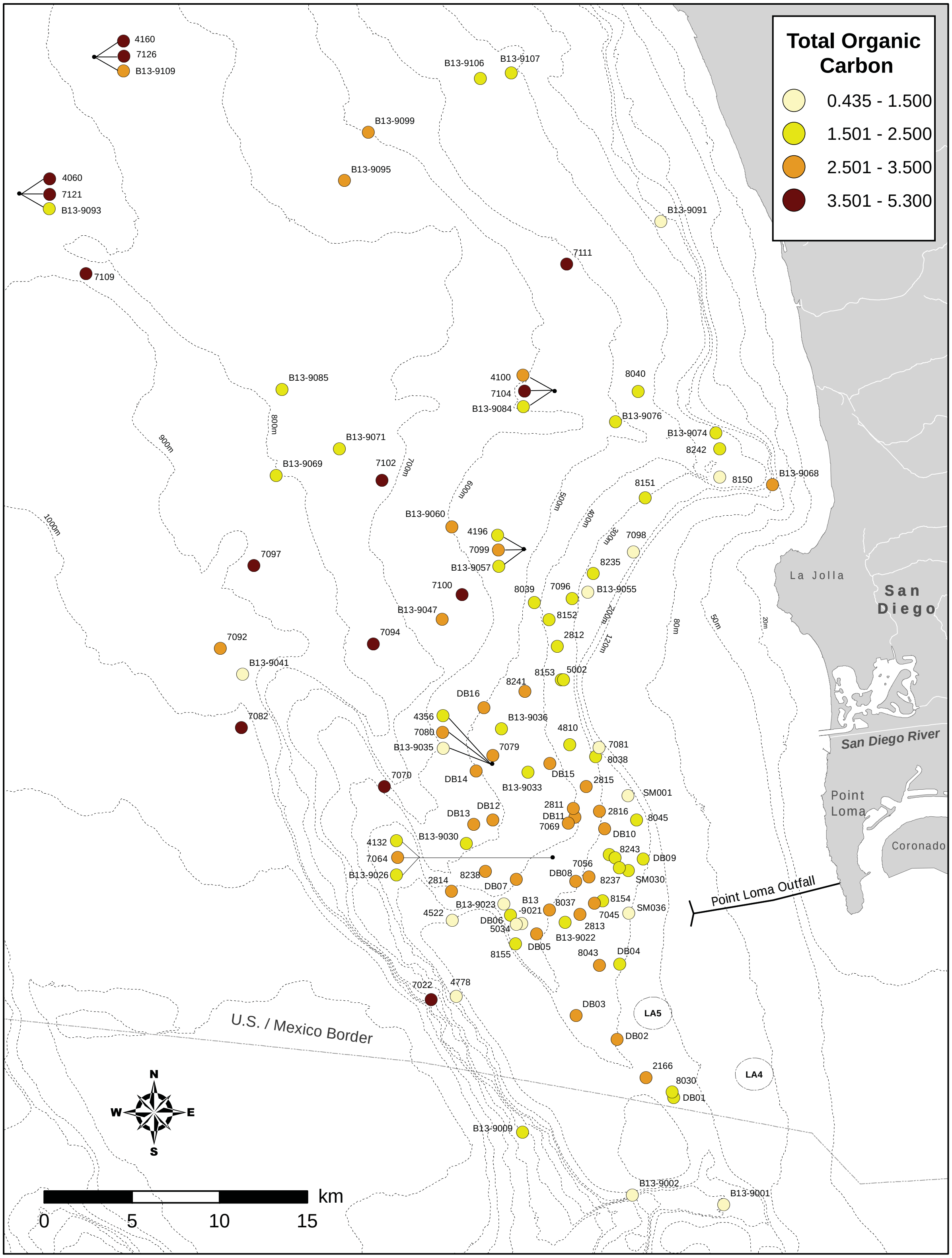


FIGURE C.5-2d
Distribution of total organic carbon (% weight) across slope stations included in the Deep Benthic Habitat Assessment Study.

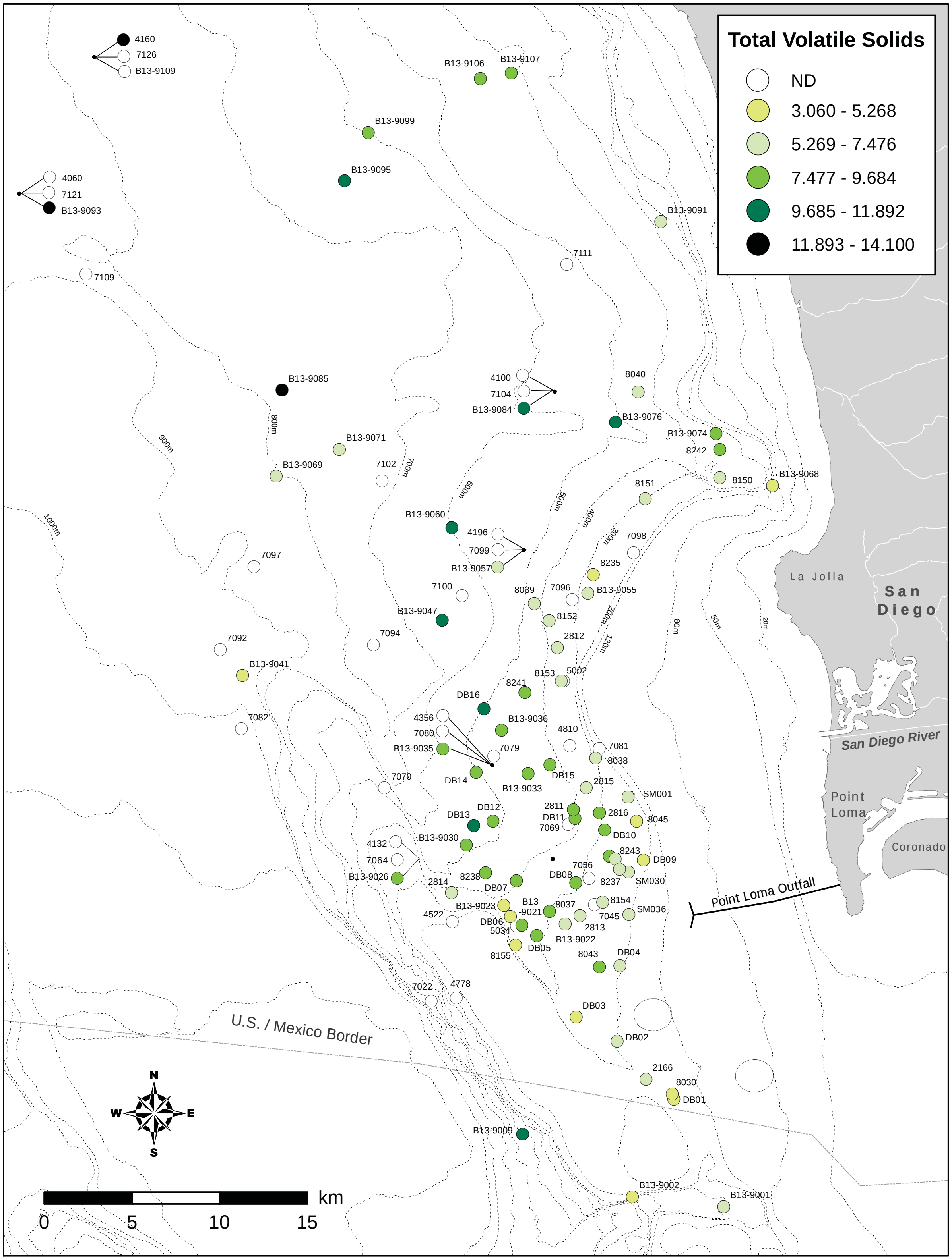


FIGURE C.5-2e

Distribution of total volatile solids (% weight) across slope stations included in the Deep Benthic Habitat Assessment Study.

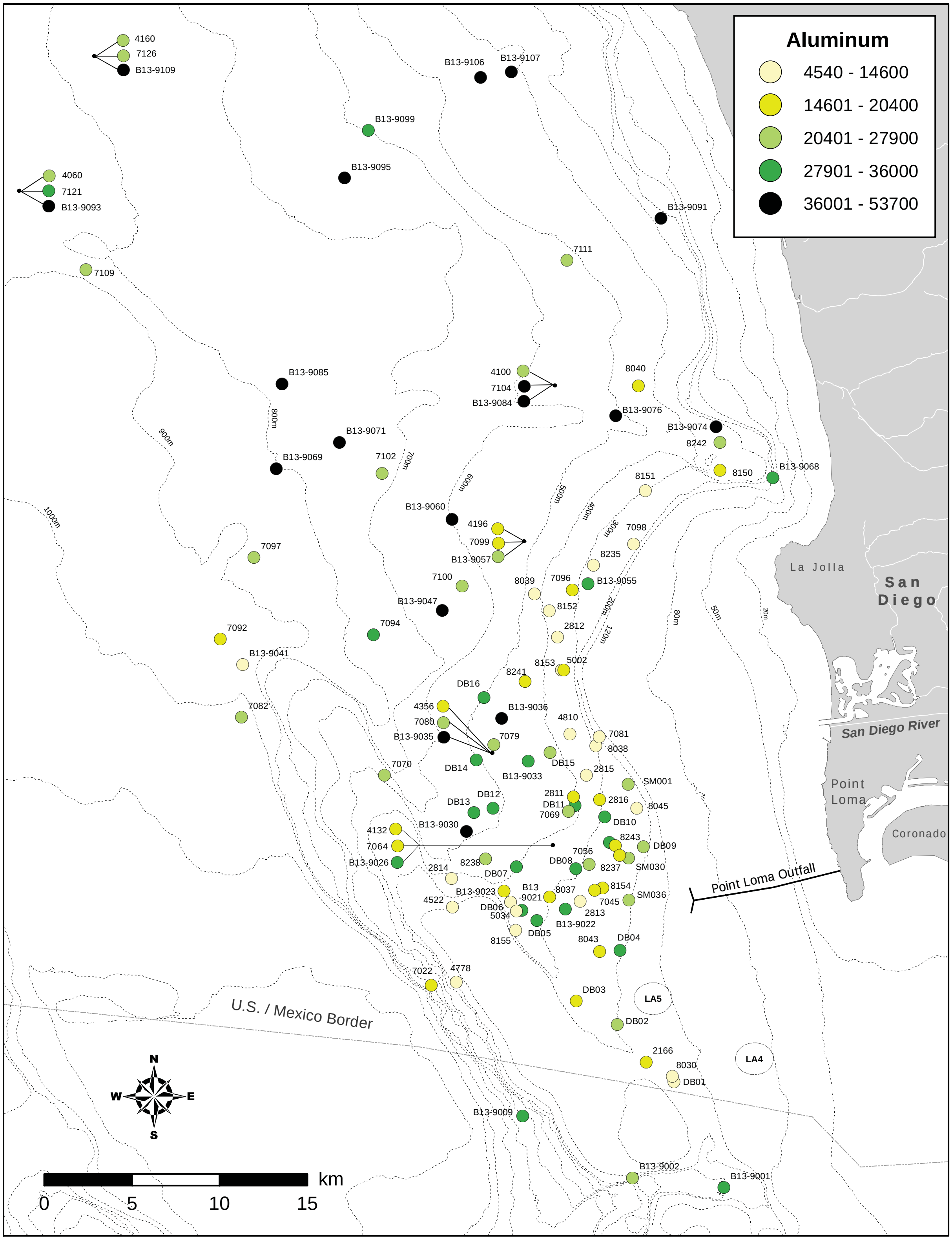


FIGURE C.5-2f
Distribution of aluminum (ppm) across slope stations included in the Deep Benthic Habitat Assessment Study.

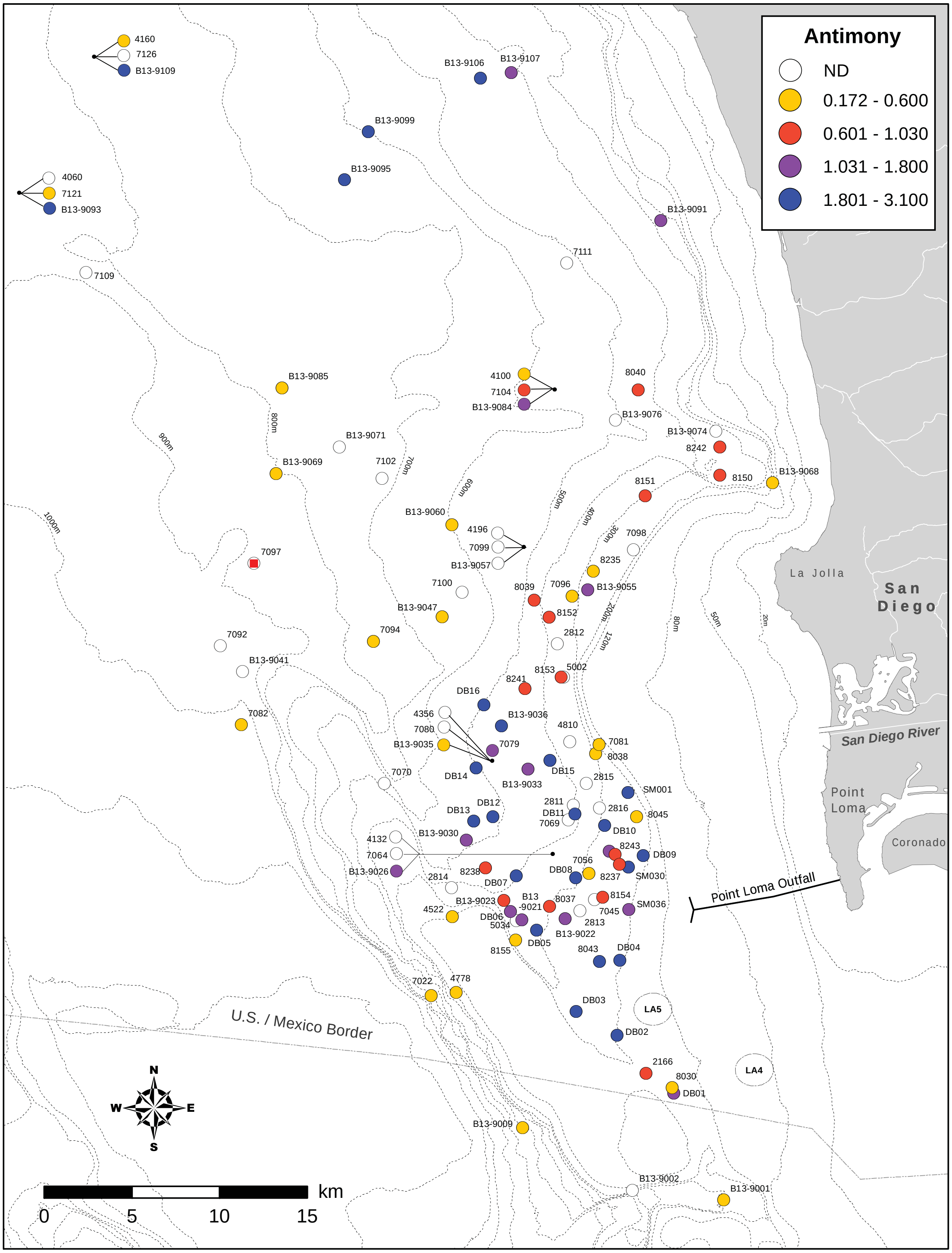


FIGURE C.5-2g
Distribution of antimony (ppm) across slope stations included in the Deep Benthic Habitat Assessment Study.

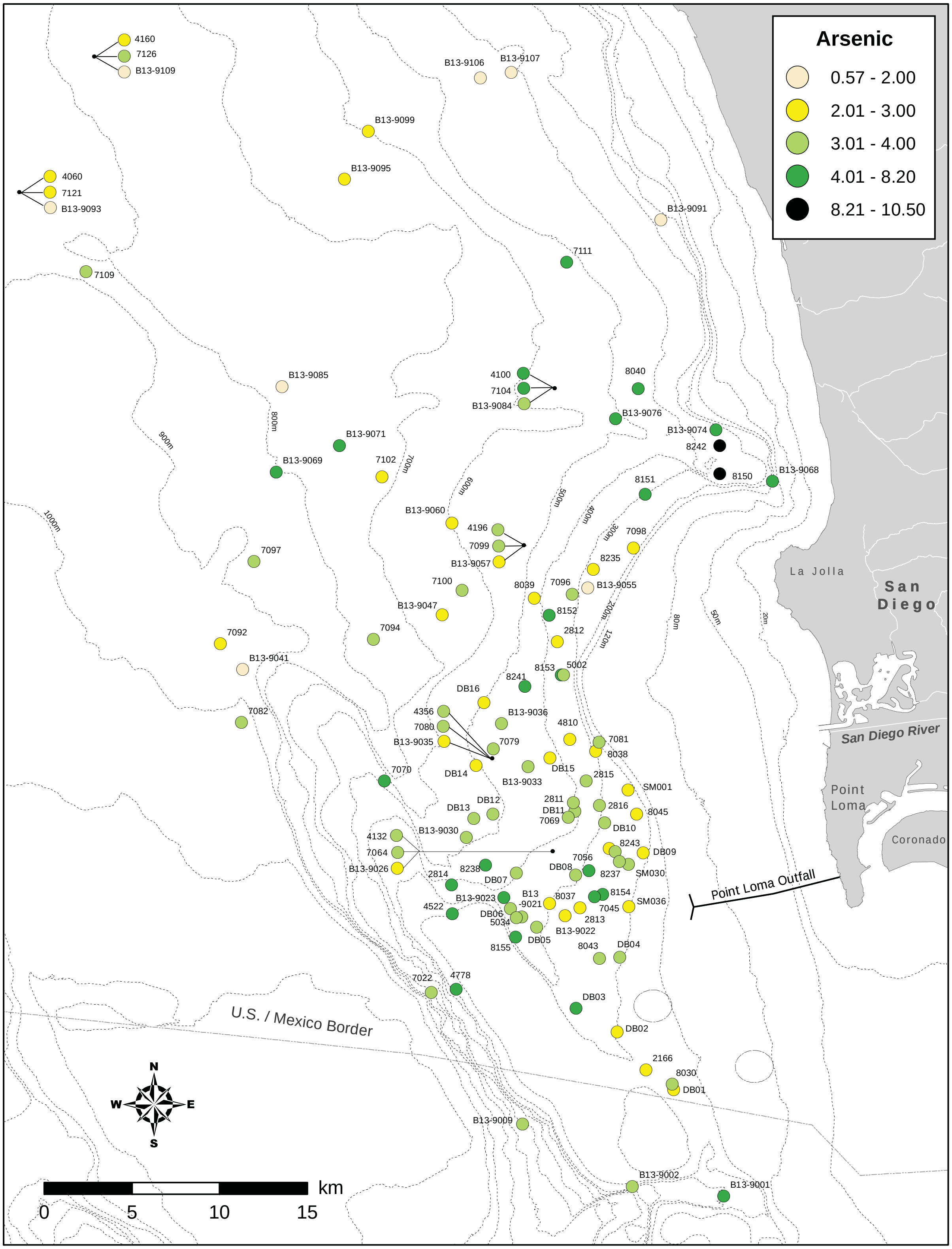


FIGURE C.5-2h

Distribution of arsenic (ppm) concentrations across slope stations included in the Deep Benthic Habitat Assessment Study. The ERL for arsenic is 8.2 ppm (see Long et al. 1995).

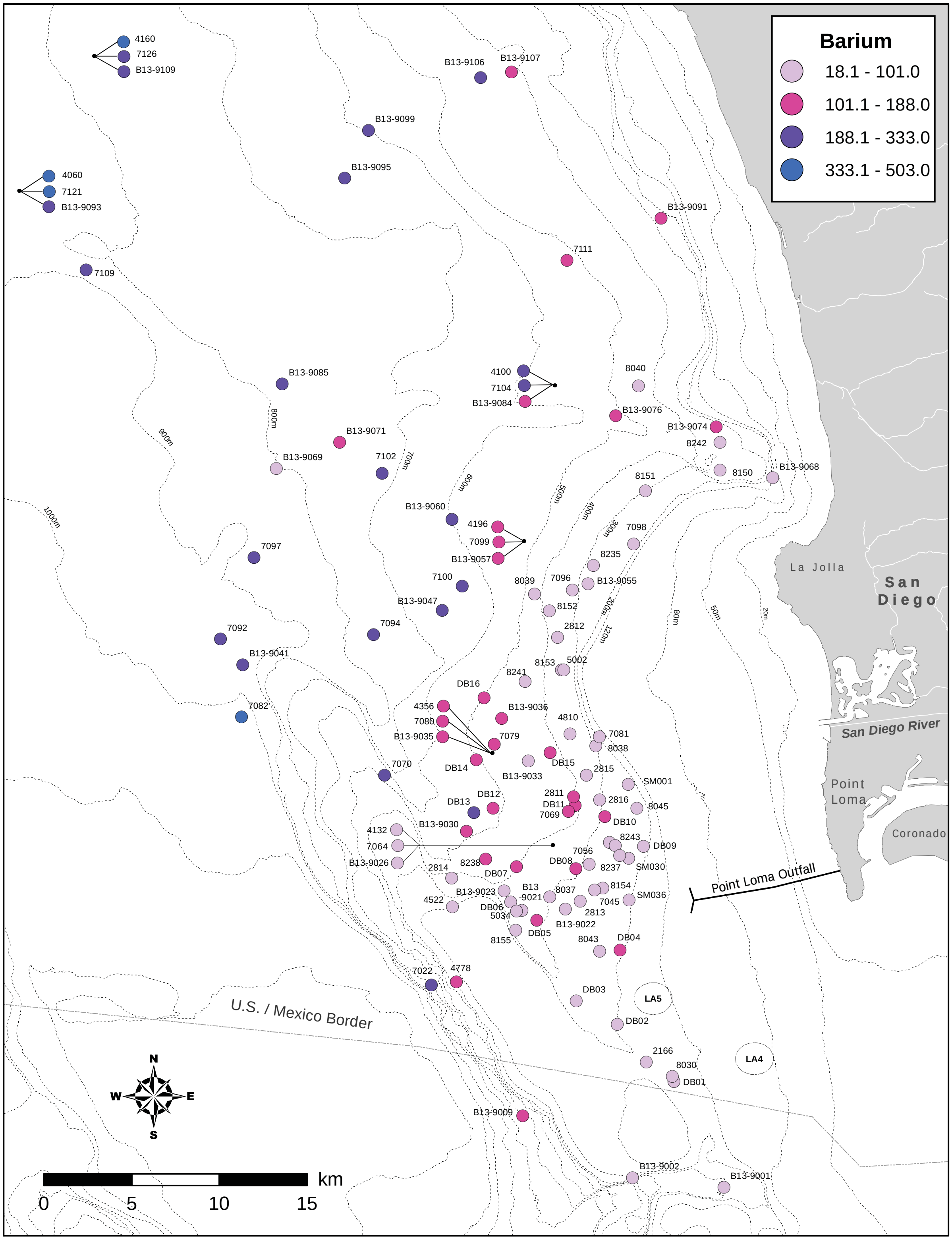


FIGURE C.5-2i
Distribution of barium (ppm) concentrations across slope stations included in the Deep Benthic Habitat Assessment Study.

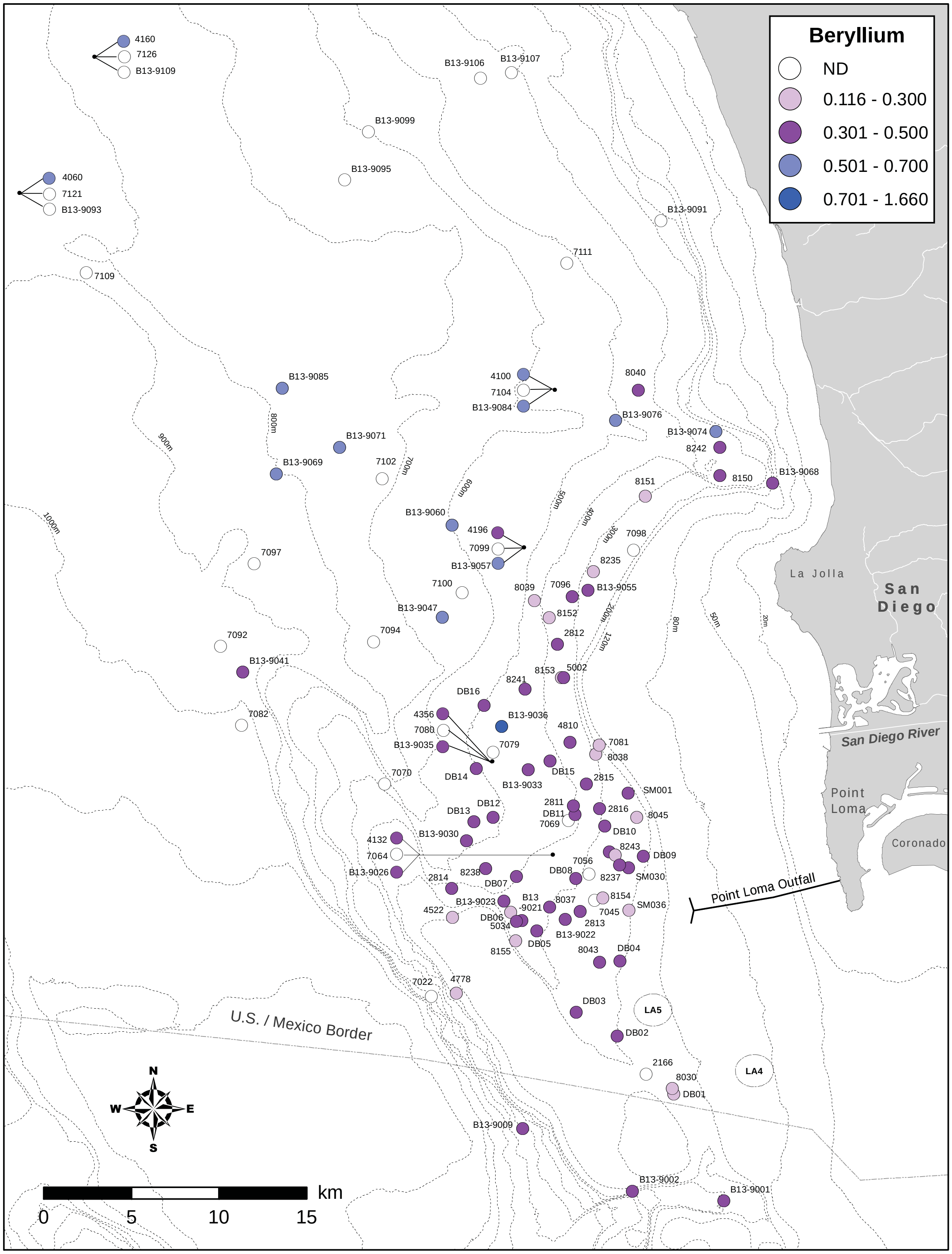


FIGURE C.5-2j
Distribution of beryllium (ppm) concentrations across slope stations included in the Deep Benthic Habitat Assessment Study.

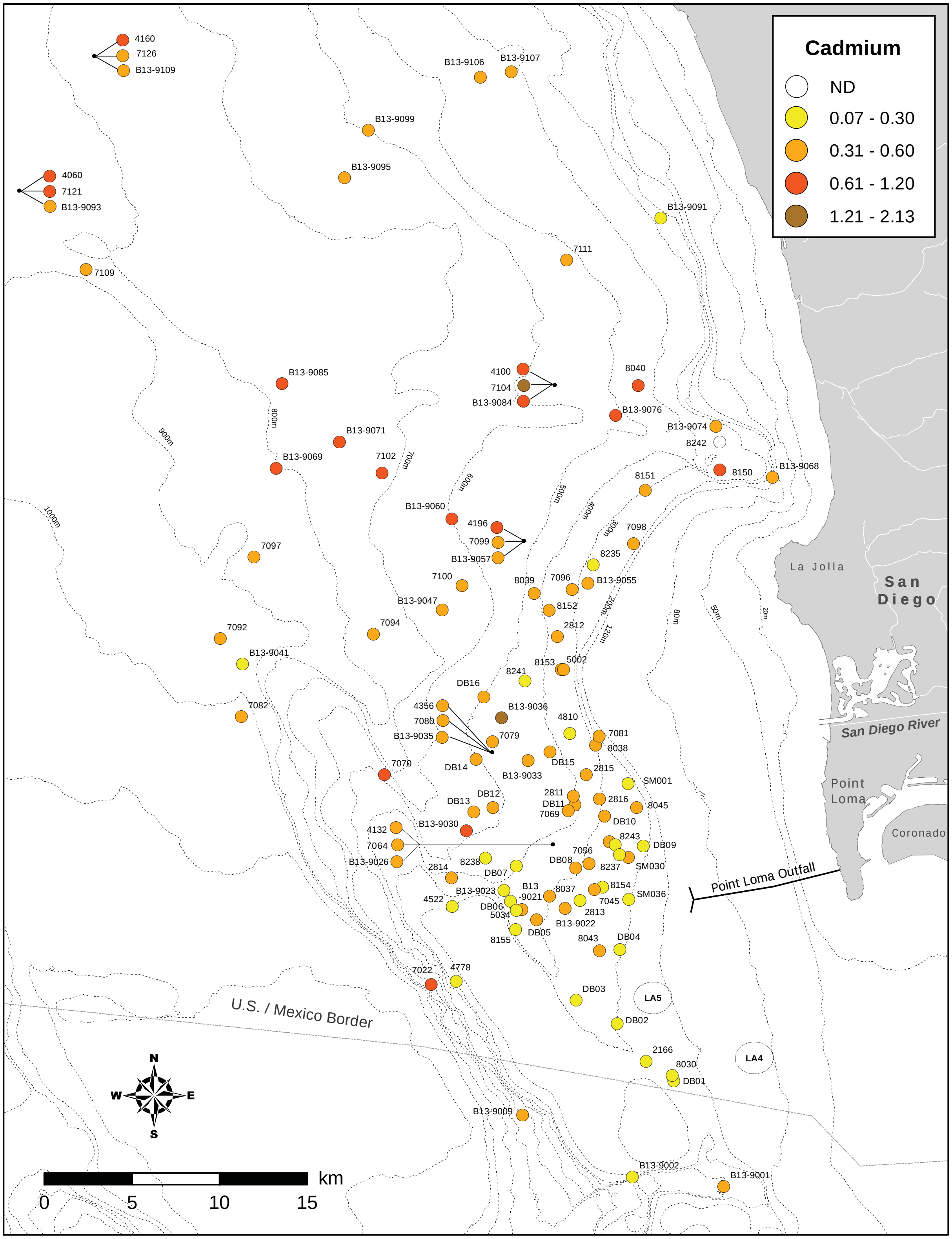


FIGURE C.5-2k

Distribution of cadmium (ppm) concentrations across slope stations included in the Deep Benthic Habitat Assessment Study. The ERL for cadmium is 1.2 ppm (see Long et al. 1995).

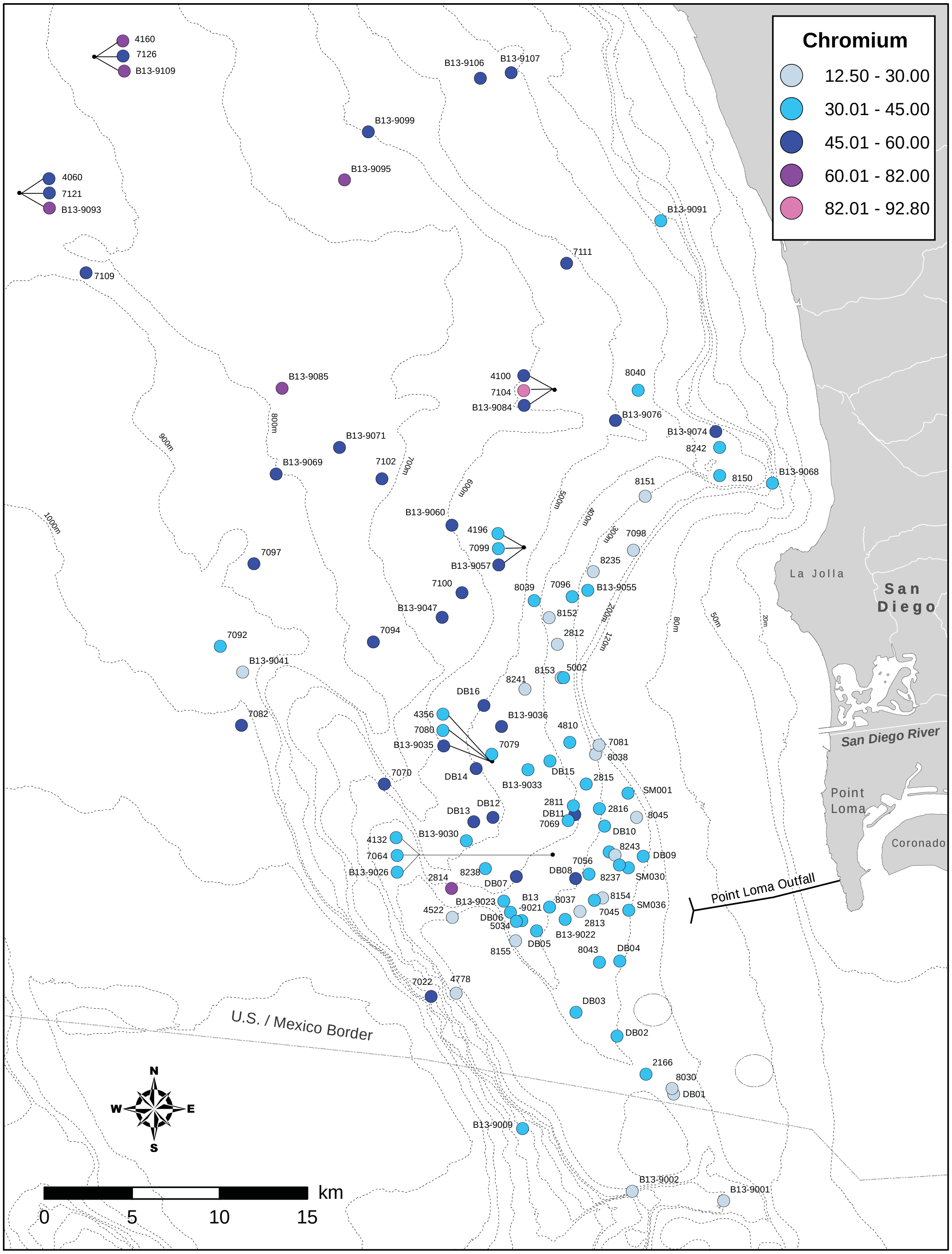


FIGURE C.5-2l
Distribution of chromium (ppm) concentrations across slope stations included in the Deep Benthic Habitat Assessment Study. The ERL for chromium is 81 ppm (see Long et al. 1995).

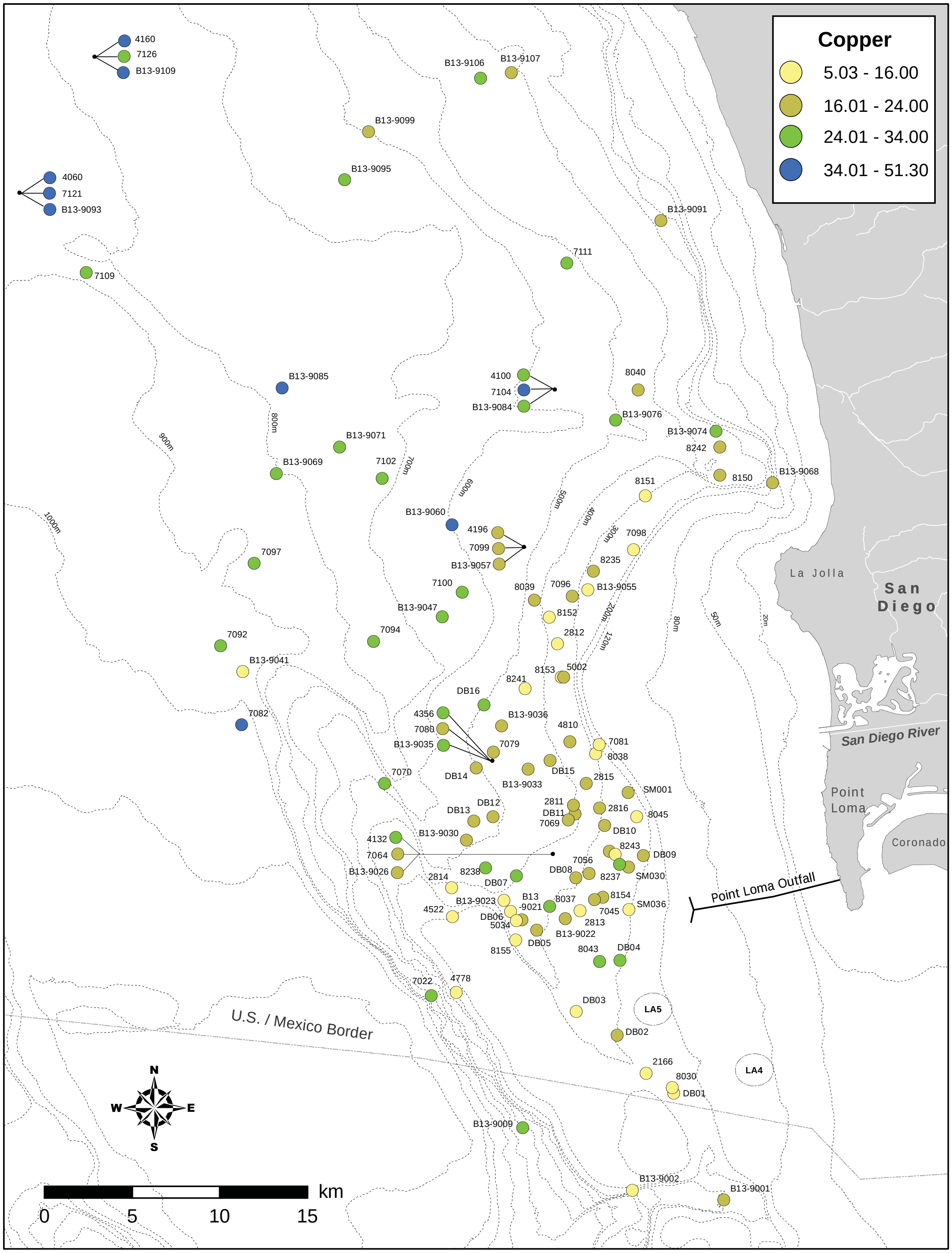


FIGURE C.5-2m

Distribution of copper (ppm) concentrations across slope stations included in the Deep Benthic Habitat Assessment Study. The ERL for copper is 34 ppm (see Long et al. 1995).

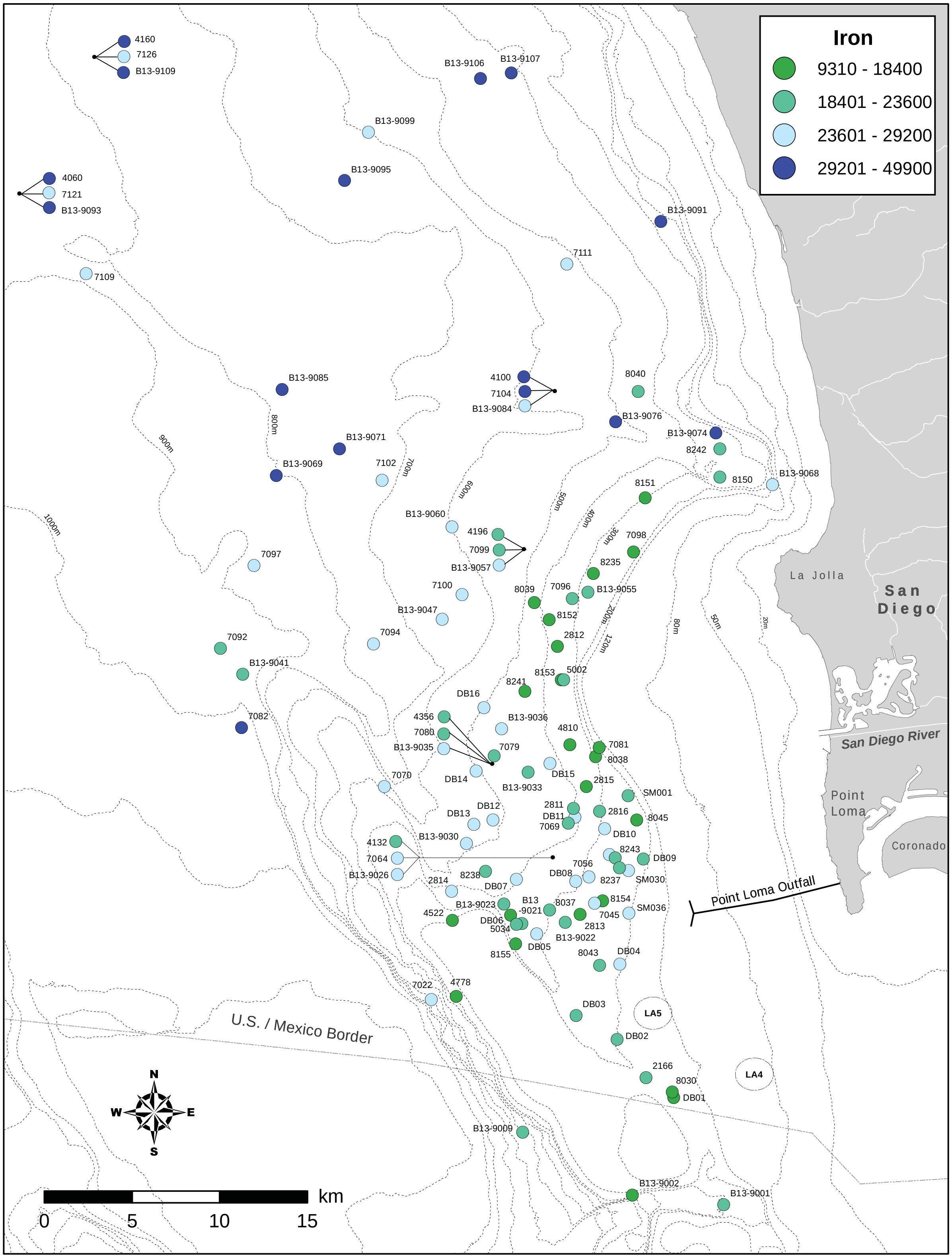


FIGURE C.5-2n

Distribution of iron (ppm) concentrations across slope stations included in the Deep Benthic Habitat Assessment Study.

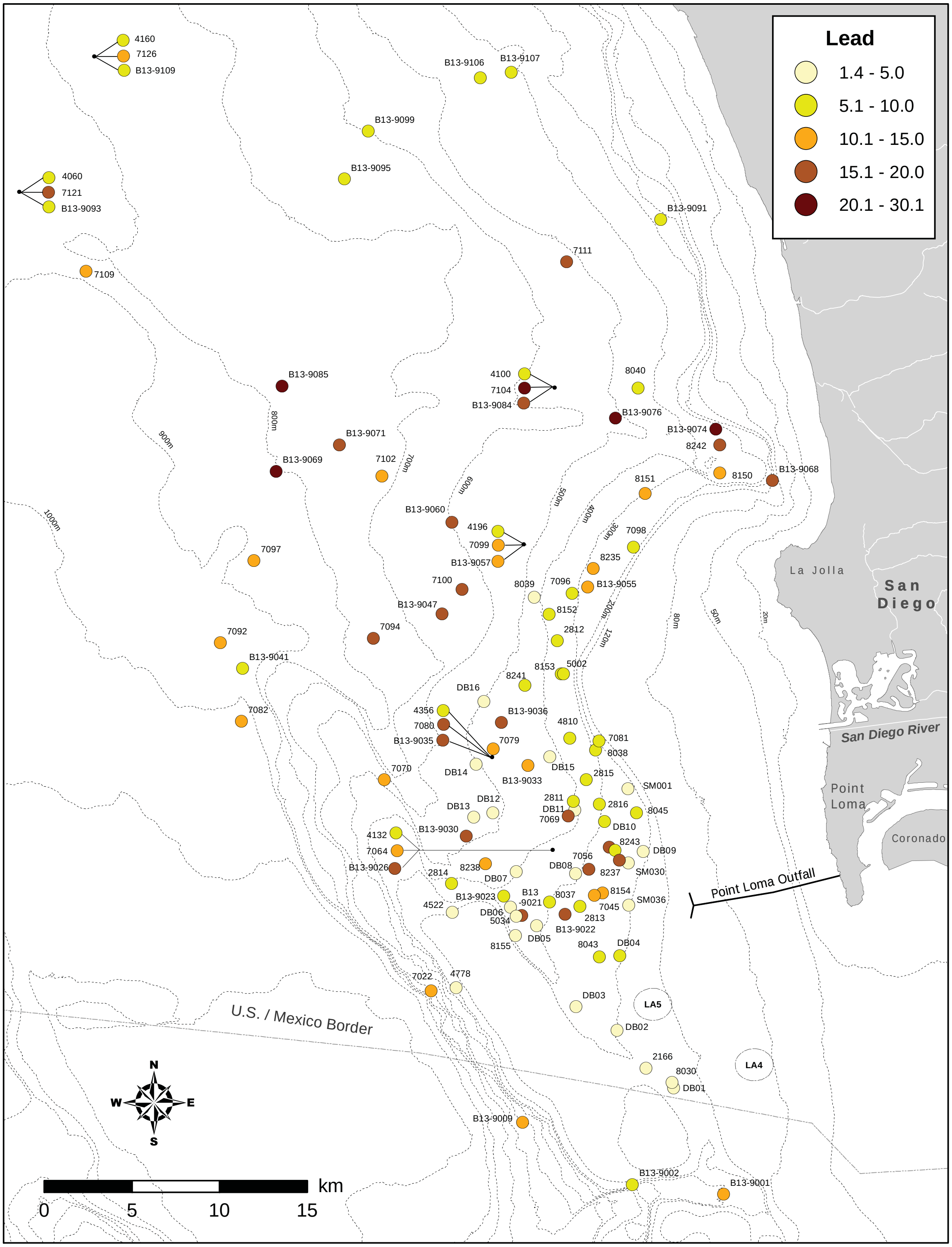


FIGURE C.5-2o

Distribution of lead (ppm) concentrations across slope stations included in the Deep Benthic Habitat Assessment Study. The ERL for lead is 46.7 ppm (see Long et al. 1995).

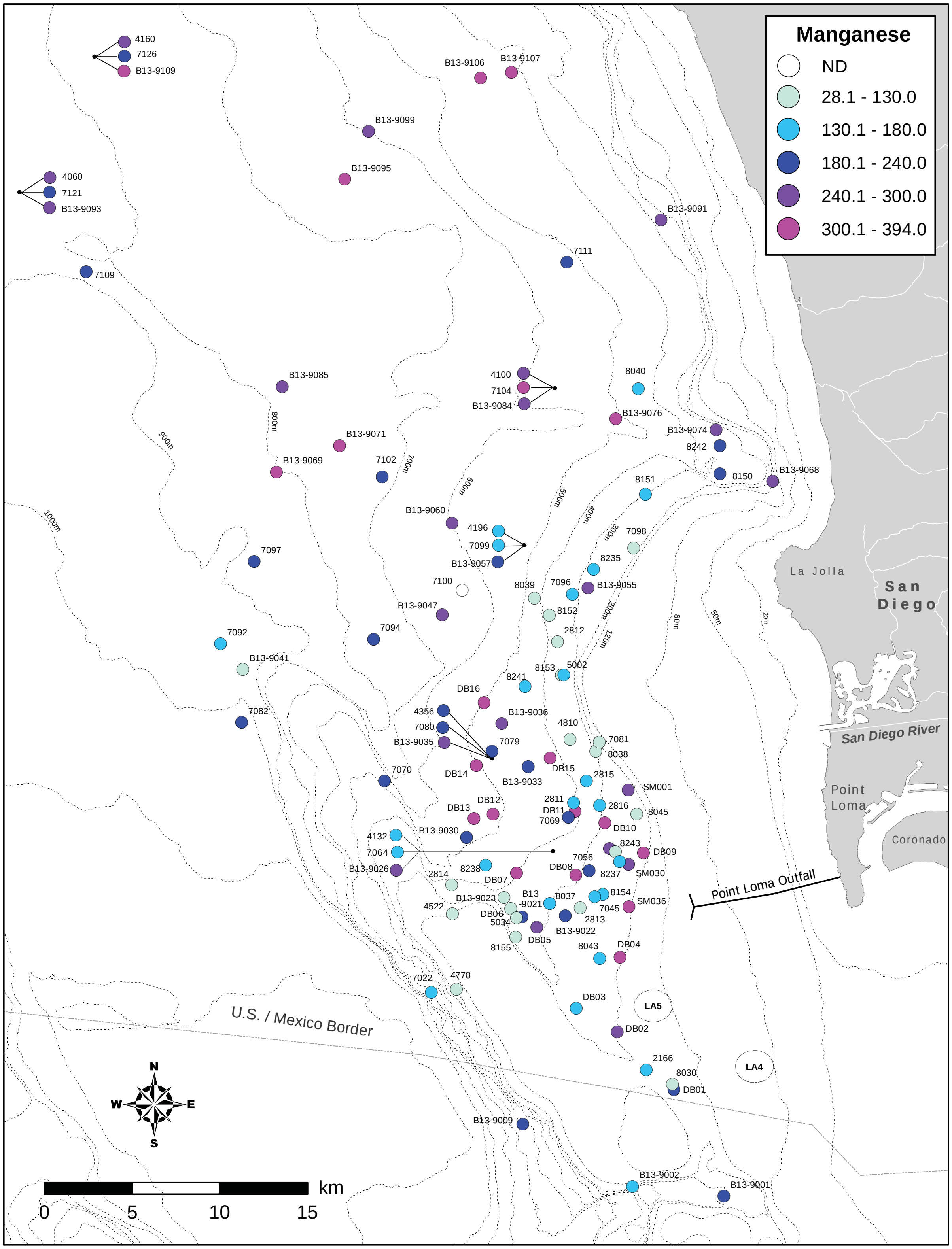


FIGURE C.5-2p

Distribution of manganese (ppm) concentrations across slope stations included in the Deep Benthic Habitat Assessment Study.

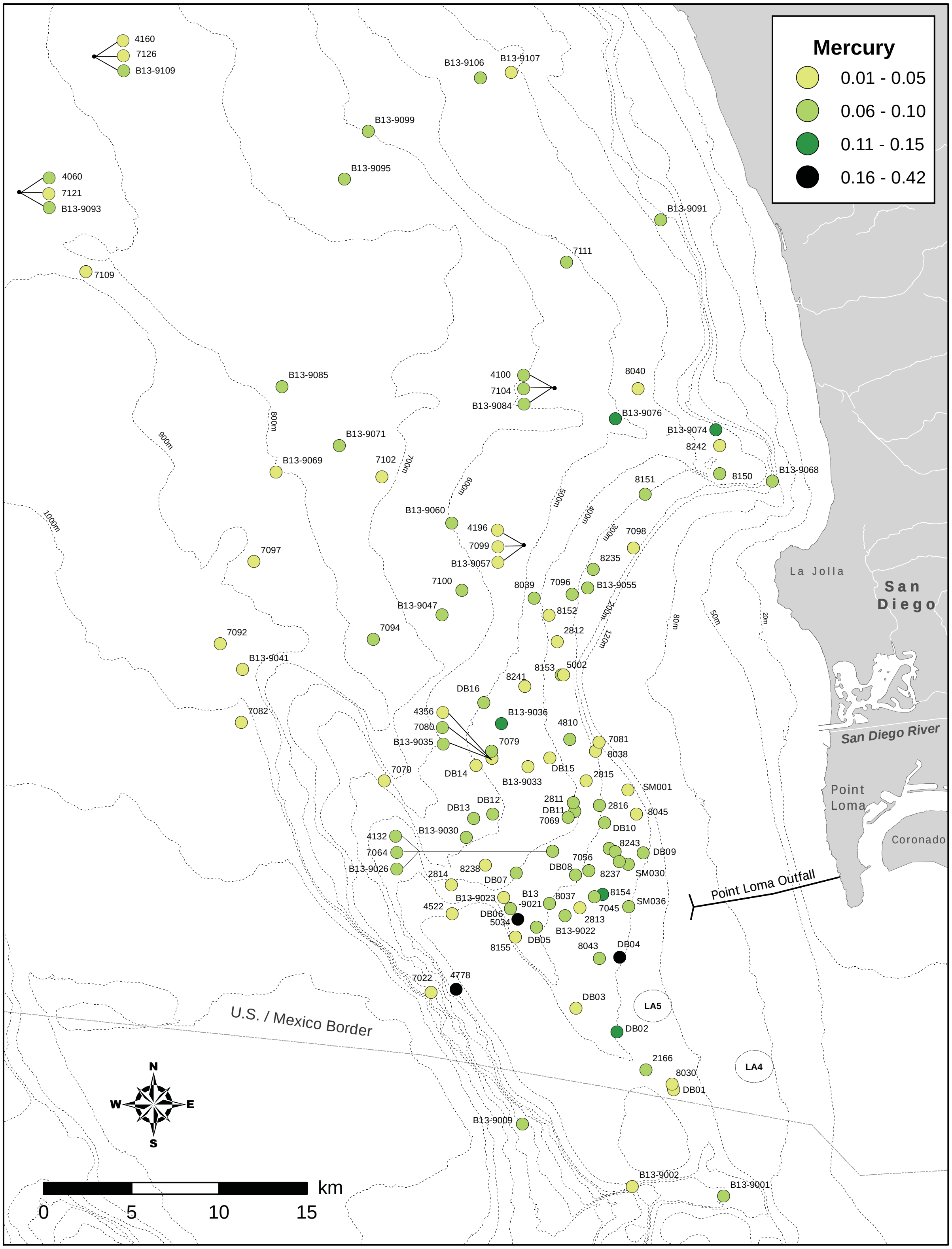


FIGURE C.5-2q

Distribution of mercury (ppm) concentrations across slope stations included in the Deep Benthic Habitat Assessment Study. The ERL for mercury is 0.15 ppm (see Long et al. 1995).

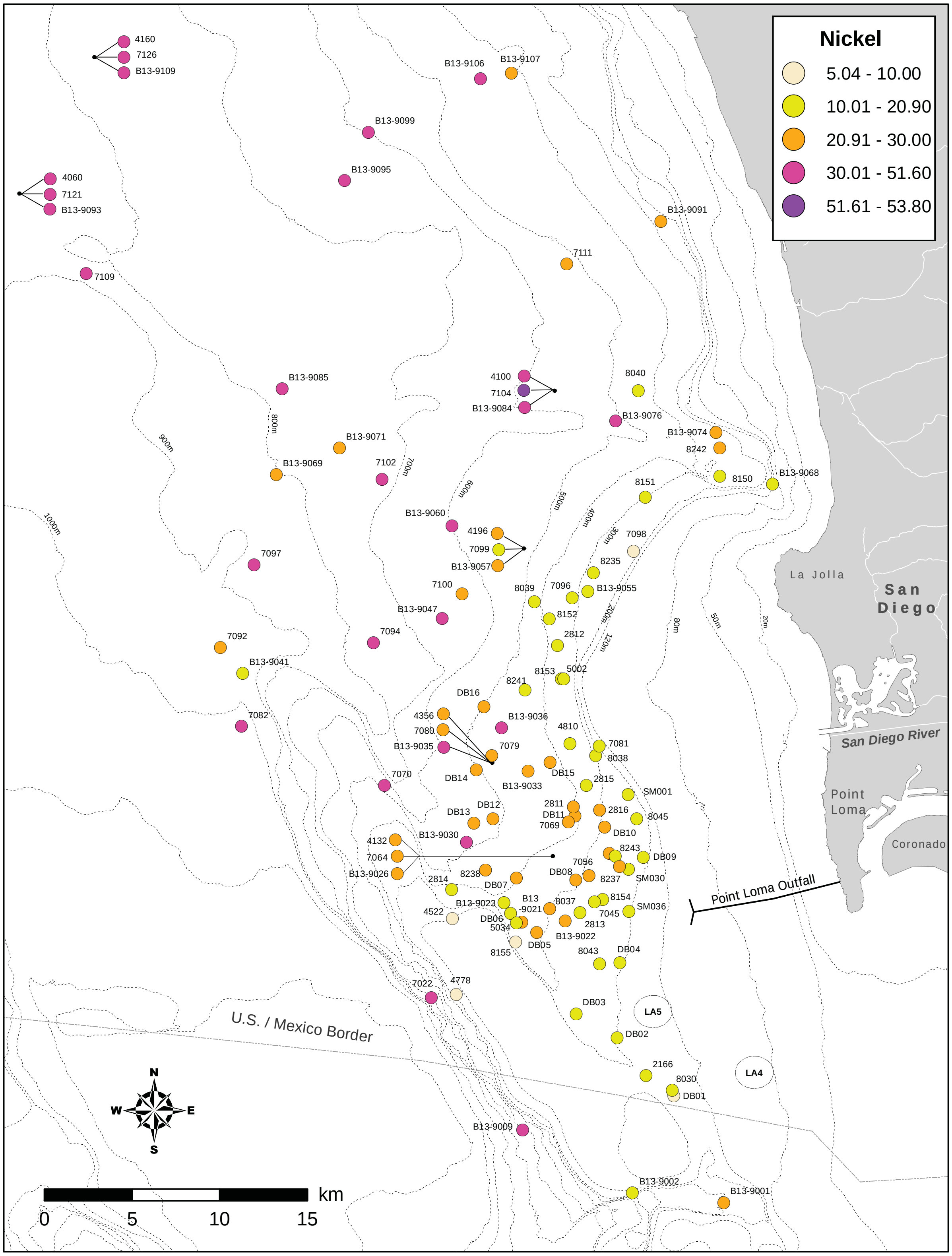


FIGURE C.5-2r

Distribution of nickel (ppm) concentrations across slope stations included in the Deep Benthic Habitat Assessment Study. The ERL for nickel is 20.9 ppm and the ERM is 51.6 (see Long et al. 1995).

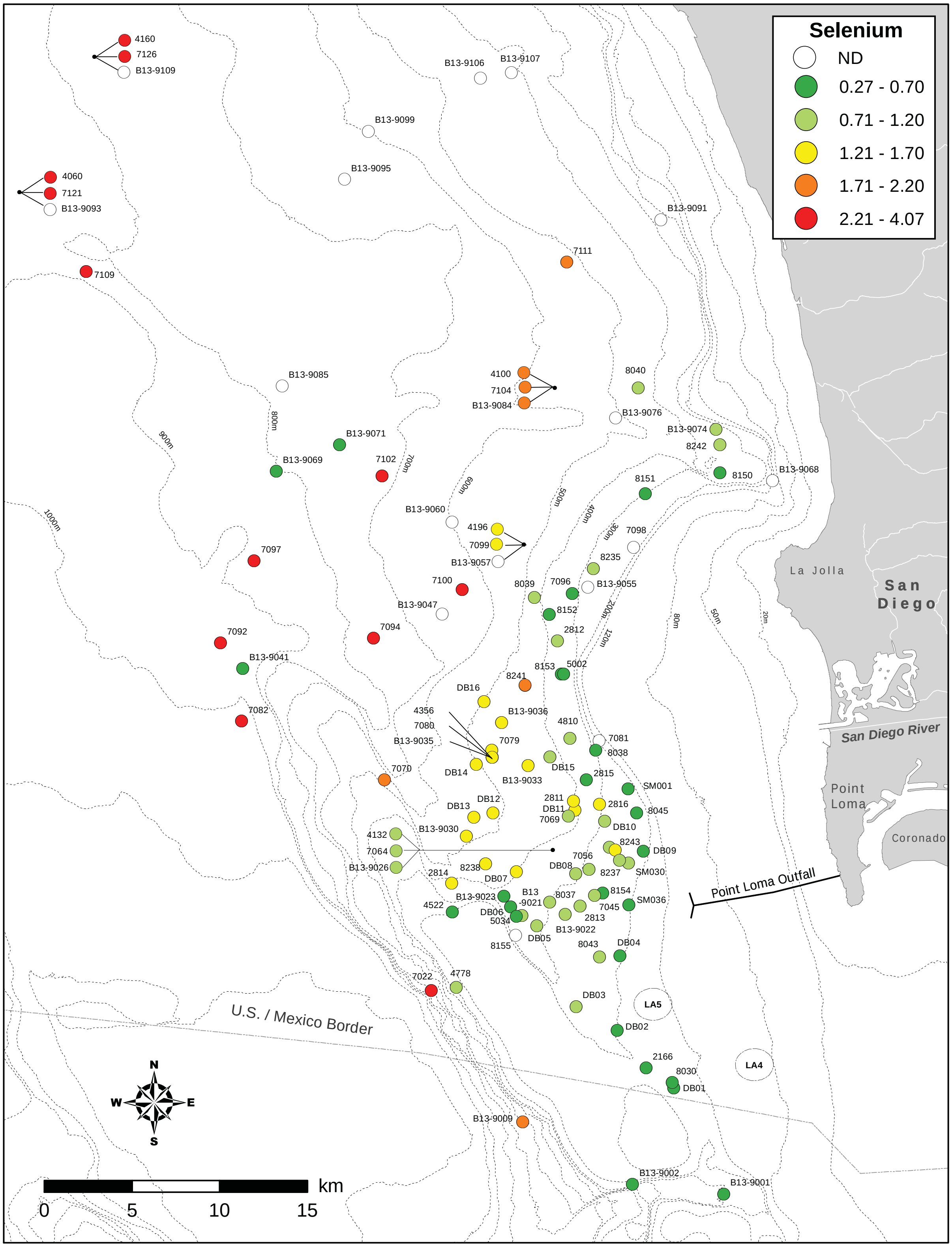


FIGURE C.5-2s
Distribution of selenium (ppm) concentrations across slope stations included in the Deep Benthic Habitat Assessment Study.

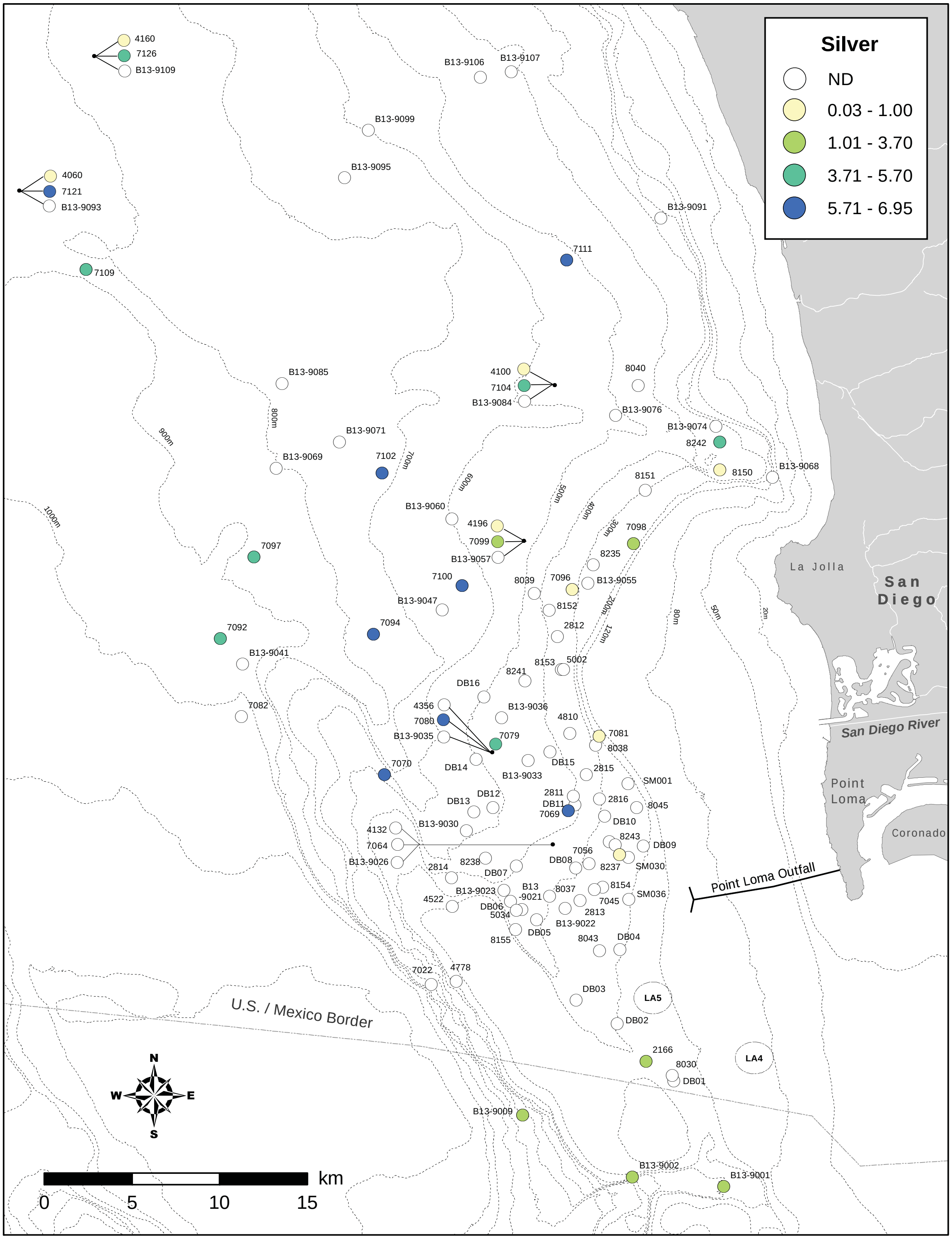


FIGURE C.5-2t

Distribution of silver (ppm) concentrations across slope stations included in the Deep Benthic Habitat Assessment Study. The ERL for silver is 1.0 ppm and the ERM is 3.7 (see Long et al. 1995).

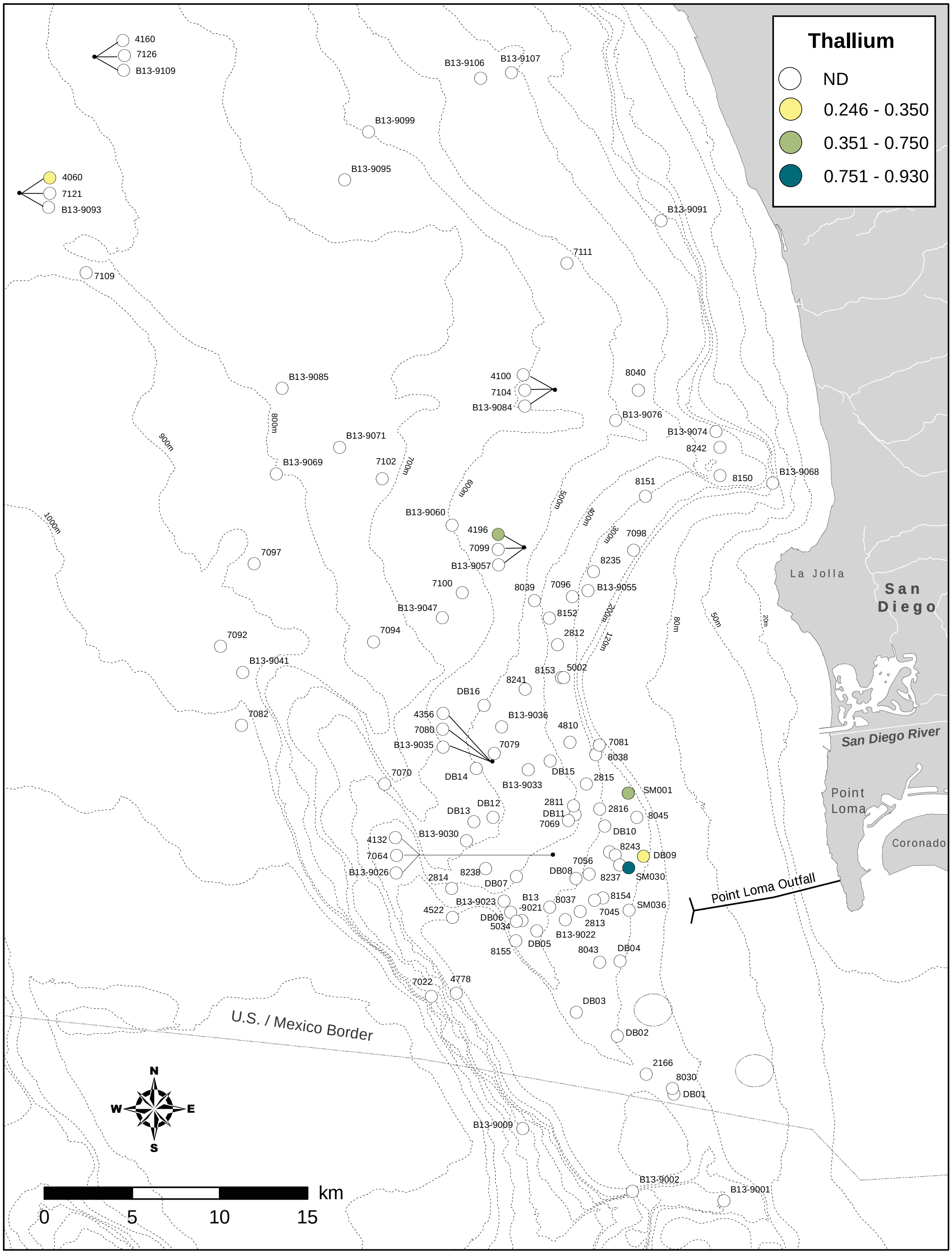


FIGURE C.5-2u

Distribution of thallium (ppm) concentrations across slope stations included in the Deep Benthic Habitat Assessment Study.

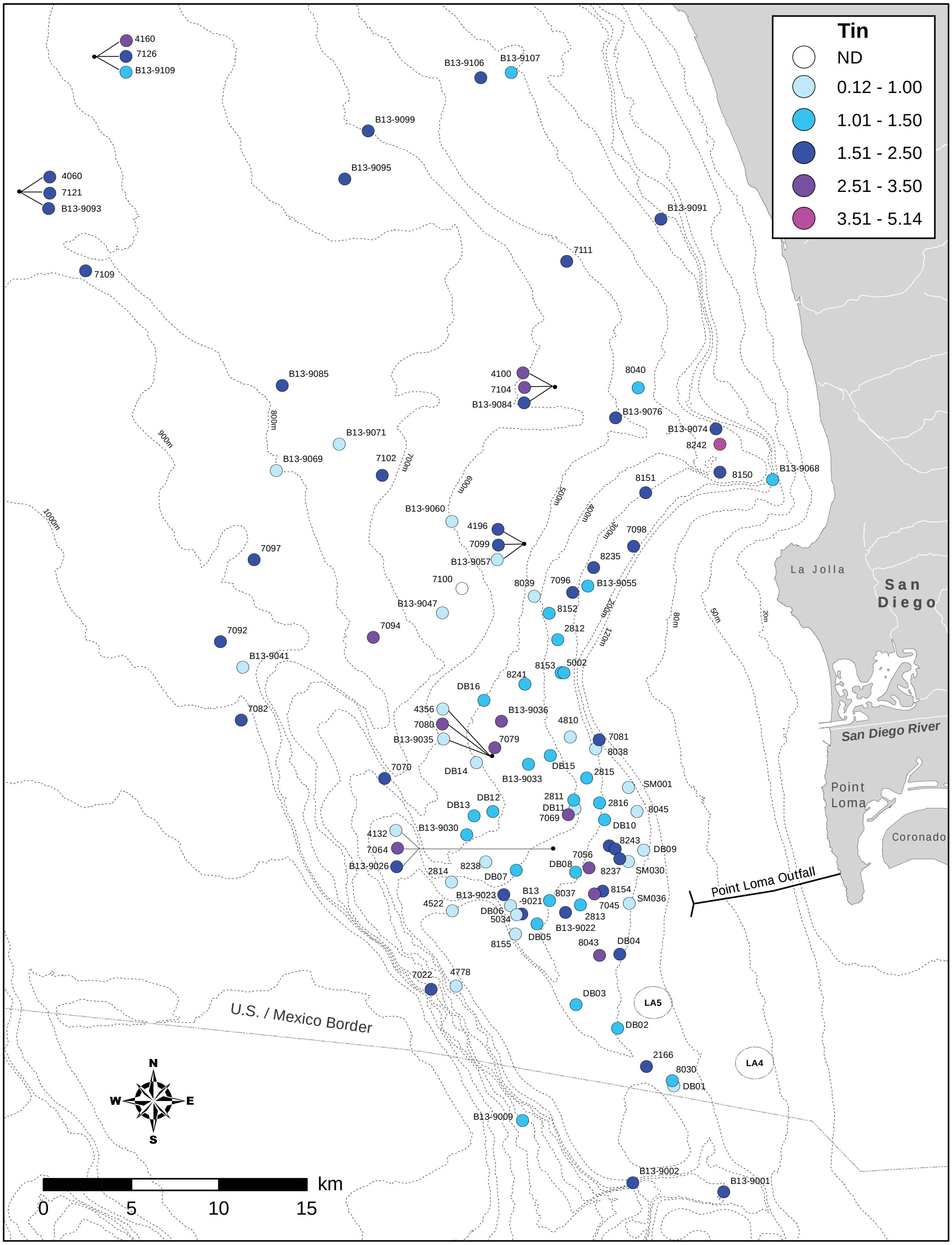


FIGURE C.5-2v

Distribution of tin (ppm) concentrations across slope stations included in the Deep Benthic Habitat Assessment Study.

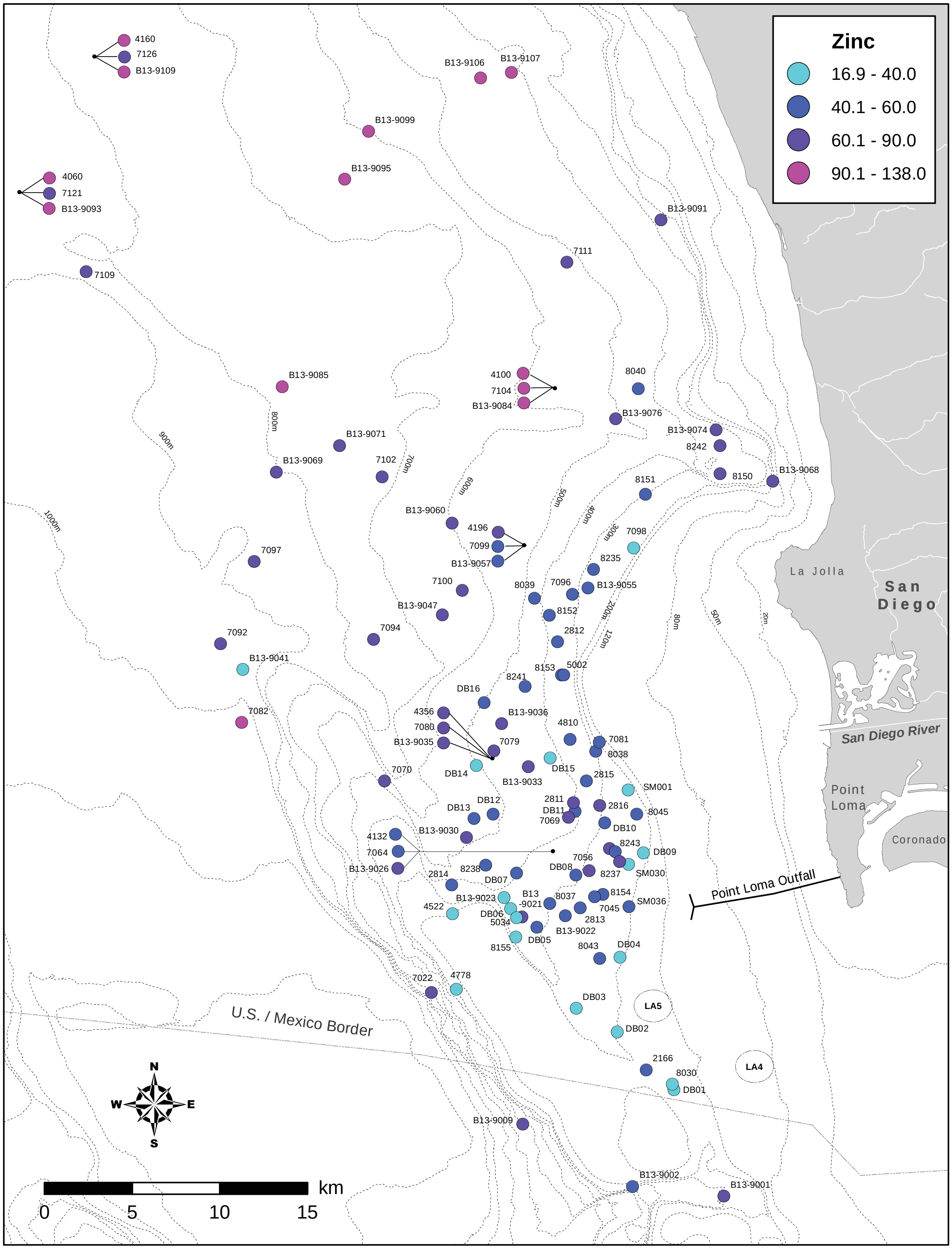


FIGURE C.5-2w

Distribution of zinc (ppm) concentrations across slope stations included in the Deep Benthic Habitat Assessment Study. The ERL for zinc is 150 ppm (see Long et al. 1995).

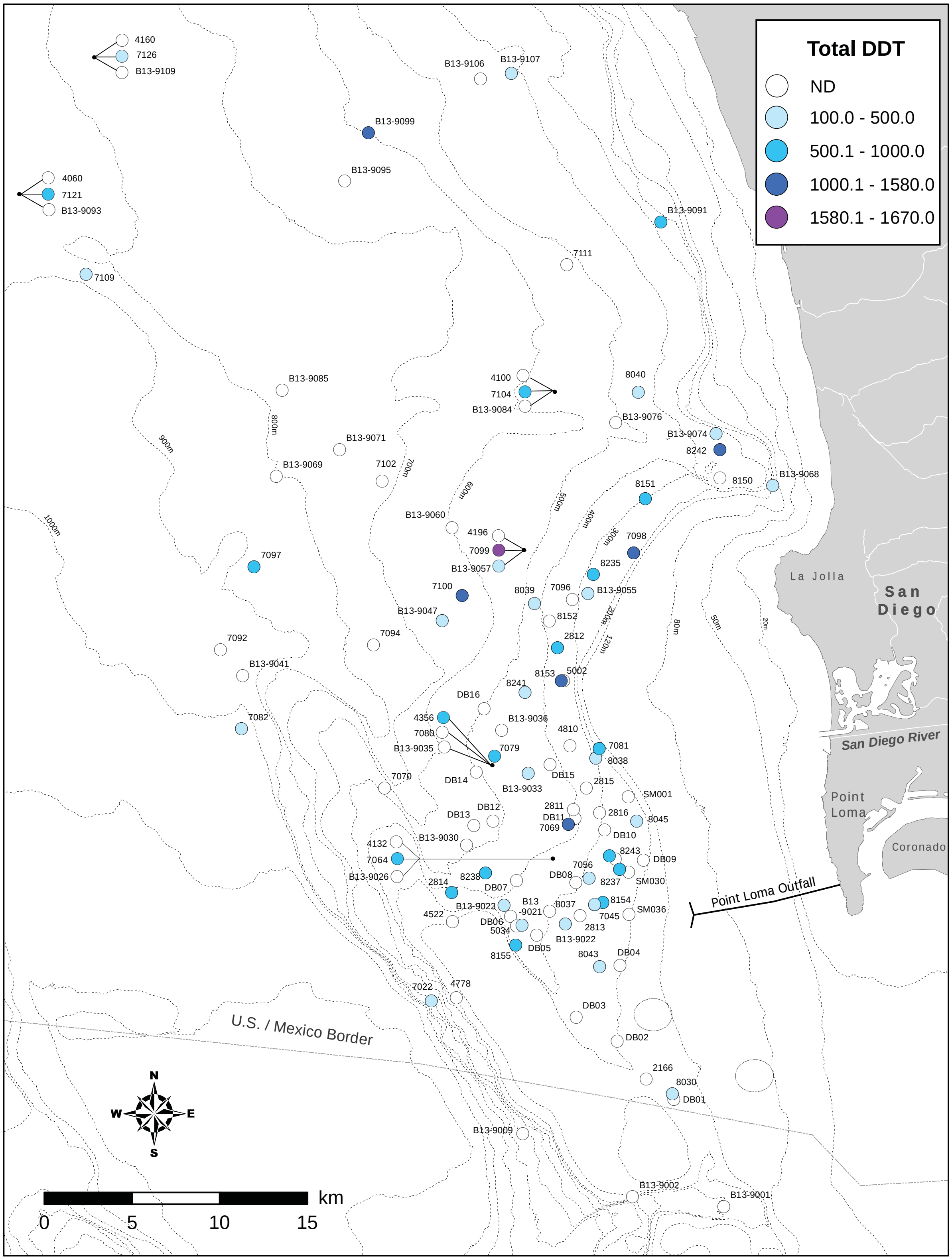


FIGURE C.5-2x
Distribution of total DDT (ppt) concentrations across slope stations included in the Deep Benthic Habitat Assessment Study. The ERL for total DDT is 1580 ppt (see Long et al. 1995).

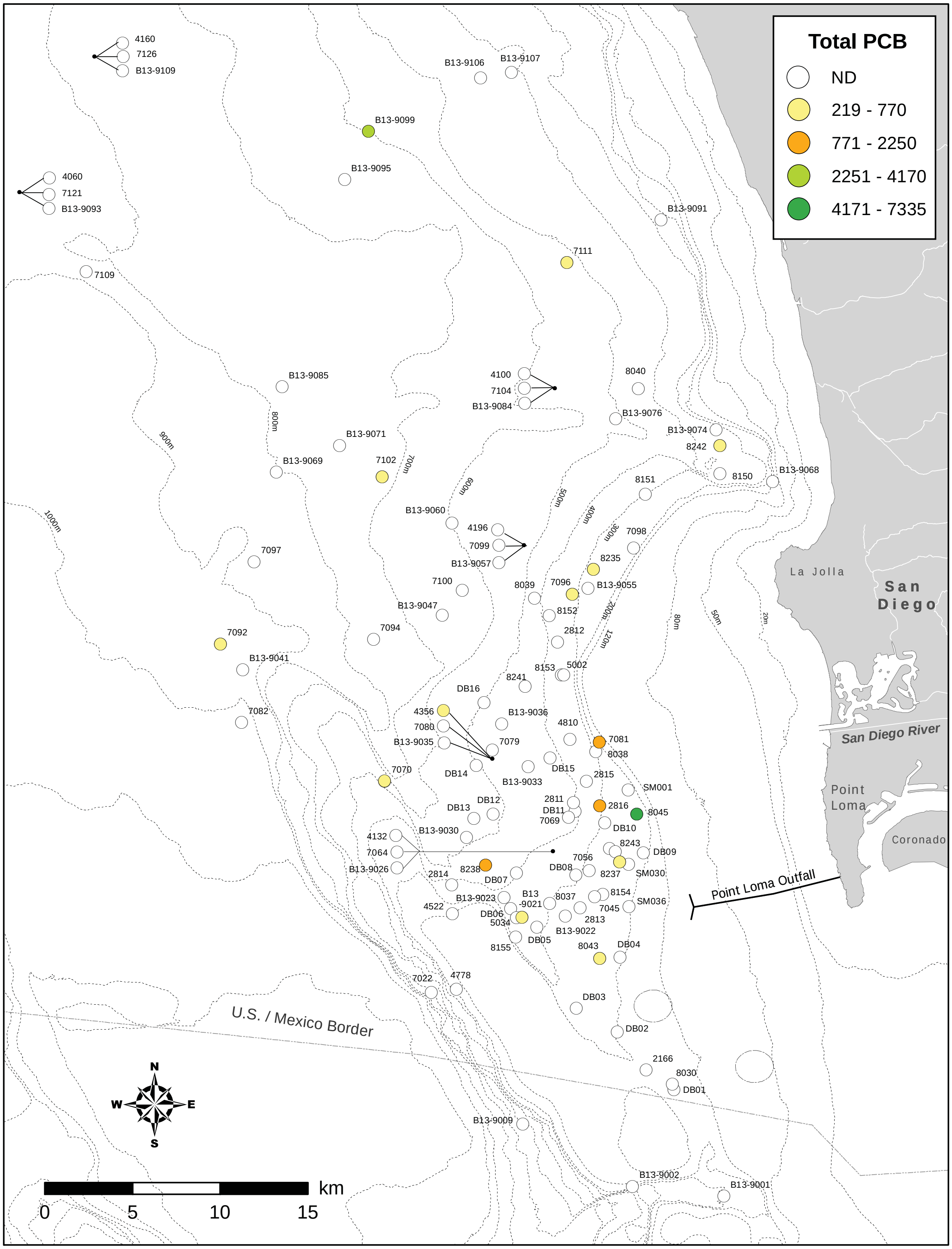


FIGURE C.5-2y

Distribution of total PCB (ppt) concentrations across slope stations included in the Deep Benthic Habitat Assessment Study.

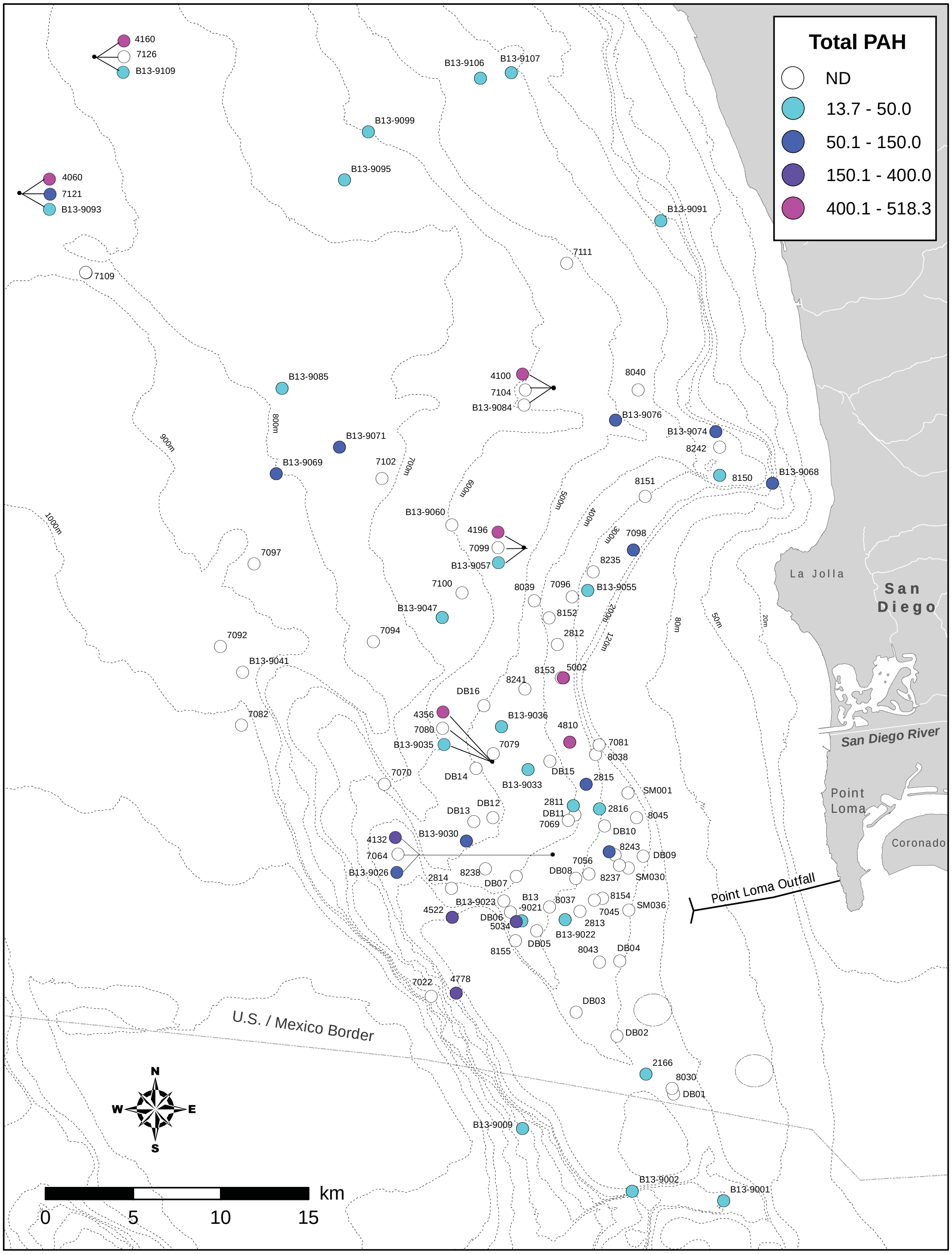
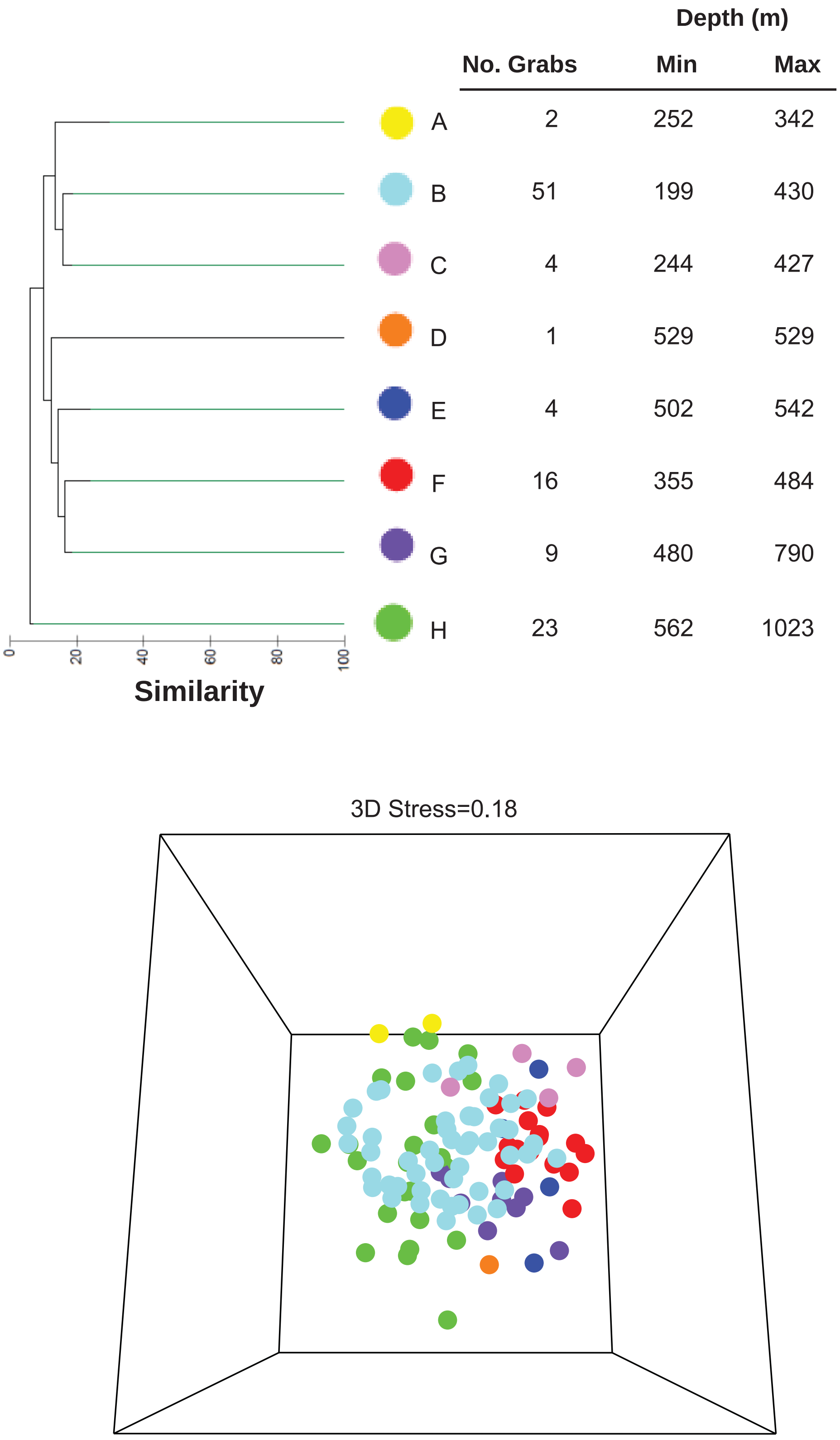


FIGURE C.5-2z

Distribution of total PAH (ppb) concentrations across slope stations included in the Deep Benthic Habitat Assessment Study.



		Depth (m)	
	No. Grabs	Min	Max
● A	2	252	342
● B	51	199	430
● C	4	244	427
● D	1	529	529
● E	4	502	542
● F	16	355	484
● G	9	480	790
● H	23	562	1023

FIGURE C.5-3

Results of classification and nMDS ordination analyses of macrofaunal abundance data from slope stations included in the Deep Benthic Habitat Assessment Study.

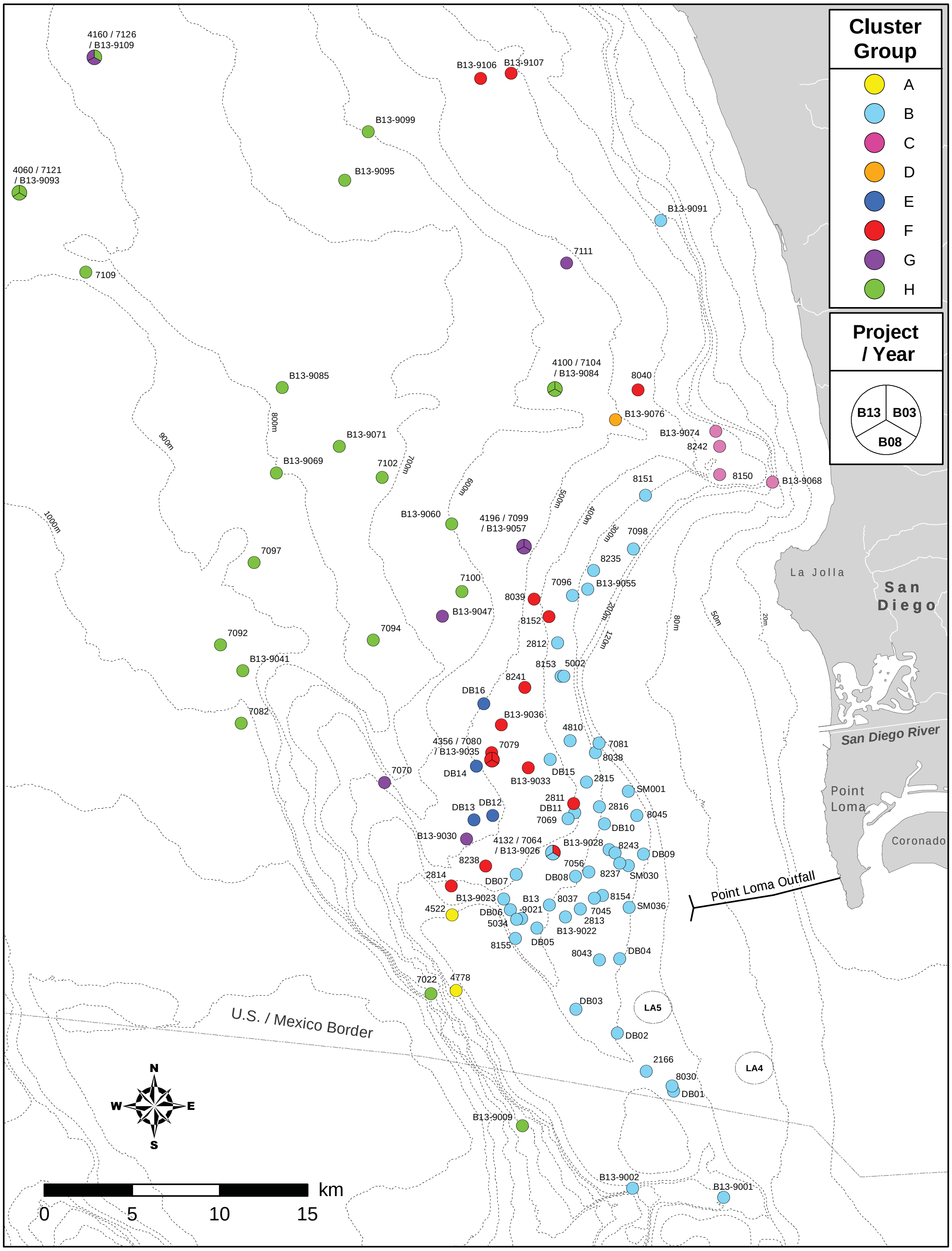


FIGURE C.5-4

Spatial distribution of cluster groups A–H off San Diego. Colors correspond to colors in Figure C.5-3.

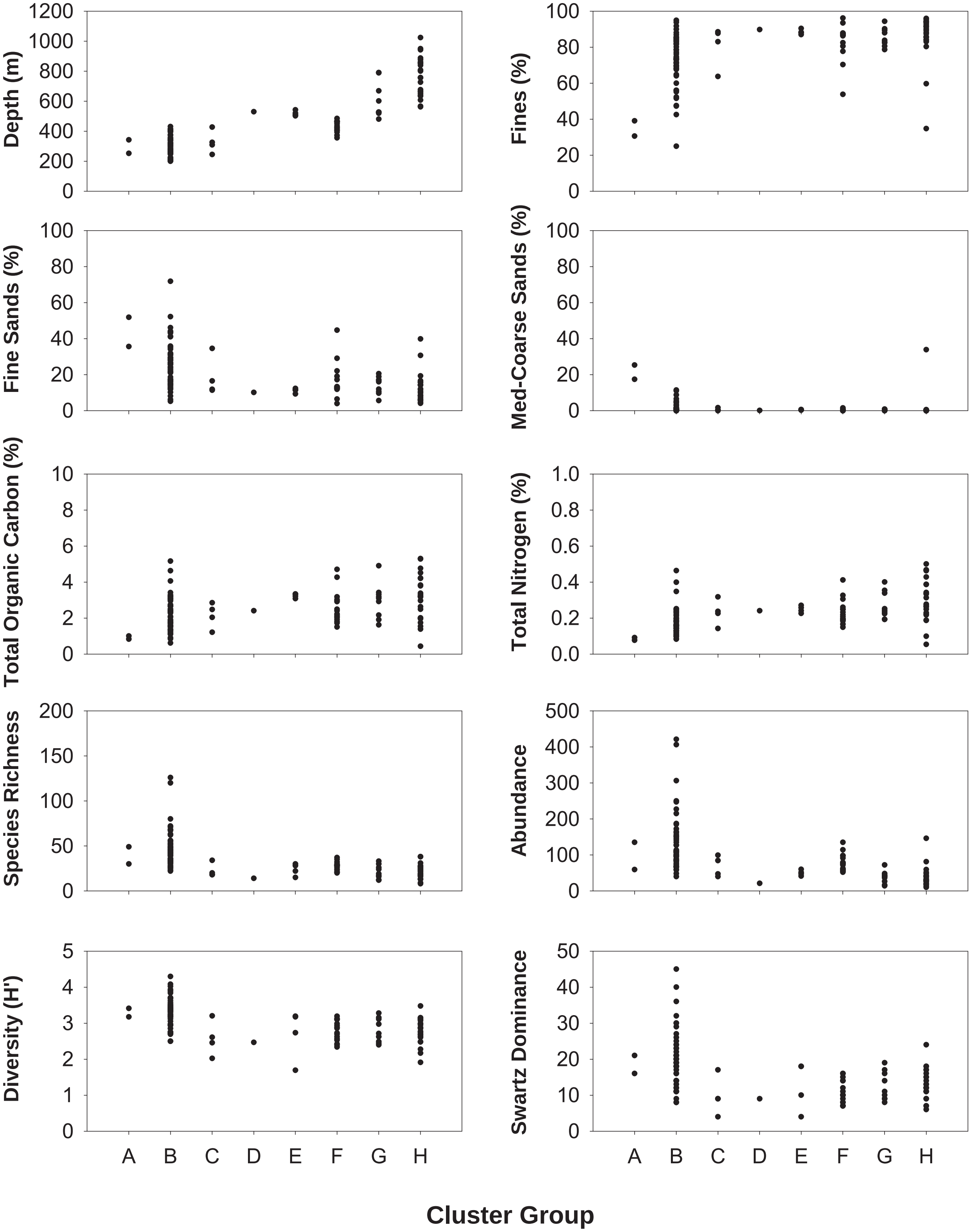


FIGURE C.5-5

Depth, sediment composition, total organic carbon, total nitrogen, community parameters, and abundances of select species by cluster group (see Figure C.5-2). Each data point represents a single sediment or grab sample.

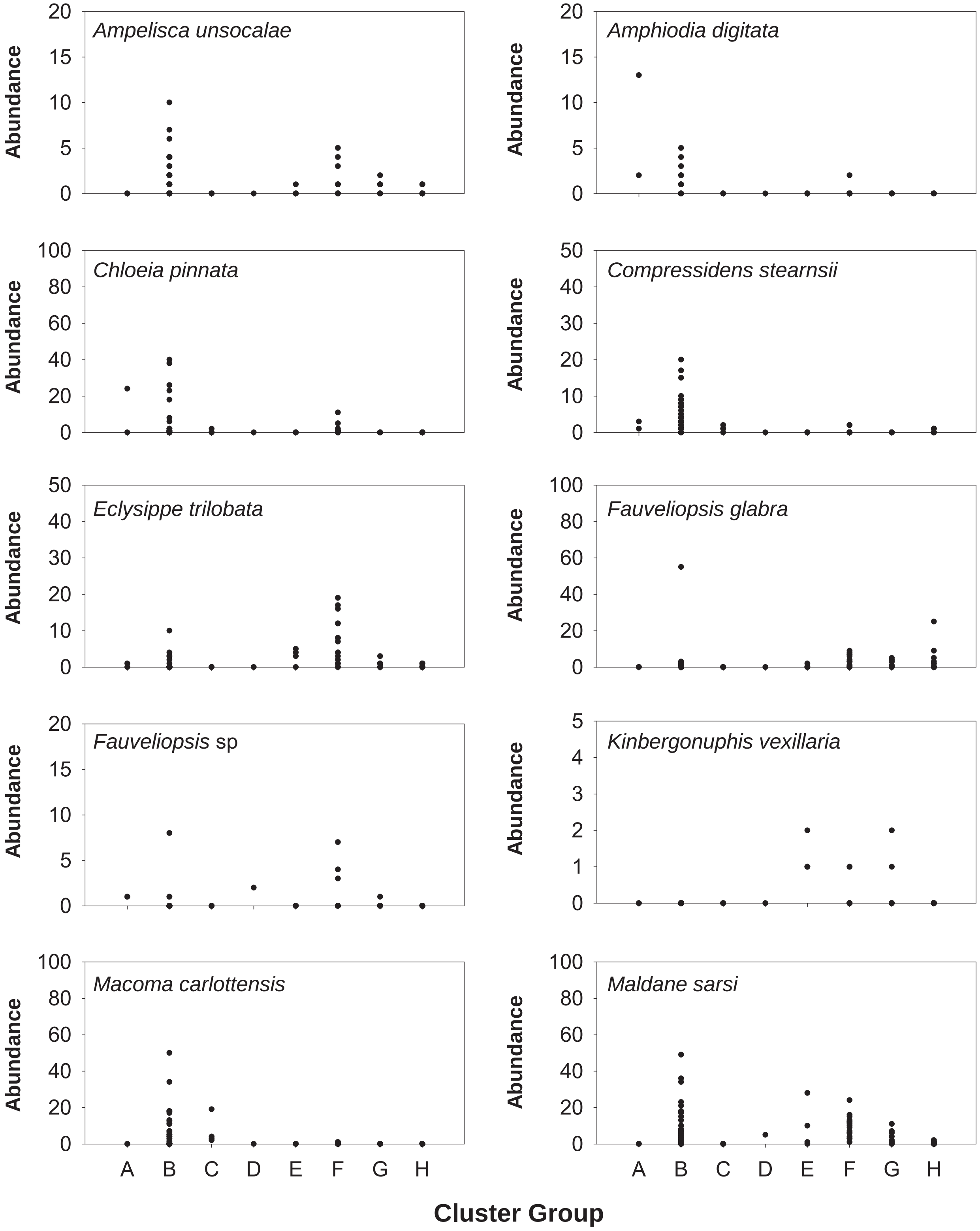


FIGURE C.5-5 (continued)

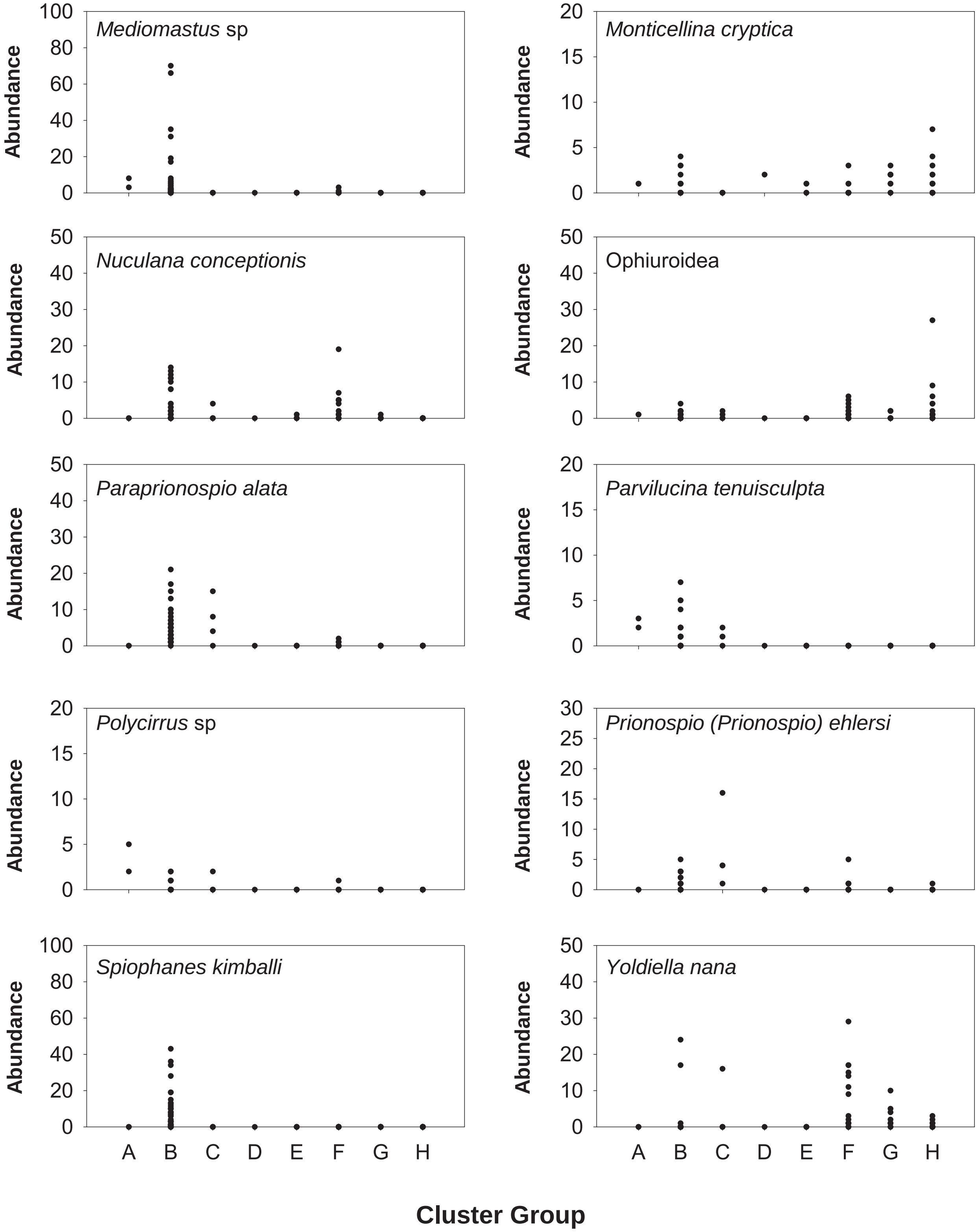


FIGURE C.5-5 (continued)

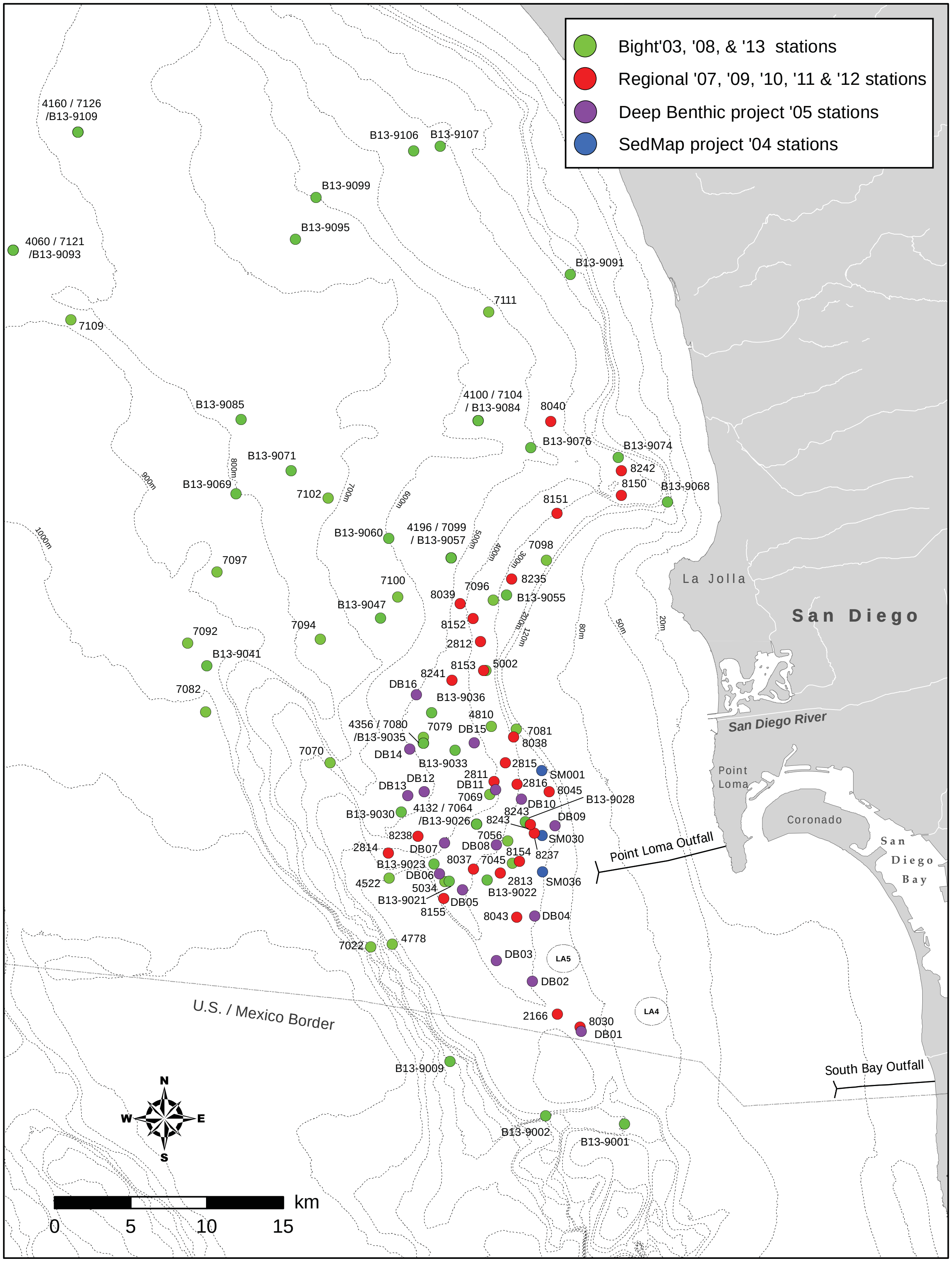
APPENDIX C.5

Deep Benthic Habitat Assessment Study

ATTACHMENTS

ATTACHMENT C.5-A

Station map showing locations of all slope sites included in the Deep Benthic Habitat Assessment Study.



ATTACHMENT C.5-B

Constituents and method detection limits (MDLs) used for the analysis of sediments collected at slope stations from 2003-2005 and 2007-2013. na = not analyzed.

Constituents	2003	2004	2005	2007	2008	2009	2010	2011	2012	2013
Organic Indicators										
Total Sulfides (ppm)	na	na	0.14	0.14	na	0.14	0.14	0.14	0.14	na
Total Nitrogen (%)	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
Total Organic Carbon (%)	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Total Solids (% weight)	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24
Total Volatile Solids (%)	na	0.11	0.11	0.11	na	0.11	0.11	0.11	0.11	0.11
Trace Metals (ppm)										
Aluminum	1.15	1.15	1.15	1.2	2	2	2	2	2	2
Antimony	0.13	0.13	0.13	0.13	0.3	0.3	0.3	0.3	0.3	0.3
Arsenic	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33
Barium	0.002	0.002	0.002	0.002	0.02	0.02	0.02	0.02	0.02	0.02
Beryllium	0.001	0.001	0.001	0.001	0.01	0.01	0.01	0.01	0.01	0.01
Cadmium	0.01	0.01	0.01	0.01	0.06	0.06	0.06	0.06	0.06	0.06
Chromium	0.016	0.016	0.016	0.016	0.1	0.1	0.1	0.1	0.1	0.1
Copper	0.028	0.028	0.028	0.028	0.2	0.2	0.2	0.2	0.2	0.2
Iron	0.76	0.76	0.76	0.76	9	9	9	9	9	9
Lead	0.142	0.142	0.142	0.142	0.8	0.8	0.8	0.8	0.8	0.8
Manganese	0.004	0.004	0.004	0.004	0.08	0.08	0.08	0.08	0.08	0.08
Mercury	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.004	0.004	0.004
Nickel	0.036	0.036	0.036	0.036	0.1	0.1	0.1	0.1	0.1	0.1
Selenium	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24
Silver	0.013	0.013	0.013	0.013	0.04	0.04	0.04	0.04	0.04	0.04
Thallium	0.022	0.221	0.221	0.22	0.5	0.5	0.5	0.5	0.5	0.5
Tin	0.059	0.059	0.059	0.059	0.3	0.3	0.3	0.3	0.3	0.3
Zinc	0.052	0.052	0.052	0.052	0.2	0.2	0.25	0.25	0.25	0.25

ATTACHMENT C.5-B (continued)

Constituents	2003	2004	2005	2007	2008	2009	2010	2011	2012	2013
Pesticides (ppt)										
Aldrin	240	na	700	700	700	700	700	430	430	70
Alpha Endosulfan	99	na	700	700	700	700	700	240	240	720
Beta Endosulfan	110	na	700	700	700	700	700	350	350	780
Dieldrin	140	na	700	700	700	700	700	310	310	340
Endosulfan Sulfate	110	na	700	700	700	700	700	260	260	1100
Endrin	160	na	700	700	700	700	700	830	830	510
Endrin aldehyde	110	na	700	700	700	700	700	830	830	2400
Hexachlorobenzene	140	na	400	400	400	400	400	470	470	70
Mirex	197	na	700	700	700	700	700	500	500	60
Hexachlorocyclohexane (HCH)										
Alpha isomer	97	na	400	400	400	400	400	150	150	100
Beta isomer	220	na	400	400	400	400	400	310	310	50
Delta isomer	220	na	400	400	400	400	400	700	700	220
Gamma isomer	68	na	400	400	400	400	400	260	260	190
Chlordane										
Alpha (cis) Chlordane	140	5700	700	700	700	700	700	240	240	160
Cis Nonachlor	90	na	700	700	700	700	700	240	240	380
Gamma (trans) Chlordane	200	3800	700	700	700	700	700	350	350	190
Heptachlor	760	na	700	700	700	700	700	1200	1200	120
Heptachlor epoxide	140	na	700	700	700	700	700	120	120	300
Methoxychlor	250	na	700	700	700	700	700	1100	1100	90
Oxychlordane	93	5700	700	700	700	700	700	240	240	1200
Trans Nonachlor	110	na	700	700	700	700	700	250	250	240

ATTACHMENT C.5-B (continued)

Constituents	2003	2004	2005	2007	2008	2009	2010	2011	2012	2013
Dichlorodiphenyltrichloroethane (DDT)										
o,p-DDD	97	5700	400	400	400	400	400	830	830	100
o,p-DDE	100	5700	700	700	700	700	700	720	720	60
o,p-DDT	100	3800	700	700	700	700	700	800	800	110
p,p-DDD	81	3800	700	700	700	700	700	470	470	160
p,p-DDE	110	3800	400	400	400	400	400	260	260	90
p,p-DDMU	na	—	—	—	—	—	—	—	—	—
p,p-DDT	200	11000	700	700	700	700	700	800	800	70
Polychlorinated Biphenyl Congeners (ppt)										
PCB 18	170	2600	700	700	700	700	700	540	540	90
PCB 28	90	3000	700	700	700	700	700	660	660	60
PCB 37	110	2100	700	700	700	700	700	340	340	90
PCB 44	76	2600	700	700	700	700	700	890	890	100
PCB 49	200	2700	700	700	700	700	700	850	850	70
PCB 52	90	3100	700	700	700	700	700	1000	1000	90
PCB 66	150	2100	700	700	700	700	700	920	920	100
PCB 70	200	2700	700	700	700	700	700	1100	1100	60
PCB 74	160	2700	700	700	700	700	700	900	900	100
PCB 77	190	2100	700	700	700	700	700	790	790	110
PCB 81	230	2500	700	700	700	700	700	590	590	130
PCB 87	180	2800	700	700	700	700	700	600	600	200
PCB 99	390	2500	700	700	700	700	700	660	660	120
PCB 101	240	2600	700	700	700	700	700	430	430	100
PCB 105	110	2600	700	700	700	700	700	720	720	50
PCB 110	340	2900	700	700	700	700	700	640	640	110
PCB 114	130	3000	700	700	700	700	700	700	700	130
PCB 118	250	2700	700	700	700	700	700	830	830	90
PCB 119	150	2400	700	700	700	700	700	560	560	80
PCB 123	190	2800	700	700	700	700	700	660	660	130

ATTACHMENT C.5-B (continued)

Constituents	2003	2004	2005	2007	2008	2009	2010	2011	2012	2013
PCB 126	310	3000	1500	1500	1500	1500	1500	720	720	70
PCB 128	210	2700	700	700	700	700	700	570	570	80
PCB 138	160	3000	700	700	700	700	700	590	590	80
PCB 149	330	2500	700	700	700	700	700	500	500	110
PCB 151	200	2500	700	700	700	700	700	640	640	80
PCB 153/168	200	1200	700	700	700	700	700	600	600	150
PCB 156	51	2900	700	700	700	700	700	620	620	90
PCB 157	80	2700	700	700	700	700	700	700	700	100
PCB 158	72	2600	700	700	700	700	700	510	510	70
PCB 167	60	3000	700	700	700	700	700	620	620	30
PCB 169	150	2300	700	700	700	700	700	610	610	90
PCB 170	57	3100	700	700	700	700	700	570	570	80
PCB 177	100	3000	700	700	700	700	700	650	650	70
PCB 180	92	2600	400	400	400	400	400	530	530	80
PCB 183	310	2700	700	700	700	700	700	530	530	60
PCB 187	260	2700	700	700	700	700	700	470	470	110
PCB 189	85	2300	400	400	400	400	400	620	620	60
PCB 194	140	2300	700	700	700	700	700	420	420	80
PCB 201	34	2900	700	700	700	700	700	530	530	70
PCB 206	95	1900	700	700	700	700	700	510	510	50
Polycyclic Aromatic Hydrocarbons (PAHs, ppb)										
1-methylnaphthalene	41	na	na	70	70	20	20	20	20	20
1-methylphenanthrene	41	na	na	41	41	20	20	20	20	20
2,3,5-trimethylnaphthalene	21	na	na	134	134	20	20	20	20	20
2,6-dimethylnaphthalene	32	na	na	106	106	20	20	20	20	20
2-methylnaphthalene	12	na	na	0	102	20	20	20	20	20
3,4-benzo(B)fluoranthene	63	na	na	63	63	20	20	20	20	20
Acenaphthene	28	na	na	11	40	20	20	20	20	20
Acenaphthylene	15	na	na	11	40	30	30	30	30	30

ATTACHMENT C.5-B (continued)

Constituents	2003	2004	2005	2007	2008	2009	2010	2011	2012	2013
Anthracene	18	na	na	14	40	20	20	20	20	20
Benzo[A]anthracene	55	na	na	34	40	20	20	20	20	20
Benzo[A]pyrene	55	na	na	55	55	20	20	20	20	20
Benzo[e]pyrene	57	na	na	57	73	20	20	20	20	20
Benzo[G,H,I]perylene	56	na	na	56	66	20	20	20	20	20
Benzo[K]fluoranthene	82	na	na	82	82	20	20	20	20	20
Biphenyl	10	na	na	89	89	30	30	30	30	30
Chrysene	36	na	na	36	40	40	40	40	40	40
Dibenzo(A,H)anthracene	52	na	na	32	50	20	20	20	20	20
Fluoranthene	24	na	na	24	40	20	20	20	20	20
Fluorene	13	na	na	18	40	20	20	20	20	20
Indeno(1,2,3-CD)pyrene	76	na	na	76	76	20	20	20	20	20
Naphthalene	21	na	na	21	40	30	30	30	30	30
Perylene	23	na	na	58	58	30	30	30	30	30
Phenanthrene	21	na	na	32	40	30	30	30	30	30
Pyrene	35	na	na	35	40	20	20	20	20	20

Appendix D
BIOACCUMULATION ASSESSMENT

Renewal of NPDES CA0107409

APPENDIX D

BIOACCUMULATION ASSESSMENT

THE CITY OF SAN DIEGO • STATE OF CALIFORNIA •

SEMPER VIGILANS

January 2015

APPENDIX D

Bioaccumulation Assessment

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APPENDIX D

Bioaccumulation Assessment

SECTION D.1 | SUMMARY OF FINDINGS

Demersal fishes can accumulate chemical contaminants from the environment, including surrounding waters, benthic sediments, and from the food they consume. The City of San Diego currently monitors the bioaccumulation of contaminants in fishes inhabiting areas surrounding the Point Loma Ocean Outfall by analyzing liver tissues of species collected from four trawl zones (6 stations) and muscle tissues of species collected from two rig fishing stations. These stations are located along the mainland shelf at depth ranges similar to where wastewater is discharged (~98 m). Specific species are targeted for analysis based on their ecological or commercial importance.

Results are presented for contaminant levels of 11 metals, DDT and other chlorinated pesticides, and polychlorinated biphenyl compounds (PCBs) measured in 22 species of fish collected from surveys conducted between October 1995 and October 2013. Six trace metals (arsenic, cadmium, copper, mercury, selenium, zinc), DDT, and PCBs occurred in ≥73% of all liver tissue samples from trawl-caught fishes, while chromium, lead, nickel, silver, tin, hexachlorobenzene and chlordane were found in 13% to 54% of the liver samples. Five metals (arsenic, copper, mercury, selenium, zinc), DDT, and PCBs also occurred frequently (≥61%) in the muscle tissue samples from fishes collected at rig fishing stations. The remaining metals had muscle tissue detection rates that ranged from 2% for lead to 38% for chromium. Tissue contaminant concentrations varied substantially among different species, across stations, and over time, although none showed patterns relative to the Point Loma outfall. Overall, contaminant concentrations were considerably less in the muscle tissues of fish than in liver tissues, and contaminant loads were generally within the range of those reported previously for other Southern California Bight (SCB) fish assemblages. With exception of a single sample, muscle tissues from sport fish collected in the region had concentrations of mercury below United States Food and Drug Administration (USFDA) and California Department of Health Services (CDHS) advisory levels. However, some tissue samples composed of various rockfish species and California scorpionfish had arsenic, chromium, and selenium concentrations above median international standards, and concentrations of mercury, total DDT and total PCB above the California Office of Environmental Health Hazard Assessment (OEHHA) fish contaminant goals. Elevated levels of these contaminants are not uncommon in sport fish from the greater San Diego region, including the Coronado Islands.

SECTION D.2 | INTRODUCTION

Bioaccumulation is the process of biological uptake and retention of chemical contaminants from various exposure pathways (USEPA 2000). Marine organisms can accumulate pollutants through adsorption or absorption of dissolved chemical constituents from the surrounding water or from the ingestion and assimilation of pollutants from different food sources (Rand 1995). Because of their proximity to seafloor sediments, demersal fish and other bottom dwelling organisms can also be exposed to pollutants through ingestion of suspended particulates and the subsequent assimilation of chemicals into body tissues. Once a contaminant becomes incorporated into an organism’s tissues, it may resist normal metabolic excretion and accumulate (Walker et al. 1996). In addition, higher trophic level organisms may feed on contaminated prey and further concentrate pollutants in their tissues (Suedel et al. 1994). This food web magnification may lead to tissue burdens in fish that have both ecological and human health implications (USEPA 1997).

The City of San Diego’s Ocean Monitoring Program includes extensive sampling to detect any effects on demersal fish communities associated with wastewater discharge from the Point Loma Ocean Outfall (PLOO). The bioaccumulation portion of the program presently consists of two components, including: (1) analysis of liver tissues from trawl-caught fishes; (2) analysis of muscle tissues from fishes collected by rig fishing. Fishes collected from trawling activities are considered representative of the general demersal fish community that dominates the region, and certain species are targeted based on their ecological significance. Chemical analyses are performed using livers of these fishes because this is the organ where contaminants typically concentrate. In contrast, fishes targeted for collection at rig fishing sites represent species from a typical sport fisher’s catch, and are therefore of recreational and commercial importance. Muscle tissue is analyzed from these fish because it is the tissue most often consumes by humans, and therefore the results have implications concerning seafood safety issues and public health.

The data presented herein represent an update of the analyses presented in the City's previous 301(h) waiver application in 2007, which addressed monitoring data collected from 1995 through calendar year 2006. Significant changes were made to the MRP requirements for the Point Loma region with the adoption of Addendum No.1 to Order No. R9-2002-0025, NPDES Permit No. CA0107409, which may affect comparisons between sampling periods. Therefore, all data were completely reanalyzed for this application in order to account for the major changes to the bioaccumulation monitoring requirements that became effective on August 1, 2003, as follows: (1) data from trawl stations SD9 and SD11 were excluded from all analyses; (2) only results from liver tissues are reported for trawl-caught fishes; (3) only results from muscle tissues are reported for fishes collected from rig fishing stations; (4) no polycyclic aromatic hydrocarbons (PAHs) data are reported, as they have not been analyzed in tissue samples from the Point Loma region since 2003 (see City of San Diego 2007 for the latest PAH assessment).

SECTION D.3 | GENERAL METHODOLOGY

Appendix D reviews the results of the bioaccumulation analyses for fishes collected off San Diego for the period October 1995 through October 2013. The fishes analyzed herein were collected from six trawling stations corresponding to four zones and at two rig fishing locations (stations RF1 and RF2) (see Figure D-1). Trawl Zone 1 represents the nearfield zone and is defined as the area within a 1-km radius of stations SD10 and SD12, which are located just south and just north of the PLOO, respectively; Trawl Zone 2 is considered the northern farfield zone, defined as the area within a 1-km radius of stations SD13 and SD14; Trawl Zone 3 is defined as the area within a 1-km radius of Station SD8 and represents a farfield zone near the LA-5 dredged materials disposal site; Trawl Zone 4 is considered the southernmost farfield zone, and is defined as the area centered within a 1-km radius of station SD7. Trawl-caught fishes were collected, measured, and weighed following guidelines described in the 2013 Point Loma Ocean Outfall Receiving Waters Monitoring and Assessment Report (City of San Diego 2014a). Fishes were collected at the rig fishing sites using rod and reel fishing tackle, and then also measured and weighed. Table D-1 lists the scientific and common names of the different flatfishes and rockfishes taken for assessment of contaminant bioaccumulation.

Fishes were collected semi-annually (April, October) from October 1995 through April 2003. During this time, three composite liver tissue samples and three muscle tissue samples were obtained at each station. Beginning in August 2003 as a result of NPDES permit revisions, fishes for bioaccumulation analysis were only collected during October each year. Additionally, the individual trawl stations were combined into the four trawl zones described above, and sampling was limited to liver tissues from trawl-caught fishes and muscle tissues from fishes collected at the rig fishing sites. At this time, up to nine composite liver samples were obtained per trawl

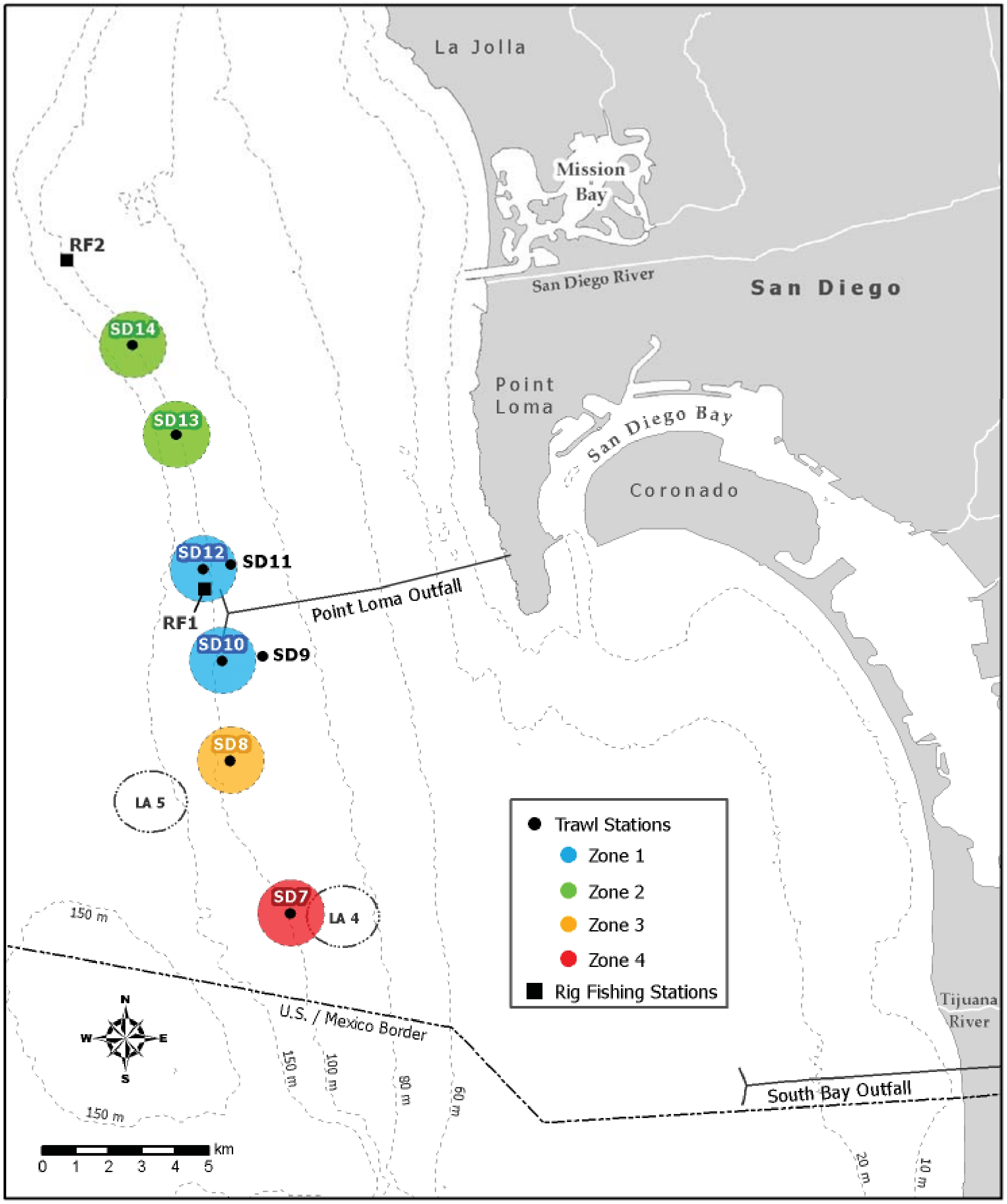

FIGURE D-1
Otter trawl and rig fishing monitoring stations and fish collection zones surrounding the City of San Diego's Point Loma Ocean Outfall. Stations SD7, SD8, SD10, SD12, SD13, and SD14 equal the current monitoring sites that are the focus of the analyses presented herein; sampling at stations SD9 and SD11 was discontinued in late 2003. See text for details of zone descriptions and changes to sampling program over time. LA-4 and LA-5 are EPA designated dredge materials disposal sites.

TABLE D-1

Scientific and common names of fishes analyzed as part of the City of San Diego's Ocean Monitoring Program.

Common Name	Scientific Name
TRAWL-CAUGHT	
Bigmouth sole	*Hippoglossina stomata*
Dover sole	*Microstomus pacificus*
English sole	*Pleuronectes vetulus*
Hornyhead turbot	*Pleuronichthys verticalis*
Longfin sanddab	*Citharichthys xanthostigma*
Pacific sanddab	*Citharichthys sordidus*
Mixed sanddab	*Citharichthys* spp.
California scorpionfish	*Scorpaena guttata*
Flag rockfish	*Sebastes rubrivinctus*
Greenblotched rockfish	*Sebastes rosenblatti*
Greenspotted rockfish	*Sebastes chlorostictus*
Halfbanded rockfish	*Sebastes semicinctus*
Squarespot rockfish	*Sebastes hopkinsi*
Stripetail rockfish	*Sebastes saxicola*
Vermilion rockfish	*Sebastes miniatus*
Mixed rockfish	*Sebastes* spp.
HOOK and LINE CAUGHT	
California scorpionfish	*Scorpaena guttata*
Bocaccio	*Sebastes paucispinis*
Canary rockfish	*Sebastes pinniger*
Chilipepper	*Sebastes goodei*
Copper rockfish	*Sebastes caurinus*
Flag rockfish	*Sebastes rubrivinctus*
Greenblotched rockfish	*Sebastes rosenblatti*
Greenspotted rockfish	*Sebastes chlorostictus*
Rosethorn rockfish	*Sebastes helvomaculatus*
Speckled rockfish	*Sebastes ovalis*
Squarespot rockfish	*Sebastes hopkinsi*
Starry rockfish	*Sebastes constellatus*
Vermilion rockfish	*Sebastes miniatus*
Yellowtail rockfish	*Sebastes flavidus*
Mixed rockfish	*Sebastes* spp.

zone; however, the number of required liver tissue samples was subsequently reduced to three per zone in October 2005. The number of required composite muscle tissue samples remained the same at the rig fishing stations (i.e., three per station).

For all samples, only fish greater than 12 cm standard length were retained for tissue analyses. Composite samples were typically made up of a single species, with a minimum of three individuals comprising each composite; the only exceptions occurred when multiple species of a single genus were required to obtain the minimum number of fish for a sample. The species caught at each station or zone in sufficient quantity to make up adequate tissue samples are indicated in Tables D-2 and D-3.

Tissue samples (liver and muscle) were analyzed for trace metals, chlorinated pesticides, and polychlorinated biphenyl compounds (PCBs). The data presented in this report are limited to: (a) detected values; and (b) estimated values for parameters determined to be present in a sample with high confidence (i.e., peaks are confirmed by mass-spectrometry), although they occur at levels below the MDL. Consideration of only detected values (i.e., ignoring non-detects) is used herein as a conservative way of handling contaminant concentrations as it creates a strong upward bias in the data and respective summary statistics, and therefore may represent a worst-case scenario (e.g., see Helsel 2005a, b, 2006 for discussions of non-detect data). In addition, values for pollutants composed of many individual constituents (e.g., DDT and PCBs) are reported herein as totals (e.g., total DDT and total PCB). A detailed description of the analytical protocols may be obtained from the City of San Diego Wastewater Chemistry Laboratory (City of San Diego 2014b).

For the sake of continuity between the two permit periods, all analyses were limited to liver tissue data from fishes collected at the six trawl stations currently sampled and muscle tissue data from fishes collected at the two rig fishing stations. Individual trawl stations sampled prior to October 2003 were assigned to their corresponding zone. In order to highlight conditions over the past five years, spatial analyses included data summarized by trawl zone and rig fishing station for two post-discharge periods: (1) 1995–2008 and (2) 2009–2013. Since concentrations of contaminants vary with season, temporal comparisons presented in various figures were limited to data collected only during the October surveys. Both spatial and temporal analyses of the trawl-caught fishes were limited to samples from Pacific, longfin and mixed sanddabs. These species were considered collectively as a “sanddab feeding guild” after Allen et al. (2002), forming the best basis for assessment because of the sample size and coverage in both space and time. California scorpionfish are absent from these analyses for this application because the targeting of California scorpionfish for tissue analysis ended in April 2003 (i.e., there are no new data to report for California scorpionfish since the last waiver application). Spatial and temporal analyses for the rig fishing stations were limited to muscle tissues from various rockfish species.

TABLE D-2

Summary of fish species collected by station for tissue analysis from October 1995 through April 2003. LS= longfin sanddab; PS=Pacific sanddab; DS=Dover sole; ES=English sole; CS=California scorpionfish; MR=mixed rockfish; BS=bigmouth sole; HT=hornyhead turbot; HR=halfbanded rockfish; GR=greenblotched rockfish; SR=stripetail rockfish; VR=vermilion rockfish; StR=starry rockfish; SqR=squarespot rockfish; SpR=speckled rockfish; CR=copper rockfish; CaR=canary rockfish; FR=flag rockfish; MS=mixed sanddabs; B=Bocaccio; GsR=greenspotted rockfish; ns=not sampled; na=not applicable.

Station	Zone	Rep	Oct 95	Apr 96*	Oct 96	Apr 97	Oct 97	Apr 98*	Oct 98	Apr 99	Oct 99	Apr 00	Oct 00	Apr 01	Oct 01	Apr 02	Oct 02	Apr 03
SD7	Zone 4	1	LS	CS/LS	LS	LS	LS	CS	LS	CS	LS	LS	LS	LS	LS	PS	LS	PS
		2	LS	CS/LS	LS	CS	LS	CS	LS	CS	LS	CS	HT[a]	CS	LS	ES	DS[a]	CS
		3	LS	LS/LS	LS	CS	HT[g]	CS	LS	CS	LS	CS	CS	CS	LS	CS	LS	CS
SD8	Zone 3	1	LS	LS[a]/LS	PS	LS	LS	CS/CS[d]	LS	PS[g]	FR	LS	LS	VR	PS	PS	CS	CS
		2	LS	LS[b,c]/PS	LS[e]	PS	HR	CS[e]	LS	LS	FR	CS	MR	GR	PS	GR[h]	LS	PS
		3	PS	MR[b]/MR	MR	DS[a]	HR	CS	LS	CS	LS	DS	CS**	MR	GsR	LS	PS	PS
SD10	Zone 1	1	LS	PS[b,d]/PS	LS	HR	LS	CS	LS[a]	CS	LS	LS	LS	DS[a]	ES	PS	LS	CS
		2	LS	CS/SR	LS	CS	LS	CS[e]	LS	CS	LS	CS	LS	MS[a]	ES	CS[h]	PS	CS
		3	DS	CS/CS	ES	CS	CS	CS	CS	CS	LS	LS	CS	CS	PS	CS	CS	CS
SD12	Zone 1	1	PS	CS/LS	ES	CS	LS	PS[a]	CS	CS	CS	CS	CS	CS	LS	LS	CS	PS
		2	CS	LS[a]/PS	ES	CS	CS	DS[a,d]	CS	CS	CS	CS	CS	CS	GR	PS	DS	CS
		3	CS	ns/PS	GR	CS	CS	CS	LS[a]	CS	CS	CS	CS	CS	CS	CS	PS	CS
SD13	Zone 2	1	LS	CS/CS	ES	DS[a]	CS	CS	LS[a]	CS	LS	PS	LS	LS	LS	LS	LS	CS
		2	LS	CS/PS	PS	PS[e]	LS	CS	CS[a]	CS	CS	CS	PS	CS	CS	PS	CS	LS
		3	LS	PS[b,d]/PS	LS[e]	ns/BS	LS	CS	CS	CS	CS	CS	ES	CS	GsR	CS	CS	PS
SD14	Zone 2	1	PS	SqR[e,d]/DS[d]	LS[f]	LS[f]	LS	BS[a]	LS[a]	PS	LS	CS	PS	CS	LS	PS	PS	PS
		2	PS	PS[e,c]/PS	PS	DS[a]	LS	CS	LS[a]	CS	CS	CS	LS	CS	PS	PS	PS	PS
		3	PS	CS/CS	PS	BS[a]	LS	CS	CS[a]	CS	CS	CS	LS	CS	CS	CS	PS	CS
RF1	na	1	CR	MR[b]/MR	CR	VR	CS	VR	MR[a]	MR	CS	CR	VR	CR	VR	VR	CR	VR
		2	VR	MR/MR	VR	VR	CS	VR	CS	VR	CS	CR	VR	VR	VR	CR	CR	MR
		3	VR	MR/MR	MR	VR	MR	VR	CR	CR	CS	CR	MR	VR	CR	CS	MR	VR
RF2	na	1	MR	SpR/SpR	SpR	StR	StR	StR	StR	MR	SpR	MR	VR	B	StR	MR	FR	MR
		2	MR	ns/SpR	SpR	SpR[e]	SqR[f]	CS	VR	FR	CS	VR	MR	MR	MR	VR	VR**	B
		3	CaR	ns/SpR	MR	SpR[a]	SpR[e]	MR	VR	MR	VR	StR	VR	MR	ns	FR	ns	MR

*First sample is liver tissue, second is muscle tissue ** only two specimens used in composite sample

a) no metals; b) no metals except Hg, Se, As; c) no pesticides, PAHs, PCBs; d) no PAHs; e) no metals except Hg, Se; f) no Se; g) no metals except Hg; h) no Hg

TABLE D-3

Summary of fish species collected by station for tissue analysis from October 2003 through October 2013. LS= longfin sanddab; PS=Pacific sanddab; ES=English sole; MR=mixed rockfish; BS=bigmouth sole; HT=hornyhead turbot; GR=greenblotched rockfish; VR=vermilion rockfish; SqR=squarespot rockfish; SpR=speckled rockfish; StR=starry rockfish; CR=copper rockfish; RR=rosethorn rockfish; YR=yellowtail rockfish; Cp=chilipepper; GsR=greenspotted rockfish; CS=California scorpionfish; FR=flag rockfish; na=not applicable.

Station	**Zone**	**Rep**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
SD7	Zone 4	1	PS	PS	PS	PS	PS	PS	PS	PS	PS	PS	PS
	Zone 4	2	PS	PS	PS	PS	PS	PS	PS	PS	PS	PS	PS
	Zone 4	3	PS	PS	PS	ES	PS	PS	PS	PS	PS	PS	PS
	Zone 4	4	BS[a]										
	Zone 4	5	LS[a]										
SD8	Zone 3	1	PS	PS	PS	PS	PS	PS	PS	PS	PS	PS	PS
	Zone 3	2	PS	PS	PS	PS	PS	PS	PS	PS	PS	PS	PS
	Zone 3	3	PS	PS	PS	PS	PS	PS	PS	PS	PS	PS	PS
	Zone 3	4		ES									
	Zone 3	5		ES									
	Zone 3	6		LS									
SD10/ SD12	Zone 1	1	ES	ES	PS	PS	PS	PS	PS	PS	PS	PS	PS
	Zone 1	2	ES	ES	PS	PS	PS	PS	PS	PS	PS	PS	PS
	Zone 1	3	ES	ES	PS	PS	ES	ES	PS	PS	PS	PS	PS
	Zone 1	4	PS	PS									
	Zone 1	5	PS	PS									
	Zone 1	6	PS	PS									
	Zone 1	7	HT	LS									
	Zone 1	8	HT[a]	LS									
	Zone 1	9		LS									
SD13/ SD14	Zone 2	1	LS	ES	PS	PS	PS	PS	PS	PS	PS	PS	PS
	Zone 2	2	LS	ES	PS	PS	PS	PS	PS	PS	PS	PS	PS
	Zone 2	3	LS	ES	PS	PS	PS	PS	PS	PS	PS	PS	PS
	Zone 2	4	ES	PS									
	Zone 2	5	ES	PS									
	Zone 2	6	ES	PS									
	Zone 2	7	PS	LS									
	Zone 2	8	PS	LS									
	Zone 2	9	PS	LS									
RF1	na	1	CR	CR	RR	CR	VR	CR	CR	CS	VR	VR	MR
		2	MR	CR	MR	CR	VR	MR	VR	CS	VR	CR	MR
		3	VR	MR	MR	CR	CR	GR	MR	CS	VR	MR	StR
RF2	na	1	VR	GR	SqR	StR	GR	VR	VR	VR	Cp	StR	SpR
		2	VR	MR	SqR	YR	GR	VR	VR	MR	Cp	GsR	SpR
		3	VR	MR	SpR	YR	MR	MR	MR	MR	FR	MR	SpR

a) no metals

SECTION D.4 | RESULTS & DISCUSSION

Metals

Mercury: Mercury is a common trace element in ocean waters and sediments and has a wide variety of natural and anthropogenic sources (Mearns et al. 1991). It may be injected into the atmosphere by volcanism, transported into coastal waters by rain and runoff, or released directly into the ocean through geothermal springs. Man-made sources include the use of mercury in fungicides, plastics, medical preparations, and in smelting and mining processes, while electrochemical industries also generate mercury waste. Although elemental mercury is moderately toxic, organic mercury compounds (e.g., methylmercury) are highly toxic. Additionally, organic mercury readily penetrates biological membranes and may bioaccumulate in the tissues of organisms at higher trophic levels due to its chemical stability and lipid solubility.

Mercury is probably the metal with the greatest potential for bioaccumulation in Southern California Bight marine organisms (Mearns et al. 1991). It is also the only metal with action limits set by the USFDA and the CDHS for fish and shellfish sold for human consumption (USEPA 1997). Although typically found in low concentrations in southern California invertebrates, concentrations of total mercury reach their highest levels at the top of the food web. For example, one of the highest mercury concentrations (~8.2 ppm) in a southern California marine animal was found in the muscle tissue of a white shark captured near Santa Catalina Island (Schafer et al. 1982). Elevated levels of mercury have also been reported in muscle tissues of other carnivorous fish, with swordfish having the highest reported value of 2.6 ppm for the bony fish (Mearns et al. 1991).

Studies in the Southern California Bight (SCB) over the last 35 years have shown no relationship between elevated concentrations of mercury in marine organisms and point sources of contamination. Eganhouse and Young (1978) found that in spite of elevated mercury levels in Palos Verdes sediments, resident animals had low tissue concentrations of both total and organic mercury. In addition, mercury levels in edible tissues of seafood organisms collected near a major point source of contamination were comparable to samples from offshore islands and coastal control sites (see Young et al. 1981). Other investigations also indicate that mercury levels in southern California fish have not increased with exposure to contaminated sediments (Mearns et al. 1991).

Tissue concentrations of mercury in all trawl and rig-caught fishes collected off Point Loma from October 1995 through the end of 2013 are summarized in Table D-4. Mercury was detected in

TABLE D-4

Summary of mercury concentrations (ppm) in liver and muscle tissue samples for each fish species sampled from October 1995 through October 2013. Data are summarized for liver tissues from trawl zones and muscle tissues from rig fishing stations during all surveys (April and October); nd=not detected.

Species	Total	Detect	Freq	Min	Max	Mean
Liver Tissues (Trawl Zones)						
California scorpionfish	115	99	86	0.038	0.556	0.160
Dover sole	3	3	100	0.056	0.139	0.100
English sole	25	20	80	0.032	0.130	0.058
Flag rockfish	2	2	100	0.135	0.156	0.145
Greenblotched rockfish	3	2	67	0.114	0.146	0.130
Greenspotted rockfish	3	3	100	0.054	0.349	0.158
Halfbanded rockfish	3	3	100	0.079	0.131	0.099
Hornyhead turbot	2	2	100	0.121	0.137	0.129
Longfin sanddab	89	67	75	0.018	0.238	0.095
Mixed rockfish	4	3	75	0.130	0.409	0.279
Pacific sanddab	172	140	81	0.020	0.579	0.090
Squarespot rockfish	1	1	100	0.246	0.246	0.246
Vermilion rockfish	1	0	0	nd	nd	nd
ALL SPECIES	423	345	82	0.018	0.579	0.113
Muscle Tissues (RF Stations)						
Bocaccio	2	2	100	0.058	0.193	0.125
California scorpionfish	12	9	75	0.075	0.339	0.160
Canary rockfish	1	1	100	0.063	0.063	0.063
Chilipepper	2	2	100	0.061	0.093	0.077
Copper rockfish	22	22	100	0.079	0.790	0.261
Flag rockfish	4	3	75	0.125	0.648	0.307
Greenblotched rockfish	3	3	100	0.114	0.282	0.195
Greenspotted rockfish	2	2	100	0.273	0.291	0.282
Mixed rockfish	41	37	90	0.020	0.595	0.183
Rosethorn rockfish	1	1	100	0.108	0.108	0.108
Speckled rockfish	13	13	100	0.027	0.175	0.075
Squarespot rockfish	3	3	100	0.148	0.260	0.207
Starry rockfish	9	9	100	0.112	0.276	0.191
Vermilion rockfish	43	36	84	0.020	1.250	0.102
Yellowtail rockfish	2	2	100	0.072	0.079	0.075
ALL SPECIES	160	145	91	0.020	1.250	0.164

the tissues of all species sampled, with overall detections rates of 82% for liver tissues from trawl-caught fishes and 91% for muscle tissues from fishes collected at the rig fishing stations. Mercury averaged 0.164 ppm in fish muscle tissues, ranging from a low of 0.020 ppm for vermilion and mixed rockfish to a high of 1.25 ppm for vermilion rockfish. Mercury averaged 0.113 ppm in fish liver tissues, ranging from 0.018 ppm for longfin sanddabs to 0.579 for Pacific sanddabs. Muscle and liver tissue values for both individual species and all species combined are similar to mercury levels reported in the City's prior waiver applications (City of San Diego 1995, 2001a, b, 2007).

Mercury concentrations in sanddab liver tissues from 1995 through 2013 are summarized by zone in Table D-5 and Figures D-2 and D-3. The average concentrations of mercury for the sanddab feeding guild ranged from 0.065 to 0.110 ppm per zone. No discernible relationship to the outfall was evident amongst zones for the sanddab feeding guild in terms of mercury concentrations over surveys combined for the two post-discharge periods (Figure D-2) or over time (Figure D-3).

Mercury concentrations in muscle tissues from rockfish collected at the two rig fishing sites from 1995 through 2013 are summarized in Table D-5 and Figures D-4 and D-5. The average concentrations for rockfish at stations RF1 (nearfield) and RF2 (farfield) were 0.192 and 0.140 ppm, respectively. No discernible relationship to wastewater discharge was evident during the two post-discharge periods (Figure D-4) or over time (Figure D-5). Although some relatively high mercury values (>0.5 ppm) were recorded at RF1 during October surveys, these were limited to six rockfish muscle samples collected over just three years (2002–2004).

The limits set by the USFDA and CDHS for mercury in seafood sold for human consumption are 1.0 ppm and 0.5 ppm, respectively (Mearns et al. 1991, USEPA 1997). In addition, OEHHA has a fish contaminant goal for mercury of 0.22 ppm (Klasing and Brodberg 2008). Table D-6 and Figure D-6 compare these thresholds to maximum mercury values in muscle tissues for all species collected at rig fishing stations from October 1995 through 2013. Figure D-6 also presents mean mercury concentrations per species. Over the past 19 years, mercury concentrations have frequently exceeded the OEHHA goal in rockfish muscle tissues at both of the rig fishing stations (e.g., Figure D-5), resulting in nine species with maximum values over this threshold (Figure D-6). Maximum values in copper rockfish, flag rockfish, and mixed rockfish also exceeded the CDHS advisory level, while only a single vermilion rockfish sample exceeded the USFDA action limit. However, on average, no species had mercury concentrations that exceeded either the CDHS or USFDA limits, while only three (copper, flag and greenspotted rockfish) exceeded the OEHHA fish contaminant goal (Figure D-6). These results suggest that the occurrence of mercury values above the CDHS and USFDA limits is sporadic, and may be due to the capture of relatively large and therefore older fishes. Additionally, elevated levels of

TABLE D-5

Summary of mercury concentrations (ppm) in sanddab and rockfish tissues by station/zone. Data are summarized over all samples collected during the April and October surveys from October 1995 through October 2013. CI=confidence interval.

	Sanddab Liver Tissues				**Rockfish Muscle Tissues**	
	Zone 1	**Zone 2**	**Zone 3**	**Zone 4**	**RF1**	**RF2**
Total	60	84	59	58	71	77
Detected	51	59	50	47	63	73
Frequency	85	70	85	81	89	95
Minimum	0.020	0.018	0.034	0.034	0.024	0.020
Median	0.077	0.058	0.086	0.100	0.106	0.112
Maximum	0.579	0.165	0.473	0.314	1.250	0.648
Mean	0.100	0.065	0.099	0.110	0.192	0.140
95% CI	0.023	0.007	0.018	0.017	0.057	0.025

FIGURE D-2

Comparisons of mercury concentrations in sanddab liver tissues by trawl zone for all surveys (April and October) from 1995 through 2013. Data are means +/- 95% confidence intervals.

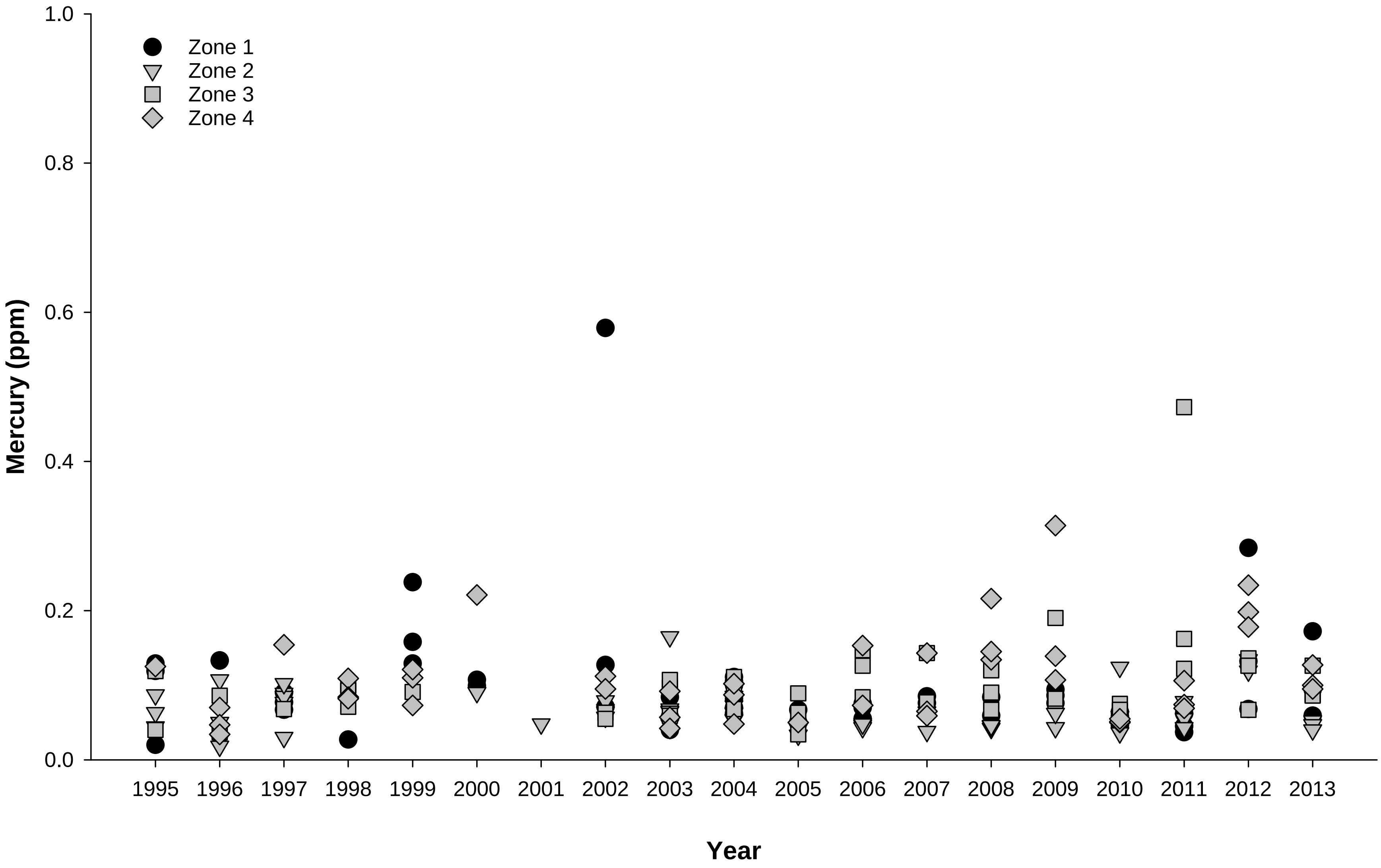

FIGURE D-3

Mercury concentrations detected in sanddab guild liver tissues for Trawl Zone 1 versus Zones 2-4 for October surveys from 1995 through 2013.

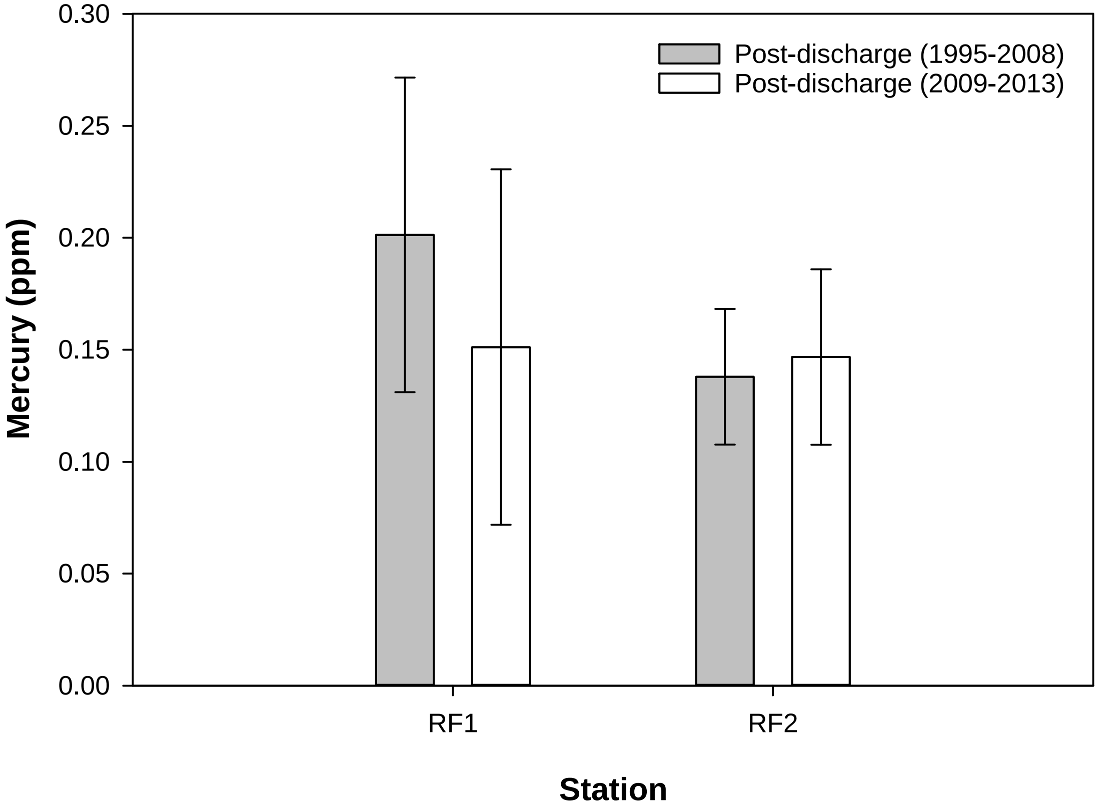

FIGURE D-4

Comparisons of mercury concentrations in rockfish muscle tissues by rig fishing station for all surveys (April and October) from 1995 through 2013. Data are means +/- 95% confidence intervals.

FIGURE D-5

Mercury concentrations detected in rockfish muscle tissues for rig fishing station RF1 versus RF2 for October surveys from 1995 through 2013.

TABLE D-6

Maximum concentrations of various metals (ppm), pesticides (ppb) and total PCB (ppb) in muscle tissue samples for California scorpionfish and each rockfish species collected at rig fishing stations sampled from October 1995 through October 2013; na=not available; nd=not detected.

Species	Arsenic	Cadmium	Chromium	Copper	Lead	Mercury	Selenium	Tin	Zinc	tChlordane	tDDT	tPCB
Bocaccio	1.50	nd	nd	1.79	nd	0.193	0.296	nd	3.35	nd	9.9	9.2
Canary rockfish	nd	nd	nd	nd	nd	0.063	0.250	nd	3.82	nd	14	15
Chilipepper	0.93	nd	nd	0.36	nd	0.093	0.530	0.24	3.72	0.4	6.9	3.7
Copper rockfish	4.11	0.178	0.529	4.79	nd	0.790	0.690	1.77	15.20	2.2	217.3	76.8
Flag rockfish	2.15	nd	nd	1.31	nd	0.648	0.540	0.28	4.38	0.9	71	33.7
Greenblotched rockfish	5.75	0.083	0.306	0.77	nd	0.282	0.381	2.01	5.09	nd	9.7	1.3
Greenspotted rockfish	2.25	nd	0.2	0.14	nd	0.291	0.370	0.24	3.88	nd	13.3	3.5
Mixed rockfish	6.10	0.055	1.78	8.96	nd	0.595	0.730	2.02	10.00	2.7	82.6	89.3
Rosethorn rockfish	2.49	nd	nd	0.76	nd	0.108	0.367	nd	2.91	nd	2.3	0.8
Speckled rockfish	1.71	nd	0.56	0.88	0.34	0.175	0.400	1.08	4.11	nd	16	3.3
Squarespot rockfish	2.54	nd	0.087	0.46	0.42	0.260	0.440	nd	3.37	2.3	20	3.8
Starry rockfish	1.32	0.162	0.42	5.88	nd	0.276	0.695	1.55	11.10	4.3	118.8	54
Vermilion rockfish	15.20	0.050	0.795	8.56	nd	1.250	0.545	2.12	14.30	2	40.1	28
Yellowtail rockfish	0.46	0.156	0.474	0.45	nd	0.079	0.350	1.71	4.28	0.1	6.3	1.2
California scorpionfish	10.60	na	0.141	1.63	nd	0.339	0.400	nd	6.91	nd	69.6	9
OEHHA[a]	na	na	na	na	na	0.220	7.400	na	na	5.6	21	3.6
USFDA Action Limit[b]	na	na	na	na	na	1.000	na	na	na	300	5000	na
CDHA Advisory Level[c]	na	na	na	na	na	0.500	na	na	na	na	na	na
Median IS[b]	1.40	1.000	1.00	20.00	2	0.500	0.300	175	70	100	5000	na

[a] Klasing and Brodberg 2008

[b] Mearns et al. 1991

[c] USEPA 1997

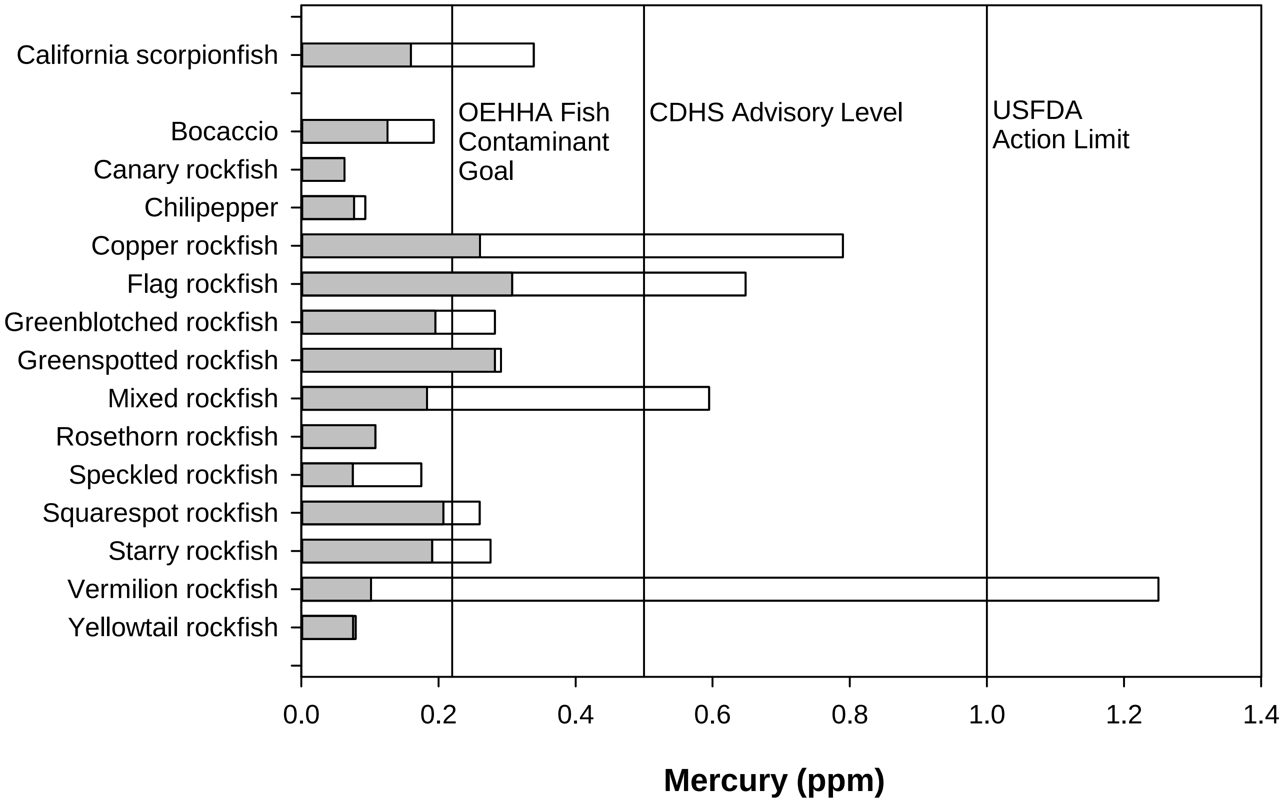

FIGURE D-6
Mean and maximum concentrations of mercury in muscle tissues of all fishes collected off San Diego at rig fishing stations compared to the USFDA action limit (from Mearns et al. 1991), the CDHS advisory level (USEPA 1997) and the OEHHA fish contaminant goal (Klasing and Brodberg 2008). See Table D-4 for sample sizes.

mercury are not uncommon in sport fish from other areas of the San Diego region. For example, muscle tissue samples from fishes collected since 1995 in the South Bay outfall survey area, including the Coronado Islands, have occasionally had concentrations of mercury that exceeded the OEHHA fish contaminant goal (see City of San Diego 2014c and references therein).

Arsenic: Arsenic is a common trace element, well known for its toxic effects. It occurs naturally in seawater and is used by man in herbicides, insecticides, wood preservatives, and in a variety of industrial applications (Mearns et al. 1991). In organisms, it is detoxified via production of organic forms of arsenic which are less toxic and more readily excreted. Southern California marine coastal waters have a significant natural source of arsenic originating from the Punta Banda submarine hot springs in Baja California. These hot springs discharge water containing up to 420,500 ppb arsenic compared to 3 ppb that naturally occur in seawater. For reference purposes, arsenic concentrations in Point Loma effluent ranged from 0.72 to 1.12 ppb during calendar year 2013.

Arsenic occurs in high concentrations in sediments throughout the southern California marine environment. Arsenic in outfall depth sediments off Point Loma have ranged from 1.0 to 7.9 ppm since monitoring began, with means of 2.4 and 3.2 ppm during the pre- and post-discharge periods, respectively (see Table C.1-3, Appendix C.1). These concentrations are comparable to background conditions in the southern California Bight reported by Mearns et al. (1991) and found regionally off San Diego (e.g., City of San Diego 2013).

Arsenic had an overall detection rate of 73% in liver samples from all trawl-caught fishes and 70% in muscle samples from all rig-caught fish off Point Loma (Table D-7). Muscle tissue concentrations of arsenic averaged 2.67 ppm, ranging from 0.40 ppm in a mixed rockfish sample to 15.20 ppm in a vermilion rockfish sample. Liver tissue concentrations averaged 4.51 ppm, ranging from 0.06 ppm in longfin and Pacific sanddab samples to 33.90 ppm in an English sole sample. Data for the sanddab feeding guild and rockfish are summarized by zone/station in Table D-8 and Figures D-7 through D-10. There were no consistent trends in arsenic residues relative to the Point Loma outfall or the onset of wastewater discharge. Instead, arsenic concentrations in sanddab livers increased across the survey area through 2004 then dropped substantially and stayed relatively low through 2013. Arsenic concentrations in muscle tissues were highest in 1998 at the rig-fishing stations, while they have stayed near their lowest values since 2010.

There are no USFDA, CDHS, or OEHHA standards for arsenic in food. However, arsenic concentrations in fishes caught off Point Loma are high relative to the Median International Standard (MIS) of 1.4 ppm applied to shellfish and to the sale of seafood for human consumption in some countries (Table D-6 and Figure D-11). Mearns et al. (1991) reviewed studies conducted in the SCB and concluded that (a) there is no correspondence between point sources of arsenic

TABLE D-7

Summary of arsenic concentrations (ppm) in liver and muscle tissue samples for each fish species sampled from October 1995 through October 2013. Data are summarized for liver tissues from trawl stations and muscle tissues from rig fishing stations during all surveys (April and October); nd=not detected.

Species	Total	Detect	Freq	Min	Max	Mean
Liver Tissues (Trawl Zones)						
California scorpionfish	112	51	46	1.40	14.10	3.14
Dover sole	3	2	67	0.07	3.70	1.89
English sole	25	23	92	1.80	33.90	6.98
Flag rockfish	2	0	0	nd	nd	nd
Greenblotched rockfish	3	1	33	1.55	1.55	1.55
Greenspotted rockfish	3	0	0	nd	nd	nd
Halfbanded rockfish	3	1	33	3.83	3.83	3.83
Hornyhead turbot	1	1	100	4.79	4.79	4.79
Longfin sanddab	86	68	79	0.06	18.50	8.06
Mixed rockfish	3	0	0	nd	nd	nd
Pacific sanddab	167	152	91	0.06	12.40	3.06
Vermilion rockfish	1	0	0	nd	nd	nd
ALL SPECIES	409	299	73	0.06	33.90	4.51

Species	Total	Detect	Freq	Min	Max	Mean
Muscle Tissues (RF Stations)						
Bocaccio	2	1	50	1.50	1.50	1.50
California scorpionfish	12	12	100	1.06	10.60	3.72
Canary rockfish	1	0	0	nd	nd	nd
Chilipepper	2	2	100	0.71	0.93	0.82
Copper rockfish	22	13	59	0.68	4.11	1.85
Flag rockfish	4	2	50	0.73	2.15	1.44
Greenblotched rockfish	3	3	100	1.41	5.75	2.98
Greenspotted rockfish	2	2	100	1.94	2.25	2.09
Mixed rockfish	41	29	71	0.40	6.10	2.20
Rosethorn rockfish	1	1	100	2.49	2.49	2.49
Speckled rockfish	13	6	46	0.43	1.71	1.03
Squarespot rockfish	3	3	100	1.84	2.54	2.18
Starry rockfish	9	3	33	0.54	1.32	0.96
Vermilion rockfish	43	34	79	0.96	15.20	3.80
Yellowtail rockfish	2	1	50	0.46	0.46	0.46
ALL SPECIES	160	112	70	0.40	15.20	2.67

TABLE D-8

Summary of arsenic concentrations (ppm) in sanddab and rockfish tissues by station/zone. Data are summarized over all samples collected during the April and October surveys from October 1995 through October 2013. CI=confidence interval.

	Sanddab Liver Tissues				Rockfish Muscle Tissues	
	Zone 1	Zone 2	Zone 3	Zone 4	RF1	RF2
Total	59	80	56	58	71	77
Detected	50	67	49	54	53	47
Frequency	85	84	88	93	75	61
Minimum	0.06	0.06	0.07	0.31	0.40	0.43
Median	3.47	3.47	3.03	3.33	2.08	1.65
Maximum	12.80	18.50	15.30	13.30	15.20	11.40
Mean	4.64	4.97	4.14	4.55	2.87	2.19
95% CI	0.89	0.98	1.02	0.90	0.81	0.58

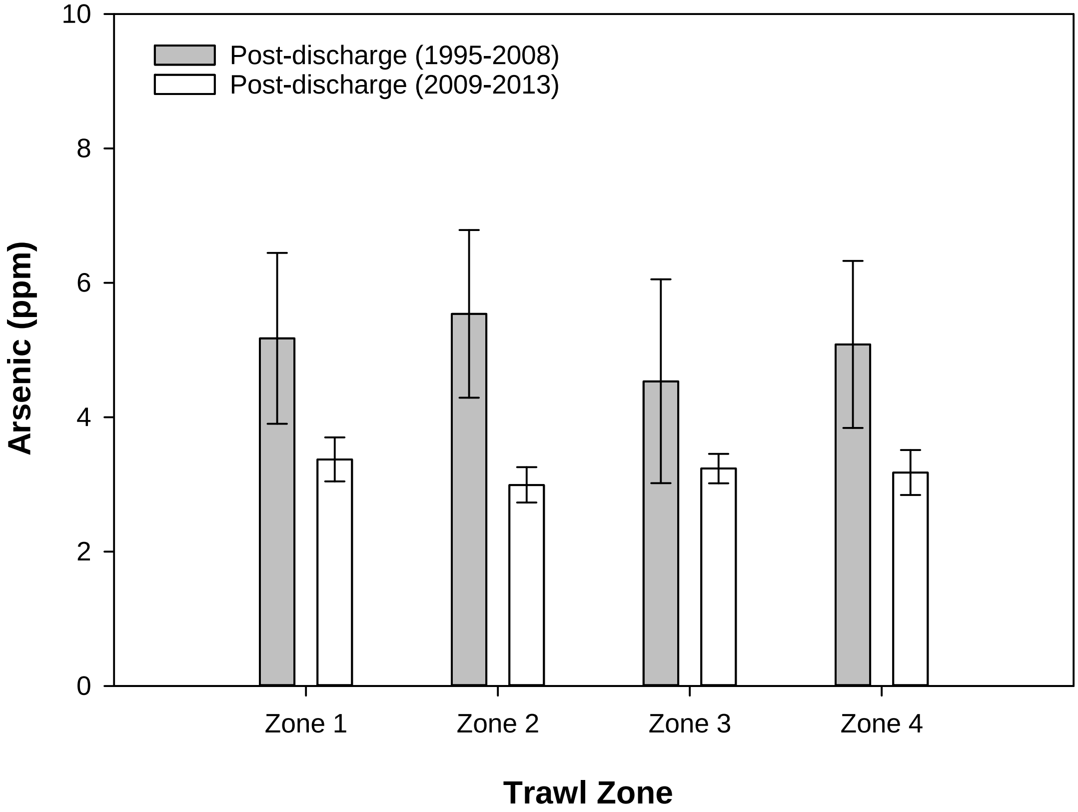

FIGURE D-7
Comparisons of arsenic concentrations in sanddab liver tissues by trawl zone for all surveys (April and October) from 1995 through 2013. Data are means +/- 95% confidence intervals.

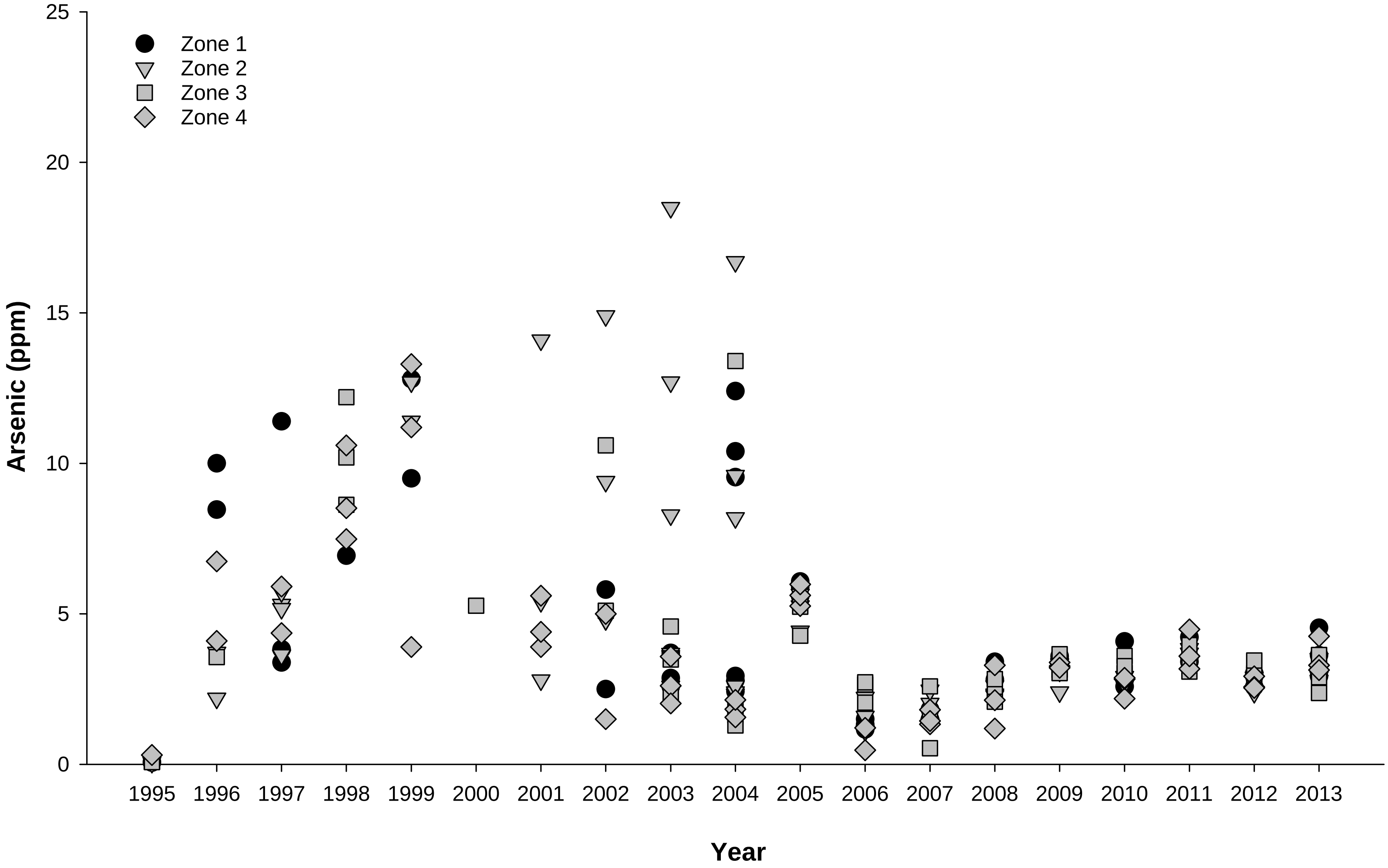

FIGURE D-8

Arsenic concentrations detected in sanddab guild liver tissues for trawl Zone 1 versus Zones 2-4 for October surveys from 1995 through 2013.

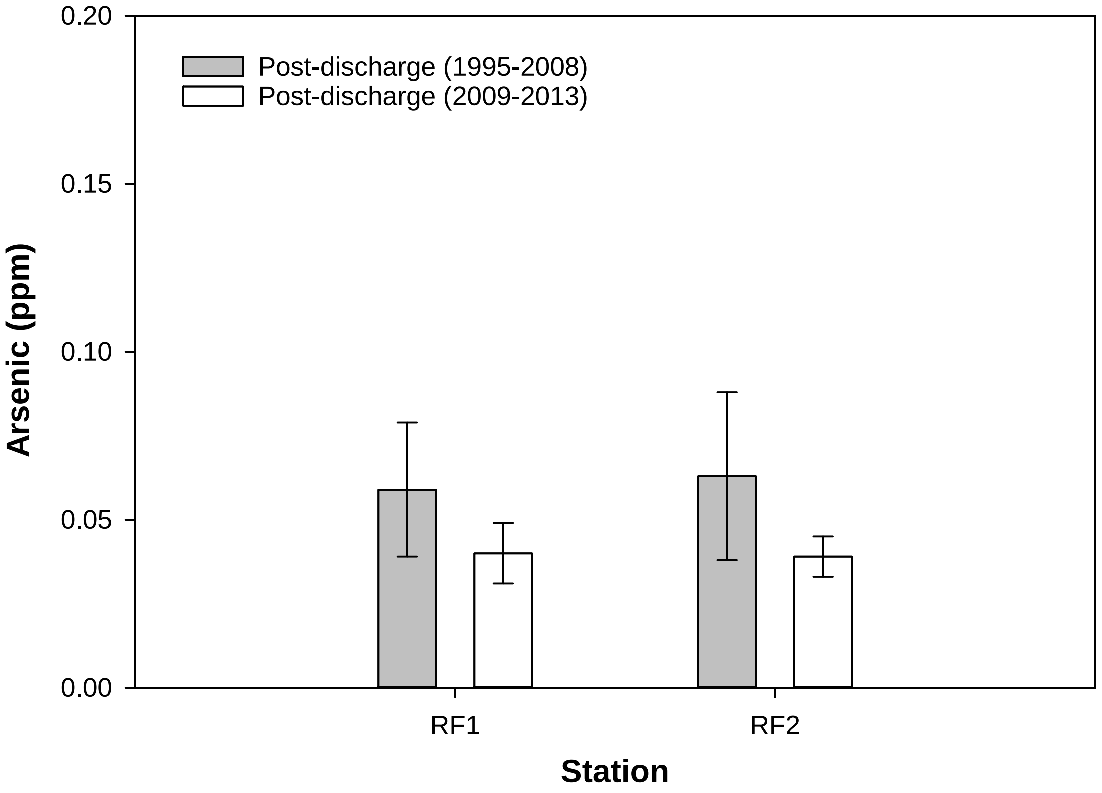

FIGURE D-9
Comparisons of arsenic concentrations in rockfish muscle tissues by rig fishing station for all surveys (April and October) from 1995 through 2013. Data are means +/- 95% confidence intervals.

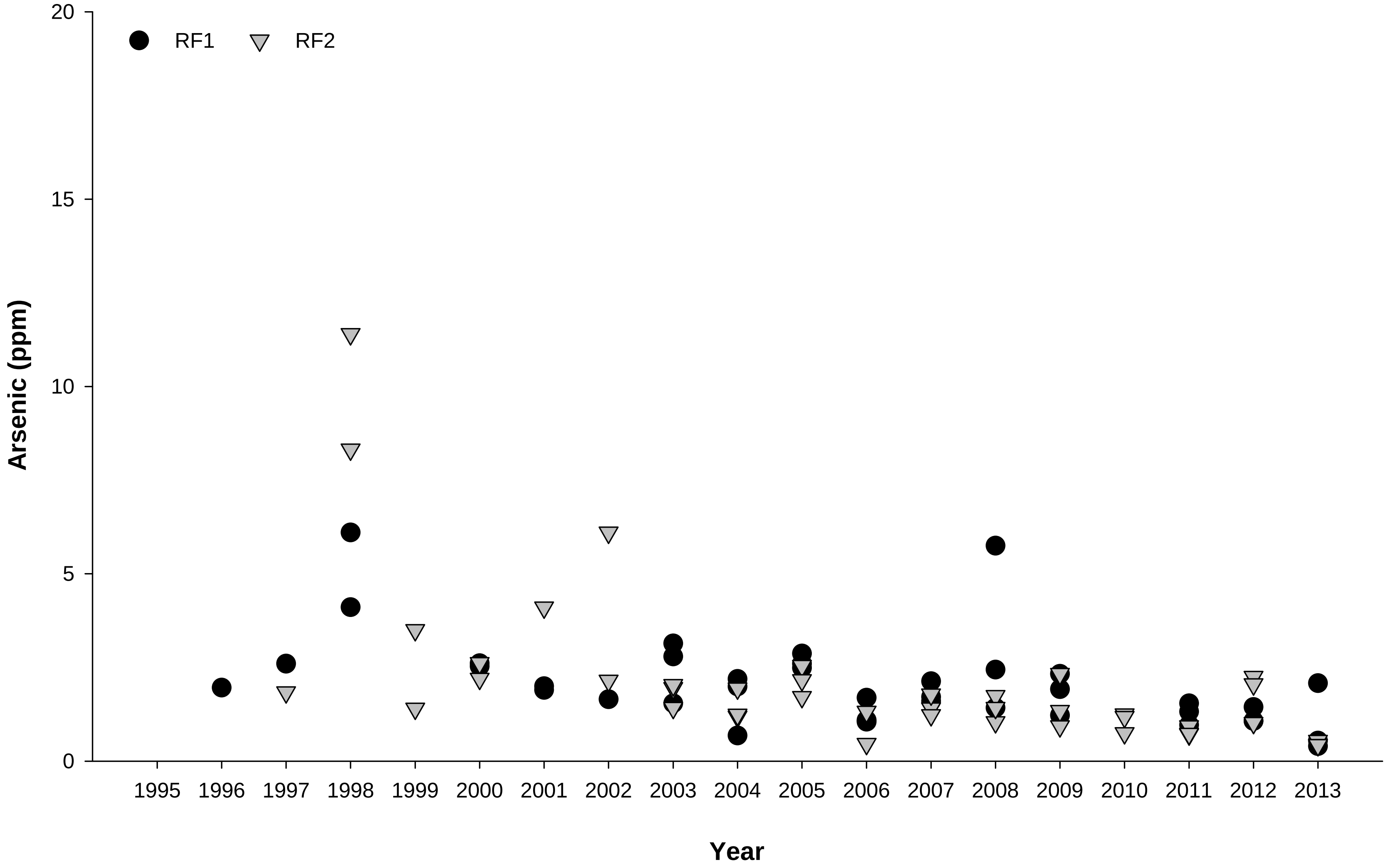

FIGURE D-10

Arsenic concentrations detected in rockfish muscle tissues for rig fishing station RF1 versus RF2 for October surveys from 1995 through 2013.

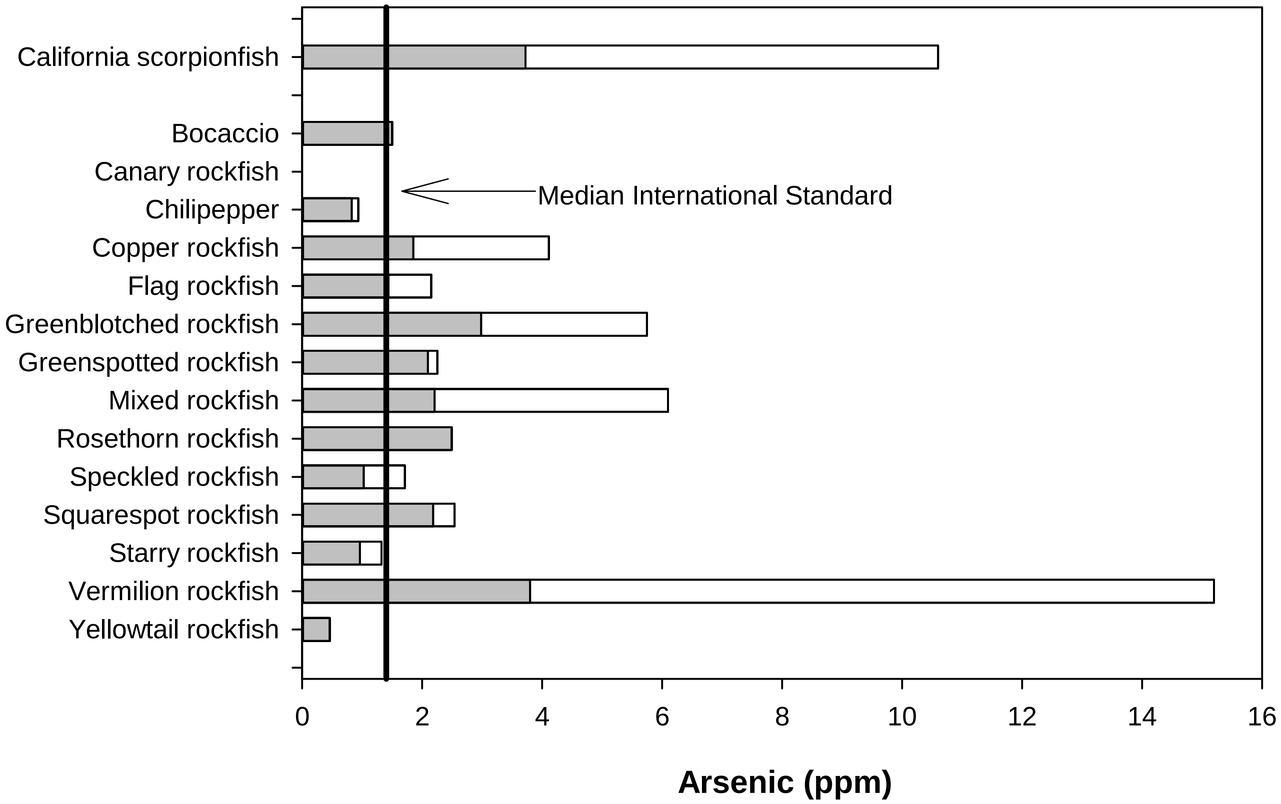

FIGURE D-11
Mean and maximum concentrations of arsenic in muscle tissues of all fishes collected off San Diego at rig fishing stations compared to the median international standard (from Mearns et al. 1991). See Table D-7 for sample sizes.

and arsenic concentrations in the tissues of marine animals, and (b) arsenic tissue concentrations generally decrease with trophic level. Consequently, high levels of arsenic in regional fishes are probably due to elevated levels that occur in the natural environment and not to exposure to anthropogenic sources and subsequent food web magnification. Additionally, as with mercury, elevated levels of arsenic have been detected in sport fish from other areas of the San Diego region, including the Coronado Islands (see City of San Diego 2014c and references therein).

Cadmium: Cadmium is widely used in electroplating, as a pigment in paints, in batteries, and as a plastic stabilizer. It has been one of the metals targeted for source control in the San Diego pretreatment program resulting in a significant decline in effluent concentrations over time. For example, cadmium was not detected in PLOO wastewater effluent samples analyzed in 2013. While cadmium has been detected in 90% of liver tissue samples from trawl-caught fishes collected off Point Loma over the past 19 years, it was found in only 8% of the muscle tissue samples from fishes collected at the rig fishing stations (Table D-9). Cadmium concentrations in liver tissues ranged from 0.36 ppm in an English sole sample to 19.20 ppm in a Pacific sanddab sample; cadmium concentrations in muscle tissues ranged from 0.04 ppm in a vermilion rockfish sample to 0.18 ppm in a copper rockfish sample.

The cadmium data summarized in Table D-10 and Figures D-12 through D-15 show no consistent differences in the bioaccumulation of this metal between fishes captured at the nearfield and farfield trawl zones or between the two rig fishing sites. However, cadmium concentrations in sanddab livers were significantly higher over the past five years across all zones (Figure D-12), and appear to have increased throughout the region since October 2003 (Figure D-13). This region wide increase off San Diego, which has been sustained since that time, corresponds to a permit-driven change in sample collection requirements that resulted in Pacific sanddabs replacing longfin sanddabs as the dominant trawl-caught species used for bioaccumulation assessments. Overall, cadmium levels in liver tissues of Pacific sanddabs have averaged 5.52 ppm compared to 1.95 ppm for longfin sanddabs (Table D-9). In contrast to sanddab liver tissues, the detection of cadmium in rockfish muscle tissues was limited to thirteen samples collected at both rig fishing stations during 2006, 2007, and 2008 (Figure D-15), all of which had concentrations below the MIS of 1.00 ppm (Table D-6).

Chromium: Chromium has also been a target of source control efforts for the San Diego metal plating industry. Detectable levels of chromium in fish tissues were limited to relatively few samples overall, with detection rates of 50% for liver tissue samples from trawl-caught fishes and 38% for muscle tissue samples from fishes collected at the rig fishing stations (Table D-11). Liver concentrations of chromium ranged from 0.11 to 22.80 ppm, while muscle concentrations ranged from 0.09 to 1.78 ppm. The chromium data summarized in Table D-12 and Figures D-16 through D-19 reveal no discernible spatial or temporal patterns that correlate with wastewater

TABLE D-9

Summary of cadmium concentrations (ppm) in liver and muscle tissue samples for each fish species sampled from October 1995 through October 2013. Data are summarized for liver tissues from trawl stations and muscle tissues from rig fishing stations during all surveys (April and October); nd=not detected.

Species	Total	Detect	Freq	Min	Max	Mean
Liver Tissues (Trawl Zones)						
California scorpionfish	112	105	94	0.41	6.51	2.53
Dover sole	3	0	0	nd	nd	nd
English sole	25	19	76	0.36	1.07	0.68
Flag rockfish	2	0	0	nd	nd	nd
Greenblotched rockfish	3	3	100	0.46	3.75	1.69
Greenspotted rockfish	3	2	67	1.77	1.99	1.88
Halfbanded rockfish	3	3	100	1.09	1.71	1.34
Hornyhead turbot	1	1	100	5.07	5.07	5.07
Longfin sanddab	86	72	84	0.37	4.79	1.95
Mixed rockfish	3	3	100	2.05	7.59	4.84
Pacific sanddab	167	161	96	0.38	19.20	5.52
Vermilion rockfish	1	0	0	nd	nd	nd
ALL SPECIES	409	369	90	0.36	19.20	3.63
Muscle Tissues (RF Stations)						
Bocaccio	2	0	0	nd	nd	nd
California scorpionfish	12	0	0	nd	nd	nd
Canary rockfish	1	0	0	nd	nd	nd
Chilipepper	2	0	0	nd	nd	nd
Copper rockfish	22	4	18	0.06	0.18	0.13
Flag rockfish	4	0	0	nd	nd	nd
Greenblotched rockfish	3	3	100	0.05	0.08	0.07
Greenspotted rockfish	2	0	0	nd	nd	nd
Mixed rockfish	41	1	2	0.05	0.05	0.05
Rosethorn rockfish	1	0	0	nd	nd	nd
Speckled rockfish	13	0	0	nd	nd	nd
Squarespot rockfish	3	0	0	nd	nd	nd
Starry rockfish	9	1	11	0.16	0.16	0.16
Vermilion rockfish	43	2	5	0.04	0.05	0.04
Yellowtail rockfish	2	2	100	0.14	0.16	0.15
ALL SPECIES	160	13	8	0.04	0.18	0.10

TABLE D-10

Summary of cadmium concentrations (ppm) in sanddab and rockfish tissues by station/zone. Data are summarized over all samples collected during the April and October surveys from October 1995 through October 2013. CI=confidence interval.

	Sanddab Liver Tissues				Rockfish Muscle Tissues	
	Zone 1	**Zone 2**	**Zone 3**	**Zone 4**	**RF1**	**RF2**
Total	59	80	56	58	71	77
Detected	55	77	50	51	7	6
Frequency	93	96	89	88	10	8
Minimum	0.38	0.37	0.58	0.99	0.04	0.05
Median	3.84	2.73	4.64	4.93	0.08	0.10
Maximum	18.10	10.90	19.20	12.10	0.18	0.16
Mean	4.42	3.29	5.17	5.39	0.10	0.10
95% CI	0.85	0.51	1.15	0.91	0.04	0.04

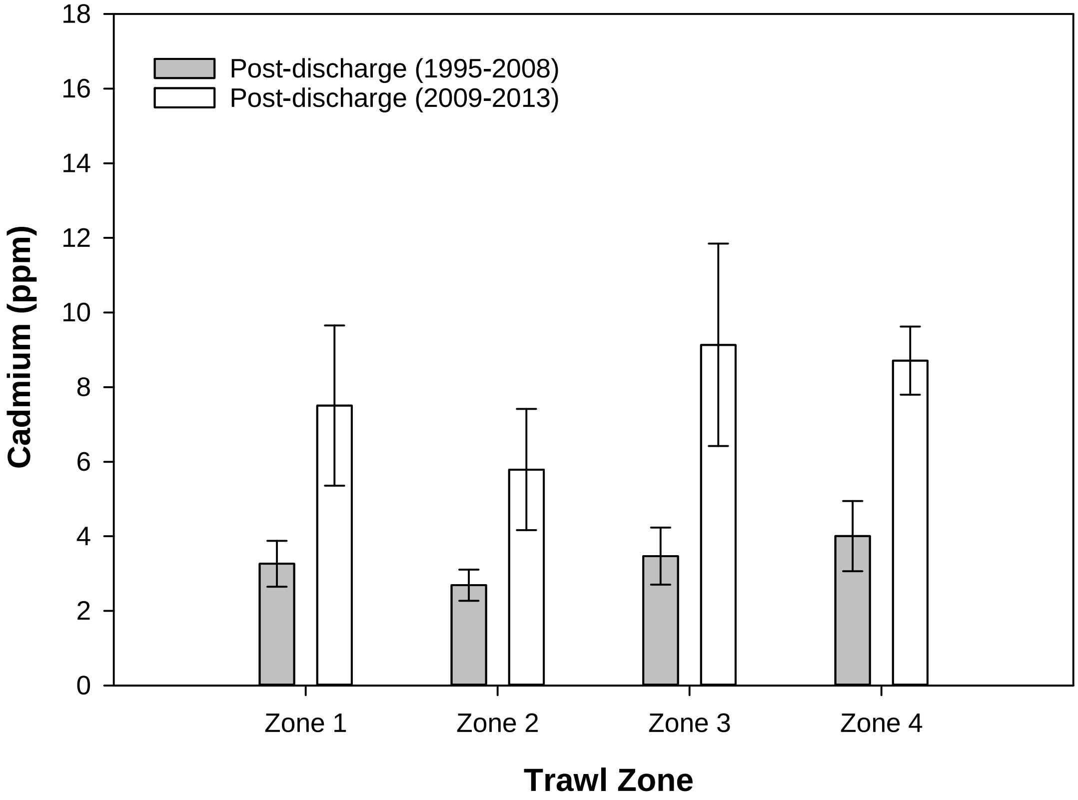

FIGURE D-12

Comparisons of cadmium concentrations in sanddab liver tissues by trawl zone for all surveys (April and October) from 1995 through 2013. Data are means +/- 95% confidence intervals.

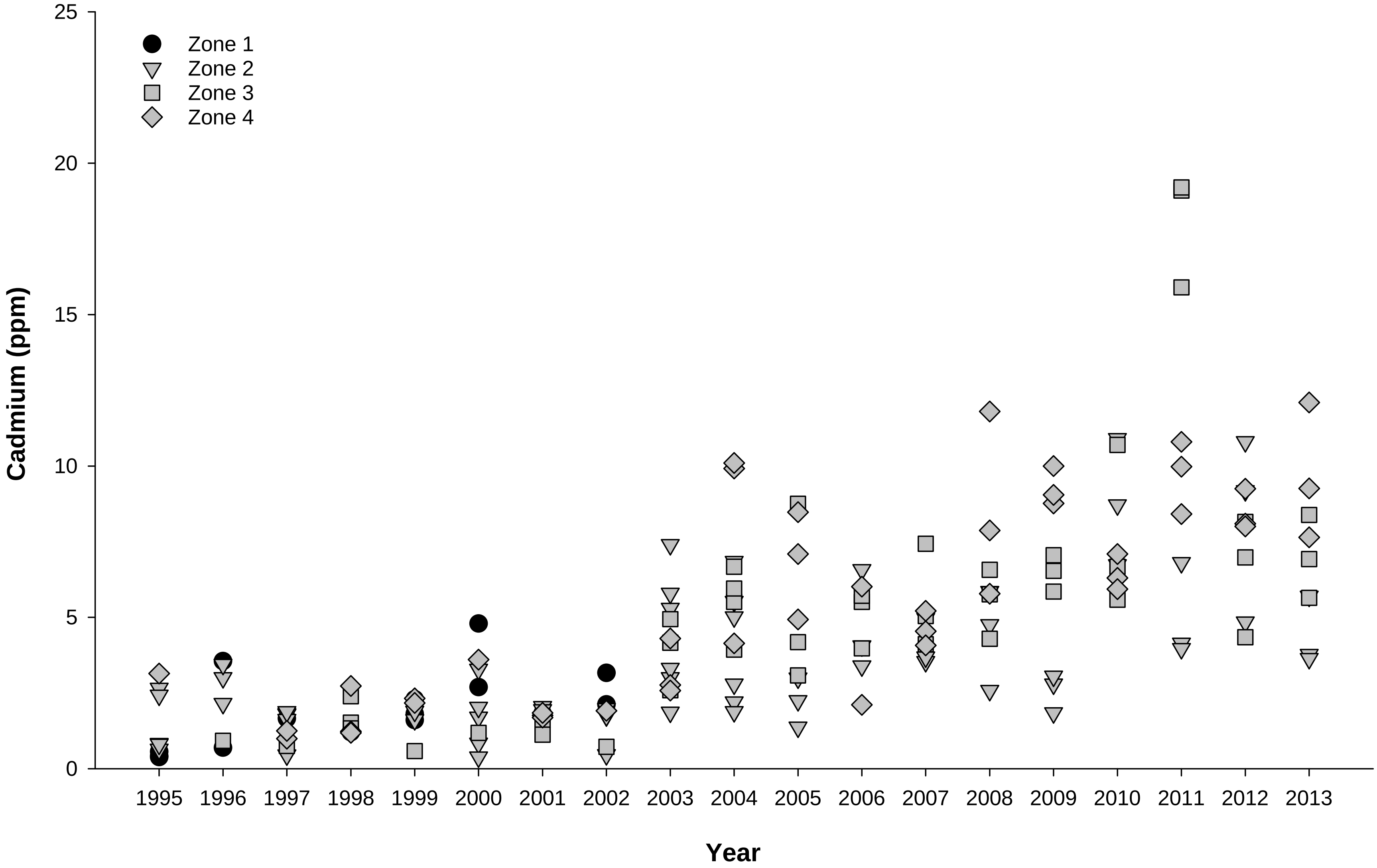

FIGURE D-13

Cadmium concentrations detected in sanddab guild liver tissues for trawl Zone 1 versus Zones 2-4 for October surveys from 1995 through 2013.

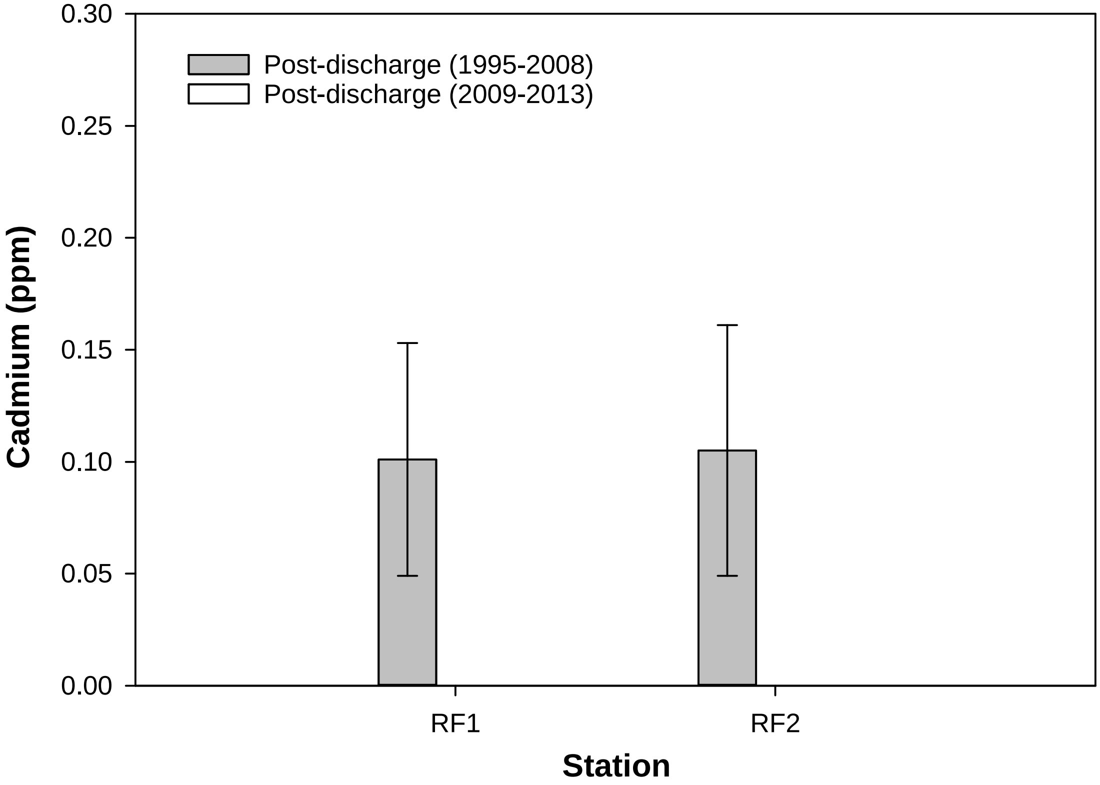

FIGURE D-14
Comparisons of cadmium concentrations in rockfish muscle tissues by rig fishing station for all surveys (April and October) from 1995 through 2013. Data are means +/- 95% confidence intervals.

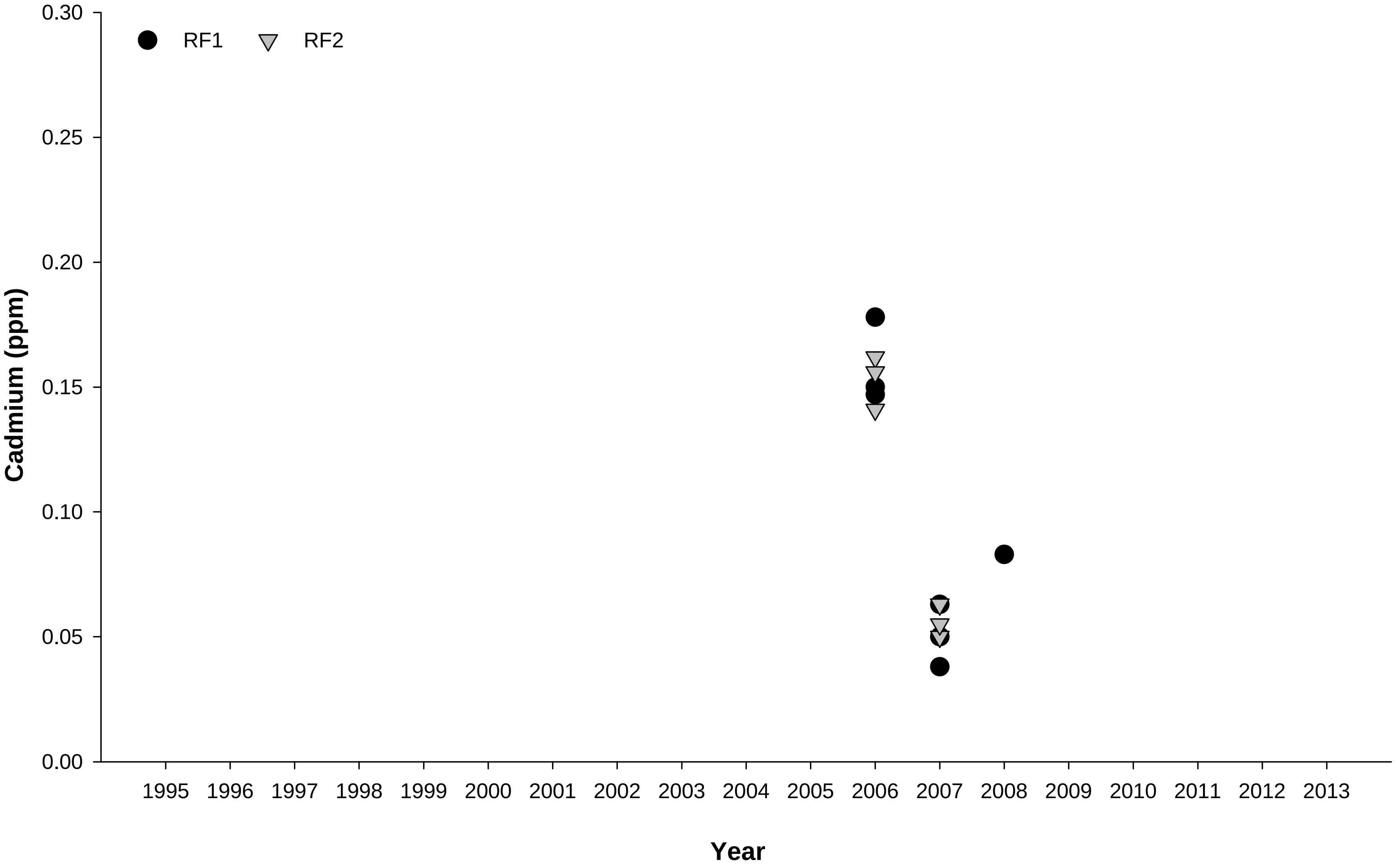

FIGURE D-15

Cadmium concentrations detected in rockfish muscle tissues for rig fishing station RF1 versus RF2 for October surveys from 1995 through 2013.

TABLE D-11

Summary of chromium concentrations (ppm) in liver and muscle tissue samples for each fish species sampled from October 1995 through October 2013. Data are summarized for liver tissues from trawl stations and muscle tissues from rig fishing stations during all surveys (April and October); nd=not detected.

Species	Total	Detect	Freq	Min	Max	Mean
Liver Tissues (Trawl Zones)						
California scorpionfish	112	21	19	0.37	4.29	1.11
Dover sole	3	0	0	nd	nd	nd
English sole	25	20	80	0.17	1.14	0.33
Flag rockfish	2	0	0	nd	nd	nd
Greenblotched rockfish	3	1	33	1.14	1.14	1.14
Greenspotted rockfish	3	2	67	1.77	1.99	1.88
Halfbanded rockfish	3	2	67	0.38	1.23	0.80
Hornyhead turbot	1	1	100	0.27	0.27	0.27
Longfin sanddab	86	35	41	0.23	22.80	1.51
Mixed rockfish	3	1	33	1.00	1.00	1.00
Pacific sanddab	167	125	75	0.11	4.48	0.40
Vermilion rockfish	1	0	0	nd	nd	nd
ALL SPECIES	409	206	50	0.11	22.80	0.66
Muscle Tissues (RF Stations)						
Bocaccio	2	0	0	nd	nd	nd
California scorpionfish	12	1	8	0.14	0.14	0.14
Canary rockfish	1	0	0	nd	nd	nd
Chilipepper	2	0	0	nd	nd	nd
Copper rockfish	22	9	41	0.10	0.53	0.30
Flag rockfish	4	0	0	nd	nd	nd
Greenblotched rockfish	3	3	100	0.21	0.31	0.27
Greenspotted rockfish	2	2	100	0.19	0.20	0.20
Mixed rockfish	41	16	39	0.14	1.78	0.34
Rosethorn rockfish	1	0	0	nd	nd	nd
Speckled rockfish	13	3	23	0.14	0.56	0.32
Squarespot rockfish	3	1	33	0.09	0.09	0.09
Starry rockfish	9	5	56	0.16	0.42	0.29
Vermilion rockfish	43	19	44	0.11	0.79	0.29
Yellowtail rockfish	2	2	100	0.36	0.47	0.42
ALL SPECIES	160	61	38	0.09	1.78	0.30

TABLE D-12

Summary of chromium concentrations (ppm) in sanddab and rockfish tissues by station/zone. Data are summarized over all samples collected during the April and October surveys from October 1995 through October 2013. CI=confidence interval.

	Sanddab Liver Tissues				Rockfish Muscle Tissues	
	Zone 1	**Zone 2**	**Zone 3**	**Zone 4**	**RF1**	**RF2**
Total	59	80	56	58	71	77
Detected	39	50	35	36	29	31
Frequency	66	63	63	62	41	40
Minimum	0.13	0.11	0.15	0.15	0.10	0.09
Median	0.30	0.34	0.30	0.37	0.21	0.20
Maximum	22.80	4.33	4.48	2.06	1.06	1.78
Mean	0.95	0.57	0.56	0.50	0.28	0.32
95% CI	1.13	0.23	0.28	0.13	0.07	0.11

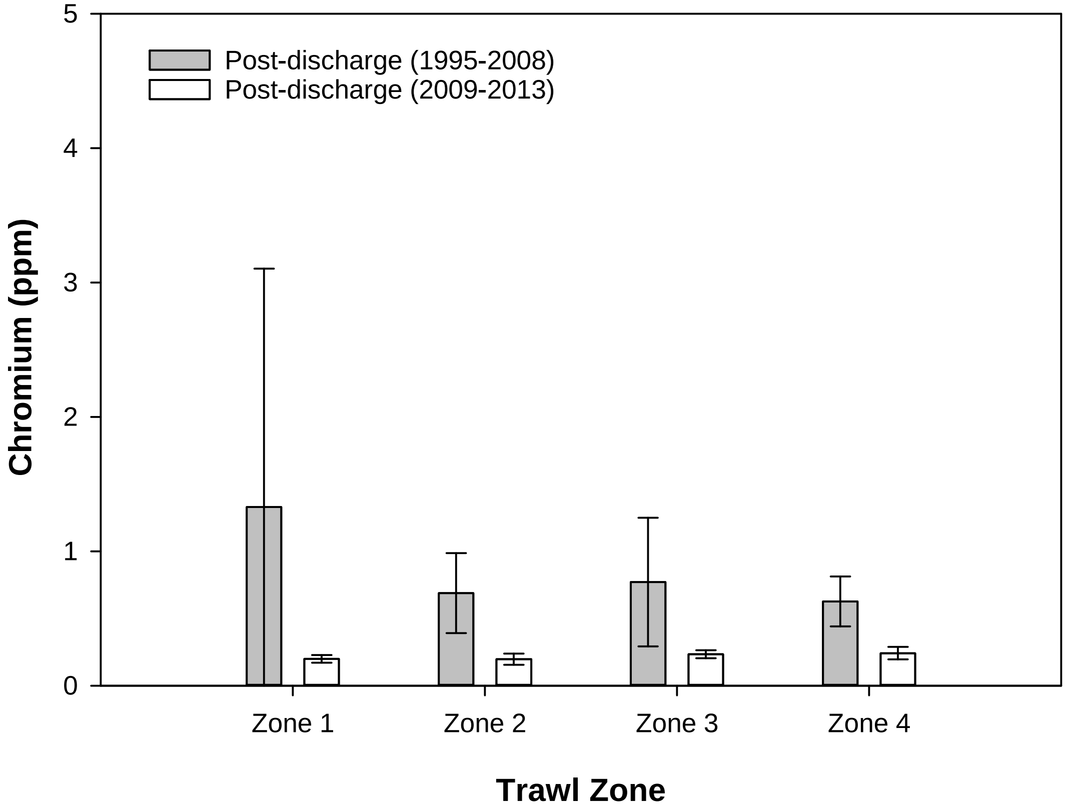

FIGURE D-16
Comparisons of chromium concentrations in sanddab liver tissues by trawl zone for all surveys (April and October) from 1995 through 2013. Data are means +/- 95% confidence intervals.

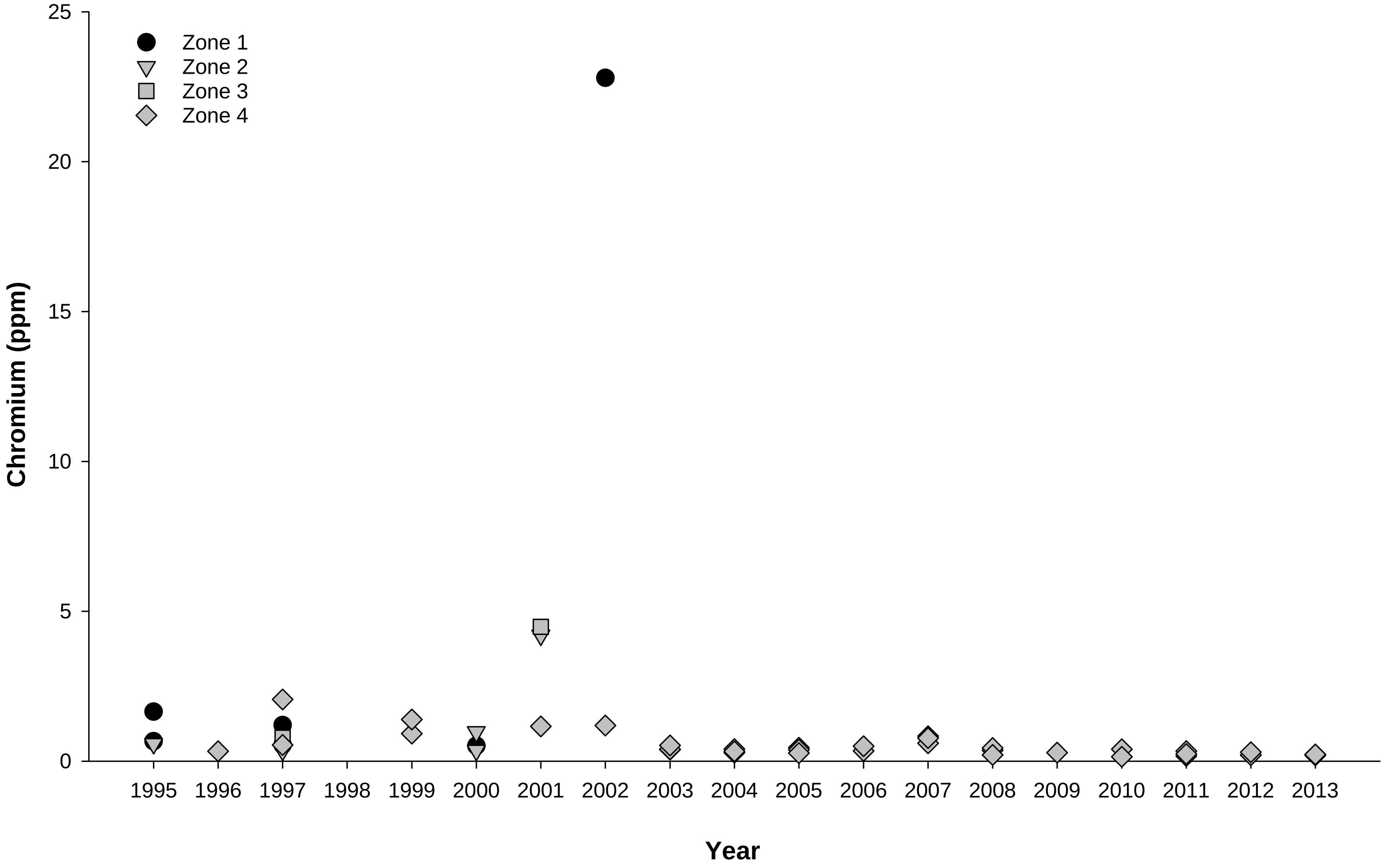

FIGURE D-17

Chromium concentrations detected in sanddab guild liver tissues for trawl Zone 1 versus Zones 2-4 for October surveys from 1995 through 2013.

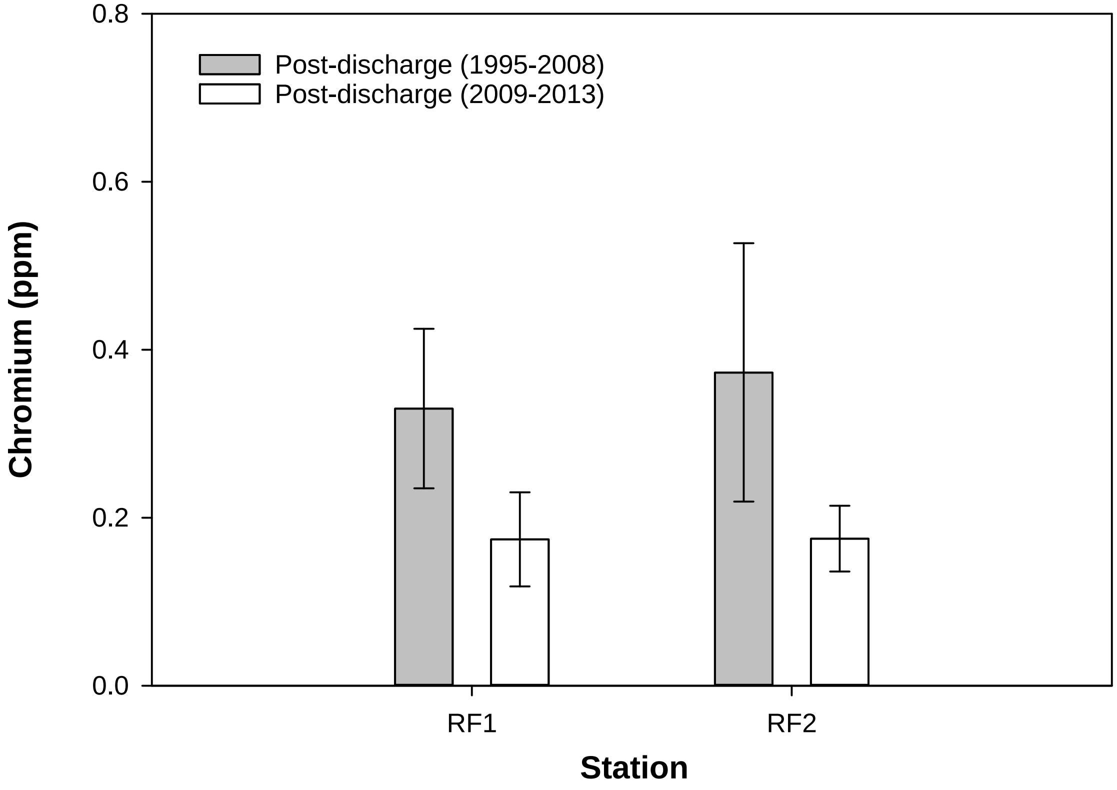

FIGURE D-18

Comparisons of chromium concentrations in rockfish muscle tissues by rig fishing station for all surveys (April and October) from 1995 through 2013. Data are means +/- 95% confidence intervals.

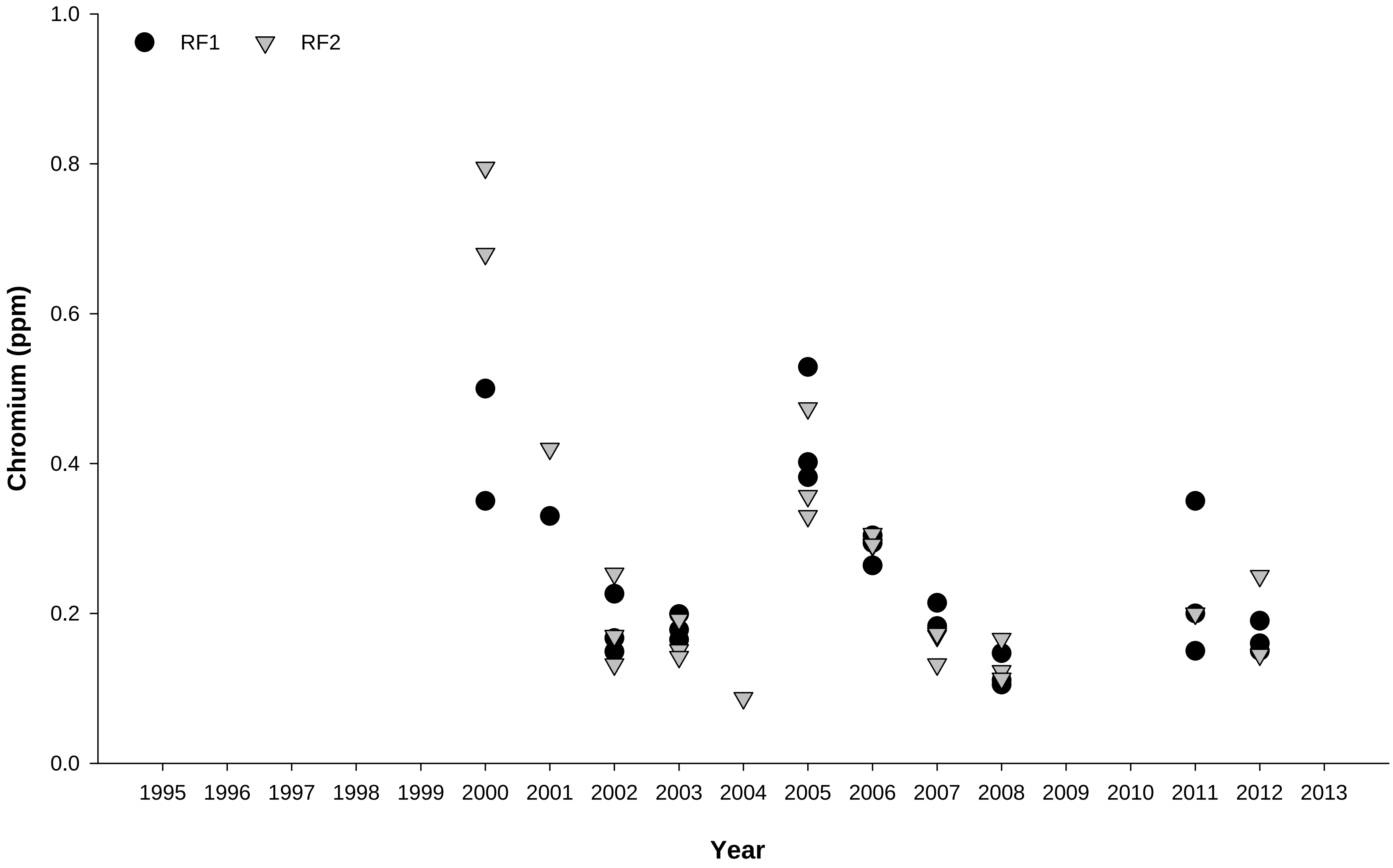

FIGURE D-19
Chromium concentrations detected in rockfish muscle tissues for rig fishing station RF1 versus RF2 for October surveys from 1995 through 2013.

discharge from the Point Loma outfall. With the exception of a single anomalous value recorded in October 2002 for trawl zone 1, chromium concentrations in sanddabs remained below 5 ppm across all stations (Figure D-17). Chromium levels in muscle tissues were below the MIS of 1.0 ppm in all species except mixed rockfish (Table D-6, Figure D-20).

Copper: Copper is typically the metal that occurs in the second highest concentrations in Point Loma effluent due to its widespread use in industrial commercial and household products and applications (i.e., zinc occurs in higher concentrations; see below). For example, copper is leached from many materials that are part of the sewage flow entering the treatment plant, and it also originates from copper water pipes. Even so, copper concentrations in Point Loma effluent have decreased to about 16 µg/L as a result of source control.

Overall, copper was detected in ~100% of the liver tissue samples from trawl-caught fishes and 61% of the muscle tissue samples from fishes collected at rig fishing stations off Point Loma (Table D-13). Average copper concentrations were 12.22 ppm in liver tissues and 1.57 ppm in muscle tissues. The highest copper concentration was 166 ppm from a flag rockfish liver tissue sample. All other species had much lower concentrations of copper in both liver and muscle tissues, and all fishes collected at the rig fishing stations had copper concentrations below the MIS of 20 ppm (Table D-6). The copper data summarized in Table D-14 and Figures D-21 through D-24 also show no discernible spatial or temporal relationships to the Point Loma outfall among either the trawl or rig fishing sites. Although copper concentrations were higher in samples from fishes collected at all stations from 2000 to 2002, tissue concentrations of this metal have since returned to their low levels (see Figures D-22 and D-24).

Lead: Lead is widely distributed in the environment as a result of its prior use in gasoline and paints. Lead in wastewater has its origin in various industrial uses and lead solder in water piping systems. Lead levels in wastewater have been declining over the years and are now mostly below detection levels in the Point Loma effluent. Lead was only detected in 54 of the 409 samples (13%) of liver tissue from trawl-caught fishes (Table D-15). The highest lead concentration of 8.8 ppm occurred in a Pacific sanddab liver tissue sample. No discernible spatial or temporal relationships to the Point Loma outfall were observed among the trawl zones (Table D-16, Figures D-25 and D-26). Additionally, lead was detected in just three of the rockfish muscle tissue samples analyzed from October 1995 through October 2013 (Table D-15, Figures D-27 and D-28). All three samples were collected in October 2005 from station RF2 (Figure D-28), and all three had concentrations below the MIS of 2 ppm (Table D-6).

Nickel: Nickel also has broad industrial applications and has become widespread in the environment. However, it was only detected in 16% of the liver tissues samples from trawl-caught fishes and 8% of the muscle tissue samples from fishes collected at rig fishing stations

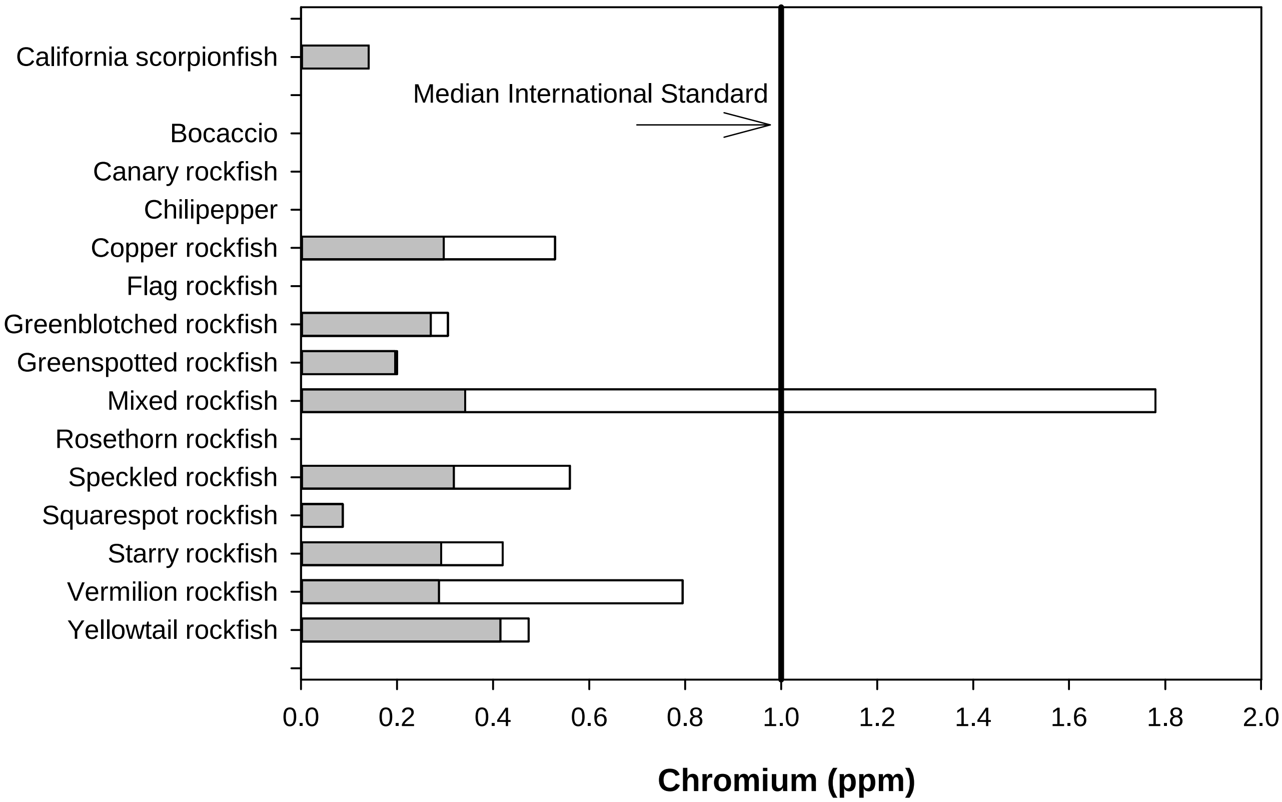

FIGURE D-20
Mean and maximum concentrations of chromium in muscle tissues of all fishes collected off San Diego at rig fishing stations compared to the median international standard (from Mearns et al. 1991). See Table D-11 for sample sizes.

TABLE D-13

Summary of copper concentrations (ppm) in liver and muscle tissue samples for each fish species sampled from October 1995 through October 2013. Data are summarized for liver tissues from trawl stations and muscle tissues from rig fishing stations during all surveys (April and October); nd=not detected.

Species	Total	Detect	Freq	Min	Max	Mean
Liver Tissues (Trawl Zones)						
California scorpionfish	112	112	100	6.10	84.10	26.51
Dover sole	3	3	100	1.48	4.30	3.05
English sole	25	25	100	0.86	15.80	5.29
Flag rockfish	2	2	100	42.60	166.00	104.30
Greenblotched rockfish	3	3	100	3.87	22.20	10.39
Greenspotted rockfish	3	3	100	11.70	22.20	16.77
Halfbanded rockfish	3	3	100	2.01	13.40	8.94
Hornyhead turbot	1	1	100	5.74	5.74	5.74
Longfin sanddab	86	86	100	1.31	31.20	7.49
Mixed rockfish	3	3	100	12.10	20.30	16.73
Pacific sanddab	167	166	99	1.24	16.50	5.05
Vermilion rockfish	1	1	100	21.50	21.50	21.50
ALL SPECIES	409	408	99.8	0.86	166.00	12.22
Muscle Tissues (RF Stations)						
Bocaccio	2	2	100	1.76	1.79	1.77
California scorpionfish	12	7	58	0.21	1.63	0.96
Canary rockfish	1	0	0	nd	nd	nd
Chilipepper	2	2	100	0.33	0.36	0.34
Copper rockfish	22	16	73	0.14	4.79	1.48
Flag rockfish	4	4	100	0.34	1.31	0.99
Greenblotched rockfish	3	3	100	0.51	0.77	0.63
Greenspotted rockfish	2	1	50	0.14	0.14	0.14
Mixed rockfish	41	25	61	0.11	8.96	1.77
Rosethorn rockfish	1	1	100	0.76	0.76	0.76
Speckled rockfish	13	4	31	0.26	0.88	0.68
Squarespot rockfish	3	2	67	0.25	0.46	0.36
Starry rockfish	9	3	33	0.33	5.88	2.93
Vermilion rockfish	43	25	58	0.32	8.56	2.14
Yellowtail rockfish	2	2	100	0.38	0.45	0.42
ALL SPECIES	160	97	61	0.11	8.96	1.57

TABLE D-14

Summary of copper concentrations (ppm) in sanddab and rockfish tissues by station/zone. Data are summarized over all samples collected during the April and October surveys from October 1995 through October 2013. CI=confidence interval.

	Sanddab Liver Tissues				Rockfish Muscle Tissues	
	Zone 1	**Zone 2**	**Zone 3**	**Zone 4**	**RF1**	**RF2**
Total	59	80	56	58	71	77
Detected	59	80	56	57	43	47
Frequency	100	100	100	98	61	61
Minimum	1.66	1.31	1.24	1.66	0.11	0.14
Median	4.40	4.99	4.73	5.80	0.77	0.59
Maximum	16.50	17.30	31.20	16.00	8.96	5.88
Mean	5.46	6.16	5.71	6.10	1.92	1.34
95% CI	0.87	0.85	1.12	0.79	0.67	0.46

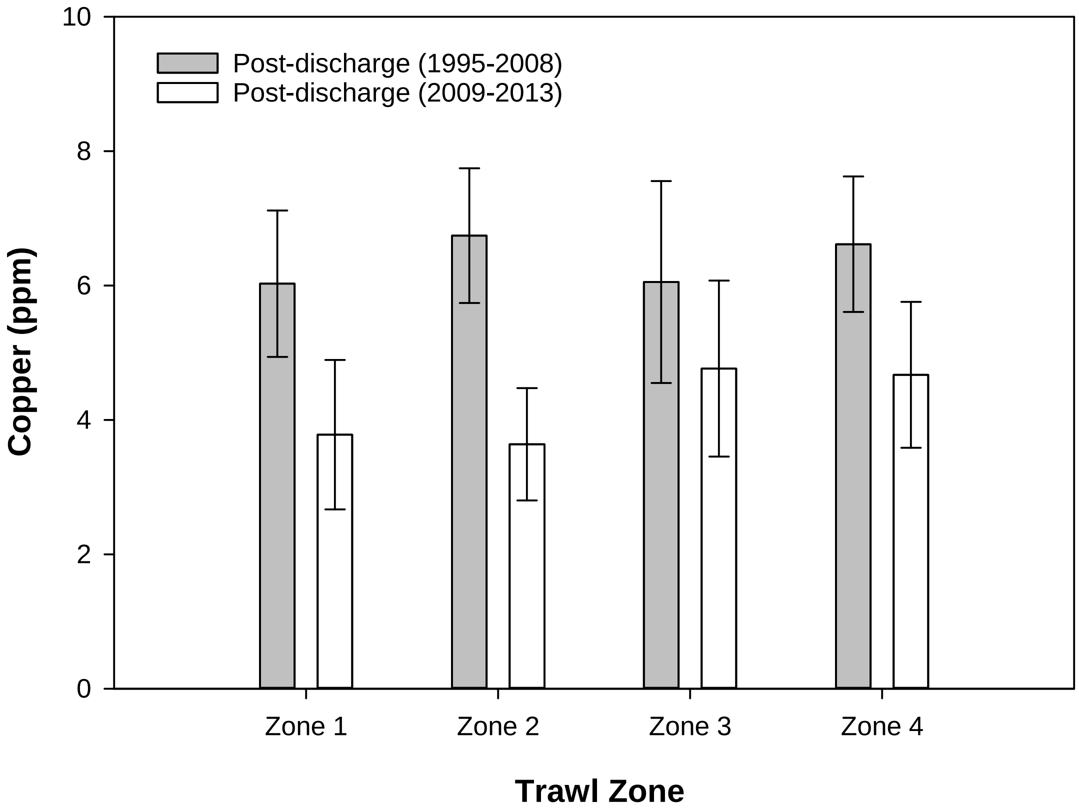

FIGURE D-21
Comparisons of copper concentrations in sanddab liver tissues by trawl zone for all surveys (April and October) from 1995 through 2013. Data are means +/- 95% confidence intervals.

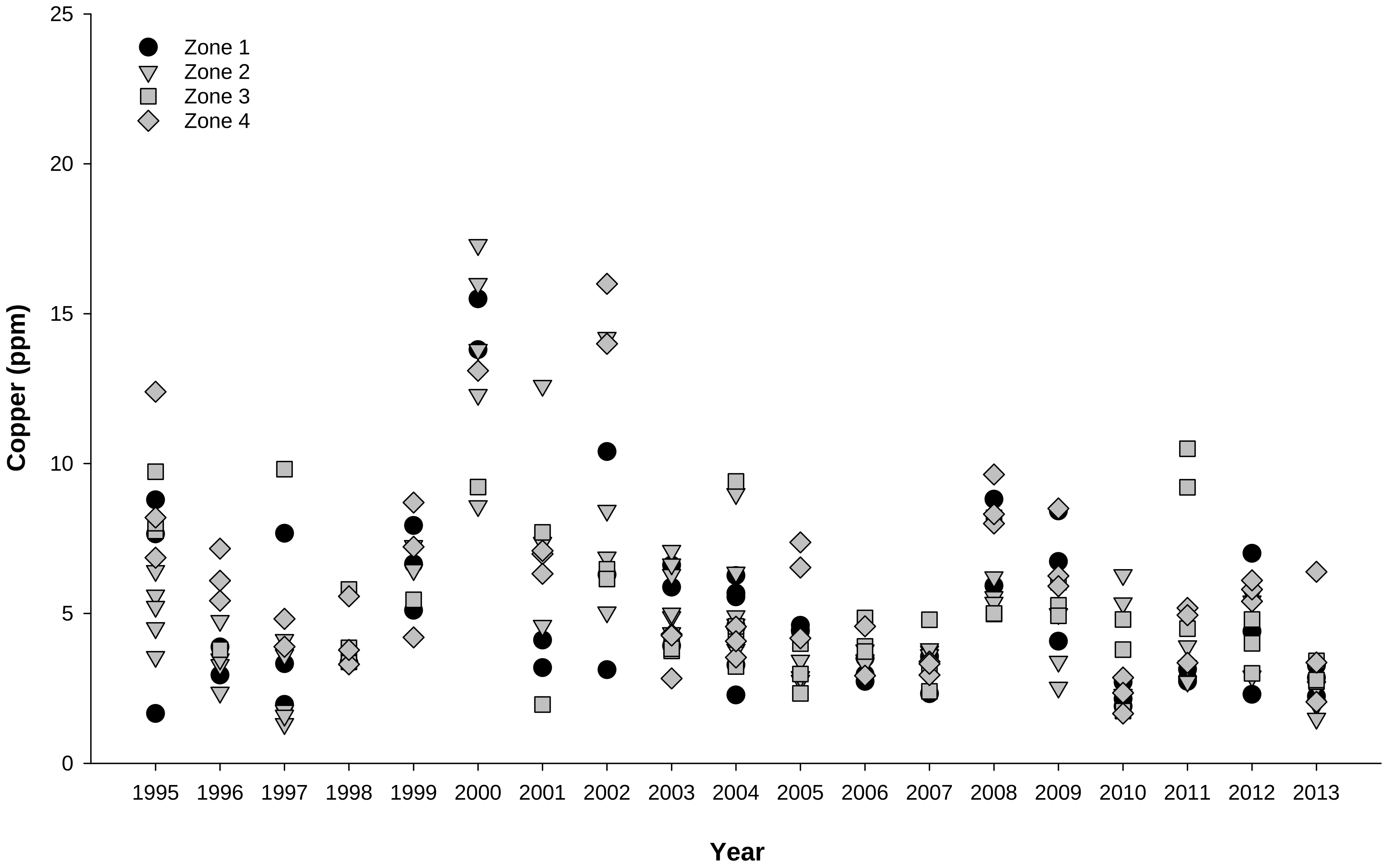

FIGURE D-22

Copper concentrations detected in sanddab guild liver tissues for trawl Zone 1 versus Zones 2-4 for October surveys from 1995 through 2013.

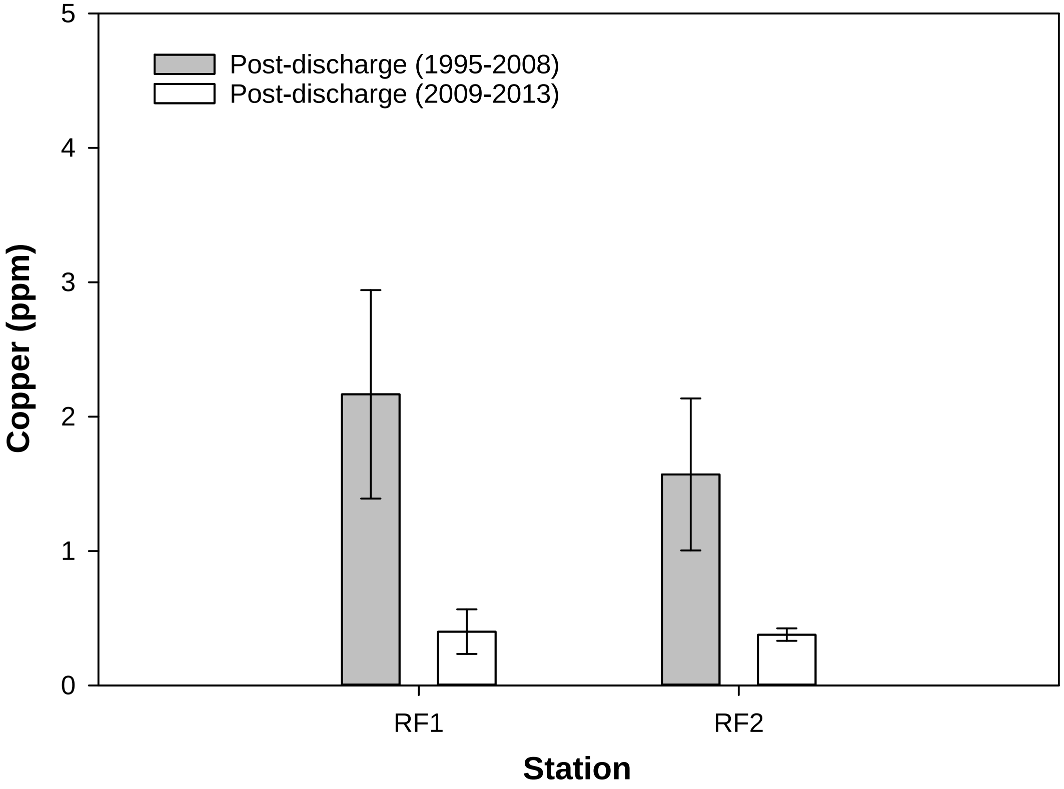

FIGURE D-23

Comparisons of copper concentrations in rockfish muscle tissues by rig fishing station for all surveys (April and October) from 1995 through 2013. Data are means +/- 95% confidence intervals.

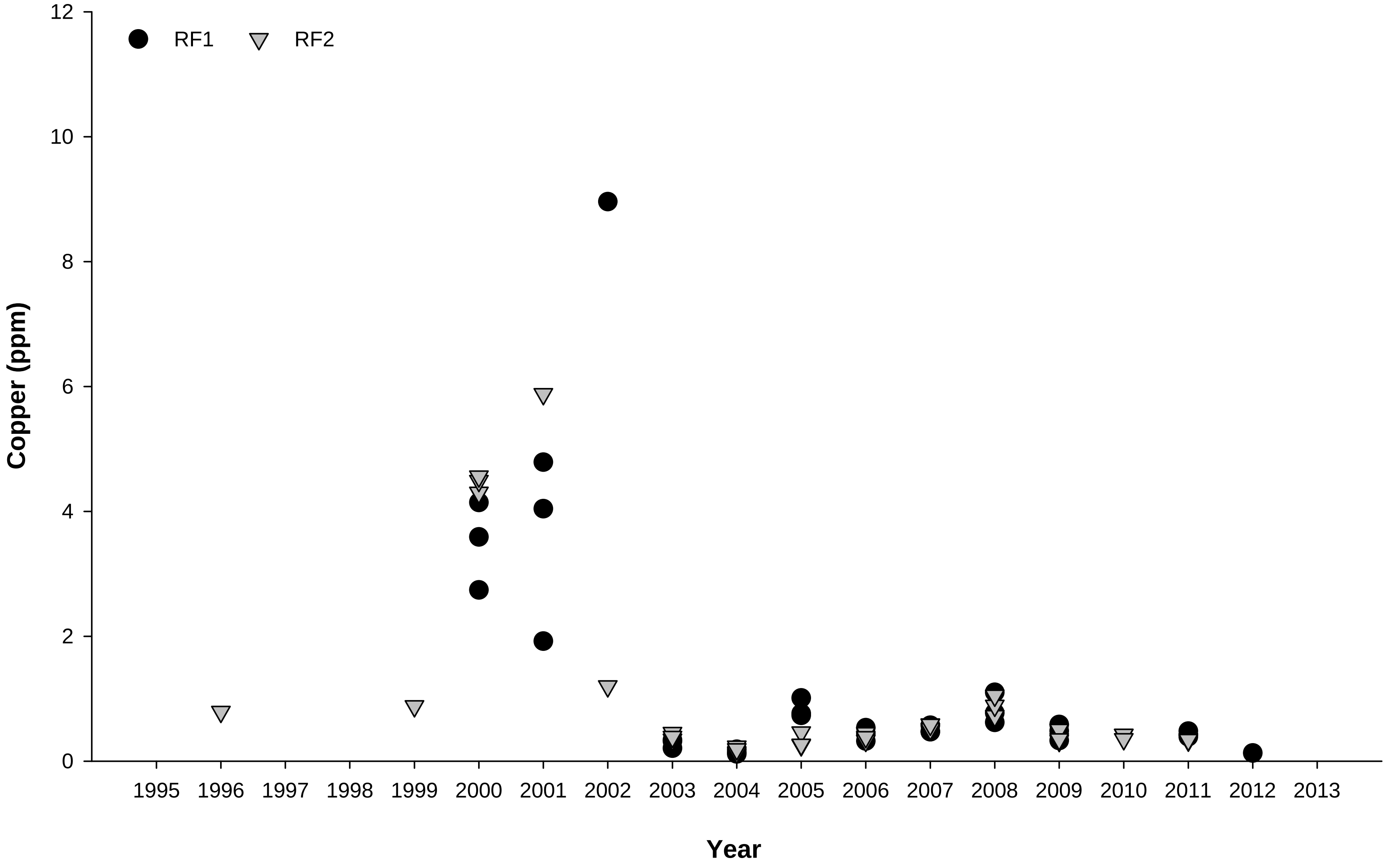

FIGURE D-24

Copper concentrations detected in rockfish muscle tissues for rig fishing station RF1 versus RF2 for October surveys from 1995 through 2013.

TABLE D-15

Summary of lead concentrations (ppm) in liver and muscle tissue samples for each fish species sampled from October 1995 through October 2013. Data are summarized for liver tissues from trawl stations and muscle tissues from rig fishing stations during all surveys (April and October); nd=not detected.

Species	Total	Detect	Freq	Min	Max	Mean
Liver Tissues (Trawl Zones)						
California scorpionfish	112	6	5	2.60	3.50	2.95
Dover sole	3	0	0	nd	nd	nd
English sole	25	12	48	0.40	2.58	1.01
Flag rockfish	2	0	0	nd	nd	nd
Greenblotched rockfish	3	0	0	nd	nd	nd
Greenspotted rockfish	3	0	0	nd	nd	nd
Halfbanded rockfish	3	0	0	nd	nd	nd
Hornyhead turbot	1	0	0	nd	nd	nd
Longfin sanddab	86	2	2	2.60	5.70	4.15
Mixed rockfish	3	0	0	nd	nd	nd
Pacific sanddab	167	34	20	0.20	8.80	1.09
Vermilion rockfish	1	0	0	nd	nd	nd
ALL SPECIES	409	54	13	0.20	8.80	1.39
Muscle Tissues (RF Stations)						
Bocaccio	2	0	0	nd	nd	nd
California scorpionfish	12	0	0	nd	nd	nd
Canary rockfish	1	0	0	nd	nd	nd
Chilipepper	2	0	0	nd	nd	nd
Copper rockfish	22	0	0	nd	nd	nd
Flag rockfish	4	0	0	nd	nd	nd
Greenblotched rockfish	3	0	0	nd	nd	nd
Greenspotted rockfish	2	0	0	nd	nd	nd
Mixed rockfish	41	0	0	nd	nd	nd
Rosethorn rockfish	1	0	0	nd	nd	nd
Speckled rockfish	13	1	8	0.34	0.34	0.34
Squarespot rockfish	3	2	67	0.32	0.42	0.37
Starry rockfish	9	0	0	nd	nd	nd
Vermilion rockfish	43	0	0	nd	nd	nd
Yellowtail rockfish	2	0	0	nd	nd	nd
ALL SPECIES	160	3	2	0.32	0.42	0.36

TABLE D-16

Summary of lead concentrations (ppm) in sanddab and rockfish tissues by station/zone. Data are summarized over all samples collected during the April and October surveys from October 1995 through October 2013. CI=confidence interval; nd = not detected.

	Sanddab Liver Tissues				Rockfish Muscle Tissues	
	Zone 1	Zone 2	Zone 3	Zone 4	RF1	RF2
Total	59	80	56	58	71	77
Detected	6	11	10	9	0	3
Frequency	10	14	18	16	0	4
Minimum	0.30	0.27	0.25	0.20	nd	0.32
Median	0.51	0.47	0.76	0.36	nd	0.34
Maximum	5.60	8.80	2.70	5.70	nd	0.42
Mean	1.42	1.63	0.95	1.05	nd	0.36
95% CI	1.66	1.52	0.50	1.15	nd	0.06

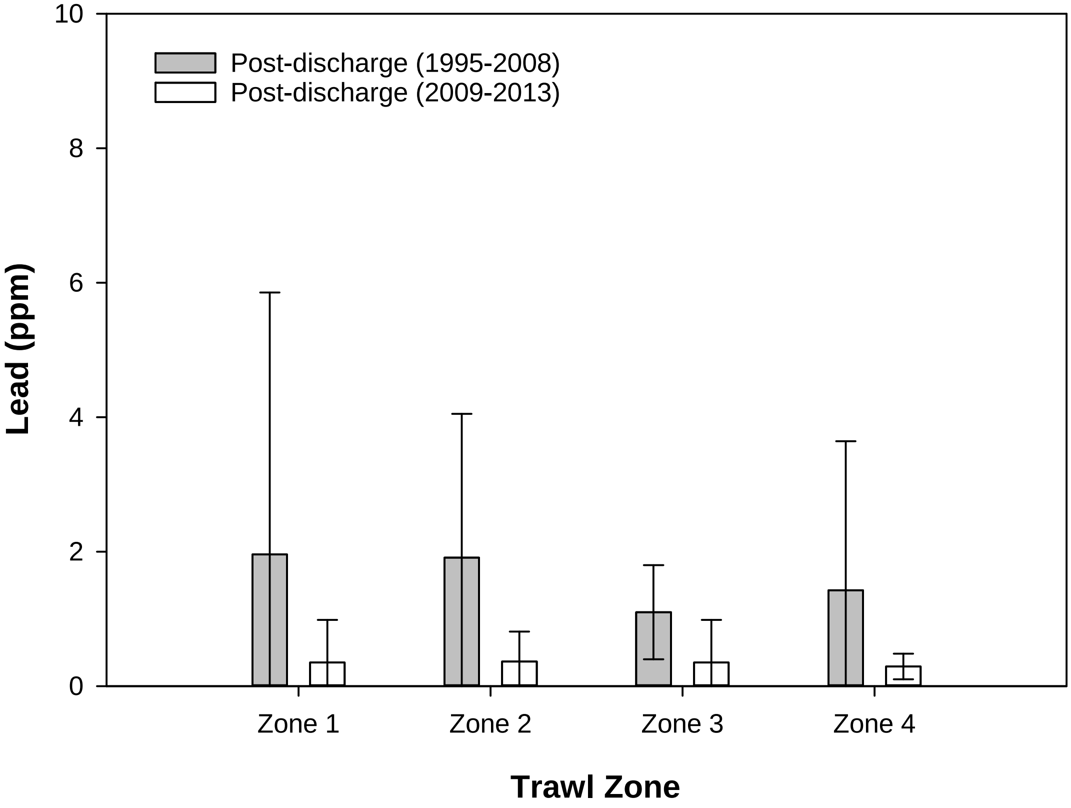

FIGURE D-25
Comparisons of lead concentrations in sanddab liver tissues by trawl zone for all surveys (April and October) from 1995 through 2013. Data are means +/- 95% confidence intervals.

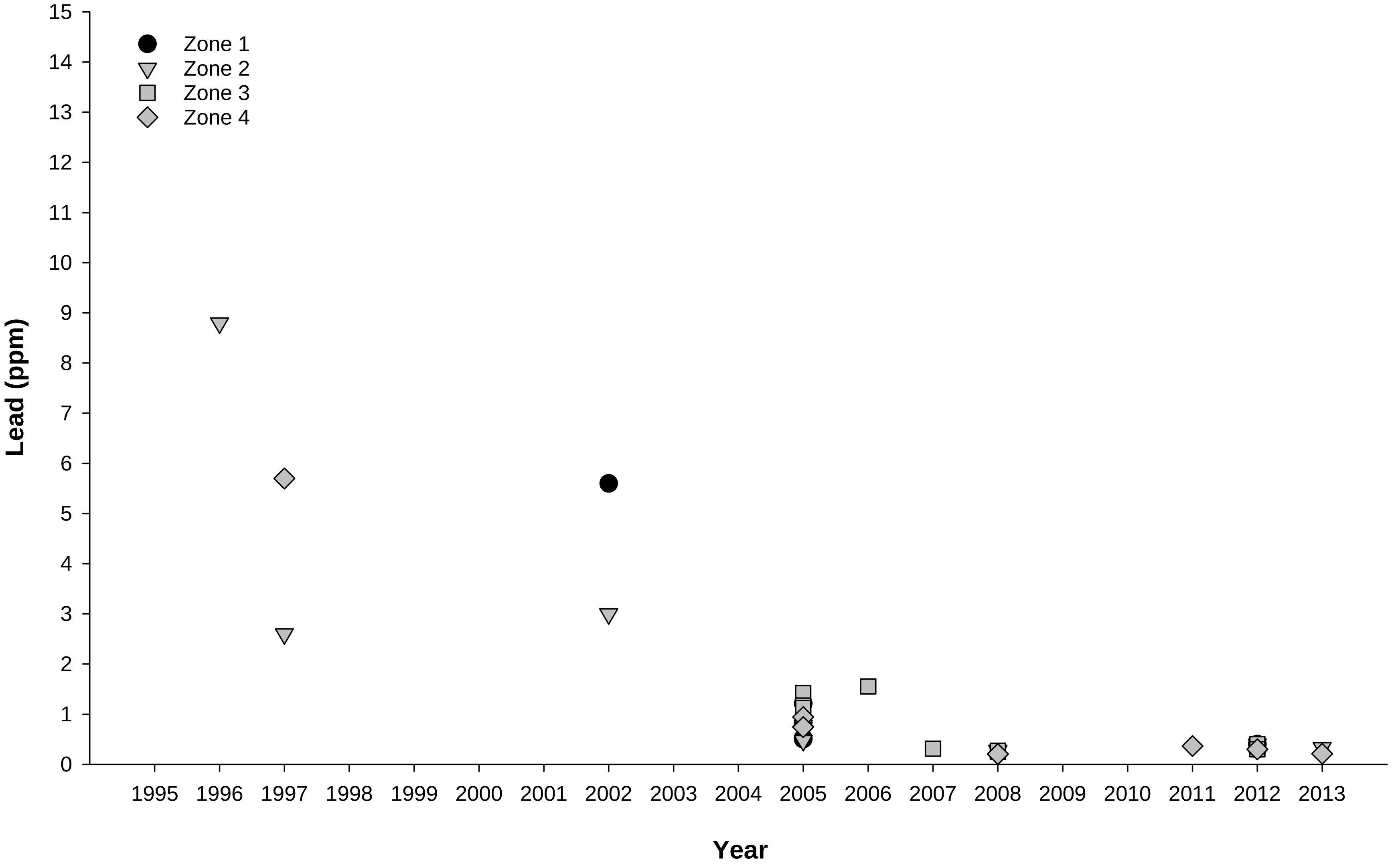

FIGURE D-26

Lead concentrations detected in sanddab guild liver tissues for trawl Zone 1 versus Zones 2-4 for October surveys from 1995 through 2013.

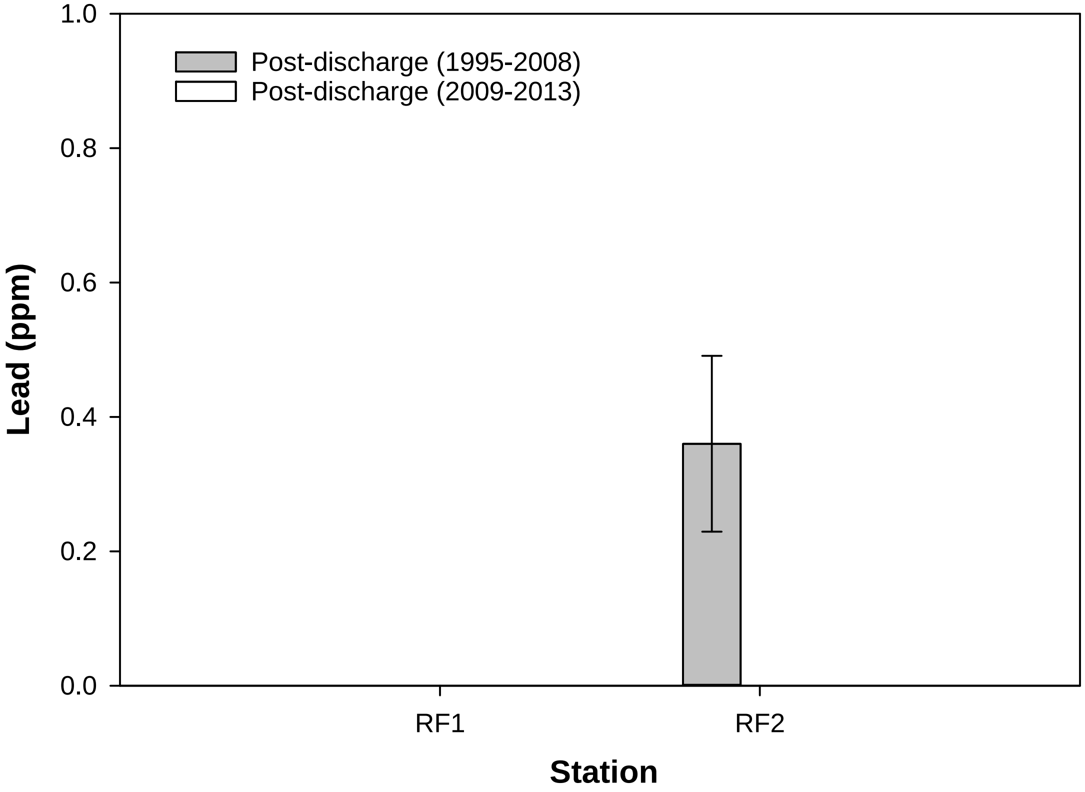

FIGURE D-27
Comparisons of lead concentrations in rockfish muscle tissues by rig fishing station for all surveys (April and October) from 1995 through 2013. Data are means +/- 95% confidence intervals.

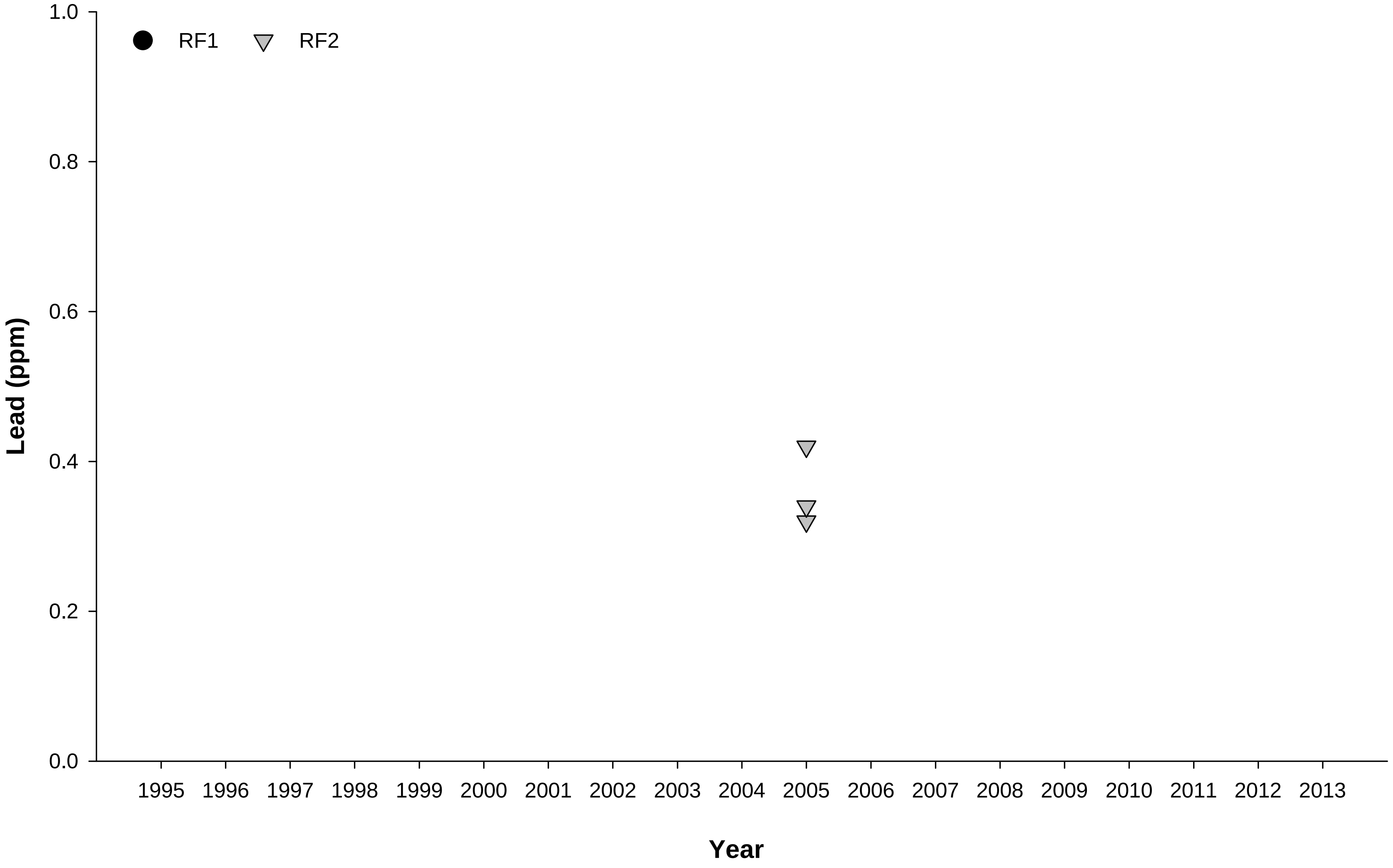

FIGURE D-28
Lead concentrations detected in rockfish muscle tissues for rig fishing station RF1 versus RF2 for October surveys from 1995 through 2013.

from 1995 through 2013 (Table D-17). The maximum nickel concentration of 18.9 ppm was found in a longfin sanddab liver sample. Concentrations of nickel in muscle tissues were all ≤0.38 ppm. No discernible spatial or temporal relationships to the Point Loma outfall were observed among the trawl zones or rig fishing sites (Table D-18, Figures D-29 through D-32). There is no U.S. or international standard for concentrations of nickel in seafood.

Selenium: Natural weathering of rocks and soils accounts for most of the selenium in the environment although it also has agriculture and industrial uses. Considered an essential biological element, selenium has anti-carcinogenic properties and appears to protect against toxic effects of other metals such as arsenic, cadmium, copper, mercury, silver, and thallium (Mearns et al. 1991). At high concentrations, however, selenium itself has considerable toxicity and can adversely affect species of fish and birds. For example, selenium, concentrated by evaporation of agricultural water in the Kesterson Wildlife Refuge (San Joaquin Valley, California), was found to cause wildlife mortalities and reproductive deformities (Burau 1985).

Selenium was detected in 100% of the liver tissue samples from trawl-caught fishes and 99% of the muscle tissues samples from fishes collected at rig fishing stations from 1995 through 2013 (Table D-19). Selenium concentrations in liver tissues never exceeded 5 ppm, while all muscle tissue concentrations were below 1 ppm. No discernible spatial or temporal relationships to the Point Loma outfall were observed among the trawl zones or rig fishing sites (Table D-20, Figures D-33 through D-36). Although the highest selenium values occurred in rockfishes from station RF1 over several surveys (Figure D-36), the range of values was very narrow and differences did not appear significant (Figure D-35). Selenium concentrations exceeded the MIS of 0.3 ppm in muscle tissues from California scorpionfish and 12 rockfish species, but none of the samples had concentrations higher than the OEHAA fish contaminant goal of 7.4 ppm (Table D-6 and Figure D-37). As with mercury and arsenic, elevated levels of selenium are not uncommon in sport fish from other areas of the San Diego region, including the Coronado Islands (see City of San Diego 2014c and references therein).

Silver: Silver has historically been present in wastewater as a result of its use in photography and dentistry. However these inputs have dropped significantly over the years with the implementation of stringent source control measures. Over the past 19 years, silver has been detected in just 23% of the liver samples from trawl-caught fishes, at concentrations up to 1.66 ppm, and in just 4% of the muscle samples from fishes collected at rig fishing stations, at concentrations up to 0.50 ppm (Table D-21). No discernible spatial or temporal relationships to the Point Loma outfall were observed among the trawl zones or rig fishing sites (Table D-22, Figures D-38 through D-41). There is no U.S. or international standard for concentrations of silver in seafood.

TABLE D-17

Summary of nickel concentrations (ppm) in liver and muscle tissue samples for each fish species sampled from October 1995 through October 2013. Data are summarized for liver tissues from trawl stations and muscle tissues from rig fishing stations during all surveys (April and October); nd=not detected.

Species	**Total**	**Detect**	**Freq**	**Min**	**Max**	**Mean**
Liver Tissues (Trawl Zones)						
California scorpionfish	112	3	3	0.87	0.97	0.93
Dover sole	3	0	0	nd	nd	nd
English sole	25	9	36	0.17	3.64	0.57
Flag rockfish	2	1	50	0.91	0.91	0.91
Greenblotched rockfish	3	1	33	2.46	2.46	2.46
Greenspotted rockfish	3	0	0	nd	nd	nd
Halfbanded rockfish	3	0	0	nd	nd	nd
Hornyhead turbot	1	1	100	0.20	0.20	0.20
Longfin sanddab	86	6	7	0.10	18.90	3.60
Mixed rockfish	3	0	0	nd	nd	nd
Pacific sanddab	167	45	27	0.10	2.26	0.35
Vermilion rockfish	1	0	0	nd	nd	nd
ALL SPECIES	409	66	16	0.10	18.90	0.74
Muscle Tissues (RF Stations)						
Bocaccio	2	0	0	nd	nd	nd
California scorpionfish	12	0	0	nd	nd	nd
Canary rockfish	1	0	0	nd	nd	nd
Chilipepper	2	0	0	nd	nd	nd
Copper rockfish	22	4	18	0.14	0.38	0.22
Flag rockfish	4	0	0	nd	nd	nd
Greenblotched rockfish	3	2	67	0.12	0.15	0.13
Greenspotted rockfish	2	0	0	nd	nd	nd
Mixed rockfish	41	1	2	0.13	0.13	0.13
Rosethorn rockfish	1	0	0	nd	nd	nd
Speckled rockfish	13	0	0	nd	nd	nd
Squarespot rockfish	3	0	0	nd	nd	nd
Starry rockfish	9	1	11	0.14	0.14	0.14
Vermilion rockfish	43	2	5	0.16	0.17	0.17
Yellowtail rockfish	2	2	100	0.15	0.16	0.16
ALL SPECIES	160	12	8	0.12	0.38	0.17

TABLE D-18

Summary of nickel concentrations (ppm) in sanddab and rockfish tissues by station/zone. Data are summarized over all samples collected during the April and October surveys from October 1995 through October 2013. CI=confidence interval.

	Sanddab Liver Tissues				Rockfish Muscle Tissues	
	Zone 1	**Zone 2**	**Zone 3**	**Zone 4**	**RF1**	**RF2**
Total	59	80	56	58	71	77
Detected	13	15	14	9	6	6
Frequency	22	19	25	16	8	8
Minimum	0.10	0.17	0.10	0.14	0.14	0.12
Median	0.27	0.21	0.24	0.26	0.17	0.15
Maximum	18.90	0.55	2.26	0.75	0.38	0.16
Mean	1.81	0.25	0.50	0.32	0.20	0.14
95% CI	2.80	0.06	0.31	0.12	0.07	0.01

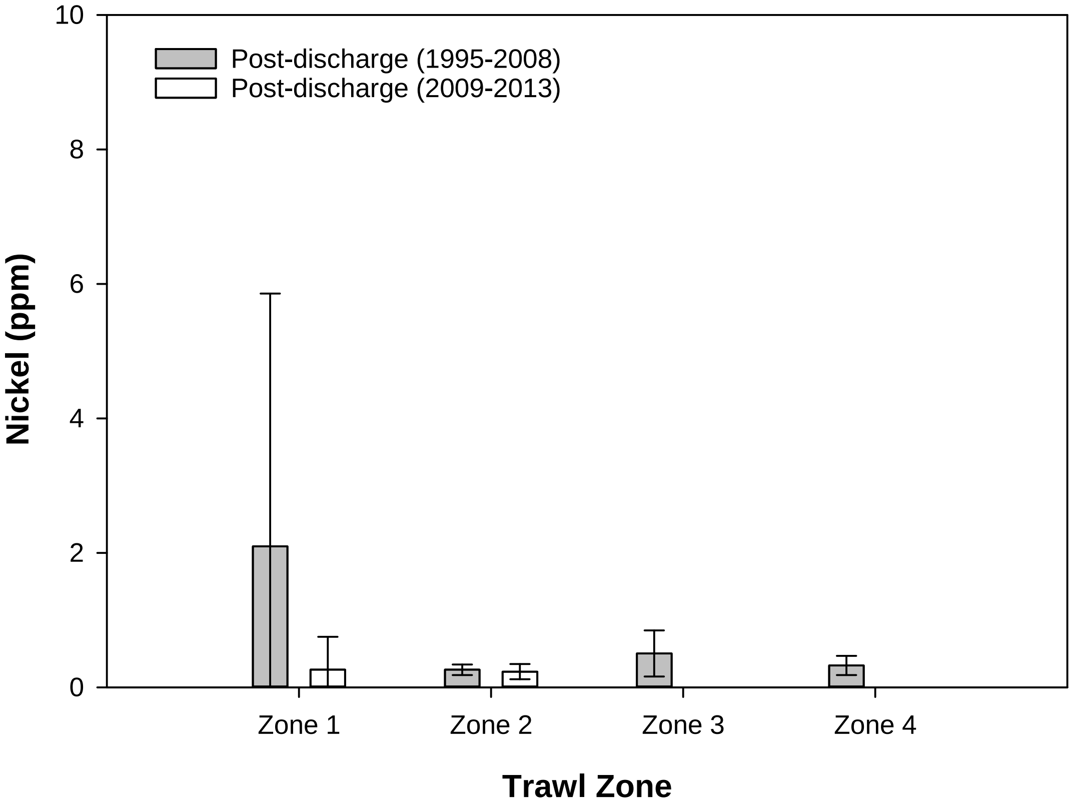

FIGURE D-29

Comparisons of nickel concentrations in sanddab liver tissues by trawl zone for all surveys (April and October) from 1995 through 2013. Data are means +/- 95% confidence intervals.

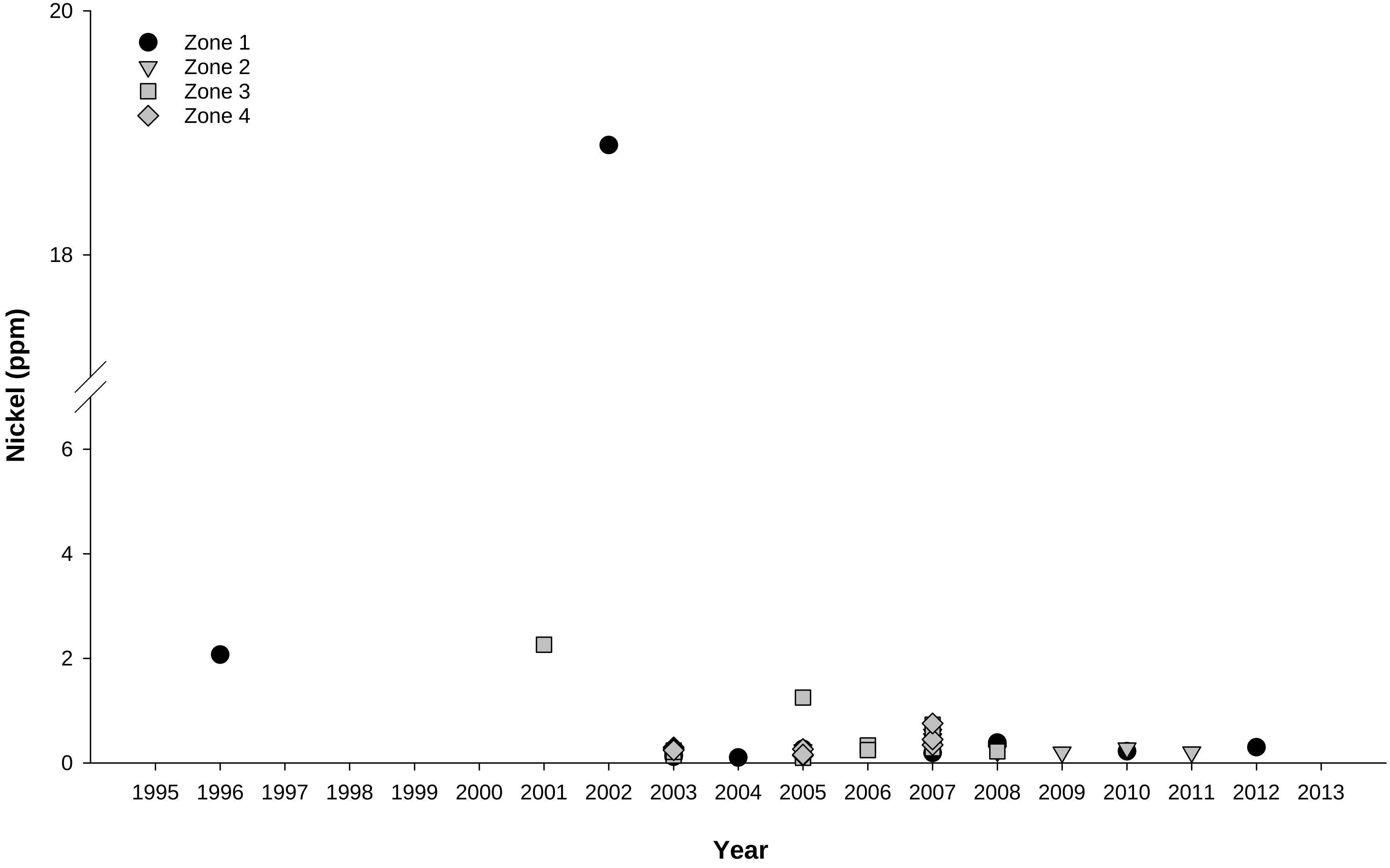

FIGURE D-30

Nickel concentrations detected in sanddab guild liver tissues for trawl Zone 1 versus Zones 2-4 for October surveys from 1995 through 2013.

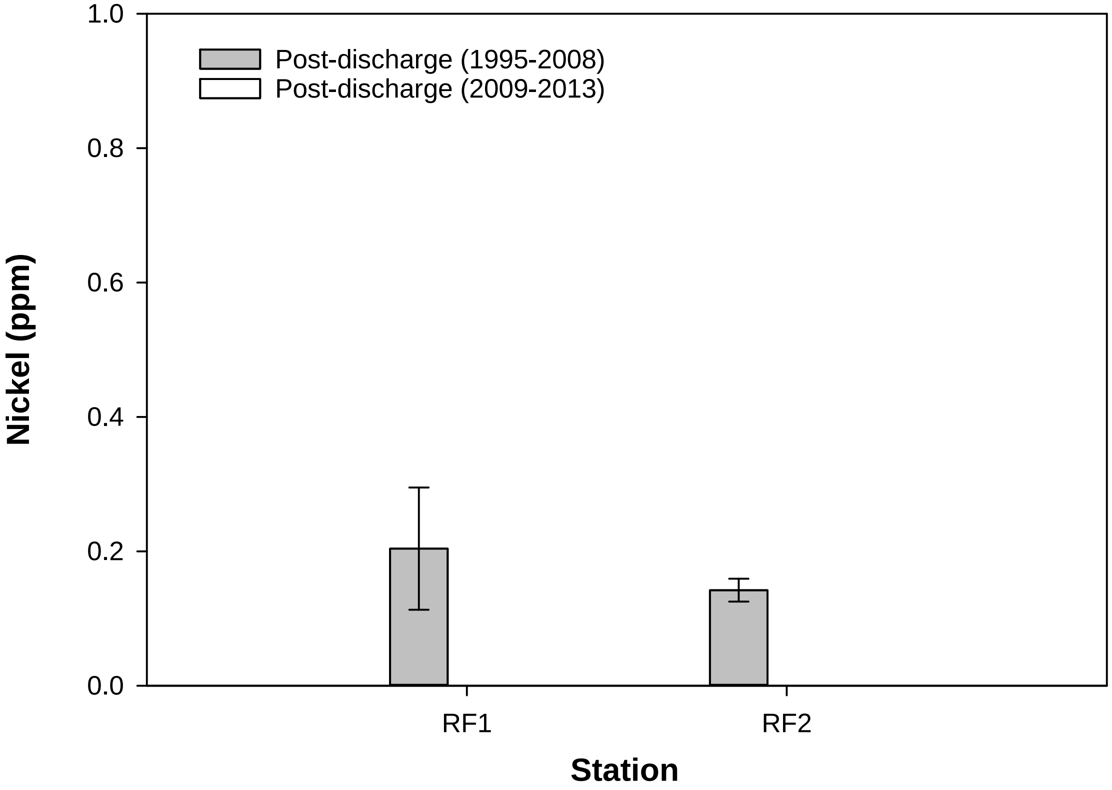

FIGURE D-31
Comparisons of nickel concentrations in rockfish muscle tissue by rig fishing station for all surveys (April and October) from 1995 through 2013. Data are means +/- 95% confidence limits.

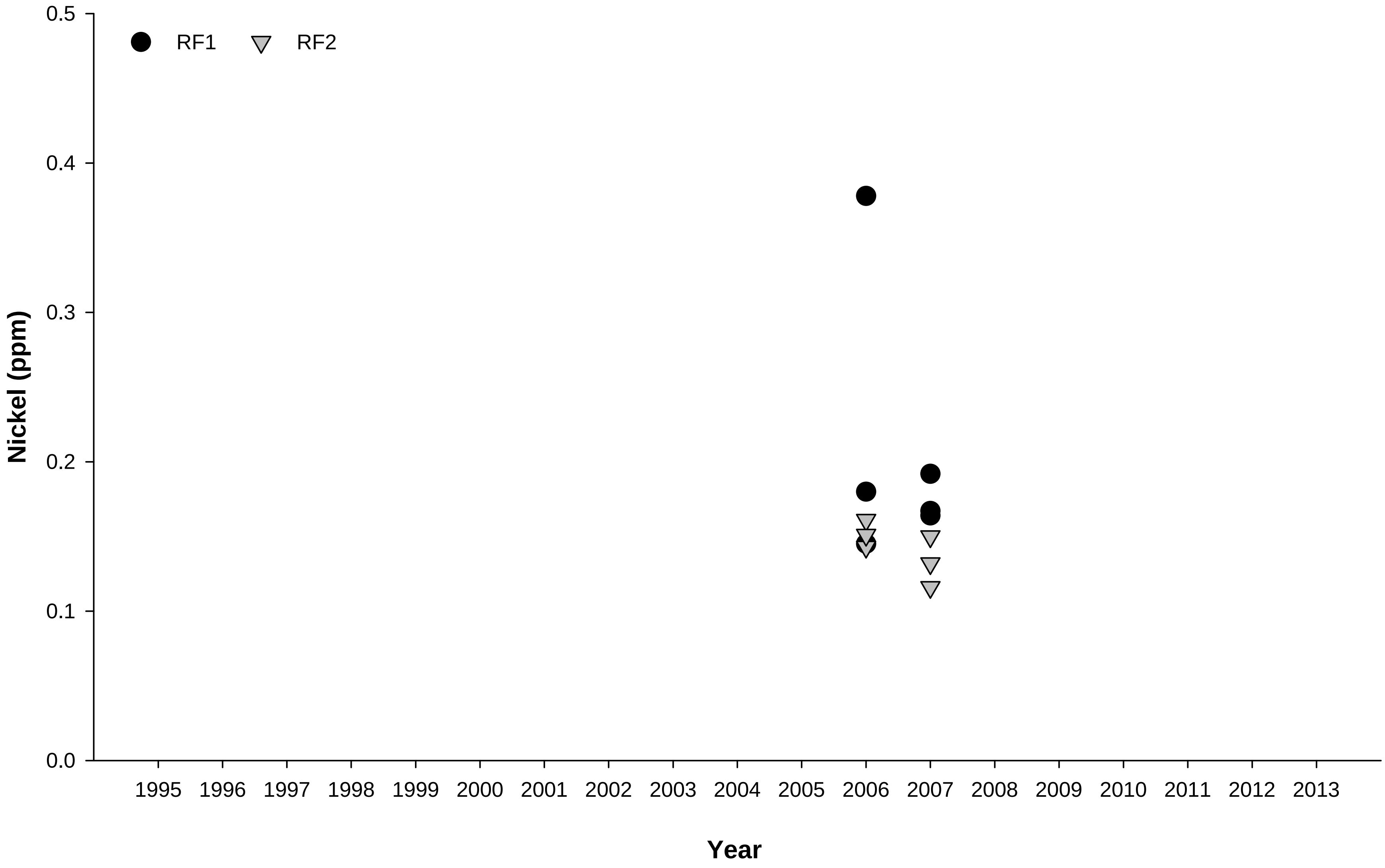

FIGURE D-32
Nickel concentrations detected in rockfish muscle tissues for rig fishing station RF1 versus RF2 for October surveys from 1995 through 2013.

TABLE D-19

Summary of selenium concentrations (ppm) in liver and muscle tissue samples for each fish species sampled from October 1995 through October 2013. Data are summarized for liver tissues from trawl stations and muscle tissues from rig fishing stations during all surveys (April and October); nd=not detected.

Species	Total	Detect	Freq	Min	Max	Mean
Liver Tissues (Trawl Zones)						
California scorpionfish	115	115	100	0.42	4.55	0.86
Dover sole	3	3	100	0.72	2.77	1.75
English sole	25	25	100	0.99	3.21	2.26
Flag rockfish	2	2	100	1.42	2.58	2.00
Greenblotched rockfish	3	3	100	1.03	3.05	2.09
Greenspotted rockfish	3	3	100	2.37	2.87	2.68
Halfbanded rockfish	3	3	100	1.69	4.99	3.43
Hornyhead turbot	1	1	100	0.89	0.89	0.89
Longfin sanddab	87	87	100	0.61	4.37	1.84
Mixed rockfish	4	4	100	1.95	3.22	2.38
Pacific sanddab	171	171	100	0.18	3.23	0.89
Squarespot rockfish	1	1	100	3.38	3.38	3.38
Vermilion rockfish	1	1	100	1.31	1.31	1.31
ALL SPECIES	419	419	100	0.18	4.99	1.23
Muscle Tissues (RF Stations)						
Bocaccio	2	2	100	0.18	0.30	0.24
California scorpionfish	12	12	100	0.14	0.40	0.27
Canary rockfish	1	1	100	0.25	0.25	0.25
Chilipepper	2	2	100	0.43	0.53	0.48
Copper rockfish	22	22	100	0.13	0.69	0.42
Flag rockfish	4	4	100	0.23	0.54	0.37
Greenblotched rockfish	3	3	100	0.33	0.38	0.35
Greenspotted rockfish	2	2	100	0.20	0.37	0.29
Mixed rockfish	41	39	95	0.13	0.73	0.34
Rosethorn rockfish	1	1	100	0.37	0.37	0.37
Speckled rockfish	13	13	100	0.13	0.40	0.27
Squarespot rockfish	3	3	100	0.27	0.44	0.36
Starry rockfish	9	9	100	0.24	0.69	0.39
Vermilion rockfish	43	43	100	0.14	0.54	0.29
Yellowtail rockfish	2	2	100	0.30	0.35	0.33
ALL SPECIES	160	158	99	0.13	0.73	0.33

TABLE D-20

Summary of selenium concentrations (ppm) in sanddab and rockfish tissues by station/zone. Data are summarized over all samples collected during the April and October surveys from October 1995 through October 2013. CI=confidence interval.

	Sanddab Liver Tissues				Rockfish Muscle Tissues	
	Zone 1	**Zone 2**	**Zone 3**	**Zone 4**	**RF1**	**RF2**
Total	60	82	58	58	71	77
Detected	60	82	58	58	69	77
Frequency	100	100	100	100	97	100
Minimum	0.26	0.44	0.39	0.18	0.13	0.13
Median	1.00	1.03	0.96	1.00	0.34	0.30
Maximum	3.51	4.37	3.73	2.77	0.73	0.55
Mean	1.17	1.31	1.16	1.15	0.36	0.31
95% CI	0.18	0.19	0.18	0.14	0.03	0.02

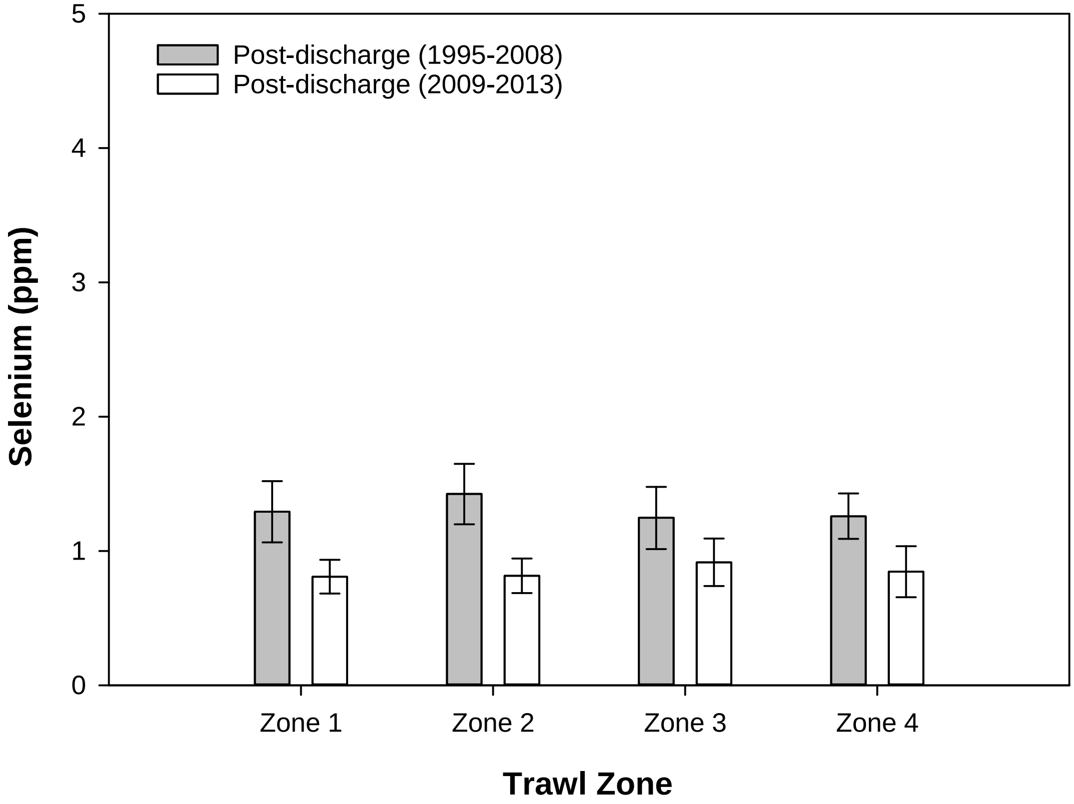

FIGURE D-33

Comparisons of selenium concentrations in sanddab liver tissues by trawl zone for all surveys (April and October) from 1995 through 2013. Data are means +/- 95% confidence intervals.

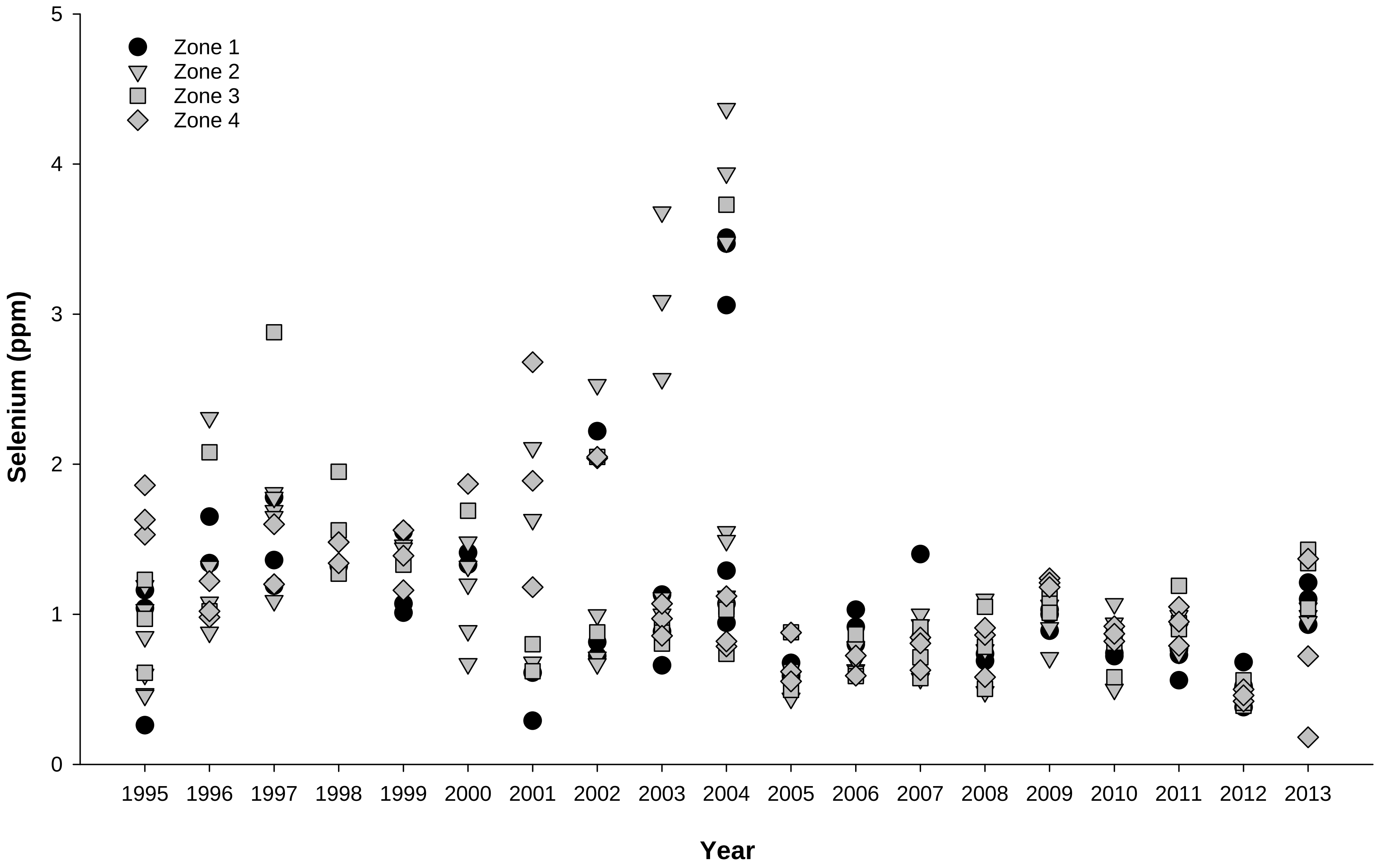

FIGURE D-34

Selenium concentrations detected in sanddab guild liver tissues for trawl Zone 1 versus Zones 2-4 for October surveys from 1995 through 2013.

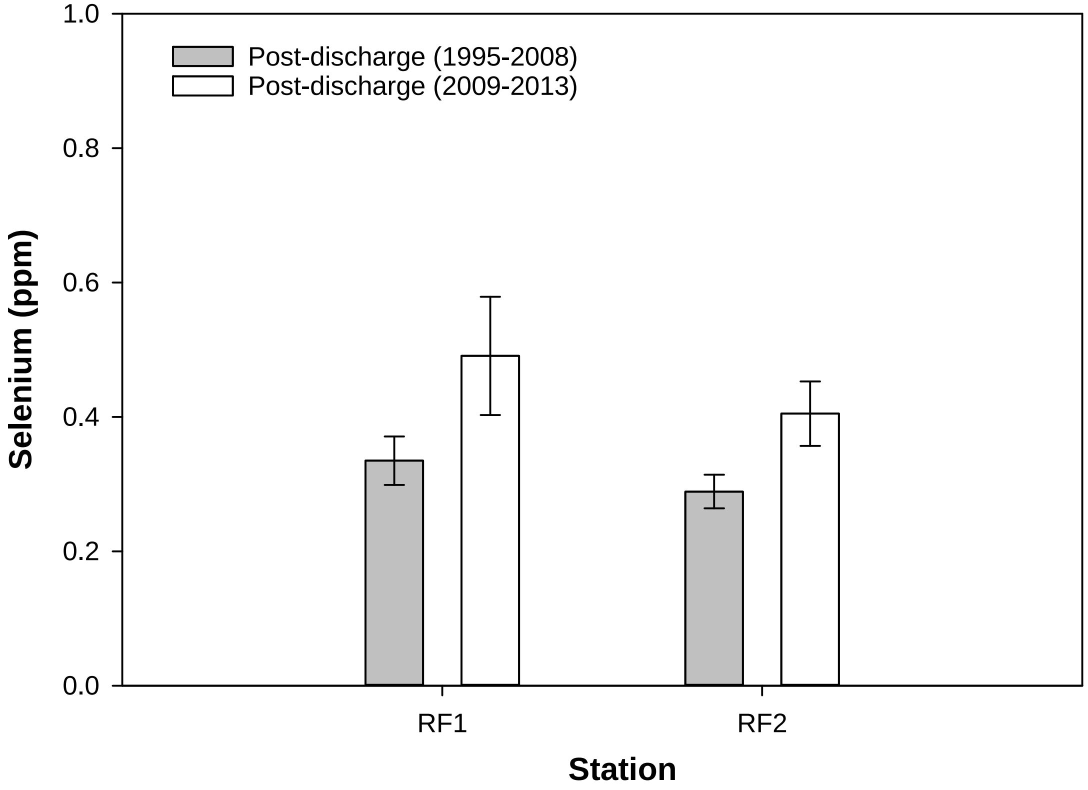

FIGURE D-35

Comparisons of selenium concentrations in rockfish muscle tissues by rig fishing station for all surveys (April and October) from 1995 through 2013. Data are means +/- 95% confidence intervals.

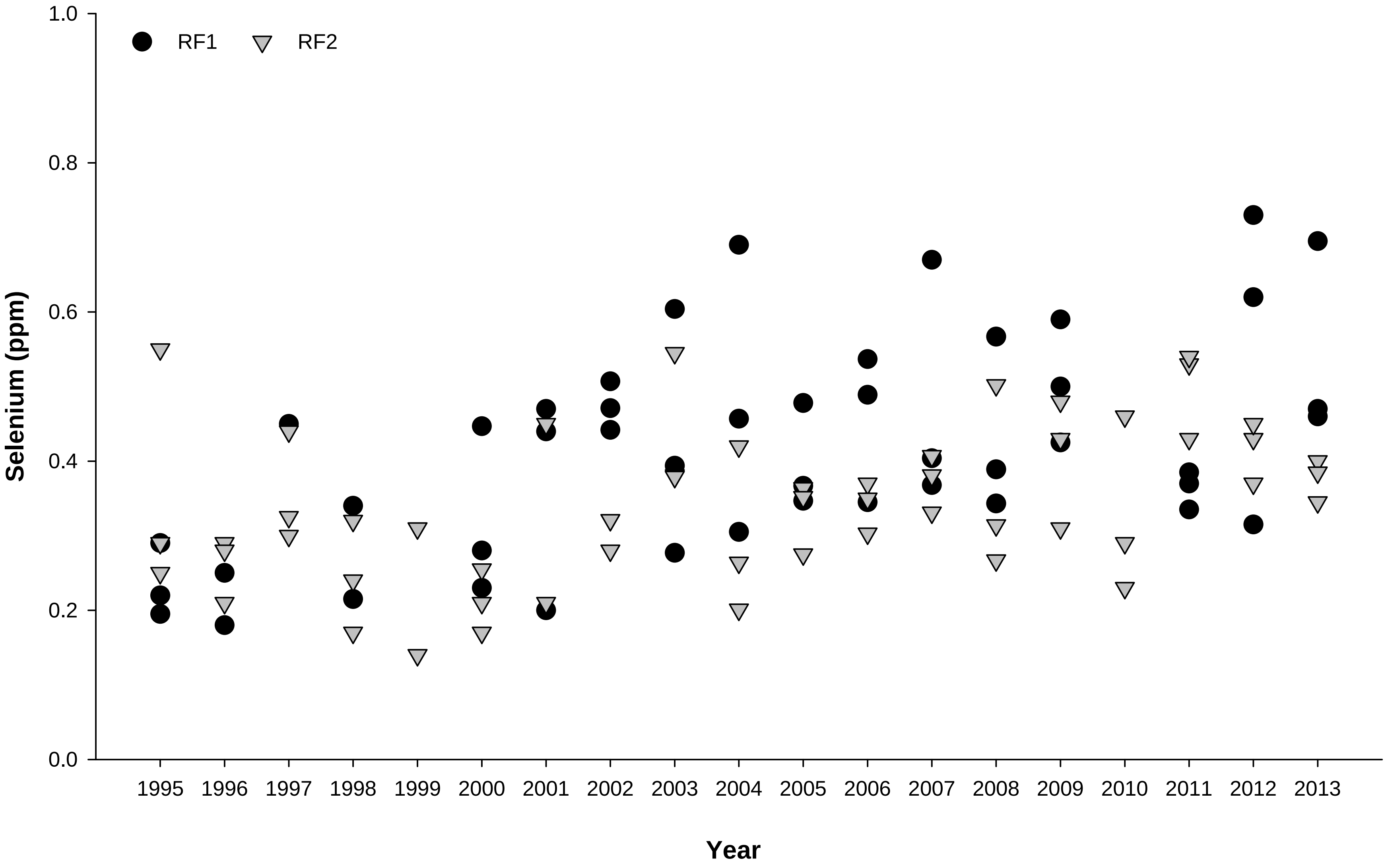

FIGURE D-36

Selenium concentrations detected in rockfish muscle tissues for rig fishing station RF1 versus RF2 for October surveys from 1995 through 2013.

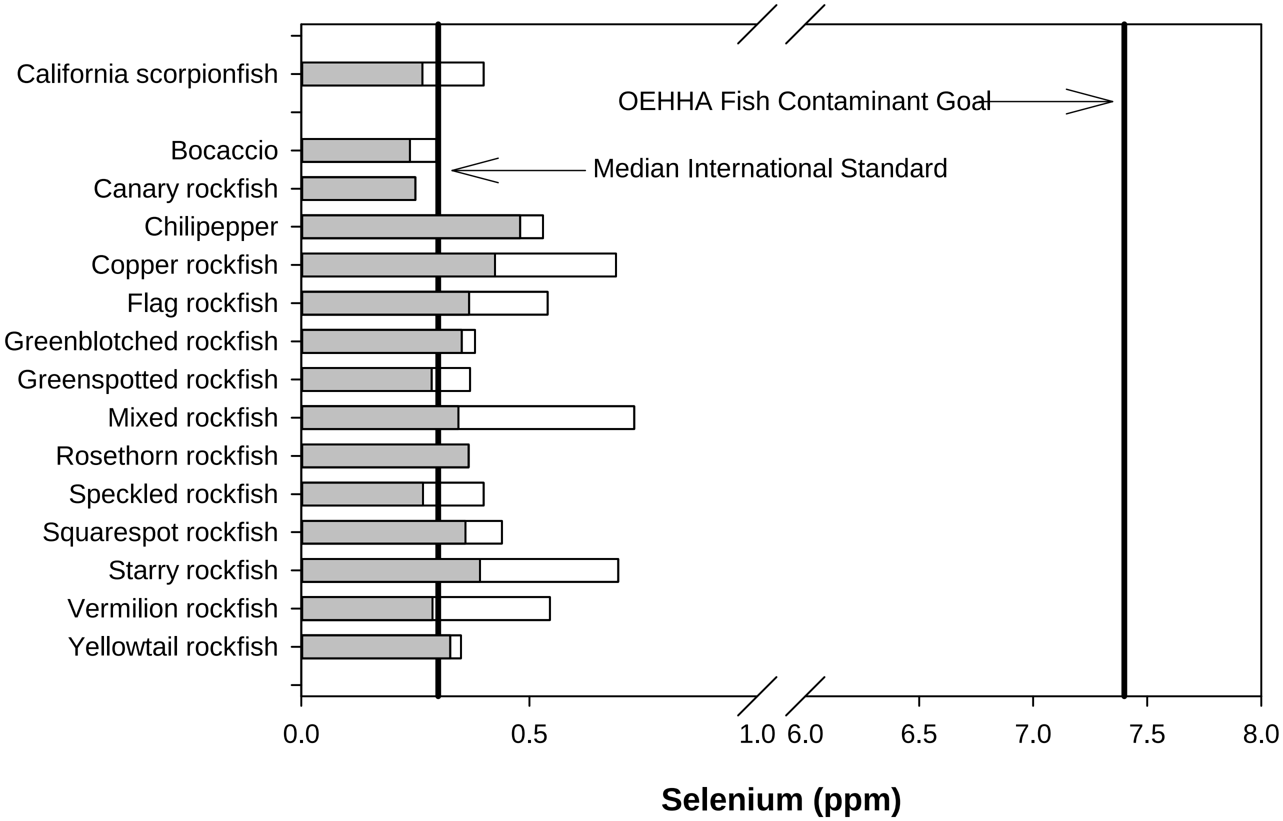

FIGURE D-37

Mean and maximum concentrations of selenium in muscle tissues of all fishes collected off San Diego at rig fishing stations compared to the median international standard (from Mearns et al. 1991) and the OEHHA fish contaminant goal (Klasing and Brodberg 2008). See Table D-19 for sample sizes.

TABLE D-21

Summary of silver concentrations (ppm) in liver and muscle tissue samples for each fish species sampled from October 1995 through October 2013. Data are summarized for liver tissues from trawl stations and muscle tissues from rig fishing stations during all surveys (April and October); nd=not detected.

Species	Total	Detect	Freq	Min	Max	Mean
Liver Tissues (Trawl Zones)						
California scorpionfish	112	7	6	0.68	1.12	0.85
Dover sole	3	0	0	nd	nd	nd
English sole	25	17	68	0.06	0.49	0.18
Flag rockfish	2	1	50	0.68	0.68	0.68
Greenblotched rockfish	3	0	0	nd	nd	nd
Greenspotted rockfish	3	0	0	nd	nd	nd
Halfbanded rockfish	3	0	0	nd	nd	nd
Hornyhead turbot	1	1	100	0.27	0.27	0.27
Longfin sanddab	86	15	17	0.16	1.14	0.45
Mixed rockfish	3	0	0	nd	nd	nd
Pacific sanddab	167	53	32	0.05	1.66	0.16
Vermilion rockfish	1	0	0	nd	nd	nd
ALL SPECIES	409	94	23	0.05	1.66	0.27
Muscle Tissues (RF Stations)						
Bocaccio	2	0	0	nd	nd	nd
California scorpionfish	12	0	0	nd	nd	nd
Canary rockfish	1	0	0	nd	nd	nd
Chilipepper	2	0	0	nd	nd	nd
Copper rockfish	22	0	0	nd	nd	nd
Flag rockfish	4	0	0	nd	nd	nd
Greenblotched rockfish	3	0	0	nd	nd	nd
Greenspotted rockfish	2	0	0	nd	nd	nd
Mixed rockfish	41	1	2	0.07	0.07	0.07
Rosethorn rockfish	1	0	0	nd	nd	nd
Speckled rockfish	13	1	8	0.50	0.50	0.50
Squarespot rockfish	3	0	0	nd	nd	nd
Starry rockfish	9	0	0	nd	nd	nd
Vermilion rockfish	43	5	12	0.05	0.07	0.06
Yellowtail rockfish	2	0	0	nd	nd	nd
ALL SPECIES	160	7	4	0.05	0.50	0.12

TABLE D-22

Summary of silver concentrations (ppm) in sanddab and rockfish tissues by station/zone. Data are summarized over all samples collected during the April and October surveys from October 1995 through October 2013. CI=confidence interval.

	Sanddab Liver Tissues				Rockfish Muscle Tissues	
	Zone 1	**Zone 2**	**Zone 3**	**Zone 4**	**RF1**	**RF2**
Total	59	80	56	58	71	77
Detected	18	22	13	15	2	5
Frequency	31	28	23	26	3	6
Minimum	0.059	0.064	0.051	0.056	0.070	0.051
Median	0.129	0.152	0.076	0.080	0.072	0.054
Maximum	0.830	0.940	1.660	1.140	0.074	0.500
Mean	0.211	0.222	0.254	0.216	0.072	0.142
95% CI	0.099	0.099	0.247	0.172	0.004	0.175

FIGURE D-38
Comparisons of silver concentrations in sanddab liver tissues by trawl zone for all surveys (April and October) from 1995 through 2013. Data are means +/- 95% confidence intervals.

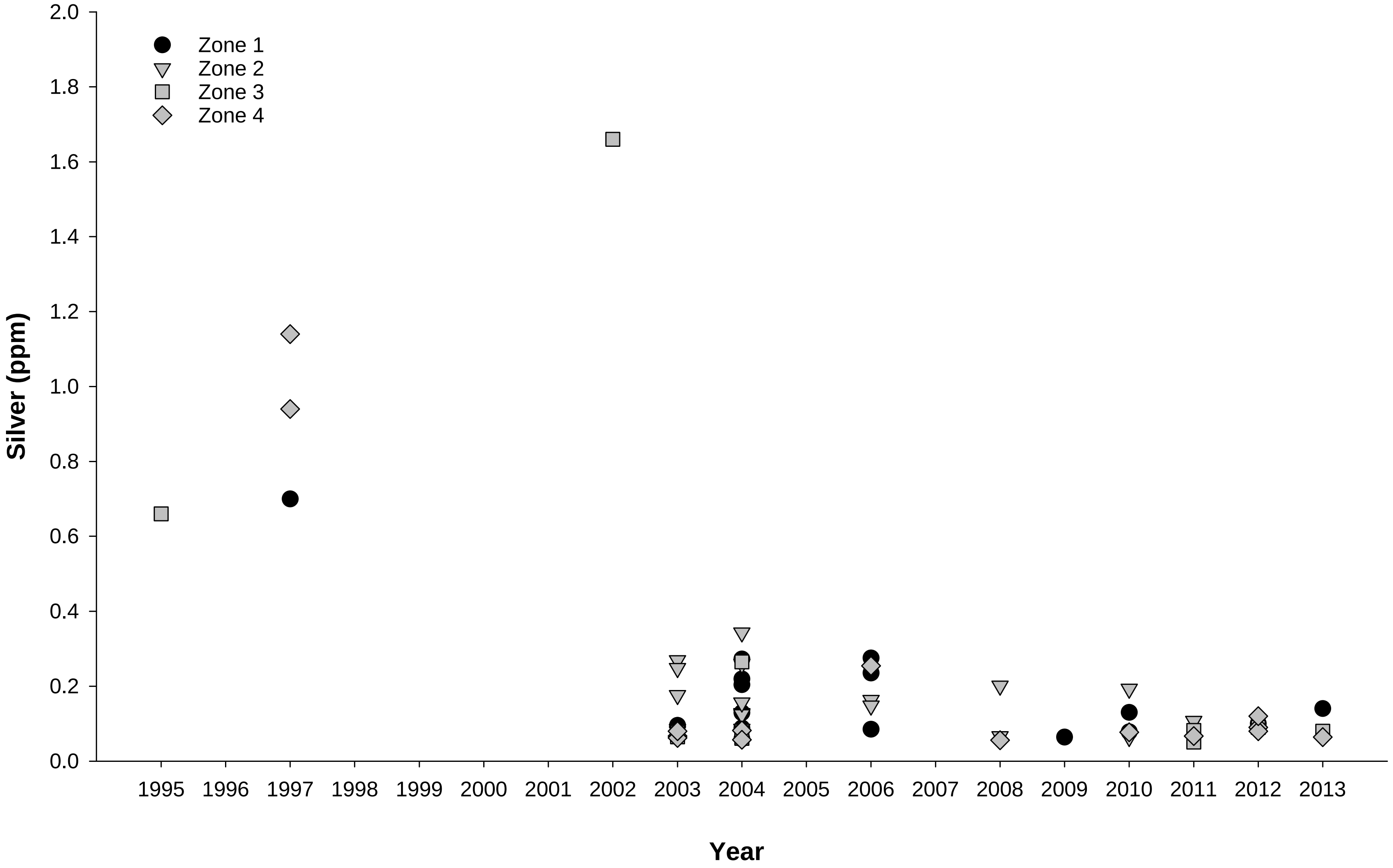

FIGURE D-39

Silver concentrations detected in sanddab guild liver tissues for trawl Zone 1 versus Zones 2-4 for October surveys from 1995 through 2013.

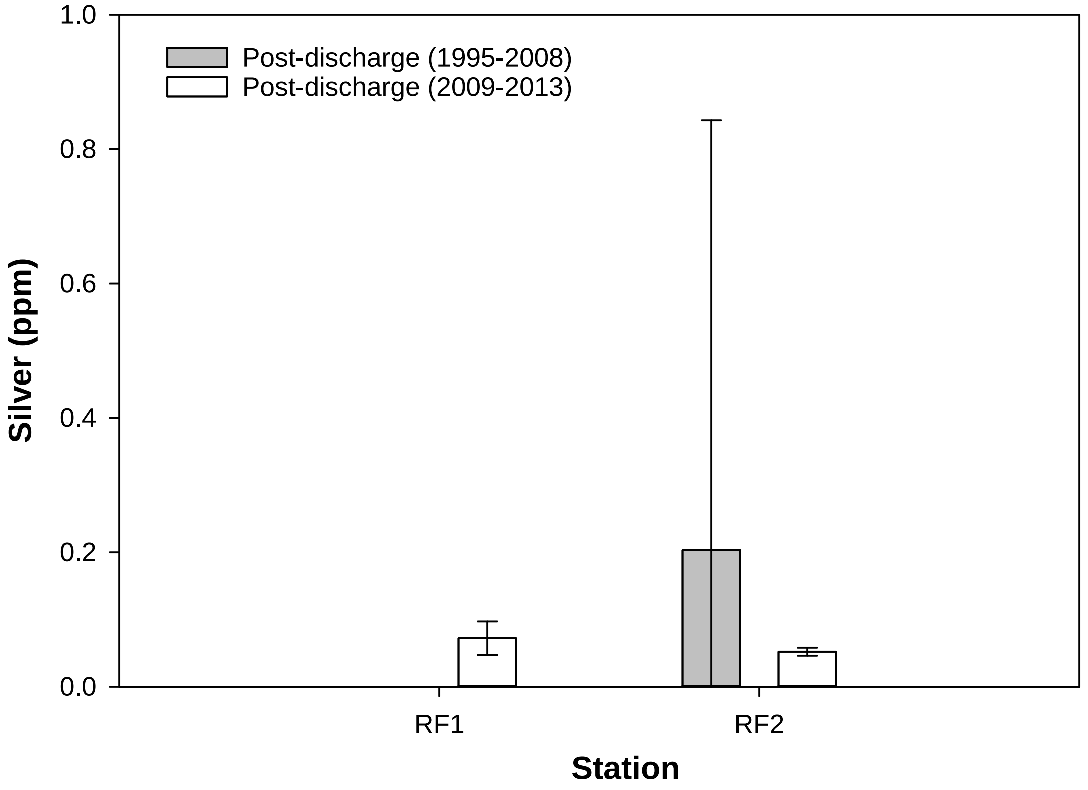

FIGURE D-40

Comparisons of silver concentrations in rockfish muscle tissues by rig fishing station for all surveys (April and October) from 1995 through 2013. Data are means +/- 95% confidence intervals.

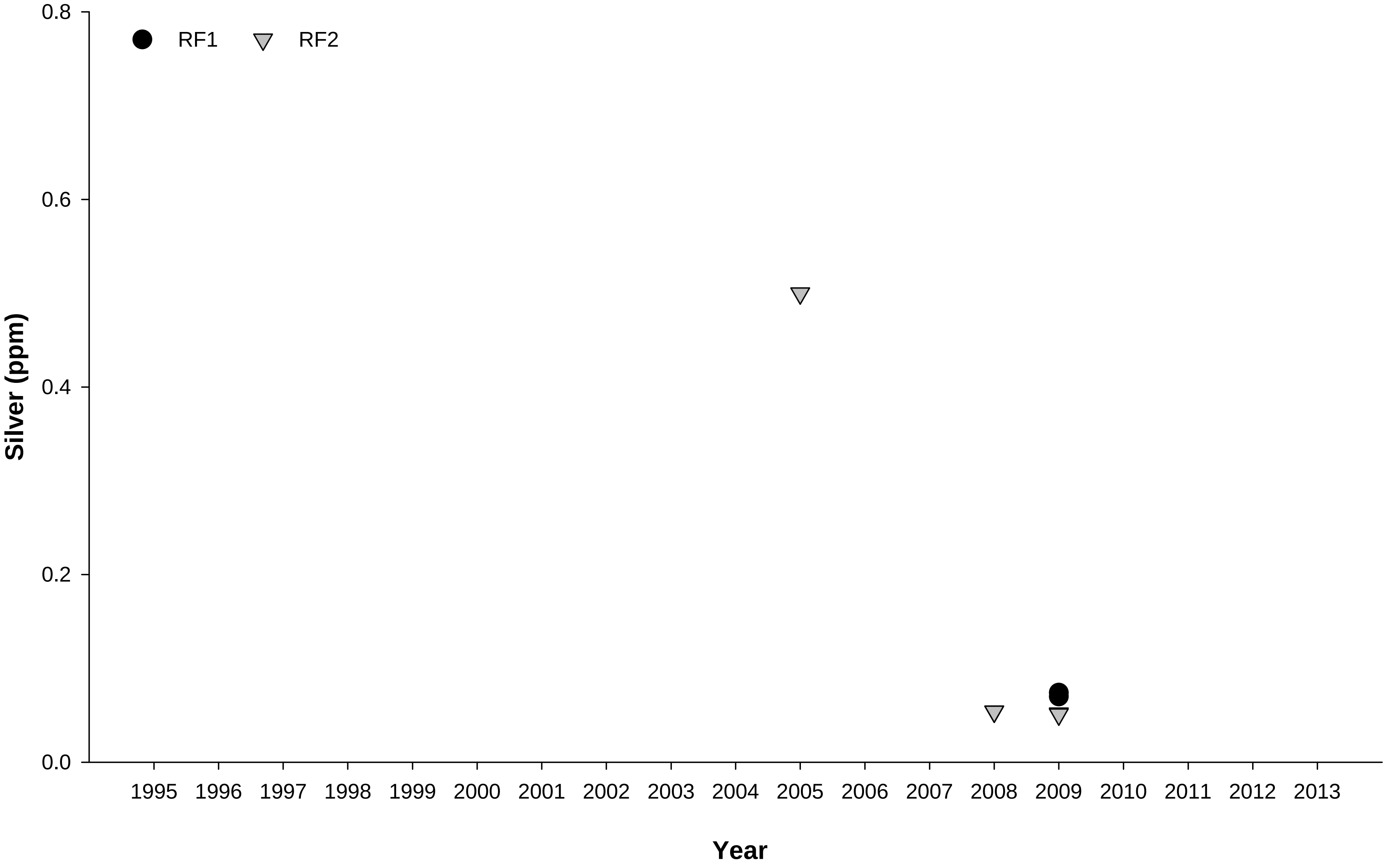

FIGURE D-41

Silver concentrations detected in rockfish muscle tissues for rig fishing station RF1 versus RF2 for October surveys from 1995 through 2013.

Tin: Historically, sources of tin to the ocean environment have included marine paints, municipal sewage, industrial discharges, and aerial fallout (Mearns et al. 1991). These inputs have dropped significantly over the years with the implementation of source control measures and increased regulation. As with silver, detection rates of tin have been relatively low in the tissues of fishes sampled off Point Loma. For example, only 33% and 23% of the liver and muscle tissue samples, respectively, have been found with concentrations high enough to be detected (Table D-23). Concentrations of tin in liver tissues were as high as 90.5 ppm, whereas concentrations in muscle tissues were all less than 2.12 ppm. No discernible spatial or temporal relationships to the Point Loma outfall were observed among the trawl zones or rig fishing sites (Table D-24, Figures D-42 through D-45). All of the muscle tissue concentrations were well below the MIS of 175 ppm for tin (Table D-6).

Zinc: Zinc is the metal with typically the highest metal loads in Point Loma effluent. This metal is used routinely in batteries, vehicle tires, and a variety of industrial, commercial and household products, and it has been found distributed throughout the southern California marine environment. However, source control efforts have resulted in decreasing concentrations of zinc in Point Loma wastewater and bringing average effluent concentrations down to 28 µg/L for 2013.

Zinc was detected in every liver tissue sample from trawl-caught fishes and all but one muscle tissue sample from fishes collected at rig fishing stations from October 1995 through October 2013 (Table D-25). Concentrations of zinc in liver tissues were much higher and more variable than in muscles, with concentrations ranging from 8.61 ppm in a Pacific sanddab sample to 213.00 ppm in a California scorpionfish sample. Zinc concentrations in muscle tissues ranged from 1.02 in a vermilion rockfish sample to 15.20 in a copper rockfish sample. All of the muscle tissue concentrations were well below the MIS of 70 ppm for zinc (Table D-6). Overall, there is no consistent or discernible trend relative to wastewater discharge in space or time for zinc (Table D-26, Figures D-46 through D-49). Although the highest zinc values occurred in rockfishes from station RF1 over several surveys (Figure D-49), the range of values was very narrow and differences did not appear significant (Figure D-48).

Chlorinated Hydrocarbons

Chlorinated hydrocarbons like the pesticide DDT and polychlorinated biphenyl compounds (PCBs) are persistent environmental contaminants with widespread distribution and well known bioaccumulation in southern California. The impact of these synthetic chemicals was most notable in the late 1960s and 1970s when DDT discharged from Whites Point outfall in Los Angeles County accumulated in fish-eating birds and marine mammals causing reproductive

TABLE D-23

Summary of tin concentrations (ppm) in liver and muscle tissue samples for each fish species sampled from October 1995 through October 2013. Data are summarized for liver tissues from trawl stations and muscle tissues from rig fishing stations during all surveys (April and October); nd=not detected.

Species	Total	Detect	Freq	Min	Max	Mean
Liver Tissues (Trawl Zones)						
California scorpionfish	112	2	2	7.40	11.10	9.25
Dover sole	3	0	0	nd	nd	nd
English sole	25	16	64	0.26	2.67	0.97
Flag rockfish	2	0	0	nd	nd	nd
Greenblotched rockfish	3	0	0	nd	nd	nd
Greenspotted rockfish	3	0	0	nd	nd	nd
Halfbanded rockfish	3	0	0	nd	nd	nd
Hornyhead turbot	1	1	100	1.17	1.17	1.17
Longfin sanddab	86	10	12	0.45	1.58	0.83
Mixed rockfish	3	0	0	nd	nd	nd
Pacific sanddab	167	105	63	0.20	90.50	2.59
Vermilion rockfish	1	0	0	nd	nd	nd
ALL SPECIES	409	134	33	0.20	90.50	2.35
Muscle Tissues (RF Stations)						
Bocaccio	2	0	0	nd	nd	nd
California scorpionfish	12	0	0	nd	nd	nd
Canary rockfish	1	0	0	nd	nd	nd
Chilipepper	2	1	50	0.24	0.24	0.24
Copper rockfish	22	6	27	0.58	1.77	1.49
Flag rockfish	4	1	25	0.28	0.28	0.28
Greenblotched rockfish	3	3	100	1.31	2.01	1.63
Greenspotted rockfish	2	1	50	0.24	0.24	0.24
Mixed rockfish	41	8	20	0.36	2.02	0.97
Rosethorn rockfish	1	0	0	nd	nd	nd
Speckled rockfish	13	3	23	0.88	1.08	0.99
Squarespot rockfish	3	0	0	nd	nd	nd
Starry rockfish	9	2	22	0.97	1.55	1.26
Vermilion rockfish	43	10	23	0.21	2.12	0.97
Yellowtail rockfish	2	2	100	1.69	1.71	1.70
ALL SPECIES	160	37	23	0.21	2.12	1.11

TABLE D-24

Summary of tin concentrations (ppm) in sanddab and rockfish tissues by station/zone. Data are summarized over all samples collected during the April and October surveys from October 1995 through October 2013. CI=confidence interval.

	Sanddab Liver Tissues				Rockfish Muscle Tissues	
	Zone 1	**Zone 2**	**Zone 3**	**Zone 4**	**RF1**	**RF2**
Total	59	80	56	58	71	77
Detected	30	33	27	25	17	20
Frequency	51	41	48	43	24	26
Minimum	0.27	0.20	0.21	0.20	0.21	0.24
Median	0.79	1.25	1.82	1.70	1.36	1.05
Maximum	90.50	4.93	4.80	4.74	2.01	2.12
Mean	4.35	1.60	2.01	1.70	1.13	1.09
95% CI	5.84	0.43	0.57	0.52	0.30	0.29

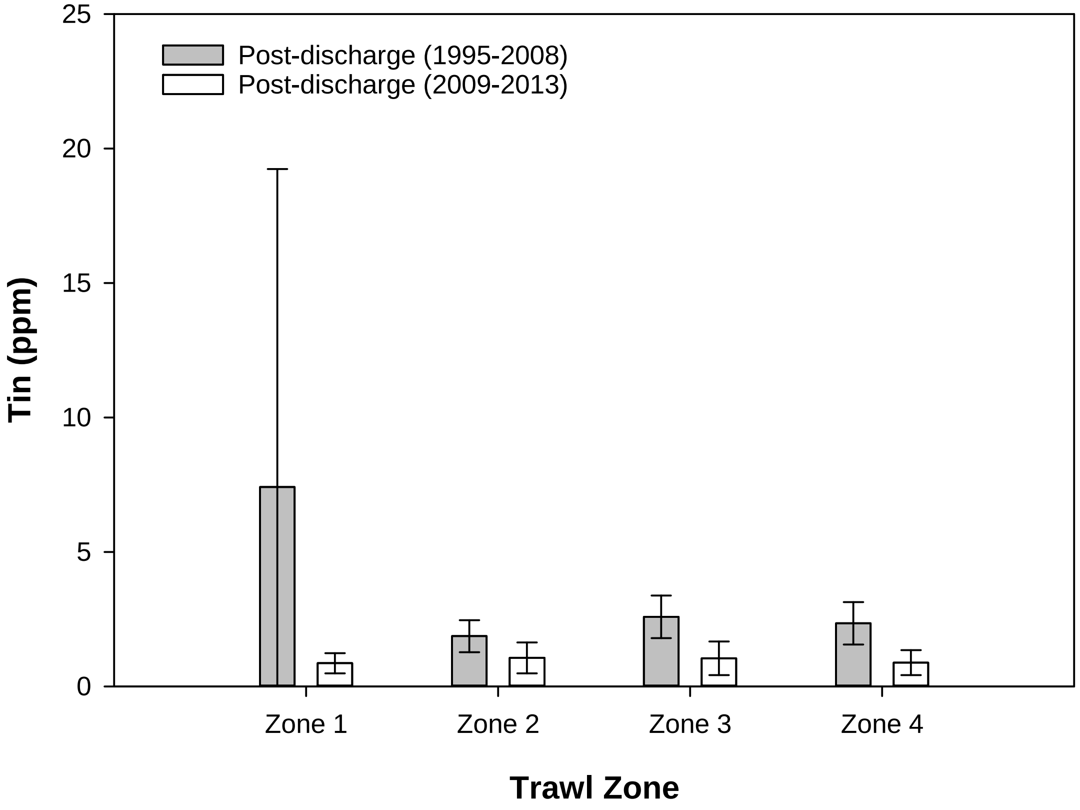

FIGURE D-42
Comparisons of tin concentrations in sanddab liver tissues by trawl zone for all surveys (April and October) from 1995 through 2013. Data are means +/- 95% confidence intervals.

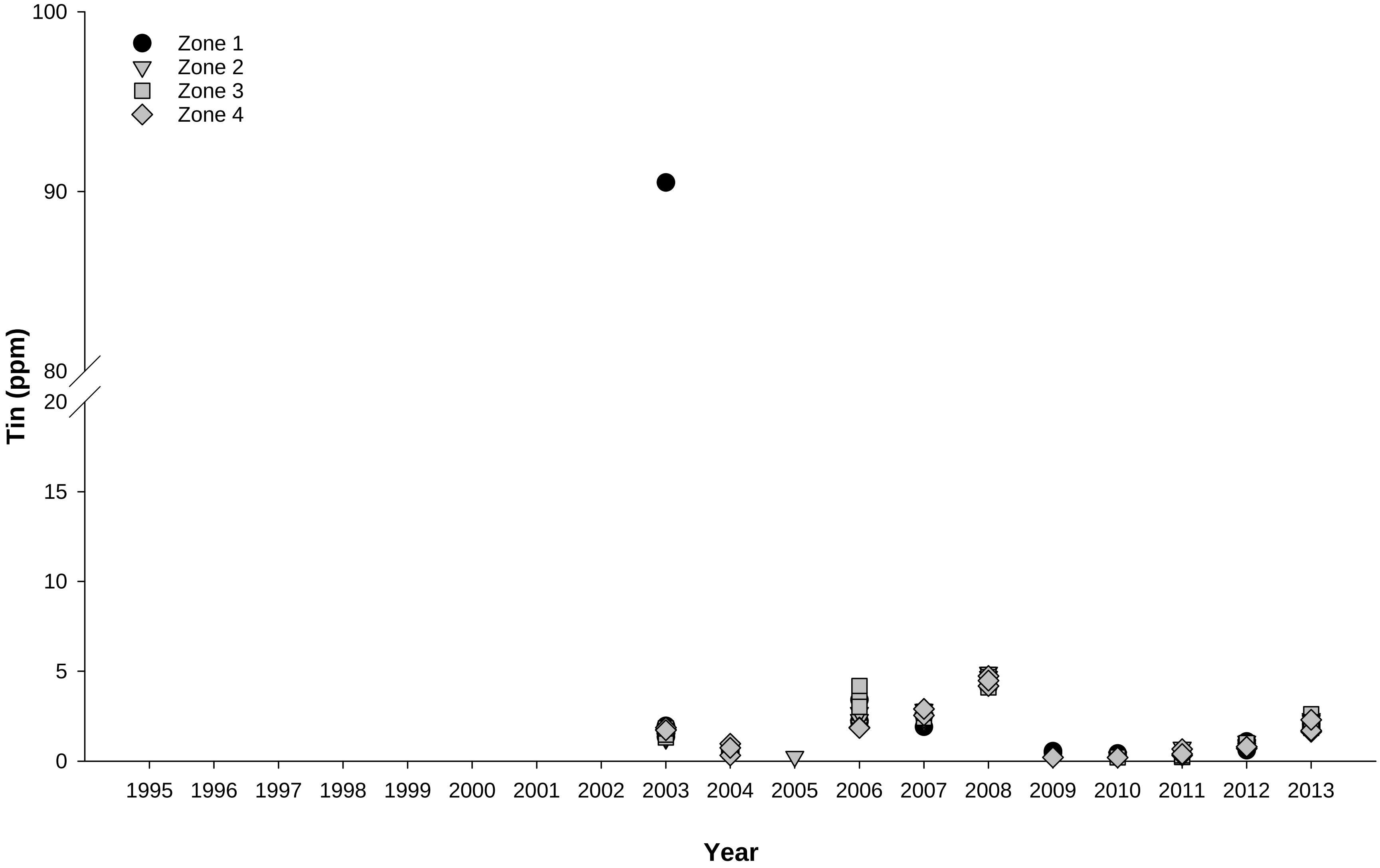

FIGURE D-43

Tin concentrations detected in sanddab guild liver tissues for trawl Zone 1 versus Zones 2-4 for October surveys from 1995 through 2013.

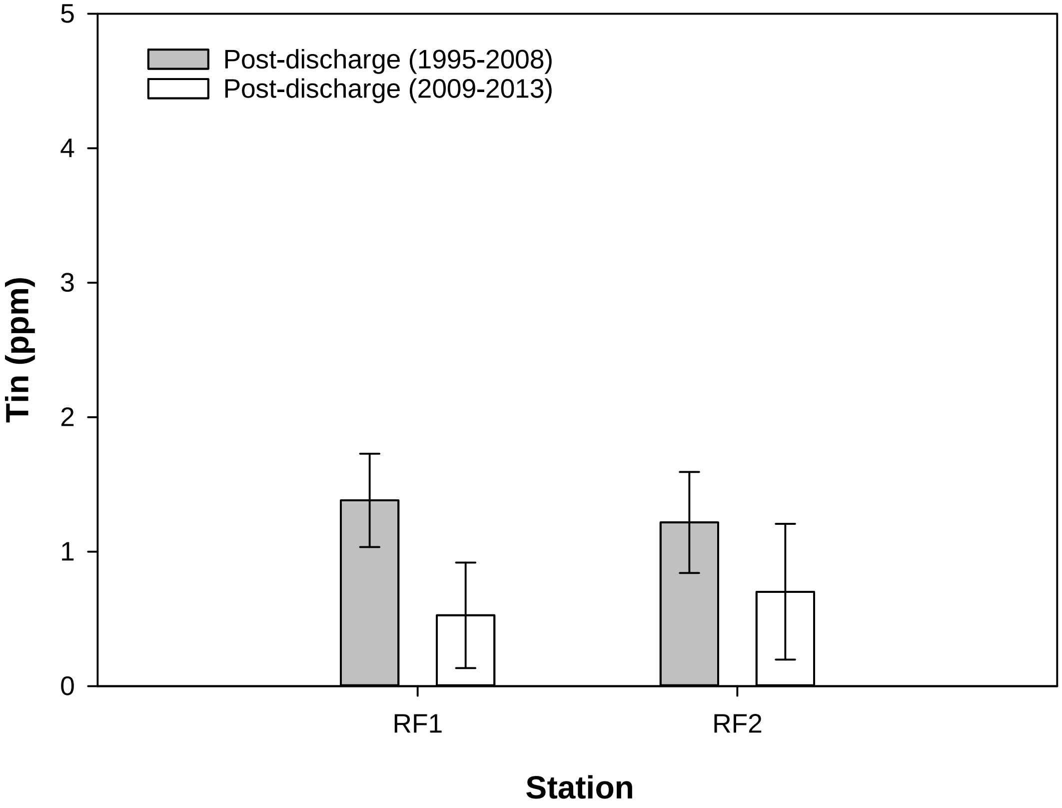

FIGURE D-44
Comparisons of tin concentrations in rockfish muscle tissues by rig fishing station for all surveys (April and October) from 1995 through 2013. Data are means +/- 95% confidence intervals.

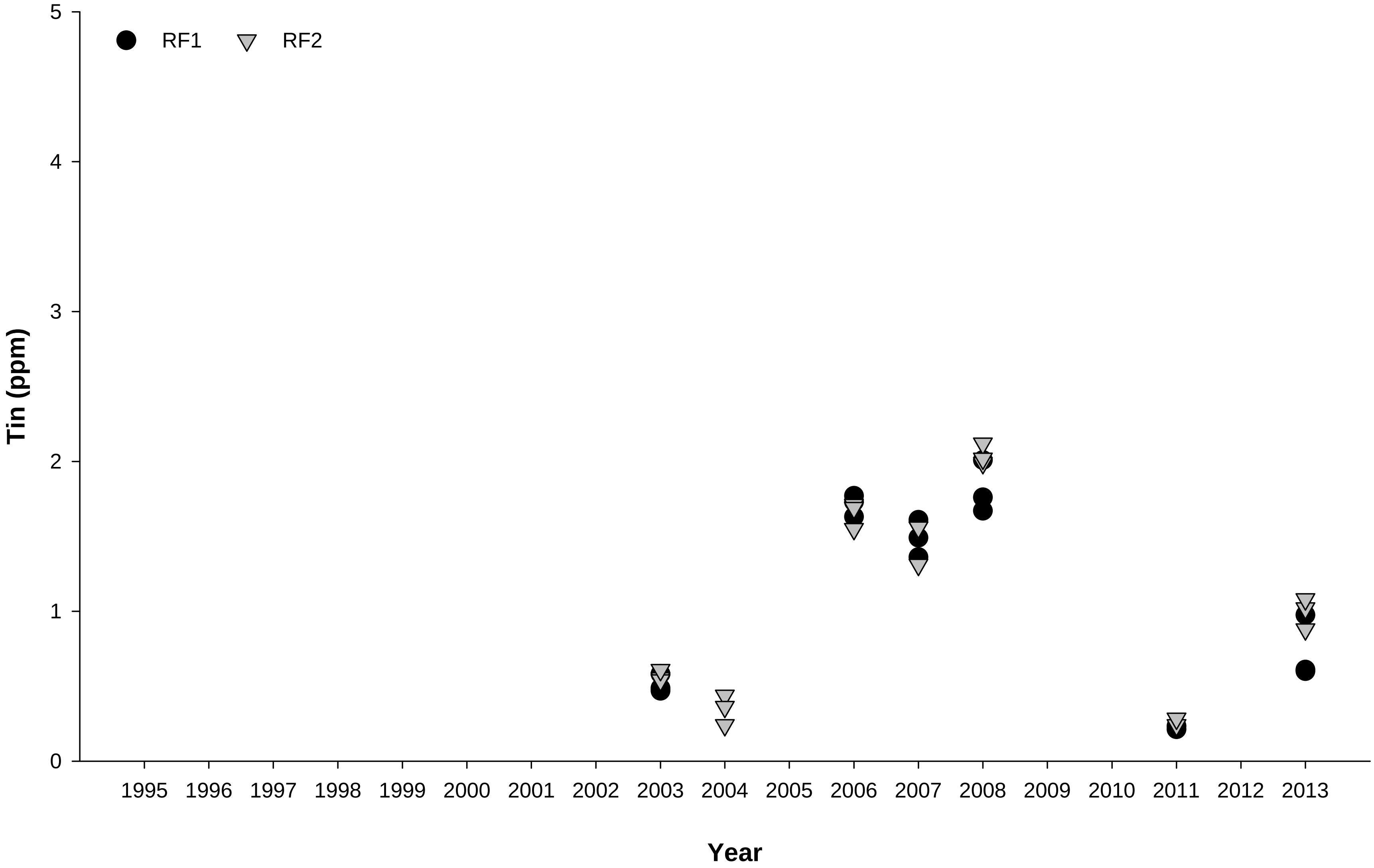

FIGURE D-45

Tin concentrations detected in rockfish muscle tissues for rig fishing stations RF1 versus RF2 for October surveys from 1995 through 2013.

TABLE D-25

Summary of zinc concentrations (ppm) in liver and muscle tissue samples for each fish species sampled from October 1995 through October 2013. Data are summarized for liver tissues from trawl stations and muscle tissues from rig fishing stations during all surveys (April and October); nd=not detected.

Species	Total	Detect	Freq	Min	Max	Mean
Liver Tissues (Trawl Zones)						
California scorpionfish	112	112	100	22.90	213.00	101.82
Dover sole	3	3	100	19.40	40.20	29.50
English sole	25	25	100	27.60	86.90	51.06
Flag rockfish	2	2	100	53.00	65.70	59.35
Greenblotched rockfish	3	3	100	45.50	66.80	55.60
Greenspotted rockfish	3	3	100	46.80	72.80	61.67
Halfbanded rockfish	3	3	100	12.90	74.40	42.67
Hornyhead turbot	1	1	100	65.10	65.10	65.10
Longfin sanddab	86	86	100	10.30	80.20	22.95
Mixed rockfish	3	3	100	47.00	118.00	73.87
Pacific sanddab	167	167	100	8.61	41.40	24.71
Vermilion rockfish	1	1	100	33.90	33.90	33.90
ALL SPECIES	409	409	100	8.61	213.00	48.38
Muscle Tissues (RF Stations)						
Bocaccio	2	2	100	3.15	3.35	3.25
California scorpionfish	11	11	100	3.34	6.91	4.09
Canary rockfish	1	1	100	3.82	3.82	3.82
Chilipepper	2	2	100	3.67	3.72	3.69
Copper rockfish	22	22	100	2.01	15.20	5.31
Flag rockfish	4	4	100	2.29	4.38	3.24
Greenblotched rockfish	3	3	100	4.46	5.09	4.70
Greenspotted rockfish	2	2	100	3.29	3.88	3.58
Mixed rockfish	41	41	100	1.69	10.00	3.53
Rosethorn rockfish	1	1	100	2.91	2.91	2.91
Speckled rockfish	13	12	92	2.08	4.11	3.04
Squarespot rockfish	3	3	100	3.24	3.37	3.32
Starry rockfish	9	9	100	1.85	11.10	4.28
Vermilion rockfish	43	43	100	1.02	14.30	3.78
Yellowtail rockfish	2	2	100	3.77	4.28	4.02
ALL SPECIES	159	158	99	1.02	15.20	3.91

TABLE D-26

Summary of zinc concentrations (ppm) in sanddab and rockfish tissues by station/zone. Data are summarized over all samples collected during the April and October surveys from October 1995 through October 2013. CI=confidence interval.

	Sanddab Liver Tissues				Rockfish Muscle Tissues	
	Zone 1	**Zone 2**	**Zone 3**	**Zone 4**	**RF1**	**RF2**
Total	59	80	56	58	71	77
Detected	59	80	56	58	71	76
Frequency	100	100	100	100	100	99
Minimum	8.61	14.90	13.80	15.40	1.69	1.02
Median	21.70	21.95	24.40	23.30	3.71	3.34
Maximum	59.40	41.40	80.20	39.70	15.20	14.30
Mean	22.38	23.09	26.82	24.67	4.13	3.67
95% CI	1.77	1.20	2.89	1.62	0.48	0.41

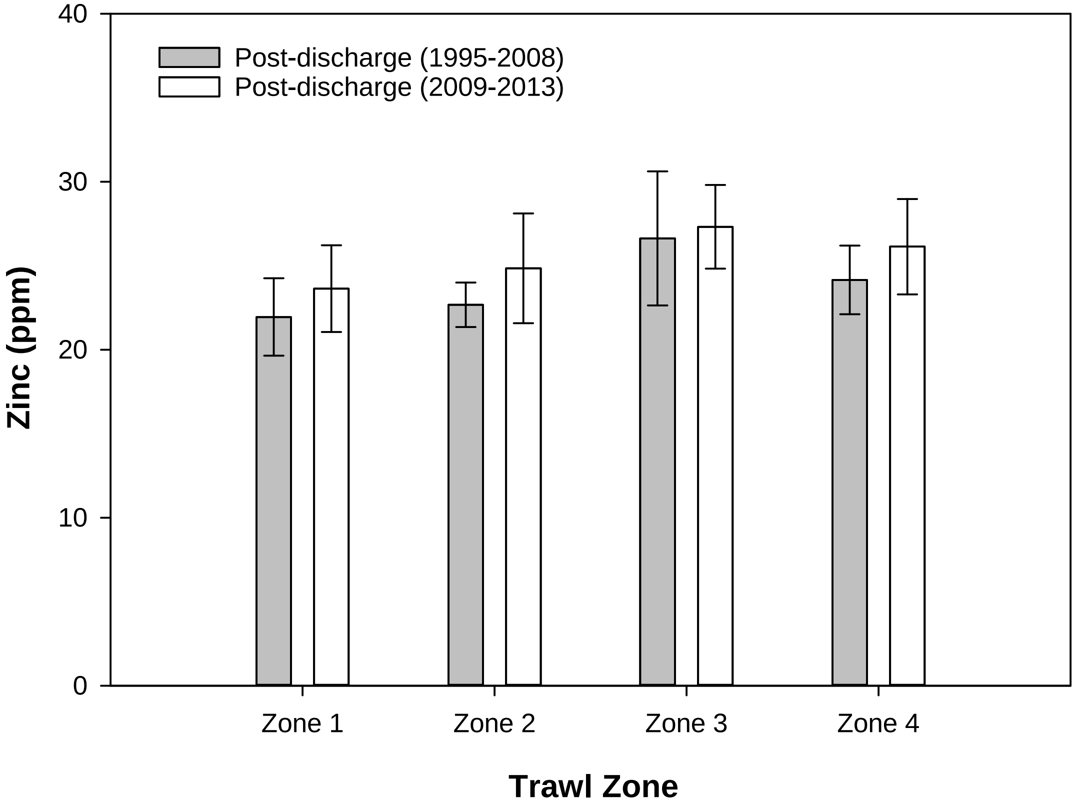

FIGURE D-46
Comparisons of zinc concentrations in sanddab liver tissues by trawl zone for all surveys (April and October) from 1995 through 2013. Data are means +/- 95% confidence intervals.

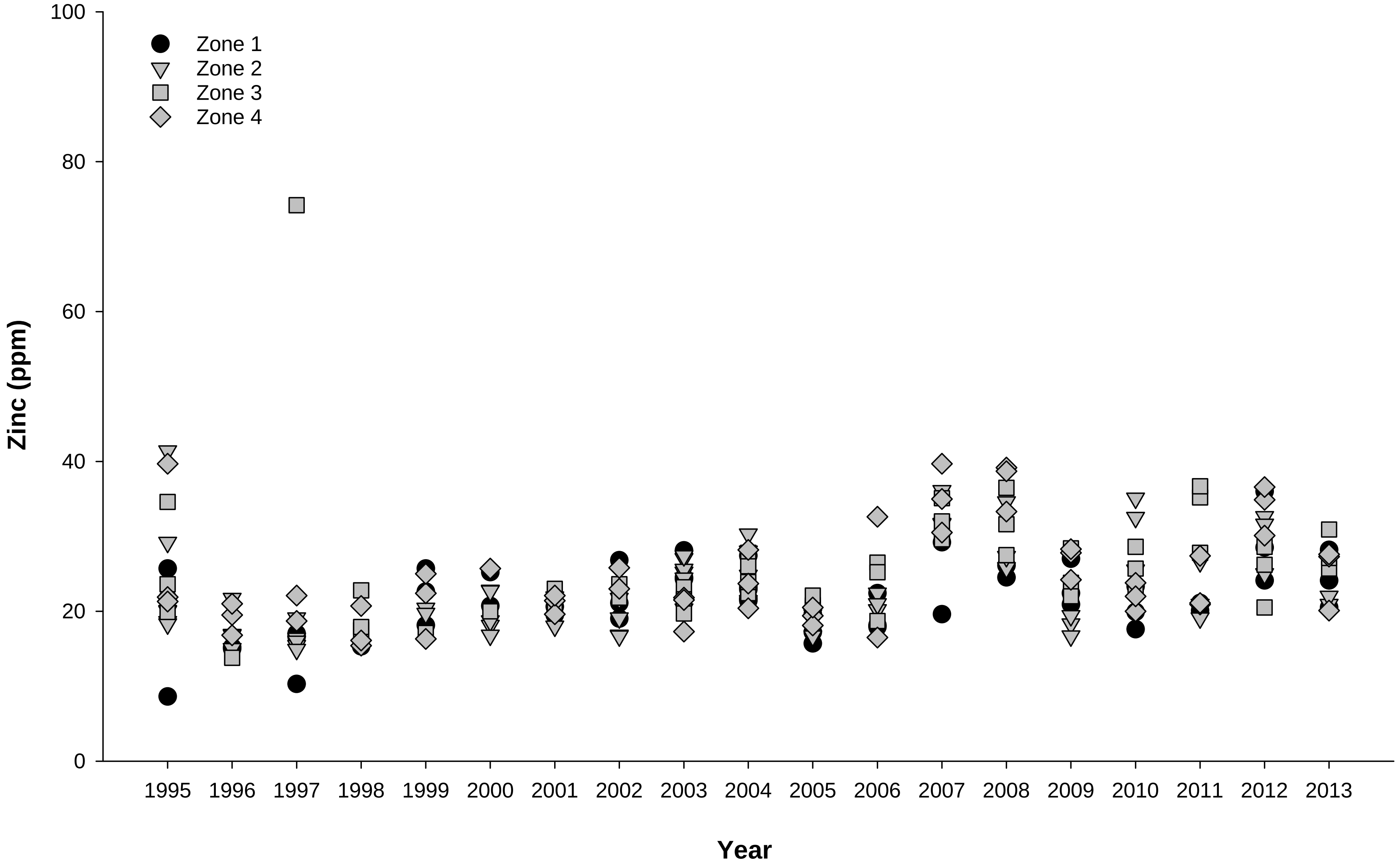

FIGURE D-47

Zinc concentrations detected in sanddab guild liver tissues for trawl Zone 1 versus Zones 2-4 for October surveys from 1995 through 2013.

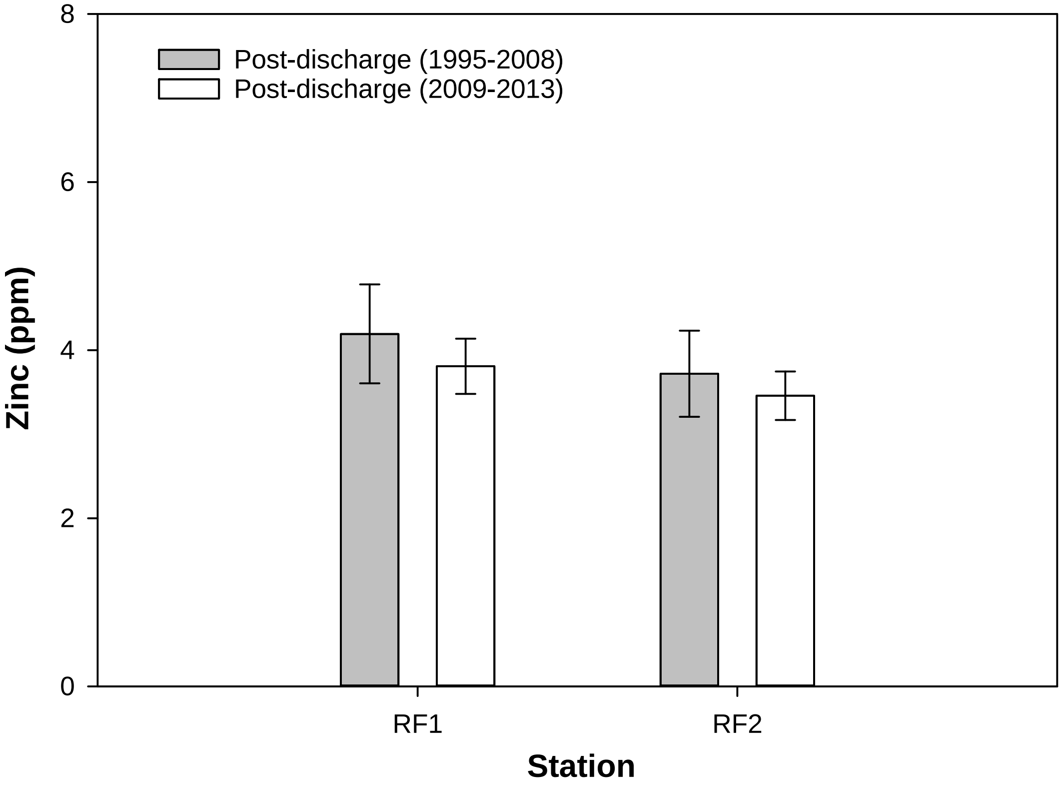

FIGURE D-48
Comparisons of zinc concentrations in rockfish muscle tissues by rig fishing station for all surveys (April and October) from 1995 through 2013. Data are means +/- 95% confidence intervals.

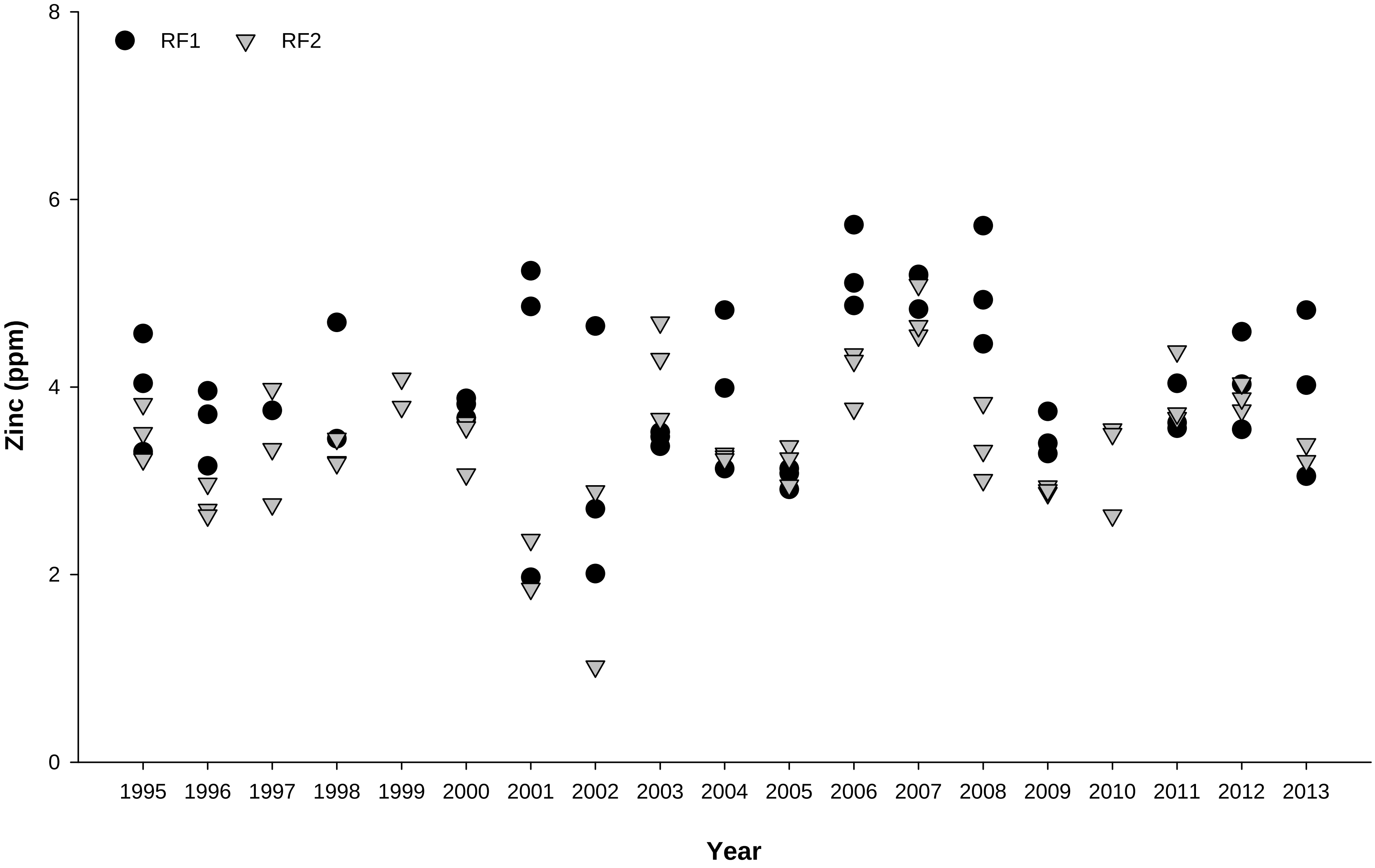

FIGURE D-49

Zinc concentrations detected in rockfish muscle tissues for rig fishing station RF1 versus RF2 for October surveys from 1995 through 2013.

effects and population declines (Mearns et al. 1991). Since the ban of these chemicals in the early 1970s, environmental levels have steadily decreased. Most current residues in marine animals are from the reservoir of these contaminants still present in marine sediments (i.e., legacy contaminants), especially off the Palos Verdes Peninsula and in some local bays and harbors.

DDT metabolites were not detected in Point Loma effluent prior to 2006, and have been detected very rarely since due to improvements in technology. Even with these improvements, PCBs still remain undetected. DDT was detected at a rate of 53% in sediments at primary core stations off Point Loma, although at low levels compared to elsewhere in southern California and without any apparent outfall-related effect on benthic invertebrates (see City of San Diego 2014a). PCBs were only found intermittently in sediments off Point Loma (detection rate =11% at primary core stations), with the highest values occurring near the LA-5 dredge materials disposal site (see City of San Diego 2014a).

DDT and other Chlorinated Pesticides: DDT was found in all species of fish collected off Point Loma with detections rates of 99% for liver tissues from trawl-caught fishes and 97% for muscle tissues from fishes collected at rig fishing stations (Table D-27). Total DDT concentrations in Point Loma area fish tissues were highly variable, with values ranging from 2.1 to 23,336 ppb in liver tissues and from 0.1 to about 217 ppb in muscle tissues. The highest concentration was found in a liver sample from California scorpionfish collected in trawl zone 2 (City of San Diego 2007). There does not appear to be any relationship between DDT levels and distance from the Point Loma outfall (Table D-28, Figures D-50 through D-53). DDT concentrations in fish tissues appear to be declining over time at all stations and zones. This pattern corresponds to changes observed in benthic sediments as well (see Appendix C.1, City of San Diego 2014a). Total DDT levels exceeded the OEHHA fish contaminant goal of 21 ppb in tissue samples from at least six species, including California scorpionfish, copper rockfish, flag rockfish, starry rockfish, vermilion rockfish, and mixed rockfish (>1 species/sample), but never exceeded the USFDA action limit of 5,000 ppb (Table D-6 and Figure D-54). As with several of the metals, levels of DDT in exceedance of the OEHHA fish contaminant goal are not uncommon in sport fish from other areas of the San Diego region, including the Coronado Islands (see City of San Diego 2014c and references therein).

Several other chlorinated pesticides have been detected in fish tissues off Point Loma, but their detection rates and concentrations have consistently been low in muscle tissues, and highly variable in liver tissues (Table D-29). For example, overall detection rates for hexachlorobenzene and total chlordane were both 54%, whereas detection rates for (beta) endosulphan, dieldrin, endrin, mirex, total HCH were below 5%, and aldrin, (alpha) endosulfan, endosulfan sulfate, and toxaphene have never been detected. Concentrations of these pesticides were also highly

TABLE D-27

Summary of total DDT concentrations (ppb) in liver and muscle tissue samples for each fish species sampled from October 1995 through October 2013. Data are summarized for liver tissues from trawl stations and muscle tissues from rig fishing stations during all surveys (April and October); nd=not detected.

Species	Total	Detect	Freq	Min	Max	Mean
Liver Tissues (Trawl Zones)						
Bigmouth sole	3	3	100	88.0	349.0	222.3
California scorpionfish	117	117	100	137.8	23366.0	1700.1
Dover sole	9	9	100	37.0	425.0	130.5
English sole	25	25	100	2.1	2713.2	307.5
Flag rockfish	2	2	100	900.0	1930.0	1415.0
Greenblotched rockfish	3	3	100	140.0	749.5	500.7
Greenspotted rockfish	3	3	100	228.1	961.3	482.5
Halfbanded rockfish	3	3	100	180.0	370.0	290.0
Hornyhead turbot	4	4	100	4.5	220.0	104.1
Longfin sanddab	96	94	98	350.1	3800.0	1291.1
Mixed rockfish	4	4	100	247.7	1842.0	687.4
Mixed sanddabs	1	1	100	750.7	750.7	750.7
Pacific sanddab	172	171	99	13.5	1844.7	424.0
Squarespot rockfish	1	1	100	210.0	210.0	210.0
Vermilion rockfish	1	1	100	498.5	498.5	498.5
ALL SPECIES	444	441	99	2.1	23366.0	937.8
Muscle Tissues (RF Stations)						
Bocaccio	2	2	100	6.8	9.9	8.3
California scorpionfish	12	12	100	1.6	69.6	20.9
Canary rockfish	1	1	100	14.0	14.0	14.0
Chilipepper	2	2	100	5.2	6.9	6.0
Copper rockfish	22	21	95	0.1	217.3	33.0
Flag rockfish	4	4	100	1.3	71.0	31.6
Greenblotched rockfish	3	3	100	4.2	9.7	7.7
Greenspotted rockfish	2	2	100	3.0	13.3	8.1
Mixed rockfish	41	39	95	0.9	82.6	18.1
Rosethorn rockfish	1	1	100	2.3	2.3	2.3
Speckled rockfish	13	12	92	1.5	16.0	6.4
Squarespot rockfish	3	3	100	12.4	20.0	15.8
Starry rockfish	9	9	100	17.0	118.8	55.4
Vermilion rockfish	43	42	98	0.7	40.1	9.8
Yellowtail rockfish	2	2	100	3.6	6.3	4.9
ALL SPECIES	160	155	97	0.1	217.3	18.8

TABLE D-28

Summary of total DDT concentrations (ppb) in sanddab and rockfish tissues by station/zone. Data are summarized over all samples collected during the April and October surveys from October 1995 through October 2013. CI=confidence interval.

	Sanddab Liver Tissues				Rockfish Muscle Tissues	
	Zone 1	**Zone 2**	**Zone 3**	**Zone 4**	**RF1**	**RF2**
Total	65	86	59	59	71	77
Detected	65	83	59	59	68	75
Frequency	100	97	100	100	96	97
Minimum	13.5	106.9	93.8	44.8	0.1	0.7
Median	551.6	518.5	462.6	534.5	9.3	8.2
Maximum	2280.0	2242.2	2400.0	3800.0	217.3	118.8
Mean	765.9	680.8	657.6	839.5	20.8	16.5
95% CI	145.2	101.2	133.8	192.9	7.7	5.0

FIGURE D-50

Comparisons of total DDT concentrations in sanddab liver tissues by trawl zone for all surveys (April and October) from 1995 through 2013. Data are means +/- 95% confidence intervals.

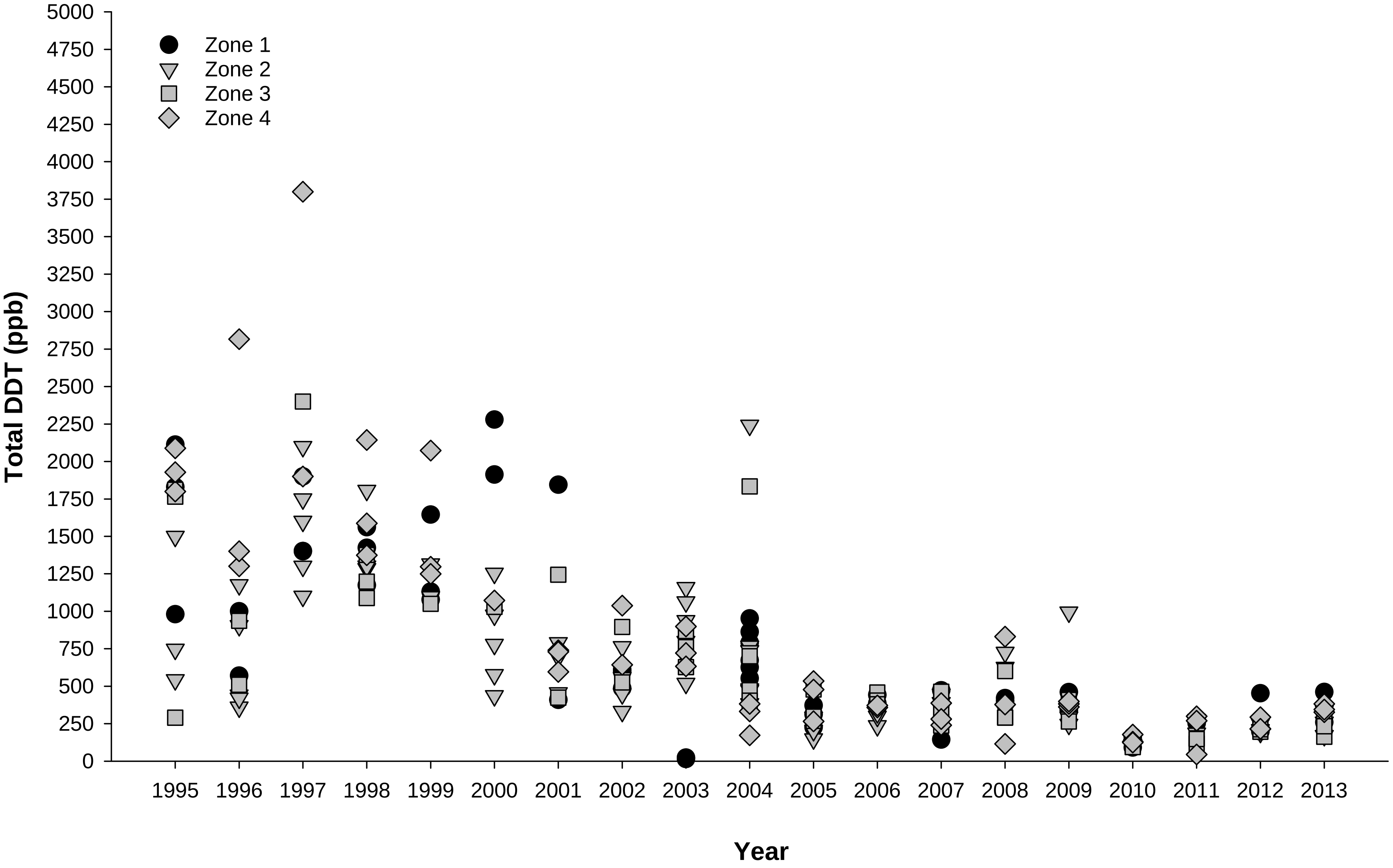

FIGURE D-51
Total DDT concentrations detected in sanddab guild liver tissues for trawl Zone 1 versus Zones 2-4 for October surveys from 1995 through 2013.

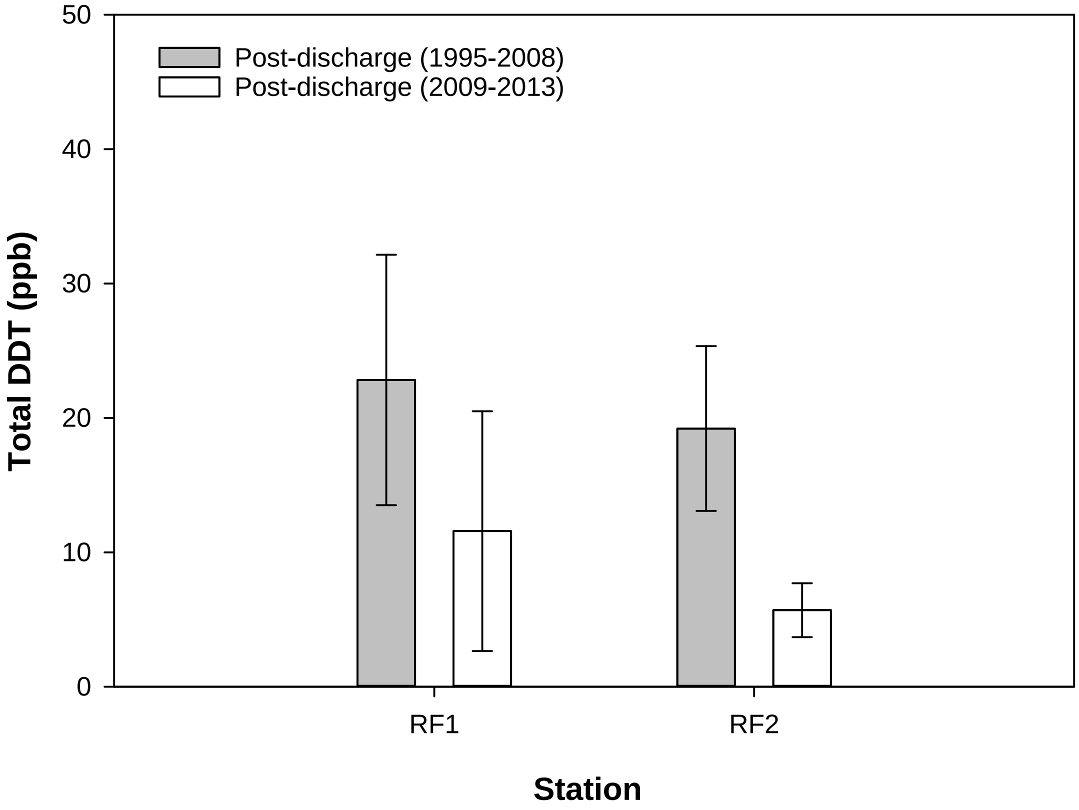

FIGURE D-52
Comparisons of total DDT concentrations in rockfish muscle tissues by rig fishing station for all surveys (April and October) from 1995 through 2013. Data are means +/- 95% confidence intervals.

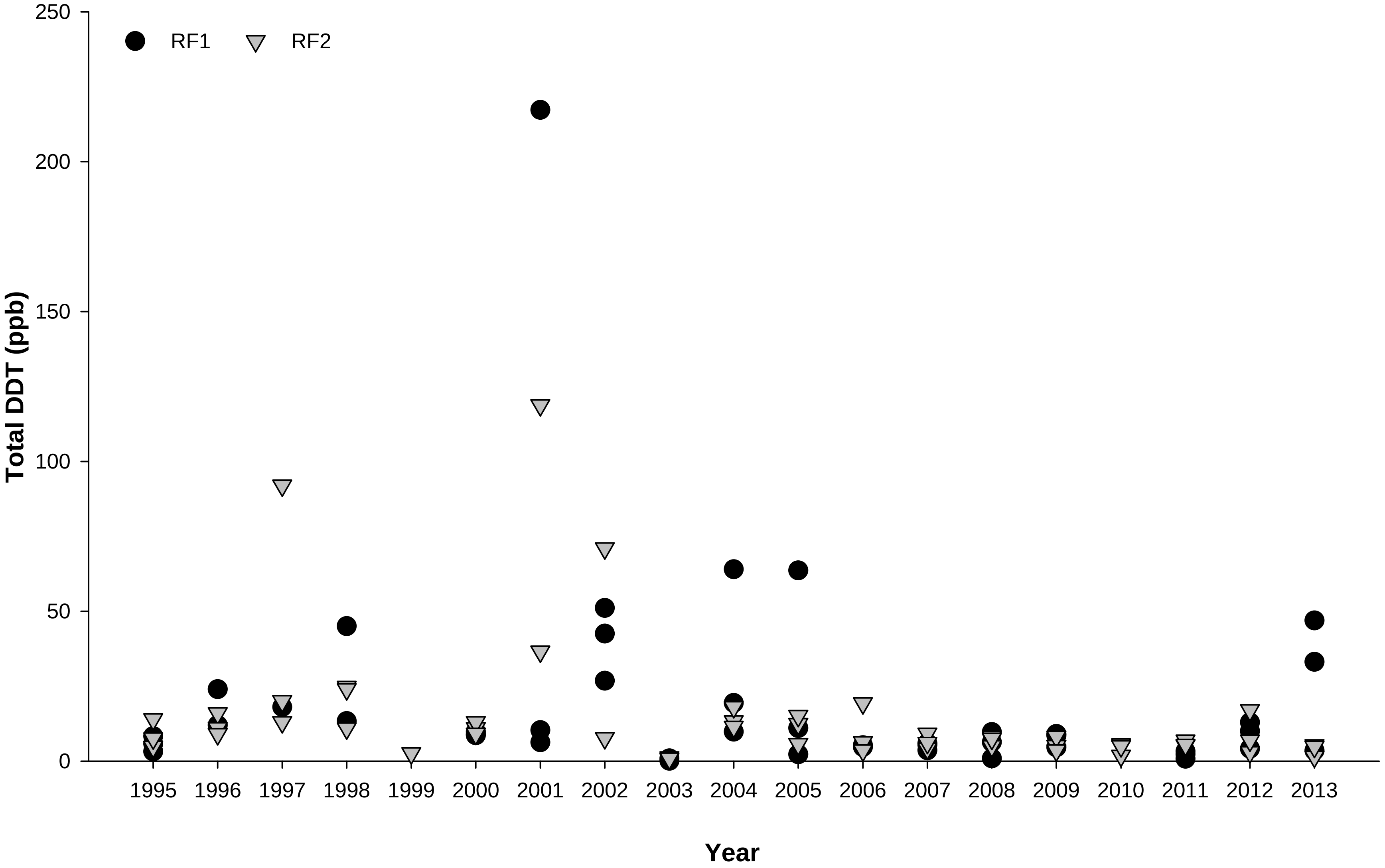

FIGURE D-53

Total DDT concentrations detected in rockfish muscle tissues for rig fishing station RF1 versus RF2 for October surveys from 1995 through 2013.

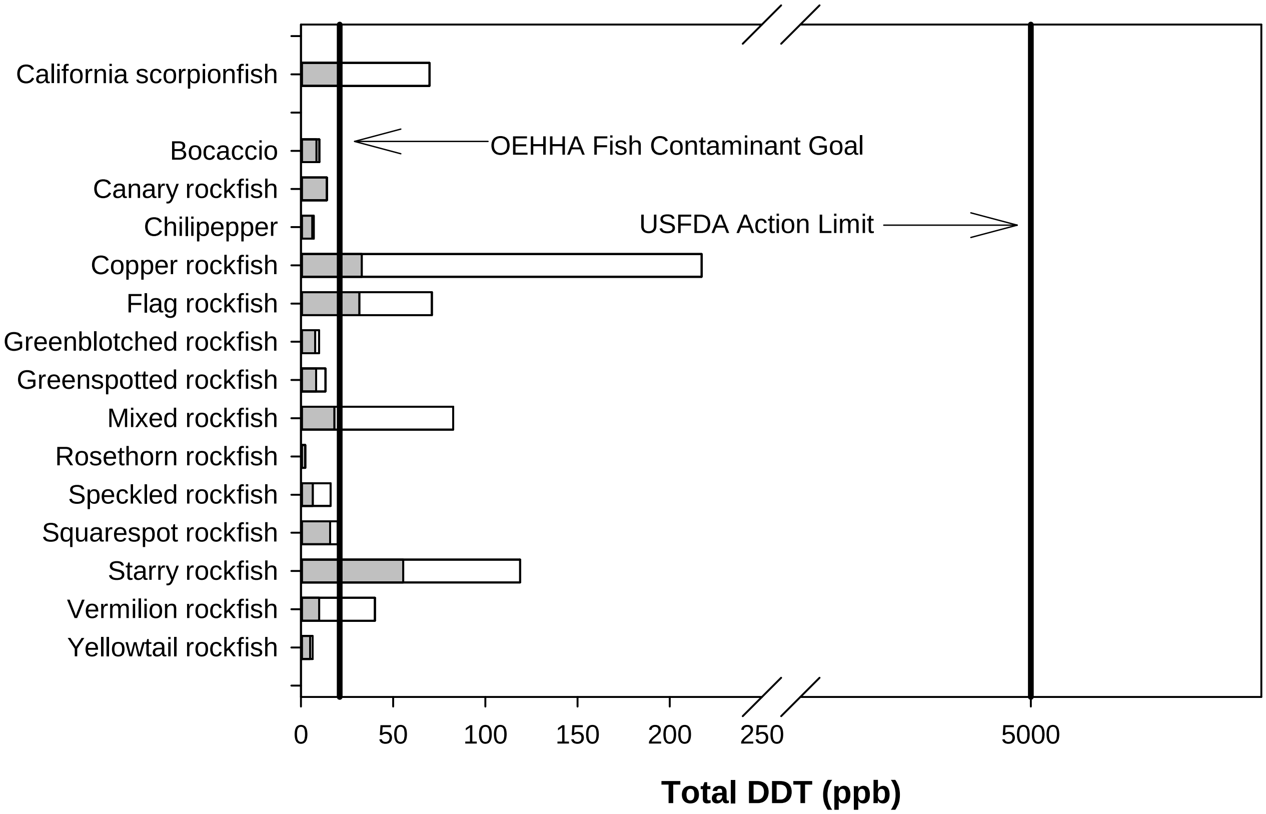

FIGURE D-54
Mean and maximum concentrations of total DDT in muscle tissues of all fishes collected off San Diego at rig fishing stations compared to the USFDA action limit (from Mearns et al. 1991) and the OEHHA fish contaminant goal (Klasing and Brodberg 2008). See Table D-27 for sample sizes.

Table D-29

Summary of pesticide concentrations (ppb) in liver and muscle tissue samples for each fish species sampled from October 1995 through October 2013. Data are summarized for liver tissues from trawl stations and muscle tissues from rig fishing stations during all surveys (April and October); ns=not sampled; nd=not detected.

		Liver Tissues (Trawl Zones)						Muscle Tissues (RF Stations)					
Pesticide	**Species**	**Total**	**Detect**	**Freq**	**Min**	**Max**	**Mean**	**Total**	**Detect**	**Freq**	**Min**	**Max**	**Mean**
Aldrin	OVERALL SPECIES	444	0	0	nd	nd	nd	160	0	0	nd	nd	nd
Alpha Endosulfan	OVERALL SPECIES	444	0	0	nd	nd	nd	160	0	0	nd	nd	nd
Beta Endosulfan	California scorpionfish	82	1	1	290.0	290.0	290.0	8	0	0	nd	nd	nd
	OVERALL SPECIES	206	1	<1	290.0	290.0	290.0	72	0	0	nd	nd	nd
Endosulfan Sulfate	OVERALL SPECIES	206	0	0	nd	nd	nd	72	0	0	nd	nd	nd
Dieldrin	California scorpionfish	117	2	2	14.3	36.0	25.1	12	0	0	nd	nd	nd
	Longfin sanddab	96	2	2	14.0	15.8	14.9	ns	—	—	—	—	—
	Pacific sanddab	172	1	1	93.0	93.0	93.0	ns	—	—	—	—	—
	OVERALL SPECIES	444	5	1	14.0	93.0	34.6	160	0	0	nd	nd	nd
Endrin	California scorpionfish	117	2	2	7.6	68.0	37.8	12	0	0	nd	nd	nd
	Longfin sanddab	96	1	1	50.0	50.0	50.0	ns	—	—	—	—	—
	Pacific sanddab	172	2	1	11.0	90.0	50.5	ns	—	—	—	—	—
	OVERALL SPECIES	444	5	1	7.6	90.0	45.3	160	0	0	nd	nd	nd

TABLE D-29 (continued)

		Liver Tissues (Trawl Zones)						Muscle Tissues (RF Stations)					
Pesticide	**Species**	**Total**	**Detect**	**Freq**	**Min**	**Max**	**Mean**	**Total**	**Detect**	**Freq**	**Min**	**Max**	**Mean**
Hexachlorobenzene	Bigmouth sole	3	1	33	1.4	1.4	1.4	ns	—	—	—	—	—
	Bocaccio	ns	—	—	—	—	—	2	1	50	0.1	0.1	0.1
	California scorpionfish	117	31	26	0.8	13.4	3.5	12	1	8	0.4	0.4	0.4
	Chilipepper	ns	—	—	—	—	—	2	2	100	0.3	0.4	0.3
	Copper rockfish	ns	—	—	—	—	—	22	11	50	0.1	1.0	0.3
	Dover sole	9	3	33	0.7	24.0	8.6	ns	—	—	—	—	—
	English sole	25	13	52	0.9	5.2	1.9	ns	—	—	—	—	—
	Flag rockfish	2	0	0	nd	nd	nd	4	2	50	0.1	0.4	0.2
	Greenblotched rockfish	3	2	67	1.8	2.8	2.3	3	2	67	0.5	15.0	7.8
	Greenspotted rockfish	3	3	100	0.8	4.0	2.8	2	2	100	0.1	0.1	0.1
	Hornyhead turbot	4	2	50	1.7	2.0	1.8	ns	—	—	—	—	—
	Longfin sanddab	96	28	29	1.2	7.7	3.6	ns	—	—	—	—	—
	Mixed rockfish	4	1	25	3.0	3.0	3.0	41	17	41	0.0	0.7	0.3
	Mixed sanddabs	1	1	100	2.3	2.3	2.3	ns	—	—	—	—	—
	Pacific sanddab	172	152	88	1.1	18.0	5.1	ns	—	—	—	—	—
	Speckled rockfish	ns	—	—	—	—	—	13	4	31	0.1	0.3	0.2
	Squarespot rockfish	1	0	0	nd	nd	nd	3	2	67	0.1	0.2	0.1
	Starry rockfish	ns	—	—	—	—	—	9	4	44	0.2	0.5	0.4
	Vermilion rockfish	1	1	100	3.1	3.1	3.1	43	18	42	0.0	0.5	0.2
	Yellowtail rockfish	ns	—	—	—	—	—	2	2	100	0.1	0.1	0.1
	OVERALL SPECIES	444	238	54	0.7	24.0	4.5	160	68	43	0.0	15.0	0.5

TABLE D-29 (continued)

		Liver Tissues (Trawl Zones)						Muscle Tissues (RF Stations)					
Pesticide	**Species**	**Total**	**Detect**	**Freq**	**Min**	**Max**	**Mean**	**Total**	**Detect**	**Freq**	**Min**	**Max**	**Mean**
Mirex	California scorpionfish	117	1	1	1.9	1.9	1.9	12	0	0	nd	nd	nd
	Longfin sanddab	96	5	5	1.7	48.0	11.6	ns	—	—	—	—	—
	Mixed sanddabs	1	1	100	3.3	3.3	3.3	ns	—	—	—	—	—
	Pacific sanddab	172	2	1	1.1	3.6	2.4	ns	—	—	—	—	—
	OVERALL SPECIES	444	9	2	1.1	48.0	7.6	160	0	0	nd	nd	nd
Toxaphene	OVERALL SPECIES	298	0	0	nd	nd	nd	106	0	0	nd	nd	nd
HCH, Alpha isomer	California scorpionfish	75	1	1	5.4	5.4	5.4	8	0	0	nd	nd	nd
	Longfin sanddab	49	1	2	45.0	45.0	45.0	ns	—	—	—	—	—
	Pacific sanddab	158	4	3	6.8	18.0	11.1	ns	—	—	—	—	—
	OVERALL SPECIES	322	6	2	5.4	45.0	15.8	118	0	0	nd	nd	nd
HCH, Beta isomer	California scorpionfish	75	1	1	74.0	74.0	74.0	8	0	0	nd	nd	nd
	Longfin sanddab	49	2	4	27.0	53.0	40.0	ns	—	—	—	—	—
	Mixed rockfish	ns	—	—	—	—	—	31	1	3	0.6	0.6	0.6
	Pacific sanddab	158	4	3	3.3	22.0	8.8	ns	—	—	—	—	—
	Squarespot rockfish	ns	—	—	—	—	—	2	1	50	5.8	5.8	5.8
	OVERALL SPECIES	322	7	2	3.3	74.0	27.1	118	2	2	0.6	5.8	3.2
HCH, Delta isomer	California scorpionfish	75	1	1	6.9	6.9	6.9	8	0	0	nd	nd	nd
	Longfin sanddab	49	1	2	160.0	160.0	160.0	ns	—	—	—	—	—
	Mixed rockfish	ns	—	—	—	—	—	31	1	3	0.5	0.5	0.5
	Pacific sanddab	158	2	1	3.4	43.0	23.2	ns	—	—	—	—	—
	Squarespot rockfish	ns	—	—	—	—	—	2	1	50	7.6	7.6	7.6
	OVERALL SPECIES	322	4	1	3.4	160.0	53.3	118	2	2	0.5	7.6	4.0

TABLE D-29 (continued)

		Liver Tissues (Trawl Zones)						Muscle Tissues (RF Stations)					
Pesticide	**Species**	**Total**	**Detect**	**Freq**	**Min**	**Max**	**Mean**	**Total**	**Detect**	**Freq**	**Min**	**Max**	**Mean**
HCH, Gamma isomer	Greenblotched rockfish	3	0	0	nd	nd	nd	3	1	33	0.7	0.7	0.7
	Longfin sanddab	96	2	2	19.0	130.0	74.5	ns	—	—	—	—	—
	OVERALL SPECIES	444	2	<1	19.0	130.0	74.5	160	1	1	0.7	0.7	0.7
Total HCH	California scorpionfish	117	2	2	6.9	79.4	43.1	12	0	0	nd	nd	nd
	Greenblotched rockfish	3	0	0	nd	nd	nd	3	1	33	0.7	0.7	0.7
	Longfin sanddab	96	3	3	19.0	388.0	144.7	ns	—	—	—	—	—
	Mixed rockfish	ns	—	—	—	—	—	41	1	2	1.1	1.1	1.1
	Pacific sanddab	172	8	5	3.3	61.0	15.8	ns	—	—	—	—	—
	Squarespot rockfish	1	0	0	nd	nd	nd	3	1	33	13.4	13.4	13.4
	OVERALL SPECIES	444	13	3	3.3	388.0	49.7	160	3	2	0.7	13.4	5.1
Alpha (cis) Chlordane	California scorpionfish	117	17	15	3.2	15.0	7.1	12	0	0	nd	nd	nd
	Chilipepper	ns	—	—	—	—	—	2	1	50	0.4	0.4	0.4
	Copper rockfish	ns	—	—	—	—	—	22	2	9	0.5	0.7	0.6
	Greenblotched rockfish	3	1	33	4.4	4.4	4.4	3	0	0	nd	nd	nd
	Greenspotted rockfish	3	1	33	5.8	5.8	5.8	2	0	0	nd	nd	nd
	Longfin sanddab	96	31	32	4.0	58.0	11.5	ns	—	—	—	—	—
	Mixed rockfish	ns	—	—	—	—	—	41	4	10	0.3	1.0	0.6
	Mixed sanddabs	1	1	100	6.0	6.0	6.0	0	—	—	—	—	—
	Pacific sanddab	172	89	52	1.3	31.0	7.1	0	—	—	—	—	—
	Squarespot rockfish	1	0	0	nd	nd	nd	3	1	33	0.9	0.9	0.9
	Starry rockfish	ns	—	—	—	—	—	9	3	33	0.3	1.3	0.7
	Vermilion rockfish	1	1	100	3.6	3.6	3.6	43	1	2	1.3	1.3	1.3
	OVERALL SPECIES	444	141	32	1.3	58.0	8.0	160	12	8	0.3	1.3	0.7
Alpha Chlordene	OVERALL SPECIES	54	0	0	nd	nd	nd	18	0	0	nd	nd	nd

TABLE D-29 (continued)

		Liver Tissues (Trawl Zones)						Muscle Tissues (RF Stations)					
Pesticide	**Species**	**Total**	**Detect**	**Freq**	**Min**	**Max**	**Mean**	**Total**	**Detect**	**Freq**	**Min**	**Max**	**Mean**
Cis Nonachlor	California scorpionfish	75	2	3	4.4	13.0	8.7	8	0	0	nd	nd	nd
	Longfin sanddab	49	8	16	5.7	19.0	12.3	ns	—	—	—	—	—
	Mixed rockfish	ns	—	—	—	—	—	31	2	6	0.4	0.5	0.4
	Pacific sanddab	158	33	21	0.8	7.6	3.4	ns	—	—	—	—	—
	Starry rockfish	ns	—	—	—	—	—	5	1	20	0.6	0.6	0.6
	OVERALL SPECIES	322	43	13	0.8	19.0	5.3	118	3	3	0.4	0.6	0.5
Gamma (trans) Chlordane	California scorpionfish	75	1	1	27.0	27.0	27.0	8	0	0	nd	nd	nd
	Longfin sanddab	49	4	8	4.8	16.0	10.2	ns	—	—	—	—	—
	Mixed rockfish	ns	—	—	—	—	—	31	2	6	0.3	0.6	0.4
	Pacific sanddab	158	15	9	0.5	21.0	3.4	ns	—	—	—	—	—
	Squarespot rockfish	ns	—	—	—	—	—	2	1	50	1.0	1.0	1.0
	Vermilion rockfish	ns	—	—	—	—	—	32	1	3	0.7	0.7	0.7
	OVERALL SPECIES	322	20	6	0.5	27.0	5.9	118	4	3	0.3	1.0	0.6
Heptachlor	Longfin sanddab	96	1	1	12.5	12.5	12.5	ns	—	—	—	—	—
	Pacific sanddab	172	1	1	25.0	25.0	25.0	ns	—	—	—	—	—
	OVERALL SPECIES	444	2	<1	12.5	25.0	18.8	160	0	0	nd	nd	nd
Heptachlor epoxide	OVERALL SPECIES	444	0	0	nd	nd	nd	160	0	0	nd	nd	nd
Methoxychlor	OVERALL SPECIES	84	0	0	nd	nd	nd	30	0	0	nd	nd	nd
Oxychlordane	OVERALL SPECIES	322	0	0	nd	nd	nd	118	0	0	nd	nd	nd

TABLE D-29 (continued)

		Liver Tissues (Trawl Zones)						Muscle Tissues (RF Stations)					
Pesticide	**Species**	**Total**	**Detect**	**Freq**	**Min**	**Max**	**Mean**	**Total**	**Detect**	**Freq**	**Min**	**Max**	**Mean**
Trans Nonachlor	California scorpionfish	117	65	56	5.1	78.0	15.8	12	0	0	nd	nd	nd
	Copper rockfish	ns	—	—	—	—	—	22	7	32	0.1	1.5	0.7
	English sole	25	2	8	3.2	3.3	3.2	ns	—	—	—	—	—
	Flag rockfish	2	0	0	nd	nd	nd	4	1	25	0.9	0.9	0.9
	Greenblotched rockfish	3	2	67	7.2	13.0	10.1	3	0	0	nd	nd	nd
	Greenspotted rockfish	3	2	67	5.8	20.0	12.9	2	0	0	nd	nd	nd
	Longfin sanddab	96	52	54	4.2	91.0	18.4	ns	—	—	—	—	—
	Mixed rockfish	4	2	50	4.7	22.0	13.3	41	6	15	0.4	1.2	0.7
	Mixed sanddabs	1	1	100	11.0	11.0	11.0	ns	—	—	—	—	—
	Pacific sanddab	172	107	62	0.8	28.0	8.9	ns	—	—	—	—	—
	Squarespot rockfish	1	0	0	nd	nd	nd	3	1	33	0.4	0.4	0.4
	Starry rockfish	ns	—	—	—	—	—	9	3	33	0.3	2.4	1.1
	Vermilion rockfish	1	1	100	6.4	6.4	6.4	43	0	0	nd	nd	nd
	Yellowtail rockfish	ns	—	—	—	—	—	2	1	50	0.1	0.1	0.1
	OVERALL SPECIES	444	234	53	0.8	91.0	13.0	160	19	12	0.1	2.4	0.7

TABLE D-29 (continued)

		Liver Tissues (Trawl Zones)						Muscle Tissues (RF Stations)					
Pesticide	**Species**	**Total**	**Detect**	**Freq**	**Min**	**Max**	**Mean**	**Total**	**Detect**	**Freq**	**Min**	**Max**	**Mean**
Total Chlordane	California scorpionfish	117	66	56	5.1	78.0	18.1	12	0	0	nd	nd	nd
	Chilipepper	ns	—	—	—	—	—	2	1	50	0.4	0.4	0.4
	Copper rockfish	ns	—	—	—	—	—	22	7	32	0.1	2.2	0.8
	English sole	25	2	8	3.2	3.3	3.2	ns	—	—	—	—	—
	Flag rockfish	2	0	0	nd	nd	nd	4	1	25	0.9	0.9	0.9
	Greenblotched rockfish	3	2	67	11.6	13.0	12.3	3	0	0	nd	nd	nd
	Greenspotted rockfish	3	2	67	5.8	25.8	15.8	2	0	0	nd	nd	nd
	Longfin sanddab	96	53	55	4.2	128.0	27.6	ns	—	—	—	—	—
	Mixed rockfish	4	2	50	4.7	22.0	13.3	41	7	17	0.4	2.7	1.2
	Mixed sanddabs	1	1	100	17.0	17.0	17.0	ns	—	—	—	—	—
	Pacific sanddab	172	110	64	2.1	64.0	16.1	ns	—	—	—	—	—
	Squarespot rockfish	1	0	0	nd	nd	nd	3	1	33	2.3	2.3	2.3
	Starry rockfish	ns	—	—	—	—	—	9	3	33	0.6	4.3	2.1
	Vermilion rockfish	1	1	100	10.0	10.0	10.0	43	1	2	2.0	2.0	2.0
	Yellowtail rockfish	ns	—	—	—	—	—	2	1	50	0.1	0.1	0.1
	OVERALL SPECIES	444	239	54	2.1	128.0	19.0	160	22	14	0.1	4.3	1.2

variable, but tended to be highest in California scorpionfish, and longfin and Pacific sanddabs. These pesticides were detected in fish samples from all stations, no matter what distance the stations were from the outfall. All rockfish muscle samples from the rig fishing stations had total chlordane concentrations below the OEHHA fish contaminant goal of 5.6 ppb, as well as the MIS of 100 ppb and the USFDA Action Limit of 300 ppb (Table D-6).

PCBs: PCBs were detected in 95% of liver tissue samples from trawl-caught fishes and 66% of muscle tissue samples from fishes captured at the rig fishing stations (Table D-30). Maximum concentrations of total PCB (sum of all congeners detected) was 13,264 ppb in liver tissues and 89.3 ppb in muscles. PCB levels appear to be lower across the region over the past five years, with no distinguishable pattern relative to the outfall in sanddab or rockfish samples from the four trawl zones and the two rig fishing sites (Table D-31, Figures F-55 through F-58). Instead, the overall highest total PCB concentrations were found in sanddab liver tissues from trawl zone 3, located near the LA-5 disposal site (Table D-31, Figure D-55). These results are consistent with previous assessments of bioaccumulation of PCB in fishes off San Diego (City of San Diego 2007, Parnell et al. 2008).

Total PCB exceeded the OEHHA fish contaminant goal of 3.6 ppb in 8 species, including California scorpionfish, bocaccio, canary rockfish, copper rockfish, flag rockfish, mixed rockfish, starry rockfish, and vermilion rockfish (Table D-6 and Figure D-59). As with several of the metals and total DDT, elevated levels of PCB over the OEHHA fish contaminant goal are not uncommon in sport fish from other areas of the San Diego region, including the Coronado Islands (see City of San Diego 2014c and references therein).

A more detailed analysis of the distribution of individual PCB congeners detected in fish tissues revealed patterns similar to total PCB. More than 40 different congeners were detected in sanddab liver tissue samples and rockfish muscle tissue samples collected between 1995 and 2013 (Figures D-60 and D-61). Concentrations of most of these PCBs were highest in fish collected near the LA-5 site (i.e., trawl zone 3). The six congeners with the highest concentrations in liver tissues were PCB-153/168, PCB-138, PCB-118, PCB-87, PCB-180, and PCB-187. The five congeners with the highest concentrations in muscle tissues were PCB-8, PCB-87, PCB-126, PCB-153/168, and PCB-200. Overall, there were no patterns consistent with an outfall effect.

SECTION D.5 | SUMMARY & CONCLUSIONS

Several trace metals, PCB congeners, and chlorinated pesticides (e.g., DDT) were detected in liver tissues from trawl-caught fishes collected in the Point Loma outfall region from 1995

TABLE D-30

Summary of total PCB concentrations (ppb) in liver and muscle tissue samples for each fish species sampled from October 1995 through October 2013. Data are summarized for liver tissues from trawl stations and muscle tissues from rig fishing stations during all surveys (April and October); nd=not detected.

Species	Total	Detect	Freq	Min	Max	Mean
Liver Tissues (Trawl Zones)						
Bigmouth sole	3	2	67	80.60	82.00	81.30
California scorpionfish	117	108	92	11.00	13264.00	583.31
Dover sole	9	6	67	12.00	222.60	87.32
English sole	25	22	88	39.60	326.50	129.41
Flag rockfish	2	2	100	1199.00	2227.00	1713.00
Greenblotched rockfish	3	2	67	384.30	1175.00	779.65
Greenspotted rockfish	3	3	100	251.60	545.30	363.73
Halfbanded rockfish	3	0	0	nd	nd	nd
Hornyhead turbot	4	4	100	48.00	155.80	93.07
Longfin sanddab	96	96	100	107.00	2929.00	835.33
Mixed rockfish	4	3	75	201.60	5320.00	3004.53
Mixed sanddabs	1	1	100	541.30	541.30	541.30
Pacific sanddab	172	172	100	35.20	2978.00	292.36
Squarespot rockfish	1	0	0	nd	nd	nd
Vermilion rockfish	1	1	100	152.00	152.00	152.00
ALL SPECIES	444	422	95	11.00	13264.00	505.13
Muscle Tissues (RF Stations)						
Bocaccio	2	2	100	0.80	9.20	5.00
California scorpionfish	12	5	42	1.00	9.00	4.54
Canary rockfish	1	1	100	15.00	15.00	15.00
Chilipepper	2	2	100	2.10	3.70	2.90
Copper rockfish	22	17	77	1.30	76.80	13.50
Flag rockfish	4	3	75	0.30	33.70	12.32
Greenblotched rockfish	3	3	100	1.10	1.30	1.20
Greenspotted rockfish	2	2	100	0.60	3.50	2.05
Mixed rockfish	41	27	66	0.30	89.30	13.54
Rosethorn rockfish	1	1	100	0.80	0.80	0.80
Speckled rockfish	13	5	38	0.20	3.30	1.40
Squarespot rockfish	3	3	100	3.20	3.80	3.47
Starry rockfish	9	6	67	7.30	54.00	21.13
Vermilion rockfish	43	27	63	0.70	28.00	4.22
Yellowtail rockfish	2	2	100	0.50	1.20	0.85
ALL SPECIES	160	106	66	0.20	89.30	9.00

TABLE D-31

Summary of total PCB concentrations (ppb) in sanddab and rockfish tissues by station/zone. Data are summarized over all samples collected during the April and October surveys from October 1995 through October 2013. CI=confidence interval.

	Sanddab Liver Tissues				**Rockfish Muscle Tissues**	
	Zone 1	**Zone 2**	**Zone 3**	**Zone 4**	**RF1**	**RF2**
Total	65	86	59	59	71	77
Detected	65	86	59	59	47	54
Frequency	100	100	100	100	66	70
Minimum	108.1	46.0	111.1	35.2	0.5	0.2
Median	363.0	234.1	445.0	341.4	4.4	3.1
Maximum	2030.9	1797.3	2978.0	1626.0	76.8	89.3
Mean	527.0	339.3	724.0	421.4	9.9	8.7
95% CI	106.2	58.5	180.5	76.0	3.8	4.5

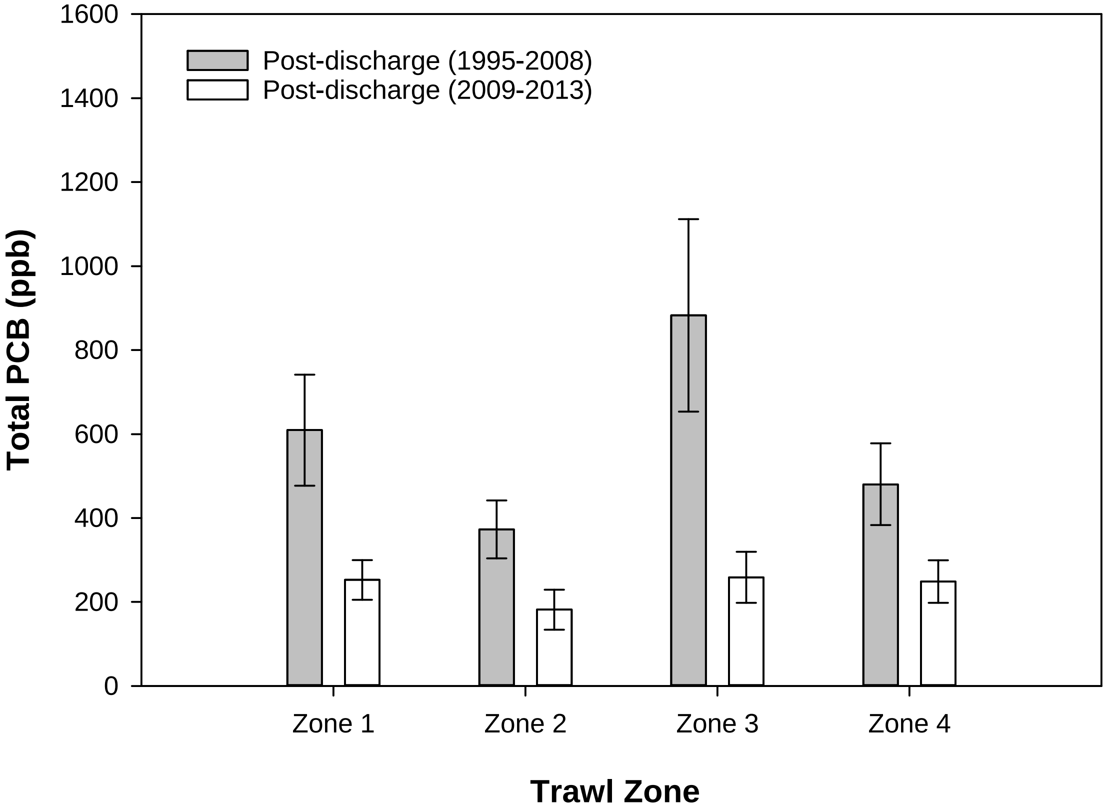

FIGURE D-55
Comparisons of total PCB concentrations in sanddab liver tissues by trawl zone for all surveys (April and October) from 1995 through 2013. Data are means +/- 95% confidence intervals.

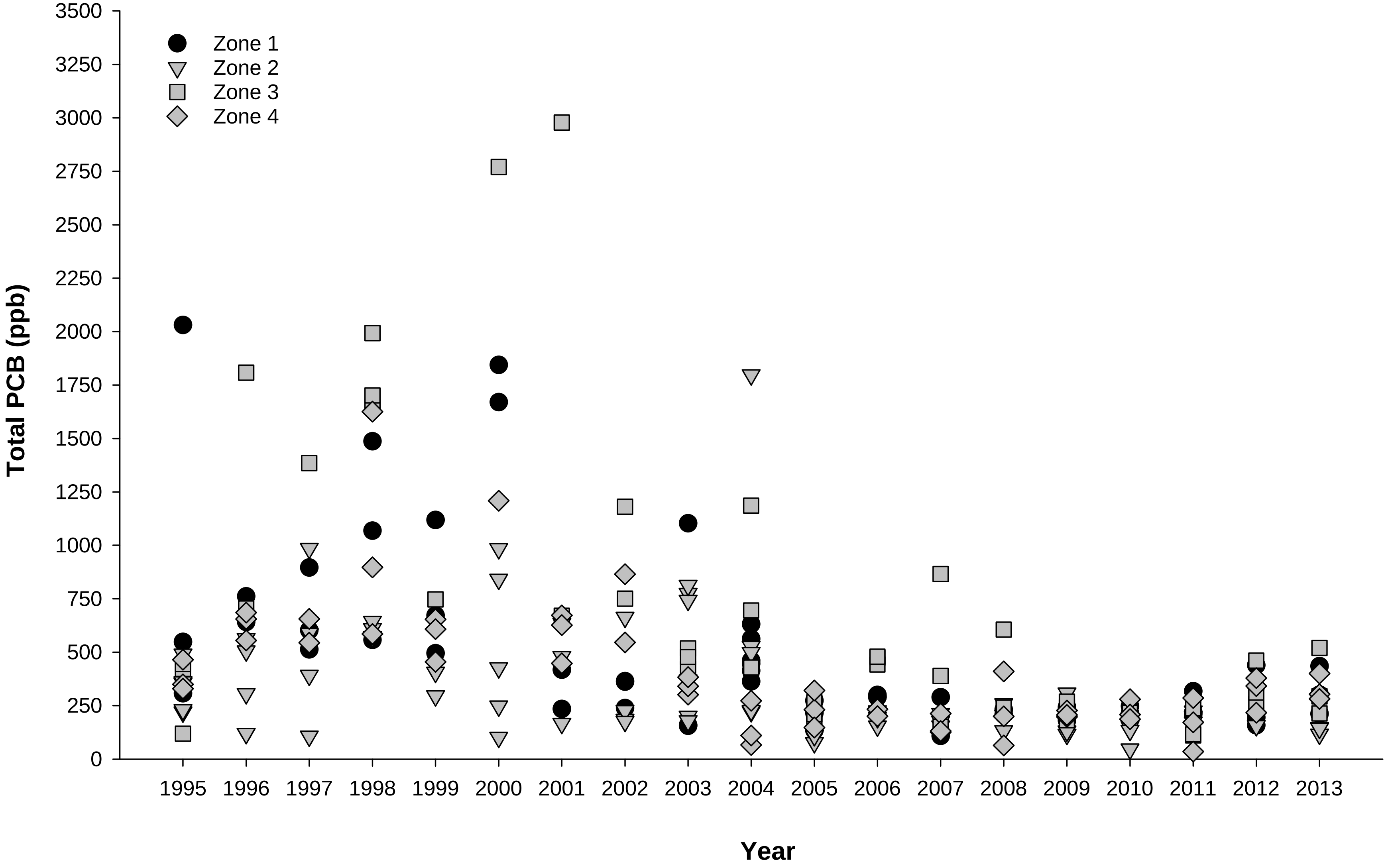

FIGURE D-56

Total PCB concentrations detected in sanddab guild liver tissues for trawl Zone 1 versus Zones 2-4 for October surveys from 1995 through 2013.

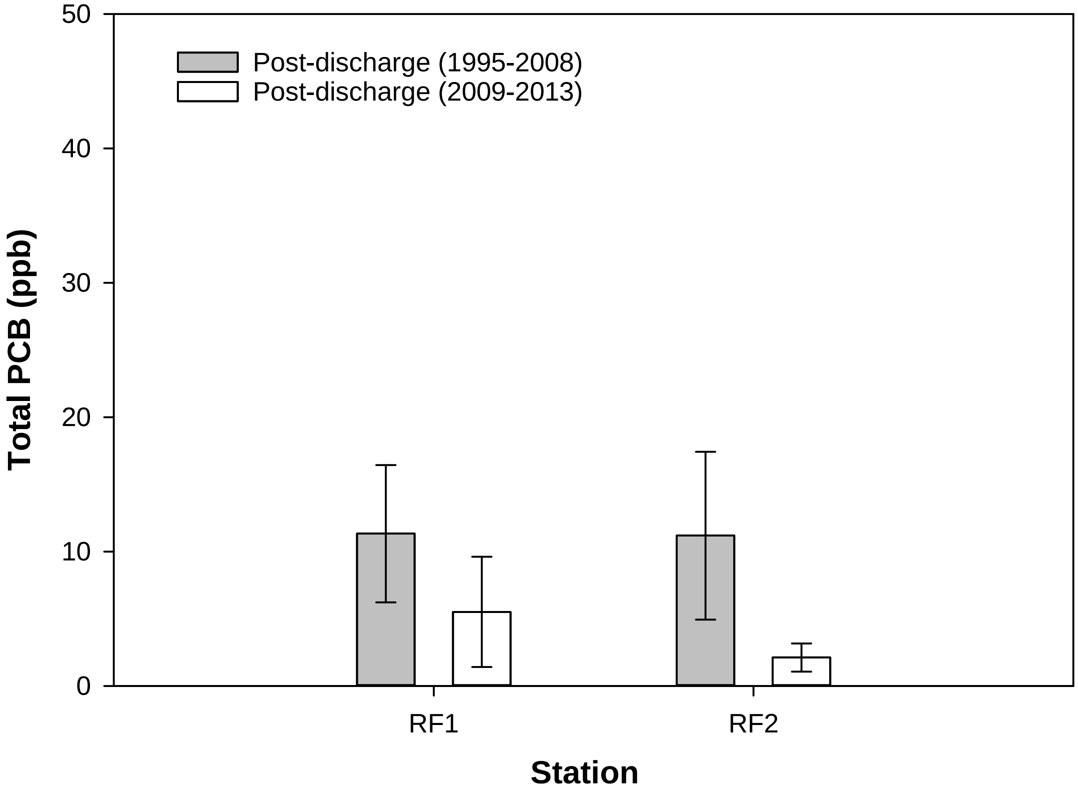

FIGURE D-57
Comparisons of total PCB concentrations in rockfish muscle tissues by rig fishing station for all surveys (April and October) from 1995 through 2013. Data are means +/- 95% confidence intervals.

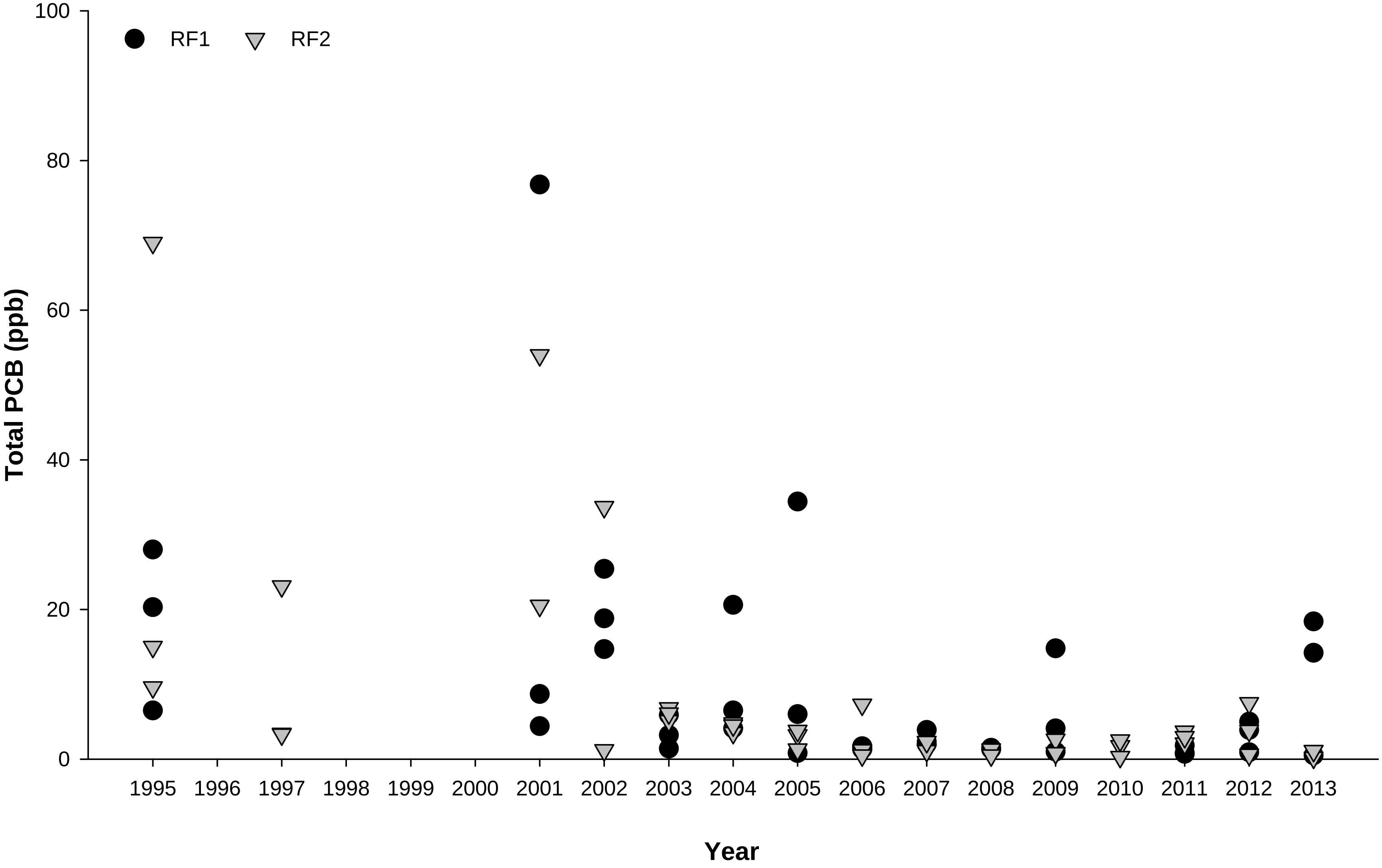

FIGURE D-58

Total PCB concentrations detected in rockfish muscle tissues for rig fishing stations RF1 versus RF2 for October surveys from 1995 through 2013.

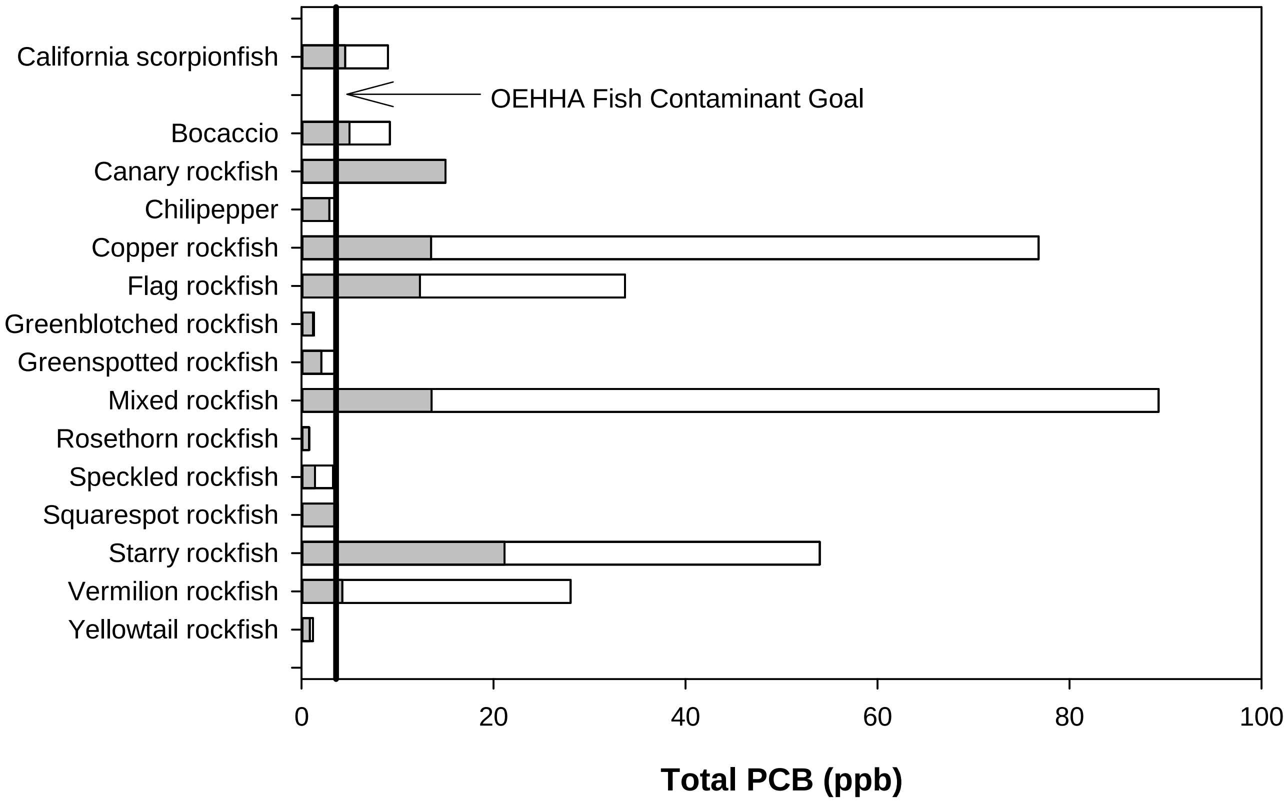

FIGURE D-59

Mean and maximum concentrations of total PCB in muscle tissues of all fishes collected off San Diego at rig fishing stations compared to the OEHHA fish contaminant goal (Klasing and Brodberg 2008).
See Table D-26 for sample sizes.

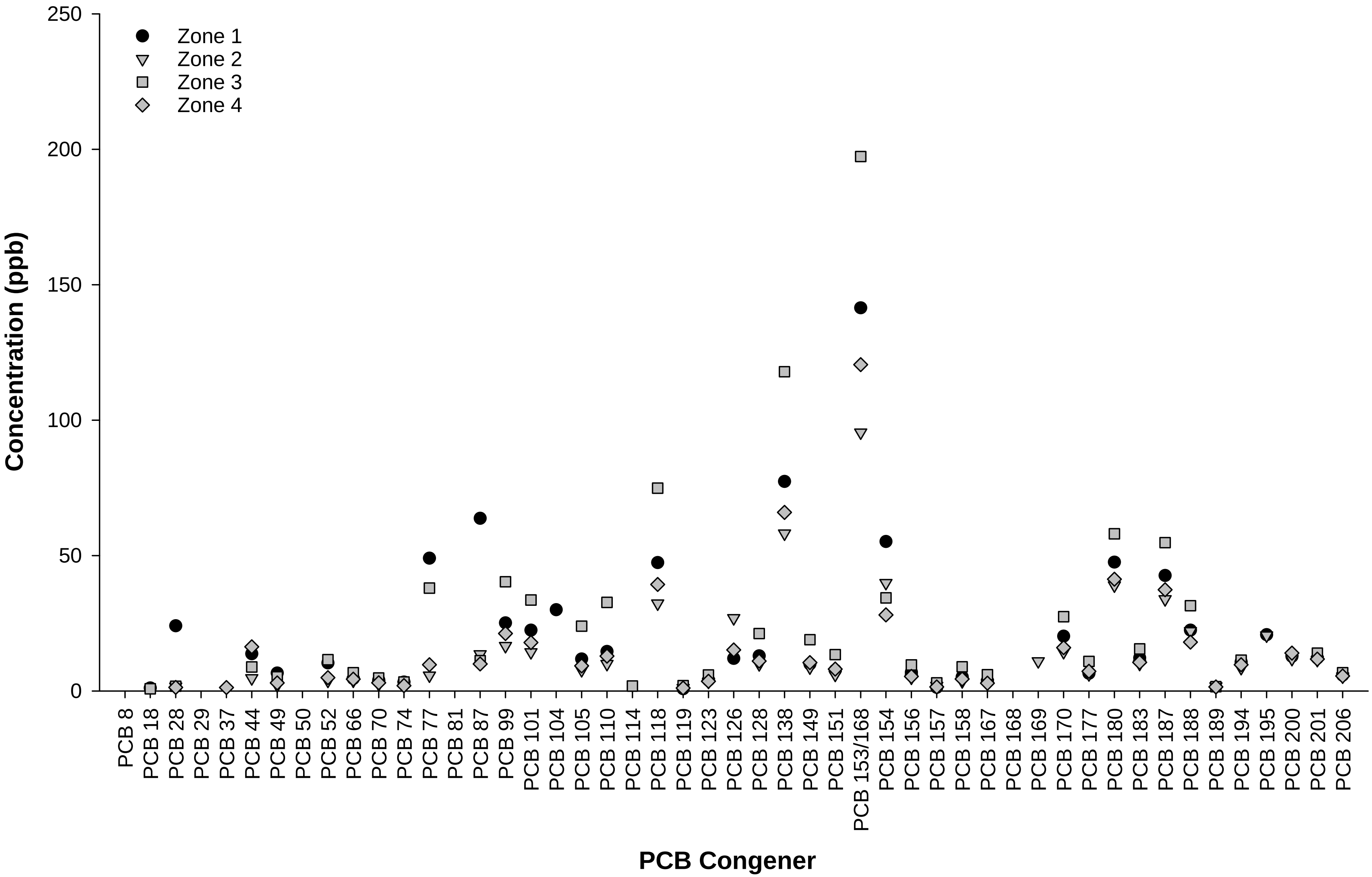

Figure D-60

Concentrations (ppb) of individual PCB congeners in sanddab liver tissue for each trawl zone. Data are means of all surveys sampled from 1995 through 2013.

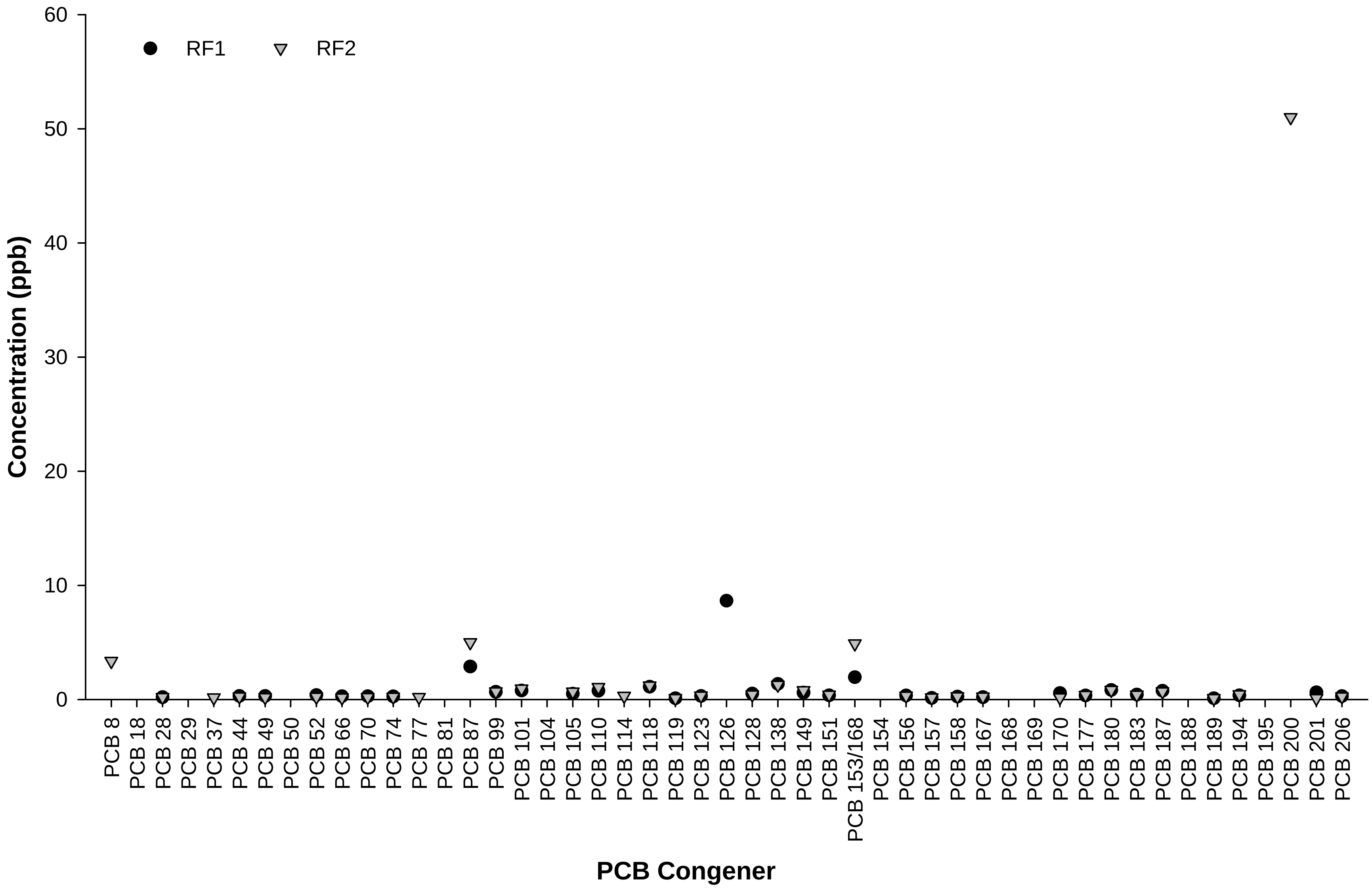

Figure D-61

Concentrations (ppb) of individual PCB congeners in rockfish muscle tissue for each rig fishing station. Data are means of all surveys sampled from 1995 through 2013.

through 2013. Many of the same metals, PCBs, DDT and other pesticides were also detected in rockfish muscle tissues from rig fishing stations over the past 19 years, although often less frequently and/or in lower concentrations. Although tissue contaminant concentrations varied among different species of fish and between stations/zones, all values were within ranges reported previously for Southern California Bight (SCB) fishes (see Mearns et al. 1991, Allen et al 1998, 2002, City of San Diego 2000, City of San Diego 2014c). In addition, concentrations of these contaminants were generally similar to those reported previously by the City of San Diego for this survey area (City of San Diego 2001a, b, 2007).

All but one of 160 muscle tissue samples from sport fish collected in the region had concentrations of mercury and total DDT below USFDA action limits. Although several species had arsenic, chromium, and selenium concentrations above median international standards for human consumption, and some had concentrations of mercury, total DDT and total PCB above OEHHA limits, elevated levels of these contaminants are not uncommon in sport fish from the PLOO survey area (e.g., City of San Diego 2014a) or from the rest of the San Diego region (e.g., see City of San Diego 2014c). For example, muscle tissue samples from fishes collected since 1995 in the South Bay outfall survey area, including the Coronado Islands, have occasionally had concentrations of arsenic, mercury, selenium and total PCB that exceeded different consumption limits.

The frequent occurrence of metals and chlorinated hydrocarbons in local fish tissues may be due to multiple factors. Many metals occur naturally in the environment, although little information is available on background levels in fish tissues. Brown et al. (1986) determined that there may be no area in the SCB sufficiently free of chemical contaminants to be considered a reference site, while Mearns et al. (1991) described the distribution of several contaminants such as arsenic, mercury, DDT and PCB as being ubiquitous. This has been supported by more recent work regarding PCBs and DDT in southern California waters (e.g., Allen et al. 1998, 2002).

Other factors that affect contaminant loading in fish tissues include the physiology and life history of different species (see Groce 2002 and references therein). Exposure to contaminants can also vary greatly between different species of fish and among individuals of the same species depending on migration habits (Otway 1991). Fishes may be exposed to contaminants in a highly polluted area and then move into an area that is not. For example, California scorpionfish tagged in Santa Monica Bay have been recaptured as far south as the Coronado Islands (Hartmann 1987, Love et al. 1987). This is of particular concern for fishes collected in the vicinity of the PLOO, as there are many point and non-point sources that may contribute to local contamination in the region, including the San Diego River, San Diego Bay, and offshore dredged material disposal sites (see Appendix C.1, Parnell et al. 2008). In contrast, assessments of contaminant loading in sediments surrounding the outfall have revealed no evidence to indicate that the PLOO is a major source of pollutants to the area (Parnell et al. 2008, City of San Diego 2014a).

Overall, there was no evidence that the discharge of wastewater via the Point Loma outfall has caused abnormal body burdens of any toxic pollutants known to have adverse effects on marine fishes or their consumers. Fishes collected in the region do not appear to be significantly affected by the discharge of wastewater from the outfall or from other possible sources of contamination. Concentrations of most contaminants were generally similar across zones or stations, and no relationship relevant to the PLOO was evident. These results are consistent with findings of two other assessments of bioaccumulation in fishes off San Diego (City of San Diego 2007, Parnell et al. 2008). Finally, the absence of physical abnormalities or any indication of disease (e.g., fin rot, tumors) on local fishes indicates that populations in the Point Loma region remain healthy after 20 years of wastewater discharge (e.g., see City of San Diego 2014a).

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