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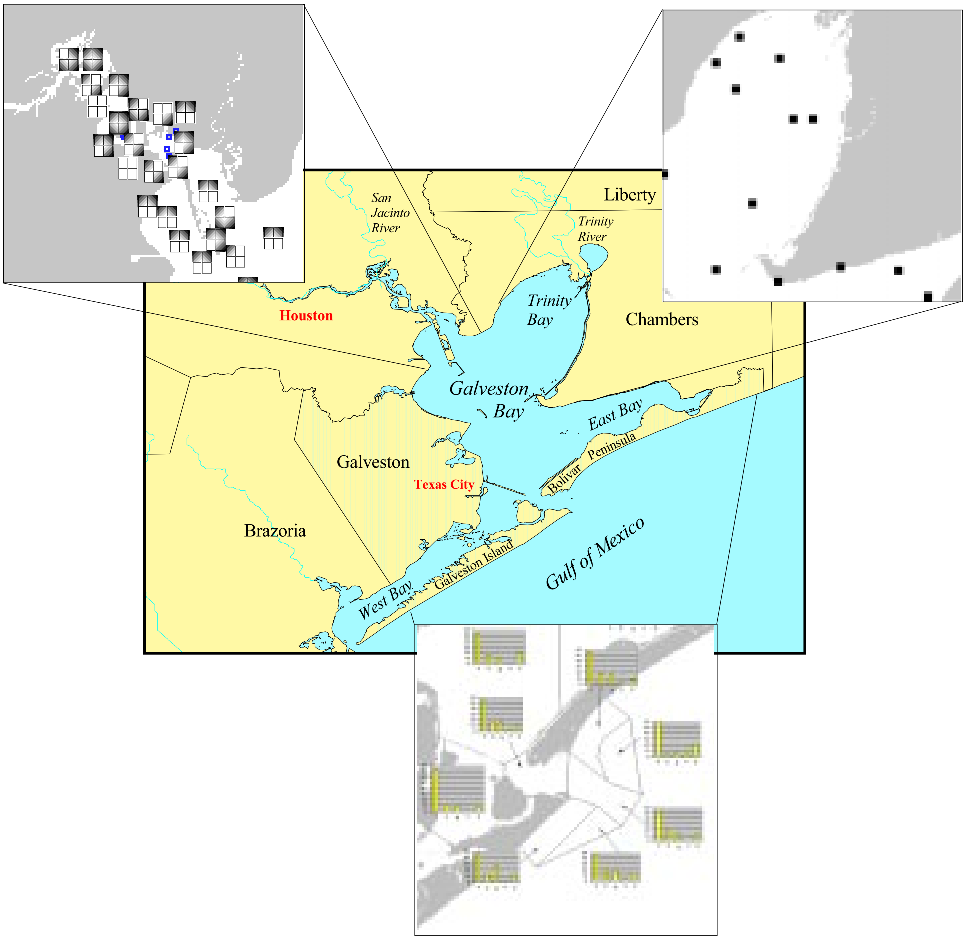
National Status and Trends Program
for Marine Environmental Quality

Sediment Contamination, Toxicity, and Macroinvertebrate Infaunal Community in Galveston Bay



Silver Spring, Maryland
December 2003

US Department of Commerce

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Notice

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Department of Commerce

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EXECUTIVE SUMMARY

This report summarizes the results of NOAA's study of Galveston Bay to assess sediment contamination, toxicity, and the benthic community, and was done as a component of the National Status and Trends (NS&T) Program for marine environmental quality. To date, sediment toxicity studies have been completed in over 20 estuaries as part of the program.

Sediment contamination in U.S coastal waters is a major concern, posing both ecological and, indirectly, human health risks. Contaminated sediments pose a long-term threat as a reservoir for recalcitrant pollutants, which through biological and physical processes can be redistributed to the ecosystem long after inputs from land-based sources of pollution have ceased. Habitats impacted by sediment contamination frequently exhibit lower density and diversity of benthic organisms, as well as impaired health of individual animals. Human health concerns arise as a result of consumption of fish and wildlife from these contaminated areas.

Galveston Bay is the largest estuary on the Texas coast, and is composed of four major sub-bays including Galveston, Trinity, East, and West bays. It is a relatively shallow system, with an average natural depth of approximately 2 m. The major freshwater sources for the bay include the Trinity and San Jacinto rivers; the major tidal inlet is Bolivar Roads, between Galveston Island and Bolivar Peninsula. The bay is home to the world's largest industrial complex, with an estimated annual sea trade value of over $50 billion, and a population approaching 5 million. At the same time, the bay has a variety of habitats including wetlands, submerged vegetation, mud and sand flats, and oyster reefs, and is home to a number of commercially and recreationally important species of finfish and shellfish.

The Galveston Bay study area covered 1,351 sq. km, and included the Houston Ship Channel, the four sub-bays, and approaches to the bay from the Gulf of Mexico. The study area was divided into 22 irregular shaped strata, and sites within each stratum were selected on a random basis in consultation with state and local officials. Seventy-five sites were sampled in July and August 1996.

Sediments were analyzed for a large suite of contaminants including metals, polycyclic aromatic hydrocarbons (PAHs), pesticides, and polychlorinated biphenyls (PCBs).

A battery of sediment toxicity tests, including amphipod survival, sea urchin fertilization and development, Microtox®, and P450 Reporter Gene System (RGS) were carried out. Benthic community analysis was completed as well.

Sediment contaminant levels were compared with the Effects Range-Low (ER-L), and Effects Range-Medium (ER-M) guideline values. ER-L values are those sediment contaminant concentrations below which adverse biological effects are not likely to occur; contaminant levels above the ER-M are likely to cause adverse effects.

In general, trace elements were distributed relatively uniformly throughout the study area, with the exception of mercury, which was concentrated in the Houston Ship Channel. None of the trace element concentrations exceeded the ER-M values at any of the 75 sites, although numerous sites exceeded the ER-L values for arsenic, chromium, mercury, nickel and zinc. Arsenic concentrations exceeded the ER-L value in 29% of the study area, nickel in 25% of the study area, while chromium, mercury and zinc ER-L exceedences together totalled less than 1% of the study area.

The highest total PAH concentration was found in the middle of Galveston Bay, and exceeded the ER-L value. Individual ER-L values were exceeded in the middle of the bay and in the upper bay for compounds such as acenapthene, anthracene, and fluorene. The calculated spatial extent of ER-L exceedences for each PAH as well as for total PAH was 2% or less. In general, measured pesticides and PCBs were uniformly low. However, the ER-M guideline for total DDT was exceeded at two sites on the Houston Ship Channel. Total ER-L exceedences for DDT included 6% of the study area.

Results from the sediment toxicity tests were highly variable. No samples were found to be significantly toxic in the amphipod survival test. Sea urchin fertilization as a percent of the control was significantly reduced at 53% of the sites (100% porewater test). Samples from the Houston Ship Channel, upper bay, Clear Lake and east of the approach jetties to Galveston Bay showed the lowest fertilization success. Sea urchin embryonic development results followed a pattern similar to fertilization. The lowest mean Microtox® EC_{50} values were widely spread throughout the study area. Approximately 79% of the samples produced a value that was significantly lower than the control in the Microtox® test. Results from the

P450 RGS indicated that only 9% of the sites exceeded a threshold toxicity value, while only one site exceeded a value indicative of toxicological significance.

Estimates of the spatial extent of sediment toxicity were also made. Using a criteria of less than 80% of the control values, none of the area was deemed toxic in terms of amphipod survival, 45% of the study area was toxic using sea urchin fertilization, 25% of the area was toxic to sea urchin development using this criteria, and 87% of the Galveston Bay study area was toxic in terms of the Microtox® test. However, an alternative nonparametric analysis indicated that all Microtox® values were below levels that would be considered moderately toxic. For P450 RGS, approximately 5% of the study area exceeded a moderate value of enzyme induction.

An analysis of the relationships between sediment contamination and the sediment toxicity tests revealed no correlations between sediment contaminants and either the amphipod mortality or Microtox® tests. The sea urchin fertilization test correlated with several PAHs, and the sea urchin development test correlated with total PAHs, a number of low molecular weight PAHs, and two PCBs. As expected, the P450 RGS assay correlated highly with PAHs.

A total of 5,089 organisms, representing 211 taxa, were identified in the 22 strata. The total number of taxa varied from a low of four in Clear Lake, to a high of 90 in West Bay. The majority of organisms counted were polychaetes (71%), followed distantly by bivalves (8.3%), gastropods (6.6%), and amphipods (3.6%). The mean density of organisms was lowest in upper Galveston Bay, and highest in West Bay. Similarly, faunal diversity (H') was lowest in Clear Lake and highest in lower Galveston Bay.

In summary, there was no toxicity observed when amphipods were exposed to bulk sediment. For other tests, based on more sensitive life stages and metabolic response, the toxicity pattern was similar to those found in other large estuaries in the United States. Although the toxicological endpoints of exposure to sediment porewater or organic extracts are easily understood, their ecological significance can only be described as tenuous. The infaunal benthic community in the bay appears reflective of the substratum type, i.e., sandy or muddy bottom. The study results should be viewed in light of its principal objective, i.e., estimate the spatial extent and patterns of sediment contamination, sediment toxicity and infaunal benthic communities.

The study results do not preclude continued monitoring and periodic assessments of sediment contamination and toxicity in areas of concern. This study also does not address other major environmental issues in Galveston Bay, such as loss of wetland acreage, freshwater inflow, and shellfish harvest restrictions.

Sediment Contamination, Toxicity, and Macroinvertebrate Infaunal Community in Galveston Bay

INTRODUCTION

As part of the National Status and Trends (NS&T) Program, NOAA conducts studies to determine the spatial extent and severity of chemical contamination and associated adverse biological effects in coastal bays and estuaries of the United States. Results from previous NS&T sediment toxicity studies in over 20 coastal waters and estuaries have been published (Long et al., 1996; Turgeon et al., 1998; Long, 2000).

Galveston Bay is located along the northeastern Texas coastline and harbors the world's largest industrial complex. Houston, connected to the bay by the Houston Ship Channel (HSC), is the fourth largest port in the United States in terms of waterborne trade. The city of Galveston, located on the Gulf of Mexico, occupies nearly the entire 32 mile long island and is also a major port. These two ports, together with the Port of Texas City, account for sea trade of over $50 billion each year (US ACOE, 2001). The Houston-Galveston-Brazoria metropolitan area is inhabited by nearly 5 million people, nearly doubling its population during the past two decades (USCB, 2001). The bay, separated from the Gulf of Mexico by barrier islands, is a highly productive estuary with many species of finfish, shellfish and wildlife. A variety of habitats including wetlands, submerged aquatic vegetation, mud and sand flats, and oyster reefs provide extensive shallow water habitats important for the continued survival of regional populations, and for biodiversity. One-third of the commercial fishing income and over one-half of the expenditures related to recreational fishing in Texas are derived from Galveston Bay (GBEP, 2002). Eastern oysters, blue crabs and shrimp (white and brown) comprise the commercial shellfish catch in the bay with an economic impact of nearly one-half billion dollars.

Over the past couple of decades, significant anthropogenic changes in Galveston Bay have become a matter of concern. The Galveston Bay National Estuary Program identified 17 environmental issues that required an improved scientific understanding as well as management action by public agencies. Loss of habitat (some of it from land subsidence), water and sediment contamination, declining population trends in some wildlife species, and shellfish harvest restrictions due to coliform bacteria and other pathogens, were identified among the higher priority issues for the bay (GBNEP, 1994).

Coastal contamination emerged as an important environmental issue in Galveston Bay beginning in the 1930's when oil and petrochemical industries began to proliferate along Buffalo Bayou. By the late 1960's, the EPA had listed this area, including the HSC extending to Morgan's Point, as one of the top 10 most polluted bodies of water in the United States. At that time, some locations rarely had measurable dissolved oxygen concentrations, however, since then all industrial effluents have become subject to secondary treatment or better, and municipal wastewater and sewage treatment plants have been upgraded and expanded. (Gardinali, 1996; GBNEP, 1994; GBNEP, 1992).

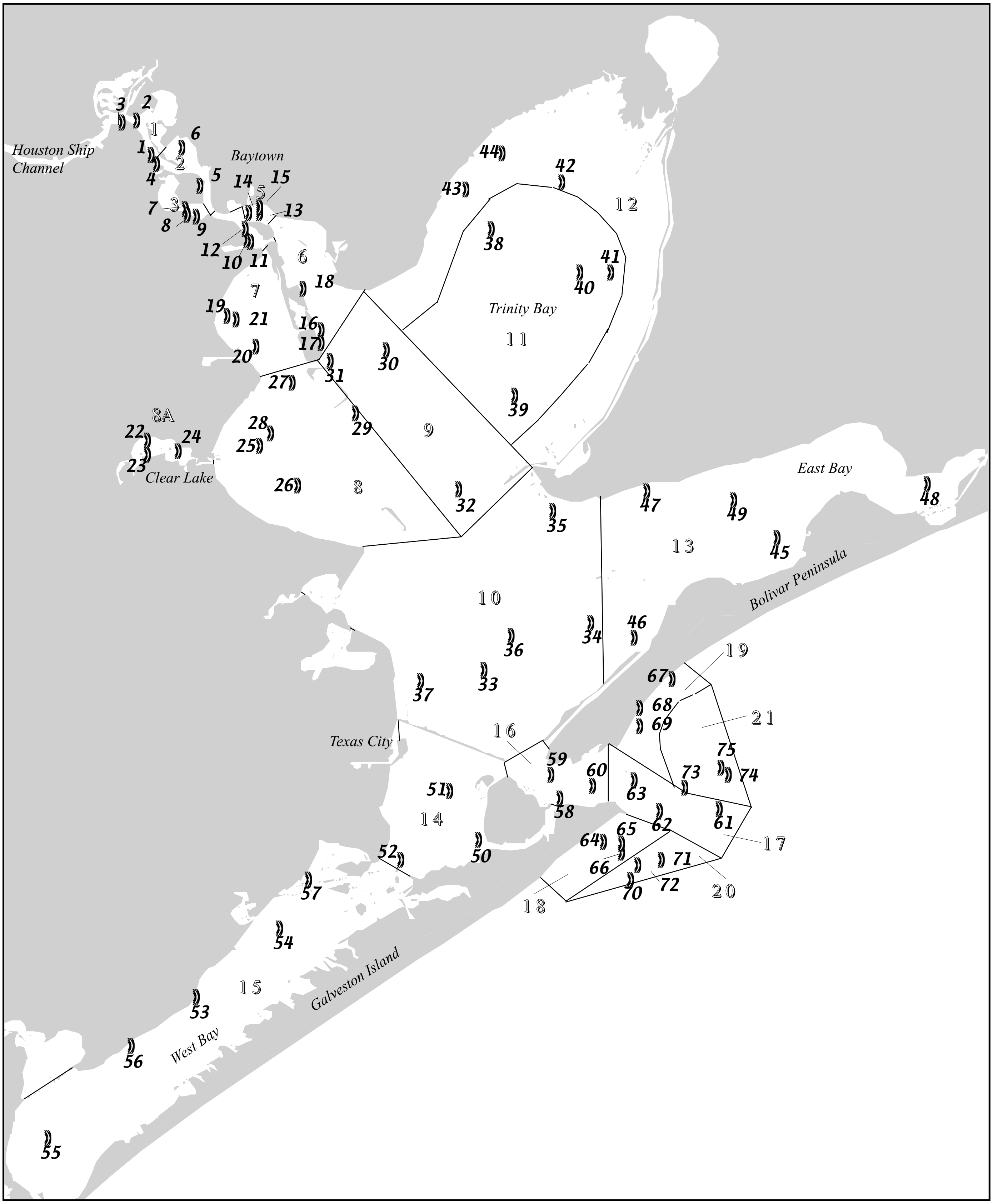
STUDY AREA

Galveston Bay has a surface area of 1,360 sq. km, and includes several major embayments: Trinity Bay, Galveston Bay, East Bay, and West Bay (Figure 1). The drainage area of the bay is approximately 63,300 sq. km. The estuary receives most of its freshwater from the Trinity River, with much smaller contributions from the San Jacinto River (measured as spillover from Lake Houston Reservoir), HSC drainage (Buffalo Bayou and tributaries) and Chocolate Bayou. The average natural depth of the estuary is 2 m, with oyster reefs creating numerous shoal areas that alter the flow regime. Wind is the primary driving force for currents with tides having a relatively minor, modifying influence. Relatively deep navigation channels, e.g., the 12 m deep HSC, and waterways that traverse the bay have created areas of higher salinity, altered flows and restricted water exchange. In addition, dredged material disposal sites, notably those in the vicinity of HSC, restrict water exchange and circulation across the channel.

The average near-surface salinity of Galveston Bay is approximately 15 parts per thousand (ppt) (Criner and Johnican, 2001), although there is considerable spatial and temporal variability. Surface salinity generally varies from nearly 30 ppt near the entrance to the Gulf of Mexico to 3 ppt near major points of freshwater inflow, such as the Trinity River. Due to shallowness of the bay, vertical stratification in salinity is either slight or nonexistent. Large fluctuations in salinity ranging from 6 to 28 ppt also occur, due to the influence of wind and tide.

Given the shallowness of the estuary, sediments are easily redistributed by currents and tides (GBNEP, 1994; GBNEP, 1992). Surficial sediment in Trinity Bay is composed primarily of mud; sandy sediment predominates in West Bay; coarse-grained sand and shell material dominate the bay's entrance to the Gulf

Figure 1. Galveston Bay study area, including site locations and strata delineations.



of Mexico and in isolated reef areas throughout the bay.

The overall purpose of this study was to describe the environmental conditions in Galveston Bay in terms of sediment contamination and associated adverse biological effects. The objectives were to determine the incidence and degree of surficial sediment toxicity; determine the spatial patterns or gradients in chemical contamination and toxicity, if any; and determine the association among measures of sediment contamination, toxicity and benthic macroinvertebrate community.

The project study area extended from the upper reaches of HSC in the north to beyond the jetties at the entrance to Galveston Bay, including West, East and Trinity bays, and Clear Lake (Figure 1). The area of study as well as the dimensions of the sampling strata were selected in consultation with state and local resource management officials.

METHODS

SAMPLING DESIGN

A stratified-random sampling design similar to those used in previous NOAA surveys (Long et al., 1996) was applied in Galveston Bay. The study area was subdivided into 22 irregular shaped strata (Table 1 and Figure 1). Sampling sites within each substratum were selected on a random basis. Large strata were established in the open waters of the bay where topographic features and oceanographic conditions were relatively uniform and toxicant concentrations expected to be low. In contrast, relatively small strata were established in the upper and mid bay near suspected sources of contamination or where environmental conditions were expected to be heterogeneous or transitional. The boundaries of the strata were also established to coincide with the dimensions of major basins, bayous, waterways etc., in which hydrographic, bathymetric and sedimentological conditions were expected to be relatively homogeneous. This approach combines the strengths of a stratified design with the random-probabilistic selection of sampling locations, allowing the data generated within each stratum to be attributed to the dimensions of that stratum. Therefore, these data can be used to estimate the spatial extent of toxicity with a quantifiable degree of confidence (Heimbuch et al., 1995).

Seventy-five sites were sampled between 29 July and 16 August 1996 (Table 2). The locations of individual sampling sites within each stratum were chosen randomly using a computer-based program applied to digitized nautical charts produced by

Table 1. Galveston Bay sampling strata.

Zone	Stratum Number	Stratum Name	Area ($1{,}351\ km^2$)	Percent of Total Area
A	1	Upper Houston Ship Channel	1.55	0.11
	2	Scott Bay	6.13	0.45
	3	Upper San Jacinto Bay	3.38	0.25
B	4	Lower San Jacinto Bay	2.96	0.22
	5	Tabbs Bay	3.64	0.27
C	6	Upper Galveston Bay - East	29.56	2.19
	7	Upper Galveston Bay - West	31.44	2.33
D	8	Central Galveston Bay -West	101.65	7.52
	8A	Clear Lake	5.59	0.41
	9	Central Galveston Bay - East	124.01	9.18
	10	Lower Galveston Bay	248.89	18.42
E	11	Trinity Bay - Offshore	183.54	13.58
	12	Trinity Bay - Nearshore	125.36	9.28
F	13	East Bay	156.61	11.59
G	14	Texas City	38.67	2.86
H	15	West Bay	156.55	11.59
I	16	Bolivar Roads	18.60	1.38
	17	Galveston Bay - Entrance	25.16	1.86
J	18	Galveston Island - Nearshore	17.96	1.33
	19	Bolivar Peninsula - Nearshore	23.09	1.71
	20	Galveston Island - Offshore	22.28	1.65
	21	Bolivar Peninsula - Offshore	24.47	1.81

NOAA's National Ocean Service. The program was used to select a primary and three alternate sites. At least three sites were sampled within each stratum; four or five sites were sampled in larger strata. In instances where the primary site could not be sampled due to non-accessibility or an unsuitable substratum, the next sequential alternate site was sampled. In all cases, the primary or first alternate site was acceptable and sampled.

The elements of the sediment quality triad used in this study are shown in Figure 2. NS&T's standard suite of chemical analyses, multiple toxicity tests, and benthic community assessments were performed on sediment samples from all 75 sites. Samples were collected on board the NOAA ship FERREL or from its launch. Toxicity and chemistry samples were collected with a Kynar-coated $0.1m^2$ Young modified Van Veen grab sampler deployed with a hydraulic or electric winch. The grab sampler

Table 2. Sampling site locations in Galveston Bay.

Stratum	Site Number	Alternate	Site Location	Latitude (N)	Longitude (W)
1	1	1	Houston ship channel-40ft North of R 120 outside of channel, SW of Brownwood, oil industries there and to the south	29° 44.429	95° 3.437
1	2	2	Houston ship channel-NE of San Jacinto State Park, SE of Lynchburg Landing, South of high tension power lines	29° 45.703	95° 4.022
1	3	1	Houston ship channel - near ferry crossing, Lynchburg Range, south of Lynchburg landing, north of San Jacinto obelisk, nearby restaurant and Monument Inn, industries	29° 45.688	95° 4.705
2	4	1	Houston ship channel - SW of tank farm and numerous smoke stacks, East of San Jacinto monument, 20ft north of R 116	29° 44.101	95° 3.201
2	5	1	Houston ship channel-west of channel, 100m east of Alexander Island, 50m off G111	29° 43.333	95° 1.363
2	6	1	Scott Bay, 200m W of Petrochemical facility and residential homes	29° 44.744	95° 2.124
3	7	1	Upper San Jacinto Bay - between Alexander Island and Brinson Pt. (Dupont Petrochemical facility), appr. 100m North of R10 (100m north of channel)	29° 42.405	95° 1.948
3	8	1	Upper San Jacinto Bay - 100m North of Brinson Pt. Petro chemical (Dupont) facility, 200m east of G11	29° 42.228	95° 1.914
3	9	2	Upper San Jacinto Bay - 10m from G5 marker from channel in the bay, 200m NW of Spilmans Island, 500m west of suspension bridge over Houston ship channel, on Spilmans Island there is a Dupont Petrochemical facility	29° 42.149	95° 1.55
4	10	1	Houston ship channel-NE of entrance to Barbours Cut	29° 41.283	94° 59.312
4	11	1	Houston ship channel, entrance to Barbours Cut	29° 41.204	94° 59.187
4	12	1	Houston Ship Channel- 50m south of Hog Island NW edge seawall, 300m north of tall power cables, 100m SE of cable warning sign	29° 41.714	94° 59.402
5	13	1	Tabbs Bay - Appr. 300m east of low abandoned railroad bridge pilings, North of Hog Island	29° 42.288	94° 58.798
5	14	1	Tabbs Bay-Midway between Hog Island and mainland. Appr. 400m south of mainland, Appr. 300m west of old railroad bridge pilings	29° 42.293	94° 59.237
5	15	1	Tabbs Bay - 100m south of mainland, 300m east of abandoned railroad bridge pilings	29° 42.527	94° 58.822
6	16	1	Upper Galveston Bay eastern area-east of R80 of Houston Ship Channel	29° 37.901	94° 56.19
6	17	2	Upper Galveston Bay eastern area- 1 mi ESE R80 Houston ship channel	29° 37.48	94° 56.194
6	18	1	Upper Galveston Eastern side - East of Atkinson Island, west of Mesquite Knoll	29° 39.492	94° 56.968
7	19	1	Upper Galveston Bay western side-east of Little Cedar Bayou appr. 1 mi	29° 38.492	95° 0.196
7	20	1	Upper Galveston Bay western side-east of Bayside Terrace(appr. 2 mi)	29° 37.324	94° 58.941
7	21	1	Upper Galveston Bay western side-SE of Sylvan Beach	29° 38.328	94° 59.801
8A	22	1	Clear Lake-south of Apt/condos w/boat slips in western Clear Lake	29° 33.81	95° 3.587
8A	23	1	Clear Lake - southern edge of channel 100m SE of G19, 200m N of Lakeside shore	29° 33.299	95° 3.634
8A	24	1	Clear Lake - northern shore on the eastern end, 200m SW of apt complex with flags, 500m NW of R N14	29° 33.411	95° 2.302

Table 2. Sampling site locations in Galveston Bay (continued).

Stratum	Site Number	Alternate	Site Location	Latitude (N)	Longitude (W)
8	25	1	Upper Galveston Bay western side, 2.5 mi east of water tower, appr. 0.75 mi NE of beginning of channel into Clear Creek/Lake	29° 33.647	94° 58.835
8	26	1	Upper Galveston Bay western area-east of bridge over Clear creek, NE of radio antennae	29° 32.174	94° 57.21
8	27	1	Upper Galveston Bay western area-west of Bulkhead Reef, east of Red Bluff, appr. 0.5 mi west of Houston Ship channel	29° 35.985	94° 57.408
8	28	1	Upper Galveston Bay western area- appr 2.5 mi west of Houston Ship channel, 2.25 mi east of Todville	29° 34.101	94° 58.309
9	29	1	Upper Galveston Bay - NE of R70 marking Houston Ship Channel	29° 34.833	94° 54.714
9	30	1	Eastern side of Upper Galveston Bay and mouth of Trinity Bay, 3 mi south of Beach City	29° 37.209	94° 53.42
9	31	1	Eastern side of Upper Galveston Bay-0.5 mi ESE of Rear(after) range marker for the Bayport ship channel G180 6sec light, 60ft high	29° 36.783	94° 55.786
9	32	1	North of Trinity River Channel, just south of "L" shaped oil platform, two smaller oil obstructions close by	29° 32.009	94° 50.296
10	33	1	Central Galveston Bay, off east edge of Houston Ship Channel, NE of R 36	29° 25.328	94° 49.213
10	34	1	Central Galveston Bay, NW of Sievers Cove, South of Hanna Reef, 5 mi south of mainland	29° 27.019	94° 44.695
10	35	1	Central Galveston Bay, SE of Smith Pt., 2000yds from shore, North of Hanna Reef, sparse, residential area	29° 31.233	94° 46.287
10	36	1	Central Galveston Bay, East of Houston Ship Channel, NE of R 40, 1.5 mi east if R 42	29° 26.544	94° 48.093
10	37	1	Central Galveston Bay, appr. 1 mile east of Texas City, west of G47 marking Houston Ship Channel	29° 24.864	94° 51.964
11	38	1	Trinity Bay-deep, Central-west bay almost 3 mi off shore, residential	29° 41.7	94° 48.906
11	39	1	Trinity Bay-deep, SE area, near Galveston Bay, appr. 2.5 mi north of Smith Pt.	29° 35.49	94° 47.897
11	40	1	Trinity Bay-deep, 2 mi west of spoil bank near Black Pt, 1 mi due west of site #41, near some oil construction (platforms)	29° 40.088	94° 45.172
11	41	1	Trinity Bay - deep, east-central Bay, about 1 mi west of spoil bank near Black Pt	29° 40.092	94° 43.87
12	42	1	Trinity Bay-shallow, north central Bay , south of private marker #2	29° 43.451	94° 45.942
12	43	1	Trinity Bay-shallow, about 1 mi SE of Pt Barrow, residential	29° 43.198	94° 49.984
12	44	1	Trinity Bay - shallow, SE of mouth of Cooling System Discharge Canal (NW area of Bay)	29° 44.543	94° 48.453
13	45	1	East Bay, west of Goat Island, Long Pt or Big Pasture Bayou, North of ICW, marshy areas surrounding	29° 30.218	94° 36.703
13	46	1	East Bay, NW of Sievers Cove near the mouth of East Bay, north of ICW	29° 26.516	94° 42.807
13	47	1	East Bay SW of Lake Surprise and Stephenson Pt. near shore appr. 1000 yds away	29° 31.98	94° 42.31
13	48	1	East Bay, north of the ICW, east of Frozen Pt. and NW of Mussel Pt., surrounded by marshy area	29° 32.197	94° 30.35
13	49	1	East Bay, SE of Lake Surprise, NW of Big Pasture Bayou by 2.5 mi	29° 31.645	94° 38.591
14	50	1	Industrial area in Gal Bay, west of Pelican Island, north of mouth of Gal Channel, NW of Bascule Bridge along the beach	29° 18.97	94° 49.489
14	51	1	Industrial area north of ICW, south of Texas City Channel, west of spoil area/marsh	29° 20.802	94° 50.681
14	52	1	Industrial, north of bridge separating lower Gal Bay and West Bay, East of ICW	29° 18.228	94° 52.763

Table 2. Sampling site locations in Galveston Bay (continued).

Stratum	Site Number	Alternate	Site Location	Latitude (N)	Longitude (W)
15	53	1	West Bay, south of Carancahua Pt	29° 13.101	95° 1.508
15	54	1	West Bay, 2 mi ESE of Greens Lake	29° 15.703	94° 57.957
15	55	1	North of San Luis Pass, South of ICW, west end of West Bay	29° 7.907	95° 7.848
15	56	1	West Bay, south of Cow Bayou, R 2 marker	29° 11.301	95° 4.303
15	57	1	West Bay, SE of mouth of Basford Bayou SW of Tiki Is. (residential)	29° 17.494	94° 56.73
16	58	1	Southern edge of Bolivar Roads channel where it turns to the NE to enter Galveston Bay, ENE of Galveston Coast Guard Bay appr 0.5 mi	29° 20.503	94° 45.976
16	59	1	Bolivar Roads-100m east of outer bar channel rear range marker, 0.5 mi south of Bolivar penninsula light house	29° 21.381	94° 46.37
16	60	1	Bolivar Roads-west end of Anchorage area, north of Inner Bar channel	29° 20.991	94° 33.242
17	61	1	Located in a discontinued dumping ground according to the chart, appr. 1.75 mi ESE from the north jetty end marker	29° 20.139	94° 39.193
17	62	1	Entrance to Galveston Bay-South of Outer Bar Channel, appr 200m south of G "7" marker of channel	29° 20.079	94° 41.764
17	63	1	Entrance to Galveston Bay-20m off north jetty, 300m north of yellow buoy "A"(YA), 200 m east of Galveston Bay entrance channel range A front	29° 21.224	94° 42.839
18	64	1	Offshore shallow-1.5 mi south of south jetty, 0.5mi east of Galveston Island shore(last hotel building)	29° 18.941	94° 44.121
18	65	1	Offshore shallow - appr 1 mi from shore, south of jetty	29° 18.829	94° 43.385
18	66	1	Offshore shallow - appr. 1 mi offshore, appr. 2 mi SW of south jetty marker	29° 18.488	94° 43.401
19	67	1	Offshore shallow - 300m east of Bolivar penninsula, 300m north of charted wreck	29° 24.951	94° 41.186
19	68	1	Offshore shallow - 200m east of Bolivar penninsula	29° 23.875	94° 42.599
19	69	1	Offshore shallow- 1 mi east of Bolivar penninsula shore @ radio tower appr. 0.25 mi south of charted wreck above surface	29° 23.229	94° 42.594
20	70	1	Offshore deep - SSW of south jetty marker, appr 2 mi	29° 17.472	94° 42.978
20	71	1	Offshore deep-appr. 2 mi due south of south jetty end marker	29° 18.215	94° 41.642
20	72	1	Offshore deep- south of jetties, south of East Beach appr. 2mi	29° 18.07	94° 42.685
21	73	1	Just ENE of north jetty marker	29° 20.912	94° 40.687
21	74	1	NE of jetty marker by appr. 1.75 mi, SE by appr. 0.5 mi of marker near ship wrecks	29° 21.425	94° 38.831
21	75	1	just SE of marker near ship wrecks, north of jettys	29° 21.643	94° 39.138

and sampling utensils were acid washed with 10% HCl and then rinsed with deionized, ultra-filtered water at the start of sampling each day, and thoroughly cleaned with acetone and site water before collection of samples at each site. At least three or four deployments of the sampler were required to provide sufficient surficial sediment for the toxicity tests and chemical analyses. Only the upper 2-3 cm of the sediment was used in order to assure collection of recently deposited materials. A sediment sample was discarded if the jaws of the grab were open, the sample was partly washed out, or if the sediment sample in the grab was less than 5 cm deep. Sediments were removed with a scoop made of high-impact styrene; sediment was composited in an acetone rinsed, high-density polyethylene (HDPE) bucket. Between each deployment of the sampler, the bucket was covered with an HDPE lid to minimize sample oxidation and exposure to atmospheric contamination. The material was carefully homogenized in the field with an acetone-rinsed, HDPE paddle before being distributed to prepared sample containers. Samples were immediately placed on ice. Samples for contaminant analyses and P450 RGS testing were frozen as soon as possible.

Samples for the benthic community analyses were collected at each site with a small (413 cm^2), Young-modified Van Veen grab. The entire contents of an acceptable grab (at least 5 cm deep at the center of the grab) was retained and sieved in the field with a 0.5 mm screen. Material retained on the sieve was preserved in 10% buffered formalin with Rose bengal stain.

SQT Components

- **Chemical contaminant concentrations for over 70 analytes**
    - **- metals**
    - **- polycyclic aromatic hydrocarbons**
    - **- pesticides**
    - **- polychlorinated biphenyls**
- **Sediment toxicity tests**
    - **-10-day amphipod survival**
    - **- sea urchin fert/48 hr embryonic dev.**
    - **- Microtox@ response**
    - **- P450 RGS**
- **Benthic macroinvertebrate community characterization**
    - **- species richness/abundance**
    - **- diversity indices**
    - **- dominant taxa**

Figure 2. Elements of the sediment quality triad.

Samples for toxicity testing and chemistry analyses were shipped in ice chests packed with water ice or blue ice to the testing laboratories by overnight courier. Samples for toxicity tests were kept chilled on ice until extractions or tests were initiated.

Samples for chemical analyses were kept frozen until thawed for analyses. All samples were accompanied by chain of custody forms which included the date and time of sample collection and site number.

CONTAMINANT ANALYSES

Chemical analyses on all 75 samples were performed under contract by the Texas A&M University/Geochemical and Environmental Research Group (TAMU/GERG), located in College Station, Texas.

Trace and Major Elements

Trace and major element analyses (Table 3) were based on homogenized samples that underwent complete dissolution, typically using concentrated nitric and hydrofluoric acids at high temperature in Teflon® containers. For mercury, samples were digested using concentrated sulfuric and nitric acid. Table 3 also provides the methods used to determine trace element concentrations and method detection limits (MDLs). Sediment samples were digested for final analysis by procedures specific to the instrument method used (e.g., flame, graphite furnace, or cold vapor atomic absorption). Concentrations of trace and major elements were calculated by comparing the analytical signals of the unknowns with those of the calibration standards, and then multiplying by the instrumental and digestion dilution factors.

Organic Contaminants

The organic contaminants determined in the analyses are listed in Table 4, along with their representative MDLs. Quantification was performed using the internal standards method. PAHs were analyzed by gas chromatography/mass spectrometry in the selected ion mode. Sediment samples analyzed for butyltins were extracted with DCM containing 2% tropolone, hexylated, purified by silica gel chromatography, and concentrated. Butyltins were analyzed by gas chromatography using a flame photometric detector equipped with a tin-selective filter. PCBs and chlorinated pesticides were determined by gas chromatography/electron capture detection. Concentrations of sediment organic compounds are reported on a dry weight basis.

Table 3. Trace and major element detection limits, 1996 (Lauenstein and Cantillo, 1998) and analytical methods.

Element	Method Detection Limit (ppm, dry weight)	Analytical Method *
Aluminum	106	FAA
Iron	290	FAA
Manganese	2.5	FAA
Arsenic	0.31	GFAA
Cadmium	0.003	GFAA
Chromium	0.64	GFAA
Copper	0.30	GFAA
Lead	0.35	GFAA
Mercury	0.005	CVAA
Nickel	0.19	GFAA
Selenium	0.02	GFAA
Silver	0.011	GFAA
Tin	0.11	GFAA
Zinc	0.78	FAA

* FAA = Flame atomic absorption
GFAA = Graphite furnace atomic absorption
CVAA = Cold vapor atomic absorption

Table 4. Organic compounds measured in Galveston Bay sediments and method detection limits, 1996 (Lauenstein and Cantillo, 1998).

Polycyclic Aromatic Hydrocarbons	Method Detection Limit (ppb, dry weight)
Naphthalene	2.2
C1-Naphthalenes	
C2-Naphthalenes	
C3-Naphthalenes	
C4-Naphthalenes	
Biphenyl	0.3
Acenaphthylene	0.3
Acenaphthalene	0.5
Fluorene	0.5
C1-Fluorenes	
C2-Fluorenes	
C3-Fluorenes	
Phenanthrene	0.8
Anthracene	0.5
C1-Phenanthrenes/Anthracenes	
C2-Phenanthrenes/Anthracenes	
C3-Phenanthrenes/Anthracenes	
C4-Phenanthrenes/Anthracenes	
Dibenzothiophene	0.3
C1-Dibenzothiophenes	
C2-Dibenzothiophenes	
C3-Dibenzothiophenes	
Fluoranthene	1
Pyrene	1.1
C1-Fluoranthenes/Pyrenes	
Benzo(a)anthracene	0.2
Chrysene	0.7
C1-Chrysenes	
C2-Chrysenes	
C3-Chrysenes	
C4-Chrysenes	
Benzo(b)fluoranthene	1.3
Benzo(k)fluoranthene	0.5
Benzo(e)pyrene	0.6
Benzo(a)pyrene	0.6
Perylene	0.6
Indeno(1,2,3-c,d)pyrene	0.3
Dibenzo(a,h)anthracene	0.5
Benzo(g,h,i)perylene	1.3
1-Methylnaphthalene	1
2-Methylnaphthalene	1.7
2,6-Dimethylnaphthalene	2.4
1,6,7-Trimethylnaphthalene	0.4
1-Methylphenanthrene	0.2

Polychlorinated Biphenyls	Method Detection Limit (ppb, dry weight)
PCB8/5	0.12
PCB18/17	0.82
PCB28	0.09
PCB44	0.1
PCB52	0.42
PCB66	0.07
PCB101/90	0.15
PCB105	0.06
PCB118	0.07
PCB128	0.14
PCB138 /160	0.07
PCB153/132	0.08
PCB170/190	0.17
PCB180	0.05
PCB187	0.08
PCB195/208	0.09
PCB206	0.05
PCB209	0.1

Pesticides	Method Detection Limit (ppb, dry weight)
Endosulfan II	0.06
Hexachlorobenzene	0.07
Alpha HCH	0.37
Beta HCH	0.17
Gamma HCH (Lindane)	0.08
Delta HCH	0.05
Heptachlor	0.05
Heptachlor Epoxide	0.04
Oxychlordane	0.07
Gamma Chlordane	0.15
Alpha Chlordane	0.23
Trans-Nonachlor	0.1
Cis-Nonachlor	0.04
Aldrin	0.13
Dieldrin	0.04
Endrin	
Mirex	0.11
2,4' DDE	0.08
4,4' DDE	0.06
2,4' DDD	0.18
4,4' DDD	0.07
2,4' DDT	0.05
4,4' DDT	0.09

Quality Assurance/Quality Control

All analytical methods conformed to performance-based protocols and employed the quality-assurance steps of the NS&T Program (Lauenstein and Cantillo eds, 1998). Quality assurance procedures included analyses of duplicates, standard reference materials, and spiked internal standards. For trace elements, analyses included a full suite of quality assurance samples with an emphasis on certified reference materials. In the organic analyses, internal standards were added at the start of the procedure and carried through the extraction, cleanup, and instrumental analysis steps. The organic recovery rate data was used to correct analytical data before reporting. The following specific quality assurance steps were used to insure measurement accuracy and precision. For pesticides, PCBs and PAHs, one procedural blank, one matrix spike, one duplicate spike and one standard reference material were run with each batch of no more than 20 samples. Surrogate recoveries were tracked.

Grain Size and Total Organic Carbon

Grain size was determined by the standard pipette method following sieving for the sand and gravel fractions. Total organic carbon was determined using a Leco Carbon Analyzer. Grain size duplicates were run every 20 samples. For TOC, one method blank, one duplicate, and one standard reference material were run every 20 samples.

SEDIMENT TOXICITY TESTS

Amphipod mortality, sea urchin fertilization and development impairment, Microtox®, and cytochrome P450 Reporter Gene System (RGS) tests were carried out on the sediment samples.

Amphipod Survival Test

The testing of amphipod survival in sediments is the most widely and frequently used assay in sediment toxicity evaluations in North America, in part because the test integrates effects of complex contaminant mixtures in relatively unaltered sediment, and also because amphipods are a fairly common and ecologically important species in coastal bays and estuaries. The species *Ampelisca abdita* has most commonly been used in NOAA-sponsored studies, as well as studies sponsored by other agencies, such as the Environmental Protection Agency. This euryhaline species occurs in fine sediments from the intertidal zone to a depth of 60 m, with a distribution that extends from Newfoundland to south-central Florida, including the eastern Gulf of Mexico, and more recently, portions of the California coast. *A. abdita* builds soft, membranous tubes and feeds on surface deposited particles as well as particles in suspension. In previous studies, this species has shown relatively little sensitivity to nuisance factors such as grain size, ammonia, and organic carbon. The tests are performed using juveniles exposed to relatively unaltered, bulk sediments.

TRAC Laboratories, Inc. in Pensacola, FL conducted the amphipod toxicity tests. All tests were initiated within 8 days of sample collection with the exception of sites 26, 27, 28 and 22, 23, 24, and 25 whose samples were held 11 and 12 days, respectively. Test animals were purchased by TRAC Laboratories from Brezina and Associates, Inc. of Dillon Beach, CA (lots AA-96-A and AA-96-B). *A. abdita* were collected by Brezina in northern San Francisco Bay, and shipped to TRAC Laboratories within 48 hours. Amphipods were packed in native sediment with 8-10 liters of seawater in doubled plastic bags. Oxygen was injected into the bags and shipped via overnight courier to the testing lab. Upon arrival, amphipods were acclimated and maintained at 20°C for at least one day prior to the initiation of the test.

The testing followed procedures detailed in the Standard Guide for Conducting 10 day Static Sediment Toxicity Tests with Marine and Estuarine Amphipods (ASTM, 1992). Each test had five replicates of 20 healthy animals (good color, full guts, and 2-4 mm in size) under static conditions using natural seawater. An aliquot of 200 ml of test or negative control sediment was placed in the bottom of 1 l test chambers, and covered with approximately 750 ml of natural seawater from the Gulf of Mexico, diluted to 30 ppt. Temperature was maintained at 20°C. Lighting was continuous during the 10 day exposure period to encourage amphipods to burrow and to inhibit swimming. Data on temperature, salinity, dissolved oxygen, pH and ammonia in the test chambers were obtained during tests of each batch of samples. A sixth replicate was run for daily dissolved oxygen, pH, and temperature measurements. Salinity was measured four times during the 10 day testing period. The jars were checked daily and the number of dead animals, animals on the water or sediment surface, and those in the water column were recorded. Amphipods on the water surface were gently pushed down into the water to enable them to burrow; dead amphipods were removed.

Amphipods were also exposed to negative and positive control sediments. Negative control sediments were collected by TRAC Laboratories at site C-17 in Perdido Bay, located near Pensacola, Florida. These sediments have been tested by TRAC and found to be consistently nontoxic in amphipod tests, and are also uncontaminated. A positive control (reference toxicant) test was used to document the sensitivity of each batch of test organisms. The positive control consisted of 96 hr water-only exposures to sodium dodecyl sulfate (SDS). LC50 values were calculated for each test run. Control charts maintained by TRAC Laboratories showed consistent results in tests of both the positive and negative controls.

Statistical Analysis. Analysis of variance (ANOVA), or a one-tailed test was used to determine whether any of the observed differences between the control and experimental data were statistically significant. If the observed differences were found to be significant, Dunnett's procedure for multiple comparisons was used to test the difference between the mean of the reference and experimental populations.

Sea Urchin Fertilization and Embryological Development Tests

Sediment porewater toxicity was tested using the sea urchin *Arbacia punctulata*. The tests were performed by the Marine Ecotoxicology Research Station of the Biological Resources Division, U.S. Geological Survey, located in Corpus Christi, Texas. Sediment porewater was extracted as soon as possible after receipt of samples, however, no sediments were held longer than 8 days from the time of collection or 48 hours after their receipt by the laboratory. Sediment samples were held refrigerated (4° C) until the porewater was extracted with a pressurized pneumatic extraction device made of polyvinyl chloride with a 5 µm polyester filter (Carr, 1998). After extraction, porewater samples were centrifuged in polycarbonate bottles at 1,200 x g for 20 minutes to remove any particulate matter and then frozen at -20° C until the start of the tests. Two days before the start of a toxicity test, samples were transferred from the freezer to a refrigerator at 4° C. One day prior to testing, the samples were thawed in a tepid water bath. Experiments performed previously at the laboratory have demonstrated no effects upon toxicity attributable to freezing of the porewater samples.

Sample temperatures during the tests were maintained at 20±1° C. Sample salinity was measured and adjusted to 30±1 ppt, if necessary, using purified deionized water or concentrated brine. Other water quality measurements included dissolved oxygen, temperature, pH, sulfide and ammonia. Samples with less than 80% dissolved oxygen saturation were gently aerated by stirring the sample on a magnetic stir plate. After these measurements and any necessary adjustments were made, the samples were refrigerated at 4° C overnight. The samples were returned to 20±1° C before testing started. The tests were performed with 100% porewater, or with 50% and 25% dilutions of each sample. Samples were diluted with 30 ppt filtered (0.45 µm) seawater, and five replicates were tested for each sample.

The tests were conducted with gametes of the sea urchin *A. punctulata* following the procedures outlined in Carr et al. (1996). Adult male and female urchins were stimulated to spawn with a mild electric shock and the gametes were collected separately. The tests involved exposing the sperm to 5 ml of the test solution for 30 minutes followed by the addition of 2,000 eggs. After an additional 30 minutes of incubation, the test was terminated by the addition of formalin. An aliquot of the egg suspension was examined under a microscope to determine the presence or absence of a fertilization membrane surrounding the egg, and percent fertilization was recorded for each replicate.

The embryological development test followed the same basic procedures as the fertilization test. A suitable (predetermined) concentration of sperm was incubated with eggs for 10 minutes to allow fertilization to take place. After this time, eggs were viewed under a microscope to ensure that 70-90% of the eggs were fertilized. Additional sperm was added if needed to achieve at least 70% fertilization. The embryos were then pipetted into the test vials containing porewater, and incubated for 48 hours at 20° C. The test was terminated by the addition of formalin. An aliquot of the embryos was then examined under a compound microscope to determine the percentage of embryos developing to the echinopluteus stage and having normal features. Reference toxicity (positive control) tests with SDS were run with each series of tests to assess the sensitivity of the gametes.

Porewater from a reference area in Redfish Bay, Texas located near the testing facility was used as a negative control. Sediment porewater from this site has been used successfully in the past. A positive control consisting of a dilution series of SDS and a dilution blank of filtered seawater and one of reconstituted brine were also conducted as part of the testing procedure.

Statistical Analysis. Transformed (arcsine square root) data sets were screened for outliers by comparing the studentized residuals to a critical value from a t-distribution using a Bonferroni-type adjustment (SAS, 1992). The adjustment is based on the number of observations (n) so that the overall probability of a Type 1 error is at most 5%. After the outliers were removed, the transformed data sets were tested for normality and homogeneity of variance. Additional statistical comparisons among sea urchin fertilization and embryo development treatments were made using an

ANOVA and Dunnett's one-tailed t-test, which controls for the experiment-wise error rate, on the transformed data (SAS, 1989). The trimmed Spearman-Karber method (Hamilton et al., 1977) with Abbott's correction (Morgan, 1992) was used to calculate EC_{50} (50% effective concentration) values for the dilution series tests.

Microtox® Test

This test is based on the premise that in a particular strain of the bacterium *Vibrio fischeri*, bioluminescence is closely tied to cellular respiration, and any inhibition of cellular activity would result in a decreased rate of respiration and a corresponding decrease in luminescence. A decrease in respiration could result from exposure to toxicants. The test is relatively simple and inexpensive; there are published data on the Microtox® response to hundreds of chemicals and environmental samples from harbors, industrial waste streams, waste dump sites, etc. (Johnson and Long, 1998). Since the test in this study is based on the relative toxicity of organic extracts of sediments, the effects of nuisance environmental factors such as grain size, ammonia, and organic carbon are avoided. However, organic extracts would tend to include contaminants that may or may not be readily bioavailable in the actual sediment. Therefore, this test is generally considered a test of the potential toxicity of environmental samples. However, a strong linear relationship has been documented between Microtox® response (effective concentration), and the lethal concentration in a variety of aquatic fauna, particularly for contaminants with a relatively simple chemical structure (Kaiser, 1998).

The equipment and supplies, including the freeze dried bacteria necessary to perform the Microtox® Basic assay, were obtained from AZUR Environmental in Carlsbad, CA. All sediment samples and extracts were stored in the dark (<10 days) at 4°C until processing or testing was initiated.

Prior to the initial homogenization, surface water and large debris (shells and pebbles) were removed. Samples were then centrifuged at 1,000 x g for five minutes. The water was decanted and moisture content determined and recorded for each sample. A 10 g sediment sample from each site was weighed, recorded, and placed into a dichloromethane (DCM) rinsed 50 ml centrifuge tube. A 15 g portion of sodium sulfate was added to each sample and mixed. Spectral grade DCM (30 ml) was added and mixed. The mixture was shaken for 10 seconds, vented and tumbled overnight.

The next day samples were centrifuged again at 1,000 x g for 5 min. The sediment extracts were then transferred to a Kuderna-Danish flask. Five ml of acetone were added and the volume reduced to approximately 2 ml. The extract was then transferred to a DCM rinsed flask. Acetone was used to completely rinse the Kuderna-Danish flask. A stream of nitrogen gas reduced the extract volume to approximately 1 ml. To make the final extract volume 10 ml, dimethylsulfoxide (DMSO) was added. DMSO is compatible with the Microtox® system, having a relatively low toxicity and good solubility with a broad array of apolar chemicals (Johnson and Long, 1998).

A suspension of *V. fischeri* was thawed and hydrated with toxicant-free distilled water, covered and stored in a 4°C well on the Microtox® analyzer. To determine toxicity, each sample was diluted into four test concentrations. Percent decrease in luminescence of each cuvette relative to the reagent blank was calculated. Based upon these data, the sediment concentrations that caused a 50% decrease in light production (EC_{50}) over a 5 minute period were reported as mg equivalent sediment wet weight with 95% confidence intervals for the replicates.

The sediment extracts were prepared by ABC Laboratories, Inc. according to the basic liquid phase test protocols and QA/QC performance standards described by Microbics Corporation (1992). In addition to an extraction blank prepared with DMSO, the toxicity of the samples was determined using the Redfish Bay reference site value (EC_{50} value = 35.97 mg eq. /ml) and a phenol spiked control (EC_{50} value = 12.17 mg eq. /ml). A Control Sediment Index (CSI) value was calculated for each sample by taking the EC_{50} value of the reference site and dividing it by the EC_{50} value of the test sample. If the resulting number was greater than one, the sample was deemed toxic, if the resulting number was lower than one, the sample was considered nontoxic relative to the control. The Phenol Spiked Index (PSI) was calculated by dividing the reference phenol spiked control EC_{50} value by the test sample EC_{50}. If the resulting number was greater than one, then the test sample was considered more toxic than the spiked (phenol) control.

Statistical Analysis. The results were analyzed using the software package Microtox® Data Reduction developed by Microbics Corporation (1992), to determine the concentration of the extract that inhibited luminescence by 50% after a 5 minute exposure period. The EC_{50} values were reported as the mean of three replicates. An ANOVA and

Dunnett's one tailed t-test were used to compare the test sample results.

Cytochrome P450 Reporter Gene System (RGS) Assay

The RGS assay (now known as the Human Reporter Gene System assay, or HRGS) was used to determine the presence of organic chemicals that bind to the aryl hydrocarbon receptor and induce the cytochrome P450 1A1 locus on the vertebrate chromosome. Several classes of chemicals are also known to cause direct chemical toxicity or genotoxicity in a variety of species. They include planar polychlorinated biphenyls (PCBs), higher molecular weight polycyclic aromatic hydrocarbons (PAHs), dioxins and furans.

The test uses a transgenic cell line (101L), derived from the human hepatoma cell line (HepG2), in which the flanking sequences of the CYP1A gene, containing the xenobiotic response elements (XREs), have been stably linked to the firefly luciferase gene (Postlind et al. 1993). As a result, the enzyme luciferase is produced in the presence of compounds that bind to the XREs. Induction at the CYP1A site in this cell line results in the production of luciferase, the amount of which is readily estimated as emitted light when the cell extracts are injected with the light-producing pigment luciferin. Details of the testing methods have been published as a standard method or analytical protocol by a number of organizations (ASTM, 1997; APHA, 1996; US EPA, 2000). For quality assurance purposes, all sample analysis batches were accompanied by testing method blanks, spiked samples, and reference toxicants.

In the assay, 40 g of sediment from each site were extracted using EPA Method 3540 to produce 1 ml of DCM/extract mixture. A 2 µl portion of the extract was applied to approximately 1 million human liver cells contained in three replicate wells with 2 ml of culture medium. After 16 hours of incubation, the cells were washed, lysed, and centrifuged. The enzyme reaction was then initiated by addition of luciferin. Small portions (50 µl) were used in measuring luminescence. Solvent blanks and the reference toxicant (2, 3, 7, 8 - dioxin) were tested with each batch of samples. Tests performed on extracts from Redfish Bay were used as a negative control.

Benzo[a]pyrene equivalents (B[a]PEq) were calculated for sample extracts and any duplicate samples. B[a]PEq is a response measure relative to benzo[a]pyrene, for all CYP1A-inducing chemicals present in the sample and is calculated as follows: B[a]PEq (µg/g) = (fold induction/60) x (volume factor/dry weight) x d.f. Fold induction was calculated as mean relative light units (RLU) produced by the sample divided by mean RLU produced by the solvent blank. The factor 60 represents the approximate fold induction produced by 1 µg of benzo[a]pyrene/ml. The volume factor represents the total extract volume divided by the volume of extract applied to the cells. Dividing by the dry weight of each sample yields B[a]PEq in µg/g. For samples that were diluted, the B[a]PEq value is multiplied by the dilution factor.

Statistical Analysis. Since the RGS assay lacks an assessment endpoint, statistical analyses of accumulated data from NOAA's previous studies have been used to derive threshold or critical values. A recent analysis of these data indicated that the 90% upper prediction limit of observations (n=530) was 37. Eliminating the 90th percentile of the data set (values greater than 37.4), the upper prediction limit is reduced further, i.e. to 11.1. This new data set could be construed to mean that it excludes outliers, i.e., heavily contaminated sites. So, if a future value exceeds this limit, one would assume that the observation was from a different distribution. Earlier, Anderson et al. (1999) showed the upper confidence limit of the mean response value to be 32.8, and the lower confidence limit to be 12.8. These authors noted that a value greater than 32.8 would indicate toxicological significance. It has been shown that RGS assay responses higher than 60 are usually associated with degraded infaunal communities (Fairey et al., 1998). Based on these results and testing of sediments from apparently uncontaminated sites, an RGS assay response value of approximately 10 is considered a background level for estuarine sediment. For environmental assessment purposes, values of 10 (background level), 35 (toxicological significance), and 60 (impaired benthic habitat conditions) could be useful.

BENTHIC COMMUNITY ANALYSIS

The density and diversity of benthic infauna can be used as an indicator of benthic community health. The methods used by Barry A. Vittor and Associates are based on Holmes and McIntyre (1984). For this study, the samples were preserved in a 10% formalin and Rose bengal solution, and delivered to the laboratory via overnight courier. In the laboratory, the samples were rinsed through a 0.5 mm sieve and re-stained, if necessary. Samples were stored in the dark in 70% isopropanol in a temperature controlled room before and after sorting. Sample containers were continually monitored for evaporation, leakage and spills.

Using a Wild M-5A dissecting microscope, all macroinvertebrates or fragments thereof were then sorted and placed in vials of 70% isopropanol. Samples were sorted into major taxa, i.e. Annelida, Crustacea, Mollusca, Echinodermata, and miscellaneous. The remaining samples were saved in the original container. All macroinvertebrates were identified to the lowest possible level and only heads of animals collected alive were counted. Each identification was subject to an in house verification and a number of samples were sent out to taxonomic experts for verification. In addition, 10% of the samples were resorted to ensure consistency.

As NOAA's sediment toxicity studies cover different salinity zones, Barry A. Vittor and Associates treated the marine and the brackish/ freshwater samples differently. The freshwater samples, likely to contain large numbers of oligochaetes and chironomids were sorted using a quadrant petri dish with vials distributed evenly in the dish. The sample was considered complete when 200 chironomids and 100 oligochaetes had been mounted and the quadrant filled. The formula developed by Klemm et al. (1990) was used to calculate the number of a species in a sample. In addition, a reference collection was assembled and archived. It included representative individuals for each species stored in covered vials, preserved and labeled. The macroinfauna was characterized by standard community structure parameters such as species abundance, species composition, and diversity indices. These initial analyses were followed by pattern and classification analysis.

In this study, infaunal abundance is reported as the total number of individuals per site and/or stratum, and the density is reported as the number of individuals per square meter. Species richness is the total number of taxa in the sample for each site and/or strata. The Shannon-Wiener function H', was used to calculate species richness for each sample as follows:

$$H' = -\sum_{i=1}^{s} p_i(\mathit{ln}\, p_i)$$

where,

s = the number of taxa in the sample

i = the ith taxa in the sample

p_i = the number of individuals of the ith taxa divided by the total number of individuals in the sample.

Pielou's Index J', also based on the Shannon-Wiener function, was used to describe evenness (or equitability) of abundance among species:

$$J' = H'/\mathit{ln}S$$

thus, $J' = H'/H'_{max}$.

The maximum possible diversity occurs when all taxa have the same number of individuals, or

$$\mathit{ln}S = H'_{max}.$$

Statistical Analysis. Once the initial characterizations had been completed, some components of the data were analyzed further. Total density values were tested for normality using Shapiro-Wilk (SAS Institute, 1995). Nonparametric methods such as the Wilcoxon test or the Kruskal-Wallis test were used to test for differences between means (SAS Institute, 1995). In addition to the community analyses described above, normal and inverse classification analyses were performed using the faunal data to determine the within and between strata differences and to compare the composition from one stratum to another. These analyses were carried out using the Community Analysis System 5.0 software package (Bloom, 1994).

RESULTS

The characteristics of the sediments at the sampling sites in Galveston Bay are shown in Appendix A. The field logs are contained in Appendix B.

SEDIMENT CONTAMINANTS

Table 5 lists the mean and range of contaminant concentrations measured in the Galveston Bay study area. Also listed are the elements and organic contaminants for which NOAA has developed a sediment quality guideline, along with their associated values. Appendices C-F provide a complete listing of contaminant concentrations measured at each site in the study area.

Table 6 provides the spatial extent of ER-L and ER-M (Long et al., 1995) contaminant guideline exceedences. The extent of ER-L and ER-M exceedences were recalculated to account for the three alternate sites, and the extent of exceedences changed minimally.

Trace Elements

In general, concentrations were distributed relatively uniformly throughout the study area. An exception to this was mercury. There were clearly higher concentrations found in the upper portions of the study area as can be seen in Figure 3 and in Appendix C. NOAA's ER-M sediment quality guidelines were not exceeded at any of the 75 sites, although numerous sites exceeded ER-L values for As, Cr, Hg, Ni, and Zn (Table 6 and Figures 3-8). Arsenic concentrations in excess of the ER-L guideline include 29% of the study area. Similarly, nickel exceedences totaled 25% of the study area. Chromium, mercury, and zinc exceedences were minimal; between the three the spatial extent of ER-L exceedences totaled less than 1% of the study area. Two sites in the upper portion of the study area (Sites 6 and 3, Figure 1) had multiple ER-L

Table 5. Summary of selected chemical contaminants in Galveston Bay sediments.

Trace/major elements	Range of concentrations	Mean concentration ±SD	ER-L (ppm, dry wt.)	ER-M (ppm, dry wt.)
Arsenic	ND - 13.35	5.91 ± 3.40	8.2	70
Cadmium	0.01 - 0.21	0.09 ± 0.056	1.2	9.6
Chromium	3.44 - 84.13	41.03 ± 18.55	81	370
Copper	1.61 - 33.22	10.72 ± 6.32	34	270
Lead	5.72 - 37.7	16.85 ± 6.41	46.7	218
Mercury	ND - 0.17	0.05 ± 0.032	0.15	0.71
Nickel	ND - 28.95	15.09 ± 7.4	20.9	51.6
Silver	0.04 - 0.52	0.12 ± 0.06	1.0	3.7
Zinc	6.77 - 167.57	65.8 ± 31.92	150	410

Organic compounds	Range of concentrations	Mean concentration ±SD	ER-L (ppb, dry wt.)	ER-M (ppb, dry wt.)
Acenapthene	0.2 - 34.9	1.8 ± 4.54	16	500
Acenapthylene	ND - 26.6	3.1 ± 4.24	44	640
Anthracene	0.1 - 228.3	8.8 ± 28.38	85.3	1,100
Fluorene	0.2 - 34.5	2.4 ± 5.15	19	540
2-Methyl napthalene	0.2 - 11.0	2.4 ± 2.12	70	670
Napthalene	0.5 - 18.4	4.2 ± 2.72	160	2,100
Phenanthrene	0.2 - 501.5	13.6 ± 59.10	240	1,500
Low mol. wt. PAHs	4.3 - 1,944.5	138.4 ± 254.71	552	3,160
Benzo(a)anthracene	0.1 - 676.4	19.1 ± 78.79	261	1,600
Benzo(a)pyrene	0.1 - 335.3	16.0 ± 41.46	430	1,600
Chrysene	0.1 - 711.6	22.8 ± 83.85	384	2,800
Dibenz(a,h)anthracene	ND - 66.1	3.5 ± 8.29	63.4	260
Fluoranthene	0.1 - 1,473.0	38.6 ± 170.85	600	5,100
Pyrene	0.2 - 1,502.7	43.8 ± 175.03	665	2,600
High mol. wt. PAHs	1.5 - 8,393.3	317.6 ± 993.01	1,700	9,600
Total PAHs	5.4 - 10,586.7	468.4 ± 1,262.78	4,022	44,792
p,p'-DDE	ND - 2.16	0.13 ± 0.30	2.2	27
Total DDT	ND - 451.54	7.37 ± 52.32	1.58	46.1
Total PCBs	2.27 - 60.79	7.61 ± 8.60	22.7	180

SD, standard deviation; ER-L, effects range low; ER-M, effects range medium

exceedences for these elements. Site 6 located in Scott Bay exceeded ER-L concentrations for Cr, Hg, Ni, and Zn. Site 3 located in the uppermost reach of NOAA's study area exceeded ER-L values for As, Hg, and Ni.

Pesticides and PCBs

Measured pesticides and PCBs were uniformly low (Figures 9-12 and Appendices D-E). Although concentrations in the upper reaches were higher, they were still below the ER-M sediment quality

Table 6. Spatial extent of contaminants exceeding NOAA's Sediment Quality Guidelines (SQGs) in Galveston Bay.

Trace and major elements	>ER-L		>ER-M	
	Toxic area (km^2)	% of Total area (1,351 km^2)	Toxic area (km^2)	% of Total area (1,351 km^2)
Arsenic	386	29	0	0
Cadmium	0	0	0	0
Chromium	2	0.1	0	0
Copper	0	0	0	0
Lead	0	0	0	0
Mercury	3	0.2	0	0
Nickel	336	25	0	0
Silver	0	0	0	0
Zinc	2	0.1	0	0
Organic compounds	>ER-L		>ER-M	
	Toxic area (km^2)	% of Total area (1,351 km^2)	Toxic Area (km^2)	% of Total area (1,351 km^2)
Acenaphthene	32	2	0	0
Acenaphthylene	0	0	0	0
Anthracene	31	2	0	0
Fluorene	32	2	0	0
2-Methyl naphthalene	0	0	0	0
naphthalene	0	0	0	0
phenanthrene	31	2	0	0
Low-molecular wt. PAH	0	0	0	0
Benzo(a)anthracene	31	2	0	0
Benzo(a)pyrene	0	0	0	0
chrysene	0	0	0	0
dibenz(a,h)anthracene	0	0	0	0
Fluoranthene	0	0	0	0
pyrene	0	0	0	0
high molecular wt. PAH	0	0	0	0
total PAH	31	2	0	0
p,p'-DDE	0	0	0	0
total DDT	75	6	2	0.1
total PCBs	0	0	0	0
	Toxic area (km^2)	% of Total area (1,351 km^2)		
Mean ER-M quotient >0.1	64	4.7		

Figure 3. Mercury in sediments at sites in Galveston Bay.

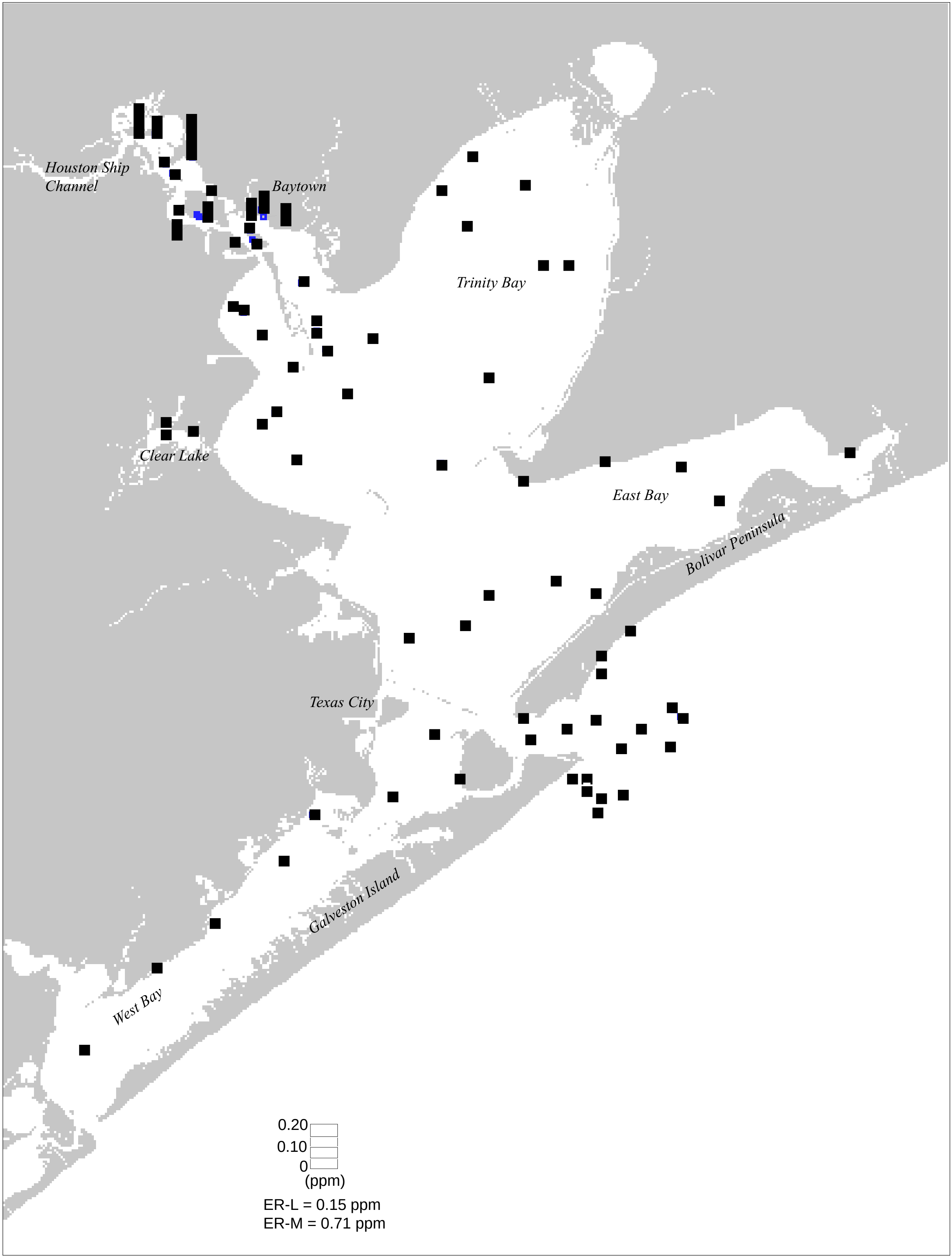


Figure 4. Arsenic in sediments at sites in Galveston Bay.

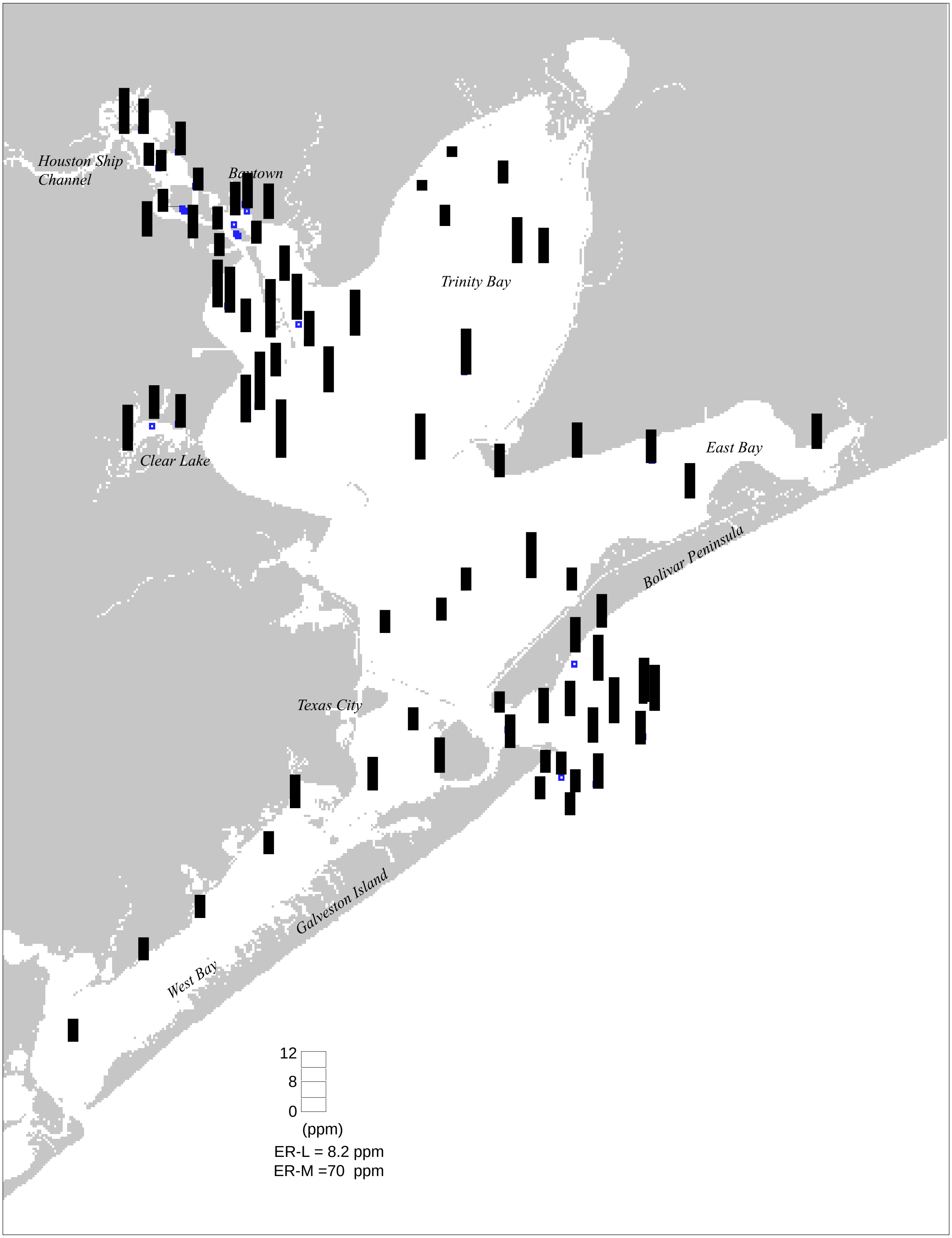


Figure 5. Cadmium in sediments at sites in Galveston Bay.

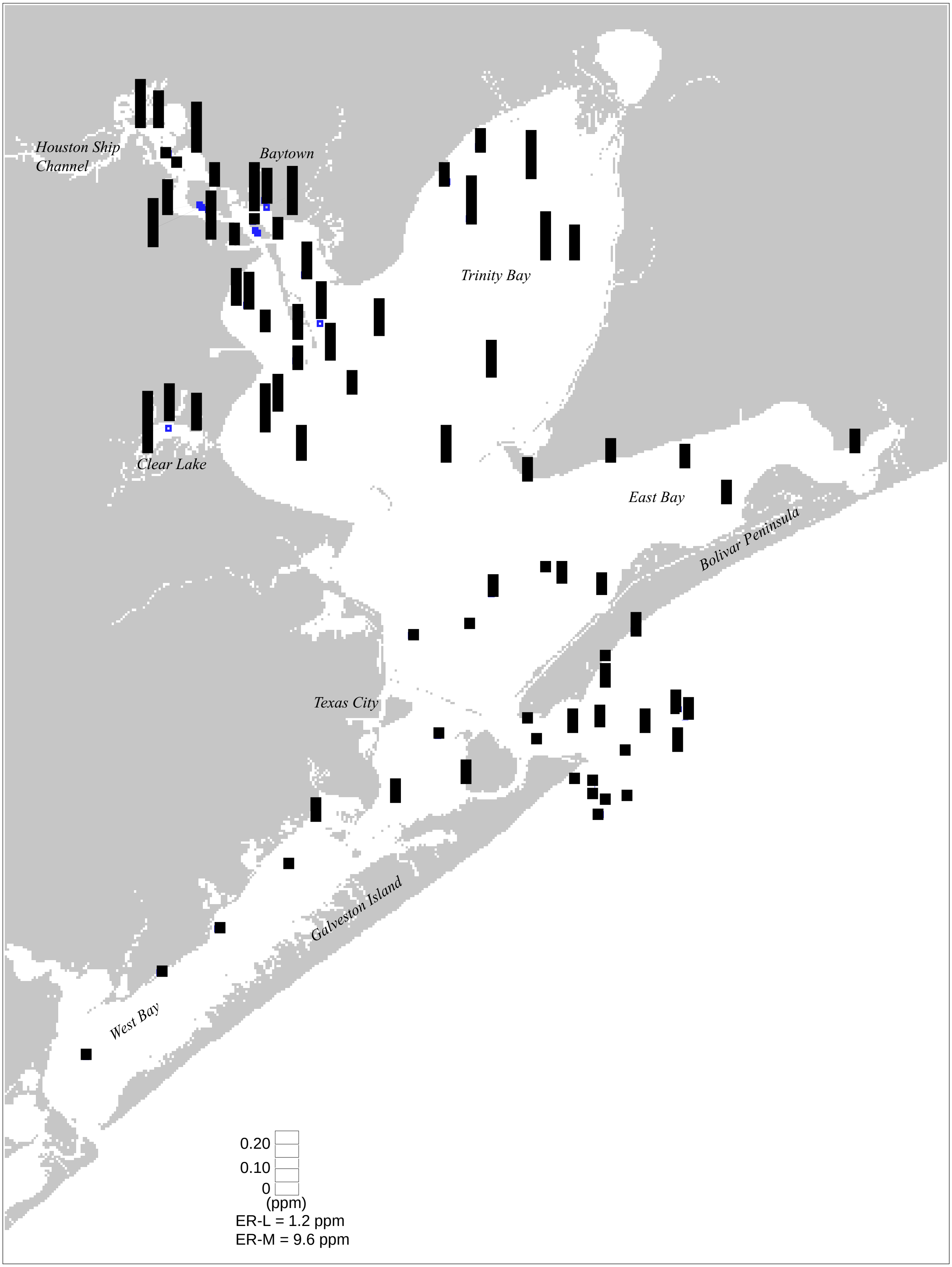


Figure 6. Chromium in sediments at sites in Galveston Bay.

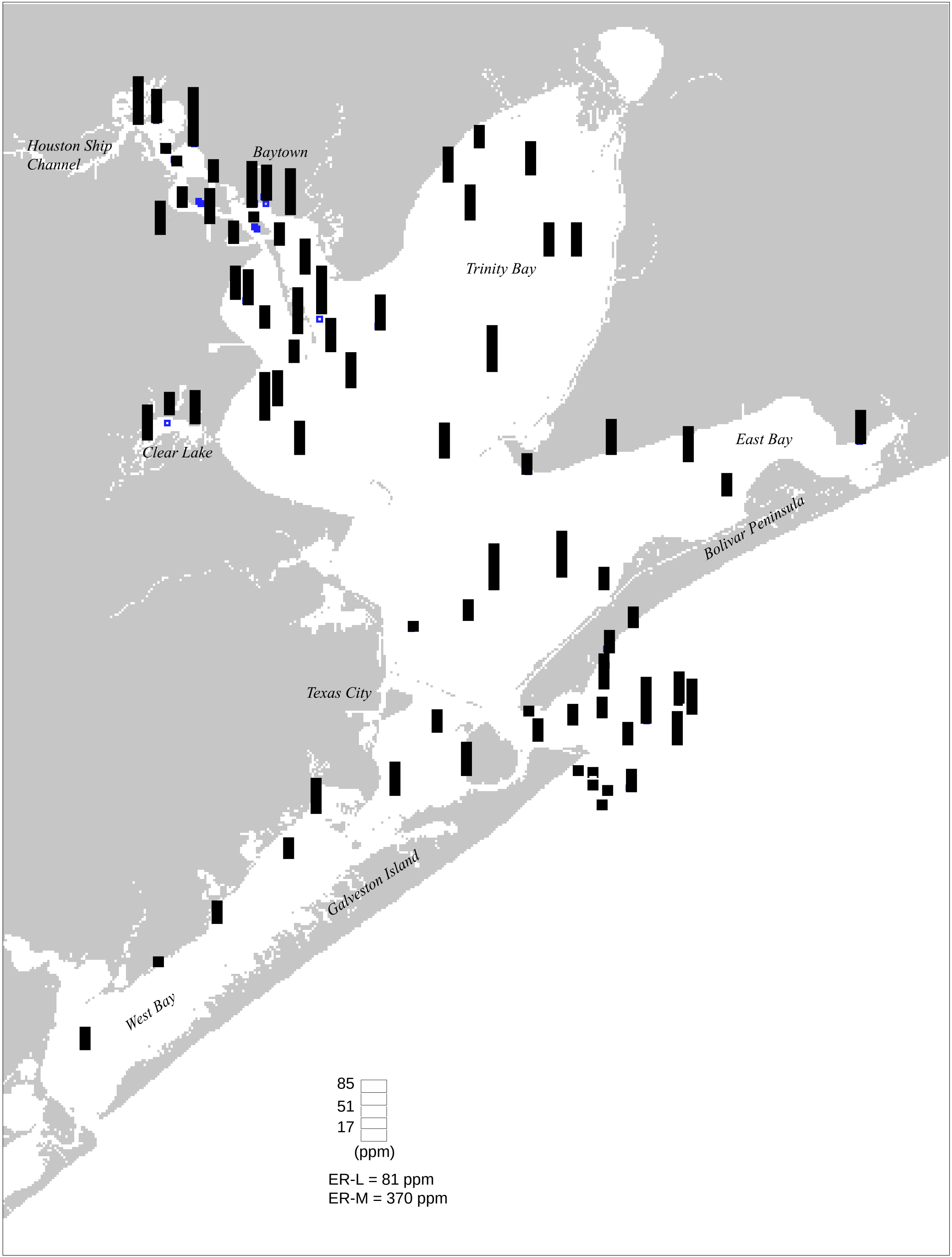


Figure 7. Nickel in sediments at sites in Galveston Bay.

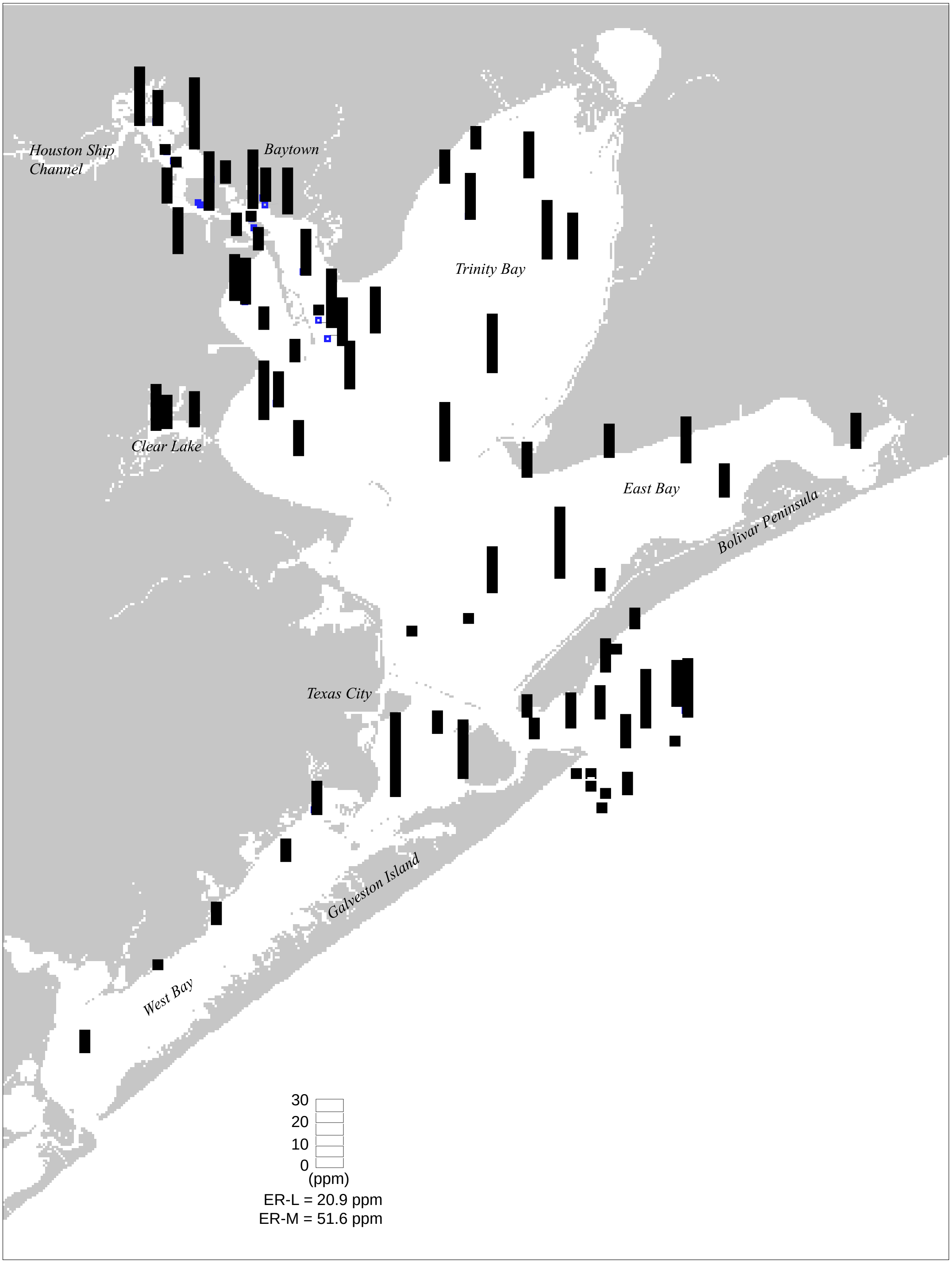


Figure 8. Zinc in sediments at site in Galveston Bay.

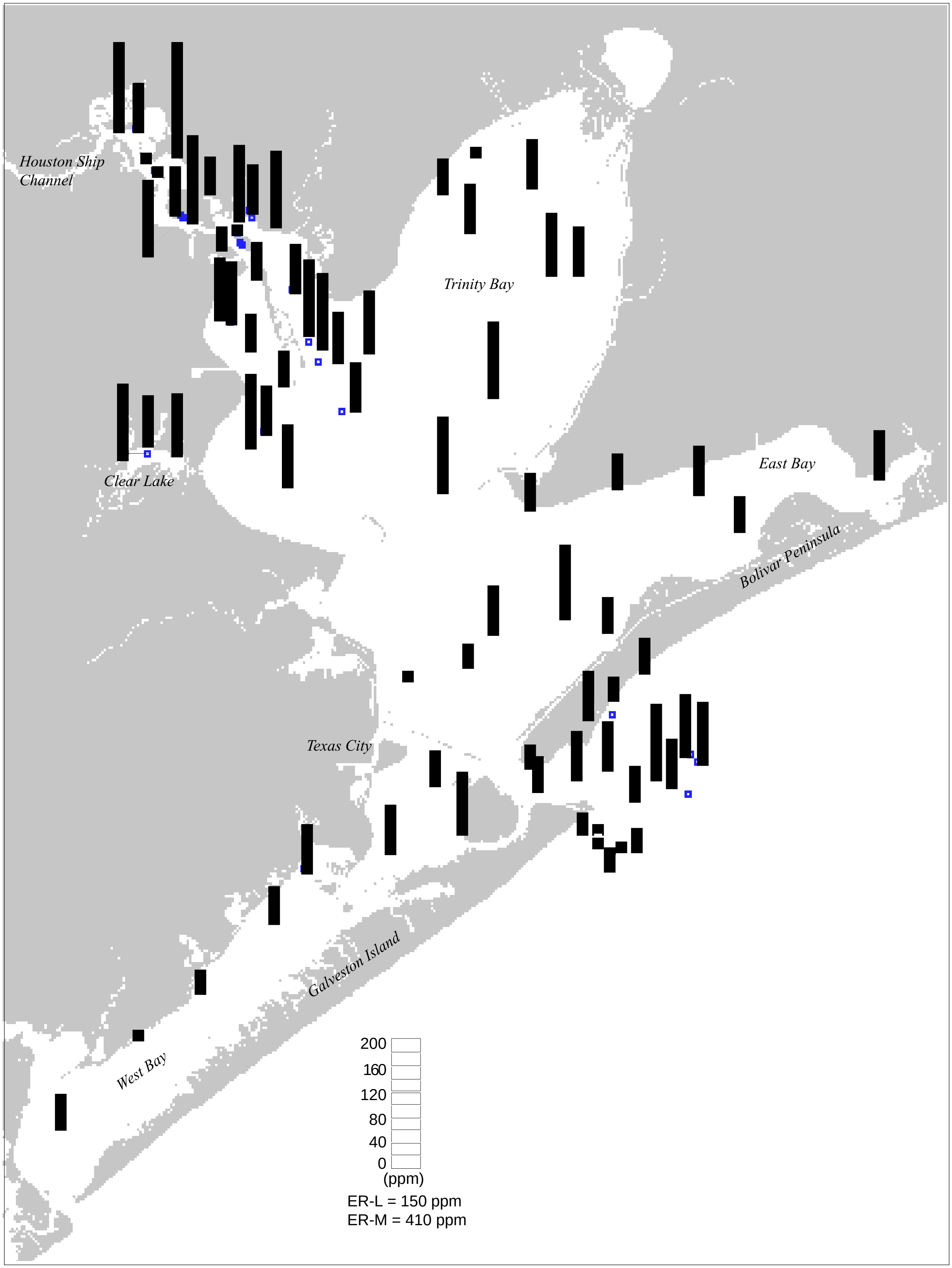


Figure 9. Hexachlorobenzene in sediments at sites in Galveston Bay.

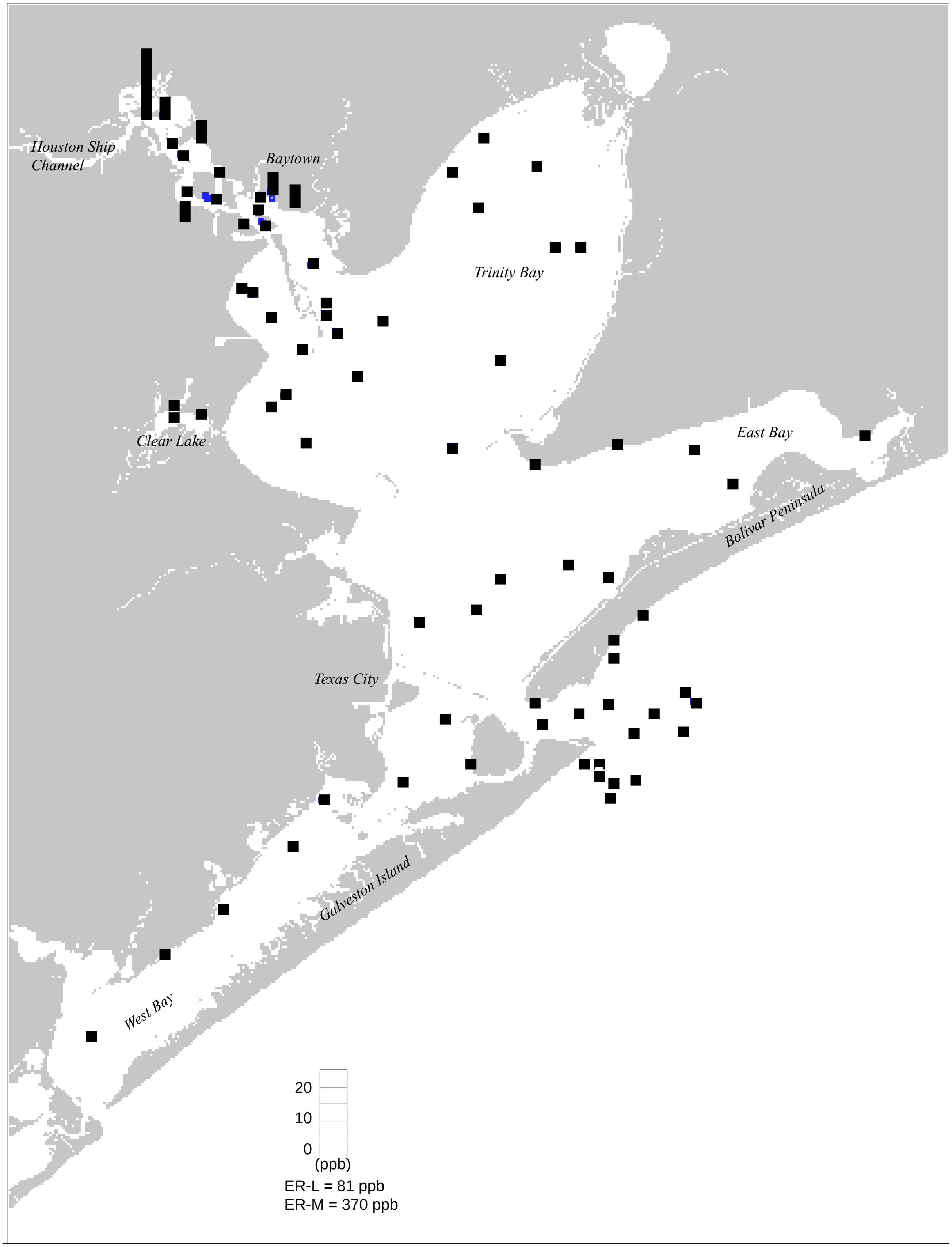


Figure 10. Total chlordane in sediments at sites in Galveston Bay.

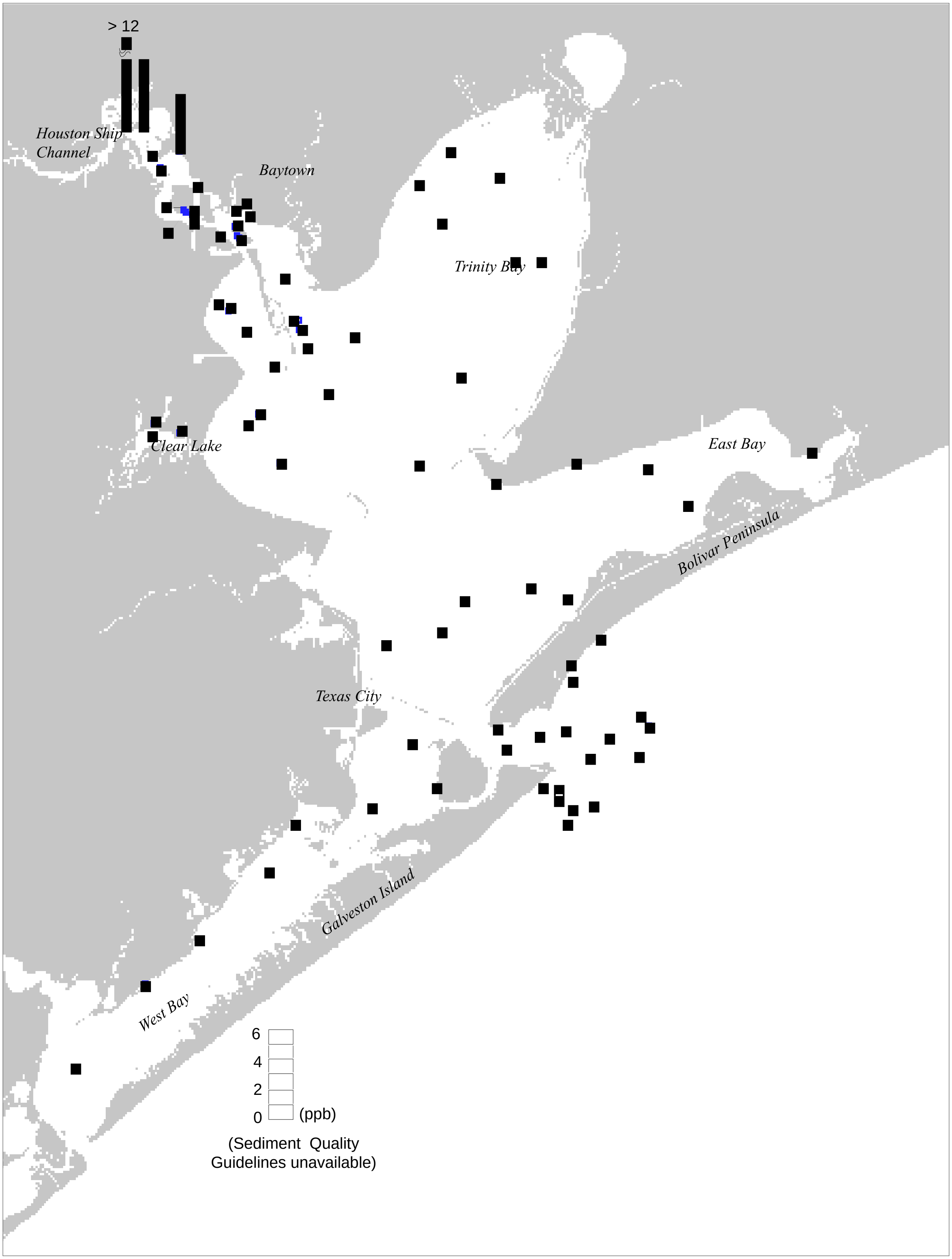


Figure 11. Total DDT in sediments at sites in Galveston Bay.

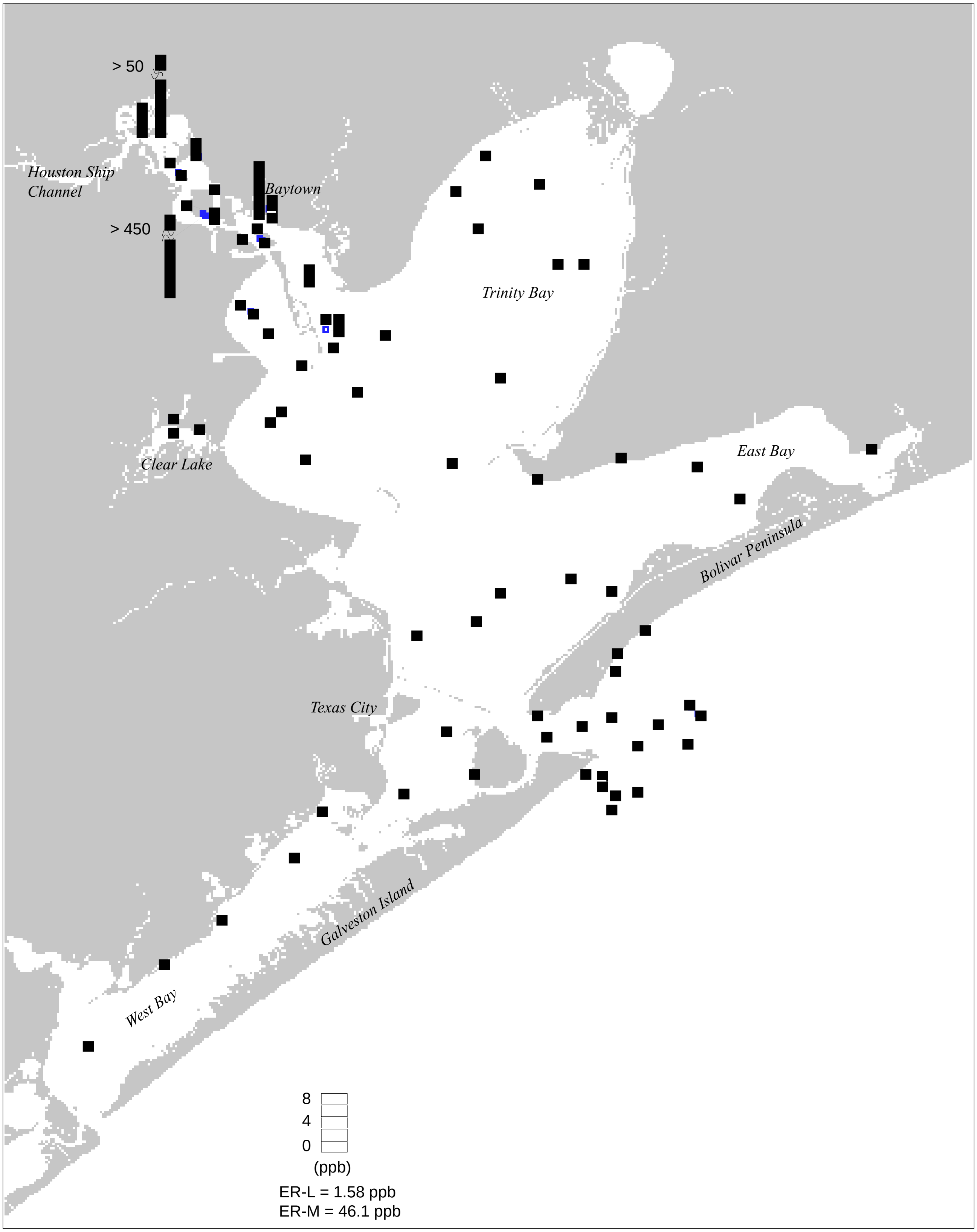
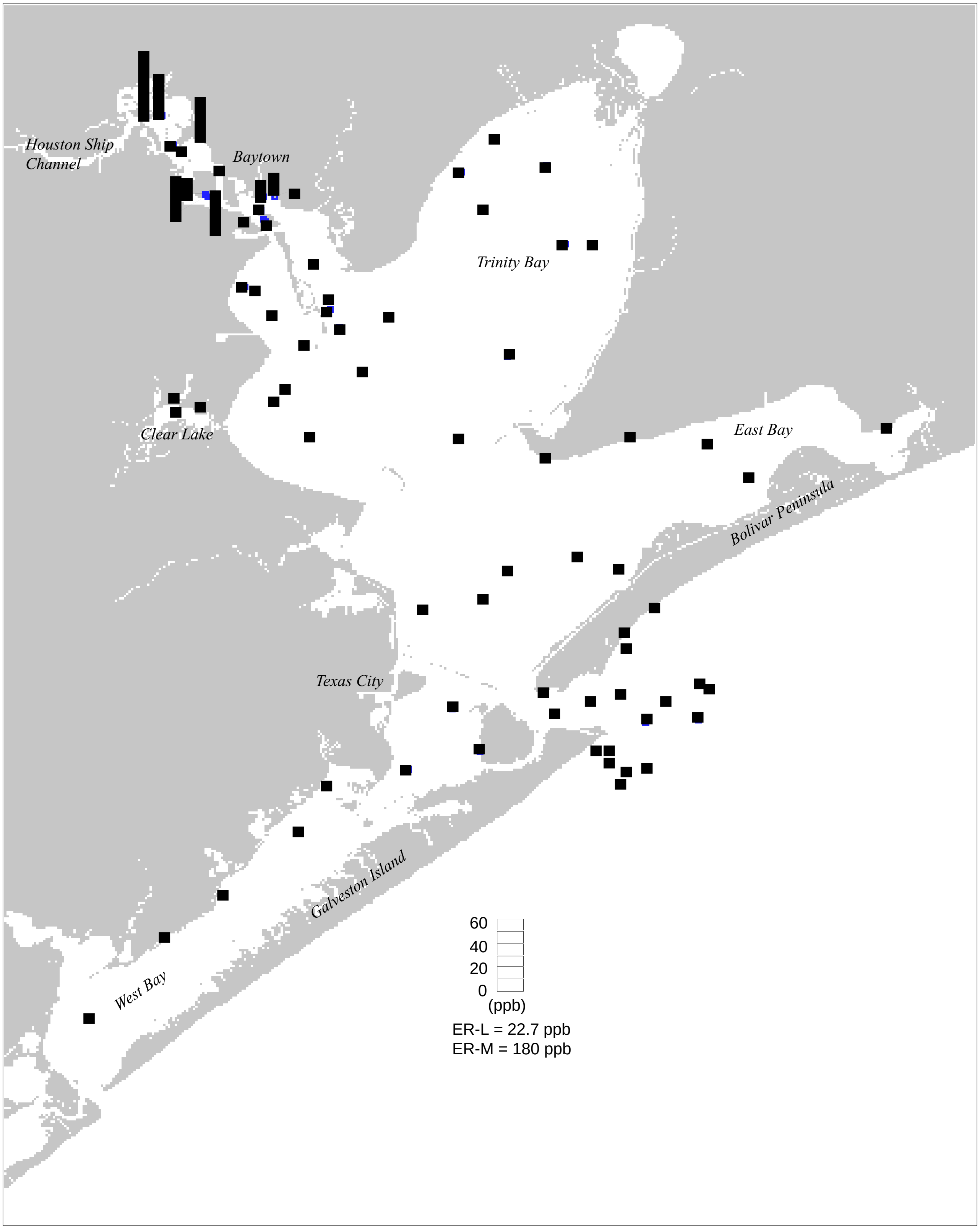


Figure 12. Total PCBs in sediments at sites in Galveston Bay.



guidelines with the exception of total DDT. Sites 2 (50 ppb) and 8 (450 ppb) were higher than the ER-M guideline of 46.1 ppb for DDT. The ER-L guideline for DDT was exceeded at nine additional sites, all in the upper reaches of the study area. Although the total DDT value at Site 8 is almost an order of magnitude higher than the ER-M guideline, the spatial extent is less than 1% of the study area. Total DDT ER-L exceedences include 6% of the study area (Table 6).

PAHs

Concentrations were low throughout most of Galveston Bay as well as Trinity, West, and East bays, and the approaches to Galveston Bay (Figure 13). The highest concentration (>10,000 ppb tPAH) was found in the middle of the bay at Site 32 and exceeded the ER-L of 4,022 ppb. Site 32 also exceeded the ER-L value for acenaphthene, anthracene, fluorene, phenanthrene and benzo[a]anthracene. The upper most site in the study area (Site 3) exceeded the ER-L concentration for acenaphthene and fluorene. Slightly higher concentrations of tPAHs were found in the HSC, Clear Lake, and south of the Texas City Dike, although all were below the ER-L concentration. The calculated spatial extent of ER-L exceedences was 2% or less of the study area for each PAH as well as for tPAH. The concentrations of PAHs were distributed somewhat differently than the other organic contaminants, with some high concentrations in the middle of Galveston Bay (Site 32).

SEDIMENT TOXICITY TESTS

Amphipod Toxicity Test

Amphipod toxicity testing was carried out between 6 and 30 August 1996 using *A. abdita*. Sediment samples from all 75 sampling sites were tested. Mean amphipod survival, as a percent of the control, ranged from 88% to 120% (Table 7). No samples were found to be significantly toxic.

Sea Urchin Fertilization and Embryonic Development Tests

The sea urchin fertilization and embryonic development tests were conducted in August 1996 using *A. punctulata*. Fertilization success was significantly reduced at 53%, 13%, and 4% of the sites for 100%, 50%, and 25% porewater concentrations, respectively (Table 8). Fertilization as a percent of the control in 100% porewater ranged from 3% to 102%. Samples from the HSC, upper bay area, Clear Lake, and to the east of the approach jetties to Galveston Bay showed the lowest fertilization successes. The

Figure 13. Total PAHs in sediments at sites in Galveston Bay.

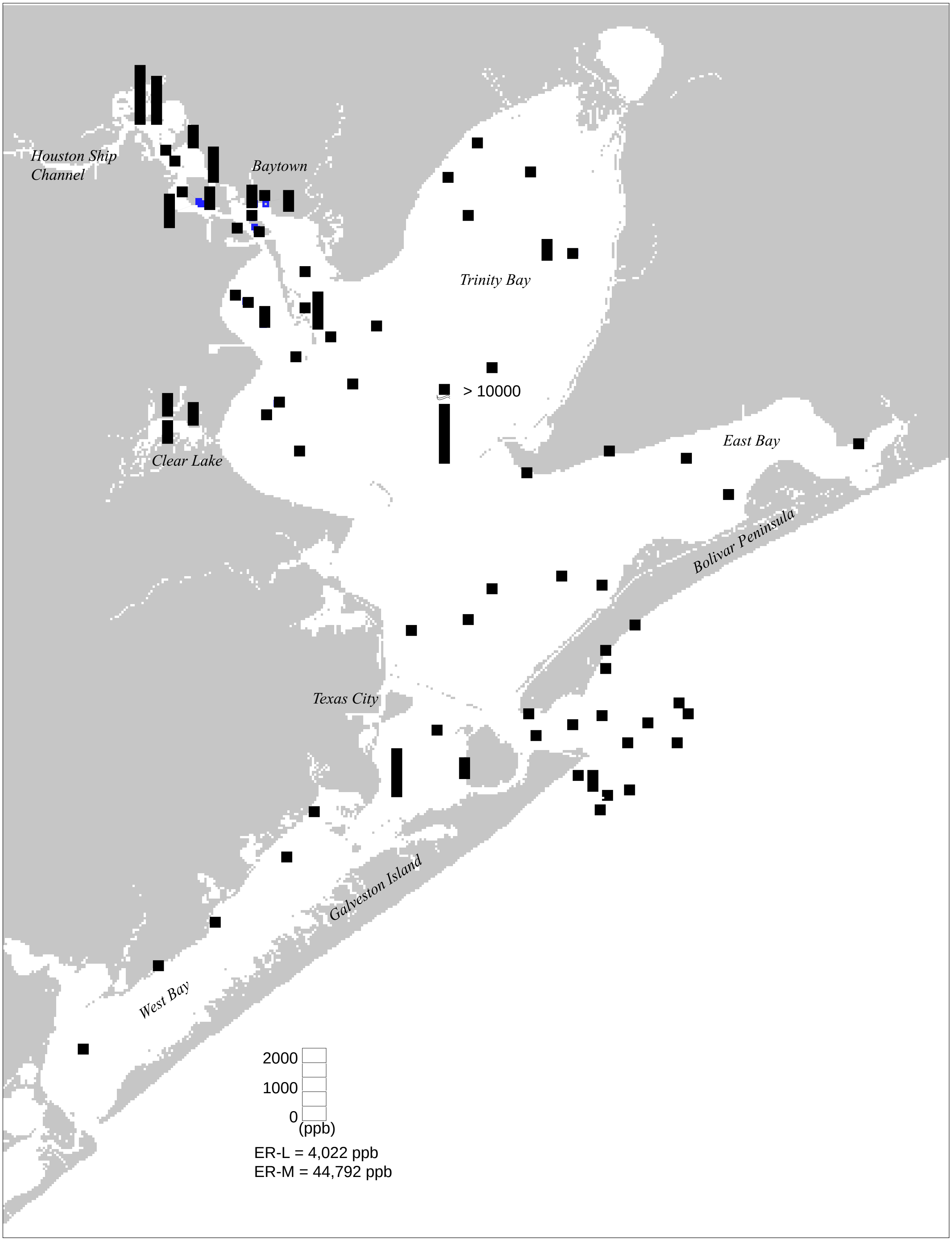


Table 7. Amphipod (*Ampelisca abdita*) toxicity test results.

Strata	Site number	Mean amphipod survival (%)	Mean survival in control	Mean amphipod survival as % of control	Significance
1	1	99	100	99	
1	2	98	100	98	
1	3	100	100	100	
2	4	97	100	97	
2	5	97	100	97	
2	6	100	97	103	
3	7	96	97	99	
3	8	98	97	101	
3	9	97	97	100	
4	10	98	100	98	
4	11	100	97	103	
4	12	100	97	103	
5	13	100	97	103	
5	14	100	97	103	
5	15	98	100	98	
6	16	96	100	96	
6	17	95	100	95	
6	18	100	100	100	
7	19	98	100	98	
7	20	97	100	97	
7	21	99	100	99	
8A	22	97	100	97	
8A	23	97	100	97	
8A	24	93	100	93	
8	25	100	100	100	
8	26	95	100	95	
8	27	97	100	97	
8	28	100	100	100	
9	29	98	100	98	
9	30	89	100	89	
9	31	96	100	96	
9	32	100	83	120	
10	33	99	99	100	
10	34	96	99	97	
10	35	99	99	100	
10	36	98	99	99	
10	37	100	99	101	
11	38	98	83	118	
11	39	93	83	112	
11	40	99	83	119	
11	41	99	83	119	
12	42	97	83	117	
12	43	97	83	117	
12	44	91	83	110	

Table 7. Amphipod (*Ampelisca abdita*) toxicity test results (continued).

Strata	Site number	Mean amphipod survival (%)	Mean survival in control	Mean amphipod survival as % of control	Significance
13	45	94	100	94	
13	46	97	100	97	
13	47	98	100	98	
13	48	98	100	98	
13	49	100	99	101	
14	50	95	99	96	
14	51	97	99	98	
14	52	96	99	97	
15	53	97	99	98	
15	54	98	99	99	
15	55	96	99	97	
15	56	99	100	99	
15	57	94	100	94	
16	58	94	100	94	
16	59	99	100	99	
16	60	100	100	100	
17	61	100	100	100	
17	62	97	100	97	
17	63	96	100	96	
18	64	88	100	88	
18	65	99	96	103	
18	66	100	100	100	
19	67	99	100	99	
19	68	100	96	104	
19	69	100	96	104	
20	70	98	96	102	
20	71	92	96	96	
20	72	99	96	103	
21	73	100	96	104	
21	74	97	96	101	
21	75	99	96	103	

greatest fertilization success occurred in Trinity Bay and the area to the west of the approach jetties.

Sea urchin embryonic development (Table 9) was significantly inhibited at 45%, 13%, and 5% of the 75 sites at 100%, 50%, and 25% porewater concentrations, respectively. As a percent of the controls at 100% porewater concentration, mean normal development ranged from 0% to 107%. The percent normal development followed a pattern

Table 8. Sea urchin *(Arbacia punctulata)* fertilization test results.

		100% Porewater			50% Porewater			25% Porewater		
Strata	Site Number	Mean % Fertilization	% of Control	Statistical Significance[†]	Mean % Fertilization	% of Control	Statistical Significance[†]	Mean % Fertilization	% of Control	Statistical Significance[†]
1	1	89.0	90		96.4	98		99.4	101	
1	2	80.6	82	**	97.0	99		98.6	101	
1	3	68.6	70	**	96.2	98		97.2	99	
2	4	97.6	99		98.0	100			101	
2	5	98.2	100		99.0	101		98.4	100	
2	6	53.0	54	**	94.8	97		97.8	100	
3	7	75.8	77	**	97.0	99		98.4	100	
3	8	68.4	70	**	96.6	99		98.6	101	
3	9	86.4	88		97.6	100		98.6	101	
4	10	88.6	90		97.8	100		99.2	101	
4	11	85.6	87		98.2	100		99.0	101	
4	12	98.6	100		99.0	101		99.2	101	
5	13	81.2	83	**	95.8	98		98.6	101	
5	14	95.2	97		97.8	100		99.2	101	
5	15	64.4	65	**	94.4	96		98.6	101	
6	16	94.2	96		97.6	100		98.8	101	
6	17	84.8	86	*	97.8	100		98.6	101	
6	18	78.4	80	**	96.8	99		97.8	100	
7	19	67.0	68	**	95.4	97		98.8	101	
7	20	53.2	54	**	79.4	81	**	96.2	98	
7	21	60.2	61	**	94.0	96		97.0	99	
8A	22	43.0	44	**	89.4	91		97.2	99	
8A	23	29.2	30	**	76.0	78	**	96.6	98	
8A	24	45.0	46	**	87.2	89		97.0	99	
8	25	80.6	82	**	96.2	98		98.6	101	
8	26	64.4	65	**	90.2	92		96.0	98	
8	27	57.8	59	**	93.0	95		99.0	101	
8	28	35.4	36	**	93.2	95		96.6	98	
9	29	66.4	67	**	89.0	91		96.8	99	
9	30	61.6	63	**	88.0	90		96.2	98	
9	31	87.6	89		89.4	91		95.6	97	
9	32	95.2	97		96.6	99		97.4	99	
10	33	76.4	78	**	96.8	99		96.4	98	
10	34	95.0	97		95.6	98		98.0	100	
10	35	78.6	80	**	93.4	95		96.2	98	
10	36	98.0	100		99.0	101		98.6	101	
10	37	84.8	86	*	97.6	100		98.4	100	
11	38	99.8	102		99.4	101		98.6	100	
11	39	99.2	101		98.8	101		98.4	100	
11	40	100.0	102		99.2	101		99.8	101	
11	41	98.8	101		99.4	101		98.2	100	
12	42	99.4	101		99.3	101		99.4	101	
12	43	69.6	71	**	85.2	87	*	93.8	95	
12	44	90.0	92		93.8	96		96.8	98	
13	45	72.6	74	**	88.4	90		94.6	96	
13	46	98.2	100		98.8	101		99.6	101	
13	47	97.0	99		98.4	100		99.4	101	
13	48	97.4	99		98.2	100		99.2	101	
13	49	87.2	89		96.6	98		99.0	100	

[†] Dunnett's t-test: *p< 0.05; ** p< 0.01

Table 8. Sea urchin *(Arbacia punctulata)* fertilization test results (continued).

Strata	Site Number	100% Porewater			50% Porewater			25% Porewater		
		Mean % Fertilization	% of Control	Statistical Significance†	Mean % Fertilization	% of Control	Statistical Significance†	Mean % Fertilization	% of Control	Statistical Significance†
14	50	62.2	63	**	92.2	94		95.4	97	
14	51	88.0	90		95.4	97		98.0	99	
14	52	98.0	100		99.0	101		99.6	101	
15	53	96.0	98		99.2	101		99.6	101	
15	54	21.0	21	**	84.0	86	*	97.0	98	
15	55	78.2	80	**	93.6	95		99.0	100	
15	56	99.4	101		99.4	101		99.4	101	
15	57	86.8	88		96.2	98		99.2	101	
16	58	5.8	6	**	68.4	70	**	94.6	96	
16	59	49.2	50	**	84.4	86	*	94.6	96	
16	60	6.8	7	**	67.8	69	**	93.8	95	
17	61	11.5	12	**	38.8	40	**	74.6	76	**
17	62	31.6	32	**	53.2	54	**	76.4	77	**
17	63	24.0	24	**	64.0	65	**	84.2	85	*
18	64	97.6	99		95.8	98		96.2	98	
18	65	95.2	97		93.0	95		91.8	93	
18	66	97.4	99		94.8	97		93.0	94	
19	67	33.2	34	**	98.4	100		97.8	99	
19	68	99.3	101		97.6	99		97.2	99	
19	69	37.8	39	**	97.8	100		98.0	99	
20	70	99.0	101		98.6	100		97.4	99	
20	71	97.8	100		99.4	101		98.8	100	
20	72	97.4	99		97.6	99		96.8	98	
21	73	3.6	4	**	98.6	100		99.2	101	
21	74	40.8	42	**	99.8	102		98.8	100	
21	75	2.8	3	**	98.6	100		98.4	100	

† Dunnett's t-test: *$p < 0.05$; ** $p < 0.01$

similar to the fertilization success results. The lowest percent normal development occurred in the HSC, upper bay area, Clear Lake, and east of the jetties at the mouth of Galveston Bay, while portions of Trinity Bay (stratum 12), East Bay and the area to the west of the approach jetties had the highest percentage of normal embryo development.

Microtox® Test

The Microtox® test was conducted by the USGS in Columbia, MO in August, 1996. The mean EC_{50} values ranged from 0.99 to 105.33 mg eq./ml (Table 10). The lowest mean EC_{50}s were widely spread throughout the study area. With the exception of Stratum 18, Galveston Bay – Nearshore, each stratum had at least one site in which the CSI (Control Sediment Index) was significantly higher than that of the Redfish Bay reference site. Some of the most highly significant CSIs occurred in Strata 16, 17, and 21 - approaches to Galveston Bay, Stratum 3 - Upper San Jacinto Bay, and Stratum 8A

Table 9. Sea urchin (*Arbacia punctulata*) embryonic development test results.

Strata	Site Number	100% Porewater			50% Porewater			25% Porewater		
		Mean % Normal Development	% of Control	Statistical Significance†	Mean % Normal Development	% of Control	Statistical Significance†	Mean % Normal Development	% of Control	Statistical Significance†
1	1	77	81	**	95.8	99		98.4	104	
1	2	42.4	44	**	93.6	96		97	102	
1	3	0	0	**	0.2	0	**	69.2	73	**
2	4	88.2	92		97.6	101		98.2	104	
2	5	10.2	11	**	98	101		99.4	105	
2	6	53.2	56	**	96.4	99		95	100	
3	7	59	62	**	93.8	97		96.6	102	
3	8	0	0	**	95	98		96	101	
3	9	0	0	**	95.4	98		98.6	104	
4	10	78	82	**	94.2	97		98.8	104	
4	11	75.2	79	*	96.6	99		95.2	100	
4	12	95.2	100		95.4	98		97.8	103	
5	13	0	0	**	93.4	96		98	103	
5	14	0	0	**	90.6	93		97.2	103	
5	15	91	95		93.8	97		97.8	103	
6	16	81	85	*	95.8	99		98.4	104	
6	17	0	0	**	0	0	**	0	0	**
6	18	84.2	88		95.8	99		95.8	101	
7	19	89.6	94		95.8	99		91.4	96	
7	20	84.4	88		97	100		95.8	101	
7	21	78.4	82		94.8	98		98.6	104	
8A	22	45	47	**	94.8	98		95.8	101	
8A	23	0	0	**	92.6	95		95.4	101	
8A	24	0	0	**	85.6	88		95	100	
8	25	87.2	91		97	100		97.2	103	
8	26	92.6	97		97	100		94	99	
8	27	90.2	94		96.8	100		97.4	103	
8	28	80.6	84	*	96.4	99		96.6	102	
9	29	88.8	93		96.2	99		94	99	
9	30	87	91		94.8	98		96.8	102	
9	31	95	99		93	96		94.6	100	
9	32	94.8	99		94.8	98		96	101	
10	33	85.6	90		94.8	98		93.6	99	
10	34	92.25	96		91.6	94		97	102	
10	35	90.2	94		92.8	96		95	100	
10	36	95.2	100		93.8	97		96.4	102	
10	37	75.6	79		97.25	100		96.8	102	
11	38	84.2	96		89.6	99		86.2	98	
11	39	0	0	**	84.8	94		90.4	103	
11	40	50.8	58	**	93.8	104		92.4	105	
11	41	66.2	76	**	91.4	101		90.4	103	
12	42	85.8	98		88	97		91.8	104	
12	43	87.2	100		92.4	102		91.2	104	
12	44	93.4	107		91.8	101		93.4	106	
13	45	91.2	104		92.4	102		89.2	101	
13	46	85.8	98		89	98		86.6	98	
13	47	86.4	99		85.4	94		89.6	102	
13	48	87.4	100		91	101		90.2	102	
13	49	68.6	78	**	92.8	103		93.2	106	

†Dunnett's t-test: *p < 0.05; ** p < 0.01

Table 9. Sea urchin (*Arbacia punctulata*) embryonic development test results (continued).

Strata	Site Number	100% Porewater			50% Porewater			25% Porewater		
		Mean % Normal Development	% of Control	Statistical Significance[†]	Mean % Normal Development	% of Control	Statistical Significance[†]	Mean % Normal Development	% of Control	Statistical Significance[†]
14	50	0.2	0	**	89.2	99		89.8	102	
14	51	90.4	103		90.6	100		90	102	
14	52	88.8	101		89.6	99		91.4	104	
15	53	88.8	101		92.8	103		91	103	
15	54	74.2	85		91.6	101		94	107	
15	55	84.8	97		88.8	98		90.6	103	
15	56	0.6	1	**	92	102		90.6	103	
15	57	77.2	88		92.6	102		90	102	
16	58	0	0	**	0	0	**	56.8	64	**
16	59	46.2	53	**	91.8	101		91	103	
16	60	0	0	**	0	0	**	27.2	31	**
17	61	0	0	**	0	0	**	87.2	99	
17	62	76.8	88		89	98		89.2	101	
17	63	0	0	**	39	43	**	91	103	
18	64	91.6	105		92.6	102		92	104	
18	65	88.8	101		89	98		91	103	
18	66	89	102		92.4	102		87.8	100	
19	67	0	0	**	46.6	51	**	89.6	102	
19	68	87	99		92.8	103		91.2	104	
19	69	4.6	5	**	92	102		89.6	102	
20	70	87.2	100		88	97		88.8	101	
20	71	78.75	90		87.2	96		91.2	104	
20	72	92.8	106		72.4	80		91	103	
21	73	0	0	**	0	0	**	91.2	104	
21	74	0.2	0	**	1.8	2	**	89	101	
21	75	0	0	**	4	4	**	90.8	103	

[†] Dunnett’s t-test: *$p < 0.05$; ** $p < 0.01$

- Clear Lake (Table 10). The highest CSI (36.24) recorded during the study was at Site 63, in the Galveston Bay entrance stratum. Overall, the CSI was significantly different from the reference site at 59 sites (Table 10). Of these, 35 sites exhibited a significantly higher PSI (Phenol Spiked Index), indicating these sites produced a greater decrease in luminescence than the phenol-spiked (positive control) reference sediment.

P450 Reporter Gene System Assay

Results of the cytochrome P450 RGS assays are shown in Table 11. Responses reported as B[a]PEq (µg/g) ranged from 0.33 to 34.28. Nine percent of the sites exceeded the threshold value of 11.1 µg/g, while only one site (Site 5, Stratum 2) exceeded the upper confidence limit of the mean response value (Table 11). The distribution of the highest responses did not follow any apparent spatial pattern. Site numbers 2, 5, 16, and 32 induced the highest responses. In addition there were a number of sites that had responses as low as the control test. These

Table 10. Microtox® test results.

Strata	Site Number	Mean EC 50 (mg equivalent sediment weight)	Control Sediment Index	Phenol Spiked Index
1	1	12.03	2.99**	1.01
1	2	5.03	7.15**	2.42**
1	3	105.33	0.34	0.12
2	4	72.87	0.49	0.17
2	5	9.47	3.80**	1.29
2	6	19.60	1.84**	0.62
3	7	2.80	12.86**	4.36**
3	8	3.37	10.69**	3.62**
3	9	8.57	4.20**	1.42
4	10	8.57	4.20**	1.42
4	11	2.50	14.40**	4.88**
4	12	76.97	0.47	0.16
5	13	7.27	4.95**	1.68**
5	14	83.80	0.43	0.15
5	15	3.33	10.80**	3.66**
6	16	11.93	3.02**	1.02
6	17	20.33	1.77**	0.60
6	18	22.43	1.60*	0.54
7	19	3.97	9.08**	3.08**
7	20	10.20	3.53**	1.20
7	21	4.53	7.94**	2.69**
8A	22	3.20	11.25**	3.81**
8A	23	5.53	6.51**	2.20**
8A	24	5.23	6.88**	2.33**
8	25	5.93	6.07**	2.06**
8	26	18.97	1.90**	0.64
8	27	3.43	10.49**	3.55**
8	28	15.90	2.26**	0.77
9	29	2.50	14.40**	4.88**
9	30	12.87	2.80**	0.95
9	31	10.93	3.29**	1.12
9	32	11.43	3.15**	1.07
10	33	12.47	2.89**	0.98
10	34	80.13	0.45	0.15
10	35	9.50	3.79**	1.28
10	36	66.83	0.54	0.18
10	37	7.60	4.74**	1.61*
11	38	16.13	2.23**	0.76
11	39	21.60	1.67*	0.56
11	40	6.40	5.63**	1.91**
11	41	6.80	5.29**	1.79**
12	42	28.30	1.27	0.43
12	43	5.33	6.75**	2.29**
12	44	4.77	7.55**	2.56**
13	45	4.97	7.25**	2.46**
13	46	12.70	2.83**	0.96
13	47	25.00	1.44	0.49
13	48	6.77	5.32**	1.80**
13	49	53.97	0.67	0.23

†Dunnett's t-test: *$p < 0.05$; ** $p < 0.01$

Table 10. Microtox® test results (continued).

Strata	Site Number	Mean EC 50 (mg equivalent sediment weight)	Control Sediment Index	Phenol Spiked Index
14	50	19.17	1.88**	0.64
14	51	3.17	11.37**	3.85**
14	52	9.23	3.90**	1.32
15	53	16.17	2.23**	0.75
15	54	4.63	7.77**	2.63**
15	55	5.20	6.92**	2.35**
15	56	1.20	30.00**	10.17**
15	57	66.20	0.54	0.18
16	58	1.16	30.95**	10.49**
16	59	3.67	9.82**	3.33**
16	60	1.80	20.00**	6.78**
17	61	3.97	9.08**	3.08**
17	62	3.03	11.87**	4.02**
17	63	0.99	36.24**	12.28**
18	64	33.30	1.08	0.37
18	65	44.50	0.81	0.27
18	66	54.70	0.66	0.22
19	67	11.27	3.20**	1.08
19	68	39.00	0.92	0.31
19	69	1.63	22.04**	7.47**
20	70	44.13	0.82	0.28
20	71	16.67	2.16**	0.73
20	72	31.53	1.14	0.39
21	73	2.30	15.65**	5.30**
21	74	4.23	8.50**	2.88**
21	75	2.40	15.00**	5.08**

†Dunnett's t-test: *$p < 0.05$; ** $p < 0.01$

sites were located to the southwest of the approach jetties to Galveston Bay.

Concordance of Sediment Toxicity Tests

The toxicity tests conducted as part of NOAA's study in Galveston Bay were chosen to provide complementary, not duplicative, information. Each test utilized in this study has a different endpoint and sensitivity. In all tests, a positive correlation would indicate agreement between tests, with the exception of the RGS test. In that test, the fold induction increases numerically as the potential toxicity response increases, thus a negative correlation would indicate agreement between tests. However, given the nature of toxicity endpoints and different modes of response (bulk sediment, porewater, and organic extract), a strong correlation among the test results should not be expected.

Table 12 provides the correlation coefficients for each of the toxicity tests. The porewater fertilization (100%) test covaried with the embryological

Table 11. Cytochrome P450 RGS results.

Strata	Site Number	Benzo[a]pyrene Equivalents (µg/g)	Toxicological Significance†
1	1	2.23	
1	2	22.99	
1	3	13.78	
2	4	2.04	
2	5	34.28	*
2	6	10.60	
3	7	11.05	
3	8	8.16	
3	9	10.49	
4	10	4.95	
4	11	3.28	
4	12	1.16	
5	13	5.65	
5	14	11.02	
5	15	6.82	
6	16	24.49	
6	17	6.29	
6	18	4.94	
7	19	5.36	
7	20	5.19	
7	21	6.99	
8A	22	11.21	
8A	23	9.64	
8A	24	5.86	
8	25	3.80	
8	26	1.94	
8	27	4.91	
8	28	2.70	
9	29	6.63	
9	30	4.11	
9	31	4.91	
9	32	22.53	
10	33	1.51	
10	34	3.83	
10	35	1.98	
10	36	3.00	
10	37	1.87	
11	38	1.66	
11	39	4.19	
11	40	3.19	
11	41	2.30	
12	42	3.82	
12	43	2.43	
12	44	2.03	
13	45	1.47	
13	46	1.38	
13	47	1.64	
13	48	3.44	
13	49	2.32	
14	50	6.66	
14	51	2.43	
14	52	12.68	
15	53	1.58	
15	54	1.78	
15	55	1.44	
15	56	0.44	
15	57	3.46	
16	58	1.70	
16	59	2.15	
16	60	2.06	
17	61	5.76	
17	62	1.09	
17	63	3.32	
18	64	0.34	
18	65	0.36	
18	66	0.33	
19	67	1.89	
19	68	0.61	
19	69	3.19	
20	70	0.47	
20	71	1.38	
20	72	1.21	
21	73	6.74	
21	74	3.42	
21	75	2.67	

†Value greater than upper confidence limit (32.8)

Table 12. Spearman rank coefficients of correlation between toxicity tests.

	Fertilization (100%)	Amphipod Survival	Microtox®	Development (100%)
Amphipod Survival	-0.049			
Microtox®	0.572**	0.012		
Development (100%)	0.427*	-0.115	0.301	
Cytochrome P450	-0.26	-0.035	-0.168	-0.333

* = $p < 0.05$
** = $p < 0.01$

development (100%) test and the Microtox® test, while the amphipod test as expected (no evidence of significant toxicity), did not correlate with any of the other tests.

Figure 14 illustrates the locations of significant toxicity for sea urchin fertilization and embryonic development, Microtox®, and RGS. The regional patterns suggested by the correlations between the Microtox®, fertilization, and embryological development test results are easily discernible. Sites with significant toxicity in the three tests are concentrated in the upper portion of the study area, in Clear Lake, and at the mouth and approaches to Galveston Bay.

Spatial Extent of Sediment Toxicity

The spatial extent of toxicity was determined by weighting the toxic samples to the size of the sampling strata and then summing these toxic areas to get a cumulative value for the entire location. Table 13 provides the criterion used to determine the toxicity of a sample, the total area determined toxic, and the percent of the total area that was determined to be toxic for each test. The last two columns in Table 13 represent a recalculation of the spatial extent and the percent of the area that was toxic based on alternate site locations. On three occasions alternate locations were sampled. The first instance was due to the inability to anchor or dredge at the primary location, the second primary site was too shallow to access with a launch, while the third was due to the primary location being in a dredge spoil marsh (Appendix B). In a stratum where an alternate site was sampled, the toxic results are weighted as though the stratum had an additional site for each alternate sampled within that stratum. Thus, in effect each site is weighted less for each stratum with alternate site locations. The resulting change in spatial extent of sediment toxicity, if any, was minor.

Figure 14. Summary of sediment toxicity results for each sampling site in Galveston Bay.

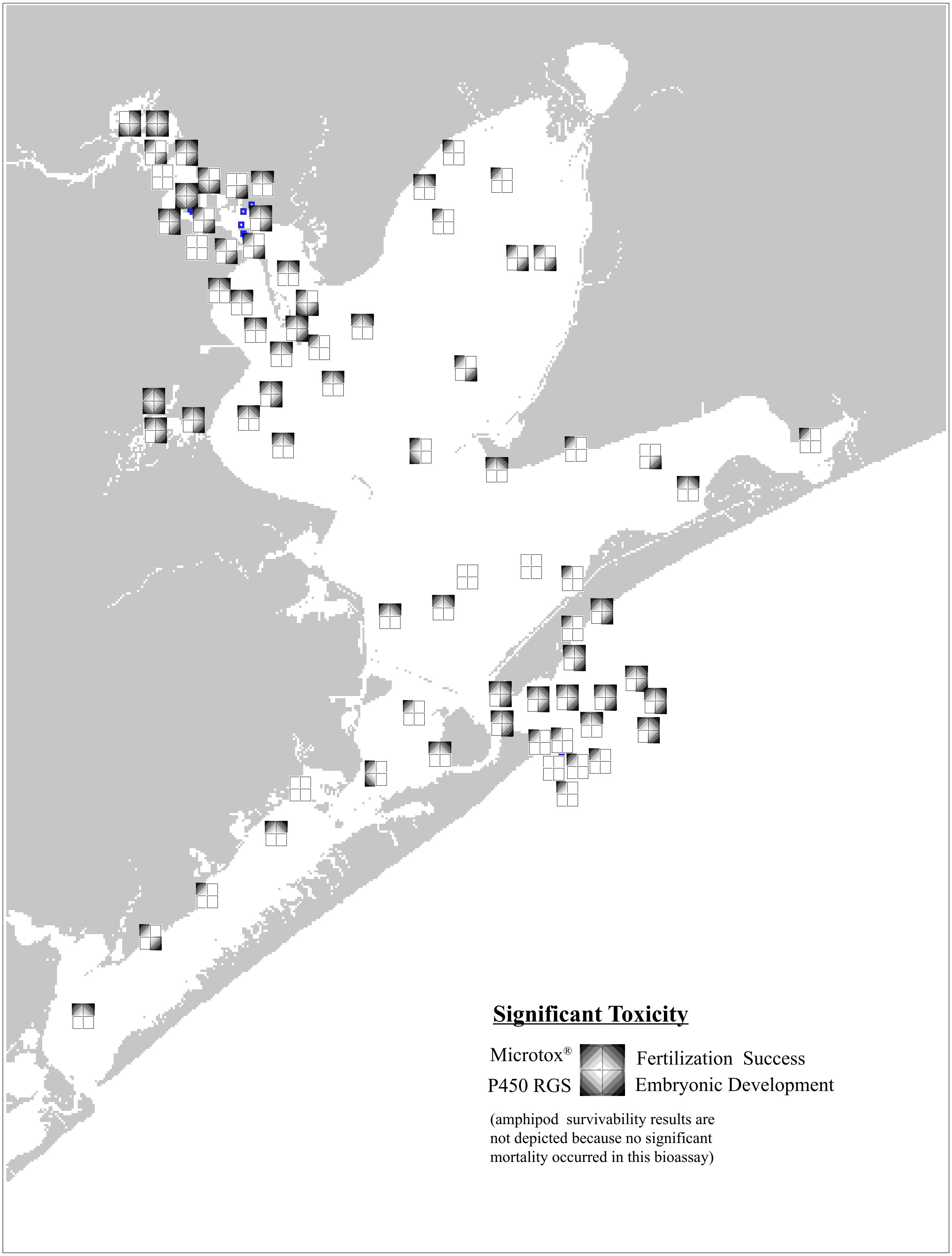


Table 13. Estimates of the spatial extent of sediment toxicity in Galveston Bay.

Toxicity Test	Criterion	Toxic Area (Km^2)	% of Total Area (1351 km^2)	Toxic Area (Km^2)[a]	% of Total Area[a] (1351 km^2)
Percent amphipod survival	<80% of control	0	0	NC[b]	NC
Percent urchin fertilization	<80% of control in 100% pore water	610	45	607	45
	<80% of control in 50% pore water	129	10	NC	NC
	<80% of control in 25% pore water	25	2	NC	NC
Percent normal urchin development	<80% of control in 100% pore water	340	25	337	25
	<80% of control in 50% pore water	72	5	70	5
	<80% of control in 25% pore water	23	2	21	1.5
Microtox bioluminescence EC50	<80% of control	1,178	87	1,175	87
Cytochrome p-450 induction	> 10 µg/g	64	5	NC	NC
	>32 µg/g	2	0.15	NC	NC

[a] recalculated to account for stations that were sampled as alternates

[b] NC - no change

As Table 13 indicates, significant toxicity in the Microtox® test was the most pervasive of all the toxicity tests, encompassing 87% of the study area when using the criterion of less than 80% of the control. Alternatively, none of the Microtox® test results were lower than the 0.06 mg/ml or 0.51 mg/ml Lower Prediction Limits (LPL) resulting from a nonparametric analyses of NOAA data (Long et al., 1999). The first value denotes the 90% LPL using the entire data set; the second value denotes the 80% confidence limit for the LPL when the lowest values i.e., most toxic, were removed from the data set. Samples with EC_{50} values between these two values would be considered moderately toxic.

Spatial extent of impaired fertilization (45% of study area) at 100% porewater was approximately half that of the Microtox® results, and the extent of impaired embryonic development (25%) was just over half that of the fertilization test, while the RGS exceeded a moderate value of enzyme induction in 5% of the study area.

Chemistry/Toxicity Relationships

The relationship between the contaminants data and the results of the five toxicity tests conducted at each site was analyzed utilizing the Spearman-rank correlation analysis (Table 14 and 15). Additional analyses (Spearman-rank) were then conducted with calculated ER-M quotients from each of the toxicity tests. The ER-M quotient is the contaminant concentration data normalized with the appropriate ER-M sediment quality values. This was done for each analyte for which an ER-M guideline was available, and also for each of the contaminant classes (Table 16). A negative correlation indicates agreement between the test results and the contaminant or analyte concentration, with the exception of the RGS assay, where a positive correlation indicates agreement.

As might be expected, the amphipod mortality test results did not correlate with any of the measured contaminant data (Table 14 and 15). In addition, the Microtox® test did not significantly covary with the contaminant data. The fertilization success test correlated ($p < 0.05$) with beta HCH, C2-phenanthrenes/anthracenes, and C3-phenanthrenes/anthracenes, while the sea urchin development test correlated ($p < 0.05$) with Mn, Zn, tPAHs, perylene, a number of the low molecular weight PAHs, PCB 153/132, and PCB 138/160. The RGS assay correlated highly ($p < 0.01$) with PAHs. The RGS assay also covaried with most PCBs and with most of the pesticides measured (Table 14 and 15), although this test does not respond to chlorinated pesticides. Thus, this observation is spurious, merely indicating co-occurrence of pesticides with PAHs and other CYP1A-inducing chemicals.

Analysis of the ER-M quotients (Table 16) followed a similar pattern, with no significant correlations being found between contaminants and the amphipod toxicity or Microtox®, but strong correlations found between the RGS P450 ER-M quotients and a number of the contaminants/classes.

BENTHIC MACROINVERTEBRATE COMMUNITY

Two hundred and eleven taxa, with a total of 5,089 individuals were identified from the 22 strata. The total number of taxa per stratum varied within the study area from a low of four in Clear Lake (8A), to a high of 90 in West Bay (15), while the mean number of taxa per stratum ranged from 2.5 to 28 in Clear Lake and West Bay, respectively (Table 17). Polychaetes comprised the most individuals (71%) of any taxa identified, followed distantly by bivalves (8.3%), gastropods (6.6%), and amphipods (3.6%) (Figure 15 and Appendix I).

Table 14. Spearman-rank correlation coefficients and probable signifiance levels between sediment toxicity tests and trace/major elements and pesticides.

Contaminant	Amphipod Toxicity	Fertilization Success (100%)	Embryological Development (100%)	Microtox Bioluminescence	RGS P450
Ag	-0.032	-0.092	-0.282	0.022	0.72 **
Al	0.009	-0.191	-0.256	-0.005	0.663 **
As	0.043	-0.43	-0.326	-0.117	0.49 **
Cd	0.005	-0.167	-0.308	-0.075	0.754 **
Cr	-0.016	-0.181	-0.245	0.046	0.667 **
Cu	-0.102	-0.262	-0.356	-0.077	0.79 **
Fe	0.004	-0.233	-0.286	-0.015	0.647 **
Hg	0.01	-0.239	-0.327	-0.052	0.795 **
Mn	-0.005	-0.341	-0.456 *	0.007	0.364 *
Ni	-0.023	-0.172	-0.263	-0.009	0.634 **
Pb	-0.038	-0.161	-0.323	0.013	0.805 **
Sb	0	-0.207	-0.288	-0.129	0.772 **
Se	0	-0.242	-0.31	-0.109	0.742 **
Sn	-0.065	-0.241	-0.288	-0.024	0.725 **
Tl	-0.099	0.027	-0.074	0.048	0.416 *
Zn	0.017	-0.289	-0.363 *	-0.062	0.721 **
Total HCHs	-0.083	-0.3	-0.337	-0.148	0.775 **
Alpha HCH	-0.087	0.094	-0.027	0.105	0.346
Beta HCH	-0.014	-0.399 *	-0.349	-0.236	0.714 **
Gamma HCH	-0.199	0.289	-0.039	0.201	0.048
Delta HCH	0.026	-0.205	-0.259	-0.056	0.54
Total chlordanes	-0.068	0.115	-0.111	0.066	0.631 **
Heptachlor					
Heptachlor epoxide	0.024	0.246	0.086	0.161	0.041
Oxychlordane	0.081	0.035	-0.15	-0.09	0.415 *
Gamma Chlordane	-0.036	-0.002	-0.119	0.028	0.452 *
Alpha Chlordane	0.031	-0.031	-0.236	0.015	0.688 **
Trans-Nonachlor	-0.043	-0.183	-0.192	-0.111	0.641 **
Cis-Nonachlor	0.063	-0.043	-0.274	-0.03	0.629 **
Hexachlorobenzene	0.002	-0.188	-0.199	-0.063	0.793 **
Aldrin	0.177	-0.076	-0.12	-0.023	0.535 **
Dieldrin	-0.001	-0.176	-0.328	-0.06	0.701 **
Endrin	-0.046	-0.157	0.098	-0.103	0.021
Mirex	-0.017	-0.146	-0.116	-0.025	0.6 **
Endosulfan II	-0.187	0.23	0.252	0.261	-0.159
Total DDT's	0.036	-0.091	-0.229	-0.01	0.779 **
2,4' DDE	0	0.104	-0.14	0.215	0.251
4,4' DDE	0.026	-0.203	-0.291	-0.112	0.862 **
2,4' DDD	0.049	0.067	-0.189	0.085	0.559 **
4,4' DDD	0.033	-0.051	-0.161	0.056	0.771 **
2,4' DDT	-0.018	-0.043	-0.15	-0.117	0.257
4,4' DDT	0.001	0.099	-0.11	0.102	0.44 *

* $p < 0.05$; ** $p < 0.01$

Table 15. Spearman-rank correlation coefficients and probable signifiance levels between sediment toxicity tests and PAHs and PCBs.

Contaminant	Amphipod Toxicity	Fertilization Success (100%)	Embryological Development (100%)	Microtox Bioluminescence	RGS P450
TPAHs	-0.017	-0.289	-0.363 *	-0.26	0.873 **
Naphthalene	0.065	-0.244	-0.375 *	-0.108	0.719 **
C1-Naphthalenes	0.054	-0.271	-0.408 *	-0.105	0.741 **
C2-Naphthalenes	-0.091	-0.135	-0.341	-0.041	0.623 **
C3-Naphthalenes	-0.047	-0.17	-0.299	-0.07	0.623 **
C4-Naphthalenes	-0.071	-0.208	-0.412 *	-0.148	0.631 **
Biphenyl	0.091	-0.252	-0.443 *	-0.18	0.752 **
Acenaphthylene	-0.034	-0.289	-0.335	-0.267	0.801 **
Acenaphthene	-0.032	-0.172	-0.359	-0.28	0.781 **
Fluorene	0.049	-0.168	-0.343	-0.171	0.802 **
C1-Fluorenes	-0.007	-0.244	-0.388 *	-0.219	0.759 **
C2-Fluorenes	0.026	-0.218	-0.338	-0.185	0.669 **
C3-Fluorenes	0.021	-0.237	-0.337	-0.192	0.66 **
Phenanthrene	-0.016	-0.234	-0.324	-0.248	0.834 **
Anthracene	0.011	-0.296	-0.347	-0.276	0.84 **
C1-Phenanthrene	0.006	-0.291	-0.382 *	-0.252	0.873 **
C2-Phenanthrene	0.013	-0.384 *	-0.372 *	-0.281	0.843 **
C3-Phenanthrene	0.042	-0.365 *	-0.325	-0.255	0.859 **
C4-Phenanthrene	0.02	-0.276	-0.272	-0.224	0.856 **
1-Methylnaphthalene	0.03	-0.272	-0.417 *	-0.099	0.729 **
1-Methylphenanthrene	0.017	-0.311	-0.381 *	-0.299	0.844 **
2-Methylnaphthalene	0.096	-0.261	-0.386 *	-0.122	0.726 **
2,6-Dimethylnaphthalene	-0.015	-0.103	-0.401 *	-0.135	0.575 **
1,6,7-Trimethylnaphthalene	-0.058	-0.059	-0.295	-0.041	0.458 *
Dibenzothiophene	0.035	-0.224	-0.342	-0.198	0.87 **
C1-Dibenzothiophene	0.013	-0.203	-0.317	-0.194	0.729 **
C2-Dibenzothiophene	0.123	-0.213	-0.354	-0.189	0.741 **
C3-Dibenzothiophene	0.12	-0.345	-0.333	-0.225	0.758 **
Fluoranthene	-0.038	-0.25	-0.287	-0.233	0.793 **
C1-Fluoranthene/pyrene	-0.056	-0.218	-0.265	-0.246	0.829 **
Pyrene	-0.029	-0.209	-0.272	-0.211	0.817 **
Benzo(*a*)anthracene	-0.034	-0.264	-0.271	-0.246	0.795 **
Chrysene	-0.015	-0.259	-0.297	-0.27	0.807 **
C1-Chrysenes	0.013	-0.229	-0.312	-0.213	0.842 **
C2-Chrysenes	0.055	-0.229	-0.326	-0.224	0.851 **
C3-Chrysenes	0.091	-0.196	-0.284	-0.128	0.737 **
C4-Chrysenes	0.097	-0.172	-0.358	-0.167	0.686 **
Benzo(*b*)fluoranthene	-0.021	-0.249	-0.276	-0.246	0.816 **
Benzo(*k*)fluoranthene	-0.008	-0.258	-0.31	-0.264	0.786 **
Benzo(*e*)pyrene	-0.038	-0.201	-0.257	-0.209	0.793 **
Benzo(*a*)pyrene	-0.019	-0.224	-0.261	-0.237	0.808 **
Perylene	-0.01	-0.261	-0.399 *	-0.234	0.894 **
Indeno(1,2,3-*cd*)pyrene	-0.01	-0.254	-0.289	-0.228	0.804 **
Dibenzo(*a,h*)anthracene	0.007	-0.278	-0.278	-0.248	0.786 **
Benzo(*g,h,i*)perylene	-0.007	-0.218	-0.288	-0.206	0.828 **
Total PCBs	-0.012	-0.234	-0.271	-0.108	0.832 **
PCB8/5	0.106	0.12	0.029	-0.049	0.123
PCB18/17	-0.046	0.034	-0.061	0.085	0.356
PCB28	-0.105	-0.14	-0.206	0.075	0.635 **
PCB52	0.032	-0.115	-0.265	-0.033	0.811 **
PCB44	-0.014	-0.046	-0.17	0.054	0.745 **
PCB66	0.071	-0.132	-0.177	-0.052	0.588 **
PCB101/90	-0.013	-0.192	-0.289	-0.058	0.787 **
PCB118	0.009	-0.338	-0.361	-0.137	0.719 **
PCB153/132	-0.067	-0.303	-0.373 *	-0.125	0.737 **
PCB105	-0.053	-0.193	-0.26	-0.125	0.615 **
PCB138 /160	-0.052	-0.304	-0.416 *	-0.126	0.707 **
PCB187	-0.016	-0.11	-0.242	-0.002	0.655 **
PCB128	0.063	-0.194	-0.322	-0.086	0.379 *
PCB180	-0.013	-0.249	-0.276	-0.084	0.855 **
PCB170/190	-0.077	-0.199	0.069	-0.24	0.125
PCB195/208	0.094	-0.17	-0.167	-0.054	0.697 **
PCB206	-0.055	-0.095	-0.198	0.07	0.608 **
PCB209	0.024	-0.18	-0.209	-0.04	0.816 **

* $p < 0.05$; ** $p < 0.01$

Table 16. Spearman-rank correlation coefficients generated from ER-M quotients.

	Spearman-rank Coefficients				
Contaminant/Class	Amphipod Toxicity	Microtox	Fertilization Success	Embryological Development	RGS P450
Ag	-0.01	0.013	-0.132	-0.317	0.697 **
As	0.032	-0.112	-0.427 *	-0.318	0.487 **
Cd	0.066	-0.035	-0.056	-0.259	0.726 **
Cr	-0.009	0.047	-0.178	-0.25	0.674 **
Cu	-0.11	-0.078	-0.265	-0.366 *	0.775 **
Hg	0.011	-0.051	-0.232	-0.325	0.795 **
Ni	-0.023	-0.012	-0.177	-0.268	0.635 **
Pb	-0.034	-0.01	-0.165	-0.319	0.811 **
Zn	0.017	-0.065	-0.299	-0.357	0.726 **
p,p'-DDE	0.026	-0.112	-0.203	-0.291	0.862 **
tDDT	0.035	-0.009	-0.09	-0.227	0.777 **
tPCB	-0.013	-0.109	-0.234	-0.272	0.833 **
tPAHs	-0.017	-0.261	-0.292	-0.364 *	0.873 **
Acenaphthene	-0.029	-0.275	-0.165	-0.364 *	0.773 **
Acenaphthylene	-0.03	-0.263	-0.286	-0.336	0.801 **
Anthracene	0.008	-0.275	-0.293	-0.344	0.84 **
Fluorene	0.036	-0.175	-0.18	-0.351	0.806 **
2-Methylnaphthalene	0.102	-0.126	-0.267	-0.391 *	0.728 **
Naphthalene	0.068	-0.107	-0.252	-0.377 *	0.719 **
phenanthrene	-0.015	-0.249	-0.235	-0.324	0.833 **
Benz(a)anthracene	-0.034	-0.247	-0.262	-0.272	0.794 **
Benzo(a)pyrene	-0.017	-0.235	-0.224	-0.261	0.809 **
Chrysene	-0.015	-0.269	-0.26	-0.296	0.808 **
Dibenzo(a,h)anthracene	0.006	-0.244	-0.271	-0.278	0.785 **
Fluoranthene	-0.045	-0.234	-0.251	-0.28	0.79 **
Pyrene	-0.027	-0.211	-0.21	-0.272	0.815 **
Low mol. wt. PAH	-0.042	-0.255	-0.328	-0.4 *	0.874 **
High mol. wt. PAH	-0.019	-0.238	-0.245	-0.297	0.84 **

* $p < 0.05$; ** $p < 0.01$

The single most dominant and widely distributed genus was *Mediomastus* (lowest possible identification level (LPIL), most likely *Mediomastus ambiseta*). *Mediomastus* represented 29.1% of the total individuals and was found in 77% of the sites. The polychaete, *Paraprionospio pinnata*, the ribbon worms *Rhynchocoela* and *Tubulanus* (LPIL), and the polychaete *Parandalia tricuspis* were present in 61%, 55%, 46%, and 41% of the sites, respectively (Appendix I).

The number of individuals, mean density of individuals m^{-2}, faunal diversity, and evenness are also provided in Table 17. The number of

Table 17. Benthic macroinvertebrate community analysis.

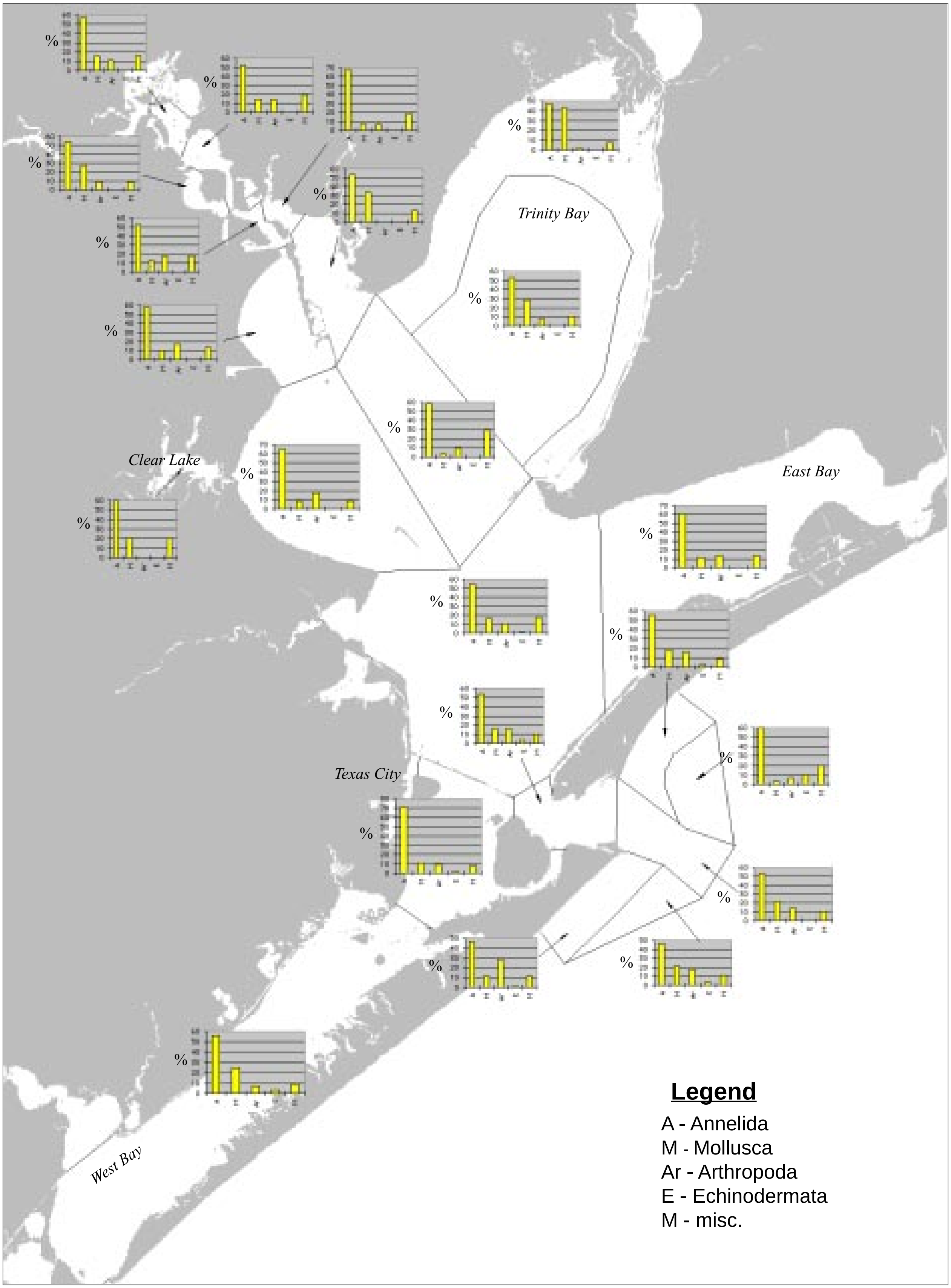
Strata	Site	Total taxa	Mean taxa per strata	Number of individuals	Mean density	Density standard deviation	Faunal diversity (H')	Evenness (J')
1	Overall	12	6.3	149	1,242	1,168	1.16	0.47
	3	5		16	400			
	2	7		103	2,575			
	1	7		30	750			
2	Overall	12	7.0	93	775	331	1.73	0.70
	4	6		41	1,025			
	6	8		36	900			
	5	7		16	400			
3	Overall	16	7.3	152	1,267	903	1.20	0.43
	9	5		13	325			
	7	10		54	1,350			
	8	7		85	2,125			
4	Overall	17	7.7	55	458	356	2.41	0.85
	12	1		2	50			
	10	11		25	625			
	11	11		28	700			
5	Overall	9	5.3	60	500	282	1.55	0.71
	14	5		7	175			
	13	6		27	675			
	15	5		26	650			
6	Overall	14	5.7	41	342	350	2.16	0.82
	18	11		28	700			
	16	6		13	325			
	17	0		0	0			
7	Overall	19	9.3	84	700	229	2.33	0.79
	20	9		26	650			
	21	11		38	950			
	19	8		20	500			
8	Overall	17	8.5	116	725	396	2.16	0.76
	25	6		12	300			
	27	7		33	825			
	28	10		22	550			
	26	11		49	1,225			
8A	Overall	4	2.5	38	475	636	1.14	0.82
	22	4		37	925			
	23	1		1	25			
9	Overall	18	7.8	74	463	60	2.38	0.82
	32	11		21	525			
	29	6		20	500			
	30	8		16	400			
	31	6		17	425			
10	Overall	52	18.8	326	1,630	511	3.30	0.84
	34	13		68	1,700			
	35	12		44	1,100			
	36	20		62	1,550			
	33	30		98	2,450			
	37	19		54	1,350			
11	Overall	28	12.3	450	2,813	3,469	1.93	0.58
	38	14		65	1,625			
	41	21		317	7,925			
	40	11		60	1,500			
	39	3		8	200			
12	Overall	28	16.3	586	4,883	1,202	2.01	0.60
	42	15		219	5,475			
	44	12		140	3,500			
	43	22		227	5,675			

Table 17. Benthic macroinvertebrate community analysis (continued).

Strata	Site	Total taxa	Mean taxa per strata	Number of individuals	Mean density	Density standard deviation	Faunal diversity (H')	Evenness (J')
13	Overall	25	8.6	164	820	251	2.62	0.81
	48	3		28	700			
	45	9		33	825			
	49	7		22	550			
	47	10		32	800			
	46	14		49	1,225			
14	Overall	51	25.0	344	2,867	1,006	3.25	0.83
	50	23		145	3,625			
	51	22		69	1,725			
	52	30		130	3,250			
15	Overall	90	28.0	1229	6,145	7,546	2.96	0.66
	55	13		30	750			
	56	10		31	775			
	53	60		638	15,950			
	54	50		507	12,675			
	57	7		23	575			
16	Overall	39	17.0	226	1,883	813	2.51	0.69
	58	11		104	2,600			
	59	27		82	2,050			
	60	13		40	1,000			
17	Overall	51	21.3	238	1,983	1,439	3.04	0.77
	61	17		70	1,750			
	63	35		141	3,525			
	62	12		27	675			
18	Overall	40	19.7	215	1,792	772	2.86	0.78
	66	18		66	1,650			
	65	19		44	1,100			
	64	22		105	2,625			
19	Overall	36	16.3	172	1,433	592	2.83	0.79
	67	17		72	1,800			
	68	11		30	750			
	69	21		70	1,750			
20	Overall	38	15.0	135	1,125	1,040	2.91	0.80
	71	22		93	2,325			
	72	14		20	500			
	70	9		22	550			
21	Overall	22	10.0	142	1,183	747	2.08	0.67
	74	16		81	2,025			
	75	8		37	925			
	73	6		24	600			

individuals ranged from 38 in Clear Lake to 1,229 in West Bay. The mean density of individuals m^{-2} ranged from 342 in Upper Galveston Bay (Stratum 6), east of the dredge spoil islands, to 6,145 in West Bay (Stratum 15). The faunal diversity (H’) followed a similar pattern with the lowest diversity in Clear Lake (1.14), and the highest diversity in lower Galveston Bay (3.30).

Figure 15. Dominant taxa in the benthic community.



DISCUSSION

Widespread destruction of Galveston City and loss of human life due to a severe hurricane in 1900, coupled with discovery of a major oilfield near Beaumont, Texas and passage of the new federal Rivers and Harbors Act in the early 1900s, provided the needed impetus to develop Houston into a major port and hub of commerce. Much of the industrial development over the next few decades was based on the transport of petroleum and manufacturing of petroleum-related products. The HSC, designated as such in 1914, has been expanded and deepened over the years to accommodate large ocean-going freighters and tankers. The shores of the channel are also home to numerous refineries, petrochemical plants, dry goods container wharves, and related businesses. During the 70-year period, 1910 to 1980, the region's population grew nearly 15-fold, to about 3 million people.

As a consequence of rapid industrial growth and concomitant increase in human population, many resource-use conflicts have emerged in Galveston Bay. Many of them concern habitat loss, seafood contamination, dwindling populations of certain wildlife species, and environmental quality in general. In the early 1970s, portions of the bay, notably those in the vicinity of the HSC, were severely degraded with anoxic waters, high levels of contaminants, seafood consumption advisories, loss of coastal vegetation, discharge of produced waters, and nutrient loadings from municipal discharges.

Over the next 25 years, recognition of major environmental problems prompted a number of corrective actions and management schemes by public agencies individually or collectively, often with support from academic and environmental communities. This has included improved wastewater treatment, minimization of sewage overflows, produced water management, and control of point source discharges of contaminants, nutrients and other pollutants. These measures have resulted in a considerable reduction in pollutant loading and improved environmental conditions in the HSC and adjoining waters. The most remarkable improvement was a reduction in biochemical oxygen demand (BOD) values in the upper reaches of the channel from over 200,000 kg of BOD per day in 1968 to less than 9,000 kg per day in 1990 (GBNEP, 1995). BOD is a measure of the amount of dissolved oxygen consumed by microorganisms in degrading organic matter in a water sample over a 5-day period, and is a commonly used parameter to describe the short-term oxygen demand exerted by sewage and industrial effluents. Levels of other contaminants, such as toxic trace elements in sediment, have either leveled off or declined since the 1970s (Carr, 1993).

Even though the protective measures were narrowly focused, most of them on permitting requirements under the National Pollution Discharge Elimination System (NPDES), they have apparently improved the sediment quality of the bay as well the water quality. The general strategy of those measures was to let the bay cleanse itself and renew its resources. Such a strategy would work if the bay were not being overwhelmed by stress. The results given by Carr et al. (1996) and those provided in this report tend to support that strategy. Results of the amphipod survival tests in this study do not indicate any areas of significant toxicity in Galveston Bay. Typically, sediment toxicity in large bays and estuaries, i.e., larger than 250 sq. km in area, is spatially quite limited: about 6%, based on results of the amphipod survival test (Hameedi et al., 1999). The spatial extent of sediment toxicity in the EMAP provinces as inferred from the amphipod survival test, ranged from zero to 10% (Long, 2000). Typically these provinces cover large areas, from 4,000 sq. km (areas studied in the California Province) to 25,000 sq. km (Louisiana Province).

The lack of bulk sediment toxicity, as indicated by the results of the amphipod *A. abdita* survival test, is notable. Carr et al. (1966) obtained similar results in the bay even though they used a different test species, *Grandidierella japonica*. *G. japonica* is a non-indigenous species of Japanese origin that has settled in estuaries and intertidal waters off central and southern California (Chapman and Dorman, 1975). It is a tube-building species found in fairly high numbers in habitats ranging from sandy to muddy substrata. Unlike *A. abdita*, this species constructs porous, U-shaped tubes; it has a much shorter generation time, and has successfully been raised under laboratory conditions (Nipper et al., 1989).

The use of a tube-building species raises questions about the mode of exposure to sediment and contaminated particles. Such species, notably *A. abdita*, maintain water circulation in their tubes by pleopods and antennae; as such, they are more likely to be exposed to overlying water, and possibly some porewater and particles in suspension. Depending on the contaminant and its affinity for association with the sediment, such species may not be fully exposed to sediment-associated contaminants. Previously obtained results as well as data from an ongoing NOAA study have shown significant differences in response between the tube-building (*A. abdita*) and burrowing (*Eohaustorius estuarius*) amphipod species (Anderson et al., 1999).

This study, as well as the one reported by Carr et al. (1996), showed significant sediment porewater toxicity in portions of the bay, based on both the fertilization success and larval development tests. In this study, all sites within Stratum 7 (HSC, Upper Galveston Bay-West), 8 (Central Galveston Bay-West) and 8A (Clear Lake), showed significant reduction in fertilization success (100% porewater).

Based on the sea urchin fertilization test and the Microtox® test, 45 and 87% of Galveston Bay showed toxic conditions, respectively. These results compare fairly well with an overall average for these tests in U.S. estuaries nationwide whose area is larger than 250 sq. km: 43% for the sea urchin test and 63% for the Microtox® test (Hameedi et al., 1999). It should be noted that a toxicity endpoint for tests like the Microtox® test or the HGS assay is not easily defined. Given the nature of the Microtox® test, comparison of samples from a study area with samples from a control site, in this case Redfish Bay, can result in a very high incidence of toxicity. In northern Puget Sound, for example, sediment samples from 97 out of 100 sites were significantly more toxic than the Redfish Bay control samples, suggesting widespread toxicity (in 98% of the area sampled). The unusually low Microtox® response to negative control samples from Redfish Bay, relative to results from the bay samples, impedes interpretation and comparability of results. Attempts have been made to define toxicity thresholds of such tests by calculating a prediction interval (Long et al., 1999) or confidence interval (Anderson et al., 1999) based on NOAA's nationwide database for these two tests. Note that a prediction interval is used to estimate what a future value will be, based on existing data. A confidence interval defines a range of values that encompasses a population parameter of interest, such as the population mean, as derived from existing data. Based on the prediction interval approach, none of the Microtox® test results were lower than the critical lower prediction limit values derived using NOAA data (Long et al., 1999). Interpretation of these data remains a judgmental issue.

The results of the RGS assay in Galveston Bay showed unexpectedly low induction of the cytochrome P450 enzyme system. The assay responds to the presence of chemicals known to cause direct chemical toxicity or genotoxicity, including planar PCBs, higher molecular weight PAHs, dioxins and furans. The RGS response was generally very low, with a mean value of approximately 5 ug/g (B[a]PEq). A recent analysis of RGS response data from NOAA's sediment toxicity studies (n=530) indicated an upper prediction limit of observations at the 90% confidence level to be 37.1. This means that there is a 90% probability that one future observation from this distribution will be less than 37.1. Eliminating the 95th or 90th percentile of the data set, the upper prediction limit would be reduced since the "population" would not contain potentially highly impacted sites (Long et al., 2000). The upper prediction limit at the 80% confidence level was 11.1 when values greater than 37.4 (90th percentile) were eliminated from the data set. Earlier, Anderson et al. (1999) showed that the 99% confidence level of the mean value (22.7) of RGS tests from nine sediment toxicity studies (n=527) was between 12.6 and 32.8. These results have been interpreted to mean that an RGS response value of approximately 10 indicates background levels for estuarine sediments. Sediments that elicit RGS responses of 60 mg/kg (B[a]PEq) or larger usually contain degraded infaunal communities (Fairey et al., 1998). The highest value for Galveston Bay samples was 34 mg/kg (B[a]PEq) at a site in Stratum 2 (HSC).

Concentrations of most metals and organic contaminants did not exceed NOAA's Sediment Quality Guidelines (ER-L and ER-M). Most of the analytes that did exceed the numeric ER-L guideline included only about 2% of the study area. The exceptions were arsenic and nickel, which extended to at least 25% of the study area. Metals concentrations have no discernible pattern in distribution throughout the study area. Pesticides and PCBs decreased in concentrations from north to south, although with the exception of DDT, all concentrations were below their respective ER-L/ ER-M guidelines. PAH concentrations have a similar north to south decreasing concentration trend except that the higher concentrations extend further into the bay itself before concentrations began to decrease. The highest PAH concentrations were in the central portion of the bay.

Using scaled values of the triad results, Carr et al. (1996) noted that eight out of 24 sampling sites in Galveston Bay showed evidence of sediment contamination, toxicity, and impaired benthos. Most of the sites were located in the HSC or fairly close to the shoreline in Trinity Bay and East Bay; the middle part of the bay was not sampled. Carr et al. (1996) chose No Observed Effect Level (NOEL) or ERL values as benchmarks to classify a site having elevated levels of contaminants. In general, NOEL values are lower than the ERL (Effects-Range Low), TEL (Threshold Effects Level) or AET (Apparent Effects Threshold) values, and thus represent a more precautionary approach. As an example, the NOEL value for tPCBs is 24 ppb, whereas the ERL value for PCBs is 50, the TEL value is 34, and the AET value based on the Microtox® test is 130. It should be noted that AET values are usually specific for a particular test or species in a particular geographical area and thus are quite variable. More recently, a group of experts derived a consensus-based "threshold effect concentration" for tPCBs in sediment of 40 ppb (MacDonald et al., 2000).

Macrobenthic community parameters, such as species richness and diversity, or derived values, such as a benthic index, have often been used to assess the ecological impacts of environmental degradation. Typically, estuarine infauna is taxonomically diverse and includes species that exhibit a wide range of feeding modes and trophic interactions and effectively exploit a wide range of habitats (clean sand to mud). However, many factors, not necessarily associated with chemical contamination, play a pivotal role in structuring infaunal benthic communities. They include depth, tidal cycles, salinity, sediment texture and organic carbon content, and temperature. It is therefore difficult to distinguish between contaminant-related changes in a benthic infaunal community from those caused by natural factors, except in cases of substantial impact.

The total number of infaunal benthos taxa identified in this study was 211 (BAV, 1997). As was shown in previous studies (e.g., Carr et al., 1996), deposit feeding annelids were numerically the most abundant taxonomic group in Galveston Bay. They comprised 71% of the total number of animals collected and represented 46% of species in the current study. Within this group *Mediomastus sp.,* generally regarded as an opportunistic species, was widespread, particularly in fine, organically rich sediments. Bivalves, gastropods and amphipods were the other numerically abundant taxa.

Preliminary results of numerical classification analysis of the infaunal benthos data showed a remarkable separation of sampling strata into three groups. Strata 14-21, located in the West Bay and in the vicinity of Galveston Bay's opening to the Gulf of Mexico, were generally similar, except Stratum 18 where fauna was dominated by amphipods. Stratum 18 was identified as a separate "group" under the classification scheme. The remaining strata, 1-13, were grouped together and represented sampling sites dominated by fine-grained sediments, primarily mud. Additionally, more detailed analyses to discern the relationship between the site groupings, as well as species groupings, will be carried out in the future.

In some studies where the sediment quality triad approach is used and concurrent data are available, it has been shown that benthic infaunal changes occurred at contaminant concentrations lower than those associated with acute toxicity tests (Hyland et al., 1999; Long, 2000; Long et al., 2002). Further, sediment samples that generated P450 induction greater than a certain threshold value have been found to be highly correlated with degraded benthos, i.e., low species diversity, abundance of opportunistic and generally pollution-tolerant species (Anderson et al., 1999; McCoy et al., 2002). Additional recent efforts, using different analytical approaches, have further elucidated the relationship between sediment contamination and degradation of infaunal benthos. These approaches have utilized aspects of multivariate analyses such as principal component analysis (Long et al., 2002), nodal analysis (Hameedi et al., 2001), or a two-step procedure involving ordination based upon principal coordinate analysis and calculating an abundance-weighted average of pollution tolerant species in a sample (Smith et al., 2001). Such analyses have not yet been performed on the Galveston Bay benthos data.

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Chemical analyses and toxicity tests were carried out either under contract or through an interagency agreement. Samples were analyzed for chemical contaminants by Texas A&M University's Geochemical and Environmental Research Group. TRAC Laboratories carried out the amphipod toxicity tests. The RGS assays were conducted by Columbia Analytical Services, Inc. The sea urchin and Microtox® tests were carried out by USGS, BRD, Columbia Environmental Research Center. Benthic faunal sorting and taxonomy determinations were made by Barry A. Vittor and Associates, Inc. Finally, the authors wish to thank Edward Long for assisting in the development of the sampling scheme and preliminary analysis of chemistry and toxicity data.

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List of Appendices

Appendix A
Sediment Characteristics

Appendix A. Sediment characteristics at sampling sites.

Stratum number	Station number	Percent sand	Percent silt	Percent clay	Percent TOC	Percent TIC	Percent TC
1	1	89.19	3.92	6.89	0.2	0.02	0.22
	2	18.12	43.56	38.32	0.95	0.05	1
	3	5.88	36.96	57.16	1.67	0.14	1.81
2	4	91.79	2.98	5.23	0.18	0.03	0.21
	5	59.67	22.18	18.15	0.54	0.08	0.62
	6	1.52	16.69	81.79	1.59	1.65	3.24
3	7	46.7	22.8	30.5	0.8	0.24	1.04
	8	24.54	29.65	45.81	1.3	0.1	1.4
	9	9.89	36.04	54.07	1.16	<0.02	1.26
4	10	64.44	21.86	13.7	0.37	0.16	0.53
	11	53	25.91	21.09	0.57	0.22	0.79
	12	99.33	0.5	0.17	0.06	0.1	0.16
5	13	3.61	47.48	48.91	1.2	<0.02	1.11
	14	2.38	41.74	55.88	1.33	<0.02	1.24
	15	4.76	63.66	31.58	0.65	0.24	0.89
6	16	3.33	34.57	62.1	1.15	0.52	1.67
	17	2.94	40.82	56.24	1.57	<0.02	1.57
	18	23.21	31.15	45.64	0.95	0.22	1.17
7	19	7	39.74	53.26	0.95	0.32	1.27
	20	49.46	29.6	20.94	0.57	0.26	0.83
	21	11.31	36.73	51.96	1.36	<0.02	1.22
8A	22	25.83	51.55	22.62	0.75	0.35	1.1
	23	10.79	44.61	44.6	1.2	0.36	1.56
	24	13.61	60.39	26	0.81	0.42	1.23
8	25	5.49	46.27	48.24	1.08	0.37	1.45
	26	22.72	49.41	27.85	0.82	0.37	1.19
	27	43.36	35.52	21.12	0.57	0.21	0.78
	28	20.65	44.91	34.44	0.74	0.34	1.08
9	29	7.64	28.6	63.76	0.87	0.39	1.26
	30	7.38	17.57	75.05	1.02	0.25	1.27
	31	17.88	35.68	46.44	0.75	0.31	1.06
	32	8.4	27.52	64.08	1.07	<0.02	1.06
10	33	86.53	7.31	6.16	0.23	0.15	0.38
	34	8.68	33.41	57.91	1.11	0.19	1.3
	35	54.69	17.03	28.28	0.49	0.17	0.66
	36	38.6	29.69	31.71	0.6	0.14	0.74
	37	86.48	6.04	7.48	0.25	<0.02	0.2

Appendix A. Sediment characteristics (continued).

Stratum number	Station number	Percent sand	Percent silt	Percent clay	Percent TOC	Percent TIC	Percent TC
11	38	31.86	32.56	35.58	0.77	0.13	0.9
	39	6.42	32.82	60.76	1.31	<0.02	1.32
	40	11.26	37.4	51.34	1.13	<0.02	1.1
	41	27.81	27.94	44.25	0.89	0.1	0.99
12	42	6.29	57.51	36.2	1.17	0.21	1.38
	43	33.29	27.99	38.72	0.76	0.09	0.85
	44	30.94	50.12	18.94	0.48	0.08	0.56
13	45	58.5	20.16	21.34	0.51	<0.02	0.45
	46	62.78	10.76	26.46	0.49	0.29	0.78
	47	33.41	41.26	25.33	0.52	0.03	0.55
	48	38.22	27.2	34.58	0.87	0.02	0.89
	49	25.51	30.79	43.7	0.83	<0.02	0.83
14	50	25.21	26.88	47.91	0.88	0.14	1.02
	51	63.65	10.69	25.66	0.37	0.05	0.42
	52	57.29	14.64	28.07	0.51	1.01	1.52
15	53	69.64	18.55	11.81	0.35	0.91	1.26
	54	68.13	11.76	20.11	0.53	1.52	2.05
	55	64.55	11.65	23.8	0.48	0.02	0.5
	56	97.58	1.04	1.38	0.24	<0.02	0.2
	57	13.8	47.89	38.31	0.71	0.06	0.77
16	58	73.04	19.73	7.23	0.93	1.03	1.96
	59	93.53	3.61	2.86	0.25	1.48	1.73
	60	53.27	28.63	18.08	0.93	0.19	1.12
17	61	36.93	23.9	39.17	1.14	0.32	1.46
	62	85.54	11.91	2.55	0.45	3.65	4.1
	63	49.94	34.23	15.83	2.29	1.53	3.82
18	64	99.31	0.52	0.17	0.25	<0.02	0.21
	65	99.25	0.56	0.19	0.31	<0.02	0.25
	66	99.47	0.4	0.13	0.25	<0.02	0.17
19	67	49.36	45.91	4.73	0.46	<0.02	0.47
	68	95.67	4.14	0.19	0.13	0.03	0.16
	69	5.07	69.99	24.94	0.91	0.21	1.12
20	70	99.33	0.5	0.17	0.11	<0.02	0.11
	71	84.3	7.92	7.78	2.32	0.26	2.58
	72	99.23	0.58	0.19	0.55	0.3	0.85
21	73	8.02	28.17	63.81	1.76	0.52	2.28
	74	8.04	31.58	60.38	1.61	0.47	2.08
	75	8.16	33.33	58.51	0.86	0.61	1.47

Appendix B
Field Logs

Appendix B. Galveston Bay field logs.

STRATA	SITE NUMBER	ALTER-NATE	DATE (mm/dd/yy)	TIME (local)	SITE LOCATION	LATITUDE (N)	LONGITUDE (W)	SEDIMENT COLOR	SEDIMENT TEXTURE	ODOR/ SHEENS	BENTHIC ORGANISMS	DEPTH(FT)	CTD	OTHER COMMENTS
1	1	1	8/5/96	2:50	Houston ship channel-40ft North of R 120 outside of channel, SW of Brownwood, oil industries there and to the south	29° 44.429	95° 3.437	brown over gray	sand over sand w/clay	none	none	8	yes	transducer not working-estimated depth
1	2	2	8/5/96	2:18	Houston ship channel-NE of San Jacinto State Park, SE of Lynchburg Landing, South of high tension power lines	29° 45.703	95° 4.022	brown mixed over gray	silt over clay	none	none	7	yes	transducer not working-estimated depth, Alt because signs for no dredging or anchoring at Alt 1
1	3	1	8/5/96	1:36	Houston ship channel - near ferry crossing, Lynchburg Range, south of Lynchburg landing, north of San Jacinto obelisk, nearby restaurant and Monument Inn, industries	29° 45.688	95° 4.705	brown over gray	silt over clay	none	diatom scum	15	yes	transducer not working-estimated depth
2	4	1	8/5/96	3:27	Houston ship channel - SW of tank farm and numerous smoke stacks, East of San Jacinto monument, 20ft north of R 116	29° 44.101	95° 3.201	lt to med brown on top w/gray below, no distinct layers	sand with some clay	none	none	7	yes	transducer not working-estimated depth
2	5	1	8/6/96	9:10	Houston ship channel-west of channel, 100m east of Alexander Island, 50m of G111	29° 43.333	95° 1.363	brown surface over gray	1st - thin layer of silt over sand, 2nd &3rd - mostly silt	after homogenizing - petro smell	none	4.5	yes	transducer not working-estimated depth
2	6	1	8/6/96	8:25	Scott Bay, 200m W of Petrochemical facility and residential homes	29° 44.744	95° 2.124	rusty brown layer over a dark grey	silt with slight shell hash	none	none	4.5	yes	transducer not working-estimated depth
3	7	1	8/6/96	10:30	Upper San Jacinto Bay - between Alexander Island and Brinsom Pt (Dupont Petrochemical facility), appr. 100m North of R10, 100m north of channel	29° 42.405	95° 1.948	brown over gray, black spots (petro?) in one grab	silt with lots of oyster shells, clay in one grab	none	mussels(small) on oyster shells	4	yes	transducer not working-estimated depth
3	8	1	8/6/96	12:50	Upper San Jacinto Bay - 100m North of Brinson Pt. Petro chemical (Dupont) facility, 200m east of G11	29° 42.228	95° 1.914	brown over dark gray	silt with some sand and liver oysters	slight petroleum odor	oysters, shrimp	4.5	yes	transducer not working-estimated depth
3	9	2	8/6/96	9:55	Upper San Jacinto Bay - 10m from G5 marker from channel in the bay, 200m NW of Spilmans Island, 500m west of suspension bridge over Houston ship channel, on Spilmans Island there is a Dupont Petrochemical facility	29° 42.149	95° 1.55	brown surface over gray	silt over clay	slight petroleum odor after mixing	juvenile flatfish(sole)	5	yes	transducer not working-estimated depth, Alt 1 was unassessible-to shallow
4	10	1	8/7/96	3:20	Houston ship channel-NE of entrance to Barbours Cut	29° 41.283	94° 59.312	brown over gray	sandy silt over sandy silty clay	none	worm tube/hole	5	yes	transducer not working-estimated depth
4	11	1	8/7/96	3:45	Houston ship channel, entrance to Barbours cut	29° 41.204	94° 59.187	brown over med gray	sandy silt over sandy silty clay	none	none	6	yes	transducer not working-estimated depth
4	12	1	8/6/96	3:43	Houston Ship Channel- 50m south of Hog Island NW edge seawall, 300m north of tall power cables, 100m SE of cable warning sign	29° 41.714	94° 59.402	light brown	sand	none	none	2	yes	transducer not working-estimated depth
5	13	1	8/6/96	2:15	Tabbs Bay - Appr 300m east of low abandoned Railroad bridge pilings, North of Hog Island	29° 42.288	94° 58.798	brown over dark gray	silt with some clay	none	none	4	yes	transducer not working-estimated depth,surrounded by oil wells-pumps, electric lines
5	14	1	8/6/96	1:40	Tabbs Bay-Midway between Hog Island and mainland. Appr. 400m south of mainland, Appr 300m west of old railroad bridge pilings	29° 42.293	94° 59.237	brown surface over gray over black	silt	none	none	4.5	yes	transducer not working-estimated depth,surrounded by oil wells-pumps
5	15	1	8/6/96	2:50	Tabbs Bay - 100m south of mainland, 300m east of abandoned Railroad bridge pilings	29° 42.527	94° 58.822	brown surface over gray	silt over clay	none	none	3	yes	transducer not working-estimated depth
6	16	1	8/7/96	11:07	Upper Galveston Bay Eastern area-east of R80 of Houston Ship Channel	29° 37.901	94° 56.19	brown over gray	thick silt layer over silty clay	none	none	7	yes	transducer not working-estimated depth
6	17	2	8/7/96	12:46	Upper Galveston Bay Eastern Bay- 1 mi ESE R80 Houston ship channel	29° 37.48	94° 56.194	brown over very dk gray	thin layer of silt over silty clay	none	none	6	yes	transducer not working-estimated depth, Alt one not used because it was located in a marsh
6	18	1	8/7/96	10:35	Upper Galveston Eastern side - East of Atkinson Island, west of Mesquite Knoll	29° 39.492	94° 56.968	brown over gray	thick silt layer w/sand over silty clay	none	none	6	yes	transducer not working-estimated depth

Appendix B. Galveston Bay field logs (continued).

STRATA	SITE NUMBER	ALTER-NATE	DATE (mm/dd/yy)	TIME (local)	SITE LOCATION	Latitude (N)	Longitude (W)	SEDIMENT COLOR	SEDIMENT TEXTURE	ODOR/ SHEENS	BENTHIC ORGANISMS	DEPTH(FT)	CTD	OTHER COMMENTS
7	19	1	8/7/96	2:43	Upper Galveston Bay western side-east of Little Cedar Bayou appr 1 mi	29° 38.492	95° 0.196	brown over med gray	silt over silty clay	none	none	8	yes	transducer not working-estimated depth, dredging nearby
7	20	1	8/7/96	1:45	Upper Galveston Bay western side-east of Bayside Terrace(appr 2mi)	29° 37.324	94° 58.941	brown over gray	silty and over silty clay	none	flatfish	8	yes	transducer not working-estimated depth
7	21	1	8/7/96	2:15	Upper Galveston Bay western side-SE of Sylvan Beach	29° 38.328	94° 59.801	lt. brown over med gray	sandy silt over silty clay	none	annelids	6	yes	transducer not working-estimated depth, dredging nearby
8	25	1	8/8/96	4:25	Upper Galveston Bay western side	29° 33.647	94° 58.835	thin brown layer over gray	silt over silty clay	none	none	10	yes	transducer not working-estimated depth
8	26	1	8/9/96	9:03	Upper Galveston Bay western area-east of bridge over Clear creek, NE of radio antennae	29° 32.174	94° 57.21	brown over gray	silt over clayey silt	none	diatom scum	9	yes	transducer not working-estimated depth
8	27	1	8/9/96	7:50	Upper Galveston Bay western area-west of Bulkhead Reef, east of Red Bluff, appr. .5mi west of Houston Ship channel	29° 35.985	94° 57.408	brown over gray	silt over silty clay	none	diatom scum, Goby	9	yes	transducer not working-estimated depth
8	28	1	8/9/96	8:30	Upper Galveston Bay western area- appr 2.5mi west of Houston Ship channel, 2.25 east of Todville	29° 34.101	94° 58.309	brown over gray	silt with shell hash	none	none	10	yes	transducer not working-estimated depth
8A	22	1	8/8/96	10:35	Clear Lake-south of Apt/condos w/boat slips in western Clear Lake	29° 33.81	95° 3.587	Brown over gray	silty clay	none	none	6	yes	transducer not working-estimated depth
8A	23	1	8/8/96	2:15	Clear Lake - southern edge of channel 100m SE of G19, 200m of Lakeside shore	29° 33.299	95° 3.634	thick light brown layer over dark gray	thick silt surface over silty clay	slight sulfur	none	6.5	yes	transducer not working-estimated depth
8A	24	1	8/8/96	3:05	Clear Lake - northern shore on the eastern end, 200m SW of apt complex with flags, 500m NW OF RED N14	29° 33.411	95° 2.302	thick brown layer over gray	silt over silty clay, light shell hash	none	none	6	yes	transducer not working-estimated depth
9	29	1	8/7/96	9:07	Upper Galveston Bay - NE of R70 marking Houston Ship Channel	29° 34.833	94° 54.714	brown over gray	thick silt layer over silty clay	none	none	7	yes	transducer not working-estimated depth
9	30	1	8/7/96	9:50	Eastern side of Upper Galveston Bay and mouth of Trinity Bay 3 mi south of Beach City	29° 37.209	94° 53.42	brown over gray	thick silt layer over silty clay	none	none	7	yes	transducer not working-estimated depth
9	31	1	8/7/96	1:11	Eastern side of Upper Galveston Bay-.5 mi ESE of Rear(after) range marker for the Bayport ship channel G180 6sec light, 60 ft high	29° 36.783	94° 55.786	brown over gray	silt w/sand over silty-clay	none	none	6	yes	transducer not working-estimated depth
9	32	1	7/31/96	4:10	North of Trinity River Channel, just south of "L" shaped oil platform, two smaller oil obstructions close by	29° 32.009	94° 50.296	brown with gray	shell (oyster) hash, silty sand	none	diatom scum	10	yes	
10	33	1	8/1/96	9:10	Central Galveston Bay, off east edge of Houston Ship Channel, NE of R 36	29° 25.328	94° 49.213	brown surface over gray	sandy clay w/shell hash	none	diatom surface	10	yes	
10	34	1	7/31/96	2:40	Central Galveston Bay, NW of Sievers Cove, South of Hanna Reef, 5 miles south of mainland	29° 27.019	94° 44.695	brown over gray, no distinct layers	clayey silt	none	worm tubes, eels	7	yes	
10	35	1	7/31/96	3:25	Central Galveston Bay, SE of Smith Pt., 2000yds from shore, North of Hanna Reef, sparse, residential area	29° 31.233	94° 46.287	gray with med brown at top	silt with some clay and sand	none	worm tubes, diatom scum	5	yes	
10	36	1	8/1/96	8:25	Central Galveston Bay, East of Houston Ship Channel, NE of R 40, 1.5m east if R 42	29° 26.544	94° 48.093	dark brown	silty clay, soft	none	diatom scum, worm tubes	9	yes	
10	37	1	8/1/96	10:05	Central Galveston Bay, appr. one mile east of Texas City, west of G47 marking Houston Ship Channel	29° 24.864	94° 51.964	brown over gray with some spots of rust	silt over sand with some shell hash	none	worm tubes, detritus below surface	7	yes	

Appendix B. Galveston Bay field logs (continued).

STRATA	SITE NUMBER	ALTER-NATE	DATE (mm/dd/yy)	TIME (local)	SITE LOCATION	Latitude (N)	Longitude (W)	SEDIMENT COLOR	SEDIMENT TEXTURE	ODOR/ SHEENS	BENTHIC ORGANISMS	DEPTH(FT)	CTD	OTHER COMMENTS
11	38	1	8/2/96	10:40	Trinity Bay-deep, Central-west bay almost 3 mi off shore, residential	29° 41.7	94° 48.906	lt. brown over gray	silt over silty clay	none	bilvalves	7	yes	All grabs had many clams
11	39	1	8/2/96	1:20	Trinity Bay-deep, SE area, near Galveston Bay, appr. 2.5 mi north of Smith Pt.	29° 35.49	94° 47.897	brown over dk gray	fine silt over silty clay, some shell hash	none	none	7	yes	transducer not working-estimated depth
11	40	1	8/2/96	12:35	Trinity Bay-deep, 2mi west of spoil bank near Black Pt.	29° 40.088	94° 45.172	lt. brown over dk gray streaks of very dk gray	silt over silty clay with some shell hash	none	some bivalves	7	yes	
11	41	1	8/2/96	11:50	Trinity Bay - deep, east-central Bay, about 1mi west of spoil bank near Black Pt	29° 40.092	94° 43.87	brown over gray with very dk gray 3rd layer	silty over silty clay	none	clams	6	yes	All grabs had many clams
12	42	1	8/2/96	8:25	Trinity Bay-shallow, north central , south of private marker #2	29° 43.451	94° 45.942	olive over gray	silt over silty clay with shell hash	none	none	7	yes	
12	43	1	8/2/96	9:58	Trinity Bay-shallow, about 1 mi SE of Pt Barrow, residential	29° 43.198	94° 49.984	brown over gray	silty over sandy silty clay	none	bivalves	5	yes	All grabs had many clams
12	44	1	8/2/96	9:10	Trinity Bay - shallow, SE of mouth of cooling system disharge canal (NW area of Bay)	29° 44.543	94° 48.453	brown over gray	silty over sandy silty clay	none	clams, oyster shells, worm tubes	6	yes	All grabs had many clams
13	45	1	7/31/96	10:10	East Bay, west of Goat Island, Long Pt or Big Pasture Bayou, North of ICW, marshy areas surrounding	29° 30.218	94° 36.703	some rust, med brown over gray	silty clay	slight sulfer	none	5	yes	
13	46	1	7/31/96	2:03	East Bay, NW of Sievers Cove near the mouth of East Bay, north of ICW	29° 26.516	94° 42.807	lt. brown/green at surface gray below	sandy clay	none	none	5	yes	
13	47	1	7/31/96	11:33	East Bay SW of Lake Surprise and Stephenson Pt. near shore appr. 1000 yds away	29° 31.98	94° 42.31	brown at surface then dark gray then lighter gray	clayey silt	none	none	4	yes	
13	48	1	7/31/96	9:05	East Bay, north of the ICW, east of Frozen Pt. and NW of Mussel Pt., surrounded by marshy area	29° 32.197	94° 30.35	med. brown over gray	silty clay	none	none	3	yes	
13	49	1	7/31/96	10:55	East Bay, SE of Lake Surprise, NW of Big Pasture Bayou by 2.5 miles	29° 31.645	94° 38.591	brown over gray	silt	none	none	6	yes	
14	50	1	7/30/96	9:35	Industrial area in Gal Bay, west of Pelican Island, north of mouth of Gal Channel,NW of Bascule Bridge along the beach	29° 18.97	94° 49.489	med brown over gray	silty clay	none	diatom scum, shrimp	8	no	
14	51	1	7/30/96	10:34	Industrial area north of ICW, south of Texas City Channel, west of spoil area/marsh	29° 20.802	94° 50.681	lt brown w/rust over gray	clay	none	worms w/eel	8	no	
14	52	1	7/30/96	11:30	Industrial, north of bridge separating lower Gal Bay and East of ICW	29° 18.228	94° 52.763	gray	clay w/shell hash	none	worms	7.5	no	
15	53	1	7/30/96	4:55	West Bay, south of Carancahua Pt	29° 13.101	95° 1.508	lt. brown over lt. gray	sandy clay with shell hash	none	gastropods, lots of echinoderms, worms	3	yes	
15	54	1	7/30/96	5:55	West Bay, 2 mi ESE of Greens Lake	29° 15.703	94° 57.957	lt. brown over dk gray(almost black)	silt over clay, with lots of shell hash	none	worm tubes	5.5	yes	
15	55	1	7/30/96	2:30	north of San Luis Pass, South of ICW, west end of West Bay	29° 7.907	95° 7.848	rusty brown over gray	silty-clay, some very fine sand, some shell hash	none	diatom scum	6	yes	
15	56	1	7/30/96	3:50	West Bay, south of Cow Bayou, R 2 marker	29° 11.301	95° 4.303	thick lt. brown over gray	sandy silt over sandy clay with lt. shell hash	none	polychaetes	4	yes	
15	57	1	7/30/96	6:39	West Bay, SE of mouth of Basford Bayou SW of Tiki Is.	29° 17.494	94° 56.73	thin lt. brown layer over gray	silt over silty clay	none	none visible	2.5	yes	
16	58	1	8/12/96	12:26	Southern edge of Bolivar Roads channel where it turns to the NE to enter Galveston Bay, ENE of Galveston Coast Guard Bay appr 0.5mi	29° 20.503	94° 45.976	brown over gray, 3rd - brown sand	sand with silt over sandy clay, 3rd grab was sand	none	none	65	yes	FERREL
16	59	1	8/14/96	5:20	Bolivar Roads-100m east of outer bar channel rear range marker, .5 mi south of Bolivar penninsula light house	29° 21.381	94° 46.37	brown over light gray over dark gray	sand w/lots of shell hash, large shells over sand over clay	none	none	8	yes	transducer not working-estimated depth
16	60	1	8/15/96	10:12	Bolivar Roads-west end of anchorage area, north of Inner Bar channel	29° 20.991	94° 33.242	lt. brown over gray	sand w/shell hash, 2 distinct layer sand over clay	sulfur	worm tubes, gastropods	40	yes	FERREL

Appendix B. Galveston Bay field logs (continued).

STRATA	SITE NUMBER	ALTER-NATE	DATE (mm/dd/yy)	TIME (local)	SITE LOCATION	Latitude (N)	Longitude (W)	SEDIMENT COLOR	SEDIMENT TEXTURE	ODOR/ SHEENS	BENTHIC ORGANISMS	DEPTH(FT)	CTD	OTHER COMMENTS
17	61	1	8/12/96	9:21	Located in a discontinued dumping ground according to the chart, appr. 1.75 miles ESE from the north jetty and marker	29° 20.139	94° 39.193	brown over gray	clay	none	worm tubes, blue crab-juv	30.5	yes	FERREL
17	62	1	8/15/96	9:13	Entrance to Galveston Bay-South of Outer Bar Channel, appr 200m south of G "7" marker of channel	29° 20.079	94° 41.764	lt. gray, spots of black clay	shell hash, rocks, coral, clay	none	crabs, shrimp, worm tubes, hermit crabs	39	yes	FERREL
17	63	1	8/14/96	4:30	Entrance to Galveston Bay-20m off north jetty, 300m north of yellow buoy "A"(YA), 200 m east of Galveston Bay entrance channel range A front	29° 21.224	94° 42.839	brown over gray over black	silt surface over clay w/shell hash	sulfur	annelids	25	yes	transducer not working-estimated depth, moved appr 100' closer to south jetty because the water deeper than the wire length on the winch, despite the chart indicating that it was a spoil area
18	64	1	8/14/96	1:40	Offshore shallow-1.5 miles south of south jetty, .5mi east of Galveston Island shore(last hotel building)	29° 18.941	94° 44.121	lt. brown, 4th-brown over gray	sand w/shell hash	none	gastropods, one shrimp	15	yes	transducer not working-estimated depth
18	65	1	8/13/96	12:54	Offshore shallow - appr 1mi from shore, south of jetty	29° 18.829	94° 43.385	brown	sand with shell hash	none	none	20	yes	FERREL
18	66	1	8/13/96	12:15	Offshore shallow - appr. 1 mi offshore, appr. 2mi SW of south jetty marker	29° 18.488	94° 43.401	brown	sand	none	shrimp,worm tubes, annelids, gastropod	22	yes	FERREL
19	67	1	8/14/96	9:20	Offshore shallow - 300 m east of Bolivar penninsula, 300m north of charted wreck	29° 24.951	94° 41.186	light brown over gray	silty sand layer(1 cm) over clay	none	none	8	yes	transducer not working-estimated depth
19	68	1	8/14/96	10:20	Offshore shallow - 200 m east of Bolivar penninsula	29° 23.875	94° 42.599	light brown, 3rd-1in. lt brown over gray	fine sand, shell hash, 3rd-fine sand over sand with clay	none	crustaceans, hermit crabs(lots)	5	yes	transducer not working-estimated depth
19	69	1	8/14/96	11:20	Offshore shallow- 1mi east of Bolivar penninsula shore @ radio tower appr .25mi south of charted wreck above surface	29° 23.229	94° 42.594	brown over gray	silty fine sand surface over silty/clay sand	none	none	8	yes	transducer not working-estimated depth
20	70	1	8/13/96	11:16	offshore deep - SSW of south jetty marker, appr 2mi	29° 17.472	94° 42.978	lt. brown	sand w/shell hash	none	worm tube	26	yes	FERREL
20	71	1	8/13/96	9:29	Offshore deep-appr. 2 mi due south of south jetty end marker	29° 18.215	94° 41.642	lt. brown over gray	sandy silty clay w/shell hash, 3rd - sandier, 5th - sand no clay, 6th-very silty	none	worm tubes	30	yes	FERREL
20	72	1	8/13/96	10:29	offshore deep- south of jetties, south of East Beach appr. 2mi	29° 18.07	94° 42.685	brown over lt. gray	sand w/shell hash	none	gastropods, worms, a shrimp, worm tubes	24	yes	FERREL
21	73	1	8/12/96	11:11	Just ENE of north jetty marker	29° 20.912	94° 40.687	gray with brown, no distinct layers	silt over clay with sand deposits, shells	none	none	40	yes	FERREL
21	74	1	8/12/96	10:01	NE of jetty marker by appr. 1.75 miles, SE by appr. 0.5 miles of marker near ship wrecks	29° 21.425	94° 38.831	brown over gray, no distinct layers	silt, silty clay	none	none	31.5	yes	FERREL
21	75	1	8/12/96	10:33	just SE of marker near ship wrecks, north of jettys	29° 21.643	94° 39.138	brown over gray layers	silt over clay	none	worm tubes	39	yes	FERREL

Appendix C
Sediment Trace and Major Elements

Appendix C. Sediment trace and major element concentrations.

Stratum Number	Site Number	Ag	Al	As	Cd	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Sb	Se	Sn	Tl	Zn
1	1	0.06	12,522	0.2(J)	0.04	12	3.7	5,164	0.031	114	3.7	8.0	0.25	0.07	0.5	0.12	20
1	2	0.18	45,619	4.5	0.14	45	14.3	19,974	0.108	217	14.4	20.3	1.10	0.35	1.5	0.21	73
1	3	0.19	68,178	9.6	0.18	65	21.2	33,811	0.151	2483	23.1	30.1	1.48	0.56	2.5	-0.07(ND)	131
2	4	0.09	10,686	0.4	0.02	11	3.7	4,242	0.023	81	3.3	7.9	0.39	0.10	0.4	0.18	15
2	5	0.12	30,692	3.5	0.06	30	8.1	12,557	0.057	211	9.9	23.4	1.02	0.17	1.0	0.25	41
2	6	0.52	87,136	7.5	0.19	84	23.1	42,030	0.174	813	28.9	37.7	1.97	0.63	3.3	0.61	168
3	7	0.13	37,936	3.6	0.13	34	11.6	15,145	0.076	219	12.5	19.1	1.04	0.29	1.0	0.38	62
3	8	0.20	58,714	6.3	0.19	53	17.2	25,739	0.094	438	20.0	25.8	1.33	0.42	2.0	0.39	108
3	9	0.18	73,387	6.5	0.19	60	21.8	33,108	0.121	535	23.6	28.0	1.50	0.43	2.3	0.58	122
4	10	0.09	28,948	3.8	0.06	22	6.9	10,649	0.037	174	9.1	12.1	0.64	0.15	0.8	0.31	37
4	11	0.09	38,659	3.8	0.07	30	8.4	15,079	0.042	276	10.9	14.5	0.65	0.22	1.0	0.33	50
4	12	0.07	7,335	1.2	0.01	3	1.6	1,530	-0.003(ND)	31	1.1	6.0	0.33	0.04	0.2	0.02 (J)	9
5	13	0.16	72,244	7.0	0.17	62	18.2	34,872	0.074	426	22.1	23.3	1.27	0.33	2.0	0.58	104
5	14	0.16	78,669	7.9	0.18	63	17.5	33,503	0.090	556	24.2	24.8	1.30	0.34	2.2	0.61	109
5	15	0.13	52,912	5.0	0.11	44	11.2	20,280	0.033	197	16.4	16.7	1.15	0.20	1.6	0.41	64
6	16	0.12	86,908	11.3	0.15	72	17.0	37,142	0.078	942	26.8	26.1	1.01	0.39	2.4	0.64	106
6	17	0.12	82,092	12.2	0.13	63	15.4	35,358	0.061	1,166	24.5	24.4	0.91	0.39	2.2	0.51	101
6	18	0.12	60,437	7.6	0.11	48	11.7	25,811	0.056	504	19.5	20.2	0.82	0.29	1.7	0.48	77
7	19	0.12	72,156	8.6	0.13	60	15.4	29,975	0.068	339	21.2	23.7	1.54	0.43	2.3	0.52	99
7	20	0.10	45,525	6.2	0.09	37	8.4	18,095	0.044	255	11.6	16.4	0.85	0.24	1.2	0.35	57
7	21	0.12	69,495	8.7	0.14	56	7.1	29,817	0.076	402	19.4	22.5	1.26	0.39	2.0	0.47	96
8A	22	0.13	41,825	5.5	0.11	36	22.7	16,398	0.033	190	14.6	14.8	0.77	0.25	1.0	0.36	62
8A	23	0.22	59,890	8.3	0.21	53	33.2	28,157	0.066	420	20.6	21.2	0.88	0.34	1.8	0.49	102
8A	24	0.13	50,919	6.7	0.14	43	27.6	21,948	0.047	309	16.3	17.7	0.95	0.30	1.4	0.35	81
8	25	0.14	71,352	9.7	0.16	64	17.2	33,721	0.074	403	24.8	25.3	1.05	0.44	2.2	0.56	107
8	26	0.11	55,413	12.3	0.13	48	14.4	27,394	0.063	330	17.1	19.7	0.90	0.36	1.6	0.49	84
8	27	0.09	36,488	7.2	0.08	37	8.5	16,919	0.047	225	11.7	15.7	0.87	0.20	1.0	0.47	53
8	28	0.12	51,702	13.4	0.13	47	13.8	25,463	0.063	303	17.3	19.1	1.09	0.36	1.5	0.46	78
9	29	0.12	64,695	8.5	0.09	52	11.5	27,547	0.052	747	22.1	18.6	0.95	0.27	1.5	0.50	79
9	30	0.13	67,660	8.5	0.12	57	12.3	31,160	0.056	488	19.3	21.4	1.03	0.30	1.8	0.54	81
9	31	0.11	60,113	7.0	0.10	47	14.0	25,155	0.051	364	17.4	19.3	0.83	0.28	1.7	0.45	72
9	32	0.14	79,680	9.3	0.14	58	13.8	35,934	0.061	391	26.2	22.0	0.94	0.35	1.8	0.62	101
10	33	0.09	30,120	1.0	0.03	24	4.0	11,310	0.024	217	7.4	10.6	0.27	0.08	0.5	0.42	40
10	34	0.13	80,679	9.6	0.09	67	17.3	38,974	0.061	807	28.3	23.4	0.90	0.36	1.9	0.72	105
10	35	0.10	40,779	6.0	0.06	34	7.9	17,038	0.019	167	13.5	12.9	0.50	0.14	0.9	0.40	46
10	36	0.12	54,049	3.6	0.07	64	10.6	24,647	0.043	406	18.0	16.3	0.62	0.19	1.1	0.58	70
10	37	0.08	16,861	0.3	0.02	18	3.9	6,065	-0.005(ND)	130	4.8	7.6	0.26	0.08	0.4	0.25	19

ND (not detected); J (below method detection limit)

Appendix C. Sediment trace and major element concentrations (continued).

Stratum Number	Site Number	Ag	Al	As	Cd	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Sb	Se	Sn	Tl	Zn
11	38	0.14	53,627	0.6	0.16	47	10.9	23,289	0.047	230	18.4	17.5	0.87	0.25	1.1	0.52	65
11	39	0.13	77,086	9.8	0.12	64	15.2	37,707	0.052	748	25.9	23.4	1.05	0.37	2.0	0.74	103
11	40	0.14	67,529	10.9	0.18	56	14.0	32,144	0.059	349	23.0	21.7	1.18	0.39	1.6	0.68	85
11	41	0.14	55,793	4.4	0.12	46	11.2	24,332	0.041	226	19.4	17.3	0.89	0.31	1.5	0.60	68
12	42	0.15	64,852	1.0	0.16	52	13.2	28,915	0.052	479	21.8	20.2	1.20	0.33	1.5	0.70	75
12	43	0.13	50,215	-0.2(ND)	0.09	43	9.9	21,329	0.047	262	15.5	14.7	0.90	0.23	1.2	0.48	60
12	44	0.13	40,258	-0.2(ND)	0.07	39	8.4	15,790	0.036	264	12.0	13.0	0.84	0.23	0.8	0.51	44
13	45	0.08	43,828	4.7	0.05	39	6.6	18,476	0.024	222	13.0	14.5	0.60	0.15	0.8	0.47	52
13	46	0.08	40,598	4.5	0.05	33	5.4	16,624	0.019	361	11.0	12.5	0.46	0.12	0.8	0.43	46
13	47	0.09	48,053	7.4	0.07	48	8.2	20,914	0.038	245	15.1	14.8	0.71	0.19	0.9	0.43	54
13	48	0.09	49,514	6.3	0.09	46	8.2	22,471	0.028	208	14.4	19.0	0.61	0.20	1.3	0.56	72
13	49	0.15	60,220	8.0	0.08	48	8.9	26,893	0.043	354	19.8	18.5	0.67	0.22	1.2	0.74	73
14	50	0.11	60,315	7.6	0.08	54	13.3	28,770	0.055	461	22.6	19.3	0.59	0.24	2.0	0.79	83
14	51	0.10	38,793	3.9	0.04	30	7.0	17,414	0.033	203	12.1	14.2	0.50	0.15	1.3	0.26	59
14	52	0.13	51,116	5.3	0.06	51	14.8	25,273	0.038	308	18.3	19.7	0.76	0.17	3.3	0.57	69
15	53	0.09	28,571	2.4	0.02	28	5.6	10,889	0.021	223	7.7	12.3	0.56	0.08	1.1	0.57	31
15	54	0.10	32,990	3.1	0.03	34	7.4	14,373	0.024	214	11.6	15.2	0.49	0.14	1.6	0.42	45
15	55	0.07	34,931	3.5	0.03	31	6.1	16,348	0.024	304	12.2	13.4	0.57	0.11	1.7	0.40	50
15	56	0.05	11,728	0.4	0.02	4	2.4	2,197	0.000(ND)	41	2.6	5.7	0.26	0.06	0.2	0.35	7
15	57	0.22	46,586	5.3	0.05	48	11.9	22,369	0.038	432	15.3	21.7	0.69	0.13	3.0	0.49	63
16	58	0.08	35,642	7.2	0.04	31	6.5	15,566	0.023	469	11.8	10.7	0.36	0.14	0.8	0.23	50
16	59	0.08	24,058	3.2	0.02	10	3.1	8,460	0.014	299	7.7	7.9	0.45	0.06	0.4	0.18	30
16	60	0.10	44,920	6.6	0.05	38	6.1	20,343	0.032	539	16.8	14.5	0.63	0.17	1.3	0.43	65
17	61	0.10	47,777	7.5	0.06	44	10.8	25,083	0.037	661	0.0(ND)	16.5	0.71	0.22	1.2	0.44	72
17	62	0.08	36,527	6.8	0.04	29	7.0	16,742	0.028	438	13.0	11.1	0.51	0.12	0.7	0.26	45
17	63	0.10	53,376	7.9	0.06	38	9.7	23,662	0.037	587	16.1	16.3	0.64	0.23	1.1	0.36	70
18	64	0.07	17,204	2.5	0.01	9	2.2	5,200	0.013	229	3.3	7.4	0.40	0.01(J)	0.2	0.17	21
18	65	0.06	16,061	2.3	0.01	7	1.8	4,654	0.004(J)	223	4.8	6.2	0.17	0.01(J)	0.2	0.10	20
18	66	0.07	14,378	2.7	0.01	9	1.8	4,518	-0.006(ND)	238	2.8	6.8	0.30	0.03	0.3	0.08	19
19	67	0.09	37,792	5.9	0.05	32	5.6	14,309	0.033	467	9.8	13.3	0.61	0.11	0.9	0.35	43
19	68	0.07	24,848	4.3	0.01	22	3.1	8,741	0.013	377	5.1	9.3	0.38	0.02(J)	0.6	0.16	26
19	69	0.12	61,571	10.8	0.07	45	10.8	27,150	0.061	710	17.0	17.8	0.75	0.21	1.3	0.42	74
20	70	0.05	15,790	2.5	0.01	9	2.0	5,136	-0.006(ND)	271	4.1	7.0	0.21	0.03	0.3	0.08	21
20	71	0.08	25,241	5.8	0.03	23	4.5	10,962	0.018	366	8.2	9.0	0.49	0.07	0.6	0.25	37
20	72	0.04	12,845	2.8	0.01	5	1.9	4,308	0.009	230	2.7	5.8	0.32	0.02(J)	0.3	0.10	18
21	73	0.09	66,993	12.0	0.09	68	15.4	36,172	0.051	1008	26.1	21.0	1.05	0.34	1.9	0.59	102
21	74	0.12	64,585	10.2	0.09	58	13.2	33,517	0.049	876	24.6	18.4	0.94	0.28	1.7	0.55	93
21	75	0.11	65,468	10.8	0.08	57	13.5	33,458	0.052	832	20.7	19.9	0.99	0.31	1.7	0.50	97

ND (not detected); J (below method detection limit)

Appendix D
Sediment Pesticides

Appendix D. Sediment pesticide concentrations.

Stratum Number	Site Number	Total HCH	Alpha HCH	Beta HCH	Gamma HCH	Delta HCH	Total Chlordane	Heptachlor	Heptachlor Epoxide	Oxychlor-dane	Gamma Chlordane	Alpha-Chlordane	Trans-Nonachlor	Cis-Nonachlor
1	1	0.09	0.02 (J)	0.04 (J)	0.02 (J)	0.01 (J)	0.69	0.00 (ND)	0.54	0.00 (ND)	0.04 (J)	0.04 (J)	0.04 (J)	0.03 (J)
1	2	0.66	0.13 (J)	0.36	0.00 (ND)	0.17	5.81	0.00 (ND)	3.96	0.00 (ND)	0.97	0.37	0.29	0.22
1	3	1.08	0.34 (J)	0.46 (J)	0.16 (J)	0.12	12.20	0.00 (ND)	10.40	0.00 (ND)	0.55	0.45	0.39	0.41
2	4	0.09	0.00 (ND)	0.07 (J)	0.01 (J)	0.01 (J)	0.43	0.00 (ND)	0.29	0.00 (ND)	0.04 (J)	0.03 (J)	0.03 (J)	0.04 (J)
2	5	0.29	0.04 (J)	0.16 (J)	0.00 (ND)	0.08	0.46	0.00 (ND)	0.00 (ND)	0.02 (J)	0.15 (J)	0.11	0.12 (J)	0.06
2	6	0.70	0.08 (J)	0.41 (J)	0.16 (J)	0.05 (J)	4.06	0.00 (ND)	2.74	0.00 (ND)	0.44	0.32	0.26 (J)	0.29
3	7	0.31	0.13 (J)	0.18 (J)	0.00 (ND)	0.00 (ND)	0.68	0.00 (ND)	0.00 (ND)	0.04 (J)	0.30	0.11 (J)	0.15 (J)	0.08
3	8	0.94	0.26 (J)	0.50	0.10 (J)	0.08 (J)	0.88	0.00 (ND)	0.00 (ND)	0.10 (J)	0.32 (J)	0.22	0.11 (J)	0.13
3	9	0.39	0.11 (J)	0.25 (J)	0.00 (ND)	0.04 (J)	1.10	0.00 (ND)	0.00 (ND)	0.44	0.25 (J)	0.15 (J)	0.17 (J)	0.09 (J)
4	10	0.22	0.04 (J)	0.12 (J)	0.02 (J)	0.03 (J)	0.17	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.03 (J)	0.02 (J)	0.10 (J)	0.02 (J)
4	11	0.12	0.04 (J)	0.08 (J)	0.00 (ND)	0.00 (ND)	0.08	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.03 (J)	0.03 (J)	0.01 (J)	0.01 (J)
4	12	0.05	0.00 (ND)	0.05 (J)	0.00 (J)	0.00 (ND)	0.00	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)
5	13	0.25	0.08 (J)	0.15 (J)	0.00 (ND)	0.02 (J)	0.39	0.00 (ND)	0.00 (ND)	0.02 (J)	0.14 (J)	0.10 (J)	0.07 (J)	0.06 (J)
5	14	0.26	0.00 (ND)	0.21 (J)	0.00 (ND)	0.05 (J)	0.39	0.00 (ND)	0.00 (ND)	0.04 (J)	0.14 (J)	0.10 (J)	0.05 (J)	0.07 (J)
5	15	0.14	0.00 (ND)	0.14 (J)	0.00 (ND)	0.00 (ND)	0.39	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.15 (J)	0.10 (J)	0.07 (J)	0.06
6	16	0.70	0.00 (ND)	0.57	0.14 (J)	0.00 (ND)	0.09	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.02 (J)	0.03 (J)	0.04 (J)
6	17	0.54	0.00 (ND)	0.39 (J)	0.09 (J)	0.07 (J)	0.07	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.03 (J)	0.04 (J)
6	18	0.18	0.04 (J)	0.14 (J)	0.00 (ND)	0.00 (ND)	0.17	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.10 (J)	0.05 (J)	0.00 (ND)	0.02 (J)
7	19	0.50	0.18 (J)	0.32 (J)	0.00 (ND)	0.00 (ND)	0.82	0.00 (ND)	0.50	0.00 (ND)	0.11 (J)	0.08 (J)	0.07 (J)	0.06 (J)
7	20	0.51	0.06 (J)	0.42	0.02 (J)	0.00 (ND)	0.25	0.00 (ND)	0.00 (ND)	0.03 (J)	0.08 (J)	0.06 (J)	0.04 (J)	0.04 (J)
7	21	0.77	0.05 (J)	0.67	0.00 (ND)	0.05 (J)	0.35	0.00 (ND)	0.00 (ND)	0.02 (J)	0.12 (J)	0.09 (J)	0.06 (J)	0.06 (J)
8A	22	0.73	0.00 (ND)	0.63	0.04 (J)	0.06 (J)	0.36	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.06 (J)	0.12 (J)	0.10 (J)	0.07
8A	23	0.54	0.00 (ND)	0.47	0.00 (ND)	0.07 (J)	0.51	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.08 (J)	0.17	0.14 (J)	0.12
8A	24	0.67	0.00 (ND)	0.62	0.00 (ND)	0.05 (J)	0.32	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.04 (J)	0.11 (J)	0.10 (J)	0.07
8	25	0.89	0.00 (ND)	0.84	0.00 (ND)	0.05 (J)	0.09	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.04 (J)	0.05 (J)
8	26	0.53	0.00 (ND)	0.48	0.00 (ND)	0.05 (J)	0.02	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.02 (J)	0.00 (ND)
8	27	0.51	0.00 (ND)	0.48	0.00 (ND)	0.03 (J)	0.17	0.00 (ND)	0.00 (ND)	0.02 (J)	0.06 (J)	0.03 (J)	0.03 (J)	0.03 (J)
8	28	0.52	0.00 (ND)	0.48	0.00 (ND)	0.04 (J)	0.05	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.02 (J)	0.02 (J)
9	29	0.15	0.01 (J)	0.09 (J)	0.02 (J)	0.02 (J)	0.02	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.01 (J)	0.02 (J)
9	30	0.15	0.00 (ND)	0.13 (J)	0.00 (ND)	0.02 (J)	0.03	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.03 (J)	0.00 (ND)	0.00 (ND)
9	31	0.19	0.00 (ND)	0.12 (J)	0.00 (ND)	0.07 (J)	0.07	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.03 (J)	0.04 (J)	0.00 (ND)
9	32	0.26	0.00 (ND)	0.26 (J)	0.00 (ND)	0.00 (ND)	0.28	0.00 (ND)	0.00 (ND)	0.11 (J)	0.00 (ND)	0.17 (J)	0.00 (ND)	0.00 (ND)
10	33	0.04	0.02 (J)	0.01 (J)	0.02 (J)	0.00 (ND)	0.08	0.00 (ND)	0.07	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.02 (J)
10	34	0.30	0.12 (J)	0.13 (J)	0.06 (J)	0.00 (ND)	0.23	0.00 (ND)	0.07 (J)	0.00 (ND)	0.13 (J)	0.03 (J)	0.00 (ND)	0.00 (ND)
10	35	0.10	0.00 (ND)	0.07 (J)	0.03 (J)	0.00 (ND)	0.18	0.00 (ND)	0.05 (J)	0.00 (ND)	0.08 (J)	0.04 (J)	0.00 (ND)	0.00 (ND)
10	36	0.28	0.05 (J)	0.14 (J)	0.07 (J)	0.02 (J)	0.10	0.00 (ND)	0.07	0.00 (ND)	0.00 (ND)	0.03 (J)	0.00 (ND)	0.01 (J)
10	37	0.07	0.02 (J)	0.03 (J)	0.02 (J)	0.00 (ND)	0.01	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.01 (J)

ND (not detected); J (below method detection limit); EC (estimated concentration)

Appendix D. Sediment pesticide concentrations (continued).

Stratum Number	Site Number	Total HCH	Alpha HCH	Beta HCH	Gamma HCH	Delta HCH	Total Chlordane	Heptachlor	Heptachlor Epoxide	Oxychlor-dane	Gamma Chlordane	Alpha-Chlordane	Trans-Nonachlor	Cis-Nonachlor
11	38	0.08	0.00 (ND)	0.03 (J)	0.05 (J)	0.00 (ND)	0.19	0.00 (ND)	0.09	0.00 (ND)	0.00 (ND)	0.05 (J)	0.00 (ND)	0.05 (J)
11	39	0.53	0.07 (J)	0.30 (J)	0.17 (J)	0.00 (ND)	0.23	0.00 (ND)	0.15	0.00 (ND)	0.00 (ND)	0.05 (J)	0.00 (ND)	0.02 (J)
11	40	0.43	0.00 (ND)	0.23 (J)	0.18 (J)	0.02 (J)	0.21	0.00 (ND)	0.14	0.00 (ND)	0.00 (ND)	0.06 (J)	0.00 (ND)	0.02 (J)
11	41	0.14	0.04 (J)	0.05 (J)	0.04 (J)	0.01 (J)	0.22	0.00 (ND)	0.10	0.04 (J)	0.00 (ND)	0.05 (J)	0.00 (ND)	0.02 (J)
12	42	0.09	0.05 (J)	0.01 (J)	0.03 (J)	0.00 (ND)	0.11	0.00 (ND)	0.06 (J)	0.00 (ND)	0.00 (ND)	0.03 (J)	0.00 (ND)	0.02 (J)
12	43	0.10	0.04 (J)	0.02 (J)	0.03 (J)	0.01 (J)	0.11	0.00 (ND)	0.08	0.00 (ND)	0.00 (ND)	0.01 (J)	0.00 (ND)	0.02 (J)
12	44	0.09	0.02 (J)	0.03 (J)	0.03 (J)	0.01 (J)	0.20	0.00 (ND)	0.07	0.00 (ND)	0.00 (ND)	0.02 (J)	0.09 (J)	0.01 (J)
13	45	0.24	0.09 (J)	0.10 (J)	0.04 (J)	0.01 (J)	0.12	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.10 (J)	0.02 (J)	0.00 (ND)	0.00 (ND)
13	46	0.11	0.00 (ND)	0.06 (J)	0.05 (J)	0.00 (ND)	0.12	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.12 (J)	0.00 (ND)	0.00 (ND)	0.00 (ND)
13	47	0.15	0.07 (J)	0.05 (J)	0.02 (J)	0.00 (ND)	0.10	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.10 (J)	0.00 (ND)	0.00 (ND)	0.00 (ND)
13	48	0.26	0.11 (J)	0.09 (J)	0.04 (J)	0.02 (J)	0.16	0.00 (ND)	0.04 (J)	0.00 (ND)	0.11 (J)	0.00 (ND)	0.00 (ND)	0.00 (ND)
13	49	0.22	0.10 (J)	0.05 (J)	0.05 (J)	0.01 (J)	0.19	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.15 (J)	0.04 (J)	0.00 (ND)	0.00 (ND)
14	50	0.28	0.15 (J)	0.07 (J)	0.06 (J)	0.00 (ND)	0.13	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.08 (J)	0.04 (J)	0.00 (ND)	0.00 (ND)
14	51	0.13	0.06 (J)	0.05 (J)	0.02 (J)	0.00 (ND)	0.11	0.00 (ND)	0.03 (J)	0.00 (ND)	0.08 (J)	0.00 (ND)	0.00 (ND)	0.00 (ND)
14	52	0.17	0.07 (J)	0.07 (J)	0.02 (J)	0.00 (ND)	0.16	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.16 (J)	0.00 (ND)	0.00 (ND)	0.00 (ND)
15	53	0.12	0.05 (J)	0.03 (J)	0.04 (J)	0.00 (ND)	0.07	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.07 (J)	0.00 (ND)	0.00 (ND)	0.00 (ND)
15	54	0.09	0.06 (J)	0.00 (ND)	0.03 (J)	0.00 (ND)	0.07	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.07 (J)	0.00 (ND)	0.00 (ND)	0.00 (ND)
15	55	0.06	0.00 (ND)	0.04 (J)	0.03 (J)	0.00 (ND)	0.13	0.00 (ND)	0.04 (J)	0.00 (ND)	0.09 (J)	0.00 (ND)	0.00 (ND)	0.00 (ND)
15	56	0.14	0.00 (ND)	0.08 (J)	0.06 (J)	0.00 (ND)	0.06	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.06 (J)	0.00 (ND)	0.00 (ND)	0.00 (ND)
15	57	0.26	0.13 (J)	0.10 (J)	0.04 (J)	0.00 (ND)	0.12	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.12 (J)	0.00 (ND)	0.00 (ND)	0.00 (ND)
16	58	0.20	0.00 (ND)	0.20 (J)	0.00 (ND)	0.00 (ND)	0.00	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)
16	59	0.03	0.00 (ND)	0.03 (J)	0.00 (ND)	0.00 (ND)	0.00	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)
16	60	0.10	0.00 (ND)	0.10 (J)	0.00 (ND)	0.00 (ND)	0.00	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)
17	61	0.42	0.00 (ND)	0.38	0.00 (ND)	0.04 (J)	0.05	0.00 (ND)	0.01 (J)	0.00 (ND)	0.00 (ND)	0.04 (J)	0.00 (ND)	0.00 (ND)
17	62	0.02	0.00 (ND)	0.02 (J)	0.00 (ND)	0.00 (ND)	0.00	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)
17	63	0.15	0.00 (ND)	0.15 (J)	0.00 (ND)	0.00 (ND)	0.00	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)
18	64	0.07	0.00 (ND)	0.07 (J)	0.00 (ND)	0.00 (ND)	0.00	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)
18	65	0.00	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)
18	66	0.03	0.00 (ND)	0.03 (J)	0.00 (ND)	0.00 (ND)	0.00	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)
19	67	0.07	0.00 (ND)	0.07 (J)	0.00 (ND)	0.00 (ND)	0.00	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)
19	68	0.05	0.00 (ND)	0.05 (J)	0.00 (ND)	0.00 (ND)	0.00	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)
19	69	0.13	0.00 (ND)	0.13 (J)	0.00 (ND)	0.00 (ND)	0.00	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)
20	70	0.00	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)
20	71	0.04	0.00 (ND)	0.04 (J)	0.00 (ND)	0.00 (ND)	0.00	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)
20	72	0.03	0.00 (ND)	0.03 (J)	0.00 (ND)	0.00 (ND)	0.00	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)
21	73	1.11	0.00 (ND)	1.04	0.00 (ND)	0.06 (J)	0.00	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)
21	74	0.72	0.00 (ND)	0.60 (J)	0.06 (J)	0.05 (J)	0.04	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.04 (J)	0.00 (ND)	0.00 (ND)
21	75	0.13	0.00 (ND)	0.13 (J)	0.00 (ND)	0.00 (ND)	0.00	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)

ND (not detected); J (below method detection limit); EC (estimated concentration)

Appendix D. Sediment pesticide concentrations (continued).

Stratum Number	Site Number	Total DDT	2,4' DDE	4,4' DDE	2,4' DDD	4,4' DDD	2,4' DDT	4,4' DDT	Hexachloro-benzene	Aldrin	Dieldrin	Endrin	Mirex	Endosulfan II
1	1	0.46	0.04 (J)	0.10	0.10 (J)	0.19	0.00 (ND)	0.03 (J)	0.61	0.00 (ND)	0.04 (J)	0.00 (ND)	0.01 (J)	0.00 (ND)
1	2	50.75	0.18	0.91	2.66	40.32 (EC)	0.00 (ND)	6.68	3.86	0.25	0.40	0.00 (ND)	0.10 (J)	0.00 (ND)
1	3	6.08	0.21(J)	1.15	1.93	2.79	0.00 (ND)	0.00 (ND)	15.22	0.21(J)	0.63	0.00 (ND)	0.12 (J)	0.00 (ND)
2	4	0.43	0.02 (J)	0.07	0.10 (J)	0.17	0.00 (ND)	0.07 (J)	0.50	0.00 (ND)	0.04 (J)	0.00 (ND)	0.00 (ND)	0.02 (J)
2	5	1.14	0.00 (ND)	0.17	0.35	0.52	0.00 (ND)	0.09 (J)	1.11	0.03 (J)	0.12	0.00 (ND)	0.01 (J)	0.00 (ND)
2	6	3.94	0.09 (J)	0.68	0.88	1.50	0.00 (ND)	0.78	4.17	0.00 (ND)	0.38	0.00 (ND)	0.05 (J)	0.15(J)
3	7	1.67	0.00 (ND)	0.33	0.27 (J)	0.98	0.00 (ND)	0.09 (J)	1.75	0.17 (J)	0.10	0.00 (ND)	0.02 (J)	0.00 (ND)
3	8	451.54	0.05(J)	2.16	0.57	5.40	3.03	367.27 (D)	3.60	0.32	0.43	0.00 (ND)	0.03 (J)	0.00 (ND)
3	9	2.30	0.00 (ND)	0.34	0.51	1.03	0.00 (ND)	0.42	2.22	0.15 (J)	0.21	0.00 (ND)	0.02 (J)	0.00 (ND)
4	10	0.41	0.00 (ND)	0.08	0.10 (J)	0.23	0.00 (ND)	0.00 (ND)	0.46	0.04 (J)	0.00 (ND)	0.00 (ND)	0.01 (J)	0.00 (ND)
4	11	0.35	0.00 (ND)	0.07 (J)	0.08 (J)	0.20	0.00 (ND)	0.00 (ND)	0.37	0.03 (J)	0.02 (J)	0.00 (ND)	0.01 (J)	0.00 (ND)
4	12	0.01	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.01 (J)	0.00 (ND)	0.00 (ND)	0.01 (J)	0.02 (J)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)
5	13	1.28	0.00 (ND)	0.18	0.28 (J)	0.79	0.00 (ND)	0.03 (J)	5.84	0.10 (J)	0.11	0.00 (ND)	0.01 (J)	0.00 (ND)
5	14	8.75	0.00 (ND)	0.23	0.34 (J)	1.11	0.00 (ND)	7.07	2.87	0.12 (J)	0.11	0.00 (ND)	0.02 (J)	0.00 (ND)
5	15	2.60	0.00 (ND)	0.12	0.13 (J)	0.37	0.00 (ND)	1.98	4.71	0.05 (J)	0.05 (J)	0.00 (ND)	0.00 (ND)	0.00 (ND)
6	16	1.45	0.00 (ND)	0.26	0.14 (J)	0.44	0.55	0.08 (J)	0.91	0.00 (ND)	0.05 (J)	0.00 (ND)	0.00 (ND)	0.00 (ND)
6	17	4.01	0.00 (ND)	0.15 (J)	0.19 (J)	0.52	0.00 (ND)	3.25	0.71	0.05 (J)	0.00 (ND)	0.00 (ND)	0.01 (J)	0.05 (J)
6	18	3.71	0.00 (ND)	0.13 (J)	0.20 (J)	0.64	0.00 (ND)	2.74	0.89	0.15 (J)	0.00 (ND)	0.00 (ND)	0.02 (J)	0.00 (ND)
7	19	0.87	0.00 (ND)	0.19	0.21 (J)	0.48	0.00 (ND)	0.00 (ND)	1.14	0.00 (ND)	0.08 (J)	0.00 (ND)	0.01 (J)	0.00 (ND)
7	20	0.84	0.02 (J)	0.12	0.19 (J)	0.51	0.00 (ND)	0.00 (ND)	0.80	0.00 (ND)	0.04 (J)	0.00 (ND)	0.00 (ND)	0.06 (J)
7	21	0.76	0.00 (ND)	0.14	0.14 (J)	0.46	0.02 (J)	0.00 (ND)	1.24	0.00 (ND)	0.10	0.04 (J)	0.01 (J)	0.00 (ND)
8A	22	0.29	0.00 (ND)	0.11	0.06 (J)	0.12	0.00 (ND)	0.00 (ND)	0.11	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.04 (J)	0.00 (ND)
8A	23	0.44	0.00 (ND)	0.22	0.00 (ND)	0.17	0.05 (J)	0.00 (ND)	0.44	0.04 (J)	0.05 (J)	0.11 (J)	0.04 (J)	0.00 (ND)
8A	24	0.34	0.00 (ND)	0.11	0.08 (J)	0.15	0.00 (ND)	0.00 (ND)	0.33	0.00 (ND)	0.14	0.00 (ND)	0.00 (ND)	0.00 (ND)
8	25	0.51	0.00 (ND)	0.11 (J)	0.12 (J)	0.28	0.00 (ND)	0.00 (ND)	0.95	0.04 (J)	0.05 (J)	0.00 (ND)	0.02 (J)	0.02 (J)
8	26	0.11	0.00 (ND)	0.05 (J)	0.00 (ND)	0.07 (J)	0.00 (ND)	0.00 (ND)	0.51	0.02 (J)	0.02 (J)	0.00 (ND)	0.03 (J)	0.01 (J)
8	27	0.55	0.00 (ND)	0.08 (J)	0.10 (J)	0.32	0.00 (ND)	0.04 (J)	0.66	0.08 (J)	0.03 (J)	0.00 (ND)	0.03 (J)	0.01 (J)
8	28	0.63	0.00 (ND)	0.06 (J)	0.08 (J)	0.14	0.00 (ND)	0.35	0.63	0.13 (J)	0.02 (J)	0.00 (ND)	0.00 (ND)	0.01 (J)
9	29	0.17	0.00 (ND)	0.06 (J)	0.00 (ND)	0.11 (J)	0.00 (ND)	0.00 (ND)	0.15	0.04 (J)	0.01 (J)	0.00 (ND)	0.01 (J)	0.00 (ND)
9	30	0.27	0.00 (ND)	0.06 (J)	0.00 (ND)	0.22	0.00 (ND)	0.00 (ND)	0.63	0.05 (J)	0.00 (ND)	0.00 (ND)	0.02 (J)	0.00 (ND)
9	31	0.47	0.00 (ND)	0.09 (J)	0.09 (J)	0.23	0.00 (ND)	0.07 (J)	0.46	0.06 (J)	0.00 (ND)	0.00 (ND)	0.01 (J)	0.00 (ND)
9	32	0.42	0.00 (ND)	0.14 (J)	0.00 (ND)	0.28	0.00 (ND)	0.00 (ND)	0.42	0.35 (J)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)
10	33	0.57	0.11	0.01 (J)	0.43	0.02 (J)	0.00 (ND)	0.00 (ND)	0.01 (J)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.03 (J)
10	34	0.12	0.00 (ND)	0.07 (J)	0.00 (ND)	0.05 (J)	0.00 (ND)	0.00 (ND)	0.12 (J)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.03 (J)	0.11 (J)
10	35	0.03	0.00 (ND)	0.03 (J)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.06 (J)	0.00 (ND)	0.00 (ND)	0.16	0.01 (J)	0.07 (J)
10	36	0.24	0.04 (J)	0.03 (J)	0.13 (J)	0.02 (J)	0.00 (ND)	0.02 (J)	0.04 (J)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.03 (J)
10	37	0.06	0.00 (ND)	0.01 (J)	0.04 (J)	0.02 (J)	0.00 (ND)	0.00 (ND)	0.02 (J)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.01 (J)

ND (not detected); J (below method detection limit); EC (estimated concentration)

Appendix D. Sediment pesticide concentrations (continued).

Stratum Number	Site Number	Total DDT	2,4' DDE	4,4' DDE	2,4' DDD	4,4' DDD	2,4' DDT	4,4' DDT	Hexachloro-benzene	Aldrin	Dieldrin	Endrin	Mirex	Endosulfan II
11	38	0.29	0.00 (ND)	0.04 (J)	0.10 (J)	0.15	0.00 (ND)	0.00 (ND)	0.11 (J)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)
11	39	0.31	0.09 (J)	0.03 (J)	0.13 (J)	0.06 (J)	0.00 (ND)	0.00 (ND)	0.13 (J)	0.00 (ND)	0.06 (J)	0.00 (ND)	0.00 (ND)	0.04 (J)
11	40	1.59	0.15 (J)	0.06 (J)	1.34	0.05 (J)	0.00 (ND)	0.00 (ND)	0.10 (J)	0.06 (J)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.09 (J)
11	41	0.13	0.00 (ND)	0.04 (J)	0.00 (ND)	0.03 (J)	0.01 (J)	0.05 (J)	0.05 (J)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)
12	42	0.27	0.00 (ND)	0.09 (J)	0.10 (J)	0.05 (J)	0.00 (ND)	0.04 (J)	0.09 (J)	0.00 (ND)	0.01 (J)	0.00 (ND)	0.00 (ND)	0.04 (J)
12	43	0.09	0.00 (ND)	0.03 (J)	0.06 (J)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.12	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.05 (J)
12	44	0.27	0.00 (ND)	0.03 (J)	0.18 (J)	0.03 (J)	0.00 (ND)	0.03 (J)	0.22	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.03 (J)
13	45	0.00	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.01 (J)	0.00 (ND)	0.00 (ND)	0.20	0.00 (ND)	0.03 (J)
13	46	0.02	0.00 (ND)	0.02 (J)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.04 (J)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.01 (J)	0.07 (J)
13	47	0.01	0.00 (ND)	0.01 (J)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.02 (J)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.04 (J)
13	48	0.02	0.00 (ND)	0.02 (J)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.05 (J)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.04 (J)	0.08 (J)
13	49	0.00	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.02 (J)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.05 (J)
14	50	0.65	0.25	0.07 (J)	0.27 (J)	0.07 (J)	0.00 (ND)	0.00 (ND)	0.07 (J)	0.00 (ND)	0.29	0.00 (ND)	0.00 (ND)	0.11(J)
14	51	0.01	0.00 (ND)	0.01 (J)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.04 (J)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.07 (J)
14	52	0.13	0.06 (J)	0.03 (J)	0.00 (ND)	0.04 (J)	0.00 (ND)	0.00 (ND)	0.04 (J)	0.00 (ND)	0.20	0.00 (ND)	0.06 (J)	0.14
15	53	0.00	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.01 (J)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.04 (J)
15	54	0.00	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.02 (J)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.05 (J)
15	55	0.02	0.00 (ND)	0.02 (J)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.06 (J)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.07 (J)
15	56	0.00	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.03 (J)
15	57	0.00	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.03 (J)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.01 (J)	0.16
16	58	0.02	0.00 (ND)	0.02 (J)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.04 (J)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)
16	59	0.00	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.01 (J)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)
16	60	0.00	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.02 (J)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)
17	61	0.10	0.00 (ND)	0.05 (J)	0.00 (ND)	0.05 (J)	0.00 (ND)	0.00 (ND)	0.11 (J)	0.04 (J)	0.01 (J)	0.00 (ND)	0.00 (ND)	0.01 (J)
17	62	0.00	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (J)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)
17	63	0.04	0.00 (ND)	0.04 (J)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.01 (J)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)
18	64	0.00	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (J)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)
18	65	0.00	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (J)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)
18	66	0.00	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.01 (J)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.02 (J)
19	67	0.01	0.00 (ND)	0.01 (J)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.02 (J)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)
19	68	0.00	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.01 (J)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)
19	69	0.07	0.00 (ND)	0.07 (J)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.03 (J)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)
20	70	0.00	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (J)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)
20	71	0.00	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.03 (J)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)
20	72	0.00	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.02 (J)
21	73	0.08	0.00 (ND)	0.08 (J)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.31	0.00 (ND)	0.04 (J)	0.00 (ND)	0.02 (J)	0.00 (ND)
21	74	0.10	0.00 (ND)	0.06 (J)	0.00 (ND)	0.04 (J)	0.00 (ND)	0.00 (ND)	0.19	0.00 (ND)	0.04 (J)	0.00 (ND)	0.01 (J)	0.00 (J)
21	75	0.03	0.00 (ND)	0.03 (J)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.04 (J)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)

ND (not detected); J (below method detection limit); EC (estimated concentration)

Appendix E
Sediment PCBs

Appendix E. Sediment PCB concentrations.

Stratum Number	Site Number	Total PCB	PCB8/5	PCB18/17	PCB28	PCB52	PCB44	PCB66	PCB101/90	PCB118	PCB153/132	PCB105	PCB138/160	PCB187	PCB128	PCB180	PCB170/190	PCB 195/208	PCB206	PCB209
1	1	5.82	0.08 (J)	0.02 (J)	0.04 (J)	0.16 (J)	0.11	0.07	0.11 (J)	0.09	0.14	0.03 (J)	0.13	0.04 (J)	0.01 (J)	0.07	0.00 (ND)	0.00 (J)	0.07	0.49
1	2	27.16	0.36	0.60 (J)	0.35	0.92	0.61	0.48	0.89	0.91	1.09	0.18	0.83	0.40	0.13 (J)	0.47	0.00 (ND)	0.05 (J)	0.15	2.99
1	3	60.79	0.00 (ND)	0.53 (J)	0.46	2.78	1.14	1.02	1.51	1.51	2.03	0.55	1.69	0.90	0.23 (J)	1.01	0.00 (ND)	0.13 (J)	0.35	10.92
2	4	4.91	0.00 (ND)	0.01 (J)	0.03 (J)	0.17 (J)	0.08 (J)	0.00 (ND)	0.09 (J)	0.08	0.15	0.02 (J)	0.12	0.08	0.02 (J)	0.11	0.00 (ND)	0.01 (J)	0.03 (J)	0.27
2	5	11.20	0.00 (ND)	0.00 (ND)	0.31	0.48 (J)	0.15	0.13	0.21	0.19	0.08 (J)	0.11	0.29	0.11	0.05 (J)	0.12	0.91 (I)	0.02 (J)	0.05 (J)	0.91
2	6	25.45	0.00 (ND)	0.18 (J)	0.19 (J)	1.10 (J)	0.38	0.26	0.67	0.59	1.19	0.17	0.94	0.44	0.13 (J)	0.57	0.00 (ND)	0.12 (J)	0.27	3.42
3	7	18.25	0.00 (ND)	0.00 (ND)	0.10 (J)	0.59 (J)	0.25	0.26	0.42	0.32	0.60	0.06 (J)	0.42	0.24	0.00 (ND)	0.32	2.01 (I)	0.14 (J)	0.14	1.46
3	8	27.63	0.72	0.29 (J)	0.38	1.13	0.52	0.54	0.87	0.64	1.30	0.25	0.94	0.51	0.13 (J)	0.71	0.00 (ND)	0.23	0.21	2.23
3	9	29.40	0.84	0.03 (J)	0.62	0.86 (J)	0.63	0.53	0.58	0.46	0.92	0.10 (J)	0.56	0.42	0.13 (J)	0.57	3.00 (I)	0.16 (J)	0.18	1.82
4	10	6.75	0.00 (ND)	0.00 (ND)	0.05 (J)	0.19 (J)	0.03 (J)	0.10	0.09 (J)	0.09	0.16	0.02 (J)	0.11	0.04 (J)	0.00 (ND)	0.10	0.64 (I)	0.04 (J)	0.04 (J)	0.39
4	11	6.57	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.17 (J)	0.09 (J)	0.11 (J)	0.08 (J)	0.06 (J)	0.05 (J)	0.01 (J)	0.09 (J)	0.04 (J)	0.00 (ND)	0.06 (J)	0.87 (I)	0.04 (J)	0.04 (J)	0.29
4	12	3.05	0.06 (J)	0.00 (ND)	0.00 (ND)	0.04 (J)	0.06 (J)	0.06 (J)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.01 (J)	0.15 (J)	0.00 (ND)	0.00 (ND)	0.01 (J)
5	13	12.01	0.18 (J)	0.00 (ND)	0.07 (J)	0.54 (J)	0.12 (J)	0.24	0.34	0.28	0.43	0.07 (J)	0.30	0.10 (J)	0.04 (J)	0.20	0.00 (ND)	0.13 (J)	0.12	1.33
5	14	14.80	0.00 (ND)	0.00 (ND)	0.08 (J)	0.59 (J)	0.23	0.26	0.59	0.50	0.68	0.10 (J)	0.53	0.12 (J)	0.00 (ND)	0.23	0.00 (ND)	0.11 (J)	0.11	1.61
5	15	11.04	0.00 (ND)	0.00 (ND)	0.06 (J)	0.33 (J)	0.08 (J)	0.15	0.26	0.22	0.35	0.05 (J)	0.25	0.06 (J)	0.05 (J)	0.13	1.39 (I)	0.08 (J)	0.08	0.50
6	16	11.36	0.32	0.00 (ND)	0.23	0.29 (J)	0.23 (J)	0.00 (ND)	0.17 (J)	0.21	0.42	0.00 (ND)	0.26	0.07 (J)	0.02 (J)	0.20	0.63 (I)	0.05 (J)	0.10 (J)	0.98
6	17	10.29	0.45	0.00 (ND)	0.16 (J)	0.21 (J)	0.19 (J)	0.00 (ND)	0.12 (J)	0.18 (J)	0.41	0.00 (ND)	0.31	0.08 (J)	0.03 (J)	0.19	0.72 (I)	0.06 (J)	0.09 (J)	0.50
6	18	9.54	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.31 (J)	0.04 (J)	0.15 (J)	0.18 (J)	0.14 (J)	0.28	0.03 (J)	0.20	0.08 (J)	0.00 (ND)	0.16	0.93 (I)	0.05 (J)	0.11	0.70
7	19	11.97	0.38	0.00 (ND)	0.00 (ND)	0.26 (J)	0.13 (J)	0.00 (ND)	0.23 (J)	0.20	0.44	0.07 (J)	0.36	0.13 (J)	0.00 (ND)	0.21	0.52 (I)	0.07 (J)	0.00 (ND)	1.46
7	20	8.68	0.12 (J)	0.00 (ND)	0.13 (J)	0.26 (J)	0.15	0.00 (ND)	0.18 (J)	0.20	0.06 (J)	0.05 (J)	0.21	0.06 (J)	0.02 (J)	0.15	0.50 (I)	0.04 (J)	0.08	0.78
7	21	11.97	0.12 (J)	0.00 (ND)	0.11 (J)	0.41 (J)	0.22	0.17	0.19 (J)	0.20	0.46	0.04 (J)	0.30	0.08 (J)	0.02 (J)	0.22	0.52 (I)	0.09 (J)	0.11	1.22
8A	22	6.04	0.00 (ND)	0.05 (J)	0.08 (J)	0.25 (J)	0.08 (J)	0.12	0.15 (J)	0.20	0.30	0.04 (J)	0.19	0.03 (J)	0.03 (J)	0.14	0.00 (ND)	0.03 (J)	0.00 (ND)	0.07 (J)
8A	23	8.98	0.00 (ND)	0.00 (ND)	0.17 (J)	0.44 (J)	0.12 (J)	0.10 (J)	0.26 (J)	0.33	0.54	0.06 (J)	0.42	0.06 (J)	0.08 (J)	0.27	0.00 (ND)	0.10 (J)	0.01 (J)	0.15 (J)
8A	24	6.78	0.00 (ND)	0.00 (ND)	0.10 (J)	0.35 (J)	0.09 (J)	0.14	0.13 (J)	0.17	0.26	0.03 (J)	0.19	0.03 (J)	0.03 (J)	0.16	0.00 (ND)	0.03 (J)	0.06 (J)	0.33
8	25	9.75	0.33	0.00 (ND)	0.12 (J)	0.31 (J)	0.13 (J)	0.00 (ND)	0.11 (J)	0.16 (J)	0.10 (J)	0.00 (ND)	0.25	0.08 (J)	0.00 (ND)	0.14	0.77 (I)	0.10 (J)	0.13	0.73
8	26	5.34	0.00 (ND)	0.00 (ND)	0.10 (J)	0.15 (J)	0.08 (J)	0.08 (J)	0.06 (J)	0.09 (J)	0.08 (J)	0.00 (ND)	0.12 (J)	0.01 (J)	0.00 (ND)	0.07 (J)	0.00 (ND)	0.05 (J)	0.13	0.41
8	27	7.85	0.00 (ND)	0.00 (ND)	0.04 (J)	0.19 (J)	0.12 (J)	0.12	0.09 (J)	0.11	0.21	0.02 (J)	0.17	0.04 (J)	0.01 (J)	0.09	0.72(I)	0.04 (J)	0.04 (J)	0.58
8	28	7.76	0.00 (ND)	0.00 (ND)	0.05 (J)	0.21 (J)	0.11 (J)	0.00 (ND)	0.10 (J)	0.11 (J)	0.08 (J)	0.00 (ND)	0.20	0.07 (J)	0.00 (ND)	0.16	0.62 (I)	0.07 (J)	0.06 (J)	0.71
9	29	5.72	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.11 (J)	0.00 (ND)	0.18	0.06 (J)	0.04 (J)	0.05 (J)	0.02 (J)	0.07 (J)	0.03 (J)	0.00 (ND)	0.06 (J)	0.64 (I)	0.00 (ND)	0.02 (J)	0.33
9	30	6.83	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.16 (J)	0.00 (ND)	0.23	0.07 (J)	0.05 (J)	0.05 (J)	0.00 (ND)	0.08 (J)	0.03 (J)	0.00 (ND)	0.08 (J)	0.94 (I)	0.00 (ND)	0.07 (J)	0.36
9	31	7.95	0.20 (J)	0.00 (ND)	0.00 (ND)	0.19 (J)	0.13 (J)	0.13 (J)	0.11 (J)	0.09 (J)	0.06 (J)	0.04 (J)	0.14	0.05 (J)	0.00 (ND)	0.11	0.79 (I)	0.00 (ND)	0.06 (J)	0.54
9	32	10.80	0.61	0.09 (J)	0.48	0.29 (J)	0.18 (J)	0.87	0.32 (J)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.27	0.00 (ND)	0.14 (J)	0.00 (ND)	0.69
10	33	3.57	0.11 (J)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.03 (J)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.03 (J)	0.00 (ND)	0.00 (ND)	0.02 (J)	0.43 (I)	0.00 (ND)	0.00 (ND)	0.00 (J)
10	34	4.98	0.00 (ND)	0.00 (ND)	0.13 (J)	0.07 (J)	0.05 (J)	0.14	0.06 (J)	0.00 (ND)	0.08 (J)	0.00 (ND)	0.07 (J)	0.00 (ND)	0.11 (J)	0.04 (J)	0.22 (J)	0.00 (ND)	0.05 (J)	0.26
10	35	3.86	0.32	0.00 (ND)	0.04 (J)	0.00 (ND)	0.04 (J)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.04 (J)	0.00 (ND)	0.02 (J)	0.00 (ND)	0.19 (J)	0.03 (J)	0.00 (ND)	0.00 (ND)	0.04 (J)	0.05 (J)
10	36	3.04	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.12 (J)	0.05 (J)	0.00 (ND)	0.04 (J)	0.02 (J)	0.03 (J)	0.00 (ND)	0.07 (J)	0.00 (ND)	0.00 (ND)	0.03 (J)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.02 (J)
10	37	2.84	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.05 (J)	0.05 (J)	0.04 (J)	0.02 (J)	0.01 (J)	0.04 (J)	0.01 (J)	0.05 (J)	0.00 (ND)	0.00 (ND)	0.01 (J)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.01 (J)
11	38	3.60	0.17 (J)	0.00 (ND)	0.00 (ND)	0.11 (J)	0.00 (ND)	0.00 (ND)	0.05 (J)	0.02 (J)	0.05 (J)	0.00 (ND)	0.08 (J)	0.01 (J)	0.00 (ND)	0.03 (J)	0.00 (ND)	0.00 (ND)	0.06 (J)	0.06 (J)
11	39	4.03	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.19 (J)	0.18 (J)	0.00 (ND)	0.06 (J)	0.02 (J)	0.00 (ND)	0.02 (J)	0.11 (J)	0.01 (J)	0.00 (ND)	0.06 (J)	0.00 (ND)	0.00 (ND)	0.08 (J)	0.09 (J)
11	40	3.75	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.17 (J)	0.06 (J)	0.00 (ND)	0.13 (J)	0.00 (ND)	0.08 (J)	0.00 (ND)	0.12 (J)	0.01 (J)	0.00 (ND)	0.06 (J)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.07 (J)
11	41	3.06	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.10 (J)	0.00 (ND)	0.00 (ND)	0.04 (J)	0.01 (J)	0.05 (J)	0.00 (ND)	0.08 (J)	0.01 (J)	0.00 (ND)	0.03 (J)	0.00 (ND)	0.00 (ND)	0.04 (J)	0.04 (J)
12	42	3.48	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.12 (J)	0.07 (J)	0.00 (ND)	0.04 (J)	0.03 (J)	0.11 (J)	0.00 (ND)	0.10 (J)	0.03 (J)	0.00(J)	0.05 (J)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.03 (J)
12	43	3.10	0.17 (J)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.04 (J)	0.00 (ND)	0.01 (J)	0.03 (J)	0.05 (J)	0.00 (ND)	0.06 (J)	0.00 (ND)	0.00 (ND)	0.03 (J)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.03 (J)
12	44	3.09	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.10 (J)	0.03 (J)	0.00 (ND)	0.04 (J)	0.02 (J)	0.05 (J)	0.01 (J)	0.06 (J)	0.01 (J)	0.00 (ND)	0.03 (J)	0.00 (ND)	0.00 (ND)	0.03 (J)	0.03 (J)

ND (not detected); J (below method detection limit); I (interference)

Appendix E. Sediment PCB concentrations (continued).

Stratum Number	Site Number	Total PCB	PCB8/5	PCB18/17	PCB28	PCB52	PCB44	PCB66	PCB101/90	PCB118	PCB153/132	PCB105	PCB138/160	PCB187	PCB128	PCB180	PCB170/190	PCB 195/208	PCB206	PCB209
13	45	2.84	0.00 (ND)	0.00 (ND)	0.08 (J)	0.00 (ND)	0.04 (J)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.02 (J)	0.00 (ND)	0.00 (ND)	0.02 (J)	0.13 (J)	0.00 (ND)	0.00 (ND)	0.01 (J)
13	46	4.09	0.36	0.00 (ND)	0.09 (J)	0.00 (ND)	0.03 (J)	0.14	0.00 (ND)	0.00 (ND)	0.02 (J)	0.00 (ND)	0.02 (J)	0.00 (ND)	0.00 (ND)	0.01 (J)	0.12 (J)	0.00 (ND)	0.00 (ND)	0.07 (J)
13	47	2.87	0.00 (ND)	0.00 (ND)	0.06 (J)	0.00 (ND)	0.03 (J)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.03 (J)	0.00 (ND)	0.03 (J)	0.00 (ND)	0.00 (ND)	0.03 (J)	0.09 (J)	0.00 (ND)	0.03 (J)	0.02 (J)
13	48	3.07	0.00 (ND)	0.00 (ND)	0.12 (J)	0.10 (J)	0.08 (J)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.03 (J)	0.00 (ND)	0.04 (J)	0.00 (ND)	0.00 (ND)	0.03 (J)	0.00 (ND)	0.01 (J)	0.00 (ND)	0.00 (ND)
13	49	3.44	0.00 (ND)	0.00 (ND)	0.10 (J)	0.03 (J)	0.04 (J)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.03 (J)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.15 (J)	0.02 (J)	0.17 (J)	0.00 (ND)	0.00 (ND)	0.04 (J)
14	50	6.57	0.00 (ND)	0.19 (J)	0.21	0.11 (J)	0.07 (J)	0.34	0.27 (J)	0.06 (J)	0.21	0.04 (J)	0.14	0.05 (J)	0.00 (ND)	0.09 (J)	0.00 (ND)	0.03 (J)	0.09 (J)	0.10 (J)
14	51	4.03	0.00 (ND)	0.03 (J)	0.05 (J)	0.06 (J)	0.04 (J)	0.00 (ND)	0.06 (J)	0.05 (J)	0.09 (J)	0.02 (J)	0.07 (J)	0.02 (J)	0.00 (ND)	0.04 (J)	0.23 (I)	0.01 (J)	0.04 (J)	0.03 (J)
14	52	8.15	0.00 (ND)	0.8 (J)	0.05 (J)	0.06 (J)	0.05 (J)	0.00 (ND)	0.12 (J)	0.00 (ND)	0.12	0.04 (J)	0.05 (J)	0.00 (ND)	0.00 (ND)	0.10	1.10 (I)	0.05 (J)	0.10	0.07 (J)
15	53	3.81	0.00 (ND)	0.00 (ND)	0.02 (J)	0.05 (J)	0.02 (J)	0.00 (ND)	0.06 (J)	0.03 (J)	0.12	0.02 (J)	0.08	0.06 (J)	0.00 (ND)	0.09	0.14 (J)	0.02 (J)	0.02 (J)	0.00 (ND)
15	54	3.24	0.00 (ND)	0.00 (ND)	0.03 (J)	0.10 (J)	0.03 (J)	0.00 (ND)	0.03 (J)	0.00 (ND)	0.04 (J)	0.01 (J)	0.04 (J)	0.00 (ND)	0.00 (ND)	0.02 (J)	0.16 (J)	0.00 (ND)	0.01 (J)	0.01 (J)
15	55	4.10	0.24	0.00 (ND)	0.05 (J)	0.06 (J)	0.05 (J)	0.00 (ND)	0.08 (J)	0.06 (J)	0.08 (J)	0.03 (J)	0.07 (J)	0.01 (J)	0.05 (J)	0.04 (J)	0.00 (ND)	0.00 (J)	0.02 (J)	0.02 (J)
15	56	3.53	0.31	0.00 (ND)	0.00 (ND)	0.06 (J)	0.02 (J)	0.13	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.04 (J)	0.00 (ND)	0.05 (J)	0.00 (ND)	0.00 (ND)	0.00 (ND)
15	57	6.21	0.00 (ND)	0.00 (ND)	0.08 (J)	0.15 (J)	0.08 (J)	0.00 (ND)	0.30	0.23	0.38	0.11 (J)	0.32	0.04 (J)	0.00 (ND)	0.09 (J)	0.00 (ND)	0.00 (ND)	0.03 (J)	0.02 (J)
16	58	2.86	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.02 (J)	0.00 (ND)	0.03 (J)	0.00 (ND)	0.00 (ND)	0.01 (J)	0.24 (I)	0.00 (J)	0.00 (ND)	0.01 (J)
16	59	2.75	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.24 (I)	0.00 (ND)	0.00 (ND)	0.02 (J)
16	60	5.17	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.08 (J)	0.02 (J)	0.00 (ND)	0.18 (J)	0.14	0.08 (J)	0.00 (ND)	0.32	0.03 (J)	0.06 (J)	0.09	0.32 (I)	0.01 (J)	0.00 (ND)	0.02 (J)
17	61	3.44	0.12 (J)	0.00 (ND)	0.05 (J)	0.04 (J)	0.05 (J)	0.00 (ND)	0.00 (ND)	0.05 (J)	0.05 (J)	0.00 (ND)	0.07 (J)	0.00 (ND)	0.00 (ND)	0.05 (J)	0.00 (ND)	0.00 (ND)	0.06 (J)	0.04 (J)
17	62	2.34	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.07 (J)	0.00 (ND)	0.00 (ND)	0.00 (ND)
17	63	3.90	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.03 (J)	0.00 (ND)	0.12	0.00 (ND)	0.14	0.00 (ND)	0.00 (ND)	0.06 (J)	0.41 (I)	0.00 (J)	0.00 (ND)	0.03 (J)
18	64	2.45	0.00 (ND)	0.04 (J)	0.00 (ND)	0.03 (J)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.02 (J)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.02 (J)	0.00 (ND)	0.00 (ND)	0.00 (ND)
18	65	2.38	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.09 (J)	0.00 (ND)	0.00 (ND)	0.00 (ND)
18	66	2.28	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.04 (J)	0.00 (ND)	0.00 (ND)	0.00 (ND)
19	67	3.27	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.02 (J)	0.00 (ND)	0.00 (ND)	0.04 (J)	0.00 (ND)	0.06 (J)	0.00 (ND)	0.07 (J)	0.00 (ND)	0.00 (ND)	0.01 (J)	0.28 (I)	0.00 (ND)	0.00 (ND)	0.01 (J)
19	68	2.73	0.18	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.06 (J)	0.00 (ND)	0.00 (ND)	0.00 (ND)
19	69	4.80	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.03 (J)	0.00 (ND)	0.00 (ND)	0.11 (J)	0.10	0.06 (J)	0.04 (J)	0.25	0.02 (J)	0.05 (J)	0.09	0.33 (J)	0.00 (J)	0.09	0.02 (J)
20	70	2.27	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.04 (J)	0.00 (ND)	0.00 (ND)	0.00 (ND)
20	71	2.54	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.16 (J)	0.00 (ND)	0.00 (ND)	0.00 (ND)
20	72	2.37	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.02 (J)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.06 (J)	0.00 (ND)	0.00 (ND)	0.00 (ND)
21	73	3.22	0.00 (ND)	0.00 (ND)	0.05 (J)	0.12 (J)	0.07 (J)	0.05 (J)	0.00 (ND)	0.05 (J)	0.06 (J)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.03 (J)	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.04 (J)
21	74	6.19	0.00 (ND)	0.00 (ND)	0.07 (J)	0.07 (J)	0.06 (J)	0.13 (J)	0.05 (J)	0.08 (J)	0.08 (J)	0.00 (ND)	0.20	0.00 (ND)	0.03 (J)	0.05 (J)	0.84 (I)	0.00 (ND)	0.00 (ND)	0.18 (J)
21	75	4.88	0.00 (ND)	0.00 (ND)	0.00 (ND)	0.11 (J)	0.00 (ND)	0.00 (ND)	0.08 (J)	0.10 (J)	0.16 (J)	0.04 (J)	0.16	0.00 (ND)	0.00 (ND)	0.05 (J)	0.51 (I)	0.00 (ND)	0.00 (ND)	0.02 (J)

ND (not detected); J (below method detection limit); I (interference)

Appendix F
Sediment PAHs

Appendix F. Sediment PAH concentrations.

Stratum Number	Site Number	Total PAHs with Perylene	Total PAHs without Perylene	Naphthalene	C1-Naph	C2-Naph	C3-Naph	C4-Naph	Biphenyl	Acenaph-thylene	Acenaph-thene
1	1	90.50	88.10	1.9 (J)	1.2 (J)	1.7	5.3	0.0 (ND)	0.6	1.6	0.5
1	2	1,509.10	1,468.70	10.6	15.5	12.4	29.6	36.1	1.7	11.5	3.8
1	3	2,487.10	2,434.70	18.4	18.8	27.3	67.0	41.7	4.0	26.6	20.3
2	4	84.50	82.10	1.9 (J)	1.7 (J)	2.6	8.7	2.5	0.4	1.0	0.5
2	5	1,199.90	1,181.50	5.3	8.2	10.8	20.4	52.3	1.3	2.5	1.4
2	6	654.10	633.70	8.9	9.4	6.4	30.4	11.6	1.5	6.9	2.0
3	7	441.20	424.90	5.1	5.8	8.5	7.5	9.6	1.9	5.0	1.4
3	8	1,226.10	1,189.30	6.4	7.0	11.7	18.7	14.8	2.2	12.4	2.6
3	9	858.40	825.60	8.3	8.7	9.3	25.4	12.5	2.6	7.9	2.4
4	10	177.90	171.10	2.9	3.4	4.6	10.1	2.0	0.8	1.8	0.8
4	11	200.30	190.20	3.3 (J)	3.0 (J)	0.0 (ND)	0.0 (ND)	0.0 (ND)	1.2	1.9	1.1
4	12	7.90	7.60	1.1 (J)	0.6 (J)	0.0 (ND)	0.0 (ND)	0.0 (ND)	0.4	0.2(J)	0.3 (J)
5	13	661.20	634.80	5.8	7.2	12.2	18.6	20.1	2.1	4.3	2.4
5	14	589.00	555.00	5.9	5.5	5.4	11.3	6.9	1.2	4.8	2.6
5	15	358.70	347.30	3.7	3.6 (J)	3.8	10.3	15.0	0.8	2.1	1.0
6	16	460.40	427.50	6.2	7.3	14.7	17.2	23.2	2.1	4.7	2.0
6	17	536.80	489.40	10.2	12.6	14.0	28.3	21.4	3.2	3.4	1.4 (J)
6	18	317.50	298.50	5.6	5.8	5.6	12.4	6.9	1.7	3.2	1.3
7	19	360.00	347.00	5.0	5.2 (J)	7.5	13.0	11.7	1.4	3.9	1.4
7	20	781.20	770.30	4.0	6.0	10.9	18.8	13.9	1.4	4.3	0.8
7	21	290.70	285.00	4.3	6.0	0.0 (ND)	0.0 (ND)	0.0 (ND)	1.0	4.9	1.1
8A	22	975.80	948.60	0.5 (J)	0.5 (J)	0.0 (ND)	0.0 (ND)	0.0 (ND)	1.0	6.1	1.0
8A	23	893.90	846.70	3.2 (J)	3.2 (J)	0.0 (ND)	0.0 (ND)	0.0 (ND)	0.9	4.3	1.8
8A	24	604.60	588.40	3.9	3.8 (J)	0.0 (ND)	0.0 (ND)	0.0 (ND)	0.8	8.2	2.5
8	25	405.70	394.30	6.7	5.5 (J)	0.0 (ND)	0.0 (ND)	0.0 (ND)	1.1	4.6	0.9 (J)
8	26	238.50	233.30	3.8 (J)	4.8	0.0 (ND)	0.0 (ND)	0.0 (ND)	0.6	4.0	0.8 (J)
8	27	324.10	315.70	9.3	5.4	3.4	8.7	0.0 (ND)	0.8	3.0	0.5 (J)
8	28	225.50	220.40	4.8	4.6	0.0 (ND)	0.0 (ND)	0.0 (ND)	0.7	3.3	0.7 (J)
9	29	223.00	203.80	4.4	3.2 (J)	7.1	16.9	6.6	1.8	2.2	1.1
9	30	210.10	197.70	4.3 (J)	3.0 (J)	6.9	13.8	5.8	1.5	2.1	0.9 (J)
9	31	248.60	236.20	4.1 (J)	3.7 (J)	5.5	10.3	9.6	1.2	2.6	1.1
9	32	10,586.73	10,399.60	7.3 (J)	4.6 (J)	10.8	19.7	31.2	2.9	3.8	34.9
10	33	173.40	170.40	2.6	1.8 (J)	0.0 (ND)	0.0 (ND)	0.0 (ND)	0.6	0.5	0.6
10	34	161.50	152.00	5.2	6.2	9.6	0.0 (ND)	0.0 (ND)	1.4	2.3	0.4 (J)
10	35	71.50	68.40	2.7 (J)	1.7 (J)	2.4	5.7	0.0 (ND)	0.5	0.7	0.3 (J)
10	36	124.60	119.60	3.8	4.0 (J)	5.5	10.7	0.0 (ND)	0.6	1.8	0.4 (J)
10	37	38.40	37.20	2.1 (J)	1.6 (J)	0.0 (ND)	0.0 (ND)	0.0 (ND)	0.5	0.8	0.4 (J)

ND (not detected); J (below method detection limit)

Appendix F. Sediment PAH concentrations (continued).

Stratum Number	Site Number	Total PAHs with Perylene	Total PAHs without Perylene	Naphthalene	C1-Naph	C2-Naph	C3-Naph	C4-Naph	Biphenyl	Acenaph-thylene	Acenaph-thene
11	38	80.90	76.20	3.4 (J)	1.9 (J)	0.0 (ND)	0.0 (ND)	0.0 (ND)	0.8	1.2	0.8 (J)
11	39	212.10	205.50	5.8 (J)	4.7 (J)	12.3	8.6	23.0	1.3	1.9	0.6 (J)
11	40	613.90	599.50	5.3 (J)	3.7 (J)	0.0 (ND)	0.0 (ND)	0.0 (ND)	0.7	1.7	2.4
11	41	66.40	53.20	3.6 (J)	2.6 (J)	0.0 (ND)	0.0 (ND)	0.0 (ND)	0.8	0.6	0.7 (J)
12	42	81.90	74.30	3.0 (J)	1.7 (J)	5.8	0.0 (ND)	0.0 (ND)	1.3	0.9	1.0
12	43	42.30	37.50	2.7 (J)	1.2 (J)	0.0 (ND)	0.0 (ND)	0.0 (ND)	0.4 (J)	0.4(J)	0.7 (J)
12	44	98.90	93.80	2.1 (J)	1.2 (J)	0.0 (ND)	0.0 (ND)	0.0 (ND)	0.7	0.9	1.3
13	45	96.70	93.10	2.5 (J)	1.9 (J)	0.0 (ND)	0.0 (ND)	0.0 (ND)	0.5	0.5	0.9
13	46	62.80	58.90	3.2 (J)	2.5 (J)	9.0	12.2	0.0 (ND)	0.4 (J)	0.6	0.4 (J)
13	47	31.50	29.10	2.1 (J)	2.0 (J)	0.0 (ND)	0.0 (ND)	0.0 (ND)	0.7	0.4	0.5 (J)
13	48	138.50	135.40	2.4 (J)	2.7 (J)	6.7	13.7	7.4	0.8	1.1	1.1
13	49	43.00	40.00	3.3 (J)	2.8 (J)	5.6	0.0 (ND)	0.0 (ND)	0.9	0.3(J)	0.5 (J)
14	50	704.50	687.10	6.9	7.7	6.2	19.4	14.6	2.3	8.9	1.9
14	51	122.20	117.80	2.8	1.7 (J)	0.0 (ND)	0.0 (ND)	0.0 (ND)	0.8	4.2	0.8
14	52	1,757.50	1,717.40	3.5	3.8	7.0	20.2	10.6	0.9	19.1	4.7
15	53	46.30	45.50	1.7 (J)	1.2 (J)	0.0 (ND)	0.0 (ND)	0.0 (ND)	0.4	1.0	0.7
15	54	78.60	77.00	2.2 (J)	2.4 (J)	0.0 (ND)	0.0 (ND)	0.0 (ND)	0.6	2.2	0.5 J)
15	55	46.20	44.60	1.9 (J)	1.6 (J)	2.6	3.1	0.0 (ND)	0.7	0.6	0.5 (J)
15	56	164.60	162.30	2.8	2.8	0.0 (ND)	0.0 (ND)	0.0 (ND)	1.0	6.6	1.0
15	57	13.10	12.70	4.0	2.1 (J)	0.0 (ND)	0.0 (ND)	0.0 (ND)	0.8	0.3(J)	0.7 (J)
16	58	118.40	114.10	2.8	2.4 (J)	5.0	8.5	10.7	0.7	0.9	0.8
16	59	213.50	207.60	7.1	7.1	5.4	7.0	4.1	3.7	1.6	3.4
16	60	127.90	122.00	2.6 (J)	2.0 (J)	5.5	6.6	7.3	1.0	2.0	0.4 (J)
17	61	164.10	156.20	3.5 (J)	3.2 (J)	1.9 (J)	0.0 (ND)	0.0 (ND)	0.9	2.1	1.0
17	62	38.20	36.50	2.4	1.0 (J)	0.0 (ND)	0.0 (ND)	0.0 (ND)	0.6	0.5	0.3 (J)
17	63	151.50	143.00	3.5	3.6 (J)	6.9	10.7	12.7	0.8	1.1	0.8
18	64	5.40	5.10	1.5 (J)	0.8 (J)	0.0 (ND)	0.0 (ND)	0.0 (ND)	0.2 (J)	0.1(J)	0.4 (J)
18	65	5.60	5.40	1.6 (J)	0.7 (J)	0.0 (ND)	0.0 (ND)	0.0 (ND)	0.3 (J)	0.0(J)	0.3 (J)
18	66	9.00	8.80	2.6	2.3 (J)	0.0 (ND)	0.0 (ND)	0.0 (ND)	1.0	0.2(J)	0.3 (J)
19	67	59.50	55.30	2.7	2.1 (J)	3.0	5.5	4.6	0.8	0.2(J)	0.2 (J)
19	68	7.40	7.00	1.7 (J)	0.7 (J)	0.0 (ND)	0.0 (ND)	0.0 (ND)	0.6	0.1(J)	0.4 (J)
19	69	140.30	128.30	5.5	4.3	4.9	9.7	7.6	0.8	0.9	0.7 (J)
20	70	8.70	8.10	2.2	1.5 (J)	0.0 (ND)	0.0 (ND)	0.0 (ND)	0.6	0.1(J)	0.3 (J)
20	71	48.60	46.60	1.9 (J)	1.3 (J)	3.5	10.1	9.5	0.3 (J)	0.5	0.4 (J)
20	72	5.50	5.10	1.6 (J)	0.6 (J)	0.0 (ND)	0.0 (ND)	0.0 (ND)	0.3 (J)	0.1(J)	0.4 (J)
21	73	280.60	268.20	4.1(J)	6.0	14.1	24.1	16.1	2.1	3.9	1.2
21	74	278.70	266.40	6.5	6.0	13.1	14.2	13.6	2.0	2.1	1.0
21	75	170.90	163.80	5.6	4.3 (J)	6.4	10.9	7.5	1.1	1.4	1.2

ND (not detected); J (below method detection limit)

Appendix F. Sediment PAH concentrations (continued).

Stratum Number	Site Number	Fluorene	C1-Fluorenes	C2-Fluorenes	C3-Fluorenes	Phenanthrene	Anthracene	C1-Phenanthrenes /Anthracenes	C2-Phenanthrenes /Anthracenes	C3-Phenanthrenes /Anthracenes	C4-Phenanthrenes /Anthracenes
1	1	0.6	0.0 (ND)	0.0 (ND)	0.0 (ND)	1.7	1.1	2.0	3.0	5.4	2.6
1	2	5.1	14.1	46.2	111.4	21.7	15.1	20.8	20.0	73.8	64.7
1	3	28.5	20.1	45.4	55.7	126.6	57.9	55.6	49.4	94.1	61.9
2	4	0.4 (J)	0.0 (ND)	0.0 (ND)	0.0 (ND)	1.4	0.8	2.2	2.2	4.1	2.8
2	5	1.9	6.9	42.4	104.5	9.1	13.6	27.7	65.3	90.0	91.4
2	6	3.0	4.1	9.8	16.7	11.3	6.2	12.9	12.6	23.7	14.6
3	7	2.0	2.8	15.0	23.9	7.6	5.3	10.5	19.0	22.0	19.7
3	8	4.7	3.3	16.7	33.1	21.9	19.5	17.8	27.5	36.5	29.4
3	9	4.5	5.5	20.5	26.5	14.2	12.8	18.5	26.5	32.0	35.3
4	10	1.3	2.1	2.9	5.4	5.0	2.6	4.7	5.1	7.5	8.1
4	11	1.1	2.9	5.8	11.7	3.2	2.0	5.9	10.1	10.6	8.4
4	12	0.6	0.0 (ND)	0.0 (ND)	0.0 (ND)	0.2 (J)	0.2 (J)	0.0 (ND)	0.0 (ND)	0.0 (ND)	0.0 (ND)
5	13	3.9	7.1	16.3	27.7	10.7	9.7	15.1	25.8	31.1	28.2
5	14	3.3	2.1	9.5	18.0	11.8	8.3	11.8	21.4	25.3	15.6
5	15	1.8	2.9	8.6	16.2	5.9	3.6	6.5	7.9	21.8	23.1
6	16	2.7	5.2	0.0 (ND)	0.0 (ND)	8.0	4.5	10.4	13.5	20.6	17.5
6	17	2.5	3.7	14.3	38.7	8.9	6.4	12.8	21.6	37.8	20.0
6	18	2.0	2.2	4.4	7.3	6.4	3.7	7.6	9.5	14.6	14.5
7	19	1.4	3.0	7.9	17.4	6.4	4.7	7.1	13.0	15.1	6.9
7	20	1.8	1.9	11.1	28.4	6.0	6.0	10.2	35.8	87.1	63.4
7	21	2.2	0.0 (ND)	0.0 (ND)	0.0 (ND)	6.5	6.2	10.1	14.5	18.1	14.7
8A	22	1.8	2.3	0.0 (ND)	0.0 (ND)	15.9	12.9	11.1	9.2	18.0	18.5
8A	23	0.7 (J)	2.8	0.0 (ND)	0.0 (ND)	12.8	9.2	10.5	15.5	15.7	17.7
8A	24	2.4	0.0 (ND)	0.0 (ND)	0.0 (ND)	10.7	13.5	10.1	16.2	19.5	11.8
8	25	1.6	0.0 (ND)	0.0 (ND)	0.0 (ND)	6.8	7.0	8.7	21.0	31.8	20.1
8	26	0.5 (J)	0.0 (ND)	0.0 (ND)	0.0 (ND)	5.0	3.1	8.2	14.5	19.3	13.6
8	27	1.1	0.7 (J)	3.3	11.6	4.9	3.4	7.6	16.6	28.9	16.4
8	28	1.2	0.0 (ND)	0.0 (ND)	0.0 (ND)	4.2	4.0	6.7	13.0	16.8	13.9
9	29	1.6	2.1	5.3	11.7	3.5	3.2	4.8	10.1	10.2	6.1
9	30	1.3	1.1 (J)	4.6	7.7	3.7	2.3	4.3	6.3	6.3	6.9
9	31	1.6	1.7 (J)	6.4	9.5	4.0	3.7	5.7	5.7	12.3	6.0
9	32	34.5	22.6	47.2	67.7	501.5	228.3	228.5	235.1	240.3	156.2
10	33	0.5 (J)	0.0 (ND)	0.0 (ND)	0.0 (ND)	2.8	2.0	4.0	5.4	3.7	1.5
10	34	2.0	0.0 (ND)	0.0 (ND)	0.0 (ND)	4.6	1.9	6.7	9.8	9.3	8.9
10	35	0.7 (J)	1.3 (J)	2.8	2.7	1.7	0.8	2.3	4.2	3.6	2.2
10	36	1.3	0.0 (ND)	0.0 (ND)	0.0 (ND)	2.5	1.5	3.0	3.3	6.5	3.0
10	37	0.3 (J)	0.0 (ND)	0.0 (ND)	0.0 (ND)	1.1	0.6	1.1	1.8	2.4	2.8

ND (not detected); J (below method detection limit)

Appendix F. Sediment PAH concentrations (continued).

Stratum Number	Site Number	Fluorene	C1-Fluorenes	C2-Fluorenes	C3-Fluorenes	Phenanthrene	Anthracene	C1-Phenanthrenes/Anthracenes	C2-Phenanthrenes/Anthracenes	C3-Phenanthrenes/Anthracenes	C4-Phenanthrenes/Anthracenes
11	38	0.8 (J)	0.0 (ND)	0.0 (ND)	0.0 (ND)	2.4	1.0	3.0	3.6	4.2	0.0 (ND)
11	39	1.7	5.6	14.3	17.8	2.7	1.1 (J)	4.4	5.7	5.6	6.4
11	40	2.3	0.0 (ND)	0.0 (ND)	0.0 (ND)	12.5	8.6	9.0	8.6	7.2	7.5
11	41	0.4 (J)	0.0 (ND)	0.0 (ND)	0.0 (ND)	1.4	0.9	2.9	2.2	2.6	0.0 (ND)
12	42	0.7 (J)	0.0 (ND)	0.0 (ND)	0.0 (ND)	2.1	1.0	2.8	3.0	4.8	2.8
12	43	0.3 (J)	0.0 (ND)	0.0 (ND)	0.0 (ND)	1.1 (J)	0.6 (J)	2.1	2.5	0.0 (ND)	0.0 (ND)
12	44	1.1	0.0 (ND)	0.0 (ND)	0.0 (ND)	3.4	1.7	2.0	2.8	2.6	2.1
13	45	0.3 (J)	0.0 (ND)	0.0 (ND)	0.0 (ND)	2.0	1.3	2.9	3.9	4.5	2.7
13	46	0.4 (J)	0.0 (ND)	0.0 (ND)	0.0 (ND)	1.5	1.0	0.0 (ND)	0.0 (ND)	0.0 (ND)	0.0 (ND)
13	47	0.4 (J)	0.0 (ND)	0.0 (ND)	0.0 (ND)	1.4	0.8	0.0 (ND)	0.0 (ND)	0.0 (ND)	0.0 (ND)
13	48	0.8	0.0 (ND)	0.0 (ND)	0.0 (ND)	2.8	1.8	4.1	4.4	9.9	5.2
13	49	0.7 (J)	0.0 (ND)	0.0 (ND)	0.0 (ND)	1.5	1.1	0.0 (ND)	0.0 (ND)	0.0 (ND)	0.0 (ND)
14	50	9.1	2.6	7.0	15.4	15.5	76.5	12.4	17.0	14.9	6.1
14	51	1.3	0.0 (ND)	0.0 (ND)	0.0 (ND)	3.6	2.5	4.0	4.6	4.2	3.8
14	52	8.2	5.1	9.1	8.5	38.0	44.7	27.1	18.8	14.1	15.0
15	53	0.5 (J)	0.0 (ND)	0.0 (ND)	0.0 (ND)	1.8	0.9	1.8	2.0	3.5	3.7
15	54	0.7	0.0 (ND)	0.0 (ND)	0.0 (ND)	2.7	1.3	2.8	3.8	5.4	4.1
15	55	0.3 (J)	0.0 (ND)	0.0 (ND)	0.0 (ND)	1.3	0.5 (J)	1.4	2.3	2.2	1.9
15	56	1.5	0.0 (ND)	0.0 (ND)	0.0 (ND)	6.8	3.0	5.2	3.2	4.1	4.8
15	57	0.2 (J)	0.0 (ND)	0.0 (ND)	0.0 (ND)	0.5 (J)	0.3 (J)	0.0 (ND)	0.0 (ND)	0.0 (ND)	0.0 (ND)
16	58	0.8	1.5	3.8	6.2	1.9	1.5	3.0	3.7	4.6	2.6
16	59	4.7	1.7	3.2	6.0	2.3	3.0	2.3	3.3	5.7	2.5
16	60	1.0	0.0 (ND)	0.0 (ND)	0.0 (ND)	2.4	2.2	4.0	4.9	7.3	3.6
17	61	1.3	0.0 (ND)	0.0 (ND)	0.0 (ND)	3.2	3.5	6.0	13.1	11.8	5.7
17	62	0.3 (J)	0.0 (ND)	0.0 (ND)	0.0 (ND)	1.9	0.9	1.6	2.8	3.1	0.0 (ND)
17	63	1.0	2.2	4.6	7.6	2.2	1.7	4.6	7.8	9.3	2.7
18	64	0.3 (J)	0.0 (ND)	0.0 (ND)	0.0 (ND)	0.2 (J)	0.3 (J)	0.0 (ND)	0.0 (ND)	0.0 (ND)	0.0 (ND)
18	65	0.2 (J)	0.0 (ND)	0.0 (ND)	0.0 (ND)	0.4 (J)	0.3 (J)	0.0 (ND)	0.0 (ND)	0.0 (ND)	0.0 (ND)
18	66	0.4 (J)	0.0 (ND)	0.0 (ND)	0.0 (ND)	0.5 (J)	0.3 (J)	0.0 (ND)	0.0 (ND)	0.0 (ND)	0.0 (ND)
19	67	0.5 (J)	0.0 (ND)	0.0 (ND)	0.0 (ND)	1.2	0.4 (J)	2.3	3.3	3.0	1.9
19	68	0.4 (J)	0.0 (ND)	0.0 (ND)	0.0 (ND)	0.6 (J)	0.5	0.0 (ND)	0.0 (ND)	0.0 (ND)	0.0 (ND)
19	69	0.6 (J)	1.7	4.8	6.7	2.4	1.0	3.5	5.4	6.8	3.2
20	70	0.3 (J)	0.0 (ND)	0.0 (ND)	0.0 (ND)	0.6 (J)	0.2 (J)	0.0 (ND)	0.0 (ND)	0.0 (ND)	0.0 (ND)
20	71	0.4 (J)	0.0 (ND)	0.0 (ND)	0.0 (ND)	0.8 (J)	0.5 (J)	1.2	2.5	0.0 (ND)	0.0 (ND)
20	72	0.3 (J)	0.0 (ND)	0.0 (ND)	0.0 (ND)	0.3 (J)	0.1 (J)	0.0 (ND)	0.0 (ND)	0.0 (ND)	0.0 (ND)
21	73	1.1	4.2	8.7	16.6	4.4	2.7	10.0	20.9	14.9	10.8
21	74	2.4	4.6	6.5	22.1	3.9	3.4	6.8	12.7	14.3	6.4
21	75	1.4	2.7	6.8	13.2	3.3	1.9	5.4	7.5	7.6	5.3

ND (not detected); J (below method detection limit)

Appendix F. Sediment PAH concentrations (continued).

Stratum Number	Site Number	Dibenzo-thiophene	C1-Dibenzo-thiophenes	C2-Dibenzo-thiophenes	C3-Dibenzo-thiophenes	Fluoranthene	Pyrene	C1-Fluoranthenes/ Pyrenes	Benzo(a)-anthracene
1	1	0.7	1.1	2.6	3.7	4.6	9.3	5.2	1.3
1	2	2.5	8.1	47.3	98.3	87.4	122.3	95.5	29.5
1	3	11.1	12.3	34.0	59.3	203.3	246.5	166.6	69.7
2	4	0.6	1.2	2.2	3.9	4.1	7.3	4.6	1.2
2	5	2.6	12.6	31.6	83.1	14.2	44.7	121.0	10.0
2	6	1.6	3.5	8.7	24.4	34.6	59.6	37.5	11.9
3	7	1.5	4.6	8.3	17.1	17.8	35.7	28.8	7.2
3	8	2.7	6.3	13.4	19.5	77.8	100.7	50.9	41.5
3	9	2.1	5.5	15.9	23.8	50.1	74.1	64.3	30.9
4	10	0.9	2.5	3.0	3.0	8.8	14.3	8.6	4.0
4	11	1.0	1.5	4.2	9.6	8.3	12.4	8.4	4.4
4	12	0.1 (J)	0.0 (ND)	0.0 (ND)	0.0 (ND)	0.6 (J)	0.6 (J)	0.0 (ND)	0.2 (J)
5	13	2.1	4.7	9.8	16.2	33.6	41.5	34.8	16.6
5	14	1.7	5.0	8.0	13.5	37.6	44.1	32.4	19.0
5	15	1.3	3.2	7.4	18.5	15.9	20.8	17.7	9.1
6	16	1.2	4.8	14.6	20.1	18.3	25.3	23.5	10.4
6	17	1.9	6.2	10.8	17.7	16.2	22.7	20.8	8.6
6	18	1.2	1.9	5.7	5.3	15.3	21.6	12.5	6.2
7	19	1.3	3.0	5.8	10.1	18.3	25.2	12.9	8.7
7	20	1.2	4.3	23.9	42.5	28.7	45.8	72.4	19.4
7	21	1.5	3.2	6.9	10.1	17.5	25.2	12.4	7.0
8A	22	1.2	0.0 (ND)	0.0 (ND)	0.0 (ND)	99.8	85.8	39.9	51.7
8A	23	1.3	0.0 (ND)	0.0 (ND)	10.4	75.0	66.9	32.0	36.0
8A	24	1.3	2.1	3.8	5.3	50.3	45.2	25.4	27.1
8	25	1.5	2.3	7.0	11.2	19.4	26.1	18.7	12.8
8	26	0.6	2.6	3.5	10.4	11.8	16.6	9.6	7.5
8	27	0.7	2.2	7.1	13.3	13.3	17.6	17.1	8.7
8	28	0.8	0.0 (ND)	4.0	14.9	10.8	16.3	1.7 (J)	6.9
9	29	0.7	2.3	3.5	5.0	7.5	9.7	9.0	5.2
9	30	0.7	3.0	3.0	5.2	9.0	13.0	11.8	4.8
9	31	0.8	2.5	3.4	9.0	10.5	16.0	11.0	5.9
9	32	29.9	36.7	93.8	156.0	1473.0	1502.7	669.9	676.4
10	33	0.3 (J)	1.4	1.8	2.8	21.8	18.8	15.1	11.1
10	34	0.6 (J)	0.0 (ND)	0.0 (ND)	0.0 (ND)	9.0	11.3	11.4	3.5
10	35	0.3 (J)	1.2	1.5	1.8	2.6	2.9	3.9	1.3
10	36	0.4 (J)	0.9 (J)	6.9	2.9	6.2	7.0	5.1	2.9
10	37	0.3 (J)	0.0 (ND)	0.0 (ND)	0.0 (ND)	2.1	2.8	1.6 (J)	1.0

ND (not detected); J (below method detection limit)

Appendix F. Sediment PAH concentrations (continued).

Stratum Number	Site Number	Dibenzo-thiophene	C1-Dibenzo-thiophenes	C2-Dibenzo-thiophenes	C3-Dibenzo-thiophenes	Fluoranthene	Pyrene	C1-Fluoranthenes/ Pyrenes	Benzo(a)-anthracene
11	38	0.5 (J)	0.0 (ND)	0.0 (ND)	0.0 (ND)	5.8	7.1	6.3	2.7
11	39	0.5 (J)	2.4	7.1	0.0 (ND)	7.1	8.2	5.1 (J)	3.6
11	40	1.1	2.0	4.8	6.6	69.4	56.4	37.3	35.6
11	41	0.5 (J)	0.0 (ND)	0.0 (ND)	0.0 (ND)	4.3	4.6	2.5 (J)	1.8
12	42	0.5 (J)	0.0 (ND)	0.0 (ND)	0.0 (ND)	4.8	5.2	3.3 (J)	2.4
12	43	0.4 (J)	0.0 (ND)	0.0 (ND)	0.0 (ND)	1.8	2.5	6.2	0.8
12	44	0.4	0.0 (ND)	0.0 (ND)	0.0 (ND)	8.1	7.7	6.2	5.3
13	45	0.2 (J)	0.0 (ND)	0.0 (ND)	0.0 (ND)	8.1	9.4	6.7	5.6
13	46	0.3 (J)	0.0 (ND)	0.0 (ND)	0.0 (ND)	3.0	3.8	0.0 (ND)	1.4
13	47	0.3 (J)	0.0 (ND)	0.0 (ND)	0.0 (ND)	2.3	3.3	0.0 (ND)	1.5
13	48	0.5	2.1	5.8	6.6	3.1	5.7	7.7	2.5
13	49	0.4 (J)	0.0 (ND)	0.0 (ND)	0.0 (ND)	2.0	2.7	0.0 (ND)	1.4
14	50	1.1	2.1	6.1	10.4	43.7	49.8	31.8	29.6
14	51	0.5	0.0 (ND)	0.0 (ND)	0.0 (ND)	8.5	12.2	7.7	4.1
14	52	2.6	3.0	5.3	8.2	100.8	146.1	100.6	106.0
15	53	0.1 (J)	0.0 (ND)	0.0 (ND)	0.0 (ND)	2.9	3.9	3.0	1.3
15	54	0.6	0.0 (ND)	0.0 (ND)	0.0 (ND)	4.6	7.3	2.5 (J)	2.7
15	55	0.2 (J)	0.0 (ND)	0.0 (ND)	0.0 (ND)	2.4	3.1	2.8	1.3
15	56	0.4	1.9	4.3	4.5	11.2	17.3	9.7	4.7
15	57	0.2 (J)	0.0 (ND)	0.0 (ND)	0.0 (ND)	0.7 (J)	0.6 (J)	0.0 (ND)	0.6
16	58	0.4	2.4	5.0	5.9	3.8	3.7	4.5	1.8
16	59	0.4	0.9	2.1	4.8	8.4	7.5	6.0	4.3
16	60	0.4 (J)	1.4	4.2	3.7	5.3	5.6	5.8	3.5
17	61	0.6	0.0 (ND)	6.5	9.2	7.9	9.2	8.9	4.8
17	62	0.2 (J)	0.0 (ND)	0.0 (ND)	0.0 (ND)	5.1	3.9	2.7	1.2
17	63	1.2	1.8	4.3	6.6	5.1	5.2	4.1	2.2
18	64	0.1 (J)	0.0 (ND)	0.0 (ND)	0.0 (ND)	0.3 (J)	0.2 (J)	0.0 (ND)	0.1 (J)
18	65	0.2 (J)	0.0 (ND)	0.0 (ND)	0.0 (ND)	0.2 (J)	0.2 (J)	0.0 (ND)	0.2 (J)
18	66	0.2 (J)	0.0 (ND)	0.0 (ND)	0.0 (ND)	0.1 (J)	0.2 (J)	0.0 (ND)	0.1 (J)
19	67	0.3 (J)	1.3	1.7	3.3	1.2	1.4	2.9	0.6
19	68	0.2 (J)	0.0 (ND)	0.0 (ND)	0.0 (ND)	0.2 (J)	0.3 (J)	0.0 (ND)	0.1 (J)
19	69	0.4 (J)	1.7	3.0	4.6	3.6	5.1	5.3	2.6
20	70	0.1 (J)	0.0 (ND)	0.0 (ND)	0.0 (ND)	0.4 (J)	0.4 (J)	0.0 (ND)	0.1 (J)
20	71	0.1 (J)	0.0 (ND)	0.0 (ND)	0.0 (ND)	1.2	1.2 (J)	1.9 (J)	0.6
20	72	0.2 (J)	0.0 (ND)	0.0 (ND)	0.0 (ND)	0.3 (J)	0.2 (J)	0.0 (ND)	0.1 (J)
21	73	0.3 (J)	3.8	5.7	8.4	8.6	9.5	8.9	3.9
21	74	1.1	3.7	4.7	12.0	11.1	10.2	10.5	5.7
21	75	0.8	2.0	4.4	4.8	5.8	6.4	5.6	3.2

ND (not detected); J (below method detection limit)

Appendix F. Sediment PAH concentrations (continued).

Stratum Number	Site Number	Chrysene	C1-Chrysenes	C2-Chrysenes	C3-Chrysenes	C4-Chrysenes	Benzo(b)-fluoranthene	Benzo(k)-fluoranthene	Benzo(e)pyrene	Benzo(a)pyrene
1	1	2.3	3.1	5.0	0.0 (ND)	0.0 (ND)	3.8	1.2	2.9	3.7
1	2	35.9	67.7	80.9	8.5	12.9	55.0	19.3	37.2	54.0
1	3	81.1	88.3	96.9	9.0	27.6	119.4	30.0	70.4	107.7
2	4	2.1	2.7	2.9	0.0 (ND)	0.0 (ND)	3.5	0.8	2.4	2.9
2	5	22.2	57.7	113.0	12.3	4.4	18.4	4.8	26.0	18.6
2	6	20.5	19.0	31.3	2.7 (J)	11.8	39.1	8.4	25.4	29.9
3	7	11.1	13.1	25.9	2.1 (J)	4.5	17.4	4.0	12.5	15.4
3	8	55.9	50.8	52.7	0.3 (J)	10.1	136.4	30.6	61.6	95.9
3	9	41.6	25.7	39.8	2.2 (J)	7.9	47.7	12.6	26.2	37.2
4	10	5.4	4.9	7.3	0.9 (J)	2.6	8.5	3.0	5.3	6.9
4	11	7.2	7.4	8.5	1.2 (J)	2.7	11.3	2.3	6.3	8.8
4	12	0.2 (J)	0.0 (ND)	0.0 (ND)	0.0 (ND)	0.0 (ND)	0.6 (J)	0.3 (J)	0.3 (J)	0.4 (J)
5	13	34.6	22.3	32.1	3.1	4.9	33.0	11.6	20.1	27.1
5	14	27.5	27.5	35.0	1.6 (J)	4.8	33.3	10.2	19.3	28.3
5	15	13.2	9.1	17.1	0.8 (J)	2.1	18.8	6.9	11.0	14.9
6	16	8.9	16.9	29.5	5.7	2.7 (J)	18.8	4.6	12.0	14.1
6	17	9.3	15.8	19.7	3.4 (J)	3.0 (J)	15.6	4.6	10.8	11.6
6	18	11.7	12.7	17.0	1.9 (J)	3.3	17.1	3.9	10.2	13.6
7	19	13.6	7.6	10.6	2.0 (J)	2.2 (J)	20.6	6.7	14.7	17.0
7	20	17.6	44.3	57.2	3.8	0.8 (J)	24.6	4.9	14.6	19.8
7	21	8.7	10.6	16.0	0.0 (ND)	0.0 (ND)	14.8	5.1	9.9	16.0
8A	22	58.3	31.8	13.8	1.6 (J)	3.5	123.2	33.7	60.2	78.4
8A	23	54.1	25.8	22.7	2.0 (J)	5.4	107.3	35.0	54.8	66.2
8A	24	36.3	19.3	14.5	1.7 (J)	4.0	62.9	24.7	33.3	43.8
8	25	12.2	13.5	25.6	4.2	3.1 (J)	23.5	11.6	15.8	20.1
8	26	6.5	9.9	13.0	0.2 (J)	1.4 (J)	12.8	3.5	7.9	9.9
8	27	9.1	12.3	17.3	1.6 (J)	2.0	16.0	3.4	9.1	12.6
8	28	6.2	9.5	16.7	2.0 (J)	1.5 (J)	11.2	3.7	7.0	9.4
9	29	8.6	5.8	8.5	0.0 (ND)	0.0 (ND)	10.1	2.2	5.2	8.1
9	30	7.1	6.3	7.7	0.0 (ND)	0.0 (ND)	10.8	2.8	6.4	8.9
9	31	8.6	7.4	10.6	2.1(J)	2.8	11.8	4.3	7.8	10.6
9	32	711.6	254.9	194.7	8.4	68.8	800.4	178.7	335.3	684.4
10	33	10.3	8.7	4.6	0.0 (ND)	1.9	13.4	4.9	6.2	10.7
10	34	5.2	4.3	7.3	0.0 (ND)	0.0 (ND)	7.9	1.8	4.5	6.2
10	35	2.0	1.3 (J)	2.1	0.0 (ND)	0.0 (ND)	3.1	0.6 (J)	1.8	2.3
10	36	4.2	3.3	3.3	0.4 (J)	1.9 (J)	7.1	1.4	3.6	5.5
10	37	1.4	1.3 (J)	1.5	0.0 (ND)	0.0 (ND)	2.1	0.7	1.2	1.7

ND (not detected); J (below method detection limit)

Appendix F. Sediment PAH concentrations (continued).

Stratum Number	Site Number	Chrysene	C1-Chrysenes	C2-Chrysenes	C3-Chrysenes	C4-Chrysenes	Benzo(b)-fluoranthene	Benzo(k)-fluoranthene	Benzo(e)pyrene	Benzo(a)pyrene
11	38	3.1	3.4	2.6	0.0 (ND)	0.0 (ND)	5.2	1.6	3.1	4.2
11	39	4.9	5.1	4.1 (J)	0.0 (ND)	0.0 (ND)	8.3	2.3	4.6	6.6
11	40	34.4	30.0	35.0	3.2 (J)	9.6	52.4	17.8	25.6	49.5
11	41	2.1	2.1 (J)	2.5	0.0 (ND)	0.0 (ND)	3.7	1.2	2.0	2.7
12	42	3.1	2.9	2.6	0.0 (ND)	0.0 (ND)	4.9	1.2	2.5	3.6
12	43	1.3	1.7 (J)	2.0 (J)	0.0 (ND)	0.0 (ND)	2.2	0.6 (J)	1.3	1.6
12	44	5.7	3.6	2.4	0.0 (ND)	0.0 (ND)	8.8	2.2	4.6	7.2
13	45	5.1	3.6	3.8	0.0 (ND)	0.0 (ND)	6.4	2.3	4.1	6.6
13	46	2.4	1.9 (J)	2.9	0.0 (ND)	0.0 (ND)	2.9	0.9	1.8	2.4
13	47	1.8	0.0 (ND)	0.0 (ND)	0.0 (ND)	0.0 (ND)	2.9	1.0	1.7	2.3
13	48	3.0	5.2	7.6	0.0 (ND)	0.0 (ND)	3.8	3.8	3.4	3.9
13	49	2.0	1.7 (J)	2.4	0.0 (ND)	0.0 (ND)	2.5	0.7 (J)	1.7	1.9
14	50	37.9	22.0	14.2	0.7 (J)	4.1	57.4	11.5	26.2	44.6
14	51	6.0	3.6	3.8	0.0 (ND)	0.0 (ND)	9.5	2.0	5.1	7.2
14	52	156.2	71.2	37.1	2.5	8.4	204.1	71.3	98.5	180.3
15	53	2.7	0.0 (ND)	0.0 (ND)	0.0 (ND)	0.0 (ND)	3.0	0.6	1.7	2.6
15	54	2.7	3.1	2.3	0.0 (ND)	0.0 (ND)	5.2	1.6	3.0	4.5
15	55	1.6	1.2 (J)	1.4 (J)	0.0 (ND)	0.0 (ND)	2.5	0.4 (J)	1.4	2.0
15	56	6.7	6.1	8.8	0.0 (ND)	2.0	9.5	2.5	5.6	9.1
15	57	0.6 (J)	0.0 (ND)	0.0 (ND)	0.0 (ND)	0.0 (ND)	0.2 (J)	0.1 (J)	0.1 (J)	0.2 (J)
16	58	2.6	2.0	2.7	0.0 (ND)	0.7 (J)	4.3	4.2	2.0	2.6
16	59	12.1	5.6	6.2	0.6 (J)	2.5	15.2	6.0	8.8	13.9
16	60	6.4	2.9	3.0	0.8 (J)	1.2 (J)	7.1	1.2	4.1	5.1
17	61	4.5	6.3	8.4	0.0 (ND)	0.0 (ND)	7.7	2.3	5.0	5.6
17	62	1.8	0.0 (ND)	0.0 (ND)	0.0 (ND)	0.0 (ND)	1.9	0.3 (J)	1.0	1.1
17	63	3.2	3.0	4.1	1.0 (J)	1.4 (J)	3.8	1.1	2.8	3.0
18	64	0.1 (J)	0.0 (ND)	0.0 (ND)	0.0 (ND)	0.0 (ND)	0.1 (J)	0.1 (J)	0.1 (J)	0.1 (J)
18	65	0.1 (J)	0.0 (ND)	0.0 (ND)	0.0 (ND)	0.0 (ND)	0.2 (J)	0.1 (J)	0.1 (J)	0.1 (J)
18	66	0.1 (J)	0.0 (ND)	0.0 (ND)	0.0 (ND)	0.0 (ND)	0.1 (J)	0.1 (J)	0.1 (J)	0.1 (J)
19	67	1.3	1.9	2.0	0.0 (ND)	0.0 (ND)	1.4 (J)	0.4 (J)	1.1	1.0
19	68	0.2 (J)	0.0 (ND)	0.0 (ND)	0.0 (ND)	0.0 (ND)	0.2 (J)	0.1 (J)	0.2 (J)	0.1 (J)
19	69	3.9	3.6	4.0	0.8 (J)	1.3 (J)	4.5	1.2	3.1	3.6
20	70	0.2 (J)	0.0 (ND)	0.0 (ND)	0.0 (ND)	0.0 (ND)	0.2 (J)	0.1 (J)	0.2 (J)	0.2 (J)
20	71	0.9	0.8 (J)	1.2 (J)	0.0 (ND)	0.0 (ND)	1.6	0.4 (J)	0.9	1.1
20	72	0.2 (J)	0.0 (ND)	0.0 (ND)	0.0 (ND)	0.0 (ND)	0.1 (J)	0.0 (J)	0.1 (J)	0.1 (J)
21	73	4.4	6.5	11.7	1.3 (J)	0 (ND)	7.1	2.4	4.6	5.3
21	74	6.5	7.2	13.9	1.4 (J)	1.8 (J)	8.9	2.7	5.3	5.9
21	75	4.6	3.2	4.5	0.0 (ND)	1.8 (J)	5.9	1.6	3.5	4.5

ND (not detected); J (below method detection limit)

Appendix F. Sediment PAH concentrations (continued).

Stratum Number	Site Number	Perylene	Indeno(1,2,3 c,d)pyrene	Dibenzo(a,h) anthracene	Benzo(g,h,i) perylene	2-Methyl-naphthalene	1-Methyl-naphthalene	2,6-Dimethyl-naphthalene	1,6,7-Trimethyl-naphthalene	1-Methyl-phenanthrene
1	1	2.4	2.9	0.6	5.0	0.7 (J)	0.5 (J)	0.5 (J)	0.5	0.4
1	2	40.4	33.6	8.9	49.7	10.4	5.1	4.0	4.0	4.3
1	3	52.4	65.5	15.0	102.0	11.0	7.7	8.7	10.0	12.3
2	4	2.4	2.3	0.5 (J)	3.8	0.9 (J)	0.8 (J)	0.4 (J)	0.4	0.3
2	5	18.4	8.7	2.9	17.9	5.6	2.6	4.9	4.8	10.3
2	6	20.5	25.3	5.6	41.3	5.0	4.3	3.7	1.1 (J)	2.4
3	7	16.2	8.6	1.9	14.9	3.6	2.2	3.1	2.5	2.3
3	8	36.8	38.6	9.2	48.2	4.4	2.6	5.1	5.0	3.6
3	9	32.7	16.5	4.0	24.4	5.5	3.2	4.5	2.6	4.0
4	10	6.8	3.8	1.0	5.5	2.3	1.2 (J)	1.7	0.3 (J)	1.0
4	11	10.1	4.8	1.3	6.6	2.0 (J)	1.0 (J)	0.0 (ND)	0.0 (ND)	0.9
4	12	0.4 (J)	0.3	0.1 (J)	0.3 (J)	0.2 (J)	0.3 (J)	0.0 (ND)	0.0 (ND)	0.1 (J)
5	13	26.4	14.5	3.5	20.4	4.1	3.1	3.5	3.0	3.2
5	14	34.0	13.7	3.6	18.6	3.4	2.1	2.4	3.8	3.1
5	15	11.5	8.2	2.0	10.7	2.5	1.1 (J)	1.1	1.2	1.5
6	16	32.9	14.1	3.2	19.1	3.1 (J)	4.2	2.4	0.7 (J)	1.8
6	17	47.4	10.9	2.6	16.3	9.5	3.1	4.2	2.9	2.2
6	18	19.0	8.3	1.9	12.6	3.9	2.0 (J)	2.4	1.0	1.6
7	19	13.1	12.1	2.8	19.8	2.9 (J)	2.3	2.9	0.9	2.0
7	20	10.8	13.5	2.9	16.7	3.9	2.1	1.9	1.9	4.6
7	21	5.7	12.1	2.4	16.2	3.3	2.6	0.0 (ND)	0.0 (ND)	1.8
8A	22	27.1	81.2	15.2	70.6	0.3 (J)	0.2 (J)	0.0 (ND)	0.0 (ND)	1.9
8A	23	47.2	72.4	14.1	67.1	1.7 (J)	1.5 (J)	0.0 (ND)	0.0 (ND)	2.7
8A	24	16.2	40.1	7.8	35.9	1.7 (J)	2.1	0.0 (ND)	0.0 (ND)	3.2
8	25	11.4	19.9	4.1	25.8	3.0 (J)	2.5 (J)	0.0 (ND)	0.0 (ND)	2.9
8	26	5.2	9.8	5.5	12.2	2.8 (J)	2.0	0.0 (ND)	0.0 (ND)	1.2
8	27	8.4	11.4	2.3	13.3	3.4	2.0	1.6	0.3 (J)	1.8
8	28	5.1	9.3	1.8	13.1	2.6 (J)	2.0	0.0 (ND)	0.0 (ND)	1.4
9	29	19.2	3.9	1.2	5.7	2.1 (J)	1.1 (J)	1.5	1.1	1.3
9	30	12.3	5.0	1.2	8.3	2.0 (J)	1.0 (J)	0.9 (J)	0.9	1.0
9	31	12.4	6.0	1.6	9.2	2.0 (J)	1.7 (J)	2.4	0.6 (J)	1.0
9	32	187.2	291.5	66.1	289.5	3.2 (J)	1.4 (J)	3.7	5.6	53.6
10	33	3.0	4.7	1.5	4.6	1.1 (J)	0.7 (J)	0.8	0.6	1.0
10	34	9.5	4.0	1.3	5.5	3.3 (J)	2.9	1.3	1.0	1.0
10	35	3.1	1.5	0.5 (J)	2.0	1.0 (J)	0.7 (J)	0.4 (J)	0.6	0.4
10	36	5.0	3.5	1.1	4.4	2.4 (J)	1.6	1.5	0.5 (J)	0.6
10	37	1.3	1.1	1.1	1.8	1.2 (J)	0.4 (J)	0.2 (J)	0.3 (J)	0.3

ND (not detected); J (below method detection limit)

Appendix F. Sediment PAH concentrations (continued).

Stratum Number	Site Number	Perylene	Indeno(1,2,3-c,d)pyrene	Dibenzo(a,h) anthracene	Benzo(g,h,i) perylene	2-Methyl-naphthalene	1-Methyl-naphthalene	2,6-Dimethyl-naphthalene	1,6,7-Trimethyl-naphthalene	1-Methyl-phenanthrene
11	38	4.8	2.8	0.7 (J)	4.1	0.8 (J)	1.1 (J)	1.3	0.4 (J)	0.5
11	39	6.6	4.7	1.2 (J)	6.6	2.4 (J)	2.3 (J)	2.2	0.7 (J)	0.8
11	40	14.3	26.3	7.3	26.0	2.6 (J)	1.2 (J)	1.0 (J)	0.4 (J)	1.8
11	41	13.2	1.9	0.4 (J)	2.6	1.4 (J)	1.2 (J)	1.0 (J)	0.3 (J)	0.6
12	42	7.6	2.3	0.7 (J)	3.3	1.1 (J)	0.6 (J)	0.9 (J)	0.8	0.5
12	43	4.9	1.2	0.3 (J)	1.8 (J)	0.7 (J)	0.5 (J)	0.4 (J)	0.8	0.4
12	44	5.0	4.2	1.1	4.6	0.6 (J)	0.6 (J)	1.0	0.4 (J)	0.5
13	45	3.6	3.2	0.8	3.5	1.2 (J)	0.6 (J)	0.5 (J)	0.5 (J)	0.8
13	46	4.0	1.5	0.3 (J)	2.3	1.7 (J)	0.8 (J)	0.8 (J)	0.7	1.0
13	47	2.4	1.5	0.4 (J)	2.0	1.2 (J)	0.8 (J)	0.9	0.3 (J)	0.4
13	48	3.0	1.9	0.8	3.3	1.4 (J)	1.3 (J)	0.7 (J)	0.5 (J)	1.1
13	49	3.0	1.4	0.4 (J)	2.2 (J)	1.6 (J)	1.2 (J)	0.6 (J)	0.8	0.5
14	50	17.3	20.5	6.6	22.9	5.8	1.8	1.5	1.7	2.2
14	51	4.5	4.3	2.1	6.7	1.0 (J)	0.7 (J)	0.8	0.3 (J)	0.9
14	52	40.2	70.3	20.6	66.4	2.0 (J)	1.8	1.4	1.9	5.6
15	53	0.8	1.6	0.6	2.5	0.4 (J)	0.8 (J)	0.7	0.4 (J)	0.4
15	54	1.6	2.6	1.1	4.6	1.3 (J)	1.1 (J)	0.6 (J)	0.6	0.7
15	55	1.7	1.2	0.3 (J)	1.7	0.6 (J)	1.0 (J)	0.8	0.2 (J)	0.3
15	56	2.3	5.0	1.5	8.9	1.9	1.0 (J)	1.1	1.3	1.3
15	57	0.4 (J)	0.1 (J)	0.1 (J)	0.3 (J)	0.8 (J)	1.3 (J)	0.8 (J)	0.7	0.3 (J)
16	58	4.2	1.6	0.6 (J)	1.9	1.4 (J)	1.0 (J)	1.3	0.9	0.7
16	59	5.8	11.7	4.6	12.2	2.9	4.2	1.7	0.2 (J)	0.7
16	60	5.9	2.9	0.9	3.8	1.1 (J)	0.8 (J)	0.7 (J)	0.4 (J)	0.6
17	61	7.8	4.9	1.7	5.7	1.6 (J)	1.7	1.8	0.0 (ND)	1.0
17	62	1.7	0.7	0.5 (J)	0.9 (J)	0.4 (J)	0.6 (J)	0.4 (J)	0.6	0.5
17	63	8.6	1.8	0.6 (J)	2.9	2.1 (J)	1.4 (J)	1.9	1.6	1.2
18	64	0.3 (J)	0.1 (J)	0.1 (J)	0.1 (J)	0.4 (J)	0.4 (J)	0.2 (J)	0.4	0.1 (J)
18	65	0.2 (J)	0.1 (J)	0.1 (J)	0.1 (J)	0.5 (J)	0.3 (J)	0.1 (J)	0.4 (J)	0.2
18	66	0.3 (J)	0.1 (J)	0.1 (J)	0.1 (J)	1.4 (J)	0.8 (J)	0.4 (J)	0.2 (J)	0.2
19	67	4.3	0.7	0.3 (J)	0.9 (J)	1.3 (J)	0.8 (J)	1.3	0.4 (J)	0.5
19	68	0.4 (J)	0.1 (J)	0.1 (J)	0.1 (J)	0.4 (J)	0.4 (J)	0.4 (J)	0.2 (J)	0.1 (J)
19	69	11.9	2.3	0.8	2.9	2.9	1.4	1.7	1.3	1.1
20	70	0.6 (J)	0.2 (J)	0.1 (J)	0.2 (J)	1.0 (J)	0.5 (J)	0.3 (J)	0.5	0.1 (J)
20	71	1.9	0.8	0.3 (J)	1.0 (J)	1.0 (J)	0.3 (J)	1.0	0.4 (J)	0.3
20	72	0.4 (J)	0.1 (J)	0.0 (J)	0.1 (J)	0.3 (J)	0.3 (J)	0.3 (J)	0.7	0.2 (J)
21	73	12.4	4.2	1.2	4.7	3.2 (J)	2.8	4.7	3.0	2.8
21	74	12.3	5.6	1.2	6.0	3.9	2.2	2.4	2.2	1.6
21	75	7.2	3.2	1.0 (J)	3.7	2.7 (J)	1.6 (J)	2.6	2.0	0.8

ND (not detected); J (below method detection limit)

Appendix G
Ancillary Amphipod Toxicity Measurements

Appendix G. Ancillary amphipod toxicity measurements.

Sample Number	Date Sample Collected	Sample Receipt Date	Arrival Temp. (oC)	Date Sample Sieved	Sieve Size	Date Sample Tested	Days Lapsed from Collection to Testing	Survival (%)	Total Ammonia (mg/L)	Temp (oC)	Salinity (ppt)	pH	Un-ionized Ammonia (mg/L)	Control Performance Series
1	8/5/96	8/12/96	20	8/12/96	2mm	8/13/96	8	99	1	20	25	8.2	0.06	7
2	8/5/96	8/12/96	20	8/12/96	1mm	8/13/96	8	98	2.22	20	16	8.3	0.16	7
3	8/5/96	8/12/96	20	8/12/96	1mm	8/13/96	8	100	3.16	20	26	8.1	0.15	7
4	8/5/96	8/12/96	20	8/12/96	1mm	8/13/96	8	97	1.06	20	24	8.2	0.06	7
5	8/6/96	8/12/96	20	8/12/96	1mm	8/13/96	8	97	0.91	20	26	8.2	0.05	7
6	8/6/96	8/9/96	11	8/12/96	1mm	8/13/96	7	100	0.72	20	25	8.2	0.04	5
7	8/6/96	8/9/96	11	8/12/96	1mm	8/13/96	7	96	1.17	20	26	8.2	0.07	5
8	8/6/96	8/9/96	11	8/12/96	1mm	8/13/96	7	98	2.88	20	22	8.2	0.17	5
9	8/6/96	8/9/96	11	8/12/96	1mm	8/13/96	7	97	1.5	20	25	8.2	0.09	5
10	8/7/96	8/9/96	10	8/12/96	1mm	8/13/96	6	98	0.48	20	27	8.2	0.03	6
11	8/7/96	8/9/96	13	8/12/96	1mm	8/13/96	6	100	1.66	20	22	8.2	0.1	5
12	8/6/96	8/9/96	13	8/12/96	1mm	8/13/96	7	100	0.64	20	20	8.3	0.05	5
13	8/6/96	8/9/96	13	8/12/96	1mm	8/13/96	7	100	1.95	20	24	8.2	0.12	5
14	8/6/96	8/9/96	13	8/12/96	1mm	8/13/96	7	100	3.34	20	20	8.2	0.2	5
15	8/6/96	8/9/96	13	8/12/96	1mm	8/13/96	7	98	0.94	20	26	8.2	0.06	6
16	8/7/96	8/9/96	9	8/12/96	1mm	8/13/96	6	96	0.57	20	30	8.2	0.04	6
17	8/7/96	8/9/96	9	8/12/96	1mm	8/13/96	6	95	13.2	20	25	8.2	0.78	6
18	8/7/96	8/9/96	11	8/12/96	1mm	8/13/96	6	100	1.17	20	28	8.1	0.06	6
19	8/7/96	8/9/96	9	8/12/96	1mm	8/13/96	6	98	1.07	20	27	8.2	0.06	6
20	8/7/96	8/9/96	9	8/12/96	1mm	8/13/96	6	97	0.6	20	28	8.2	0.04	6
21	8/7/96	8/9/96	9	8/12/96	1mm	8/13/96	6	99	0.85	20	27	8.2	0.05	7
22	8/8/96	8/16/96	14	8/19/96	2mm	8/20/96	12	97	0.78	20	27	8.19	0.05	8
23	8/8/96	8/16/96	14	8/19/96	2mm	8/20/96	12	97	1.13	20	27	8.2	0.07	9
24	8/8/96	8/16/96	14	8/19/96	2mm	8/20/96	12	93	1.67	20	26	8.2	0.1	9
25	8/8/96	8/16/96	14	8/19/96	2mm	8/20/96	12	100	1.46	20	25	8.27	0.11	9
26	8/9/96	8/16/96	11	8/19/96	2mm	8/20/96	11	95	0.67	20	28	8.2	0.04	8
27	8/9/96	8/16/96	11	8/19/96	2mm	8/20/96	11	97	0.46	20	28	8.15	0.03	8
28	8/9/96	8/16/96	11	8/19/96	2mm	8/20/96	11	100	0.64	20	27	8.15	0.04	8
29	8/7/96	8/9/96	10	8/12/96	1mm	8/13/96	6	98	0.66	20	28	8.2	0.04	7
30	8/7/96	8/9/96	10	8/12/96	1mm	8/13/96	6	89	0.83	20	28	8.2	0.05	7
31	8/7/96	8/9/96	9	8/12/96	1mm	8/13/96	6	96	3.94	25	25	8.1	0.263	7
32	7/31/96	8/9/96	10	N/A	0	8/9/96	9	100	0.15	20	30	8.5	0.02	4
33	8/1/96	8/2/96	12	N/A	0	8/6/96	5	99	0.78	21	30	8.2	0.05	3
34	7/31/96	8/2/96	12	N/A	0	8/6/96	6	96	0.22	21	29	8.2	0.01	3
35	7/31/96	8/2/96	12	N/A	0	8/6/96	6	99	0.15	21	28	8.1	0.007	3
36	8/1/96	8/2/96	12	N/A	0	8/6/96	5	98	0.14	21	30	8.2	0.008	3
37	8/1/96	8/2/96	12	N/A	0	8/6/96	5	100	1.92	20	29	8.2	0.11	3
38	8/2/96	8/9/96	8	N/A	0	8/9/96	7	98	0.24	20	26	8.3	0.02	4
39	8/2/96	8/9/96	8	N/A	0	8/9/96	7	93	0.6	20	30	8.4	0.05	4
40	8/2/96	8/9/96	8	N/A	0	8/9/96	7	99	0.27	20	30	8.6	0.04	4

Appendix G. Ancillary amphipod toxicity measurements (continued).

Sample Number	Date Sample Collected	Sample Receipt Date	Arrival Temp. (oC)	Date Sample Sieved	Sieve Size	Date Sample Tested	Days Lapsed from Collection to Testing	Survival (%)	Total Ammonia (mg/L)	Temp (oC)	Salinity (ppt)	pH	Un-ionized Ammonia (mg/L)	Control Performance Series
41	8/2/96	8/9/96	8	N/A	0	8/9/96	7	99	0.38	20	28	8.3	0.03	4
42	8/2/96	8/9/96	9	N/A	0	8/9/96	7	97	0.44	20	22	8.6	0.06	4
43	8/2/96	8/9/96	9	N/A	0	8/9/96	7	97	0.26	20	30	8.5	0.03	4
44	8/2/96	8/9/96	9	N/A	0	8/9/96	7	91	27.6	25	25	8.2	2.28	2
45	7/31/96	8/2/96	12	N/A	0	8/6/96	6	94	0.28	20	28	8.2	0.02	2
46	7/31/96	8/2/96	12	N/A	0	8/6/96	6	97	0.76	20	30	7.9	0.02	2
47	7/31/96	8/2/96	12	N/A	0	8/6/96	6	98	0.48	20	28	8	0.02	2
48	7/31/96	8/2/96	14	N/A	0	8/6/96	6	98	0.37	20	28	8.1	0.02	2
49	7/31/96	8/2/96	14	N/A	0	8/6/96	6	100	1.24	20	24	8.1	0.06	3
50	7/30/96	8/2/96	14	N/A	0	8/6/96	7	95	1.33	20	31	7.7	0.03	1
51	7/31/96	8/2/96	14	N/A	0	8/6/96	7	97	0.84	20	31	8.2	0.05	1
52	7/30/96	8/2/96	16	N/A	0	8/6/96	7	96	0.46	20	31	8	0.02	1
53	7/30/96	8/2/96	9	N/A	0	8/6/96	7	97	0.85	20	31	8.2	0.05	1
54	7/30/96	8/2/96	16	N/A	0	8/6/96	7	98	0.44	20	30	8.1	0.02	1
55	7/30/96	8/2/96	16	N/A	0	8/6/96	7	96	1.35	20	33	8.1	0.06	1
56	7/30/96	8/2/96	9	N/A	0	8/6/96	7	99	4.14	20	32	7.5	0.05	2
57	7/30/96	8/2/96	9	N/A	0	8/6/96	7	94	1.1	20	23	7.9	0.03	2
58	8/12/96	8/16/96	11	8/19/96	2mm	8/20/96	8	96	2.9	20	30	8.15	0.17	8
59	8/14/96	8/16/96	11	8/19/96	2mm	8/20/96	6	99	4.5	20	30	8.11	0.21	9
60	8/15/96	8/16/96	11	8/19/96	2mm	8/20/96	5	100	2.7	20	30	8.11	0.13	9
61	8/12/96	8/16/96	5	8/19/96	1mm	20-Aug	8	100	4.66	20	32	8.12	0.22	8
62	8/15/96	8/16/96	11	8/19/96	2mm	8/20/96	5	97	0.99	20	30	8.21	0.06	9
63	8/14/96	8/16/96	10	8/19/96	1mm	8/20/96	6	96	1.35	20	30	8.16	0.08	9
64	8/14/96	8/16/96	10	8/19/96	2mm	8/20/96	6	88	1.99	20	30	8.08	0.09	9
65	8/13/96	8/16/96	10	8/19/96	2mm	8/20/96	7	99	0.02	20	32	8.06	0.001	10
66	8/13/96	8/16/96	5	8/19/96	2mm	8/20/96	7	100	14.37	20	32	8.13	0.68	8
67	8/14/96	8/16/96	5	8/19/96	2mm	8/20/96	6	99	3.28	20	31	8.18	0.19	8
68	8/14/96	8/16/96	13	8/19/96	1mm	8/20/96	6	100	1.46	20	30	8.05	0.07	10
69	8/14/96	8/16/96	13	8/19/96	1mm	8/20/96	6	100	0.01	20	30	8.16	0.001	10
70	8/13/96	8/16/96	13	8/19/96	2mm	8/20/96	7	98	0.01	20	31	8.12	0.001	10
71	8/13/96	8/16/96	13	8/19/96	1mm	8/20/96	7	92	53.7	20	32	8.22	3.18	10
72	8/13/96	8/16/96	12	8/19/96	2mm	8/20/96	7	99	43.01	20	31	8.12	2.05	10
73	8/12/96	8/16/96	12	8/19/96	2mm	8/20/96	8	100	8.86	20	31	8.18	0.52	10
74	8/12/96	8/16/96	12	8/19/96	2mm	8/20/96	8	97	7.96	20	33	8.19	0.46	10
75	8/12/96	8/16/96	12	8/19/96	1mm	8/20/96	8	99	6.59	20	31	8.19	0.4	10
C-17-A									0.95	20	27	8.1	0.05	1
C-17-B									0.9	20	26	8	0.03	1
C-17-C									0.86	20	26	8.1	0.04	1
C-17-D									2.46	20	25	8.2	0.15	2
C-17-E									3.05	20	25	8	0.12	2
C-17-F									1.68	20	27	8.1	0.08	3
C-17-I									0.01	20	27	8.1	0.001	4
31-dup									3.02	25	25	8.1	0.202	7
44-dup									39.3	25	25	8.2	3.25	2
70-dup									0.01	20	31	8.12	0.001	10

Appendix H

Ancillary Porewater Toxicity Measurements

Appendix H. Ancillary porewater toxicity measurements.

Strata	Sample	Salinity	DO	%Sat	pH	TAN	UAN	Sulfide	% OUS
	REF1	26	7.3	96.7	8.13	0.94	39.3	< 0.1	94
	REF2	26	6.7	89	7.94	0.89	24.4	< 0.1	94
1	1	16	7.03	93.8	8.08	1.07	40.1	< 0.1	82
1	2	14	7.06	94	7.99	1.69	51.8	< 0.1	81
1	3	17	7.08	93.8	7.83	7.12	152.4	< 0.1	83
2	4	16	7.02	92.4	8.04	1.1	37.7	< 0.1	82
2	5	17	7.18	95.3	7.88	1.51	36.2	< 0.1	83
2	6	15	6.81	90.5	8.02	1.24	40.6	< 0.1	82
3	7	17	7.33	96.7	7.89	1.89	46.3	< 0.1	83
3	8	16.5	7.29	96.7	7.88	2.57	61.6	< 0.1	83
3	9	18	7.28	96.9	7.94	2.29	62.8	< 0.1	85
4	10	20	7.04	93.7	7.94	0.8	21.9	< 0.1	87
4	11	20	6.65	88.2	7.78	1.35	25.8	< 0.1	87
4	12	19	7.16	94.6	7.85	0.27	6.0	< 0.1	86
5	13	19	7.1	94	7.88	1.97	47.2	< 0.1	86
5	14	19	7.07	93.8	7.82	2.13	44.6	< 0.1	86
5	15	19	6.92	92.1	7.89	1.46	35.8	< 0.1	86
6	16	20	6.61	88.2	7.62	1.31	17.4	< 0.1	87
6	17	21	6.84	90.7	7.22	10.3	55.0	< 0.1	88
6	18	21	7.12	94.6	7.84	1.45	31.8	< 0.1	88
7	19	20	7.17	94.7	7.77	1.28	23.9	< 0.1	87
7	20	21	6.95	92.3	7.9	0.94	23.6	< 0.1	88
7	21	21	6.65	88.8	7.85	0.8	17.9	< 0.1	88
8A	22	18	9.79	90.9	8.1	1.64	64.2	< 0.1	85
8A	23	18	6.89	92.4	8	2.08	65.2	< 0.1	85
8A	24	19	6.79	90.9	8.02	2.89	94.7	< 0.1	86
8	25	21	6.85	91.4	7.91	1.65	42.3	< 0.1	88
8	26	22	6.56	87.3	7.94	1.06	29.1	< 0.1	89
8	27	22	6.57	88.4	7.78	1.16	22.2	< 0.1	89
8	28	21	6.79	90.5	7.88	1.3	31.1	< 0.1	88
9	29	22	6.91	91.6	7.75	1.31	23.4	< 0.1	89
9	30	22	6.5	86	7.8	1.4	28.0	< 0.1	89
9	31	22	6.69	88.4	7.86	1.22	27.9	< 0.1	89
9	32	24	6.95	91.7	7.86	0.82	18.8	< 0.1	92
10	33	32	6.91	90.9	8.16	1.03	46.0	< 0.1	94
10	34	28	6.94	92.3	7.8	0.45	9.0	< 0.1	97
10	35	24	6.85	91	7.77	0.5	9.3	< 0.1	92
10	36	30	6.49	86.4	7.84	0.47	10.3	< 0.1	100
10	37	28	6.5	86.8	8.04	1.11	38.0	< 0.1	97
11	38	17	6.89	89.2	8	1.64	51.4	< 0.1	83
11	39	22	6.67	87.9	7.67	3.51	52.3	< 0.1	89
11	40	18	6.61	87.6	8.02	1.64	53.7	< 0.1	85
11	41	18	7.65	98.6	8.02	1.92	62.9	< 0.1	85

Appendix H. Ancillary porewater toxicity measurements (continued).

Strata	Sample	Salinity	DO	%Sat	pH	TAN	UAN	Sulfide	% OUS
12	42	13	7.27	96.2	8.01	1	32.1	< 0.1	79
12	43	17	6.45	85.9	7.97	1.52	44.6	< 0.1	83
12	44	18	6.63	87.9	8.01	1.7	54.5	< 0.1	85
13	45	24	6.89	91.2	7.73	0.78	13.3	< 0.1	92
13	46	26	6.74	89.9	8.03	0.89	29.8	< 0.1	94
13	47	24	7.38	98.7	7.79	1.23	24.1	< 0.1	92
13	48	22	6.95	92	7.84	0.92	20.1	< 0.1	89
13	49	24	6.9	90.8	7.96	1.22	35.0	< 0.1	92
14	50	33	7.62	100.4	7.85	1.74	39.0	< 0.1	91
14	51	32	7.45	99.3	8.03	0.73	24.5	< 0.1	94
14	52	33	6.98	92	7.62	0.74	9.8	< 0.1	91
15	53	34	7.07	92.8	8.12	1.13	46.2	< 0.1	88
15	54	34	7.03	92.3	7.96	0.95	27.2	< 0.1	88
15	55	36	7.41	97.8	7.8	0.69	13.8	< 0.1	83
15	56	33	6.34	83.8	7.79	2.08	40.7	< 0.1	91
15	57	32.5	7	92	7.65	1.07	15.2	< 0.1	92
16	58	33.5	6.84	90.2	7.82	6.85	143.4	< 0.1	90
16	59	34	6.88	90.7	7.81	1.96	40.1	< 0.1	88
16	60	34	6.89	90.9	7.68	6.06	92.4	< 0.1	88
17	61	34	6.92	91.1	7.78	4.97	95.1	< 0.1	88
17	62	35	7.19	94.8	7.8	1.77	35.4	< 0.1	86
17	63	34	6.88	91.6	7.68	3.39	51.7	< 0.1	88
18	64	36	6.38	85.3	7.88	0.95	22.8	< 0.1	83
18	65	36	6.86	91.6	8.01	0.55	17.6	< 0.1	83
18	66	36	6.93	92.4	7.96	0.66	18.9	< 0.1	83
19	67	34	6.57	87.3	7.93	3.29	88.2	< 0.1	88
19	68	34.5	6.48	85.8	7.89	1.36	33.3	< 0.1	87
19	69	34.5	7.18	94.9	7.83	2.24	48.0	< 0.1	87
20	70	36	7.1	93.9	7.92	1.34	35.1	< 0.1	83
20	71	36	6.9	91.2	7.93	1.64	44.0	< 0.1	83
20	72	36	6.65	88.2	8.14	1.17	50.0	< 0.1	83
21	73	34.5	7.2	95.9	7.7	5.38	85.9	< 0.1	87
21	74	34	6.53	87.1	7.84	4.13	90.4	< 0.1	88
21	75	34	6.43	85.4	7.87	4.49	105.2	< 0.1	88

Appendix I
Taxonomic Abundance

Appendix I. Taxa abundance and occurrence by strata and stations.

Taxa	Phylum	Class	Number of Individuals	Percent of Total Individuals	Cumul. %	Number of Strata Occurred	% Strata Occurred	Station Occurred	% Station Occurred	Comments
MEDIOMASTUS (LPIL)	A	Poly	1481	29.10	29.10	22	100	57	77.0	anteroir portions only, probably *M . ambiseta* : pygidium necessary for positive ID.
PARAPRIONOSPIO PINNATA	A	Poly	259	5.09	34.19	18	81.8	45	60.8	
PARANDALIA TRICUSPIS	A	Poly	188	3.69	37.89	14	63.6	30	40.5	
SCOLETOMA VERRILLI	A	Poly	146	2.87	40.75	8	36.4	16	21.6	
MALDANIDAE (LPIL)	A	Poly	139	2.73	43.49	4	18.2	7	9.5	fragmented portion, pygidium necessary for positive identification
POLYDORA CORNUTA	A	Poly	122	2.40	45.88	3	13.6	5	6.8	
MAGELONA SP.H	A	Poly	106	2.08	47.97	7	31.8	12	16.2	
RHYNCHOCOELA (LPIL)	R		104	2.04	50.01	22	100	41	55.4	no identifible characters
STREBLOSPIO BENEDICTI	A	Poly	104	2.04	52.05	8	36.4	12	16.2	
ISCHADIUM RECURVUM	M	Pele	90	1.77	53.82	3	13.6	3	4.1	
CIRROPHORUS LYRA	A	Poly	88	1.73	55.55	2	9.1	7	9.5	
TUBULANUS (LPIL)	R		85	1.67	57.22	16	72.7	34	45.9	genus is lowest identification level
MULINIA LATERALIS	M	Pele	78	1.53	58.75	9	40.9	15	20.3	
SIGAMBRA GRUBII	A	Poly	80	1.57	60.33	11	50	24	32.4	
ACTEOCINA CANALICULATA	M	Gast	71	1.40	61.72	3	13.6	6	8.1	
PELECYPODA (LPIL)	M	Pele	66	1.30	63.02	14	63.6	21	28.4	crushed shell and/or juvenile specimen
PARAMPHINOME SP.B	A	Poly	61	1.20	64.22	6	27.3	8	10.8	
TEXADINA SPHINCTOSTOMA	M	Gast	59	1.16	65.38	3	13.6	5	6.8	
COSSURA SOYERI	A	Poly	50	0.98	66.36	5	22.7	8	10.8	
BALANOGLOSSUS (LPIL)	He		49	0.96	67.32	6	27.3	11	14.9	fragmented
FABRICIA SP.A	A	Poly	48	0.94	68.26	1	4.5	1	1.4	
HYDROBIIDAE (LPIL)	M	Gast	45	0.88	69.15	7	31.8	7	9.5	crushed shell and /or juvenile specimen
BATEA CATHARINENSIS	C	Amph	44	0.86	70.01	2	9.1	2	2.7	
PODARKEOPSIS LEVIFUSCINA	A	Poly	44	0.86	70.88	9	40.9	19	25.7	
CLYMENELLA TORQUATA	A	Poly	40	0.79	71.66	1	4.5	2	2.7	
GLYCINDE SOLITARIA	A	Poly	40	0.79	72.45	12	54.5	22	29.7	
PROTOHAUSTORIUS SP.B	C	Amph	40	0.79	73.24	1	4.5	3	4.1	
ARICIDEA PHILBINAE	A	Poly	36	0.71	73.94	1	4.5	3	4.1	
NASSARIUS ACUTUS	M	Gast	36	0.71	74.65	6	27.3	12	16.2	
RANGIA CUNEATA	M	Pele	35	0.69	75.34	2	9.1	4	5.4	
LINEIDAE (LPIL)	R		33	0.65	75.99	7	31.8	9	12.2	family is lowest identification level
PRIONOSPIO (LPIL)	A	Poly	33	0.65	76.64	2	9.1	3	4.1	missing identification characters
ONUPHIS EREMITA OCULATA	A	Poly	32	0.63	77.26	3	13.6	3	4.1	
OWENIA FUSIFORMIS	A	Poly	31	0.61	77.87	4	18.2	8	10.8	
SIGAMBRA TENTACULATA	A	Poly	31	0.61	78.48	5	22.7	10	13.5	
ACANTHOHAUSTORIUS SP.C	C	Amph	29	0.57	79.05	2	9.1	4	5.4	

Appendix I. Taxa abundance and occurrence by strata and stations (continued).

Taxa	Phylum	Class	Number of Individuals	Percent of Total Individuals	Cumul. %	Number of Strata Occurred	% Strata Occurred	Station Occurred	% Station Occurred	Comments
LEITOSCOLOPLOS FRAGILIS	A	Poly	29	0.57	79.62	4	18.2	9	12.2	
SPIONIDAE (LPIL)	A	Poly	28	0.55	80.17	6	27.3	8	10.8	missing identification characters and/or immature specimen
MONTICELLINA DORSOBRANCHIALIS	A	Poly	26	0.51	80.68	2	9.1	3	4.1	
NEREIS MICROMMA	A	Poly	26	0.51	81.19	6	27.3	8	10.8	
OGYRIDES ALPHAEROSTRIS	C	Deca	25	0.49	81.69	12	54.5	17	23.0	
PERIPLOMATIDAE (LPIL)	M	Pele	25	0.49	82.18	2	9.1	3	4.1	juvenile specimen
BRANCHIOSTOMA (LPIL)	Ce		24	0.47	82.65	4	18.2	7	9.5	genus is lowest identification level
RICTAXIS PUNCTOSTRIATUS	M	Gast	24	0.47	83.12	1	4.5	2	2.7	
CARAZZIELLA HOBSONAE	A	Poly	23	0.45	83.57	2	9.1	3	4.1	
OLIGOCHAETA (LPIL)	A	Olig	23	0.45	84.02	9	40.9	10	13.5	marine specimens only identified to Class Oligochaeta
PERIPLOMA MARGARITACEUM	M	Pele	23	0.45	84.48	4	18.2	6	8.1	
MACOMA MITCHELLI	M	Pele	22	0.43	84.91	9	40.9	14	18.9	
MALMGRENIELLA SP.A	A	Poly	22	0.43	85.34	4	18.2	5	6.8	
PHORONIS (LPIL)	Ph		22	0.43	85.77	7	31.8	10	13.5	genus is lowest identification level
PINNIXA (LPIL)	C	Deca	22	0.43	86.21	9	40.9	11	14.9	appendages missing
SPIOCHAETOPTERUS OCULATUS	A	Poly	22	0.43	86.64	9	40.9	14	18.9	
LEITOSCOLOPLOS (LPIL)	A	Poly	20	0.39	87.03	6	27.3	8	10.8	anterior segments only, abdomenal segments necessary for species identification
CRASSOSTREA VIRGINICA	M	Pele	19	0.37	87.40	3	13.6	3	4.1	
OPHIUROIDEA (LPIL)	E	Ophi	19	0.37	87.78	5	22.7	6	8.1	central disk missing characters
AMPHIODIA ATRA	E	Ophi	18	0.35	88.13	2	9.1	2	2.7	
CIRRATULIDAE (LPIL)	A	Poly	16	0.31	88.45	3	13.6	5	6.8	
NEREIS SUCCINEA	A	Poly	16	0.31	88.76	6	27.3	7	9.5	
ANACHIS OBESA	M	Gast	15	0.29	89.05	1	4.5	2	2.7	
LEITOSCOLOPLOS ROBUSTUS	A	Poly	15	0.29	89.35	4	18.2	7	9.5	
HEMIPHOLIS ELONGATA	E	Ophi	14	0.28	89.62	2	9.1	3	4.1	
CAECUM JOHNSONI	M	Gast	13	0.26	89.88	2	9.1	2	2.7	
CALLIANASSIDAE (LPIL)	C	Deca	12	0.24	90.12	4	18.2	7	9.5	
PAGURUS (LPIL)	C	Deca	12	0.24	90.35	3	13.6	3	4.1	
CAPITELLIDAE (LPIL)	A	Poly	11	0.22	90.57	3	13.6	3	4.1	
GASTROPODA (LPIL)	M	Gast	11	0.22	90.78	8	36.4	9	12.2	
PINNIXA PEARSEI	C	Deca	11	0.22	91.00	4	18.2	5	6.8	
TURBONILLA (LPIL)	M	Gast	11	0.22	91.22	1	4.5	2	2.7	
CAPITELLA CAPITATA	A	Poly	10	0.20	91.41	4	18.2	7	9.5	
LISTRIELLA BARNARDI	C	Amph	10	0.20	91.61	4	18.2	5	6.8	
LYONSIA HYALINA FLORIDANA	M	Pele	10	0.20	91.81	1	4.5	2	2.7	
ODOSTOMIA WEBERI	M	Gast	10	0.20	92.00	2	9.1	4	5.4	
ASYCHIS ELONGATUS	A	Poly	9	0.18	92.18	2	9.1	4	5.4	
COROPHIUM (LPIL)	C	Amph	9	0.18	92.36	2	9.1	2	2.7	
DIOPATRA CUPREA	A	Poly	9	0.18	92.53	7	31.8	7	9.5	
DIPOLYDORA SOCIALIS	A	Poly	9	0.18	92.71	3	13.6	6	8.1	

Appendix I. Taxa abundance and occurrence by strata and stations (continued).

Taxa	Phylum	Class	Number of Individuals	Percent of Total Individuals	Cumul. %	Number of Strata Occurred	% Strata Occurred	Station Occurred	% Station Occurred	Comments
NOTOMASTUS (LPIL)	A	Poly	9	0.18	92.89	2	9.1	2	2.7	
TELLINIDAE (LPIL)	M	Pele	9	0.18	93.06	6	27.3	6	8.1	
AMPELISCA ABDITA	C	Amph	8	0.16	93.22	4	18.2	4	5.4	
AMPHIURIDAE (LPIL)	E	Ophi	8	0.16	93.38	2	9.1	3	4.1	
NEPHTYS INCISA	A	Poly	8	0.16	93.54	4	18.2	5	6.8	
RHEPOXYNIUS EPISTOMUS	C	Amph	8	0.16	93.69	1	4.5	2	2.7	
TECTONATICA PUSILLA	M	Gast	8	0.16	93.85	2	9.1	3	4.1	
ALIGENA TEXASIANA	M	Pele	7	0.14	93.99	1	4.5	1	1.4	
CREPIDULA PLANA	M	Gast	7	0.14	94.12	1	4.5	1	1.4	
GLYCERA AMERICANA	A	Poly	7	0.14	94.26	5	22.7	6	8.1	
MAGELONA SP.I	A	Poly	7	0.14	94.40	3	13.6	4	5.4	
MYSELLA PLANULATA	M	Pele	7	0.14	94.54	2	9.1	4	5.4	
ANCISTROSYLLIS JONESI	A	Poly	6	0.12	94.66	4	18.2	5	6.8	
ARICIDEA (LPIL)	A	Poly	6	0.12	94.77	3	13.6	5	6.8	
HETEROMASTUS FILIFORMIS	A	Poly	6	0.12	94.89	3	13.6	5	6.8	
NEREIS FALSA	A	Poly	6	0.12	95.01	2	9.1	2	2.7	
ONUPHIDAE (LPIL)	A	Poly	6	0.12	95.13	2	9.1	4	5.4	
SCOLOPLOS SP.B	A	Poly	6	0.12	95.24	1	4.5	2	2.7	
TEREBELLIDAE (LPIL)	A	Poly	6	0.12	95.36	2	9.1	2	2.7	
ABRA AEQUALIS	M	Pele	5	0.10	95.46	4	18.2	4	5.4	
AMYGDALUM PAPYRIA	M	Pele	5	0.10	95.56	2	9.1	2	2.7	
APOPRIONOSPIO PYGMAEA	A	Poly	5	0.10	95.66	2	9.1	4	5.4	
CAECIDAE (LPIL)	M	Gast	5	0.10	95.76	1	4.5	1	1.4	
CYCLASPIS PUSTULATA	C	Cuma	5	0.10	95.85	2	9.1	2	2.7	
HAUSTORIIDAE (LPIL)	C	Amph	5	0.10	95.95	2	9.1	3	4.1	
HESIONIDAE (LPIL)	A	Poly	5	0.10	96.05	4	18.2	4	5.4	
NEREIDAE (LPIL)	A	Poly	5	0.10	96.15	4	18.2	4	5.4	
PYRAMIDELLIDAE (LPIL)	M	Gast	5	0.10	96.25	2	9.1	2	2.7	
SERPULIDAE (LPIL)	A	Poly	5	0.10	96.35	2	9.1	3	4.1	
SIGAMBRA BASSI	A	Poly	5	0.10	96.44	2	9.1	3	4.1	
SYLLIS MARYAE	A	Poly	5	0.10	96.54	1	4.5	1	1.4	
ACTINIARIA (LPIL)	Cn	Acti	4	0.08	96.62	3	13.6	3	4.1	
AMPELISCA (LPIL)	C	Amph	4	0.08	96.70	3	13.6	4	5.4	
DEUTELLA INCERTA	C	Amph	4	0.08	96.78	1	4.5	1	1.4	
HYDROIDES DIANTHUS	A	Poly	4	0.08	96.86	2	9.1	3	4.1	
LEPTONIDAE (LPIL)	M	Pele	4	0.08	96.93	1	4.5	1	1.4	

Appendix I. Taxa abundance and occurrence by strata and stations (continued).

Taxa	Phylum	Class	Number of Individuals	Percent of Total Individuals	Cumul. %	Number of Strata Occurred	% Strata Occurred	Station Occurred	% Station Occurred	Comments
ANADARA TRANSVERSA	M	Pele	3	0.06	96.99	2	9.1	2	2.7	
ARCIDAE (LPIL)	M	Pele	3	0.06	97.05	2	9.1	7	9.5	
DIASTYLIDAE (LPIL)	C	Cuma	3	0.06	97.11	3	13.6	3	4.1	
ECHINOIDEA (LPIL)	E	Echi	3	0.06	97.17	2	9.1	2	2.7	
GONIADIDAE (LPIL)	A	Poly	3	0.06	97.23	3	13.6	3	4.1	
GRANDIDIERELLA BONNIEROIDES	C	Amph	3	0.06	97.29	1	4.5	1	1.4	
LUMBRINERIDAE (LPIL)	A	Poly	3	0.06	97.35	3	13.6	3	4.1	
MARENZELLARIA VIRIDIS	A	Poly	3	0.06	97.41	1	4.5	2	2.7	
NASSARIIDAE (LPIL)	M	Gast	3	0.06	97.47	2	9.1	2	2.7	
NEREIS (LPIL)	A	Poly	3	0.06	97.52	3	13.6	3	4.1	
PINNOTHERIDAE (LPIL)	C	Deca	3	0.06	97.58	2	9.1	1	1.4	
SCOLELEPIS TEXANA	A	Poly	3	0.06	97.64	3	13.6	3	4.1	
SPHENIA ANTILLENSIS	M	Pele	3	0.06	97.70	1	4.5	1	1.4	
TIRON TROPAKIS	C	Amph	3	0.06	97.76	2	9.1	2	2.7	
XANTHIDAE (LPIL)	C	Deca	3	0.06	97.82	3	13.6	3	4.1	
AEGINELLIDAE (LPIL)	C	Amph	2	0.04	97.86	2	9.1	2	2.7	
ANCISTROSYLLIS PAPILLOSA	A	Poly	2	0.04	97.90	2	9.1	2	2.7	
ARMANDIA AGILIS	A	Poly	2	0.04	97.94	2	9.1	2	2.7	
BHAWANIA HETEROSETA	A	Poly	2	0.04	97.98	2	9.1	2	2.7	
DISPIO UNCINATA	A	Poly	2	0.04	98.02	1	4.5	1	1.4	
DOSINIA ELEGANS	M	Pele	2	0.04	98.05	2	9.1	2	2.7	
DRILONEREIS LONGA	A	Poly	2	0.04	98.09	1	4.5	1	1.4	
EDOTIA TRILOBA	C	Isop	2	0.04	98.13	1	4.5	1	1.4	
ELASMOPUS (LPIL)	C	Amph	2	0.04	98.17	1	4.5	1	1.4	
LEPIDACTYLUS TRIARTICULATUS	C	Amph	2	0.04	98.21	1	4.5	1	1.4	
MEDIOMASTUS AMBISETA	A	Poly	2	0.04	98.25	1	4.5	1	1.4	
MELINNA MACULATA	A	Poly	2	0.04	98.29	1	4.5	1	1.4	
MYSIDAE (LPIL)	C	Mysi	2	0.04	98.33	2	9.1	2	2.7	
MYTILIDAE (LPIL)	M	Pele	2	0.04	98.37	1	4.5	1	1.4	
NAINERIS SP.A	A	Poly	2	0.04	98.41	1	4.5	1	1.4	
NEPHTYS PICTA	A	Poly	2	0.04	98.45	1	4.5	1	1.4	
NEVERITA DUPLICATA	M	Gast	2	0.04	98.49	2	9.1	2	2.7	
ODOSTOMIA (LPIL)	M	Gast	2	0.04	98.53	2	9.1	2	2.7	
PANOPEUS HERBSTII	C	Deca	2	0.04	98.57	2	9.1	2	2.7	
PARAMETOPELLA CYPRIS	C	Amph	2	0.04	98.60	1	4.5	1	1.4	
PHYLLODOCIDAE (LPIL)	A	Poly	2	0.04	98.64	1	4.5	2	2.7	

Appendix I. Taxa abundance and occurrence by strata and stations (continued).

Taxa	Phylum	Class	Number of Individuals	Percent of Total Individuals	Cumul. %	Number of Strata Occurred	% Strata Occurred	Station Occurred	% Station Occurred	Comments
PILARGIDAE (LPIL)	A	Poly	2	0.04	98.68	2	9.1	2	2.7	
SCOLOPLOS (LPIL)	A	Poly	2	0.04	98.72	1	4.5	2	2.7	
SIGAMBRA (LPIL)	A	Poly	2	0.04	98.76	2	9.1	2	2.7	
SYLLIDAE (LPIL)	A	Poly	2	0.04	98.80	2	9.1	2	2.7	
TAGELUS DIVISUS	M	Pele	2	0.04	98.84	1	4.5	1	1.4	
VIVIPARIDAE (LPIL)	M	Gast	2	0.04	98.88	1	4.5	2	2.7	
ALPHEUS ESTUARIENSIS	C	Deca	1	0.02	98.90	1	4.5	1	1.4	
AMERICAMYSIS BIGELOWI	C	Mysi	1	0.02	98.92	1	4.5	1	1.4	
AMPELISCA SP.C	C	Amph	1	0.02	98.94	1	4.5	1	1.4	
AMPHIPODA (LPIL)	C	Amph	1	0.02	98.96	1	4.5	1	1.4	
ARICIDEA SP.E	A	Poly	1	0.02	98.98	1	4.5	1	1.4	
BOWMANIELLA (LPIL)	C	Mysi	1	0.02	99.00	1	4.5	1	1.4	
CAECUM COOPERI	M	Gast	1	0.02	99.02	1	4.5	1	1.4	
CALLIANASSA (LPIL)	C	Deca	1	0.02	99.04	1	4.5	1	1.4	
CALLINECTES SAPIDUS	C	Deca	1	0.02	99.06	1	4.5	1	1.4	
CALYPTRAEIDAE (LPIL)	M	Gast	1	0.02	99.08	1	4.5	1	1.4	
CHONE (LPIL)	A	Poly	1	0.02	99.10	1	4.5	1	1.4	
CRASSINELLA LUNULATA	M	Pele	1	0.02	99.12	1	4.5	1	1.4	
CREPIDULA (LPIL)	M	Gast	1	0.02	99.14	1	4.5	1	1.4	
CYCLASPIS (LPIL)	C	Cuma	1	0.02	99.16	1	4.5	1	1.4	
DECAPODA REPTANTIA (LPIL)	C	Deca	1	0.02	99.17	1	4.5	1	1.4	
DORVILLEIDAE (LPIL)	A	Poly	1	0.02	99.19	1	4.5	1	1.4	
GALATHOWENIA OCULATA	A	Poly	1	0.02	99.21	1	4.5	1	1.4	
HAUCHIELLA SP.A	A	Poly	1	0.02	99.23	1	4.5	1	1.4	
LISTRIELLA (LPIL)	C	Amph	1	0.02	99.25	1	4.5	1	1.4	
MACTRIDAE (LPIL)	M	Pele	1	0.02	99.27	1	4.5	1	1.4	
MAJIDAE (LPIL)	C	Deca	1	0.02	99.29	1	4.5	1	1.4	
MALMGRENIELLA SP.B	A	Poly	1	0.02	99.31	1	4.5	1	1.4	
MEGALOMMA PIGMENTUM	A	Poly	1	0.02	99.33	1	4.5	1	1.4	
MICROPHTHALMUS (LPIL)	A	Poly	1	0.02	99.35	1	4.5	1	1.4	
MONOCULODES (LPIL)	C	Amph	1	0.02	99.37	1	4.5	1	1.4	
MONOCULODES SP.D	C	Amph	1	0.02	99.39	1	4.5	1	1.4	
NATICIDAE (LPIL)	M	Gast	1	0.02	99.41	1	4.5	1	1.4	
NEPHTYIDAE (LPIL)	A	Poly	1	0.02	99.43	1	4.5	1	1.4	
NEPHTYS SIMONI	A	Poly	1	0.02	99.45	1	4.5	1	1.4	
NUDIBRANCHIA (LPIL)	M	Gast	1	0.02	99.47	1	4.5	1	1.4	

Appendix I. Taxa abundance and occurrence by strata and stations (continued).

Taxa	Phylum	Class	Number of Individuals	Percent of Total Individuals	Cumul. %	Number of Strata Occurred	% Strata Occurred	Station Occurred	% Station Occurred	Comments
ODOSTOMIA IMPRESSA	M	Gast	1	0.02	99.49	1	4.5	1	1.4	
OXYUROSTYLIS (LPIL)	C	Cuma	1	0.02	99.51	1	4.5	1	1.4	
OXYUROSTYLIS SMITHI	C	Cuma	1	0.02	99.53	1	4.5	1	1.4	
PARACAPRELLA (LPIL)	C	Amph	1	0.02	99.55	1	4.5	1	1.4	
PARAONIDAE (LPIL)	A	Poly	1	0.02	99.57	1	4.5	1	1.4	
PECTINARIA GOULDII	A	Poly	1	0.02	99.59	1	4.5	1	1.4	
PECTINARIIDAE (LPIL)	A	Poly	1	0.02	99.61	1	4.5	1	1.4	
PHASCOLION STROMBI	S		1	0.02	99.63	1	4.5	1	1.4	
PHOXOCEPHALIDAE (LPIL)	C	Amph	1	0.02	99.65	1	4.5	1	1.4	
PHYLLODOCE MUCOSA	A	Poly	1	0.02	99.67	1	4.5	1	1.4	
PISTA CRISTATA	A	Poly	1	0.02	99.69	1	4.5	1	1.4	
PISTA QUADRILOBATA	A	Poly	1	0.02	99.71	1	4.5	1	1.4	
POLYGORDIUS (LPIL)	A	Poly	1	0.02	99.72	1	4.5	1	1.4	
POMATOCEROS AMERICANUS	A	Poly	1	0.02	99.74	1	4.5	1	1.4	
PROTOHAUSTORIUS (LPIL)	C	Amph	1	0.02	99.76	1	4.5	1	1.4	
PYRGOCYTHARA PLICOSA	M	Gast	1	0.02	99.78	1	4.5	1	1.4	
SABELLIDAE (LPIL)	A	Poly	1	0.02	99.80	1	4.5	1	1.4	
SCOLELEPIS (LPIL)	A	Poly	1	0.02	99.82	1	4.5	1	1.4	
SCOLETOMA (LPIL)	A	Poly	1	0.02	99.84	1	4.5	1	1.4	
SYLLIS GRACILIS	A	Poly	1	0.02	99.86	1	4.5	1	1.4	
TELLINA IRIS	M	Pele	1	0.02	99.88	1	4.5	1	1.4	
THARYX ACUTUS	A	Poly	1	0.02	99.90	1	4.5	1	1.4	
TRACHYPENAEUS (LPIL)	C	Deca	1	0.02	99.92	1	4.5	1	1.4	
TRACHYPENAEUS CONSTRICTUS	C	Deca	1	0.02	99.94	1	4.5	1	1.4	
TURBELLARIA (LPIL)	P	Turb	1	0.02	99.96	1	4.5	1	1.4	
UPOGEBIA AFFINIS	C	Deca	1	0.02	99.98	1	4.5	1	1.4	
VITRINELLIDAE (LPIL)	M	Gast	1	0.02	100.00	1	4.5	1	1.4	

TAXA KEY
Phylum
    Class
A = Annelida
    Olig = Oligochaeta
    Poly = Polychaeta
C = Arthropoda (Crustacea)
    Amph = Amphipoda
    Cuma = Cumacea
    Deca = Decapoda
    Isop = Isopoda
    Lept = Leptostraca
    Mysi = Mysidacea
    Ostr = Ostracoda
    Tana = Tanaidacea

Ce = Cephalochordata
Cn = Cnidaria
    Acti = Actiniaria
E = Echinodermata
    Aste = Asteroidea
    Echi = Echinoidea
    Holo = Holothuroidea
    Ophi = Ophiuroidea
He = Hemichordata

M = Mollusca
    Gast = Gastropoda
    Pele = Pelecypoda
    Polyp = Polyplacophora
    Scap = Scaphopoda
Ph = Phoronida
P = Platyhelminthes
    Turbellaria
R = Rhynchocoela
S = Sipuncula
U = Urochordata
    Asci = Ascidiacea