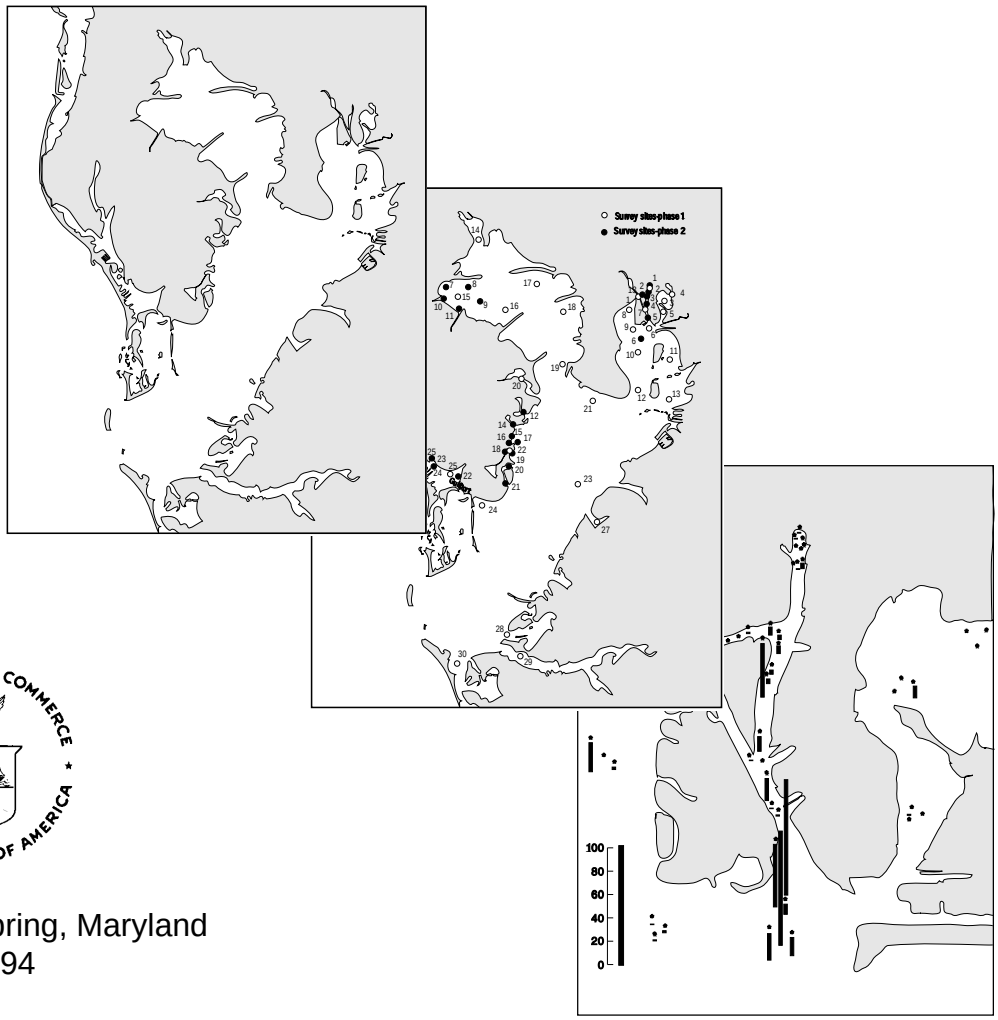
NOAA Technical Memorandum NOS ORCA 78

National Status and Trends Program
for Marine Environmental Quality

Magnitude and Extent of Sediment Toxicity in Tampa Bay, Florida



Silver Spring, Maryland
June, 1994

noaa National Oceanic and Atmospheric Administration

National Ocean Service
Office of Ocean Resources Conservation and Assessment
Coastal Monitoring and Bioeffects Assessment Division

NOAA Coastal Ocean Office

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Notice

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Silver Spring, Maryland
June, 1994

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MAGNITUDE AND EXTENT OF SEDIMENT TOXICITY IN TAMPA BAY, FLORIDA

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ABSTRACT

A survey of the toxicity of sediments was performed by NOAA's National Status and Trends Program throughout the Tampa Bay estuary. The objectives of the survey were to determine the spatial patterns and scales of toxicity, to determine the severity and degree of toxicity, and to identify the relationships between chemical contamination and toxicity. The survey was conducted in two phases: 90 samples were collected in Phase 1 in 1991; and 75 additional samples were collected in Phase 2 in 1992. The toxicity tests were performed under controlled laboratory conditions with subsamples of a composite sample. Three independent toxicity tests were performed with most or all of the samples: (1) a 10-day amphipod survival test of the solid-phase sediments with *Ampelisca abdita*; (2) a 1-hour sea urchin egg fertilization test of the pore water with *Arbacia punctulata*; and (3) a 5-minute Microtox™ bioluminescence test with solvent extracts of the sediments. The concentrations of trace metals, polynuclear aromatic hydrocarbons (PAHs), and chlorinated organic compounds were quantified in subsamples of many of the composite samples.

Of the 165 undiluted sediment pore water samples that were tested with respect to urchin egg fertilization, 79% were significantly toxic relative to controls. In contrast, only 6% of the 165 samples were toxic in the amphipod tests. In the Microtox™ tests, 27% of the 90 samples tested were significantly toxic. The three tests identified overlapping but different spatial patterns in toxicity. Overall, toxicity was most severe in northern Hillsborough Bay, especially in Ybor Channel and adjoining waterways. Also, relatively high toxicity was apparent in portions of Allen Creek, Cross Bayou Canal, Bayboro Harbor, western Old Tampa Bay, St. Petersburg yacht basins, lower Boca Ciega Bay, and Bear Creek. Toxicity was least severe in Safety Harbor, central and eastern Old Tampa Bay, lower Tampa Bay, Big Bayou, Little Bayou, and Bayou Grande.

The samples represented conditions within approximately 550 km^2 of the estuary. The sea urchin test was highly sensitive to the undiluted pore water samples, indicating that approximately 464 km^2 were significantly toxic. Collectively, the amphipod survival test, the Microtox™ bioluminescence test, and the sea urchin tests performed with the most diluted concentration of pore water tested (25%) indicated that about 0.5-0.6 km^2 of this area was highly toxic.

The causes of the toxicity were not determined. However, the concentrations of numerous trace metals, pesticides, PCB congeners, PAHs, and ammonia were highly correlated with the measures of toxicity. Also, the concentrations of many substances, especially total DDTs, endrin, total PCBs, certain PAHs, lead, and zinc, occurred at concentrations in the toxic samples that equalled or exceeded concentrations that had been previously associated with toxicity.

INTRODUCTION

The Tampa Bay estuary is a large, highly complex system composed of numerous basins or subdivisions (Figure 1). Parts of the estuary are bordered by highly industrialized and urbanized areas and other parts are bordered by mangroves, bayous, and other relatively rural areas. Toxic chemicals enter the estuary from urban runoff, industrial point sources, municipal wastewater discharges, atmospheric deposition, accidental spills, illegal dumping, pesticide applications, and agricultural practices. Toxic chemicals are known to exist in the sediments and biota of the estuary (Long et al., 1991). Data developed in studies of sediments and bivalve molluscs indicate that many potentially toxic chemicals occur in relatively high concentrations in the lower Hillsborough River, northern Hillsborough Bay, and some peripheral harbors and ports. Toxicant concentrations are moderate or intermediate in middle Tampa Bay, and parts of Boca Ciega Bay, and generally are lowest in Old Tampa Bay and lower Tampa Bay.

Relatively high concentrations of some toxicants occur in marinas and industrial harbors, and near storm drains and drainage ditches scattered around the perimeter of the estuary. Some portions of Boca Ciega Bay, for

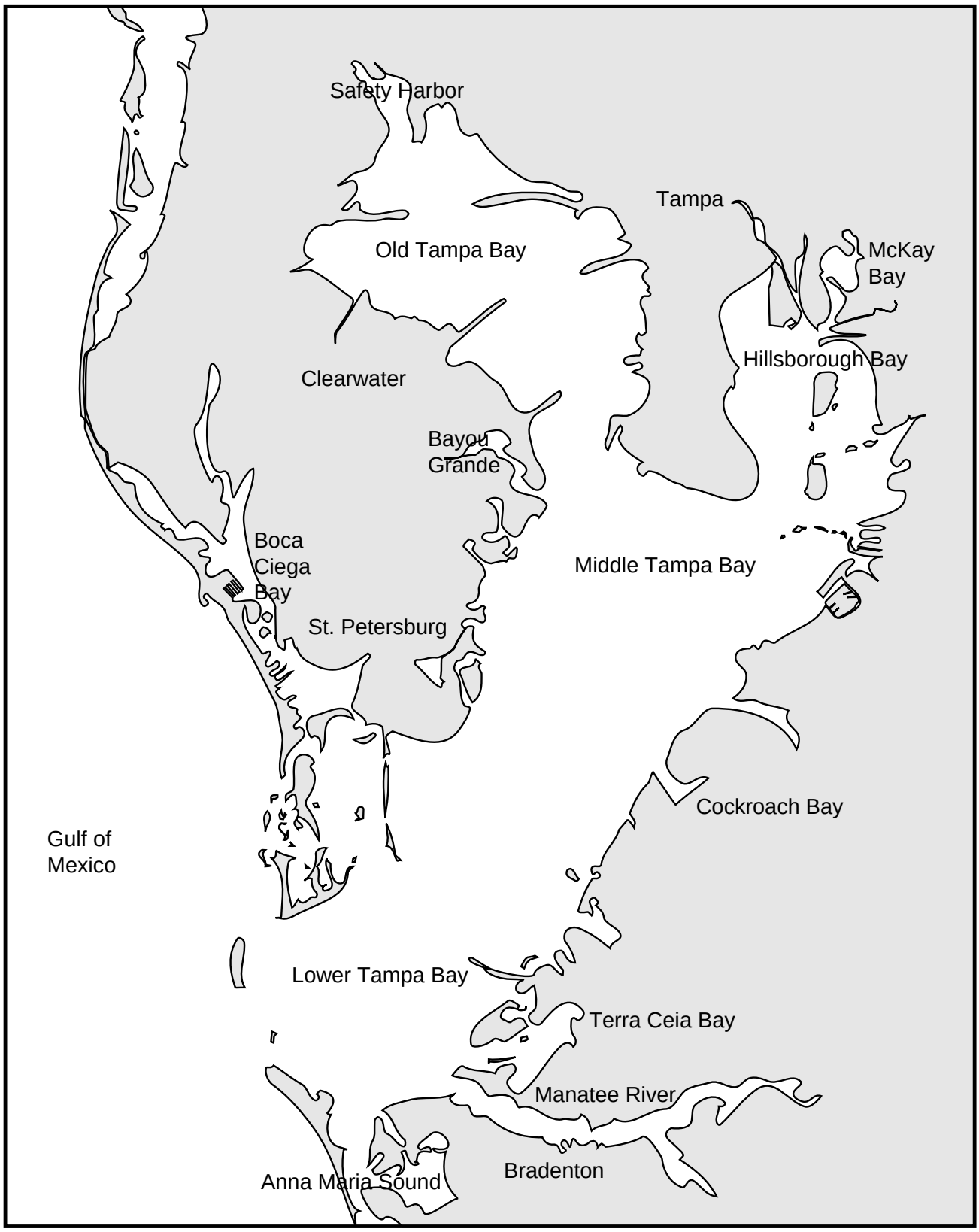

Figure 1. Tampa Bay Estuary and major regions.

example, have very high concentrations of some toxicants, while other parts of this region have very low concentrations. The concentrations of trace metals were highest in parts of northeast Hillsborough Bay, along the St. Petersburg shore, and in Boca Ciega Bay near Gulfport (Brooks and Doyle, 1992).

The National Status and Trends (NS&T) Program of NOAA has monitored the concentrations of selected toxicants in sediments, oysters, and bottom-dwelling fish in Tampa Bay since 1986 (Long et al., 1991). The occurrence of relatively high concentrations of some chemicals in the estuary prompted the NS&T Program to initiate an intensive survey (Wolfe et al., 1993) of the biological effects of toxicants in the estuary. Measures of biological effects are needed to provide perspective on the toxic chemicals that occur in the estuary. The chemical data provide evidence that portions of the estuary are contaminated, but they alone do not demonstrate that the chemicals represent a significant problem to the biota of the estuary.

NOAA's assessment of the biological effects associated with toxicants in Tampa Bay was initiated in 1990, with a research plan that involved analyses of three media: sediments, bivalve molluscs, and demersal fish (NOAA, 1990). Assessments of the health and chemical contamination of oysters (W.S. Fisher, U.S. EPA, Gulf Breeze, FL, unpublished) and demersal fish (B.B. McCain, U.S. NMFS, Seattle, WA, unpublished) were conducted to document and quantify measures of contaminant exposure and associated bioeffects in resident biota along the ambient pollution gradient in Tampa Bay. The sediment toxicity tests described in this report were carried out to provide complementary information on the potential magnitude of bioeffects and a meaningful estimate of the spatial extent of environmental degradation due to contaminants. The toxicity surveys utilize laboratory tests in which confounding 'natural' factors are controlled in assessing the significance of toxicants. The sediment toxicity surveys also provide bioeffects information with greater spatial resolution than is possible with motile resident organisms.

The objectives of the sediment toxicity surveys reported here were to determine:
(1) the spatial extent and patterns in toxicity;
(2) the severity or magnitude of toxicity; and
(3) the relationships between toxicity and the concentrations of toxicants and other potential causative factors.

II. Methods and Materials

Overall Approach. Tests of sediment toxicity are commonly performed as indicators of the quality of sediments (Baudo et al., 1990; Burton, 1992). Since the ultimate fate of toxicants often involves accumulation in sediments, tests of the toxicity of sediments can be powerful tools in assessments of toxicant-associated biological effects.

The survey was designed to sample areas that were expected to be highly, moderately, and least or not toxic to assess the severity or range in toxicity. Also, the sampling plan was designed to determine the outer geographic extent, or limits of toxicity. The sampling plan was designed after considering the known patterns in distribution and concentration of toxicants in the sediments (Long et al., 1991). Individual sampling sites were selected to represent accumulations of contaminants from multiple sources and to represent conditions in accumulation zones within each of the regions of the estuary. Some locations sampled in previous surveys of chemical contamination (e.g., Doyle et al., 1985; 1989) were resampled in this survey to ensure comparability of the data and collection of muddy material. Samples were not knowingly collected within the immediate vicinity of single point sources. Only relatively fine-grained sediments were retained for testing to ensure that depositional areas were sampled.

Sample Collection. The sediment toxicity survey was conducted in two phases. Initially, in Phase 1, 30 sites throughout the estuary were sampled in August 1991. This phase of the survey was intended to provide a broad, estuary-wide assessment of toxicity. Therefore, samples were collected at sites scattered widely in all the major components of the estuary. In August 1992 additional samples were collected in Phase 2 at 25 sites, plus a site in Charlotte Harbor. In this second phase, the intent was to verify and further define the geographic extent of toxicity observed in the first phase. Therefore, samples were collected in relatively dense patterns in four regions of the estuary: (1) Ybor Channel/northern Hillsborough Bay, (2) western Old Tampa Bay, (3) St. Petersburg shoreline, and (4) off Gulfport (Figure 2).

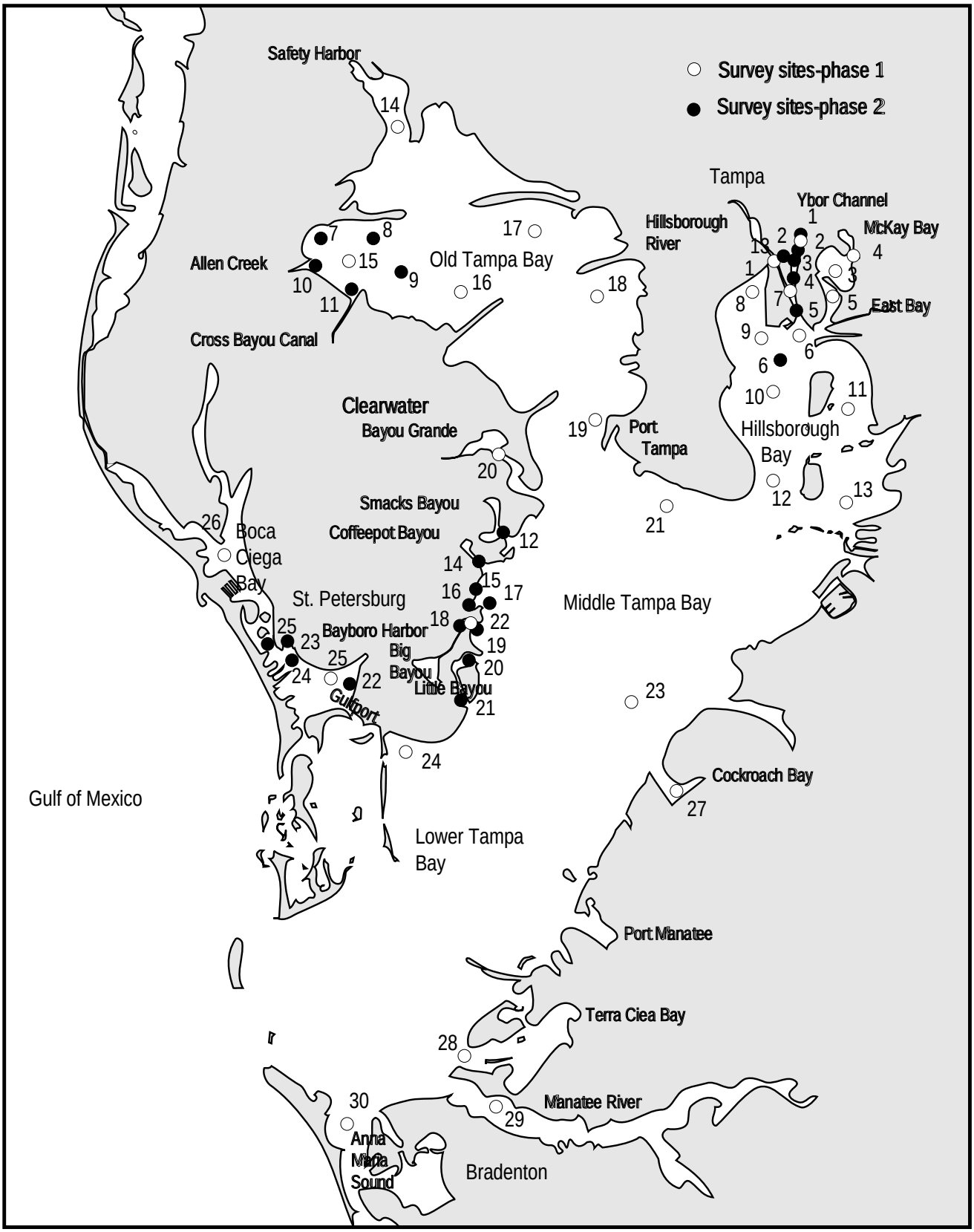

Figure 2. Locations of Phase 1 and Phase 2 sampling sites in Tampa Bay.

In Phase 1, samples were collected aboard the shrimper M/V Ocean Breeze with a Kynar-lined, modified, 0.1m^2 van Veen grab sampler. The vessel's exhaust was positioned and routed away from the sampler to minimize contamination. Vessel positioning was performed with Loran, radar ranges, and compass bearings. Once the vessel was maneuvered to the specified coordinates, the site center was marked with a buoy. Then, the vessel was maneuvered to a randomLy chosen position 50 to 100 m away from the marker buoy for the first station. Three stations were sampled at each site. The stations generally were 250m from each other, usually in a triangle around the site center, occasionally in a line. Phase 1 samples were collected during three periods: August 20-23, September 3-6, and September 24-27, in 1991.

All utensils and containers that came in contact with the samples were either Kynar- or Teflon-coated to ensure against contamination by the sampling procedures. Also, all equipment was rinsed with acetone and site seawater before use at each site to prevent cross-contamination. The upper 2 cm of sediment were removed from the sampler and retained for analyses. Repeated deployments of the sampler were required at each station to obtain sufficient material for testing, usually 8 to 10 liters. The sediment accumulated at each station was homogenized by stirring gently with a Kynar-coated, stainless steel spoon. Once the sediments appeared to be uniformLy homogenized, 500 mL were removed and placed in pre-labelled glass jars for chemical analyses by the Skidaway Institute of Oceanography.

In Phase 1, four liters of sediment were placed in plastic jars for toxicity testing by the U.S. Fish and Wildlife Service, now the National Biological Survey (NBS), in Corpus Christi, Texas, and 4 liters were placed in plastic jars for toxicity testing by Science Applications International Corporation in Narragansett, Rhode Island. At 16 of the sites, two liters of additional sediments were collected and shipped to the National Marine Fisheries Service in Seattle, Washington for toxicity testing with juvenile sand dollars (*Dendraster excentricus*) or juvenile polychaetes (*Armandia brevis*), using growth and survival as the endpoints (E. Casillas, NMFS/NWFSC Seattle, WA, unpublished). All sediments were shipped by overnight express in coolers packed with blue ice and accompanied by chain of custody forms.

In Phase 2, samples were collected aboard a Florida Department of Environmental Regulation research vessel (the RV Raja) using the same sampling device, procedures, and precautions as in Phase 1. Samples were collected during August 3-6 and August 26-29, 1992. Sediments were shipped overnight to the NBS in Corpus Christi, Texas for toxicity testing and the Skidaway Institute of Oceanography for chemical analyses.

The locations of the sites are illustrated in Figure 2 and the coordinates for the site centers are listed in Table 1. Information gathered on the position, depth, and sediment characteristics at each station are listed in Appendix A.

Table 1. Latitudes, longitudes, and depths of sites sampled in 1991 (Phase 1) and 1992 (Phase 2).

Site No.		Latitude (°N)	Longitude(°W)	Depth (m)
		PHASE 1		
Hillsborough Bay				
1.	Hillsborough River	27°56'25"	82°27'31"	7.5-9.4
2.	Ybor Channel	27°57'10"	82°26'33"	10-11
3.	McKay Bay	27°56'07"	82°25'43"	1
4.	Palm River	27°56'30"	82°24'55"	2-4
5.	East Bay	27°55'13"	82°25'39"	10-11
6.	No. Hillsborough Bay	27°54'15"	82°26'26"	4-5
7.	Sparkman Channel	27°55'30"	82°26'54"	7-11
8.	No. Hillsborough Bay	27°55'00"	82°28'30"	1.6
9.	No. Hillsborough Bay	27°54'00"	82°27'40"	1.3-1.6
10.	Cen. Hillsborough Bay	27°52'45"	82°27'20"	3.5
11.	Cen. Hillsborough Bay	27°51'40"	82°25'20"	2.6
12.	So. Hillsborough Bay	27°55'00"	82°27'25"	4.2
13.	So. Hillsborough Bay	27°48'49"	82°25'14"	3.2

Table 1 continued.

Site No.		Latitude (°N)	Longitude(°W)	Depth (m)
Old Tampa Bay				
14.	Safety Harbor	28°00’15"	82°40’17"	1.9-3.2
15.	W. Old Tampa Bay	27°56’30"	82°42’30"	3.9
16.	Cen. Old Tampa Bay	27°56’25"	82°39’00"	2.9-3.2
17.	Cen. Old Tampa Bay	27°57’10"	82°35’15"	4.5-5.2
18.	Cen. Old Tampa Bay	27°55’30"	82°33’20"	3.2
19.	So. Old Tampa Bay	27°51’32"	82°33’05"	4.5-9.0
Middle Tampa Bay				
20.	Bayou Grande	27°49’30"	82°36’14"	2.6-3.2
21.	No. middle Tampa Bay	27°48’05"	82°31’00"	4.2-4.8
22.	Bayboro Harbor	27°45’34"	82°37’45"	6.5-7.7
23.	Cen. middle Tampa Bay	27°44’13"	82°30’41"	3.5-3.9
Lower Tampa Bay				
24.	off Pt. Pinellas	27°41’50"	82°40’10"	2.6-3.2
Boca Ciega Bay				
25.	Lower Boca Ciega Bay	27°43’55"	82°42’55"	3.2-3.5
26.	Upper Boca Ciega Bay	27°47’42"	82°45’55"	1.3-2.2
Cockroach Bay				
27.	Inner Cockroach Bay	27°40’35"	82°30’50"	0.5-1.0
Terra Ceia Bay				
28.	Mouth of Bay	27°32’50"	82°39’08"	3.2
Manatee River				
29.	Bradenton	27°30’50"	82°35’37"	1.3-1.6
Anna Maria Sound				
30.	Northern Sound	27°30’30"	82°41’42"	1.0-1.3
		PHASE 2		
Northern Hillsborough Bay/Ybor Channel				
1.	Ybor Channel	27° 57' 12"	82° 26' 34"	11.0
2.	Ybor Channel	27° 57' 00"	82° 26' 34"	11.4
13.	Garrison Channel	27° 56' 24"	82° 27' 06"	6.9
3.	Ybor turning basin	27° 56' 22"	82° 26' 45"	8.9
4.	Sparkman Channel	27° 56' 00"	82° 26' 49"	13.0
5.	Cut D Channel	27° 55' 00"	82° 26' 46"	14.5
6.	No. Hillsborough Bay	27° 53' 54"	82° 26' 39"	4.5
Western Old Tampa Bay				
7.	W. Old Tampa Bay	27° 57' 05"	82° 43' 04"	2.8
8.	W. Old Tampa Bay	27° 57' 05"	82° 42' 05"	3.3
9.	W. Old Tampa Bay	27° 56' 24"	82° 41' 17"	3.8
10.	Mouth, Allen Creek	27° 56' 12"	82° 43' 29"	2.9
11.	Mouth, Cross Bayou Cl.	27° 55' 19"	82° 41' 43"	2.0
St. Petersburg Harbors				
12.	Smacks Bayou	27° 48' 18"	82° 36' 36"	4.4
14.	Lower Coffeepot Bayou	27° 47' 30"	82° 37' 30"	3.2
15.	No. St. Pete Marina	27° 46' 32"	82° 37' 48"	4.0

Table 1 continued.

Site No.		Latitude (°N)	Longitude(°W)	Depth (m)
16.	Cen. St. Pete Marina	27° 46' 04"	82° 37' 42"	5.2
17.	St. Pete Marina-entr.	27° 46' 15"	82° 37' 18"	8.0
18.	NW. Bayboro Harbor	27° 45' 40"	82° 38' 08"	3.0
19.	Bayboro Harbor-entr.	27° 45' 30"	82° 37' 30"	7.2
20.	Big Bayou	27° 44' 09"	82° 38' 12"	4.7
21.	Little Bayou	27° 43' 18"	82° 37' 54"	9.0
Gulfport/Bear Creek				
22.	Gulfport	27° 44' 07"	82° 41' 48"	2.3
23.	Inner Bear Creek	27° 45' 12"	82° 43' 57"	2.3
24.	Outer Bear Creek	27° 44' 54"	82° 44' 00"	2.5
25.	Boca Ciega Bay	27° 45' 00"	82° 44' 20"	3.5
Charlotte Harbor				
26.	Charlotte Harbor	26° 47' 24"	82° 06' 08"	6.1

Sea Urchin Egg Fertilization Test. This test was performed during both phases by the NBS laboratory in Corpus Christi, Texas. The pore water was pressure-extracted from the sediments and tested for toxicity with the sea urchin egg fertilization test. Sediments were held at 4°C and the pore water extracted within 7 days of the date of collection. Pore water was extracted using a pressurized squeeze extraction method (Carr and Chapman 1992). This method was modified to use a polyethylene filter, instead of a glass fiber filter, to decrease the amount of sorption of toxicants to the filter. The pore water was frozen immediately after extraction until the day before toxicity tests commenced. The salinity of the samples was adjusted, if necessary, to 30±1ppt by the addition of hypersaline brine, centrifuged, stored overnight, and adjusted to 20°C for testing. The water quality of pore water samples (dissolved oxygen, pH, temperature, sulfide, and ammonia) was measured before the toxicity tests were performed.

The tests were performed with water-quality adjusted pore water (100%), and with dilutions to 50% and 25% of full strength for each sample for a total of 270 tests in phase 1 and 225 tests in phase 2. Samples were diluted with 30 ppt reference seawater from the laboratory at Port Aransas, Texas. Each test was performed in quintuplicate.

The tests were conducted with the gametes of the sea urchin *Arbacia punctulata*, following the methods of Carr and Chapman (1992). In both phases, the tests were run in two batches, each consisting of roughly equal numbers of samples. Pore water from a reference area, Lydia Ann Channel in Redfish Bay, Texas, previously documented not to be toxic, was tested in each batch. Adult male and female urchins were stimulated to spawn with a mild electric shock and the gametes were collected separately. Prior to each series of tests, a pretest was conducted to determine the optimum sperm/egg ratio for maximizing the sensitivity of the test. The test involves exposing the sperm in 5 mL of the test solution for 30 min., followed by the addition of ~ 2,000 eggs. After an additional 30 min. incubation period, the test was terminated by the addition of formalin. An aliquot of the egg suspension was examined under a compound microscope to determine the presence or absence of a fertilization membrane surrounding the egg, and percent fertilization was recorded for each replicate.

Amphipod Tests. This test was performed by Science Applications International Corporation in 1991 and by the NBS in 1992. During the 1991 tests, amphipods were collected from Narragansett Bay, Rhode Island, transported to the laboratory, and identified. During the 1992 tests, amphipods were collected from San Francisco Bay by a commercial supplier and shipped to the toxicity testing laboratory. When necessary, test animals were temperature-acclimated while being fed diatoms. Ninety-six hour water-only tests with sodium dodecyl sulfate (SDS) were performed as reference toxicant (positive control) tests.

Test sediments were press-sieved through a 2.0 mm mesh stainless steel screen and homogenized. When indigenous amphipods were present in the test sediments, they were removed by sieving the sediments again,

this time through a 1.0 mm mesh sieve. A total of 200 mL of sediments were added to each quart-size glass jar and the jars were filled with about 600 mL of seawater. All jars were numbered and tested blind. All tests were conducted using standardized ASTM protocols for estuarine and marine amphipods (ASTM, 1990). Five replicates of each sample were tested for 10 days. Test chambers were aerated and lighted continuously. Tests were performed in nine batches in phase 1 and two batches in phase 2. In Phase 1, control sediments from the Central Long Island Sound (CLIS) reference site previously used in many projects were collected in May, 1991 and tested with each batch of samples. In Phase 2, control sediments were collected from the amphipod collection site in San Francisco Bay.

Twenty subadult amphipods were placed in each jar and the tests were performed at 20°C. Each jar was checked daily for dead or moribund animals. After 10 days, the sediments were sieved through a 0.5 mm mesh stainless steel screen to recover the test animals. Material retained on the screen was preserved in 5% buffered formalin with rose bengal stain, and sorted under a stereomicroscope. The number of survivors was recorded for each replicate.

Microtox™ Tests. This test was performed by Parametrix, Inc., in Kirkland, Washington only during Phase 1. Sediment subsamples were shipped frozen to Parametrix, Inc. for extractions and tests. The organic solvent extraction methods and test methods were similar to those used in a survey of toxicity in San Francisco Bay (Long and Markel, 1992). Subsamples (3 g) of thawed sediment were weighed into a 50 mL Teflon centrifuge tube for extraction. The 3-g samples were centrifuged at 1900 RPM for 5 minutes and the aqueous layers discarded. Remaining moisture was removed by adding 15 g of anhydrous sodium sulfate. Dichloromethane (30 mL) was added and the samples mixed and tumbled for 16 hours. The extraction process was repeated twice. Dry weight conversion was based on percent moisture values that were measured on separate portions of each sample by drying a weighed amount overnight in an aluminum weigh boat at 95°C and then reweighing.

Solvent exchange and concentration were conducted using a jacketed Kuderna-Danish apparatus. The DCM fraction was reduced to <5 mL at 75°C, followed by the addition of 12.5 mL of undenatured ethanol. The condensing flask was partially inverted to mix layers before condensing the mixture to a volume of < 5 mL at 105°C, thus driving off the DCM fraction. Then the samples were transferred to clean vials and brought to 5 mL with ethanol and stored until testing began under nitrogen. Method blanks were prepared following the above methods without the addition of sediments.

The tests were conducted using a Microtox™ Model 500 analyzer according to the methods described by the manufacturer (Microbics Corporation). Range-finding tests were conducted to determine the optimal sample concentration that caused a 65-90% decrease in bioluminescence after 15 minutes of exposure. This test included samples shown to be either highly toxic or not toxic to amphipods, and a dilution series of the ethanol. Based upon the results of these tests, the following sample extract concentrations were used in the definitive tests: 0.05%, 0.025%, 0.0125%, and 0.0063%

For each test series, a vial of freeze-dried bacteria was rehydrated with 1.0 mL of double-distilled, charcoal filtered water and placed in the Microtox™ analyzer at 4°C. Serial dilutions of 0.1%, 0.05%, 0.025%, and 0.0125% of sample extract, plus a negative (blank) control containing diluent only, were prepared, using a 2% NaCl diluent which had been adjusted to a pH of 7.0. Each of 10 test cuvettes received 10µL of the bacterial suspension and 500 µL of diluent. These samples were allowed to incubate for 15 minutes at 15°C before the initial light reading was recorded. Then, 500µL of each extract was dispersed into the corresponding cuvettes, in duplicates, resulting in the final extract concentrations of 0.05%, 0.025%, 0.0125%, and 0.0063%.

Light readings were taken after 5 and 15 minutes of exposure. The differences between the initial light readings and the readings at 5 and 15 minutes were corrected to those in the blank controls:

$$R = I_t/I_O,$$

where: R = blank ratio; I_t = final light reading of reagent blank; and I_O = initial light reading of reagent blank.

The blank-corrected percent decreases in light, the gamma values, were calculated as:

$$\text{gamma} = [(RI_O)-I_t/RI_O]100,$$

where I_O = initial luminescence in cuvettes with sample dilution; I_t = luminescence at the end of 15 minute exposure period; and R = blank ratio. Negative gamma values represented an increase in light output in the test.

Bivalve Larvae Tests. Selected samples collected during Phase 1 were tested for toxicity with a bivalve larvae test that had been used previously in New England. Samples chosen for testing had indicated either relatively high toxicity or no toxicity to amphipods. These tests were initiated in a single batch after sample holding times that ranged from 127 to 160 days. Coot clams (*mulinia lateralis*) were collected in Narragansett Bay, Rhode Island. They were induced to spawn in the laboratory through temperature manipulation, and the eggs and sperm were collected. The eggs were fertilized and visually examined to verify that fertilization had occurred.

Elutriates were prepared by adding 100 g of wet sediments to 500 mL of seawater. The slurry was then mixed for 30 minutes using heavy aeration continously, and with manual stirring every 10 minutes. After the mixing period, the suspensions were allowed to settle for one hour, and the resultant supernatant was filtered through a 0.4 um filter. Enough material was gathered from each sample to conduct four replicate tests. About 1200 larvae per mL were added to a vial. One mL subsamples were taken from the vial and added to the elutriates. Initial counts of embryos were performed on six vials that were set aside with 15 mL of seawater in each. The tests were conducted at 22°C for 48 hours. The tests were terminated by adding buffered formalin. The number of embryos was counted in 1.0 mL subsamples and compared with that from the six initial counts. Also, the number of survivors that had normal morphological development was counted in these subsamples.

Chemical Analyses. All chemical analyses were performed by the Skidaway Institute of Oceanography, Savannah, Georgia. Upon receipt of the samples at the laboratory, they were frozen until selection for analyses. Total digestions were performed for the trace metals analyses with nitric, perchloric, and hydrofluoric acids. Following digestion, the samples were analyzed for lithium, aluminum, iron, manganese, cadmium, copper, chromium, nickel, lead, zinc, silver, arsenic, vanadium, barium, titanium, and total phosphorus by inductively coupled plasma-mass spectrometry (ICP-MS). Mercury was quantified by ICP-MS (isotope dilution) methods (Smith 1993). Total organic carbon and total Kjeldahl nitrogen were analyzed on a carbonate-free basis, using a Perkin Elmer Model 240C elemental analyzer. Total carbonate was determined from the loss in weight in acidified samples. The following detection limits were attained in these analyses: aluminum, iron, total organic carbon, total Kjeldahl nitrogen, and total carbonate (10 ppm); titanium and total phosphorus (5 ppm); chromium and manganese (1 ppm); arsenic (0.08 ppm); barium (0.02 ppm); cadmium (0.02 ppm); copper (0.13 ppm); lead (0.04 ppm); lithium (0.58 ppm); mercury (0.007 ppm); nickel (0.25 ppm); silver (0.001 ppm); vanadium (0.005 ppm); and zinc (0.38 ppm).

The procedures used in the analyses of organic compounds followed the basic methods of MacLeod et al. (1985). For the polynuclear aromatic hydrocarbon (PAH) analyses, 50 g of wet sediment was sequentially extracted with methanol, 1:1 methanol-CH_2Cl_2, and CH_2Cl_2. The organic phase was concentrated to several mL and stored refrigerated until fractionation with column chromatography. The extracts were fractionated on columns of silica gel over alumina packed over activated copper to remove elemental sulfur. Aliphatic hydrocarbons were eluted with hexane (fraction SA1), while aromatic hydrocarbons/ PCBs/pesticides were eluted with 1:1 pentane:CH_2Cl_2 (fraction SA2). Further CH_2Cl_2 separation of the SA2 fraction was accomplished by Sephadex LH-20 chromatography. PAHs were quantified by capillary gas chromatography-mass spectrometry utilizing full scan and selected ion monitoring modes. Detection limits ranged from 0.07 to 0.23 ppm.

The pesticides and PCBs were quantified by high-resolution fused silica capillary gas chromatography (GC) with electron capture detection on a Hewlett-Packard model 5890 instrument. Pesticides were identified and quantified by comparison to authentic pesticide standards. PCB congeners of the same degree of chlorination were quantified in comparison to a single reference congener described by MacLeod et al., 1985. Detection limits ranged from 0.1 to 1 ppb. Analyses of butyltins were performed with the methods of Krone et al. (1989). Samples were analyzed with a Hewlett-Packard 5890 GC interfaced with a Finnigan Incos 50 mass spectrometer operated in the electron impact mode.

The chemical analyses were performed according to the quality control/quality assurance procedures of the NS&T Program, including instrument calibration, the use of internal standards, replication of some analyses, percent recoveries of spiked blanks, and analyses of standard reference materials.

Statistical Analyses. Amphipod test results were compared with the control survival data, using Dunnett's analysis of variance (ANOVA) followed by Dunnett's mean separation test (SAS 1985), to account for error that may accompany multiple uses of the control data. Microtox^{tm} data were analyzed using EPA's Probit Analysis

Program (U.S. EPA 1988) to determine concentrations of the extracts that inhibited luminescence by 50%. Pairwise comparisons between test samples and control samples were performed using analysis of covariance (ANCOVA). To determine if any sites were significantly toxic, the mean 50% inhibition values from the three stations within each site were compared to a single control value with a one-way t-test. Although the negative control was tested only once for the Microtox^{tm} test, repeated tests of the reference toxicant (phenol) produced very similar response curves in each of 17 test batches. This observation indicates that neither the bacterial response nor the instrument varied appreciably among test batches. For the sea urchin fertilization data, the trimmed Spearman-Karber method (Hamilton et al., 1977) with Abbott's correction (Morgan 1992) was used to calculate EC50 values for dilution series tests. One-way, pairwise t-tests were used to determine significant differences of each station from controls. Also, one-way t-tests were used to identify sites that were different from the controls. The relationships between measures of contamination and measures of toxicity were determined with non-parametric Spearman rank correlation analyses (Statview software) and reported as coefficients (Rho).

Spatial Extent of Toxicity in Tampa Bay. The areal extent of toxicity in Tampa Bay was determined by plotting the results of the toxicity tests against the size of the portions of the bay that were sampled. In this exercise, the study area was post-stratified into blocks that conformed to major physiographic features. That is, following the collection of the samples, the study area was divided into blocks that represented major regions and subregions of the estuary. The blocks used for estimation of areal extent are described in Appendix B. Ideally, stratification of the study area should have been performed before the survey was conducted. However, the locations for each sampling site were selected to avoid conditions representing any particular point or non-point source. Rather, they were selected to represent conditions in general regions and they were distributed so as to cover most of the major regions of the estuary. Therefore, the data from each site probably can be used to represent conditions within the block where that site is located. Nonetheless, the results of this attempt to determine areal extent of toxicity should be viewed as rough estimates, since bias in the sampling design may have affected the results.

A total of 57 blocks were identified. Fifty-five of these contain one (and only one) of our sampling sites. They included all of the waterways of the Port of Tampa, northern and southern Hillsborough Bay, Old Tampa Bay, the yacht basins of St. Petersburg, middle and lower Tampa Bay, upper and lower Boca Ciega Bay, several bayous, and some other embayments. These blocks were outlined on navigation charts. Then, each of the sampling sites from Phases 1 and 2 was plotted within its block. The blocks were restricted to depths of 1 meter or greater.

The area of each block (average of three trials, expressed as km^2) was determined with a Uchida model KP-80N planimeter. The size of the total area represented by the 57 blocks was determined (743.7 km^2). The percent of that total represented by each block was determined. Excluding the two blocks without sampling sites, the area covered was 550.0 km^2, out of a total study area of 743.7 km^2. The other two blocks (22, northern Old Tampa Bay and 44, mouth of Tampa Bay) were not considered in the calculations of the areal extent of toxicity.

The toxicity data from the stations within each block were used to calculate the average for the block. In all cases, three stations were sampled within each of the 55 blocks for which there were data. All toxicity data were normalized to the control tests by expressing the results as percent of the control result. The average amphipod survival and average sea urchin fertilization success for each of the dilutions of the pore waters were calculated for each block. These averages were plotted on bivariate, cumulative frequency distribution graphs against area (expressed as km^2) and percent of the total area.

Based upon many hundreds of amphipod toxicity tests performed with *Ampelisca abdita*, a significant difference from controls is observed in about 90% of the samples when survival in a test sample is less than 80% of the controls (G. A. Thursby, Science Applications International Corporation, personal communication). This pattern in test results was observed also in the Tampa Bay survey. Therefore, this value (80% of controls) was identified on the frequency distribution graphs as the criterion for significant toxicity, even though statistically significant differences are frequently detected at smaller differences from control values. A similar power analysis is currently underway (Scott Carr, NBS, personal communication) for the sea urchin fertilization data. This analysis is likely to result in a reduction in the number of toxic stations, particularly those for which the differences from the controls were small and only marginally statistically significant.

In most cases where the sea urchin fertilization success in test samples was less than 80% of the controls, a significant difference from the control was found. Also, the frequency distribution of the sea urchin data indicated that there was a group of highly toxic samples, in which fertilization success was about 20% or less. In all cases where the Microtox™ bioluminescence data were less than 80% of the controls, the samples were significantly different from controls. These two thresholds (<80% and <20% of controls) were used to identify “significantly toxic” and “highly toxic” areas, respectively, in Tampa Bay.

III. Results

Sea Urchin Egg Fertilization Test. Phase 1. The results of the toxicity tests for the controls and the 90 stations and 30 sites in Tampa Bay are listed in Table 2. The mean percent fertilization for those stations and sites that were significantly different from the controls ("α" $\leq$ 0.05) are shown with an asterisk. The mean values for each station were based upon five laboratory replicates, whereas the mean values for each site were based upon the results from the three stations sampled at each site.

In all test containers, the dissolved oxygen concentrations were well above the minimum 80% saturation level required for the test. The temperatures and pH measurements also were within acceptable limits. The EC50 values for the SDS positive control tests were 2.41 and <0.625 mg/L for the two batches of samples, which was within the acceptable limits.

The ammonia and unionized ammonia concentrations varied considerably among the samples. The egg fertilization test with *Arbacia punctulata* is relatively resistant to ammonia with an EC50 of >20 mg/L, equivalent to >1186 μg/L unionized ammonia at pH 8.2. This level of unionized ammonia was exceeded in four of the 90 samples (stations 1C, 22A, 22B, 22C), all of which were very toxic to sea urchin egg fertilization at all pore water concentrations. In addition, three of these four samples had relatively high sulfide concentrations. Samples containing measurable concentrations of sulfide (i.e., >0.1 mg/L) were invariably highly toxic.

Table 2. Phase 1. Percent fertilization of sea urchin eggs for each of three concentrations of pore water (100%, 50%, 25%) and the EC50 values (percent of water quality adjusted sample). Data listed with asterisks were significantly different from controls (Dunnett’s, one-tailed t-test).

Sampling		Pore water Concentration			
Site/Station	Test	100%	50%	25%	EC50
Lydia Ann Control 1	Series	87.0	95.0	nd	>100
Lydia Ann Control 2		87.8	90.2	92.2	>100
1-A		1.0±1.0**	6.2±2.3**	18.0±2.8**	<25
1-B		0.0±0.0**	0.2±0.4**	11.8±9.2**	<25
1-C		0.0±0.0**	0.6±0.5**	11.2±5.2**	<25
Site 1 mean	**2**	**0.3±0.6****	**2.3±3.3****	**13.7±3.8****	**<25**
2-A		0.0±0.0**	6.8±3.3**	22.2±10.4**	<25
2-B		0.0±0.0**	16.8±16.3**	73.8±7.4**	33.5
2-C		0.0±0.0**	7.2±3.7**	45.0±3.3**	<25
Site 2 mean	**2**	**0.0±0.0****	**10.3±5.7****	**47.0±25.9****	**<38.5**
3-A		0.0±0.0**	3.4±1.5**	35.0±15.4**	<25
3-B		0.2±0.4**	12.6±4.7**	54.2±7.1**	26.8
3-C		9.6±1.8**	35.8±5.4**	68.0±9.0**	37.0
Site 3 mean	**1**	**3.3±5.5****	**17.3±16.7****	**52.4±16.6****	**<29.5**
4-A		0.0±0.0**	5.2±2.1**	17.8±5.3**	<25
4-B		0.0±0.0**	0.4±0.5**	2.4±0.9**	<25
4-C		0.0±0.0**	1.0±1.2**	5.0±1.7**	<25
Site 4 mean	**2**	**0.0±0.0****	**2.2±2.6****	**8.4±8.2****	**<25**
5-A		0.0±0.0**	42.0±8.5**	61.0±17.7**	37.2
5-B		0.0±0.0**	17.4±1.7**	51.0±13.9**	25.5
5-C		0.8±1.8**	12.6±9.4**	77.4±2.9**	33.5
Site 5 mean	**1**	**0.3±0.5****	**24.0±15.8****	**63.1±13.3****	**32.1**

Table 2 continued.

Sampling Site/Station	Test Series	Pore water Concentration 100%	50%	25%	EC50
6-A		46.8±11.6**	91.6±2.7	92.2±2.6	>100
6-B		86.4±1.1	96.0±1.7	94.4±2.5	>100
6-C		7.6±2.8**	72.4±3.0**	90.0±2.5	60.0
Site 6 mean	**2**	**46.9±39.4****	**86.7±12.5ns**	**92.2±2.2ns**	**>85.0**
7-A		0.4±0.9**	59.8±11.4**	88.4±3.9	52.4
7-B		0.0±0.0**	10.0±9.7**	77.0±4.2*	33.1
7-C		11.0±10.0**	78.8±6.4	88.2±2.8	64.9
Site 7 mean	**2**	**3.8±6.2****	**49.5±35.5****	**84.5±6.5ns**	**50.1**
8-A		0.2±0.4**	36.4±4.9**	90.6±2.4	43.2
8-B		1.8±3.0**	86.0±4.7*	93.6±4.1	65.4
8-C		21.8±5.3**	80.0±9.1*	92.0±4.3	71.6
Site 8 mean	**1**	**7.9±12.0****	**67.5±27.1****	**92.1±1.5ns**	**60.1**
9-A		1.6±2.6**	90.2±1.9	91.6±1.8	68.0
9-B		0.4±0.5**	77.6±2.3**	84.8±3.8*	62.1
9-C		0.8±1.3**	88.4±3.2	94.2±1.6	66.2
Site 9 mean	**1**	**0.9±0.6****	**85.4±6.8ns**	**90.2±4.8ns**	**65.4**
10-A		1.6±0.5**	88.0±4.9	97.4±1.7	65.9
10-B		0.6±0.9**	87.4±2.3	94.8±1.3	65.5
10-C		0.8±1.3**	87.4±5.4	93.2±1.9	65.9
Site 10 mean	**1**	**1.0±0.5****	**87.6±0.3ns**	**95.1±2.1ns**	**65.8**
11-A		0.8±1.3**	75.2±9.8*	87.0±2.0	60.3
11-B		0.0±0.0**	18.2±11.5**	67.8±8.6**	32.1
11-C		0.2±0.4**	8.6±1.9**	83.2±5.9	34.1
Site 11 mean	**2**	**0.3±0.4****	**34.0±36.0****	**79.3±10.2ns**	**42.2**
12-A		52.4±5.8**	90.6±3.4	92.0±3.3	>100
12-B		72.4±14.0**	90.0±1.9	92.6±2.1	>100
12-C		27.4±6.2**	92.8±1.3	91.0±4.2	78.3
Site 12 Mean	**1**	**50.7±22.5****	**91.1±1.5ns**	**91.9±ns**	**92.8**
13-A		61.8±12.4**	82.8±4.9	90.6±1.5	>100
13-B		45.0±5.2**	76.4±3.5**	79.8±4.2*	89.4
13-C		0.6±0.9**	6.8±1.8**	76.6±2.9*	32.7
Site 13 mean	**1**	**35.8±31.5****	**55.3±42.1****	**82.3±7.3***	**>74.0**
14-A		59.8±13.6**	93.8±1.9	94.6±3.4	>100
14-B		80.4±4.4	89.8±4.3	89.8±4.9	>100
14-C		82.2±5.2	91.2±1.3	95.0±1.4	>100
Site 14 mean	**1**	**74.1±12.4ns**	**91.6±2.0ns**	**93.1±2.9ns**	**>100**
15-A		0.8±1.1**	49.2±11.0**	85.4±3.0*	47.0
15-B		0.4±0.9**	60.8±7.0**	85.8±0.8*	52.8
15-C		2.2±1.9**	55.4±2.7**	88.6±1.7*	50.8
Site 15 mean	**1**	**1.1±0.9****	**55.1±5.8****	**86.6±1.7***	**50.1**
16-A		72.0±4.7*	90.0±3.0	91.8±1.1	>100
16-B		80.8±3.5	89.4±2.1	93.2±1.6	>100
16-C		78.4±8.3	89.8±1.6	93.4±1.9	>100
Site 16 mean	**1**	**77.1±4.5ns**	**89.7±0.3ns**	**92.8±0.9ns**	**>100**
17-A		52.2±7.1**	77.4±36.0*	95.2±2.8	>100
17-B		89.0±4.2	94.8±2.6	95.2±1.6	>100
17-C		57.6±19.8**	92.2±1.3	92.0±1.4	>100
Site 17 mean	**1**	**66.3±19.9ns**	**88.1±9.4ns**	**94.1±1.8ns**	**>100**
18-A		76.4±1.8	90.4±3.0	93.6±3.3	>100
18-B		83.0±3.0	91.2±2.9	93.6±2.3	>100
18-C		84.4±3.3	92.4±1.8	94.4±1.5	>100
Site 18 mean	**1**	**81.3±4.3ns**	**91.3±1.0ns**	**93.9±0.5ns**	**>100**

Table 2 continued.

Sampling Site/Station	Test Series	Pore water Concentration 100%	50%	25%	EC50
19-A		85.0±2.0	90.2±1.9	93.0±1.4	>100
19-B		65.8±2.0**	83.8±1.9*	85.4±2.1*	>100
19-C		2.8±1.1**	75.4±2.9**	93.8±2.0	60.2
Site 19 mean	**1**	**51.2±43.0ns**	**83.1±7.4ns**	**90.7±4.6ns**	**>87.4**
20-A		80.6±2.4	87.4±3.5	91.8±2.6	>100
20-B		83.6±3.4	83.6±1.9*	91.0±1.6	>100
20-C		75.0±4.5*	84.8±3.6*	93.2±2.2	>100
Site 20 mean	**1**	**79.7±4.4ns**	**85.3±1.9ns**	**92.0±1.1ns**	**>100**
21-A		38.8±1.6**	83.8±3.0*	92.6±1.6	84.4
21-B		32.2±3.3**	91.0±1.6	92.2±2.8	80.9
21-C		28.0±13.1**	84.8±2.6*	91.8±2.8	76.5
Site 21 mean	**1**	**33.0±5.4****	**86.5±3.9ns**	**92.2±0.4ns**	**80.6**
22-A		0.0±0.0**	0.0±0.0**	10.2±10.6**	<25
22-B		0.0±0.0**	0.0±0.0**	16.6±8.1**	<25
22-C		0.0±0.0**	0.8±1.8**	17.6±9.3**	<25
Site 22 mean	**2**	**0.0±0.0****	**0.3±0.5****	**14.8±4.0****	**<25**
23-A		37.4±5.7**	85.0±4.1	87.4±3.8	82.9
23-B		37.8±6.5**	90.4±1.1	81.4±4.2*	83.9
23-C		18.8±6.1**	78.6±4.4	86.4±2.9	69.7
Site 23 mean	**2**	**31.3±10.9****	**84.7±5.9ns**	**85.1±3.2ns**	**78.8**
24-A		2.4±2.5**	82.6±5.3	90.2±3.7	64.5
24-B		69.2±6.2**	94.8±2.4	92.0±4.4	>100
24-C		10.8±3.3**	87.2±3.7	91.2±3.5	69.8
Site 24 mean	**2**	**27.5±36.4****	**88.2±6.2ns**	**91.1±0.9ns**	**78.1**
25-A		0.6±0.5**	37.6±5.4**	87.8±4.0	43.3
25-B		0.6±1.3**	56.0±3.9**	84.4±4.9	50.3
25-C		0.0±0.0**	32.4±7.1**	89.0±5.8	41.3
Site 25 mean	**2**	**0.4±0.3****	**42.0±12.4****	**87.1±2.4ns**	**45.0**
26-A		32.8±0.8**	87.0±5.4	90.2±4.4	80.4
26-B		25.0±3.1**	85.4±6.6	93.8±2.7	74.9
26-C		23.4±6.8**	69.8±3.3**	88.8±3.8	66.5
Site 26 mean	**2**	**27.1±5.0****	**80.7±9.5ns****	**90.9±2.6ns**	**73.9**
27-A		6.0±1.6**	12.8±2.9**	13.4±9.1**	<25
27-B		3.6±1.5**	16.6±3.6**	19.2±5.9**	<25
27-C		5.4±0.9**	17.2±2.9**	66.8±8.6**	31.6
Site 27 mean	**2**	**5.0±1.2****	**15.5±2.4****	**33.1±29.3****	**<27.2**
28-A		51.0±4.6**	92.8±3.9	89.8±6.4	>100
28-B		17.8±2.0**	81.4±2.4	91.8±3.3	70.3
28-C		28.2±5.5**	87.6±7.3	85.0±9.9	77.1
Site 28 mean	**2**	**32.3±17.0****	**87.3±5.7ns**	**88.8±3.5ns**	**>82.5**
29-A		18.2±2.5**	81.2±9.1	81.8±7.7*	70.0
29-B		34.0±7.9**	93.0±2.3	92.0±2.7	82.7
29-C		85.8±4.6**	94.2±3.0	94.6±1.1	>100
Site 29 mean	**2**	**46±35.4****	**89.5±7.2ns**	**89.5±6.8ns**	**>84.2**
30-A		1.8±1.1**	1.6±1.1**	11.6±4.3**	<25
30-B		1.0±1.0**	2.4±1.8**	15.2±2.5**	<25
30-C		5.6±2.9**	72.6±10.5**	84.2±1.6	60.5
Site 30 mean	**2**	**2.8±2.5****	**25.5±40.8****	**37.0±40.9****	**<36.8**

$\alpha \leq$ 0.05** *$\alpha \leq$ 0.01**

Percent fertilization was dose-responsive in all 90 samples; that is, fertilization success generally increased as the concentration of the pore water was reduced until control levels were reached. The mean EC50's indicated that sites 1-5, 22, and 27 were the most toxic.

Among the 90 samples tested with the 100% pore water, percent fertilization ranged from 0.0% in 17 samples to 89.0% in sample 17-B. Mean fertilization success was 0.0% in the samples from three sites and was 1.0% or less at nine of the sites. Results from 77 stations and 24 sites were significantly different from the controls.

In the tests with 50% pore water, 51 stations and 14 sites were significantly toxic relative to controls. Only two of the 17 samples that caused 0.0% fertilization success in the 100% pore water caused 0.0% fertilization success at this dilution. Percent fertilization ranged from 0.0% to 96.0%.

In the tests with 25% pore water, none of the samples caused 0.0% fertilization success. Results from 34 stations and 10 sites (1-5, 13, 15, 22, 27, and 30) were significantly different from controls. Generally, the results of the 25% pore water tests and the EC50's calculated from the dilution series were in agreement as to which sites were most and least toxic.

The spatial distribution of toxicity to sea urchin egg fertilization among the 90 sampling stations is illustrated in Figure 3. The most toxic samples were those that caused a significant response in the 100%, 50% and 25% pore water tests. Samples that were intermediate in toxicity caused a significant response in the 100% and 50% tests, less toxic samples caused toxicity in only the full strength (100% pore water) tests. In two samples (23B and 29A), significant differences from controls were apparent in the tests with 100% and 25% pore water, but no differences were observed in the tests of 50% pore water. In Figure 3, these stations are depicted as toxic in only the 100% pore water tests. Also, station 20B is illustrated as nontoxic, because of the results of the test with 100% pore water. Twelve of the samples were not toxic in the 100% test samples. As indicated by this test, the most toxic samples were collected in northeast Hillsborough Bay (including Ybor Channel, the mouth of the Hillsborough River, McKay Bay, and East Bay); western Old Tampa Bay; Bayboro Harbor; and Cockroach Bay. Most of the nontoxic samples were collected in Safety Harbor and Old Tampa Bay.

The spatial distribution of toxicity as determined by the site means was very similar to that based upon the individual station means (Figure 4). The site means for percent fertilization in sediments from sites 1-5 in northern Hillsborough Bay were significantly lower than the controls. Toxicity diminished into southern Hillsborough Bay and Old Tampa Bay. Sediments from site 15 in western Old Tampa Bay, site 22 in Bayboro Harbor, and site 27 in Cockroach Bay also were very toxic, even in the tests of 25% pore water. The mean percent fertilization in sediments from site 14 in Safety Harbor, sites 17-19 in eastern Old Tampa Bay, and site 20 in Bayou Grande were not significantly different from controls.

Sea Urchin Egg Fertilization Test. Phase 2. Most of the Phase 2 sea urchin tests met all of the conditions required. The dissolved oxygen concentrations were well above the minimum 80% saturation level required for the test, although a few samples required aeration to reach the minimum 80% saturation level. Also, the temperatures and pH measurements were within acceptable limits. The EC50 values for the SDS positive control tests were 7.03 and 5.43 mg/L for the two batches of samples, within the acceptable limits but higher than in the Phase 1 tests. The concentrations of total ammonia-nitrogen and unionized ammonia-nitrogen generally were within acceptable limits (below 947 µg/L unionized ammonia). However, two of the 78 samples exceeded this concentration. Also, 38 of the samples contained measurable amounts of total sulfide (i.e., >0.01 mg/L).

Some samples from all four of the regions sampled in Phase 2 were toxic in the sea urchin fertilization test (Table 3, Figures 5 and 6). Fertilization success was lower in the control sample for the 100% pore water tested in the first leg (77%) than in the second (92%), possibly reducing the sensitivity of the tests performed in the first leg. In seven samples (6C, 14B, 15B, 15C, 20A, 24B, and 25B), a significant difference from the control was apparent in either the 50% or 25% pore water test, but not in the test of 100% pore water. Most, if not all, of these seven 50% and 25% samples, however, were only marginally significant statistically. These stations are depicted as nontoxic in Figure 5. Also, significant toxicity was apparent at station 9B in the tests of 100% and 25% pore water, but not in the test of 50% pore water. This station is illustrated as toxic in 100% pore water in Figure 5.

In the Ybor Channel/northern Hillsborough Bay segment, toxicity was highest at the head of the channel. Mean fertilization success in 100% pore water ranged from 0.0 to 5.8% in sediments from sites 1-3 and 13. At site 1, toxicity was very high, especially in samples A and B collected near large storm drains at the head of the channel. At site 2, toxicity was especially high near the mouth of the Banana Docks. Sediments from Garrison Channel (site 13) were uniformLy very toxic in this test. All three samples from both sites 4 and 5 were signifi-

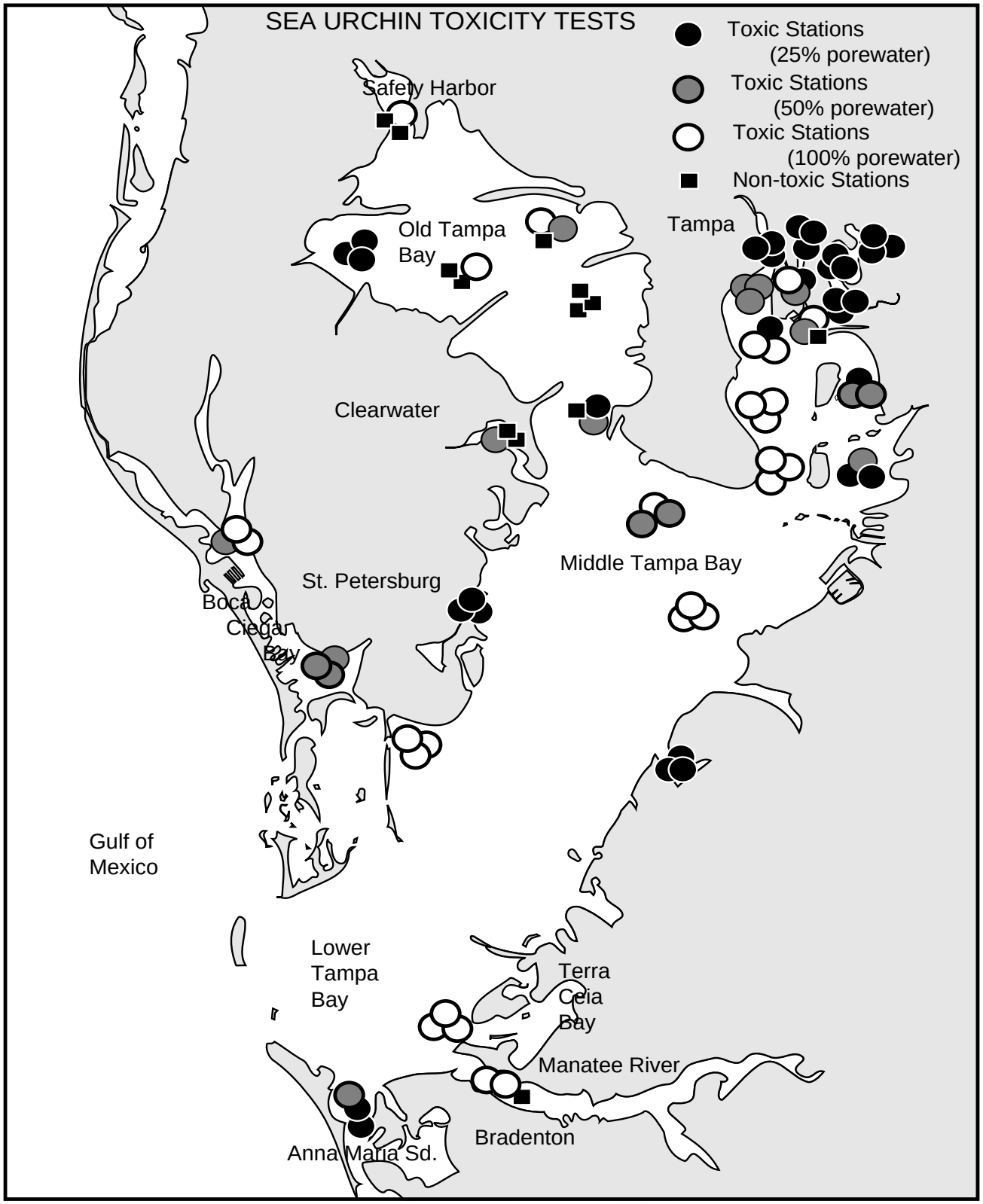

Figure 3. Sampling stations (Phase 1) in which sediments were toxic in 100% & 50% & 25% pore water, only 100% & 50% pore water, only 100% pore water, or were not toxic in sea urchin egg fertilization tests.

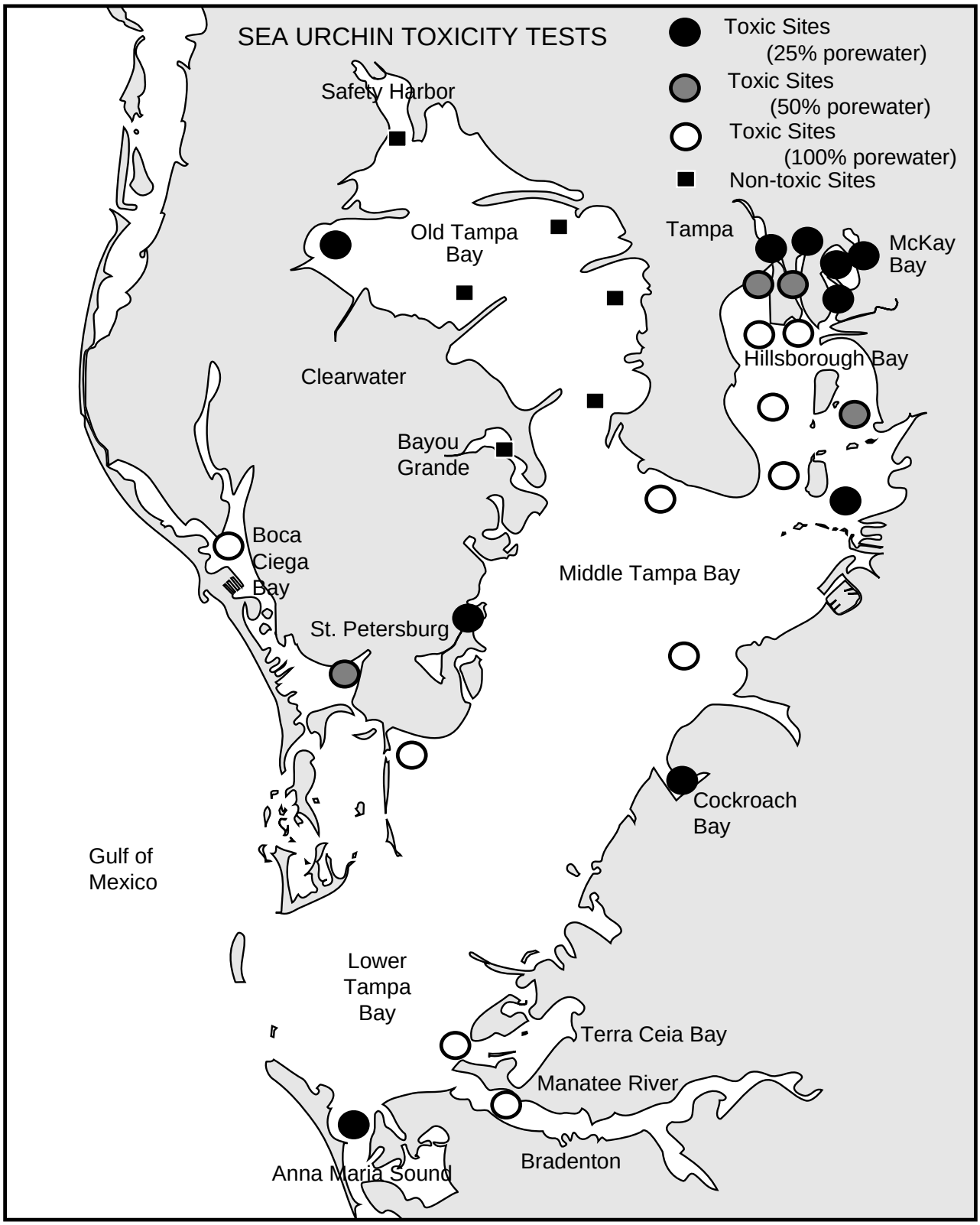

Figure 4. Sampling sites (Phase 1) in which sediments were toxic in 100% & 50% & 25% porewater, only 100% & 50% pore water, only 100% pore water, or were not toxic in sea urchin egg fertilization tests.

cantly toxic, but within-site patchiness was evident at both sites. Toxicity gradually diminished from the head of the channel downstream to Hillsborough Bay, but was still apparent south of the Davis Islands. In samples from site 6, located south of the Davis Islands, mean fertilization success in 100% pore water was 38.7% and was significantly different from controls.

In the western Old Tampa Bay segment, toxicity was very high at site 10 located in the mouth of Allen Creek. All three samples from site 10 were very significantly toxic, but the two samples (10A and 10B) collected farthest upstream were most toxic. In the mouth of the Cross Bayou Canal (site 11), toxicity was evident in all three samples. At site 11, fertilization success in 100% pore water increased from 0.0% at the upper most station (11B), to 23% at the middle station (11A), to 46% at the downstream station (11C). Compared to the sediments from sites 10 and 11, those from sites 7, 8, and 9 were considerably less toxic. Although two samples each from sites 7 and 8 were significantly different from controls, the percent fertilization success in all three samples was relatively high.

Sediment toxicity was very patchy in the sites sampled along the St. Petersburg shoreline (sites 12, 14-21). At most of the sites, one or two samples were toxic and the others were not, indicating within-site patchiness. For example, one of the three samples from each of sites 12, 14, and 15 was significantly toxic and the other two were nontoxic. The sea urchin test indicated very high toxicity in samples from site 16 (South Yacht Basin), especially those collected near the boat docks and in a bathymetric depression in the southeast corner of the basin. Also, toxicity was very high in samples from site 18 (Inner Bayboro Harbor), especially near the boat docks (stations 18B and 18C). However, there was considerable variability among the three samples, therefore, the site mean was not significantly different from the controls. The three samples from site 19 provided similar results, indicating relatively high toxicity in the entrance channel to Bayboro Harbor. None of the three samples from site 17, located off the entrance to the Central Yacht Basin, were significantly toxic. All three samples were relatively sandy. Also, samples from site 12 (Smacks Bayou), site 20 (upper Big Bayou), and site 21 (Little Bayou) were among the least toxic.

Four sites were sampled near Gulfport in lower Boca Ciega Bay, one off the mouth of Hart Creek (site 22), two off the mouth of Bear Creek (sites 23 and 24), and one west of Pasadena Island near a spoil island (site 25). One sample each from sites 22 and 25 was relatively toxic. Toxicity was very high (0.0% fertilization success in 100% pore water at station 23-A) near a marina off the mouth of Bear Creek and diminished gradually into the bay.

Table 3. Phase 2. Percent fertilization of sea urchin eggs for three concentrations of pore water (100%, 50%, 25%) and EC50 values (percent of water quality adjusted sample). Data listed with asterisks were significantly different from controls (Dunnett's, one-tailed, t-test, "a"=0.05).

Sampling	Pore water Concentration			
Site/Station	100%	50%	25%	EC50
Lydia Ann Control-1	77.2±4.4	93.6±2.1	91.8±1.9	
Lydia Ann Control-2	92.0±6.9	95.6±2.4	96.2±2.8	
1-A	0.6±0.5**	0.4±0.9**	0.6±0.5**	<25
1-B	0.6±0.9**	0.2±0.4**	0.4±0.5**	<25
1-C	0.0±0.0**	12.6±7.6**	23.6±8.5**	<25
Site 1 mean	**0.4±0.3****	**4.4±5.8****	**8.2±10.9****	
2-A	4.0±3.2**	22.4±2.5**	49.2±11.2**	<25
2-B	0.0±0.0**	2.4±2.3**	15.0±4.2**	<25
2-C	0.4±0.5**	1.4±0.5**	1.2±1.1**	<25
Site 2 mean	**1.5±1.8****	**8.7±9.7****	**21.8±20.2****	
3-A	5.8±2.3**	10.4±6.7**	38.0±9.7**	<25
3-B	3.2±1.6**	8.4±3.9**	16.0±13.4**	<25
3-C	5.6±3.4**	22.6±8.4**	61.0±12.6**	32
Site 3 mean	**4.9±1.2****	**13.8±6.3****	**38.3±18.4****	
4-A	38.8±7.6**	73.2±5.4**	86.8±4.7	84
4-B	3.4±1.8**	62.0±13.6**	87.2±7.0	56
4-C	3.0±2.1**	46.8±10.5**	77.2±12.4**	47
Site 4 mean	**15.1±16.8****	**60.7±10.8****	**83.7±4.6 ns**	

Table 3 continued.

Sampling Site/Station	Pore water Concentration 100%	50%	25%	EC50
5-A	0.8±0.8**	2.6±2.6**	16.4±8.8**	<25
5-B	0.4±0.5**	8.2±2.3**	32.6±5.7**	<25
5-C	16.0±7.5**	72.0±7.0**	82.4±4.5**	67
Site 5 mean	**5.7±7.3****	**27.6±31.5****	**43.8±28.1****	
6-A	19.2±8.3**	66.0±15.4**	77.0±19.8**	64
6-B	13.2±6.6**	72.2±16.1**	85.2±12.1	66
6-C	82.8±15.4	90.2±4.7	84.4±6.6*	>100
Site 6 mean	**38.7±31.5****	**76.1±10.2****	**82.2±3.7****	
7-A	80.6±3.9**	90.8±5.2	90.2±3.3	>100
7-B	79.2±6.0**	91.4±5.0	91.4±3.2	>100
7-C	91.6±1.8	92.6±3.2	89.0±4.1	>100
Site 7 mean	**83.8±5.5****	**91.6±0.7 ns**	**90.2±1.0 ns**	
8-A	75.2±3.3**	91.8±2.0	94.4±0.9	>100
8-B	79.0±6.7**	87.4±3.8	89.4±5.9	>100
8-C	84.2±7.0	94.0±2.9	92.2±1.9	>100
Site 8 mean	**79.4±3.7****	**91.1±2.7 ns**	**92.0±2.0 ns**	
9-A	60.2±9.5**	79.6±5.3**	79.6±25.1**	>100
9-B	71.4±5.6**	89.6±2.9	68.2±13.1**	>100
9-C	55.6±8.8**	96.2±2.2	94.4±0.9	>100
Site 9 mean	**62.4±6.6****	**88.5±6.7****	**80.7±10.7****	
10-A	0.6±0.9**	8.2±5.7**	14.6±8.4**	<25
10-B	0.6±0.5**	0.4±0.5**	35.6±5.8**	<25
10-C	0.2±0.4**	24.4±3.6**	76.4±11.6**	37
Site 10 mean	**0.5±0.2****	**11.0±10.0****	**42.2±25.7****	
11-A	22.6±11.8**	79.4±22.5**	85.4±6.9*	74
11-B	0.0±0.0**	32.8±19.9**	88.2±3.8	44
11-C	46.0±20.1**	90.2±3.6	92.6±1.5	98
Site 11 mean	**22.9±18.8****	**67.4±24.9****	**88.7±3.0***	
12-A	91.6±3.5	93.2±2.5	92.2±1.3	>100
12-B	90.2±5.0	94.2±2.6	93.0±2.6	>100
12-C	46.2±7.6**	77.6±2.9**	89.8±3.6	>100
Site 12 mean	**76.0±21.1 ns**	**88.3±7.6 ns**	**91.7±1.4 ns**	
13-A	0.0±0.0**	0.2±0.4**	16.6±8.3**	<25
13-B	0.0±0.0**	1.4±1.1**	19.8±10.6**	<25
13-C	1.0±1.2**	5.8±2.2**	16.6±5.4**	<25
Site 13 mean	**0.3±0.5****	**2.5±2.4****	**17.7±1.5****	
14-A	17.8±2.5**	62.4±3.6**	77.8±5.9**	67
14-B	84.4±6.0	84.4±6.0**	87.2±1.3	>100
14-C	75.4±7.4	88.0±5.5	89.2±3.9	>100
Site 14 mean	**59.2±29.5****	**78.1±11.3****	**84.7±5.0 ns**	
15-A	42.8±5.4**	78.2±4.5**	86.2±5.4	>100
15-B	88.2±3.4	89.2±4.3	84.4±3.9*	>100
15-C	80.8±6.2	82.4±1.7**	87.8±6.2	>100
Site 15 mean	**70.6±19.9****	**83.3±4.5 ns**	**86.1±1.4 ns**	
16-A	0.0±0.0**	36.8±7.6**	88.2±4.2	45
16-B	51.6±7.4**	81.6±5.1**	90.6±4.1	>100
16-C	8.0±2.3**	11.6±3.2**	58.4±11.4**	30
Site 16 mean	**19.9±22.7****	**43.3±28.9****	**79.1±14.6 ns**	
17-A	74.0±7.8	93.6±1.8	94.6±2.3	>100
17-B	72.6±20.3	95.8±1.3	97.0±1.0	>100
17-C	86.4±4.8	95.4±2.1	95.0±3.1	>100
Site 17 mean	**77.7±6.2 ns**	**94.9±1.0 ns**	**95.5±1.0 ns**	

Table 3 continued.

Sampling Site/Station	Pore water Concentration 100%	50%	25%	EC50
18-A	74.0±14.8**	89.2±4.7	94.6±3.8	>100
18-B	4.8±2.6**	13.2±2.7**	22.0±2.7**	<25
18-C	0.0±0.0**	0.0±0.0**	2.0±2.1**	<25
Site 18 mean	**26.3±33.8 ns**	**34.1±39.3 ns**	**39.5±39.8 ns**	
19-A	27.2±10.1**	88.6±2.7	87.8±2.8	81
19-B	17.8±3.0**	84.4±3.1**	94.0±1.4	77
19-C	19.0±3.7**	84.8±2.2*	88.8±4.2	74
Site 19 mean	**21.3±4.2****	**85.9±1.9 ns**	**90.2±2.7 ns**	
20-A	77.6±6.7	86.4±3.4*	92.4±3.4	>100
20-B	83.4±5.2	92.6±2.7	96.4±0.9	>100
20-C	61.6±6.5*	92.6±1.8	92.6±2.2	>100
Site 20 mean	**74.2±9.2 ns**	**90.5±2.9 ns**	**93.8±1.8 ns**	
21-A	64.4±14.1	88.2±3.6	88.4±3.6	>100
21-B	85.2±3.3	93.2±2.8	94.8±0.8	>100
21-C	88.4±4.0	95.8±1.6	93.6±2.5	>100
Site 21 mean	**79.3±10.6 ns**	**92.4±3.1 ns**	**92.2±2.7 ns**	
22-A	73.0±5.9	92.2±2.7	91.6±2.7	>100
22-B	88.4±4.7	93.2±3.1	92.4±3.2	>100
22-C	25.0±1.9**	76.8±3.1**	86.4±2.4	79
Site 22 mean	**62.1±27.0 ns**	**87.4±7.5 ns**	**90.1±2.7 ns**	
23-A	0.0±0.0**	2.6±1.1**	45.2±6.4**	<25
23-B	5.6±2.6**	32.8±4.7**	53.8±7.2**	31
23-C	43.0±13.4**	83.2±11.3*	88.6±4.4	94
Site 23 mean	**16/2±19.1****	**39.5±33.2****	**62.5±18.8****	
24-A	43.8±15.0**	72.6±7.3**	76.4±5.0**	>100
24-B	78.4±3.7	86.2±6.4*	86.6±3.4	>100
24-C	9.6±5.3**	38.0±3.7**	70.4±9.0**	46
Site 24 mean	**43.9±28.1****	**65.6±20.3***	**77.8±6.7***	
25-A	86.0±7.3	86.8±2.8	87.8±2.9	>100
25-B	70.4±8.5	85.0±3.7*	91.2±2.6	>100
25-C	30.8±8.4**	74.0±4.9**	89.2±3.0	82
Site 25 mean	**62.4±23.2 ns**	**81.9±5.7 ns**	**89.4±1.4 ns**	
26-A	9.0±5.3**	54.6±5.5**	86.4±6.1	54
26-B	4.8±3.3**	50.2±11.4**	76.8±6.7**	49
26-C	6.6±2.6**	37.0±7.4**	75.6±6.4**	42
Site 26 mean	**6.8±1.78****	**47.3±7.5****	**79.6±4.8 ns**	

* statistically significant at "α" ≤0.01
** statistically significant at "α" ≤0.05

Amphipod Solid-Phase Toxicity Test. Phase 1. The amphipod toxicity tests with *Ampelisca abdita* were performed in a series of nine batches that coincided with the nine sampling legs (Table 4). Mean percent survival (n=5) in the nine tests of the Central Long Island Sound (New York) controls ranged from 86.4% to 95.6%. LC50's for seven, 96-h, spiked, positive-control tests with sodium dodecyl sulfate (SDS) ranged from 5.16 to 9.56 mg/L.

Percent survival among *A. abdita* exposed to the 90 samples ranged from 39.0% to 99.0% (Table 4). Percent survival in the samples tested in each of the series was compared with survival in the respective series control, using Dunnett's one-tailed t-test. This toxicity test indicated that 10 samples and 6 sites were significantly toxic relative to controls. Percent survival was 50% or less in only 3 of the 90 samples. At most sites, the mean percent survivals among the three samples often were very similar, indicating that conditions within the sites usually were relatively homogeneous. Statistically significant results often occurred only when the within-sample variability was low. Mean amphipod survivals in the controls for test series 1 and 4 were lower (86.4% and 86.5%, respectively) than the required 90.0% (ASTM, 1990). Also, amphipod survival was highly variable among

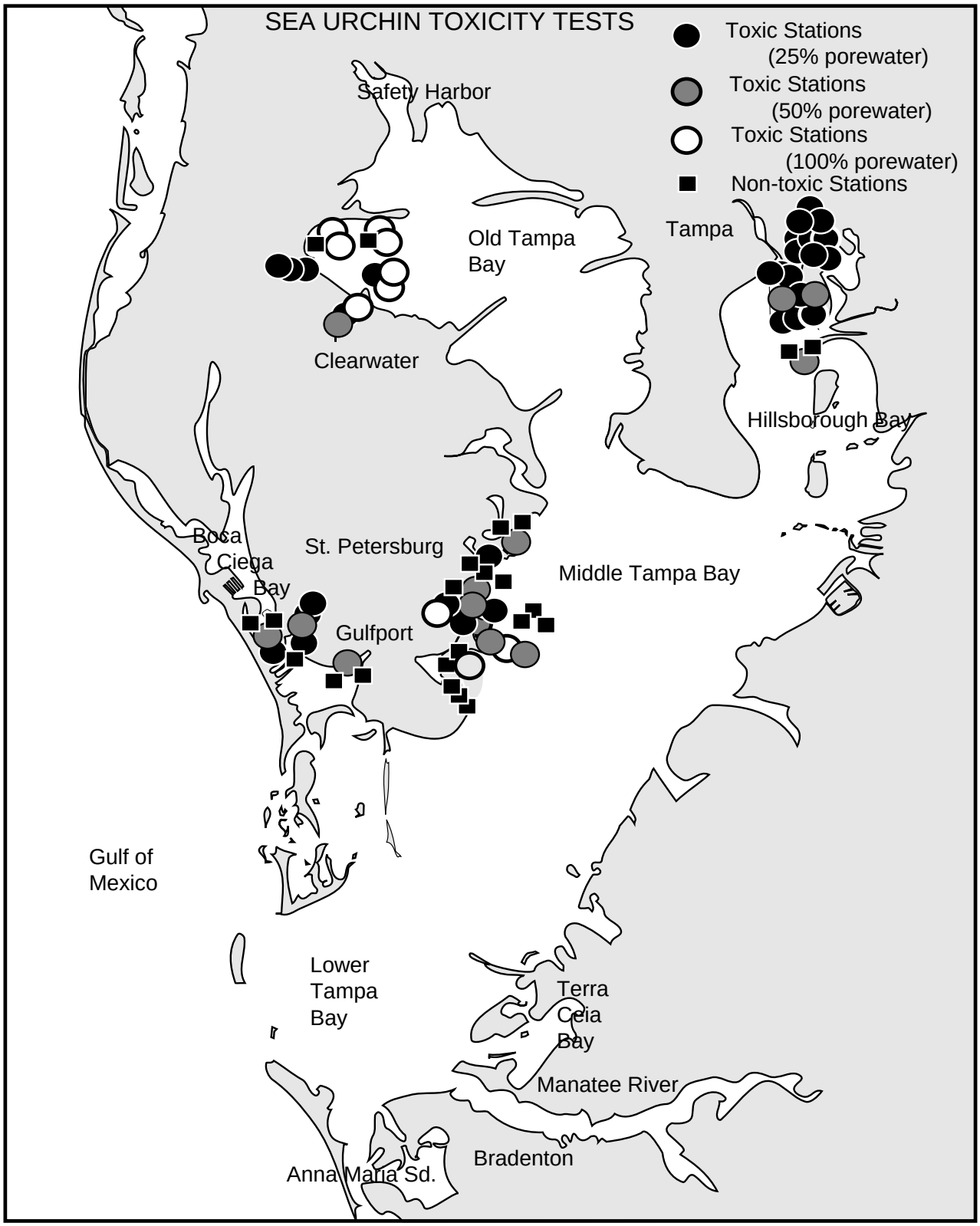

Figure 5. Phase 2 sampling stations in which sediments were toxic in 100% & 50% & 25% porewater, only 100% & 50% pore water, only 100% pore water, or were not toxic in sea urchin egg fertilization tests.

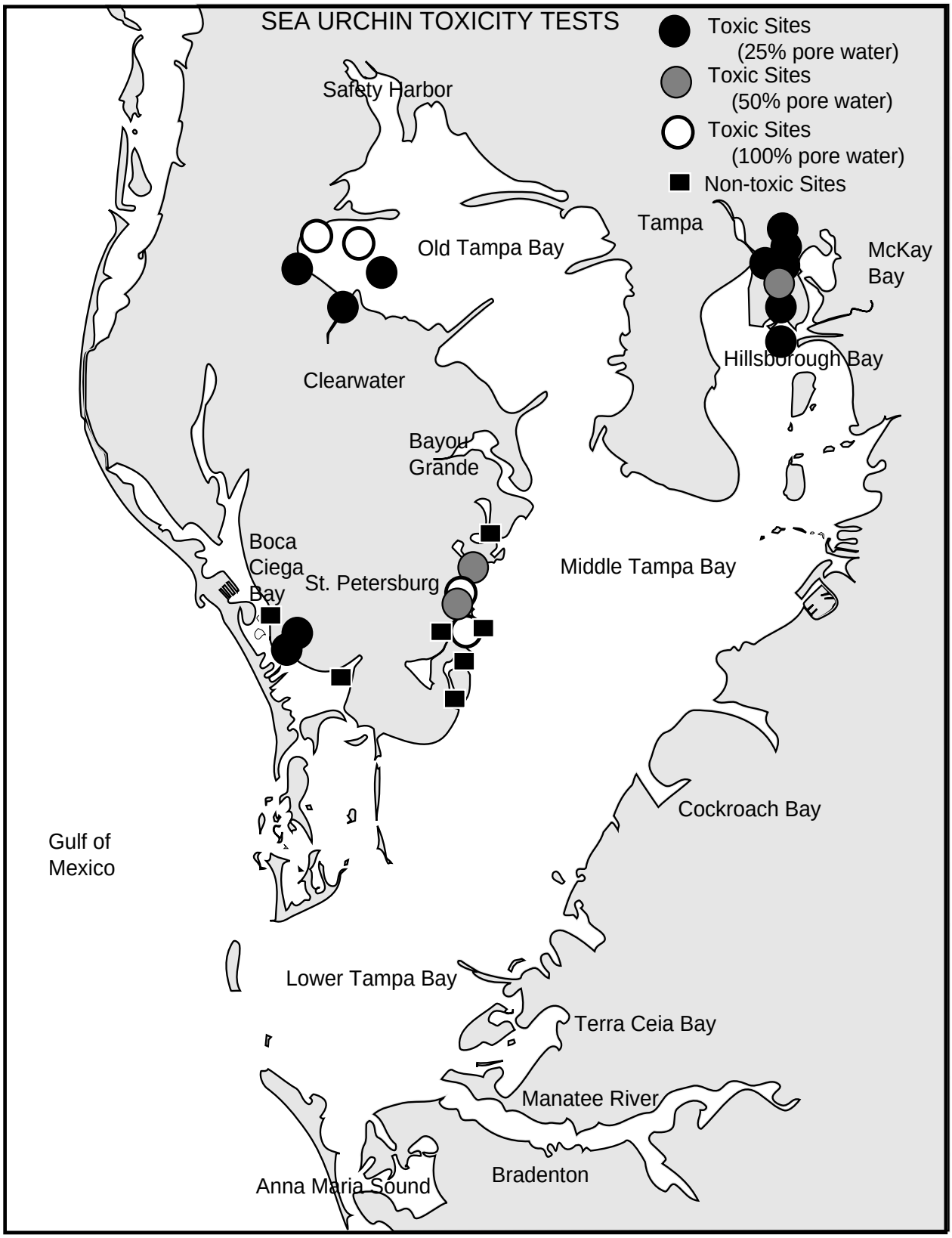

Figure 6. Phase 2 sampling sites in which sediments were toxic in 100% & 50% & 25% porewater, only 100% & 50% pore water, only 100% pore water, or were not toxic in sea urchin egg fertilization tests.

the replicates of the controls in test series 2, 4, and 5 (percent survival dropped below 80% in one or two replicates). The relatively poor performance of the test animals in test series 1, 2, 4, and 5 coupled with the within-sample variability in the results for samples tested in those series may have contributed to underestimates of toxicity.

Table 4. Phase 1. Average percent survival in amphipod tests for each station and site. Results from each station and site that were significantly different (Dunnett's, one-tailed, t-test, "a"=0.05) from controls are listed with an asterisk.

Sampling Site/station	Test Series	Mean Percent Survival±S.D.	Statistical Significance
CLIS Control	1	86.4±9.7	-
	2	91.0±12.2	-
	3	92.0±7.6	-
	4	86.5±18.3	-
	5	92.0±9.8	-
	6	95.6±3.0	-
	7	93.0±6.3	-
	8	93.0±4.5	-
	9	94.0±6.5	-
1-A	3	79.0±19.8	ns
1-B	3	77.5±6.5	*
1-C	3	92.0±4.5	ns
Site 1 mean		**82.8±6.5**	**ns**
2-A	3	45.0±11.7	*
2-B	3	39.0±13.9	*
2-B dup.	9	46.0±20.1	*
2-C	3	48.0±4.5	*
2-C dup.	9	44.0±11.4	*
Site 2 mean		**44.0±3.7**	****
3-A	2	78.0±5.7	ns
3-B	2	78.0±17.9	ns
3-C	2	86.3±2.5	ns
Site 3 mean		**80.7±3.9**	**ns**
4-A	3	73.0±13.0	*
4-B	3	77.0±13.0	*
4-C	3	86.0±6.5	ns
Site 4 mean		**78.7±5.4**	****
5-A	2	91.0±5.5	ns
5-B	2	96.0±4.2	ns
5-C	2	87.0±13.5	ns
Site 5 mean		**91.3±3.7**	**ns**
6-A	3	84.0±9.6	ns
6-B	3	82.0±10.4	ns
6-C	3	82.0±9.7	ns
Site 6 mean		**82.7±0.9**	****
7-A	3	86.0±13.9	ns
7-B	3	84.0±4.2	*
7-C	3	76.0±10.8	*
Site 7 mean		**82.0±4.3**	****
8-A	1	77.0±6.7	*
8-B	1	79.0±10.8	ns
8-B dup.	1	98.0±2.7	ns
8-C	1	77.5±11.9	ns

Table 4 continued.

Sampling Site/station	Test Series	Mean Percent Survival±S.D.	Statistical Significance
Site 8 mean		**77.8±0.8**	*****
9-A	1	80.0±8.7	ns
9-B	1	80.0±7.9	ns
9-C	1	81.0±14.7	ns
Site 9 mean		**80.3±0.5**	**ns**
10-A	2	93.1±5.5	ns
10-B	2	87.0±7.6	ns
10-C	2	91.0±6.5	ns
Site 10 mean		**90.4±2.5**	**ns**
11-A	2	86.0±4.2	ns
11-B	2	86.0±5.5	ns
11-C	2	84.0±8.2	ns
Site 11 mean		**85.3±0.9**	**ns**
12-A	7	98.0±2.7	ns
12-B	7	95.0±5.0	ns
12-C	7	99.0±2.2	ns
Site 12 mean		**97.3±1.7**	**ns**
13-A	7	99.0±2.2	ns
13-B	7	93.0±13.0	ns
13-C	7	96.0±5.5	ns
Site 13 mean		**96.0±2.4**	**ns**
14-A	4	93.0±5.7	ns
14-B	4	95.0±5.0	ns
14-C	4	97.0±4.5	ns
Site 14 mean		**95.0±1.6**	**ns**
15-A	4	90.7±4.8	ns
15-B	4	97.0±2.7	ns
15-C	4	94.0±4.2	ns
Site 15 mean		**93.9±2.6**	**ns**
16-A	4	91.3±6.3	ns
16-B	4	93.0±6.7	ns
16-C	4	93.0±4.5	ns
Site 16 mean		**92.4±0.8**	**ns**
17-A	8	96.7±2.9	ns
17-B	8	95.0±3.5	ns
17-C	8	98.3±2.9	ns
Site 17 mean		**96.6±1.3**	**ns**
18-A	6	95.0±5.0	ns
18-B	6	91.0±4.2	ns
18-C	6	90.0±4.1	ns
Site 18 mean		**92.0±2.2**	**ns**
19-A	4	93.8±2.5	ns
19-B	4	96.0±6.5	ns
19-C	4	83.0±10.4	ns
Site 19 mean		**90.9±5.7**	**ns**
20-A	5	90.0±10.8	ns
20-B	5	84.0±15.2	ns
20-C	5	98.0±2.7	ns
Site 20 mean		**90.7±5.7**	**ns**
21-A	7	96.0±4.2	ns
21-B	7	95.0±5.0	ns
21-C	7	97.0±4.5	ns

Table 4 continued.

Sampling Site/station	Test Series	Mean Percent Survival±S.D.	Statistical Significance
Site 21 mean		**96.0±0.8**	**ns**
22-A	6	85.0±9.4	ns
22-B	6	92.0±5.7	ns
22-C	6	83.0±9.7	ns
Site 22 mean		**86.7±3.9**	**ns**
23-A	8	91.3±6.3	ns
23-B	8	95.0±3.5	ns
23-C	8	95.0±3.5	ns
Site 23 mean		**93.8±1.7**	**ns**
24-A	5	98.0±2.7	ns
24-B	5	99.0±2.2	ns
24-C	5	97.0±4.5	ns
Site 24 mean		**98.0±0.8**	**ns**
25-A	6	86.0±6.5	ns
25-B	6	82.5±6.5	*
25-C	6	89.0±6.5	ns
Site 25 mean		**85.8±2.7**	****
26-A	6	86.0±10.8	ns
26-B	6	92.0±7.6	ns
26-C	6	92.0±5.7	ns
Site 26 mean		**90.0±2.8**	**ns**
27-A	9	88.8±10.3	ns
27-B	9	92.0±4.5	ns
27-C	9	91.0±9.6	ns
Site 27 mean		**90.6±1.3**	**ns**
28-A	6	92.0±5.7	ns
28-B	6	85.5±10.4	ns
28-C	6	97.0±4.5	ns
Site 28 mean		**91.5±4.7**	**ns**
29-A	5	91.0±5.5	ns
29-B	5	96.3±2.5	ns
29-C	5	92.010.4	ns
Site 29 mean		**93.1±2.3**	**ns**
30-A	9	92.0±4.5	ns
30-B	9	90.0±6.1	ns
30-C	9	92.0±9.7	ns
Site 30 mean		**91.3±0.9**	**ns**

Compared to the sea urchin tests, the results of the amphipod tests were much more uniform among sites. The majority of the individual samples that were toxic in the amphipod test were collected in northeastern Hillsborough Bay, particularly in Ybor Channel, the mouth of the Hillsborough River, McKay Bay, Sparkman Channel, and west of the Davis Islands (Figure 7). Also, one sample collected in lower Boca Ciega Bay was toxic. This test showed little indication of toxicity in southern Hillsborough Bay, Old Tampa Bay, middle Tampa Bay, and lower Tampa Bay. Based upon the means of the three stations at each site, five sites in Hillsborough Bay and one site in lower Boca Ciega Bay were significantly toxic relative to the controls (Figure 8).

Amphipod Solid-Phase Toxicity Test. Phase 2. The measures of environmental quality (temperature, salinity, DO, and pH) in the test chambers were within acceptable limits for these tests. At test termination, unionized ammonia concentrations ranged from <0.4 µg/L to 566 µg/L, all within acceptable limits for amphipods. Results of the SDS positive control dilution series differed between the two test batches. In the first batch, the

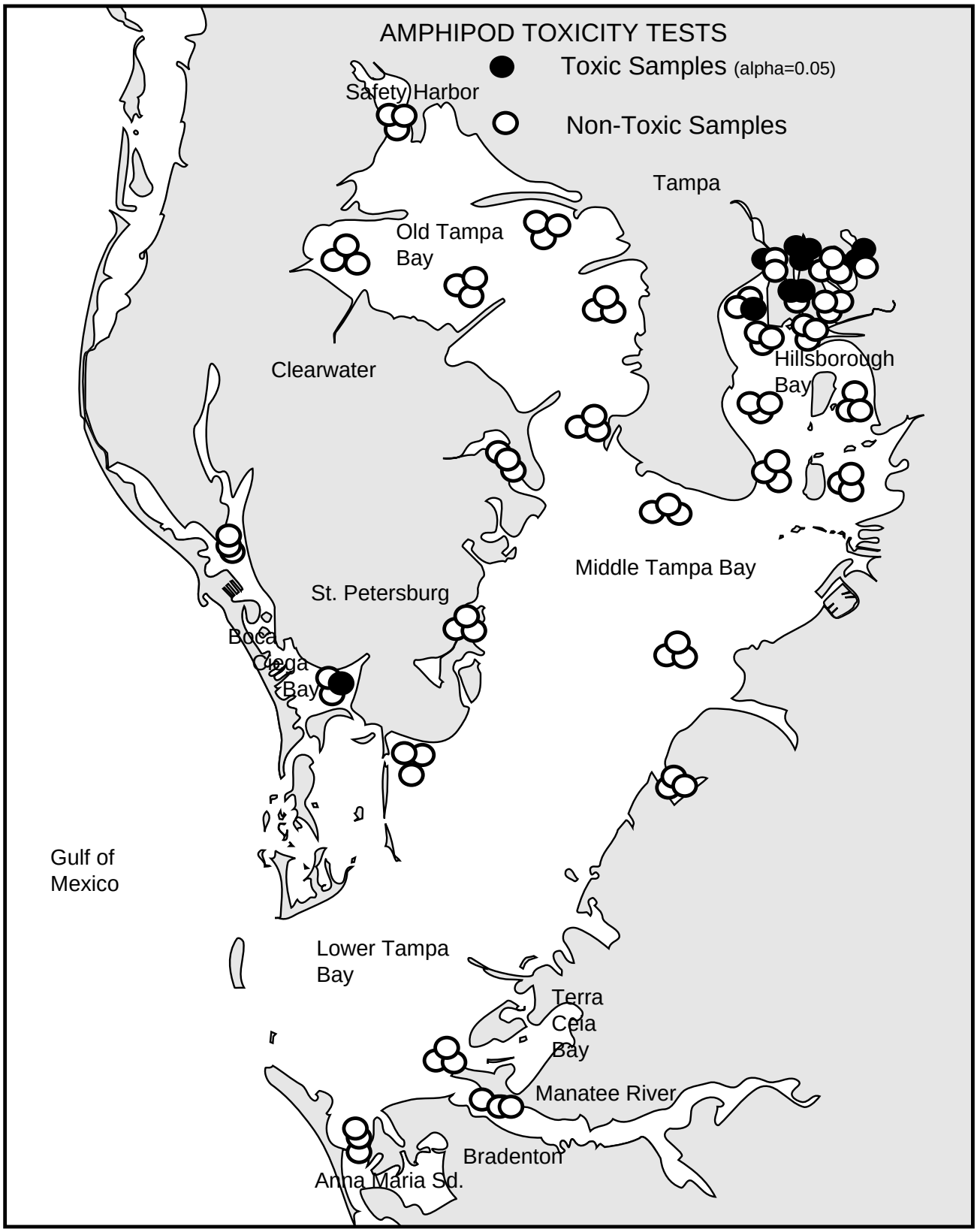

Figure 7. Sampling stations (Phase 1) in which sediments were significantly toxic to the marine amphipod, *Ampelisca abdita.*

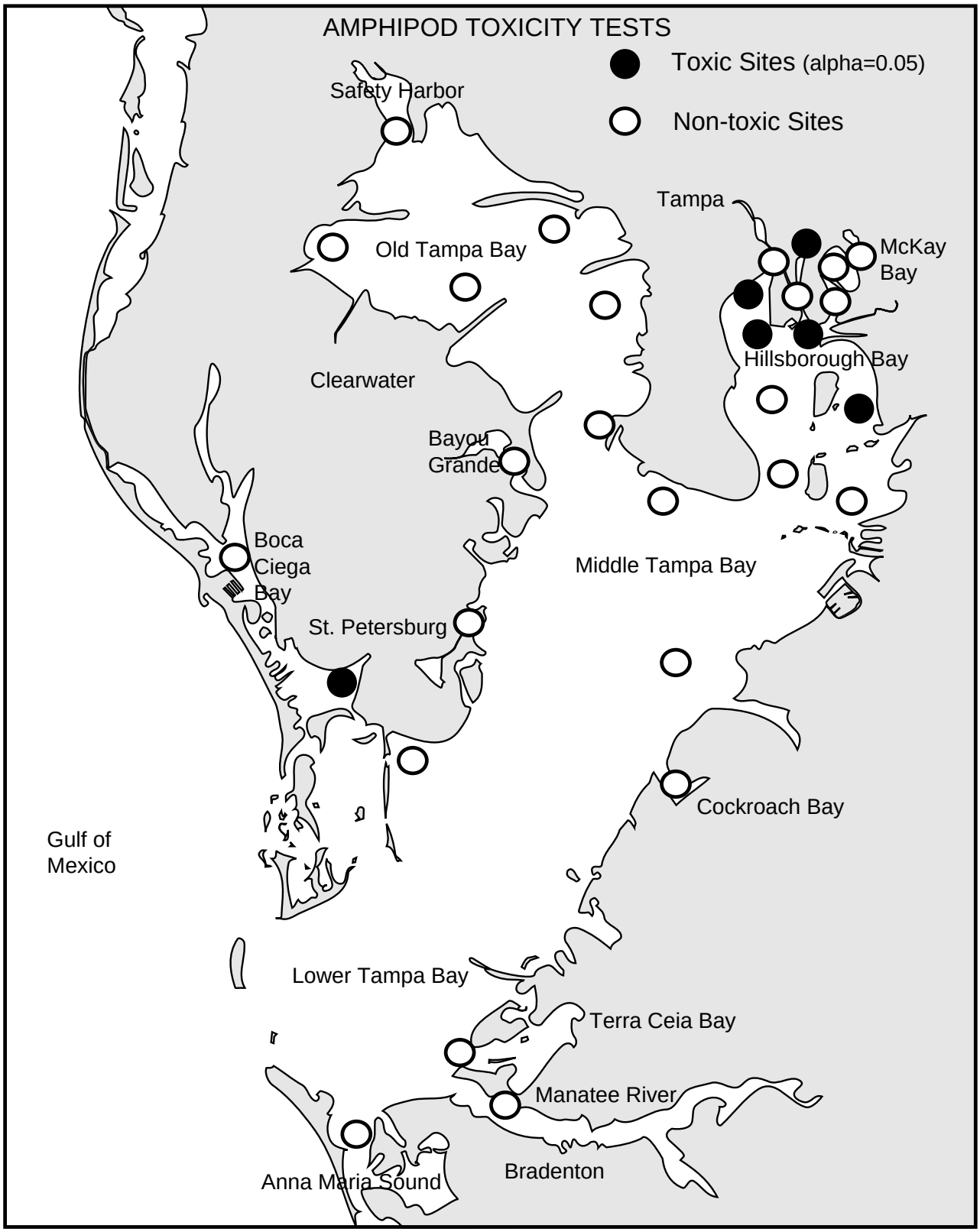

Figure 8. Sampling sites (Phase I) in which sediments were significantly toxic to the marine amphipod, *Ampelisca abdita.*

test was inadvertently terminated at 120 hrs rather than at the standard 96-hr endpoint. The 120-hr EC50 was <2 mg SDS/L. In the second batch, mortality was recorded at 96 hr, but the test was allowed to continue to 120 hr to ensure comparability with the first test batch. The EC50 in the second batch was >8 mg SDS/L at both 96 and 120 hr, suggesting that the animals used in the second batch of tests were less sensitive than those in the first batch. However, survival in the sediment controls (90% and 89%) did not reflect any differences.

None of the samples tested in Phase 2 were significantly toxic to amphipod survival (Table 5). Average survival of the controls in the two tests was 90% and 89%. Average survival in the 78 test samples ranged from 75% to 98%. Usually, a value of 75% survival in these tests would be different enough from controls to be significant, but the within-sample variability was sufficiently high to preclude significant differences at this level.

Table 5. Phase 2. Average percent survival in amphipod tests for each station and site. Statistical significance between stations or sites and controls were tested by Dunnett's, one-tailed, t-test.

Sampling Site/station	Test Series	Mean Percent Survival±S.D.	Statistical Significance
Control	1	90±9.4	-
	2	89±2.2	-
1-A	2	83±9.1	ns
1-B	2	85±0.0	ns
1-C	2	89±6.5	ns
Site 1 mean		**85.7±2.5**	**ns**
2-A	2	92±6.1	ns
2-B	2	91±8.2	ns
2-C	2	94±8.2	ns
Site 2 mean		**92.3±1.2**	**ns**
3-A	2	90±7.1	ns
3-B	2	90±11.7	ns
3-C	2	90±3.5	ns
Site 3 mean		**90.0±0.0**	**ns**
4-A	2	89±5.5	ns
4-B	2	94±4.2	ns
4-C	2	90±10.6	ns
Site 4 mean		**91.0±2.2**	**ns**
5-A	2	87±10.4	ns
5-B	2	84±15.6	ns
5-C	2	88±11.0	ns
Site 5 mean		**86.3±1.7**	**ns**
6-A	2	86±11.1	ns
6-B	2	91±10.2	ns
6-C	2	85±5.8	ns
Site 6 mean		**87.3±2.6**	**ns**
7-A	2	94±4.2	ns
7-B	2	92±5.7	ns
7-C	2	93±2.7	ns
Site 7 mean		**93.0±2.7**	**ns**
8-A	2	94±4.2	ns
8-B	2	92±4.5	ns
8-C	2	95±6.1	ns
Site 8 mean		**93.7±1.2**	**ns**
9-A	2	91±6.5	ns
9-B	2	93±4.5	ns
9-C	2	98±2.7	ns
Site 9 mean		**94.0±2.9**	**ns**
10-A	2	92±6.7	ns
10-B	2	88±9.1	ns
10-C	2	95±3.5	ns

Table 5 continued.

Sampling Site/station	Test Series	Mean Percent Survival±S.D.	Statistical Significance
Site 10 mean		**91.7±2.9**	**ns**
11-A	2	96±4.2	ns
11-B	2	93±4.5	ns
11-C	2	94±4.2	ns
Site 11 mean		**94.3±1.2**	**ns**
12-A	1	81±8.2	ns
12-B	1	82±9.7	ns
12-C	1	87±2.7	ns
Site 12 mean		**83.3±2.6**	**ns**
13-A	2	89±8.9	ns
13-B	2	91±8.2	ns
13-C	2	84±6.5	ns
Site 13 mean		**88.0±2.9**	**ns**
14-A	1	83±8.4	ns
14-B	1	87±7.6	ns
14-C	1	85±7.9	ns
Site 14 mean		**85.0±1.6**	**ns**
15-A	1	87±5.7	ns
15-B	1	82±12.0	ns
15-C	1	85±17.7	ns
Site 15 mean		**84.7±2.0**	**ns**
16-A	1	86±6.5	ns
16-B	1	80±12.7	ns
16-C	1	88±9.1	ns
Site 16 mean		**84.7±3.4**	**ns**
17-A	1	84±10.8	ns
17-B	1	87±5.7	ns
17C	1	80±14.6	ns
Site 17 mean		**83.7±2.9**	**ns**
18-A	1	82±8.4	ns
18-B	1	83±9.1	ns
18-C	1	87±4.5	ns
Site 18 mean		**81.7±1.2**	**ns**
19-A	1	90±3.5	ns
19-B	1	86±7.4	ns
19-C	1	91±6.5	ns
Site 19 mean		**89.0±2.2**	**ns**
20-A	1	91±7.4	ns
20-B	1	83±12.0	ns
20-C	1	84±13.9	ns
Site 20 mean		**86.0±3.6**	**ns**
21-A	1	83±9.1	ns
21-B	1	89±11.4	ns
21-C	1	83±12.5	ns
Site 21 mean		**85.0±2.8**	**ns**
22-A	1	78±14.0	ns
22-B	1	85±18.4	ns
22-C	1	89±5.5	ns
Site 22 mean		**84.0±4.5**	**ns**
23-A	1	83±11.5	ns
23-B	1	75±21.5	ns
23-C	1	81±10.8	ns

Table 5 continued.

Sampling Site/station	Test Series	Mean Percent Survival±S.D.	Statistical Significance
Site 23 mean		**79.7±3.4**	**ns**
24-A	1	81±6.5	ns
24-B	1	85±12.2	ns
24-C	1	77±13.0	ns
Site 24 mean		**81.0±3.3**	**ns**
25-A	1	82±5.7	ns
25-B	1	90±3.5	ns
25-C	1	84±7.4	ns
Site 25 mean		**85.3±3.4**	**ns**
26-A	2	86±4.8	ns
26-B	2	93±5.7	ns
26-C	2	91±8.9	ns
Site 26 mean		**90.0±2.9**	**ns**

Microtox™ Toxicity Test. Phase 1. Microtox™ tests were performed with organic solvent extracts from 89 samples (Table 6). An EC50 value (the sediment concentrations that caused a 50% reduction in bioluminescence) was calculated from the test results for each sample. The EC50 for the CLIS control was 0.044 mg/mL Among the 89 samples, the EC50's ranged from 0.005 to 0.575 mg/mL Sediments from 24 stations were significantly different from controls, but only two site means were significantly toxic. Variability among stations was relatively high at all sites, except at sites 1 and 2.

Table 6. Phase 1. Mean EC50 values from Microtox™ tests of organic extracts of 89 sediment samples. Significantly toxic samples are indicated with asterisks ("a"=0.05).

Sampling Site/station	Mean EC50 (mg dw/mL)	Statistical Significance[a]
CLIS Controls	0.044	-
1-A	0.009	**
1-B	0.005	**
1-C	0.008	**
Site 1 mean	**0.007±0.002**	****
2-A	0.005	**
2-B	0.010	**
2-C	0.018	**
Site 2 mean	**0.011±0.005**	****
3-A	0.031	**
3-B	0.056	ns
3-C	0.057	ns
Site 3 mean	**0.048±0.012**	**ns**
4-A	0.046	ns
4-B	0.012	**
4-C	0.103	ns
Site 4 mean	**0.054±0.004**	**ns**
5-A	0.092	ns
5-B	0.035	*
5-C	0.009	**
Site 5 mean	**0.046±0.003**	**ns**
6-A	0.161	ns

Table 6 continued.

Sampling Site/station	Mean EC50 (mg dw/mL)	Statistical Significance
6-B	0.144	ns
6-C	0.045	ns
Site 6 mean	**0.116±0.051**	**ns**
7-A	0.027	**
7-B	0.013	**
7-C	0.071	ns
Site 7 mean	**0.037±0.025**	**ns**
8-A	0.047	ns
8-B	0.078	ns
8-C	0.033	*
Site 8 mean	**0.053±0.019**	**ns**
9-A	0.072	ns
9-B	0.046	ns
9-C	0.111	ns
Site 9 mean	**0.076±0.027**	**ns**
10-A	0.063	ns
10-B	0.068	ns
10-C	0.032	*
Site 10 mean	**0.054±0.016**	**ns**
11-A	0.081	ns
11-B	0.025	**
11-C	0.087	ns
Site 11 mean	**0.064±0.028**	**ns**
12-A	0.073	ns
12-B	0.045	ns
12-C	0.035	*
Site 12 mean	**0.051±0.016**	**ns**
13-A	0.032	*
13-B	0.055	ns
13-C	0.060	ns
Site 13 mean	**0.049±0.012**	**ns**
14-A	0.093	ns
14-B	0.078	ns
14-C	0.147	ns
Site 14 mean	**0.106±0.030**	**ns**
15-A	0.019	**
15-B	0.090	ns
15-C	0.020	**
Site 15 mean	**0.043±0.033**	**ns**
16-A	>0.120	ns
16-B	>0.120	ns
16-C	>0.120	ns
Site 16 mean	**>0.120±0.0**	**ns**
17-A	no data	-
17-B	0.176	ns
17-C	0.089	ns
Site 17 mean	**0.133±0.044**	**ns**
18-A	0.213	ns
18-B	0.329	ns
18-C	0.170	ns
Site 18 mean	**0.237±0.067**	**ns**
19-A	0.051	ns

Table 6 continued.

Sampling Site/station	Mean EC50 (mg dw/mL)	Statistical Significance
19-B	0.338	ns
19-C	0.041	*
Site 19 mean	**0.143±0.138**	**ns**
20-A	>0.120	ns
20-B	>0.120	ns
20-C	>0.120	ns
Site 20 mean	**>0.120±0.0**	**ns**
21-A	0.105	ns
21-B	0.104	ns
21-C	>0.120	ns
Site 21 mean	**>0.110±0.007**	**ns**
22-A	0.043	ns
22-B	0.018	**
22-C	0.116	ns
Site 22 mean	**0.059±0.042**	**ns**
23-A	0.073	ns
23-B	0.188	ns
23-C	0.062	ns
Site 23 mean	**0.108±0.057**	**ns**
24-A	0.129	ns
24-B	0.036	*
24-C	0.129	ns
Site 24 mean	**0.098±0.004**	**ns**
25-A	0.138	ns
25-B	0.061	ns
25-C	0.056	ns
Site 25 mean	**0.085±0.037**	**ns**
26-A	0.064	ns
26-B	0.017	**
26-C	0.042	*
Site 26 mean	**0.041±0.019**	**ns**
27-A	0.424	ns
27-B	0.100	ns
27-C	0.190	ns
Site 27 mean	**0.238±0.137**	**ns**
28-A	0.500	ns
28-B	>0.120	ns
28-C	>0.120	ns
Site 28 mean	**>0.247±0.179**	**ns**
29-A	0.117	ns
29-B	0.179	ns
29-C	0.575	ns
Site 29 mean	**0.290±0.203**	**ns**
30-A	0.093	ns
30-B	0.204	ns
30-C	0.227	ns
Site 30 mean	**0.175±0.059**	**ns**

[a]* = statistically different ($\alpha \leq 0.05$) from controls; ** = Significantly different and ≤ 70% of control value.

Most of the 24 samples that were toxic in the Microtox™ tests were collected in northeastern Hillsborough Bay, particularly in the mouth of the Hillsborough River, Ybor Channel, McKay Bay, Sparkman Channel, and west of the Davis Islands (Figure 9). Other sediments that were toxic in this test were collected in southern

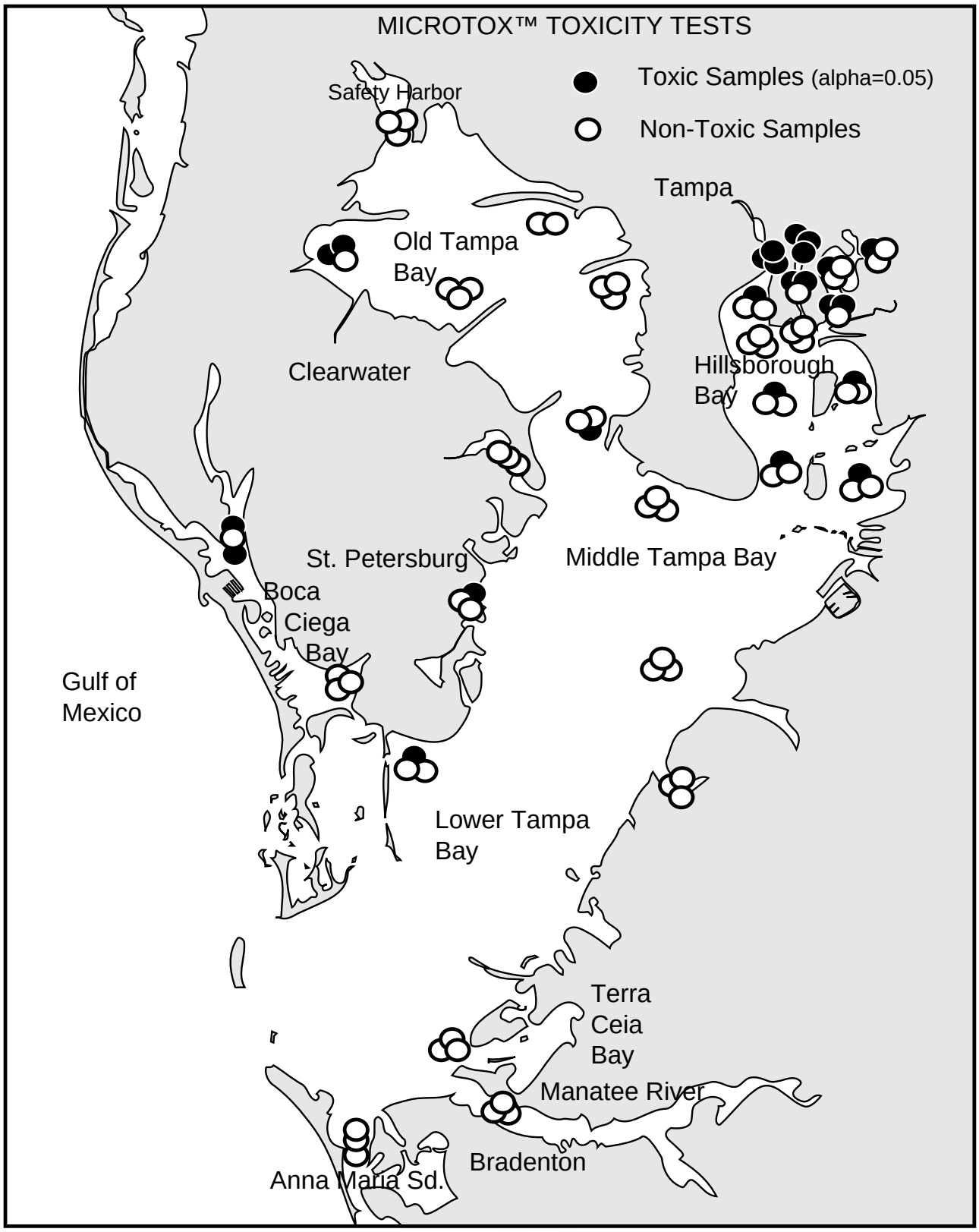

Figure 9. Sampling stations (Phase I) in which sediments were significantly toxic in the Microtox™ biouminescence test.

Hillsborough Bay, western Old Tampa Bay, Bayboro Harbor, Cockroach Bay, and upper Boca Ciega Bay. Generally, samples from Safety Harbor, much of Old Tampa Bay, Bayou Grande, middle and lower Tampa Bay, lower Manatee River, and Anna Maria Sound were not toxic. Both of the sites in which mean toxicity results were significantly different from controls were located in upper Hillsborough Bay (Figure 10).

Bivalve Embryo Tests. Phase 1. Elutriate samples from 15 of the 90 stations were tested with *Mulinia lateralis* embryos (Table 7). Mean percent survival in the CLIS controls was 71.8%, and 86.9% of these embryos developed normally. Mean percent survival was significantly lower than the controls for four samples: station 9B off the Davis Islands; station 20A in Bayou Grande; and stations 22B and 22C in Bayboro Harbor. Mean percent normal development was significantly reduced in all of the 15 samples. Percent normal development was lowest (50.1%) in sample 20C, in which percent survival was highest (65.9%). Sediments from site 2, which were clearly the most toxic to amphipods, were not appreciably more toxic in this test than the other samples tested. Indeed, none of these three samples were toxic to embryo survival.

Table 7. Phase 1. Mean percent survival and normal morphological development of *Mulinia lateralis* embryos.

Sampling Site/station	Mean percent Survival	Mean percent Normal
Seawater Control	70.9	82.6±6.6
CLIS Control	71.8±9.5	86.9±3.0
2A	61.8±10.0	62.9±13.5*
2B	64.0±4.2	55.6±6.1*
2C	65.0±3.1	67.6±6.3*
9A	59.1±11.4	62.2±11.8*
9B	48.9±11.1*	68.8±3.2*
9C	57.9±10.4	60.7±17.9*
20A	41.4±10.3*	58.4±3.6*
20B	61.6±3.6	57.4±9.6*
20C	65.9±6.0	50.1±5.5*
22A	63.6±8.9	51.5±6.9*
22B	50.5±7.5*	52.6±5.2*
22C	53.2±6.0*	63.6±16.3*
27A	59.5±10.8	66.0±8.4*
27B	57.3±3.8	67.1±13.2*
27C	59.1±8.7	70.7±7.3*

*Statistically significant reduction relative to the Central Long Island Sound control sediment, determined by Dunnett's, one-tailed, t-test ("a"=0.05).

Sediment Chemical Concentrations. The chemical concentration data for samples tested in Phases 1 and 2 are listed in Appendix C. The data are arranged in a series of tables for metals and related physical-chemical parameters, for PAHs, and for PCBs and pesticides. Relationships between contaminant concentrations and measured toxicity are discussed in sections that follow.

IV. Discussion

Summary of the Spatial Patterns in Toxicity. In this survey, sediments from 165 sampling stations were tested for toxicity with two to four complementary tests. All of the tests indicated that sediments from some locations in Tampa Bay were significantly toxic. All tests demonstrated a wide range in response. Generally, the

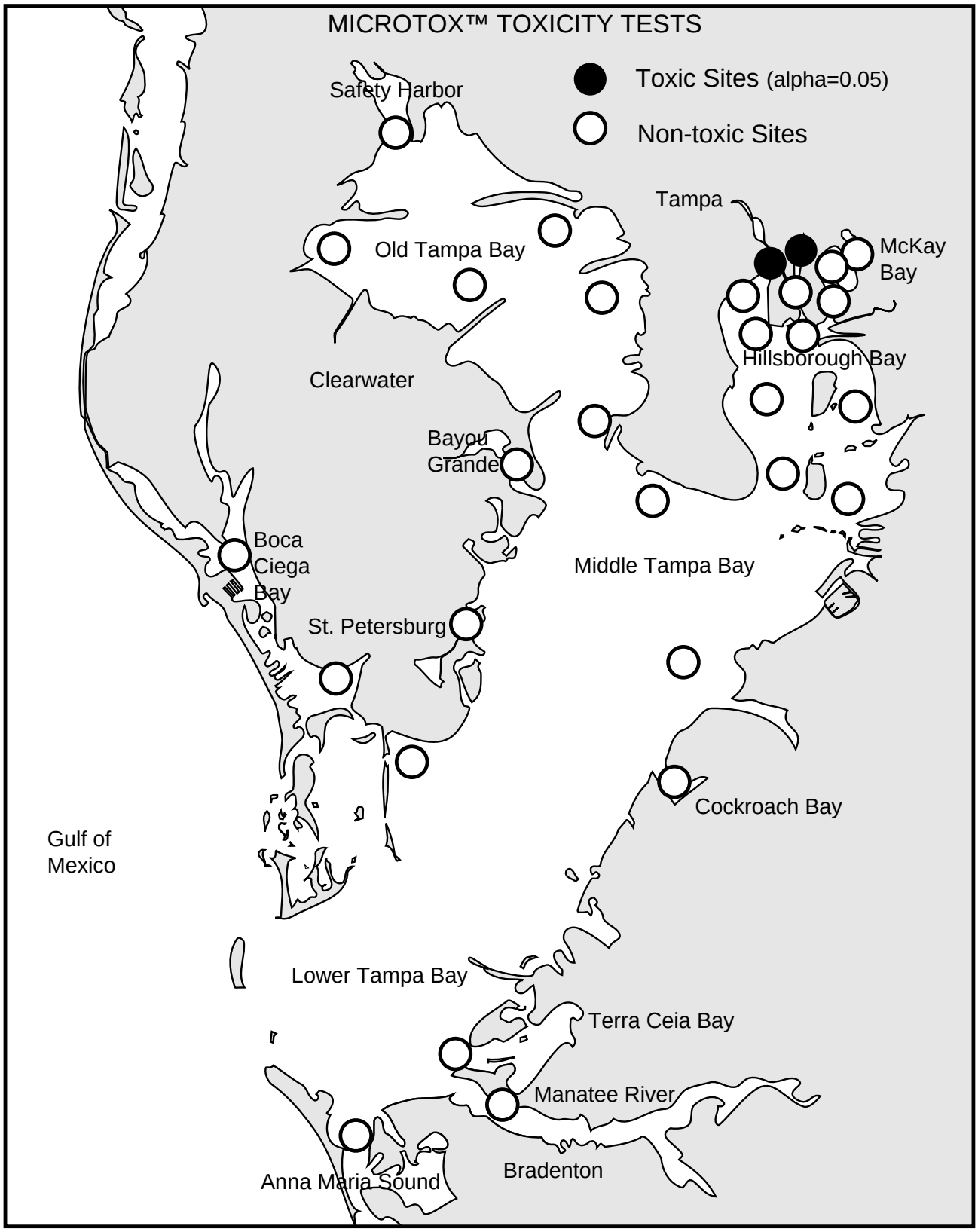

Figure 10. Sampling sites (Phase I) in which sediments were significantly toxic in the Microtox™ biouminescence test.

tests indicated that sediments from northeastern Hillsborough Bay and several peripheral harbors were among the most toxic and sediments from much of Old Tampa Bay/Safety Harbor were among the least toxic.

Table 8 presents a summary of the statistically significant results for the Phase 1 tests, by station and site. Only eleven of the 90 stations (14B, 14C, 16B, 16C, 17B, 18A, 18B, 18C, 19A, 20A, and 29C) were unanimously nontoxic in all three tests, including the 100% pore water test with sea urchins. Site 18 was not toxic at all stations for all the tests. Sites 14 and 16 were toxic at only one station in only the 100% pore water tests. Site 2 was the only site in which all three tests indicated that all three sampling stations and the site mean were significantly toxic relative to the controls. Based upon these results, it appears that the sediments at site 2 were the most toxic of the 30 sites that were sampled. The sediments collected at site 2 had visible, surface oily sheens and were anoxic. The site was located in upper Ybor Channel and was surrounded by many industries, maritime facilities, and major storm drains.

Table 8. Phase 1. Summary of toxicity test results for all stations and sites. Stations and sites that were not toxic are listed with a dash, those that were significantly different from controls are listed with an asterisk, and those in which the test results were 80% or less than controls are listed with two asterisks. The number of tests indicating significant toxicity (amphipod survival, Microtox™ bioluminescence, and/or sea urchin fertilization @ 25% pore water) is indicated for each station and site.

Sampling Site/station	Amphipod Survival	Sea urchin Fertilization 100%	50%	25%	Microtox™ Bioluminescence	Toxicity tally
1-A	-	**	**	**	**	XX
1-B	*	**	**	**	**	XXX
1-C	-	**	**	**	**	XX
Site 1 mean	**-**	****	****	****	****	**XX**
2-A	**	**	**	**	**	XXX
2-B	**	**	**	*	**	XXX
2-C	**	**	**	**	**	XXX
Site 2 mean	****	****	****	****	****	**XXX**
3-A	-	**	**	**	**	XX
3-B	-	**	**	**	-	X
3-C	-	**	**	**	-	X
Site 3 mean	**-**	****	****	****	**-**	**X**
4-A	**	**	**	**	-	XX
4-B	*	**	**	**	**	XXX
4-C	-	**	**	**	-	X
Site 4 mean	*****	****	****	****	**-**	**XX**
5-A	-	**	**	**	_	X
5-B	-	**	**	**	*	XX
5-C	-	**	**	*	**	XX
Site 5 mean	**-**	****	****	****	**-**	**X**
6-A	-	**	-	-	-	-
6-B	-	-	-	-	-	-
6-C	-	**	**	-	-	-
Site 6 mean	*****	*****	**-**	**-**	_	**X**

Table 8 continued.

Sampling Site/station	Amphipod Survival	Sea urchin Fertilization 100%	50%	25%	Microtox™ Bioluminescence	Toxicity tally[a]
7-A	-	**	**	-	**	X
7-B	*	**	**	*	**	XXX
7-C	*	**	-	-	-	X
Site 7 mean	*	**	**	-	-	X
8-A	*	**	**	-	-	X
8-B	-	**	*	-	-	-
8-C	-	**	*	-	*	X
Site 8 mean	*	**	*	-	-	X
9-A	-	**	-	-	-	-
9-B	-	**	*	*	-	X
9-C	-	**	-	-	-	-
Site 9 mean	-	**	-	-	-	-
10-A	-	**	-	-	-	-
10-B	-	**	-	-	-	-
10-C	-	**	-	-	*	X
Site 10 mean	-	**	-	-	-	-
11-A	-	**	*	-	-	-
11-B	-	**	**	**	**	XX
11-C	-	**	**	-	-	-
Site 11 mean	-	**	**	-	-	-
12-A	-	**	-	-	-	-
12-B	-	*	-	-	-	-
12-C	-	**	-	-	*	X
Site 12 mean	-	*	-	-	-	-
13-A	-	**	*	-	*	X
13-B	-	**	*	*	-	X
13-C	-	**	**	*	-	X
Site 13 mean	-	*	*	*	-	X
14-A	-	**	-	-	-	-
14-B	-	-	-	-	-	-
14-C	-	-	-	-	-	-
Site 14 mean	-	-	-	-	-	-
15-A	-	**	**	*	**	XX
15-B	-	**	**	*	-	X
15-C	-	**	**	*	**	XX
Site 15 mean	-	**	**	*	-	X
16-A	-	*	-	-	-	-

Table 8 continued.

Sampling Site/station	Amphipod Survival	Sea urchin Fertilization 100%	50%	25%	Microtox^{tm} Bioluminescence	Toxicity tally[a]
16-B	-	-	-	-	-	-
16-C	-	-	-	-	-	-
Site 16 mean	**-**	**-**	**-**	**-**	**-**	**-**
17-A	-	**	*	-	nd	-
17-B	-	-	-	-	-	-
17-C	-	**	-	-	-	-
Site 17 mean	**-**	**-**	**-**	**-**	**-**	**-**
18-A	-	-	-	-	-	-
18-B	-	-	-	-	-	-
18-C	-	-	-	-	-	-
Site 18 mean	**-**	**-**	**-**	**-**	**-**	**-**
19-A	-	-	-	-	-	-
19-B	-	**	*	*	-	X
19-C	-	**	*	-	*	X
Site 19 mean	**-**	**-**	**-**	**-**	**-**	**-**
20-A	-	-	-	-	-	-
20-B	-	-	*	-	-	-
20-C	-	*	*	-	-	-
Site 20 mean	**-**	**-**	**-**	**-**	**-**	**-**
21-A	-	**	*	-	-	-
21-B	-	**	-	-	-	-
21-C	-	**	*	-	-	-
Site 21 mean	**-**	*****	**-**	**-**	**-**	**-**
22-A	-	**	**	**	-	X
22-B	-	**	**	**	**	XX
22-C	-	**	**	**	-	X
Site 22 mean	**-**	******	******	******	**-**	**X**
23-A	-	**	-	-	-	-
23-B	-	**	-	*	-	-
23-C	-	**	-	-	-	-
Site 23 mean	**-**	******	**-**	**-**	**-**	**-**
24-A	-	**	-	-	-	-
24-B	-	**	-	-	*	X
24-C	-	**	-	-	-	-
Site 24 mean	**-**	******	**-**	**-**	**-**	**-**
25-A	-	**	**	-	-	-
25-B	*	**	**	-	-	X

Table 8 continued.

Sampling Site/station	Amphipod Survival	Sea urchin Fertilization 100%	50%	25%	Microtox™ Bioluminescence	Toxicity tally[a]
25-C	-	**	**	-	-	-
Site 25 mean	*	**	**	-	-	X
26-A	-	**	-	-	-	-
26-B	-	**	-	-	**	X
26-C	-	**	**	-	*	X
Site 26 mean	-	**	-	-	-	-
27-A	-	**	**	**	-	X
27-B	-	**	**	**	-	X
27-C	-	**	**	**	-	X
Site 27 mean	-	**	**	**	-	X
28-A	-	**	-	-	-	-
28-B	-	**	-	-	-	-
28-C	-	**	-	-	-	-
Site 28 mean	-	**	-	-	-	-
29-A	-	**	-	*	-	-
29-B	-	**	-	-	-	-
29-C	-	-	-	-	-	-
Site 29 mean	-	**	-	-	-	-
30-A	-	**	**	**	-	X
30-B	-	**	**	**	-	X
30-C	-	**	*	-	-	-
Site 30 mean	-	**	**	**	-	X

At least one of the samples from sites 1, 2, 4, and 7 was indicated as significantly toxic by all three tests (Table 8); all of these sites were located in northeastern Hillsborough Bay. The sediments from site 6 were considerably less toxic than other samples from northeastern Hillsborough Bay. Site 6 was located off the southern tip of the Davis Islands in an area near by the Hookers Point wastewater treatment plant, the Cut D Channel, and East Bay.

Figures 11 and 12 depict the spatial patterns in toxicity among stations and sites sampled in Phase 1, based upon the data from the amphipod, Microtox™, and sea urchin (25% pore water) tests. In this analysis of the data, it was assumed that the overall degree of toxicity increased with the number of significant results that were observed in the three tests. That is, a sample that caused significant toxicity in all three tests was more toxic than a sample that was toxic in, say, two of the tests. Since the sea urchin tests with 100% pore water indicated the majority of the samples were significantly toxic, the data from the 25% pore water tests were used as more conservative indicators. As estimated by the data from these three toxicity tests, the sediments from site 2 in Ybor Channel stand out as the most toxic (Figure 12).

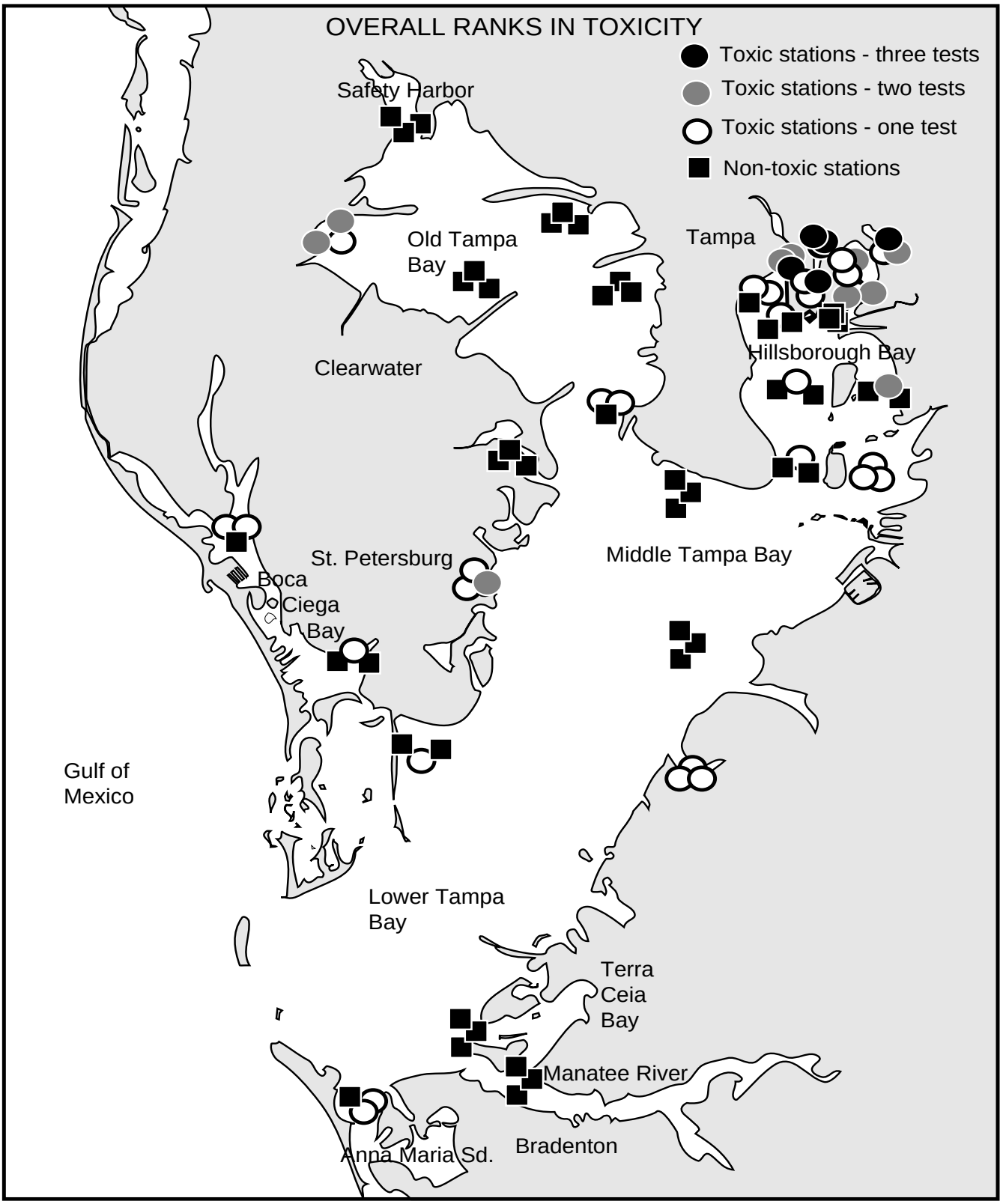

Figure 11. Distribution of toxicity in sampling stations in Tampa Bay as determined by Phase 1 results from three toxicity tests (amphipod survival, Microtox™ bioluminescence, and sea urchin fertilization @ 25% pore water).

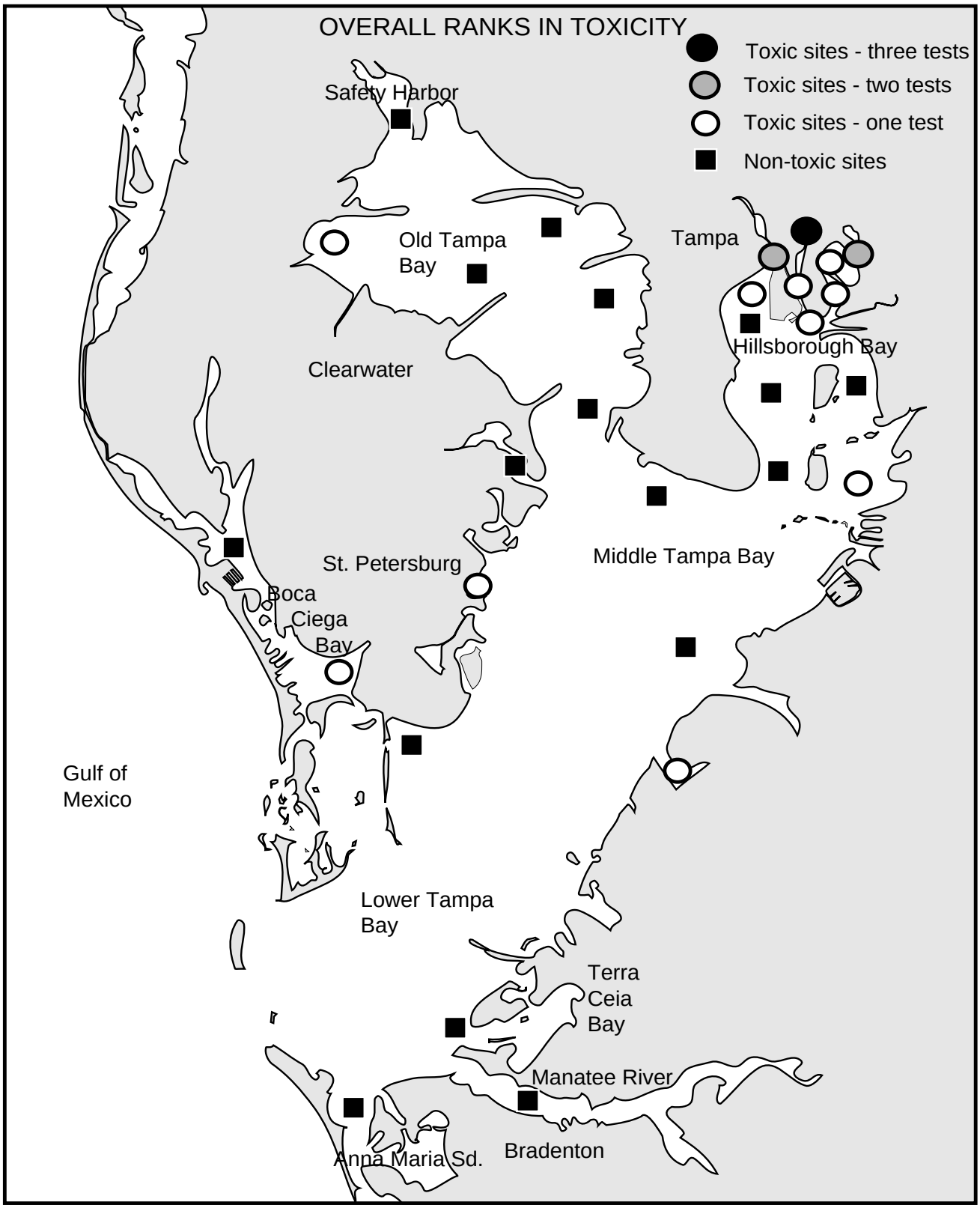

Figure 12. Distribution of toxicity in sampling sites in Tampa Bay as determined by Phase 1 results from three toxicity tests (amphipod survival, Microtox™ bioluminescence, and sea urchin fertilization @ 25% pore water).

The overall pattern indicated by the three tests is that toxicity was highest in northern Hillsborough Bay and gradually diminished toward the mouth of Hillsborough Bay. Sediments from western Old Tampa Bay, Bayboro Harbor, and Boca Ciega Bay were moderately toxic. Sediments from Safety Harbor, much of Old Tampa Bay, Bayou Grande, and middle Tampa Bay were among the least toxic.

Much of Old Tampa Bay has relatively sandy sediments, and chemical data from previous studies has shown this area to be relatively uncontaminated (Long et al. 1991). Site 15 in the western lobe of Old Tampa Bay, on the other hand, was located near the Clearwater wastewater treatment plant, and the mouths of Allen Creek and the Cross Bayou Canal, all three of which are potential sources of toxicants.

Sediments from site 20 in Bayou Grande were among the least toxic. Sediments and oysters previously sampled from Bayou Grande by the NS&T Program often have had relatively high levels of PCBs and other chemicals (Long et al., 1991). But, the sediments that were tested were very sandy and had the appearance of recent disturbance (e.g., dredging).

Sediments from sites 21 and 23 in middle Tampa Bay were toxic only to the sea urchin fertilization test. All three sediment samples from site 27 (Cockroach Bay) were toxic in all three concentrations of pore water.

At site 25 (off Gulfport), one station and the site mean were toxic to amphipods, and the samples were moderately toxic to sea urchin fertilization. All three stations in site 22 (Bayboro Harbor) were toxic in all three pore water concentrations to sea urchin fertilization and one of the samples was very toxic in the Microtox™ tests. Previous studies have shown relatively high concentrations of PAHs in the sediments of Bayboro Harbor (Doyle et al., 1985)

The amphipod tests in both Phase 1 and Phase 2 were performed with the same standardized protocols (ASTM, 1990). However, there were some differences between the tests in the two phases. The tests were performed by different laboratories; one located in Rhode Island (Phase 1) and the other in Texas (Phase 2). The test animals were collected in New England in Phase 1 and in San Francisco Bay in Phase 2. Despite these differences, amphipod survival in the negative controls was similar in the two phases (86.4% to 95.6% versus 89.0% to 90.0%, respectively). Although LC50 values determined with the positive control (SDS) bracketed similar ranges, they differed between the two phases (5.16 to 9.56 mg/L versus <2 mg/L to >8 mg/L, respectively). These differences may account for some variability in the results between Phases 1 and 2.

Since the Phase 2 amphipod tests did not indicate toxicity in any of the samples, the data from those tests have not been plotted. Also, the Microtox™ tests were not performed in Phase 2. Therefore, the Phase 1 and Phase 2 sea urchin data were merged in Figure 13 to illustrate the estuary-wide patterns in toxicity as indicated by this highly sensitive test. In Figure 13, average percent fertilization is shown for each of the 55 sites that were sampled, therefore, the shorter the bar the greater the toxicity. Sites that caused 10% fertilization success or less are noted with an asterisk.

Based upon the combined Phase 1 and Phase 2 sea urchin data, the patterns in toxicity in the Tampa Bay estuary are relatively clear (Figure 13). Very high toxicity was observed in northern Hillsborough Bay and diminished into Old Tampa Bay and Safety Harbor. Toxicity was very high at one site in western Old Tampa Bay and in the mouths of Allen Creek and the Cross Bayou Canal, and diminished into the remainder of Old Tampa Bay. Toxicity was relatively high in much of Bayboro Harbor and one site in the central St. Petersburg Yacht Basin and diminished into middle Tampa Bay and nearby bayous and inlets. Toxicity was relatively high at one site each near Gulfport and in the mouth of Bear Creek and diminished away from these sites. Toxicity was relatively high in isolated sites sampled in Anna Maria Sound and Cockroach Bay.

Because of the high incidence of toxicity in the northern Hillsborough Bay area, the sea urchin toxicity data were plotted on a smaller scale map to further define patterns in this area. The sea urchin data from Phases 1 and 2 were merged, and the data from the 100%, 50%, and 25% pore water tests were then plotted seperately as percent fertilization relative to the respective controls (Figures 14-16). Samples that were significantly different from controls are noted with asterisks.

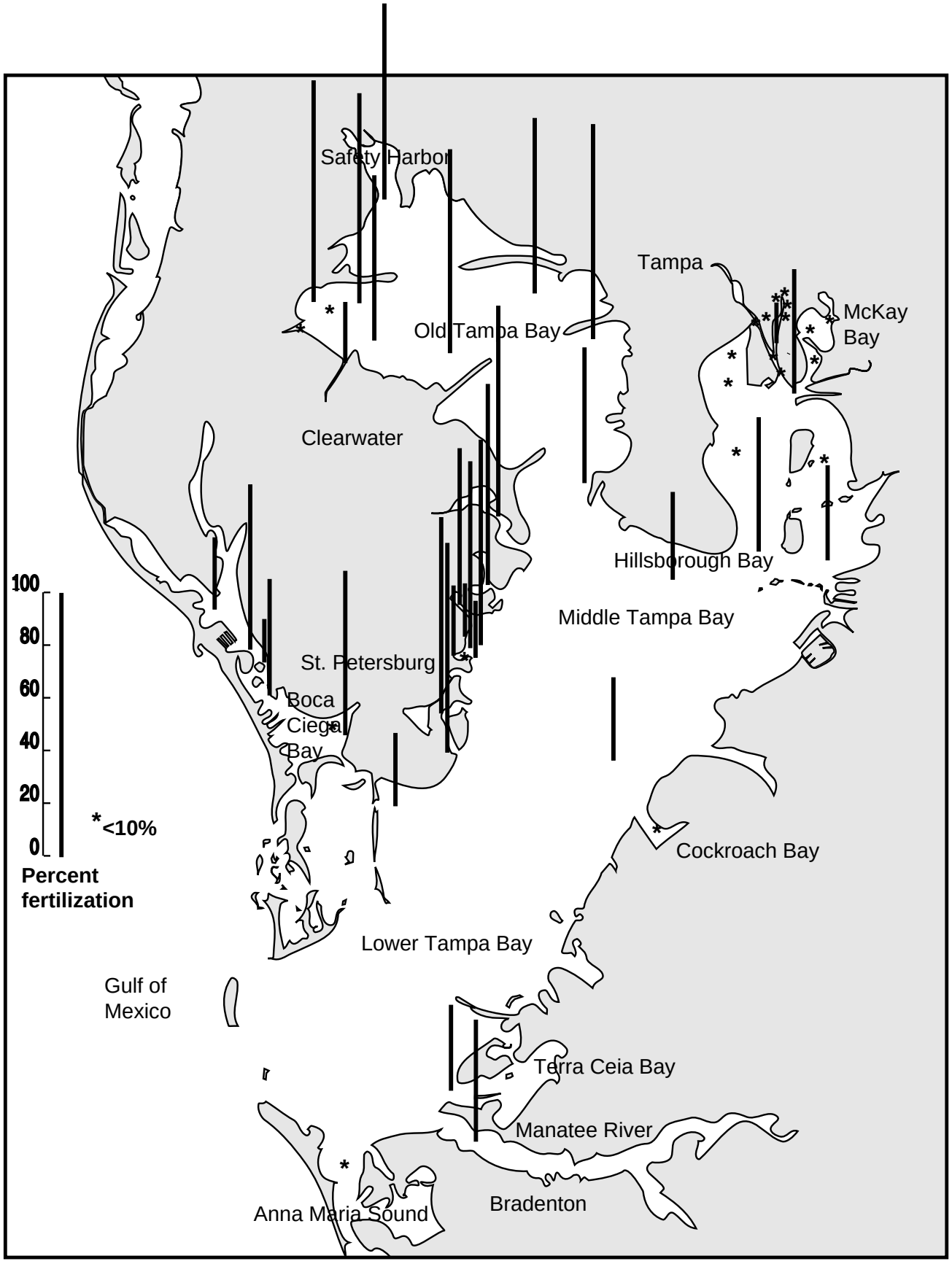

Figure 13. Combined results of Phase 1 and Phase 2 pore water toxicity tests; average percent fertilization success of sea urchin eggs exposed to 100% pore water from 55 sites.

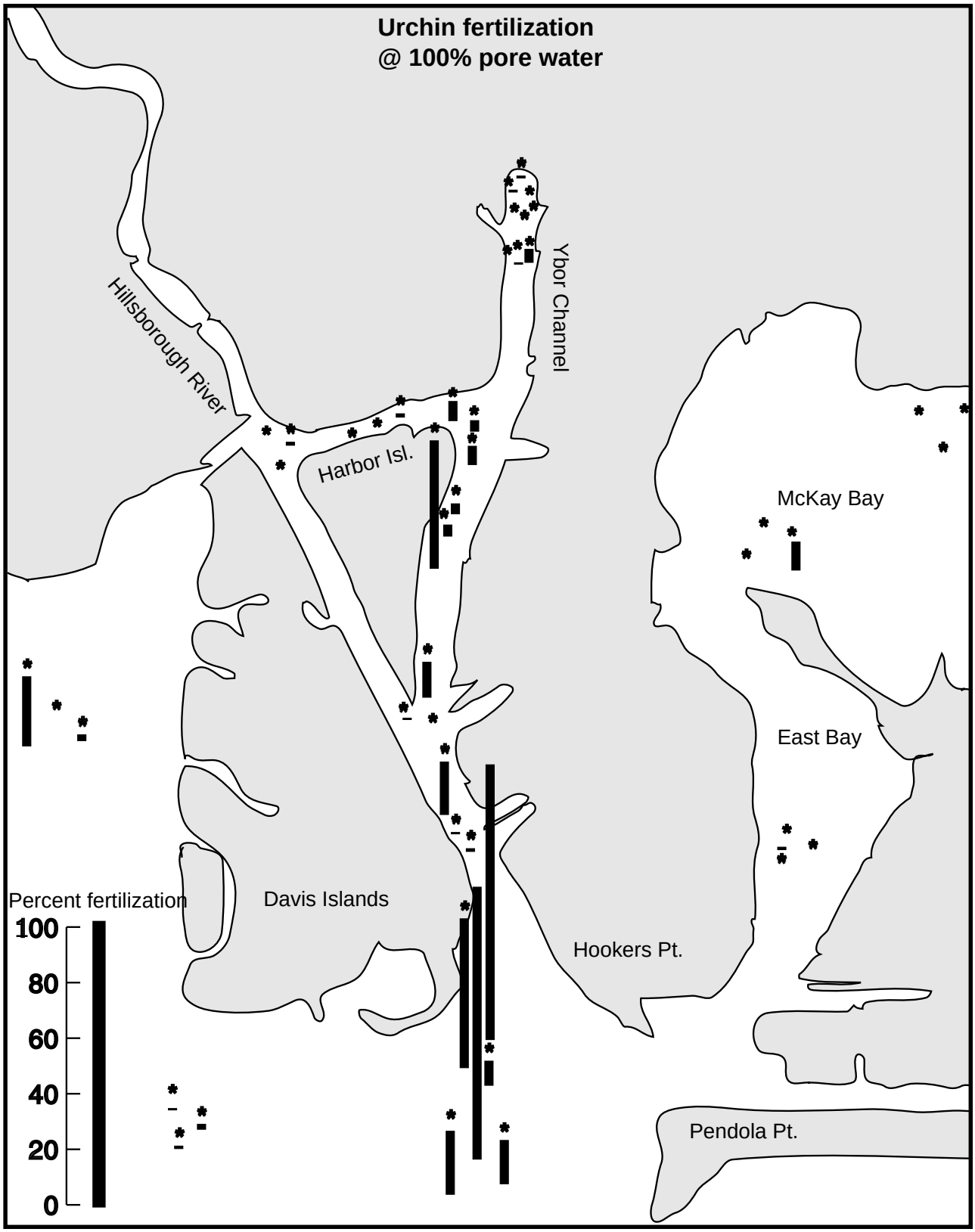

Figure 14. Percent sea urchin fertilization (Phase 1 and Phase 2) in tests of undiluted pore water samples from northern Hillsborough Bay (*significantly toxic).

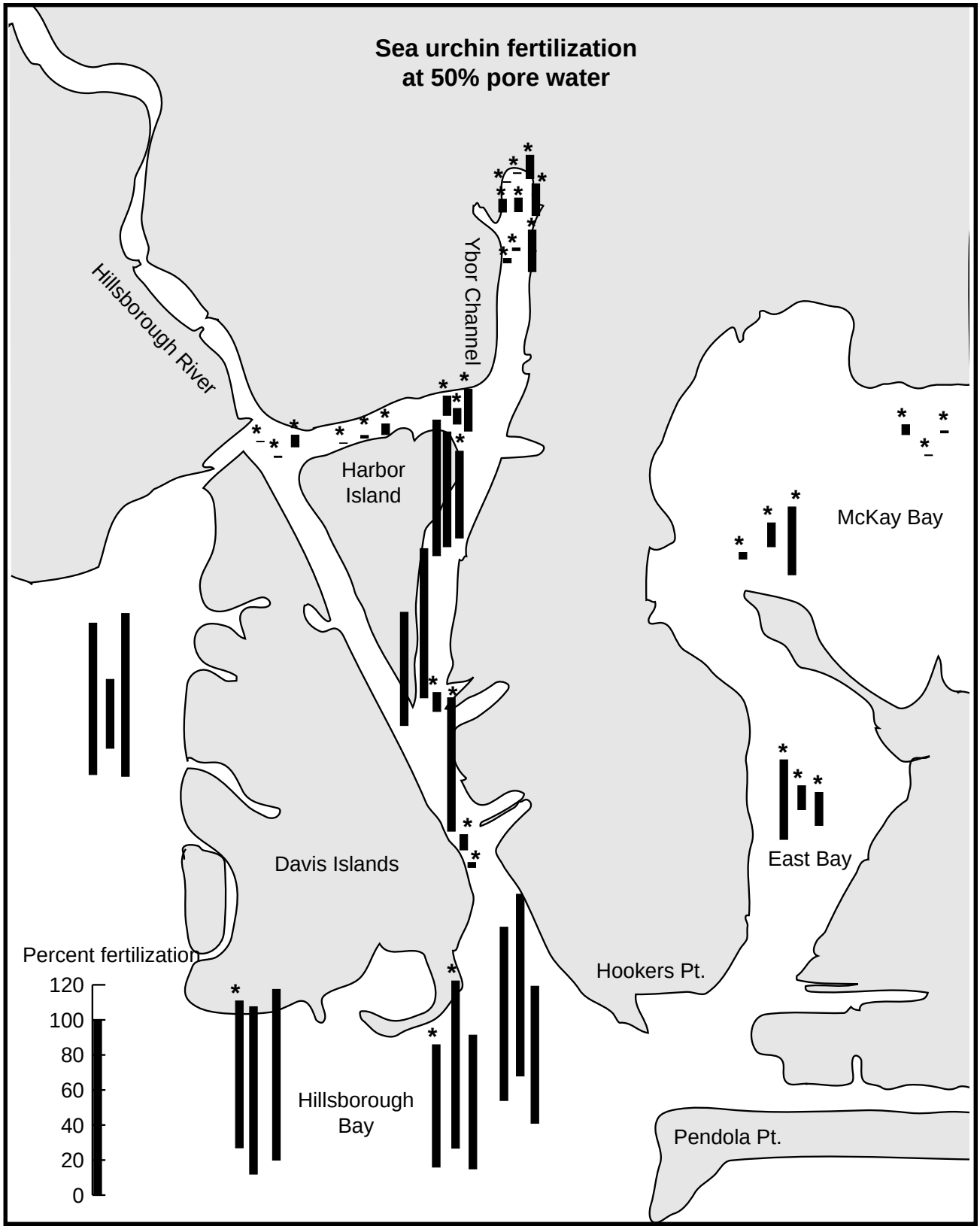

Figure 15. Percent sea urchin fertilization (Phase 1 and Phase 2) in tests of 50% pore water samples from northern Hillsborough Bay (*significantly toxic).

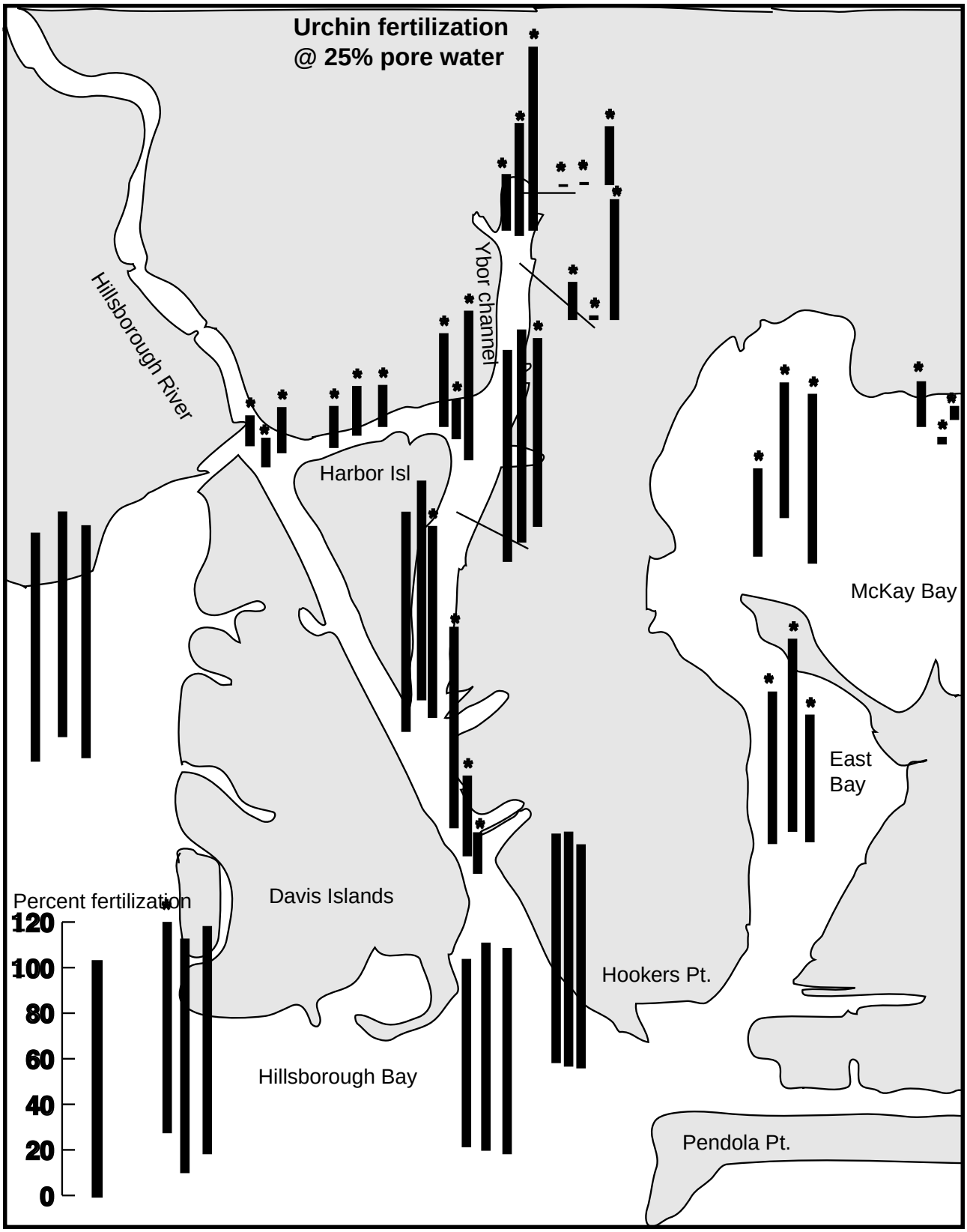

Figure 16. Percent sea urchin fertilization (Phase 1 and Phase 2) in tests of 25% pore water samples from northern Hillsborough Bay (*significantly toxic).

In the 100% pore water (Figure 14), sea urchin fertilization was very low in most of the samples, especially in those from Ybor Channel, East Bay, Garrison Channel (north of Harbor Island), and McKay Bay. Toxicity diminished in several of the samples collected south of the Davis Islands. Similar patterns in toxicity were apparent in the tests performed with 50% and 25% pore water (Figures 15 and 16). However, one additional pattern was suggested by the diluted tests. In the samples from the three sites at the head of Ybor Channel, toxicity invariably was higher in the samples from the west side of the channel than in the samples from the east side.

Summary of the Severity of Toxicity. The numbers and percentages of statistically significantly toxic stations and sites are listed in Table 9. Also identified are the numbers of stations and sites that were numerically more significantly toxic (i.e., <80% of controls). The sea urchin fertilization tests were most sensitive, followed by the Microtox^{tm} test, while the amphipod test was least sensitive. In the estuary-wide survey performed in Phase 1, 85% of the samples were toxic in the 100% pore water tests with sea urchin fertilization. In the Phase 2 survey of four selected areas, a total of 71% of the samples were toxic in this test. The statistical tests of the data for each site incorporate the within-site variability observed among the three stations at a site. Nevertheless, sediments from many of the sites (80% in 1991 and 72% in 1992) were significantly toxic, as tested by sea urchin fertilization in undiluted pore water. In the Microtox™ tests, 27% of the stations and 7% of the sites were toxic. In Phase 1, 10% of the stations and 20% of the sites were toxic in the amphipod tests, whereas in Phase 2 none of the stations or sites were significantly toxic. Differences in the Phase 1 and Phase 2 amphipod tests were discussed previously.

Table 9. Numbers (and percentages) of Tampa Bay stations and sites indicated as significantly toxic (different from controls) and numerically significant (<80% or 70% of controls) in each of the three toxicity tests.

	Number of Stations (%)		Number of Sites (%)	
Toxicity Test	**Statistically[a] Significant**	**Numerically[b] Significant**	**Statistically[a] Significant**	**Numerically[b] Significant**
Amphipod survival				
Phase 1 (n=90)	10 (11%)	4 (4%)	6 (20%)	1 (3%)
Phase 2 (n=75)	0	0	0	0
Sea urchin fertilization				
Phase 1 (n=90)				
•100%	77 (85%)	74 (82%)	24 (80%)	19 (63%)
•50%	51 (57%)	37 (41%)	14 (47%)	11 (37%)
•25%	34 (38%)	22 (24%)	10 (33%)	7 (23%)
Phase 2 (n=75)				
•100%	53 (71%)	48 (64%)	18 (72%)	16 (64%)
•50%	48 (53%)	34 (45%)	14 ((56%)	13 (52%)
•25%	33 (44%)	24 (32%)	11 (44%)	8 (32%)
Microtox^{tm} bioluminescence				
Phase 1 (n=90)				
	24 (27%)	16 (18%)	2 (7%)	2 (7%)

[a] Statistically significantly different from controls ($\alpha \leq 0.05$).
[b] Mean value 80% or less of the value from the controls for the amphipod and sea urchin tests and 70% or less of controls for the Microtox™ tests.

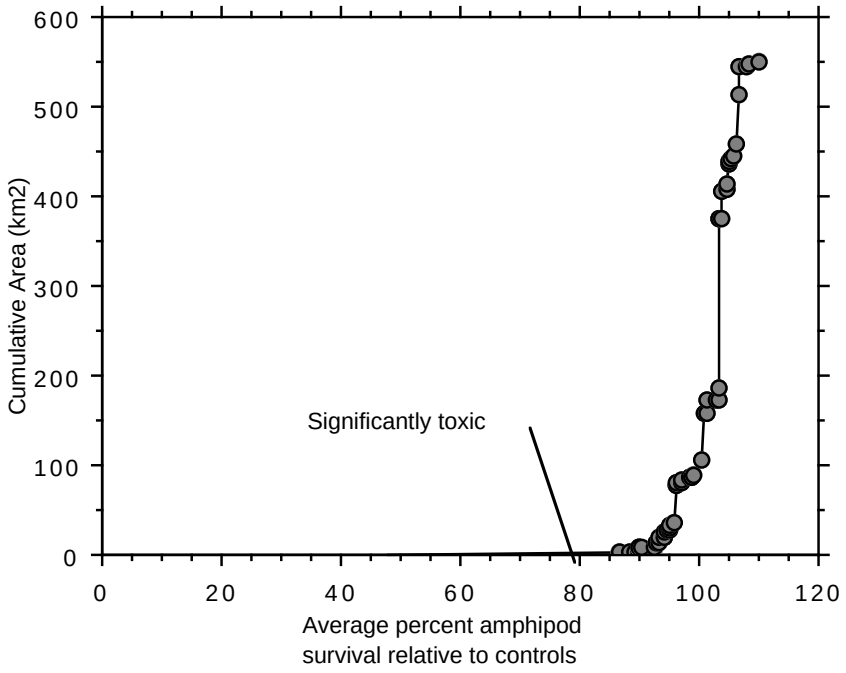

Figure 17. Spatial extent (km^2) of toxicity to amphipods within the Tampa Bay study area.

Spatial Extent of Toxicity. The spatial extent of toxicity was estimated by assigning to each sampling site an area that the site was intended to represent. For each toxicity test, the mean results for all Phase 1 and Phase 2 sites were plotted against cumulative area represented by the sites. Two criteria were used to distinguish levels of environmental degradation: significantly toxic areas (<80% of the controls) and highly toxic areas (<20% of the controls).

The spatial extent of toxicity as determined with the amphipod tests is illustrated in the frequency distribution diagram (Figure 17). The average amphipod survival was less than 80% of controls in only one sampling block. The three Phase 1 samples from Ybor Channel (site 2) were clearly the most toxic to the amphipods (average of 47% survival relative to controls). This block encompassed an area of about 0.45 km^2, representing 0.08% of the total 550 km^2 area surveyed.

The sea urchin tests were considerably more sensitive than the amphipod tests. Based upon the tests of 100% pore water, about 464 km^2 was significantly toxic, i.e., fertilization success was <80% of the controls (Figure 18). Based upon a criterion of <20% fertilization success relative to controls, about 59 km^2 was highly toxic (Figure 18). These areas represent about 84% and 11%, respectively, of the surveyed study area. As expected, the size of the areas identified as toxic diminished as the pore waters were diluted. In the tests performed with 50% pore water, about 59 km^2 was significantly toxic and 6 km^2 was highly toxic (Figure 19). These areas represent about 11% and 1%, respectively, of the surveyed study area. Based upon the tests performed with 25% pore water, only about 13 km^2 (2% of the area) was significantly toxic (Figure 20). Only four blocks (Garrison Channel, Ybor Channel, mouth of the Hillsborough River, and Palm River) were highly toxic in the tests performed with 25% pore water, encompassing 2 km^2 (0.4% of the total surveyed area). Results of the Microtox™ bioluminescence tests performed only in Phase 1 indicated that about 0.6 km^2 of the study area (mouth of the Hillsborough River and Ybor Channel) was significantly toxic (0.1% of the study area).

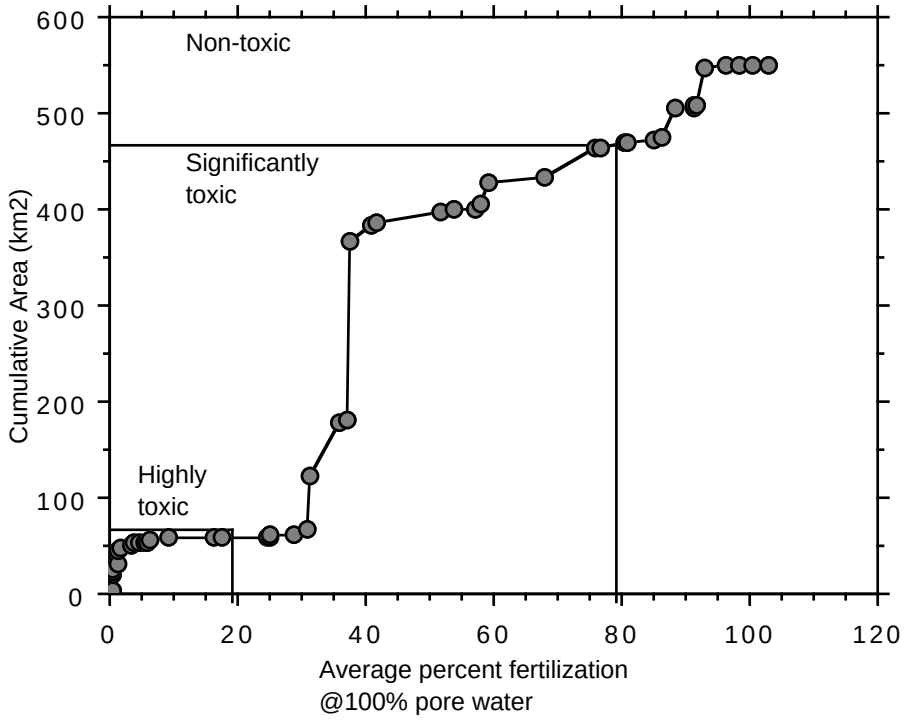

Figure 18. Spatial extent (km^2) of toxicity to sea urchin fertilization @100% pore water in the Tampa Bay study area.

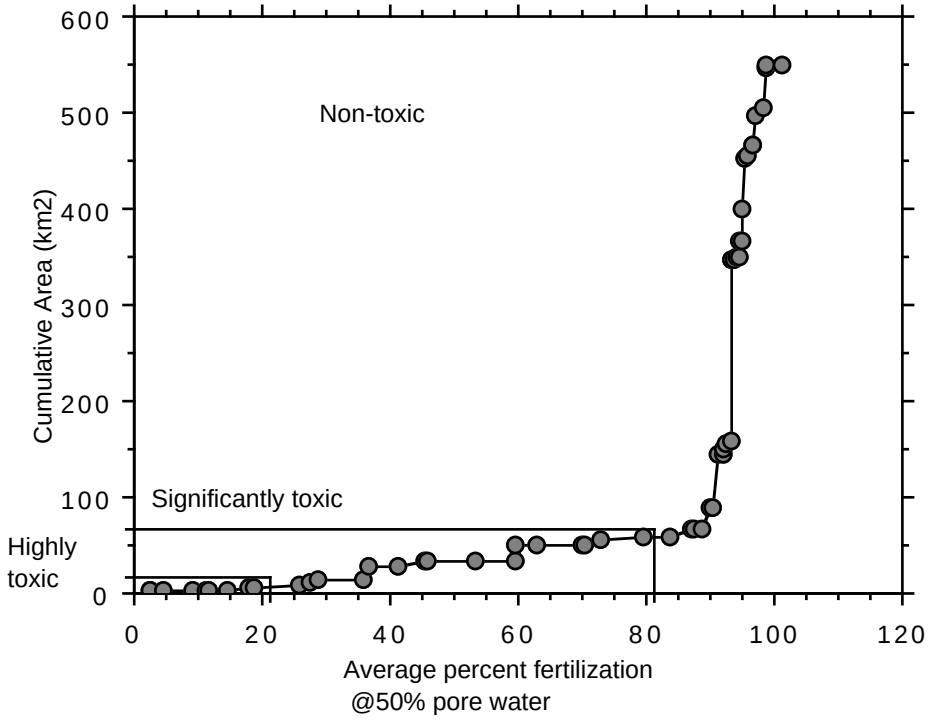

Figure 19. Spatial extent (km^2) of toxicity to sea urchin fertilization @50% pore water in the Tampa Bay study area.

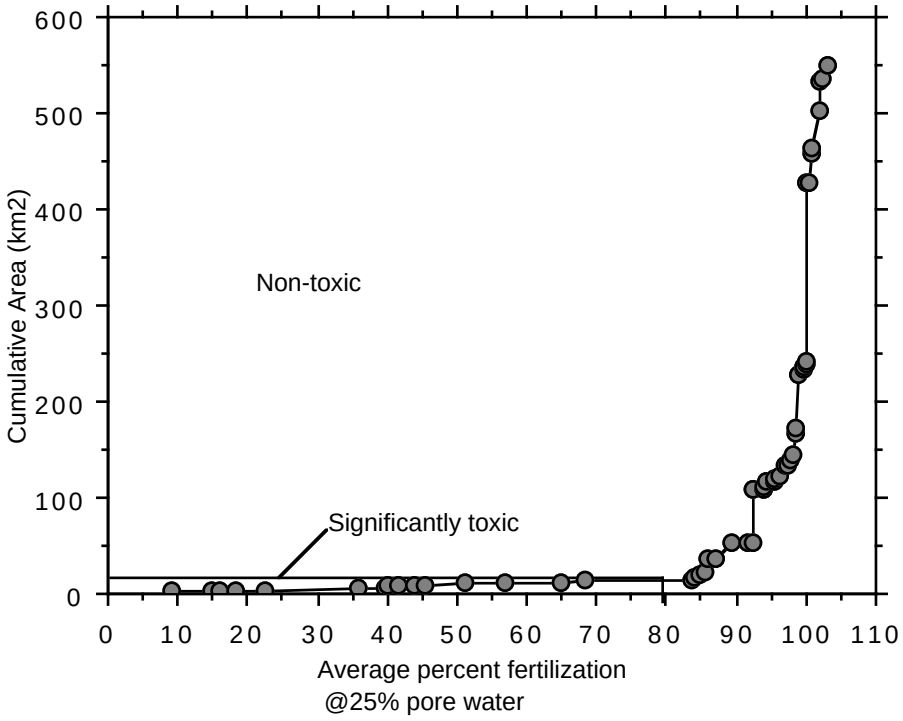

Figure 20. Spatial extent (km^2) of toxicity to sea urchin fertilization @ 25% in the Tampa Bay study area.

The estimates of the spatial extent of toxicity are summarized in Table 10, based upon the data from the three toxicity tests. Good concordance was evident among the amphipod, Microtox™, and sea urchin tests. The areas that were toxic in the Microtox™ and amphipod tests invariably were toxic in the sea urchin tests. Two sites in Phase 1 (number 1 in the mouth of the Hillsborough River and number 2 in Ybor Channel), encompassing about 0.6 km^2, were toxic in all three pore water concentrations and in the Microtox™ test. An area of about 0.45 km^2 (site 2 in Phase 1) was toxic in all three tests and at all three pore water concentrations in the sea urchin tests.

Table 10. Estimates of the spatial extent of sediment toxicity in the Tampa Bay estuary, based upon the results of three toxicity tests. Areas were defined as "toxic" when results were less than 80% of the control values.

Toxicity Tests	Area (km^2)	Percent of Area
Sea urchin @100% pore water	463.6	84.3%
Sea urchin @100% and 50% pore water	59.2	10.8%
Sea urchin @100%, 50%, 25% pore water	12.9	2.3%
Sea urchin @100%, 50%, 25% pore water and Microtox™	0.6	0.1%
Sea urchin @100%, 50%, 25% pore water, Microtox™, and amphipod	0.45	0.08%

The determination of the areal extent of toxicity involved a number of assumptions and sources of uncertainty, the most important of which was that the sampling locations correctly represented conditions within each stratification block. Ideally, the sampling locations would have been selected randomLy following the stratification of the study area into physiographic blocks. However, that kind of sampling design was not followed in this survey. The sampling design that was used may have resulted in some unknown bias that over- or underestimated the extent of toxicity. Also, the data from Phases 1 and 2 were merged to increase the number of data points for the study area. Whereas the sea urchin tests were performed by the same laboratory in both phases, the amphipod tests were performed by two different laboratories. The first laboratory identified ten of the 90 Phase 1 samples as significantly toxic, whereas the second laboratory identified none of the 75 Phase 2 samples as toxic, indicating possible differences in sample characteristics between phases or in testing between the laboratories. The boundaries and dimensions of each block were determined subjectively based upon major physiographic features, such as points of land, bridges, causeways, and the nomenclature scheme of Lewis and Whitman (1985). Some sites may have been included in adjoining blocks if other boundaries had been used.

The sizes of the blocks differed considerably. Therefore, the representativeness of the data may have differed considerably among blocks. Finally, the estimates of spatial extent of toxicity depended greatly on the sensitivity of the test; the amphipod test indicated very little of the study area was toxic, while the sea urchin test at 100% pore water indicated most of it was toxic. Other tests with different sensitivities may have resulted in different estimates of areal extent of toxicity.

In view of these uncertainties and assumptions, the estimates of the areal extent of toxicity must be regarded as rough estimates. Our toxicity test were based on different organisms, different end points, and different exposure media, and expectedly, they give quite different results. However, the most sensitive test, the urchin fertilization test with 100% pore water, clearly suggested evidence of toxicity over a majority of the study area. The serial dilutions of the pore water samples demonstrated that the most highly toxic areas were mainly in the industrialized portion of northern Hillsborough Bay. The high degree of concordance among amphipod survival, Microtox™ response, and urchin fertilization lends credence both to the overall pattern of toxicity suggested by the pore water dilution series and to the severity of contaminant effects in this highly developed portion of Tampa Bay.

Relationships among Toxicity Tests. The three toxicity tests were performed to provide complementary data from three independent and different types of tests. The solid-phase (bulk) sediments, the pore water extracted from the sediments, and extracts acquired with an organic solvent were tested. An adult amphipod, the gametes of a sea urchin, and a marine bacterium were used in the tests. The test endpoints were survival, egg fertilization success, and bioluminescent activity. Because of the large differences among these tests, they were expected to indicate different spatial patterns in toxicity and different degrees of toxicity. However, some degree of concordance among the tests was expected, especially in the least toxic and most highly toxic samples.

Spearman rank correlation coefficients were calculated to estimate the degree of concordance among the tests. In the Phase 1 tests, the correlation between percent amphipod survival and percent sea urchin fertilization (in 100% pore water) was Rho=+0.505 (p=0.0001, n=89). This correlation was relatively strong and highly significant. Similarly, the correlation between percent fertilization and the Microtox™ EC50s was very strong and highly significant (Rho=+0.564, p=0.0001, n=89). Also, the correlation between the Microtox™ EC50s and percent amphipod survival was relatively strong (Rho=+0.311, p=0.0035, n=89).

In Phase 2, however, the correlations between the amphipod survival and sea urchin fertilization test results were not significant. In the tests with 100% pore water, the correlation was Rho=-0.209 (p=0.067, n=78). In the tests with 50% and 25% pore water, the correlations were Rho=-0.091 (p=0.427) and -0.093 (p=0.415), respectively. The range of amphipod response was much wider in Phase 1 than in Phase 2, probably leading to the differences in the correlations. With the combined Phase 1 and Phase 2 data (n=141), the correlations between amphipod survival and sea urchin fertilization were significant, but weaker than in the Phase 1 data set taken alone: Rho =+0.181 in 100% pore water (p=0.032); Rho=+0.242 in 50% pore water (p=0.004); and Rho=+0.186 in 25% pore water (p=0.028). The results suggest that the amphipods used in Phase 1 may have been more sensitive than those used in Phase 2. The positive control data for the two phases reinforce this conclusion. The amphipods used in Phase 2, batch 2 exhibited lower sensitivities to SDS than did either those used in Phase 1, or those used in Phase 2, batch 1. Most of the Phase 2 sites in Upper Hillsborough Bay (where greatest toxicity was expected) were run as part of batch 2, and these results may not be directly comparable to the Phase 1

results. Unfortunately, because the amphipods were obtained from two different locations, and different control sediments were used in the two phases, no other direct comparisons are possible. This result illustrates the importance of using standardized control and reference tests to help ensure comparability of results among different test batches.

Relationships between Toxicity and Chemical Concentrations in Phases 1 and 2. The causes of toxicity in Tampa Bay sediments cannot be identified with the data collected thus far. Complex, toxicity identification evaluations performed under controlled laboratory conditions are needed to establish those relationships. However, the chemicals most associated with toxicity were identified with a two-step approach. First, the data were subjected to correlation analyses. Spearman rank correlation coefficients were determined to identify patterns in covariance between the concentrations of potential toxicants and the measures of toxicity. Because many chemicals and chemical groups co-vary as mixtures in an industrialized/urbanized system such as Tampa Bay, correlation coefficients may show strong relationships between toxicity and the concentrations of a number of potential toxicants. Therefore, a second analysis is required to clarify which chemicals are most likely contributing to toxicity. The data for those chemicals that were highly correlated with toxicity were further examined to identify those that also exceeded concentrations previously associated with toxicity in other studies. The Effects Range-Low (ERL) and Effects Range-Median (ERM) values originally proposed by Long and Morgan (1990) and updated by Long et al. (in press), were used in this step. Data for certain organic compounds were also compared to guidelines proposed by U.S. EPA (1991 a, b, c) and Swartz et al. (1994). Exceedances of the toxicity thresholds for unionized ammonia in each of the tests also were examined.

Trace Metals. Tables 11-15 summarize the Spearman rank correlation coefficients (Rho) for toxicity data and trace metals data. In Table 11, the data from Phases 1 and 2 have been merged to determine the correlation coefficients for the entire Tampa Bay study area based upon all of the data. Matching trace metals and toxicity data were produced for 141 samples. The sea urchin test results are shown for the three pore water concentrations that were tested. Many of the correlation coefficients were statistically significant. Significance levels (p) have not been adjusted for the effects of multiple comparisons in any of the correlation tables following in this report. To minimize type I errors, only the stronger associations should be considered. A Bonferroni adjustment, such as the Dunn-Sidak method [$\alpha' = 1 - (1-\alpha)^{1/k}$], where k equals the number of multiple comparisons in each analysis, estimates corrected significance levels (Sokal and Rohlf 1981). For the data in Tables 11-15, k equals 24, and only those coefficients with p less than 0.002 (i.e., including all those marked with *** or **) would remain significant at the 0.05 level after adjustment. Analogous adjustments and interpretations are advised on subsequent correlation tables as well. Amphipod survival was most highly correlated with the concentrations of lead, unionized ammonia, and sediment grain size. The sea urchin fertilization in pore waters was much more highly correlated with trace metals than was amphipod survival. Sea urchin fertilization was highly correlated with a broad suite of metals, and especially with the concentrations of cadmium, copper, lead, mercury, silver, and zinc. Also, sea urchin fertilization was highly correlated with total AVS, unionized ammonia, and sulfides. Relative to the tests with 100% and 25% pore water, many of the correlation coefficients were highest in the 50% pore water tests.

The total number of samples in which toxicity and matching trace metals data were available was sufficient to warrant splitting the data geographically. Four regions of the estuary demonstrated toxicity. Therefore, in Tables 12-15 the combined data from Phases 1 and 2 were segregated for each of four regions within Tampa Bay (Hillsborough Bay, western Old Tampa Bay, middle Tampa Bay, and Boca Ciega Bay) to determine if the toxicity/trace metals relationships differed among these regions. The Hillsborough Bay area is highly industrialized. Western Old Tampa Bay is considerably less industrialized, but is influenced by the Clearwater sewage treatment plant and urban runoff via Allen Creek and Cross Bayou Canal. Middle Tampa Bay is influenced by the many storm drains and marinas along the St. Petersburg shoreline. Boca Ciega Bay is influenced by residential/commercial districts.

In Hillsborough Bay, 51 samples were collected and tested for toxicity and metals concentrations. Amphipod survival was not correlated with any of the trace metals concentrations (Table 12). In contrast, sea urchin fertilization was highly correlated with nearly every trace metal. The correlations were highest between fertilization success and the concentrations of cadmium, lead, vanadium, and zinc. In addition, unionized ammonia was consistently highly correlated with sea urchin fertilization. Dunn-Sidak (Sokal and Rohlf 1981) adjustment would eliminate those results marked with "*" from significance at the 0.05 level.

In western Old Tampa Bay, 27 samples were tested for toxicity and trace metals concentrations (Table 13). None of the metals or physical-chemical variables were significantly correlated with amphipod survival. Trace metals, including cadmium, lead, mercury, silver, and zinc, were only modestly correlated with sea urchin fertilization. In addition, total AVS concentration was highly correlated with fertilization success.

In middle Tampa Bay, 39 samples were tested for toxicity and trace metal concentrations (Table 14). Again, trace metals were not significantly correlated with amphipod survival. Sea urchin fertilization success was significantly correlated with the concentrations of arsenic, cadmium, manganese, nickel, and zinc. In addition, fertilization success was correlated with unionized ammonia, and sulfides in the pore water.

In Boca Ciega Bay, 15 samples were tested for toxicity and trace metals concentrations (Table 15). None of the variables was significantly correlated with amphipod survival. Sea urchin fertilization was only modestly correlated with the concentrations of silver, total AVS, unionized ammonia, sulfides, and grain size (phi). Again, Dunn-Sidak (Sokal and Rohlf 1981) adjustment would eliminate those results marked with "*" from significance at the 0.05 level.

Table 11. Phases 1 and 2. Spearman rank correlation (Rho, corrected for ties) coefficients between toxicity data and concentrations of trace metals and other physical-chemical properties for all Tampa Bay sites (n=141).

	Amphipod	Sea Urchin Fertilization		
	Survival	@100%	@50%	@25%
Aluminum	-0.001	-0.400***	-0.381***	-0.373***
Arsenic	-0.064	-0.440***	-0.463***	-0.459***
Barium	-0.042	-0.372***	-0.359***	-0.372***
Cadmium	-0.216*	-0.565***	-0.577***	-0.583***
Chromium	-0.004	-0.433**	-0.408***	-0.401***
Copper	-0.247*	-0.543***	-0.577***	-0.543***
Iron	-0.028	-0.473***	-0.441***	-0.427***
Lead	-0.277**	-0.501***	-0.535***	-0.515***
Lithium	-0.041	-0.372***	-0.356***	-0.361***
Manganese	-0.030	-0.488***	-0.461***	-0.450***
Mercury	-0.139	-0.522***	-0.530***	-0.506***
Phosphorus	-0.042	-0.498***	-0.448***	-0.453***
Nickel	-0.078	-0.507***	-0.524***	-0.516***
Silver	-0.182*	-0.523***	-0.514***	-0.488***
Titanium	-0.138	-0.199*	-0.253*	-0.288**
Vanadium	-0.021	-0.475***	-0.468***	-0.459***
Zinc	-0.218*	-0.592***	-0.611***	-0.576***
% Carbon	-0.173*	-0.520***	-0.540***	-0.516***
% Nitrogen	-0.059	-0.452**	-0.474***	-0.454***
% Carbonate	-0.111	-0.510***	-0.500***	-0.486***
AVS	-0.116	-0.653***	-0.569***	-0.486***
Un-ionized NH3[a]	-0.337***	-0.679***	-0.600***	-0.521***
Sulfides		-0.576***	-0.518***	-0.410***
Grain-size (phi)	-0.381***	-0.282**	-0.180*	-0.123

[a]Measured in amphipod test chambers (n=74) or 100% pore water (n=141), respectively.
*P<0.05; **P<0.001; ***P<0.0001; (unadjusted for multiple comparisons).

Table 12. Phases 1 and 2. Spearman rank correlation (Rho, corrected for ties) coefficients between toxicity data and concentrations of trace metals and other physical-chemical properties for Hillsborough Bay (sites 1-4, 6-8, 11-13 in Phase 1 and sites 1-6, 13 in Phase 2; n=51).

	Amphipod	Sea Urchin Fertilization		
	Survival	@100%	@50%	@25%
Aluminum	-0.004	-0.455*	-0.530**	-0.527***
Arsenic	-0.102	-0.454*	-0.472**	-0.525**
Barium	-0.021	-0.421*	-0.550***	-0.650***
Cadmium	-0.153	-0.587***	-0.662***	-0.715***
Chromium	-0.014	-0.456**	-0.563***	-0.575***
Copper	-0.002	-0.476**	-0.610***	-0.679***
Iron	+0.020	-0.455*	-0.524**	-0.547***
Lead	-0.223	-0.602***	-0.700***	-0.771***
Lithium	+0.162	-0.320*	-0.507**	-0.534**
Manganese	+0.150	-0.262	-0.321*	-0.397*
Mercury	+0.046	-0.414*	-0.593***	-0.679***
Phosphorus	-0.062	-0.482**	-0.435*	-0.449*
Nickel	+0.069	-0.449*	-0.620***	-0.687***
Silver	-0.066	-0.475**	-0.556***	-0.590***
Titanium	+0.051	-0.405*	-0.632***	-0.667***
Vanadium	+0.017	-0.507**	-0.651***	-0.683***
Zinc	-0.177	-0.588***	-0.680***	-0.740***
% Carbon	-0.129	-0.585***	-0.712***	-0.734***
% Nitrogen	+0.091	-0.446*	-0.626***	-0.639***
% Carbonate	+0.301*	-0.231	-0.398*	-0.462*
AVS	-0.230	-0.471**	-0.444*	-0.458*
Unionized NH3[a]	+0.042	-0.648***	-0.591***	-0.536**
Sulfides		-0.519**	-0.520**	-0.470**
Phi	-0.224	-0.253	-0.102	+0.040

[a]Measured in amphipod test chambers (n=21) or 100% pore water (n=51), respectively.
*P<0.05; **P<0.001; ***P<0.0001; (unadjusted for multiple comparisons).

Table 13. Phases 1 and 2. Spearman rank correlation (Rho, corrected for ties) coefficients between toxicity data and concentrations of trace metals and other physical-chemical properties for western Old Tampa Bay (sites 15-19 in Phase 1 and sites 7-11 in Phase 2; n=27).

	Amphipod	Sea Urchin Fertilization		
	Survival	@100%	@50%	@25%
Aluminum	-0.101	-0.342	-0.194	-0.462*
Arsenic	-0.177	-0.091	+0.048	-0.278
Barium	+0.056	-0.024	+0.156	-0.258
Cadmium	-0.011	-0.506*	-0.363	-0.632*
Chromium	-0.181	-0.376	-0.276	-0.534*
Copper	-0.173	-0.391*	-0.270	-0.416*
Iron	+0.059	-0.422*	-0.221	-0.482*
Lead	-0.052	-0.456*	-0.322*	-0.588*
Lithium	-0.118	-0.444*	-0.331*	0.567*
Manganese	-0.086	-0.247	-0.139	-0.471*
Mercury	+0.015	-0.516*	-0.320	-0.521*
Phosphorus	-0.063	-0.246	-0.129	-0.461*
Nickel	-0.040	-0.459*	-0.283	-0.493*
Silver	-0.061	-0.413*	-0.312	-0.572*

Table 13 continued.

	Amphipod Survival	Sea Urchin Fertilization @100%	@50%	@25%
Titanium	-0.015	-0.330	-0.161	-0.372
Vanadium	-0.183	-0.358	-0.250	-0.529*
Zinc	+0.074	-0.539*	-0.318	-0.561*
% Carbon	-0.089	-0.454*	-0.364	-0.588*
% Nitrogen	-0.147	-0.455*	-0.384*	-0.554*
% Carbonate	+0.067	-0.499*	-0.394*	-0.688**
AVS	+0.069	-0.684**	-0.563*	-0.466*
Unionized NH3[a]	-0.188	-0.394*	-0.458*	-0.089
Sulfides		-0.011	-0.147	+0.338
Grain size(phi)	+0.004	-0.112	-0.143	+0.230

[a]Measured in amphipod test chambers (n=15) or 100% pore water (n=27), respectively.
*P<0.05; **P<0.001; ***P<0.0001; (unadjusted for multiple comparisons).

Table 14. Phases 1 and 2. Spearman rank correlation (Rho, corrected for ties) coefficients between toxicity data and concentrations of trace metals and other physical-chemical properties for middle Tampa Bay (sites 21-24 in phase 1 and sites 12, 14-21 in phase 2; n=39).

	Amphipod Survival	Sea Urchin Fertilization @100%	@50%	@25%
Aluminum	+0.090	-0.394*	-0.416*	-0.394*
Arsenic	+0.205	-0.595**	-0.552**	-0.503*
Barium	+0.122	-0.351*	-0.311	-0.246
Cadmium	-0.004	-0.469*	-0.515**	-0.449*
Chromium	+0.093	-0.430*	-0.437**	-0.391*
Copper	-0.023	-0.418*	-0.537**	-0.447*
Iron	+0.119	-0.478*	-0.506*	-0.461*
Lead	-0.227	-0.285	-0.478*	-0.377*
Lithium	+0.058	-0.406*	-0.441*	-0.429*
Manganese	+0.149	-0.535**	-0.497*	-0.433*
Mercury	+0.012	-0.477*	-0.519*	-0.460*
Phosphorus	+0.281	-0.501*	-0.422*	-0.436*
Nickel	+0.138	-0.561**	-0.552**	-0.503*
Silver	-0.169	-0.310	-0.361*	-0.295
Titanium	-0.407*	+0.007	-0.169	-0.032
Vanadium	+0.075	-0.430*	-0.442*	-0.413*
Zinc	-0.002	-0.500*	-0.622***	-0.539**
% Carbon	+0.069	-0.538**	-0.556**	-0.453*
% Nitrogen	+0.095	-0.572**	-0.542**	-0.446*
% Carbonate	+0.297	-0.545**	-0.434*	-0.369*
AVS	+0.236	-0.572**	-0.457*	-0.464*
Unionized NH3[a]	-0.129	-0.732***	-0.476*	-0.493*
Sulfides		-0.755***	-0.527*	-0.441*
Phi	+0.607**	-0.526*	-0.263	-0.248

[a]Measured in amphipod test chambers (n=27) or 100% pore water (n=39), respectively.
*P<0.05; **P<0.001; ***P<0.0001; (unadjusted for multiple comparisons).

Table 15. Phases 1 and 2. Spearman rank correlation (Rho, corrected for ties) coefficients between toxicity data and concentrations of trace metals and other physical-chemical properties for Boca Ciega Bay (site 25 in Phase 1 and sites 22-25 in Phase 2; n=15).

	Amphipod	Sea Urchin Fertilization		
	Survival	@100%	@50%	@25%
Aluminum	-0.118	-0.333	-0.400	-0.365
Arsenic	+0.046	-0.435	-0.452	-0.159
Barium	-0.149	-0.250	-0.306	-0.292
Cadmium	-0.341	-0.342	-0.458	-0.365
Chromium	-0.161	-0.424	-0.482	-0.399
Copper	-0.242	-0.345	-0.475	-0.441
Iron	-0.117	-0.359	-0.437	-0.375
Lead	-0.342	-0.297	-0.396	-0.349
Lithium	-0.184	-0.347	-0.425	-0.370
Manganese	-0.064	-0.370	-0.382	-0.238
Mercury	-0.170	-0.341	-0.444	-0.312
Phosphorus	-0.118	-0.309	-0.372	-0.266
Nickel	-0.288	-0.313	-0.465	-0.419
Silver	-0.207	-0.400	-0.523*	-0.493
Titanium	-0.378	+0.183	+0.004	-0.237
Vanadium	-0.177	-0.386	-0.439	-0.338
Zinc	-0.215	-0.360	-0.468	-0.366
% carbon	-0.090	-0.004	-0.064	+0.013
% nitrogen	-0.069	+0.032	-0.052	+0.034
% carbonate	-0.053	-0.322	-0.356	-0.265
AVS	+0.048	-0.611*	-0.603*	-0.154
Unionized NH3[a]	+0.035	-0.582*	-0.592*	-0.268
Sulfides		-0.589*	-0.673*	-0.580*
Phi	-0.064	-0.665*	-0.727*	-0.365

[a]Measured in amphipod test chambers (n=12) or 100% pore water (n=15), respectively.
*P<0.05; **P<0.001; ***P<0.0001; (unadjusted for multiple comparisons).

As expected, some regional differences were apparent in the correlations. The correlations between trace metals and sea urchin fertilization were strongest in Hillsborough Bay and weakest in Boca Ciega Bay. The correlations between both unionized ammonia and sediment grain size and urchin fertilization were lowest in western Old Tampa Bay. Different combinations of trace metals and physical/chemical properties were the most highly correlated with fertilization success in the different regions: lead, zinc, and carbon in Hillsborough Bay; cadmium, lead, and carbon in western Old Tampa Bay; zinc, arsenic, and nickel in middle Tampa Bay; and sulfides and silver in Boca Ciega Bay.

Table 16 compares the average concentrations of trace metals and selected physical-chemical factors in the sediments between samples that were toxic to amphipods and those that were not toxic. The table also includes the ratios between the averages as a measure of the degree of elevation of chemical concentrations in the toxic samples relative to the nontoxic samples. Finally, the average concentrations in the two categories are compared with sediment quality guidelines provided by Long et al. (in press). Where an average concentration did not exceed the corresponding ERL value of Long et al. (in press), an “ne” is listed (not in exceedance). Exceedances of the respective ERL or ERM values are listed along with the guideline value. There are no guidelines available for some chemicals such as barium and lithium. It is assumed that the chemicals most associated with toxicity will be highly correlated with toxicity (Tables 11-15), and the average concentrations will be low in nontoxic samples (i.e., less than the ERL values), and most highly elevated in the toxic samples (i.e., exceeding the ERM

values) (Table 16). Conversely, those chemicals least associated with toxicity will be poorly correlated with the bioassay results, the average concentrations in toxic samples and nontoxic samples will be very similar, and not in exceedance of effects-based guidelines in the toxic samples.

Among the trace metals that were quantified, zinc, lead, and cadmium were most elevated in the toxic samples (Table 16). Average concentrations in toxic samples exceeded those in nontoxic samples by factors of 4.4x, 3.6x, and 3.4x, respectively. In addition, the average concentrations of zinc (but, not cadmium and lead) in the toxic samples exceeded the respective ERM guideline values, indicating that these average concentrations have been associated with toxicity frequently in previous studies. Cadmium, lead, and zinc were significantly correlated with decreased amphipod survival in the correlation analyses for Tampa Bay (Table 11).

Table 16. Average concentrations of trace metals (ppm ± standard deviations) and other physical-chemical properties in toxic and nontoxic samples in the amphipod tests, ratios between the average concentrations, and exceedances of sediment quality guidelines of Long et al. (in press). Phases 1 and 2.

	Not Toxic (ave. 88.7±5.7% survival, n=131)	Significantly Toxic (ave. 67.9±16.9% survival, n=10)	Ratio of the toxic to non-toxic averages
% Aluminum	1.9±1.7	3.4±1.2	1.8
Arsenic	3.2±2.5 ne	5.5±1.8 ne	1.7
Barium	61.0±45.1	115.0±41.5	1.9
Cadmium	0.9±1.0 ne	3.1±2.2 >ERL@1.2	3.4
Chromium	49.5±45.4 ne	93.7±35.8 >ERL @81	1.9
Copper	37.9±66.1 >ERL@34	102.7±58.9 >ERL @34	2.7
% Iron	0.9±0.9	2.0±0.7	2.2
Lead	45.7±65.0 ne[a]	166.7±122.3 >ERL @46.7	3.6
Lithium	21.2±28.1±9.7	28.1±9.7	1.3
Manganese	58.5±57.0	132.5±64.0	2.3
Mercury (ppb)	137.8±150.3 ne	234.3±126.3 >ERL @150	1.7
Phosphorus	1853±1538	4634±2001	2.5
Nickel	11.4±9.8 ne	21.0±6.9 >ERL@20.9	1.8
Silver	0.4±0.5 ne	0.8±0.4 ne	2.0
Titanium	1156.4±874.5	1418±628.5	1.2
Vanadium	44.3±41.4	87.6±32.1	2.0
Zinc	106.3±155.0 ne	465.4±371.8 >ERM @410	4.4
% TOC	1.7±1.6	3.2±1.5	1.9
% Nitrogen	0.2±0.2	0.2±0.1	1.0
% CO3	14.8±12.7	26.4±11.0	1.8
Texture (Phi)	6.6±2.2	8.1±0.5	1.2
AVS (mg/g)	1.0±2.0	7.6±9.4	7.6

n[a]e=average concentration not in exceedance of the guideline value.

The relationship between amphipod survival and the concentrations of zinc is summarized in the scattergram illustrated in Figure 21. Of the 141 samples in which zinc was quantified, 10 were significantly toxic. The significant correlation coefficient (Rho=-0.218) indicates the relationship between amphipod survival and the concentration of zinc. The data indicate that some of the samples that caused relatively low amphipod survival had zinc concentrations equal to or exceeding the ERM value(410 ppm).

Both naturally occurring and contaminant metal concentrations will covary with the contents of fines in the sediments (clay and silt). For the primary naturally occuring elements Al, Li, Fe, and Mn, the concentration ratios of the toxic-to-nontoxic samples range from 1.3(Li) to 2.3(Mn). Other metals which exhibit similar ratios probably also reflect natural enrichment due to grain size differences. Zinc, lead, cadmium, and copper, by contrast, all exhibit ratios higher than the predominantly naturally occurring elements, and could be argued to be exerting contaminant-related toxicity.

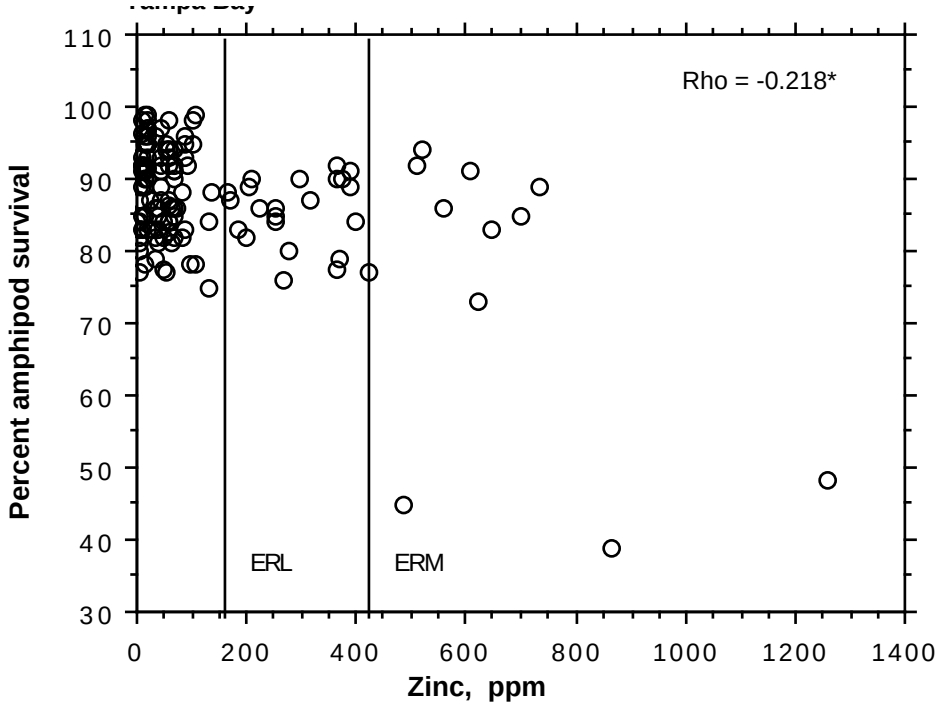

Figure 21. Relationship between amphipod survival, zinc concentrations, and sediment guidelines for zinc.

The average concentrations of trace metals in samples not toxic to sea urchin fertilization in 100% pore water are compared to the average concentrations in samples that were toxic (Table 17). Thirty samples were not significantly toxic in 100% pore water, and had an average of 82.1% fertilization. In contrast, the 26 samples that were toxic in the 100% pore water, but were not toxic in the 50% and 25% pore water, had an average of 48.1% fertilization success. A total of 90 samples were toxic in both the 100% and 50% pore water, with an average of 19.1% fertilization success in 100% pore water, while the 56 samples that were toxic in all three pore water concentrations had 6.7% fertilization success in 100% pore water.

The ratios between the average concentrations of trace metals in nontoxic and toxic samples ranged from 1.3 to 9.2 (Table 17). That is, the average trace metals concentrations were elevated by factors of 1.3x to 9.2x in the toxic samples relative to the nontoxic samples. Among the trace metals that were quantified, cadmium, copper, lead, and zinc were again most elevated in concentration in the toxic samples relative to the nontoxic samples. As expected, trace metals concentrations were highest in the samples that were toxic in all three pore water concentrations. In addition to the trace metals, the concentrations of total AVS in the sediments and sulfides in the pore water were highly elevated in the toxic samples.

None of the average trace metal concentrations in the toxic samples equalled or exceeded the respective ERM guideline values of Long et al. (in press). However, the average concentrations of cadmium, copper, lead, mercury, and zinc in the toxic samples exceeded the respective ERL values reported by Long et al. (in press).

Table 17. Average concentrations of trace metals (ug/g ± standard deviations) and physical-chemical properties in sediment samples that were not toxic to sea urchin fertilization in 100% pore water or were significantly toxic at different pore water dilutions, and ratios between the average concentrations. Phases I and 2.

	Non-toxic @ 100% (82.1±6.8% fertilization, n=30)	Toxic @ 100% (48.1±24.5% fertilization[a], n=26)	Ratio of toxic to non-toxic averages	Toxic @ 100 & 50% (19.1±20.0% fertilization[a], n=29)	Ratio of toxic to non-toxic averages	Toxic @ 100 & 50 & 25% (6.7±14.4% fertilization[a], n=56)	Ratio of toxic to non-toxic averages
% Aluminum	0.9±1.2	2.1±1.9	2.3	1.6±1.2	1.8	2.7±1.7	3.0
Arsenic	1.9±1.9	3.0±2.0	1.6	3.0±2.0	1.6	4.6±2.8	2.5
Barium	37.1±40.2	66.3±50.9	1.8	53.5±28.6	1.4	84.9±47.3	2.3
Cadmium	0.3±0.6	0.6±0.6	1.8	0.7±0.7	2.0	1.8±1.6	5.4
Chromium	23.1±32.4	55.4±50.0	2.4	40.2±32.3	1.7	73.7±46.2	3.2
Copper	9.4±13.4	15.0±23.5	1.6	25.5±39.7	2.7	81.8±88.2	8.7
% Iron	0.4±0.5	1.0±0.9	2.6	0.8±0.6	2.0	1.5±0.9	3.9
Lead	15.0±25.9	25.6v30.1	1.7	28.1±31.8	1.9	102.2±98.4	6.8
Lithium	11.3±13.9	23.6±20.7	2.1	17.4±14.0	1.5	28.6±17.6	2.5
Manganese	21.8±29.0	59.3±56.3	2.7	46.2±41.6	2.1	97.3±65.1	4.5
Mercury(ng/g)	61.6±116.7	98.2±91.9	1.6	108.3±104.8	1.8	229.4±167.8	3.7
Phosphorus	856.4±1055.7	2088.0±1679.0	2.4	1584.1±1119.6	1.9	2912.7±1843.8	3.4
Nickel	5.2±7.1	10.4±8.6	2.0	9.7±7.5	1.9	17.8±9.9	3.5
Silver	0.1±0.3	0.3±0.3	2.0	0.5±0.9	3.5	0.6±0.4	4.5
Titanium	912.0±661.8	1156.5±1163.8	1.3	971.4±651.4	1.1	1429.8±833.8	1.6
Vanadium	18.4±25.7	45.0±41.8	2.5	34.3±28.5	1.9	70.8±43.3	3.9
Zinc	27.9±46.1	55.5±62.2	2.0	69.1±73.0	2.5	255.0±263.5	9.2
% Carbon	1.0±1.7	1.3±1.0	1.3	1.7±1.5	1.6	2.6±1.6	2.6
% Nitrogen	0.1±0.2	0.2±0.1	1.3	0.2±0.2	1.5	0.2±0.1	2.1
% Carbonate	7.4±10.4	11.8±9.7	1.6	16.1±13.2	2.2	21.6±12.4	2.9
Grain size-phi	5.0±2.6	7.5±1.6	1.5	6.7±2.1	1.3	7.3±1.6	1.5
AVS(mg/l)	0.1±0.1	1.0±1.9	15.0	1.0±1.5	15.1	2.8±5.1	43.5
UAN(ug/l)	87.8±82.2	176.3±95.6	2.0	216.8±170.7	2.5	458.8±428.2	5.2
Sulfide(mg/l)	0.02±0.02	0.1±0.2	5.4	0.4±1.4	25.0	1.6±4.0	92.5

[a] average percent fertilization measured in 100% pore water

The Microtox™ bioluminescence EC50's determined only in Phase 1 were significantly correlated with all of the trace metals and physical-chemical measurements (Table 18). The Microtox™ EC50 values (indicative of high toxicity) decreased as chemical concentrations increased. The correlation coefficients were particularly strong for aluminum, barium, iron, lead, nickel, and zinc Since aluminum, barium, and iron are predominantly natural in origin, these data suggest that all of these chemicals co-varied with each other and with the Microtox™ test results. Dunn-Sidak (Sokal and Rohlf 1981) adjustment would eliminate those results marked with "*" from significance at the 0.05 level.

Table 18. Spearman rank correlation coefficients (Rho, corrected for ties) between amphipod survival (n=66) or Microtox™ bioluminescence (n=65), and the concentrations of trace metals and physical-chemical properties in the Phase 1 samples from Tampa Bay.

	Microtox™ bioluminescence EC50	Percent amphipod survival
Aluminum	-0.745***	-0.529***
Arsenic	-0.466**	-0.559***
Barium	-0.723***	-0.524***
Cadmium	-0.606***	-0.551***
Chromium	-0.682***	-0.510***
Copper	-0.687**	-0.590***
Iron	-0.751***	-0.507***
Lead	-0.729***	-0.583***
Lithium	-0.659***	-0.453**
Manganese	-0.704***	-0.495***
Mercury	-0.708***	-0.553***
Nickel	-0.722***	-0.537***
Silver	-0.656***	-0.572***
Titanium	-0.639***	-0.515***
Vanadium	-0.696***	-0.554***
Zinc	-0.732***	-0.585***
Phosphorus	-0.704***	-0.480***
% carbon	-0.695***	-0.558***
% nitrogen	-0.540***	-0.368*
% carbonate	-0.585***	-0.279*
Grain size (phi)	+0.388*	+0.326*

*P<0.05; **P<0.001; ***P<0.0001; (unadjusted for multiple comparisons).

Also included in Table 18 are the Spearman rank correlations for amphipod survival and the concentrations of trace metals and physical-chemical properties from the Phase 1 samples. The correlations are much stronger in the data from Phase 1 alone than in those from the combined data base formed with Phase 1 and 2 (Table 11) samples due, largely, to the wider range in amphipod response in Phase 1 than in Phase 2. All of the trace metals (especially copper, lead, and zinc) are highly correlated with reduced amphipod survival. Similar to the results with the Microtox™ tests, it appears that all of these metals co-varied with each other and with the toxicity to amphipods. Dunn-Sidak (Sokal and Rohlf 1981) adjustment would eliminate those results marked with "*" from significance at the 0.05 level.

The average concentrations of trace metals in samples that were toxic to Microtox™ bioluminescence are compared with those in nontoxic samples in Table 19. Also, those average concentrations that exceeded the ERL or ERM values of Long et al. (in press) are indicated. In addition, the ratios between the averages are listed for each metal. Among these trace metals, the average concentrations of copper, lead, and zinc were most elevated in toxic samples relative to nontoxic samples (ratios of 5.4, 4.0, and 4.7, respectively). None of the average concentrations of trace metals equalled or exceeded the respective ERL or ERM values in the nontoxic samples. In contrast, the average concentrations of cadmium, copper, lead, mercury, and zinc in the toxic samples exceeded the respective ERL values.

Table 19. Average trace metals concentrations (ppm ± standard deviations) in toxic and nontoxic samples in the Microtox™ bioluminescence tests, ratios between the average concentrations, and exceedances of sediment quality guidelines (from Long et al., in press).

	Not Toxic (Ave. 0.133±0.103, EC50 n=48)	Significantly Toxic (Ave. 0.021±0.012, EC50, n=17)	Ratio of toxic to non-toxic averages
% Aluminum	1.1±1.1	2.8±1.7	2.5
Arsenic	2.9±1.6 ne	4.6±2.6 ne	1.6
Cadmium	0.6±1.4 ne	1.8±1.6 >ERL@1.2	3.0
Chromium	31.1±33.2 ne	73.7±47.0 ne	2.4
Copper	12.7±21.9 ne	68.1±64.4 >ERL@34	5.4
Lead	25.2±63.6	102.1±104.1 >ERL@46.7	4.0
Mercury	0.065±0.059 ne	0.196±0.138 >ERL@0.15	3.0
Nickel	6.6±6.2 ne	16.2±9.5 ne	2.5
Silver	0.2±0.3 ne	0.6±0.4 ne	3.0
Zinc	60.1±119.7 ne	282.1±331.7 >ERL@150	4.7

Trace metal concentrations in clean sediments have been observed to co-vary with average grain size in the sediments, which, in turn, co-varies with aluminum content (Schropp et al., 1990; Schropp and Windom, 1988). By comparing trace metal concentrations to aluminum concentrations in sediment samples collected from clean reference areas in Florida, Schropp et al. (1990) determined the trace metals-to-aluminum ratios to be expected in non-polluted sediments. Also, they calculated from the same data the upper and lower 95% confidence limit of these mean trace metal-aluminum ratios. Exceedances of the upper 95% confidence limit are assumed, by this technique, to be indicative of polluted conditions. These ratios were useful in the identification of elevated trace metals concentrations in Tampa Bay (Long et al., 1991).

In Figures 22-25, the concentrations of four metals (cadmium, chromium, copper, and zinc) are plotted against the aluminum concentrations in the samples from Tampa Bay that were toxic to amphipods and nontoxic to amphipods and compared to the 95% confidence interval lines expected in reference areas, based upon the model of Schropp et al. (1990). Data points lying above the upper 95% confidence interval indicate that the metal concentration was higher than expected for the corresponding aluminum content. Data points lying between the upper and lower 95% confidence interval suggest that the metal concentrations are within the expected range for reference area sediments. Schropp et al. (1990) attributed the differences between expected trace metals concentrations and elevated concentrations to anthropogenic (human-origin) sources of metals, and view these elevated concentrations as excesses.

Cadmium, copper, lead, and zinc were found to be highly correlated with toxicity to amphipods and sea urchins, and elevated in concentration in toxic samples versus nontoxic samples, and the average concentrations in toxic samples often equalled or exceeded concentrations (ERLs/ERMs) that were previously associated with toxicity. Chromium concentrations were correlated with amphipod survival only in Phase 1 (Table 18). Figures 22-25 indicate that cadmium, copper, and zinc, but not chromium, also were frequently elevated in concentration above background levels in many of the Tampa Bay samples, including those that were toxic to amphipods. The exceedances of the upper 95% confidence intervals invariably occurred in samples in the upper end of the aluminum content range. Also, the slopes of the plots invariably were steeper than the slopes of the expected values. In eight of the ten samples that were toxic to amphipods, the cadmium and copper concentrations exceeded the upper 95% confidence interval of the expected concentrations (Figures 22, 24). In nine of the samples that were toxic to amphipods, the zinc concentrations were elevated relative to the expected concentrations (Figure 18). Clearly, there were many more samples that exceeded the upper 95% confidence limits that were not toxic than there were samples that were toxic. Therefore, the metals to aluminum ratios are not strong predictors of toxicity.

The bioavailability of some sediment-associated toxic trace metals may be influenced by the concentration of acid-volatile sulfides (AVS) in the sediments (Di Toro et al., 1990). High concentrations of AVS may reduce the bioavailability, and, therefore, prevent toxicity of relatively high concentrations of some trace metals. However, because of their volatility, AVS may be lost to the atmosphere during the collection of the sediments, particularly when the samples are exposed to air. An underestimate of the AVS concentration could lead to an overestimate of the bioavailability of certain trace metals. To quantify this potential loss, a small experiment was conducted on

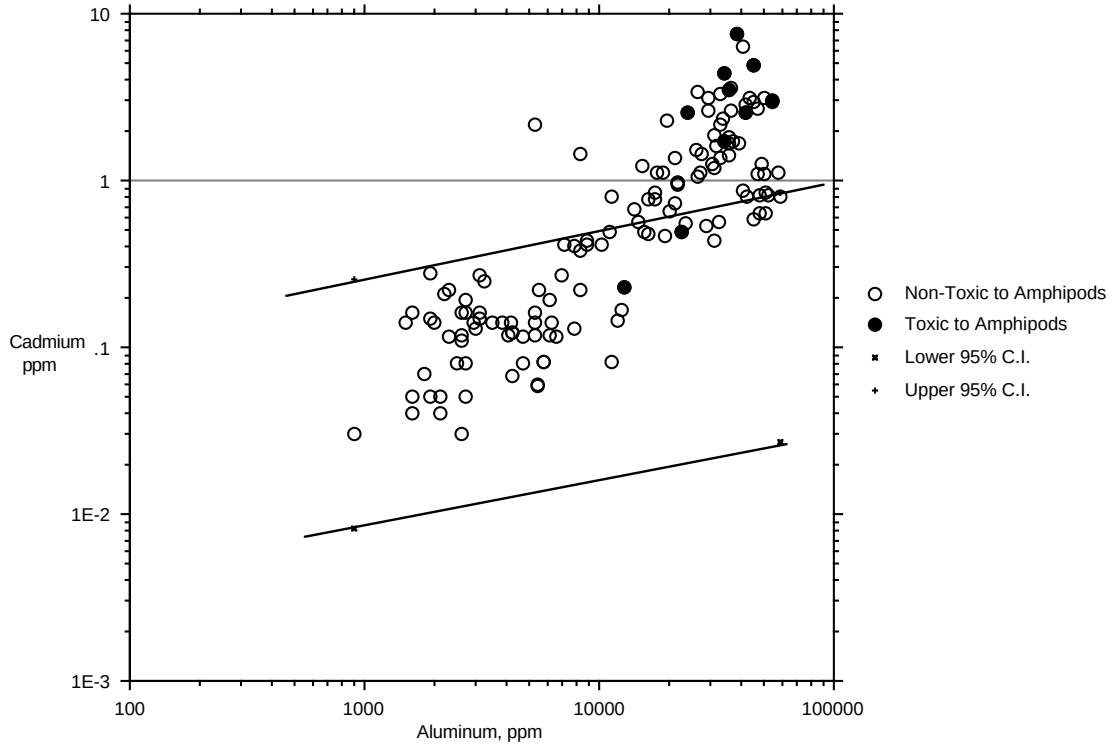

Figure 22. Ratios of cadmium to aluminum in Tampa Bay samples that were toxic to amphipods (solid circles) and non-toxic to amphipods (open circles) compared to predicted cadmium-to-aluminum ratios from reference areas (Schropp et al., 1990).

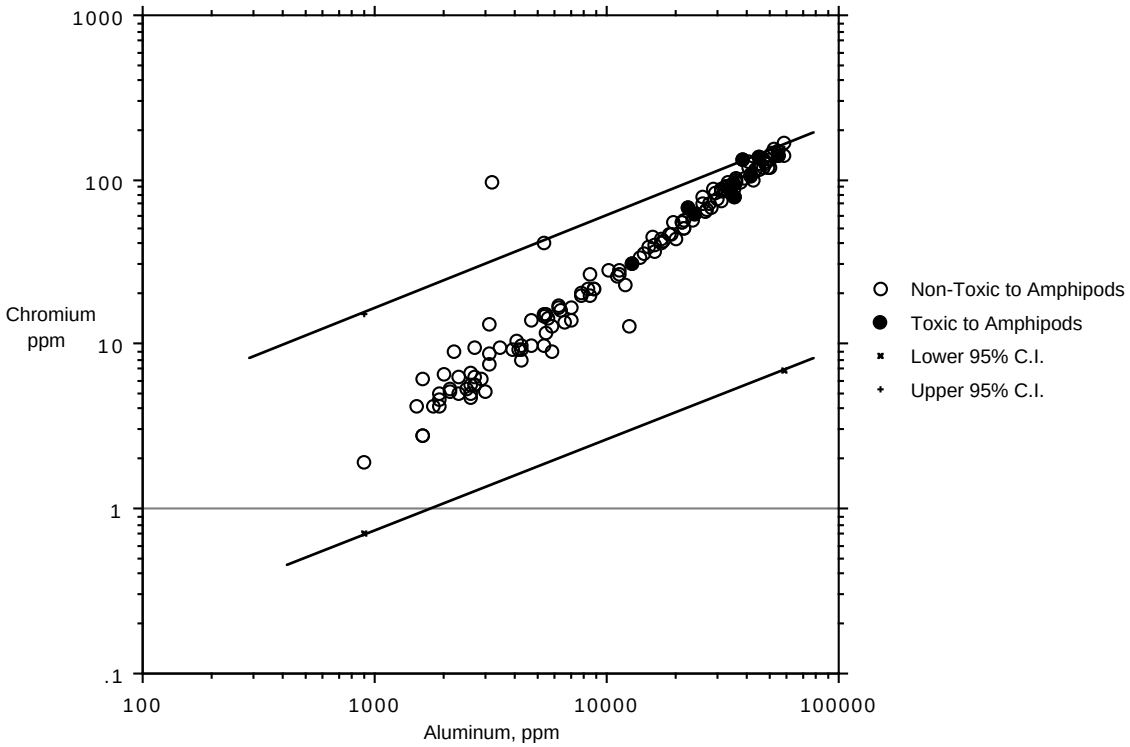

Figure 23. Ratios of chromium to aluminum in Tampa Bay samples that were toxic to amphipods (solid circles) and non-toxic to amphipods (open circles) compared to predicted chromium-to-aluminum ratios from reference areas (Schropp et al., 1990).

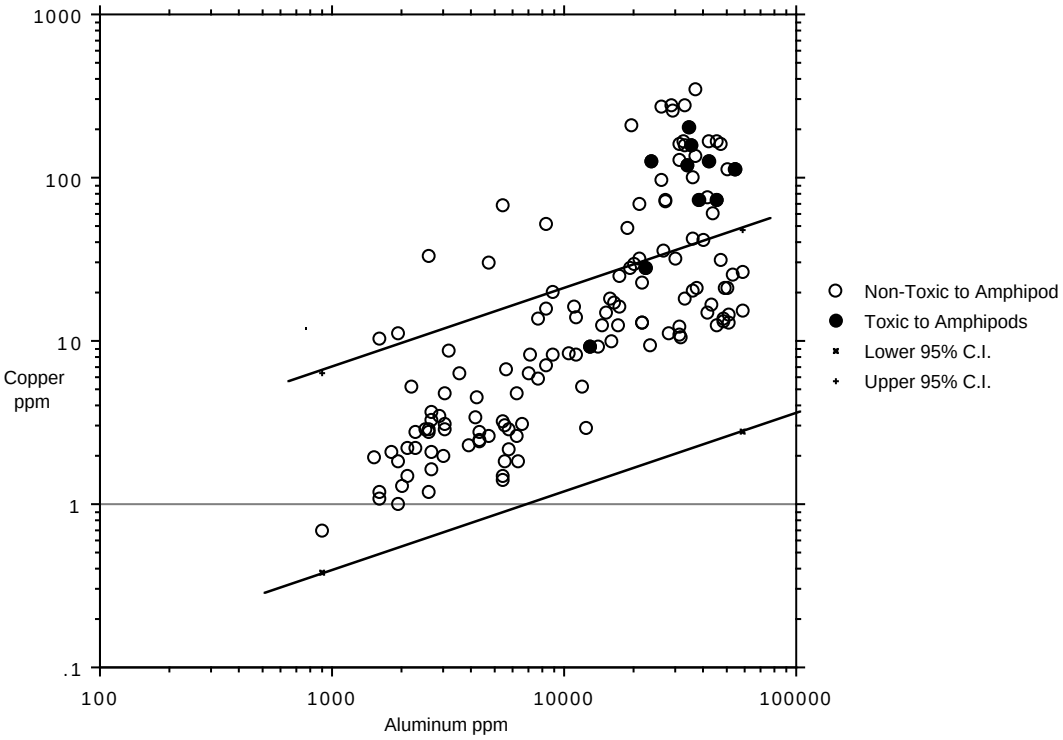

Figure 24. Ratios of copper to aluminum in Tampa Bay samples that were toxic to amphipods (solid circles) and non-toxic to amphipods (open circles) compared to predicted copper-to-aluminum ratios from reference areas (Schropp et al., 1990).

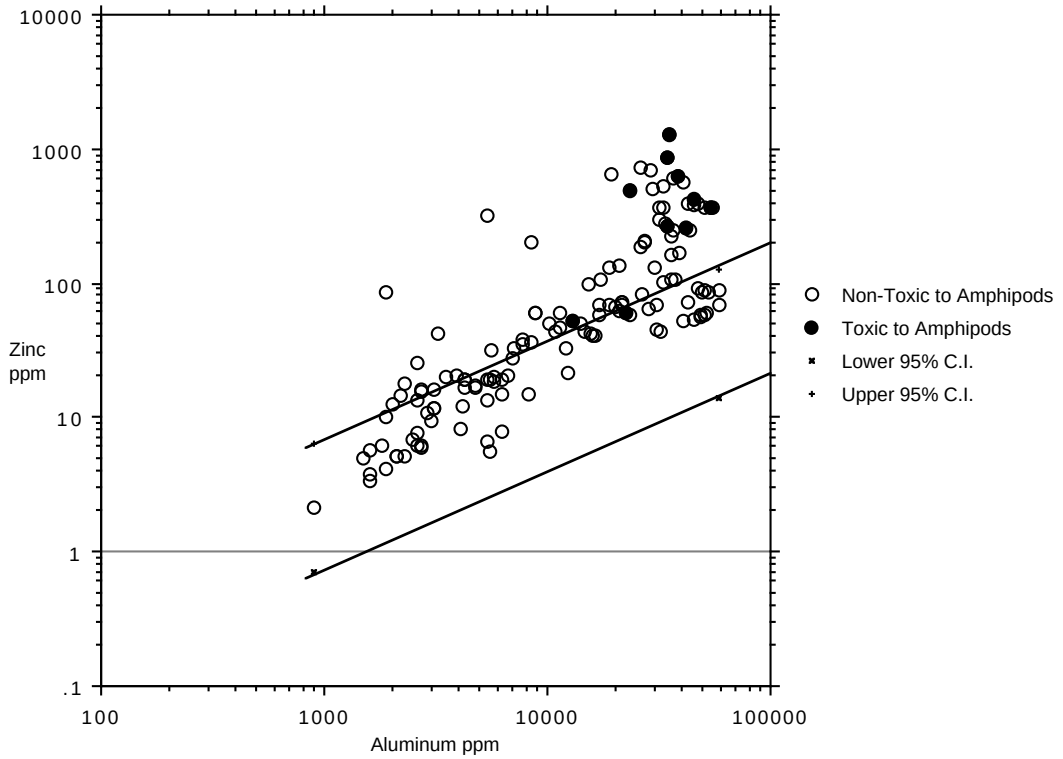

Figure 25. Ratios of zinc to aluminum in Tampa Bay samples that were toxic to amphipods (solid circles) and non-toxic to amphipods (open circles) compared to predicted zinc-to-aluminum ratios from reference areas (Schropp et al., 1990).

five samples collected during Phase 2. A 200 cc. sample was removed from the sampler before the sample was exposed to the air by pushing the vial into the sediment beneath the overlying water immediately after retrieval of the sampler. Another 200 cc. sample was removed from the respective amphipod chamber following the completion of the amphipod survival tests in the laboratory. Both sets of samples were taken with polyethylene scintillation vials, capped, and stored frozen until the AVS measurements were made at the Skidaway Institute of Oceanography.

The samples collected in the field were exposed to air for only a few seconds before the vials were capped. By contrast, the laboratory samples were exposed to air for 20-30 min., stirred in an open bowl, poured into a jug, shipped by courier, sieved, dispensed into toxicity test chambers with laboratory seawater, allowed to stand for 10 days during the amphipod tests, and sampled with the scintillation vial, frozen, and shipped to the analytical laboratory for analyses. The results are listed below:

Sample No. (Phase 2)	Field Sample % AVS	Laboratory Sample % AVS	Percent difference
1c	1.46	1.75	+19.9%
3a	0.76	3.90	+413.2%
8b	0.27	0.27	0.0%
14a	0.02	0.05	+150.0%
15c	0.51	0.14	-72.5%

The AVS concentrations were actually greater in three of the samples at the completion of the amphipod tests, compared to the time of collection. In sample 3a, the AVS concentration increased by an enormous amount. In sample 8b the AVS concentration remained unchanged and in sample 15c it decreased considerably. These data provide little evidence that AVS is lost consistently during sample handling.

To further evaluate the potential role of metallic elements in the toxicity of Tampa Bay sediments, the molar ratios of six metals (copper, nickel, zinc, cadmium, lead and mercury) to acid-volatile sulfide (AVS, See Appendix Table) were calculated. For this analysis, simultaneously-extracted metals (SEM) are typically analyzed in the hydrochloric acid extracts of the sediments used to release the acid-volatile sulfide (DiToro et al. 1990, Allen et al. 1991). Since metallic elements were analyzed only in whole sediment digests in this study, we compared the resulting concentrations of total metals (tMe) to AVS concentrations. The molar ratios of total metals (sum of copper, nickel, zinc, cadmium, lead and mercury) to AVS (tMe/AVS) ranged from 0.01 to 0.87 in the sediments collected in Phase 1 and from 0.07 to 4.88 in those from Phase 2. Altogether, twelve samples (all from Phase 2) exceeded a molar ratio of 1.0 for tMe/AVS.

In a related study with sediments from Long Island Sound (Wolfe et al. in press), the SEM represented about 13% of the total metal concentration for Cu and Ni, 36% for Zn, 58% for Pb, and 65% for Cd. Although the SEM fraction exceeded 100% (on average) of the total Hg in Tampa Bay, many of these values were near or below detection limits and the ratios were extremely variable for this element. The sum of SEM for all 6 metals averaged only about 35% of the sum of total metal concentrations in 63 sediment samples from Long Island Sound. Based on these observations, we conclude that very few, if any, of the samples from Tampa Bay were likely to have had SEM/AVS ratios in excess of 1.0. In any case, the SEM/AVS ratio was likely to have been substantially less than 1.0 in all of the samples from Phase 1, where toxicity was demonstrated in both the *Ampelisca* and Microtox™ tests.

The 12 samples with tMe/AVS greater than 1.0 generally contained lower levels of AVS (11 < 0.10 mg/g; one @ 0.14 mg/g) and greater proportions of sand (9 with phi < 6.28, other 3 ranging from 7.41 to 9.03) than the average for our Tampa Bay samples. While none of these 12 samples were toxic to *Ampelisca abdita*, the toxic response in the sea urchin fertilization test ranged from nontoxic (4 samples) to moderately toxic (2 @ 100% and 3 @ 50% pore water) to highly toxic (3 @ 25% pore water). Conversely, the samples with the greatest concentrations of AVS exhibited generally lower ratios of tMe/AVS (the 51 samples with the highest AVS values, ranging from 0.67 to 33.5 mg/g, all had tMe/AVS <0.32 with only 4 > 0.2). All the Phase 1 samples from Hillsborough Bay that elicited significant toxicity to *A. abdita* were included in this group. Because AVS covaried so closely with the metals, and was correlated to about the same degree as the metals with the toxicity results (Tables 11-15), toxicity was not significantly correlated in the end with the total metals/AVS ratio. Thus the tMe/AVS ratio was not a reliable predictor of toxicity in this study.

The particle size distributions of Phase 1 and Phase 2 sediments differed substantially. Fifty-eight of the 75 Phase 2 samples had phi <7.15 (2.33-7.14), and 68 of the 75 had phi < 8.0. By contrast, all of the 66 Phase 1 sediments had phi > 7.2 (7.2-9.2), and for 52 of these, phi exceeded 8.0. Thus the Phase 2 sediments were considerably more sandy on average that the Phase 1 samples. This difference could have contributed to the absence of detectable toxicity to amphipods in Phase 2, along with possible differences arising from the use of two different stocks of experimental animals, and control sediments from two different locations. The sediments from Phase 1 and Phase 2, however, produced remarkably similar patterns of toxicity in the sea urchin fertilization test, suggesting that grain size has a greater effect on the whole sediment test than on the pore water test. The finer-grained sediments from Phase 1 had generally higher contaminant concentrations and were more toxic to the amphipods than the phase 2 sediments.

Unionized Ammonia. One feature of sediments that can contribute to or solely cause toxicity in sediment toxicity tests is the presence of high amounts of unionized ammonia. Unionized ammonia may be present in anoxic reducing sediments and may be formed during sediment transport and storage as resident organisms excrete metabolic products, and as a result of bacterial metabolism of organic matter. Unionized ammonia can be very toxic.

The relationship between the concentrations of unionized ammonia in pore water and toxicity to sea urchin fertilization is summarized in the scattergram illustrated in Figure 26. The concentrations of unionized ammonia were determined in the pore water (after salinity adjustment) of each sample that was tested in both Phases 1 and 2. The unionized ammonia EC50 for *Arbacia punctulata* egg fertilization is 600 µg/L (R. Scott Carr, NBS, personal communication). The concentrations of unionized ammonia in the pore water samples ranged from 15 to 2244 µg/L (average = 278.0 µg/L, median = 186.4 µg/L). Only fourteen samples out of 141 had unionized ammonia concentrations that exceeded 600 µg/L in the 100% pore water samples; and all but one of these were still highly toxic to the sea urchins, at the 25% dilution where the unionized ammonia was <600µg/L. The Spearman rank correlation coefficient between sea urchin percent fertilization in undiluted pore water and unionized ammonia concentrations in the pore water chambers was highly significant for the entire Tampa Bay data set (Table 11, Figure 26; Rho=-0.679, p<0.0001, n=141). Also, the correlation coefficients between sea urchin fertilization success and unionized ammonia concentrations were significant in all four of the regions of the bay (Tables 13-16). In summary, although the concentrations of unionized ammonia co-varied with the toxicity to sea urchin fertilization success, these concentrations rarely equalled or exceeded the concentrations expected to cause toxicity. From these data, therefore, it appears that (except possibly for the 14 samples where unionized ammonia approached or exceeded 600 µg/L in the 100% pore water samples) the concentrations of unionized ammonia had a very minor role in the toxicity observed in this test. The fact that the 25% dilutions for 13 of these 14 samples were all highly toxic, even though the unionized ammonia was well below the EC50, suggests that other factors are contributing to the observed toxicity.

In laboratory bioassays with marine amphipods, the 4-day LC50's for unionized ammonia in water were 830 µg/L for *Ampelisca abdita*, 1590 µg/L for *Rhepoxynius abronius*, 2490 µg/L for *Eohaustorius estuarius*, and 3350 µg/L for *Grandidierella japonica* (Kohn, et al., 1994). In subsequent tests performed by Science Applications International Corporation (1993), the unionized ammonia LC50s for *A. abdita* were 300 µg/L, 800 µg/L, and 1100 µg/L at pHs of 7.0, 7.7, and 8.4, respectively. The corresponding no-observed-effect concentrations were 130 µg/L, 700 µg/L, and 800 µg/L, respectively.

The concentrations of unionized ammonia in the overlying water at the termination of the 10-day amphipod tests was measured only in Phase 2. Based upon the means of the replicates of each sample, the unionized ammonia concentrations ranged from 1.6 µg/L to 114 µg/L (average = 14.1 µg/L, median = 9.8 µg/L)), well below the LC50 of 830 µg/L for *Ampelisca abdita* (Figure 27) (Kline et al., 1992; Kohn et al., 1994). The Spearman rank correlation coefficient for unionized ammonia concentrations in the overlying water and percent survival of *A. abdita* indicated a weak, but significant, relationship (Rho= -0.337, p = 0.0001) in the entire Tampa Bay Phase 2 data set. However, the correlations between amphipod survival and unionized ammonia concentrations were not significant for any of the four regions of the bay. These coefficients were particularly weak in the Hillsborough Bay and Boca Ciega Bay regions. In the amphipod tests performed in Phase 2, the unionized ammonia concentrations were appreciably lower at the termination of the tests than at the initiation (average factor of 3.5X).

Physical-Chemical Properties. In addition to the trace metals and unionized ammonia in the sediments, a number of other properties of the samples were quantified to aid in data interpretation (Tables 11-19). These variables included aluminum, lithium, iron, phosphorus, nitrogen, carbon, carbonates, grain size, and acid volatile sulfides. Also, the concentrations of total sulfides in the pore water were measured.

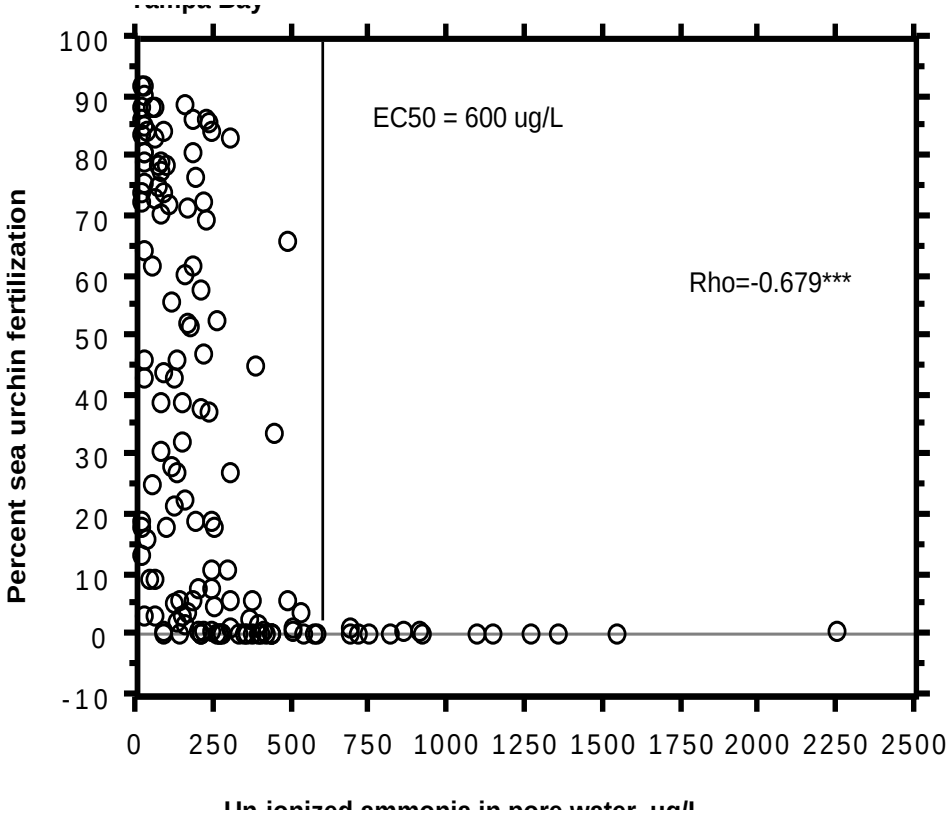

Figure 26. Relationship between sea urchin fertilization in 100% pore water and the concentration of unionized ammonia in pore water test chambers.

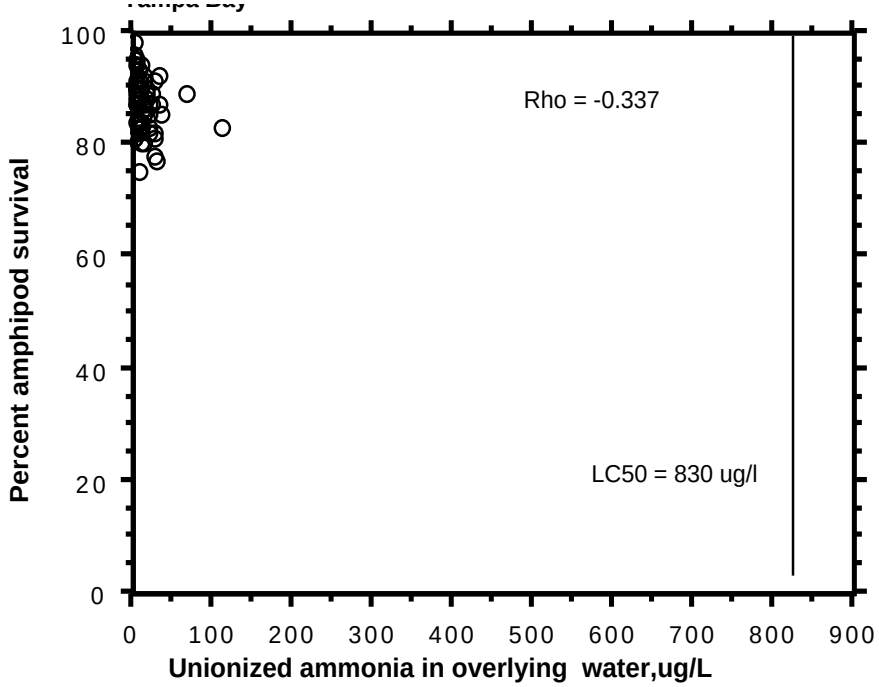

Figure 27. Relationship between amphipod survival and the concentration of unionized ammonia in the overlying water in the test chambers.

Most of these properties were poorly correlated with amphipod survival. However, sulfides were an exception, being strongly correlated with amphipod survival in all of the Tampa Bay samples (Table 11), and grain size was particularly highly correlated with amphipod survival in middle Tampa Bay (Table 14).

Many of these physical-chemical properties were relatively highly correlated with the toxicity to sea urchins. Nitrogen, phosphorus, percent carbon, percent carbonates, grain size, and total AVS in the sediments and total sulfides in the pore water often were highly correlated with toxicity and co-varied with the unionized ammonia concentrations. The potential contribution of these variables to toxicity is poorly understood.

Polynuclear Aromatic Hydrocarbons (PAHs). Table 20 summarizes the Spearman rank correlations between PAH concentrations (expressed in dry weight units) and the results of the amphipod survival tests, the sea urchin fertilization tests at each pore water concentration, and the Microtox™ bioluminescence tests. PAH analyses and toxicity tests with amphipods and sea urchins were performed with 61 samples collected during Phases 1 and 2. With k = 20, the Dunn-Sidak (Sokal and Rohlf 1981) adjustment eliminates most of the results marked "*" from significance at the 0.05 level. Matching PAH and Microtox™ data were generated for all 16 samples in Phase 1. All of the correlation coefficients were negative, indicating that amphipod survival, sea urchin fertilization, and bioluminescence decreased as the concentrations of the compounds increased. In the amphipod survival tests, the correlations were significant only for three compounds (naphthalene, acenaphthylene, and fluorene), all of which are low molecular weight compounds. Nearly all of the correlation coefficients (Rho) between sea urchin fertilization and the concentrations of PAHs were consistent among all three dilutions, highly significant, and very strong. The high molecular weight compounds were particularly highly correlated with diminished fertilization success. Similar to the sea urchins, the Microtox™ tests indicated very high and significant correlations with the PAHs, especially the high molecular weight compounds.

Table 20. Spearman rank correlations (Rho, corrected for ties) between sediment toxicity and PAH concentrations (ppb, dry wt.) in 61 samples collected in Phases 1 and 2 (all coefficients are negative values).

		Percent sea urchin fertilization			Microtox[a] bioluminescence
Chemical	Percent Amphipod Survival	@100%	@50%	@25%	EC50
Naphthalene	0.286*	0.340*	0.245	0.265*	0.547*
Acenaphylene	0.507***	0.425**	0.322*	0.315*	0.688*
Acenaphthene	0.111	0.381*	0.378*	0.439**	0.526*
Fluorene	0.275*	0.427**	0.436**	0.481**	0.782*
Phenanthrene	0.177	0.619***	0.619***	0.616***	0.664*
Anthracene	0.227	0.552***	0.559***	0.534***	0.775*
Fluoranthene	0.217	0.673***	0.700***	0.682***	0.769*
Pyrene	0.189	0.670***	0.673***	0.642***	0.764*
Benz(a)anthracene	0.215	0.584***	0.590***	0.582***	0.654*
Chrysene	0.147	0.547***	0.592***	0.597***	0.672*
Benzo(b,k)fluoranthene	0.180	0.666***	0.699***	0.673***	0.718*
Benzo(e)pyrene	0.117	0.630***	0.643***	0.613***	0.654*
Benz(a)pyrene	0.121	0.591***	0.626***	0.609***	0.643*
Perylene	0.001	0.516***	0.598***	0.570***	0.689*
Indeno(c,d)pyrene	0.232	0.610***	0.621***	0.616***	0.654*
Benzo(g,h,i)perylene	0.197	0.616***	0.650***	0.621***	0.661*
Dibenzo(a,h)anthracene	0.088	0.510***	0.488**	0.510***	0.538*
Sum LPAH	0.180	0.620***	0.619***	0.616***	0.692*
Sum HPAH	0.205	0.672***	0.696***	0.667***	0.763*
Sum total PAH	0.191	0.668***	0.692***	0.664***	0.760*

LPAH = Low molecular weight PAH
HPAH = High molecular weight PAH

*P<0.05; **P<0.001; ***P<0.0001; (unadjusted for multiple comparisons).

The organic carbon content of sediments may significantly influence the bioavailability of organic toxicants in sediments. Relatively high concentrations of toxicants may be innocuous in sediments with high organic carbon

content. Therefore, it is common practice to examine toxicity/contaminant relationships with the organic toxicant concentrations normalized to (divided by) the concentrations of TOC.

For both the sea urchin fertilization and Microtox™ tests, the correlations with PAH concentrations were consistently poorer after TOC normalization (Table 21) than before (Table 20). For the urchin test, the highly significant, negative correlations with PAH virtually vanished upon normalization to TOC, and some of the low-molecular-weight PAH became significantly positively correlated with survival (Table 21). For the Microtox™ test, the levels of correlation with PAH generally dropped with normalization to TOC, but the pattern of negative correlations was generally retained (Table 21). In sharp contrast, the negative correlations between amphipod survival and PAH concentration were generally stronger and more significant after TOC normalization (Table 21). These relationships appear to be consistent with the exposure mechanisms involved in these three tests, and suggest, at least for the amphipod test (and perhaps for Microtox™ as well), that toxicity could be related to PAH levels in the sediments. The pore water test would be expected to show the lowest sensitivities to organic contaminants with low water solubilities. Partitioning of these contaminants, including PAH, PCB, and chlorinated organics, onto the sediments should be related directly to the TOC content; and bioavailability (and toxicity) from the pore water sample should be limited except at extremely high contaminant-to-TOC ratios. The absence of any pattern of correlation between toxicity and TOC-normalized PAH data suggests that TOC was simply co-varying with toxicity, and that PAH levels were not high enough to elicit toxicity through this pathway of exposure. Conversely, the 10-day, whole sediment toxicity test with amphipods places the test organisms into maximum contact with the sediments, and permits prolonged bioaccumulation of contaminants. The enhanced correlations between amphipod survival and TOC-normalized PAH concentrations suggests that TOC is mediating the toxic response to PAH and lends credibility to a causal relationship between PAH and toxicity. The correlations between amphipod survival and the sums of low and high molecular weight compounds were similar (Rho = -0.331 and -0.336, respectively).

As was the case with the amphipod tests, the Microtox™ tests indicated negative correlations with TOC-normalized PAHs for some compounds (fluoranthene, pyrene, benzo(b,k)fluoranthene) and the sum of high molecular weight PAHs. Also, Microtox™ bioluminescence was significantly correlated with TOC content. The organic extractions used in this test, however, would effectively eliminate sediment partitioning as a limiting factor and could be expected also to reduce the mediating effect of TOC on the bioavailability and toxicity of organic contaminants. As we have observed in these data, the correlations for Microtox™ response were generally stronger with the total PAH concentrations in the samples than with TOC-normalized PAH concentrations.

Table 21. Spearman rank correlations (Rho, corrected for ties) between sediment toxicity and PAH concentrations normalized to TOC content in 61 samples collected in Phases 1 and 2.

	Percent Amphipod	Percent sea urchin fertilization		Microtox[a] bioluminescence
Chemical	**Survival**	**@100%**	**@25%**	**EC50**
Naphthalene	-0.219	+0.495***	+0.450***	+0.068
Acenaphylene	-0.295*	+0.461**	+0.514***	-0.078
Acenaphthene	-0.251*	+0.420**	+0.384*	-0.081
Fluorene	-0.323*	+0.395*	+0.378*	-0.197
Phenanthrene	-0.365*	+0.080	-0.126	-0.443
Anthracene	-0.257*	+0.275*	+0.244	-0.091
Fluoranthene	-0.379*	-0.326*	-0.351*	-0.595*
Pyrene	-0.356*	-0.336*	-0.329*	-0.529*
Benz(a)anthracene	-0.342*	+0.041	+0.001	-0.395
Chrysene	-0.316*	-0.040	-0.089	-0.490
Benzo(b,k)fluoranthene	-0.308*	-0.249	-0.275*	-0.568*
Benzo(e)pyrene	-0.263*	+0.001	-0.024	-0.430
Benz(a)pyrene	-0.254*	-0.023	-0.076	-0.342
Perylene	-0.157	+0.206	+0.156	+0.141
Indeno(1,2,3)pyrene	-0.348*	+0.064	+0.054	-0.247
Benzo(g,h,i)perylene	-0.345*	+0.067	+0.045	-0.252

Table 21 continued.

Chemical	Percent Amphipod Survival	Percent sea urchin fertilization @100%	Percent sea urchin fertilization @25%	Microtox[a] bioluminescence EC50
Dibenzo(a,h)anthracene	-0.167	+0.419*	+0.433	+0.389
Sum LPAH	-0.331*	+0.199	+0.145	-0.097
Sum HPAH	-0.336*	-0.097	-0.117	-0.529*
Sum Total PAH	-0.333*	-0.065	-0.087	-0.495
Total organic carbon	+0.060	-0.629***	-0.609***	-0.552*

[a] n=16

*P<0.05; **P<0.001; ***P<0.0001; (unadjusted for multiple comparisons).

The U.S. EPA (1993 a, b, c) has promulgated proposed sediment quality criteria for three individual aromatic hydrocarbons, using the equilibrium-partitioning modelling approach. Mean criteria for levels in salt water and their 95% confidence limits (C.L.) were prepared for each compound. These criteria are expressed in relation to concentration of organic carbon:

Acenaphthene: mean 240 $\mu g/g_{oc}$ (95% C.L., 110-500 $\mu g/g_{oc}$);
Fluoranthene: mean 300 $\mu g/g_{oc}$ (95% C.L., 140-640 $\mu g/g_{oc}$);
Phenanthrene: mean 240 $\mu g/g_{oc}$ (95% C.L., 110-510 $\mu g/g_{oc}$).

Only one of the 61 samples (#2c in Phase 1) in which PAHs were quantified exceeded the mean Sediment Quality Criterion (SQC) for any of the three compounds (Table 22). None equalled or exceeded the lower 95% confidence limit for acenaphthene. The acenaphthene concentration in station 20c of phase 2 was 89 µg/goc, which was slightly lower than the lower 95% confidence limit (110 µg/goc) for acenaphthene. The concentrations of phenanthrene in one samples #2c in Phase 1 exceeded the lower 95% confidence limit for that compound. Samples 2a, 2b, and 2c collected from upper Ybor Channel during Phase 1 were highly toxic to sea urchin fertilization and the most toxic of all samples to amphipods. Sample 20c collected from Big Bayou during Phase 2 was only moderately toxic to sea urchin fertilization, and was not toxic to amphipods. All other samples collected in Tampa Bay had much lower concentrations of these three compounds.

Table 22. Comparison of sediment quality criteria (SQC) proposed by U.S. EPA (1993 a, b, c) for three PAHs with maximum concentrations ($\mu g/g_{oc}$) in 61 Tampa Bay sediment samples from Phases 1 and 2.

Compound	Lower 95% C.L.	Mean SQC	Upper 95% C.L.	Tampa Bay maxima	Station	Phase
Acenaphthene	110	240	500	88.9	20c	2
				57.1	21b	2
				44.4	24c	2
Fluoranthene	140	300	640	348	2c	1
				184	2a	1
				171	23c	2
				164	2b	1
Phenanthrene	110	240	510	134	2c	1
				100	20c	2
				77	2a	1
				76	2b	1

Among the PAHs that were quantified, acenaphthylene was most elevated in concentration in the samples toxic to amphipods; the average was 5.7 times higher in the 8 samples that were toxic than in the 53 samples that were not toxic (Table 23). Other aromatic hydrocarbons with relatively high concentrations in toxic samples included phenanthrene, flourene, and total LPAH. The average concentrations of pyrene, dibenzo(a,h)anthracene, and total HMW PAH in the toxic samples equalled or exceeded the respective ERM values of Long et al. (in press), indicating that these average concentrations have been frequently associated with toxicity in previous studies.

Table 23. Average PAH concentrations (ppm dry wt.± standard deviations) in toxic and nontoxic samples in the Phase 1 and Phase 2 amphipod tests, ratios between the average concentrations, and exceedances of respective sediment quality guidelines of Long et al. (in press).

	Not Toxic (Ave. 87.5±5.2% survival, n=53)	Significantly Toxic (Ave. 64.8±17.6 survival, n=8)	Ratio of toxic to nontoxic averages
% TOC	2.29±1.56	3.53±1.35	1.5
Naphthalene	0.039±0.019	0.107±0.120	2.7
Acenapththylene	0.040±0.000	0.226±0.212 >ERL@0.044	5.7
Acenaphthene	0.060±0.068	0.185±0.230 >ERL@0.016	3.1
Fluorene	0.060±0.048	0.273±0.237 >ERL@0.019	4.6
Phenanthrene	0.295±0.501	1.429±1.532 >ERL@0.240	4.8
Anthracene	0.110±0.154	0.336±0.369 >ERL@0.085	3.1
Fluoranthene	1.076±1.718	3.731±3.575 >ERL@0.600	3.5
Pyrene	1.253±1.848	3.931±3.413 >ERL@2.600	3.1
Benz(a)anthracene	0.317±0.491	1.239±1.229 >ERL@0.261	3.9
Chrysene	0.589±0.924	1.688±1.359 >ERL@0.384	2.9
Benzo(b,k)fluoranthene	1.242±1.839	2.958±2.286	2.4
Benzo(e)pyrene	0.469±0.643	1.094±0.820	2.3
Benzo(a)pyrene	0.573±0.834	1.132±0.968 >ERL@0.430	2.0
Perylene	0.274±0.350	0.285±0.268	1.0
Indeno(1,2,3,-cd)pyrene	0.426±0.566	1.139±0.951	2.7
Benzo(g,h,i)perylene	0.450±0.591	1.219±0.993	2.7
Dibenzo(a,h)anthracene	0.182±0.147	0.259±0.217 >ERL@0.260	1.4
Total LMW PAH	0.604±0.766	2.556±2.625 >ERL@0.552	4.2
Total HMW PAH	6.852±9.662	18.677±15.933 >ERL@9.600	2.7
Total PAH	7.456±10.354	21.233±18.504 >ERL@4.022	2.8

[a] ne=mean concentrations not in exceedance of or equal to ERL values of Long et al. (in press).

Average concentrations of PAHs in samples that were nontoxic and in samples that were toxic to the sea urchins are compared in Table 24. Eleven samples were nontoxic in the 100% pore water and the average fertilization success was 85.2%. Eight samples were toxic only in the 100% pore water, 10 samples were toxic in both 100% and 50% pore water and 30 samples were toxic in all three pore water concentrations. The ratios in chemical concentrations between the nontoxic and toxic samples ranged from 1.0 to 24.8. The average concentrations in samples that were toxic in both the 100% and 50% pore water tests were similar to the average concentrations in samples that were toxic only in 100% pore water. The average PAH concentrations in samples that were toxic at all three pore water dilutions were considerably higher than in the samples from all the other categories. The concentrations of fluoranthene and pyrene were most elevated in the toxic samples, followed by phenanthrene, chrysene, and benzo(b,k)fluoranthene. The concentrations of high molecular weight PAHs were more elevated in the toxic samples than the concentrations of the low molecular weight compounds.

The average concentration of each of the compounds that was highly elevated in the most toxic samples (fluoranthene, pyrene, benzo(a)anthracene, phenanthrene, chrysene) exceeded the corresponding ERL values of Long et al. (In press). However, only the average concentrations of pyrene and total high molecular weight PAHs (2.626 and 12.230 ppm, respectively) in the highly toxic samples exceeded the respective ERM value (2.6 and 9.6 ppm) of Long et al. (in press).

The relationship between sea urchin fertilization success and total PAH concentrations in the sediments is illustrated in Figure 28. At total PAH concentrations below the ERL value (4.022 ppm), percent fertilization varied widely from 0.0 to over 90%. In contrast, in the samples with PAH concentrations that exceeded the ERL value, percent fertilization was much lower (generally, 10% or less). All but 3 of the 23 samples that exceeded the ERL had ≤5% fertilization success. As noted previously, urchin fertilization success was not well correlated with TOC-normalized PAH concentrations, and it is possible that covariance among contaminants contributes to the relationship illustrated in Figure 28. Nonetheless, the ERM values for PAH clearly have strong predictive value for toxicity in the urchin fertilization test.

Table 24. Average PAH concentrations (ug/g ± standard deviations) in sediment samples that were not toxic to sea urchin fertilization in 100% pore water, or were significantly toxic in different pore water dilutions, and ratios between the average concentrations. Phases 1 and 2. A value of one-half the method detection limits (MDL) was used for concentrations below the MDLs.

	Non-toxic @ 100% (85.2±4.5% fertilization, n=11)	Toxic @ 100% (48.9±24.6% fertilization[a], n=8)	Ratio of toxic to non-toxic averages	Toxic @ 100 & 50% (16.9±20.2% fertilization[b], n=10)	Ratio of toxic to non-toxic averages	Toxic @ 100 & 50 & 25% (4.8±9.5% fertilization[a], n=30)	Ratio of toxic to non-toxic averages
naphthalene	.035±0.00	.135±0.00	1.0	.035±0.00	1.0	.059±.068	1.7
acenaphthylene	.040±0.00	.040±0.00	1.0	.040±0.00	1.0	.007±.130	2.2
acenaphthene	.040±0.00	.040±0.00	1.0	.040±0.00	1.0	.110±.144	2.8
fluorene	.045±0.00	.045±0.00	1.0	.045±0.00	1.0	.126±.153	2.8
phenanthrene	.045±0.00	.159±.198	3.5	.102±.179	2.3	.760±1.001	16.9
anthracene	.045±0.00	.062±.048	1.4	.066±.065	1.5	.213±.261	4.7
fluoranthene	.096±.137	.463±.736	4.8	.573±1.280	5.9	2.386±2.600	24.8
pyrene	.127±.143	.649±.834	5.1	.725±1.575	5.7	2.626±2.598	20.6
benzo(a)anthracene	.065±0.00	.164±.192	2.5	.157±.289	2.4	.710±.848	10.9
chrysene	.092±.089	.319±.475	3.5	.410±.866	4.5	1.158±1.199	12.6
benzo(b,k)fluor.	.097±.041	.248±.345	2.5	.158±.229	1.6	1.177±2.018	12.1
benzo(e)pyrene	.112±.089	.238±.297	2.1	.308±.704	2.8	.857±.747	7.7
benzo(a)pyrene	.105±.068	.283±.416	2.7	.340±.805	3.2	1.020±.953	9.7
perylene	.094±.029	.148±.179	1.6	.213±.403	2.3	.410±.370	4.4
indeno(1,2,3)pyrene	.129±.047	.220±.221	1.7	.312±.621	2.4	.794±.750	6.2
benzo(g,h,i)peryl.	.133±.059	.235±.253	1.8	.308±.609	2.3	.850±.786	6.4
benzo(a,h)anthr.	.115±0.00	.127±.034	1.1	.153±.119	1.3	.243±.194	2.1
sum LPAH	.250±0.00	.381±.242	1.5	.327±.243	1.3	1.354±1.684	5.4
sum HPAH	1.165±.638	3.093±3.778	2.6	3.653±7.479	3.1	12.230±11.987	10.5
sum total PAH	1.415±.638	3.474±4.016	2.5	3.980±7.722	2.8	13.583±13.561	9.6

[a] average percent fertilization measured in 100% pore water

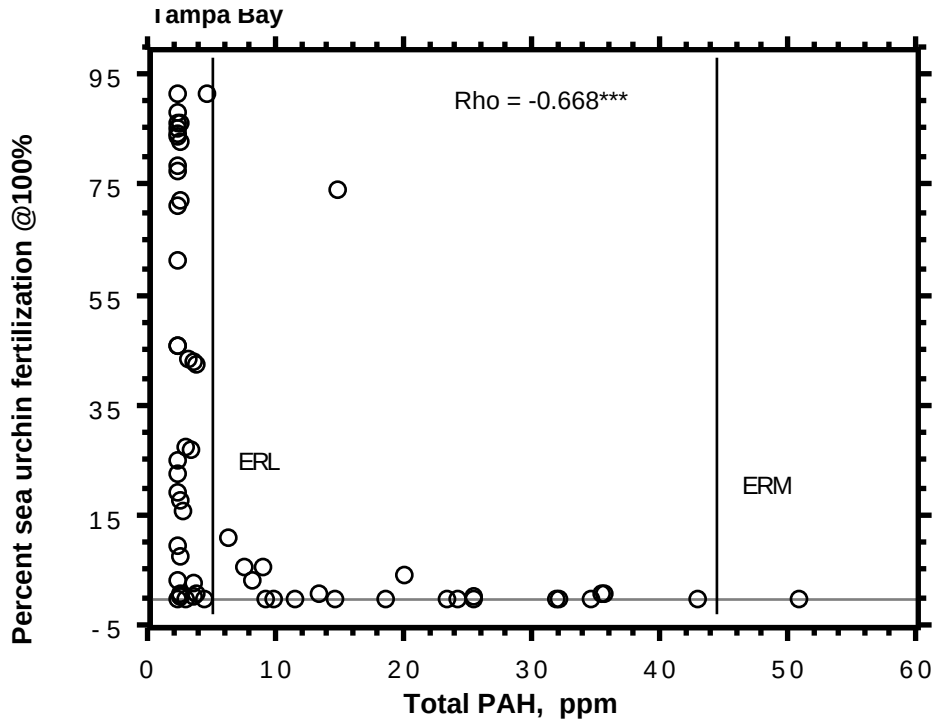

Figure 28. Relationship between sea urchin fertilization in 100% pore water and the concentration of total PAH in sediment.

As with the other toxicity tests, the Microtox™ test indicated that all PAH concentrations were higher in toxic samples than in nontoxic samples. The average PAH concentrations in samples that were nontoxic to Microtox™ bioluminescence often were below the detection limits (Table 25). Standard deviations of 0.00 indicate that all the samples were the same; invariably the listed concentrations in these cases are one-half the limits of detection. The compounds that were most elevated in concentration in samples that were toxic to Microtox™ bioluminescence were phenanthrene, fluoranthene, and benz(a)anthracene. Also, benzo(b,k)fluoranthene, anthracene, and total high molecular weight PAH were considerably elevated in concentration in the toxic samples. The average concentrations of the following compounds in the toxic samples exceeded the corresponding ERM values of Long et al. (In press.): phenanthrene (ERM = 1.5 ppm); pyrene (ERM = 2.6 ppm); dibenzo (a,h) anthracene (ERM = 0.26 ppm); and the sum of total HPAH (ERM = (0.60 ppm). Most of the other compounds listed in Table 25 exceeded the corresponding ERL values of Long et al. (In press) in the toxic samples.

Table 25. Average PAH concentrations (ppm ± standard deviation) in toxic and nontoxic Phase 1 samples in the Microtox™ bioluminescence tests, and ratios between the average concentrations. A value of one-half the method detection limit (MDL) was used for concentrations below the MDLs.

	Not Toxic (Ave. 0.066±0.033 EC50s, n=9)	Significantly Toxic (Ave. 0.017±0.012 EC50s, n=7)	Ratio of toxic to non-toxic averages
% TOC	1.89±.900	3.47±1.490	1.8
Naphthalene	.035±0.00	.117±.125	3.3
Acenapththylene	.049±.027	.241±.224	4.9
Acenaphthene	.040±0.00	.206±.240	5.2
Fluorene	.045±0.00	.306±.236	6.8
Phenanthrene	.112±.136	1.559±1.609	13.9

Table 23 continued.

	Not Toxic (Ave. 0.066±0.033 EC50s, n=9)	Significantly Toxic (Ave. 0.017±0.012 EC50s, n=7)	Ratio of toxic to non-toxic averages
Anthracene	.045±0.00	.377±.378	8.4
Fluoranthene	.377±.499	3.981±3.807	10.6
Pyrene	.607±.571	4.163±3.642	6.9
Benz(a)anthracene	.131±.130	1.323±1.313	10.1
Chrysene	.236±.275	1.749±1.495	7.4
Benzo(b,k)fluoranthene	.389±.487	3.082±2.495	7.9
Benzo(e)pyrene	.165±.163	1.136±.900	6.9
Benzo(a)pyrene	.156±.149	1.190±1.045	7.6
Perylene	.085±0.00	.314±.276	3.7
Indeno(1,2,3,-cd)pyrene	.176±.124	1.207±1.018	6.9
Benzo(g,h,i)perylene	.193±.161	1.277±1.076	6.6
Dibenzo(a,h)anthracene	.115±0.00	.280±.226	2.4
Total LMW PAH	.326±.156	2.806±2.732	8.6
Total HMW PAH	2.628±2.509	19.710±17.126	7.5
Total PAH	2.954±2.663	22.508±19.794	7.6

Pesticides, PCBs, Butyl Tins. Spearman rank correlation coefficients for toxicity and the dry weight concentrations of individual PCB congeners and total PCBs are summarized in Table 26. Most of the 23 congeners were quantified in samples from both Phases 1 and 2 (n=61). However, analyses of congeners 28, 50, and 110 were performed only in Phase 1 (n=16) and analyses of congeners 29 and 118 were performed only in Phase 2 samples (n=45). Microtox™ tests were performed only in Phase 1 (n=16). Based upon average and median concentrations, congeners 28, 50, 52, 66, 77, 101, and 110 were most abundant. The Dunn-Sidak (Sokal and Rohlf 1981)) adjustment would eliminate those results marked with "*" from significance at the 0.05 level.

Congeners 28, 50, and 110 (which were quantified only in Phase 1), and congener 8, had the highest correlations with amphipod survival. Compared to the samples tested in Phase 2, the Phase 1 samples identified a relatively wide range in response. The correlation coefficients ranged up to -0.842 for amphipod survival and individual PCB congeners. The correlation between the sum of the 23 quantified PCBs and amphipod survival was significant (Rho=-0.330). Congeners 29 and 118 were measured only in Phase 2, in which amphipod survival was similar among all samples, and they were not significantly correlated with amphipod survival. Neither of the co-planar congeners (77 and 126) that were measured were significantly correlated with amphipod survival. Because of the differences in amphipod survival between Phases 1 and 2, and the differences in PCB quantification between phases, little significance can be placed on these correlation results.

Table 26. Spearman rank correlations (Rho, corrected for ties) between sediment toxicity and the concentrations of PCB congeners and the sum of total PCBs (dry wt.).

	Percent amphipod	Percent sea urchin fertilization			Microtox™ bioluminescence
Chemical	survival	@100%	@50%	@25%	EC50
Sum of 23 PCBs	-0.330*	-0.678***	-0.631***	-0.605***	-0.683*
PCB 8	-0.558***	-0.386*	-0.282*	-0.228	-0.616*
PCB 18	-0.339*	-0.501***	-0.450**	-0.450**	-0.619*
PCB 28	-0.842*	-0.663*	-0.368	-0.512*	-0.661*
PCB 29	+0.198	-0.055	-0.155	-0.193	nd
PCB 50	-0.558*	-0.511*	-0.365	-0.486	-0.550*
PCB 52	-0.387*	-0.395*	-0.296*	-0.284*	-0.692*
PCB 44	-0.266*	-0.270*	-0.220	-0.245	-0.040
PCB 66	-0.269*	-0.494***	-0.509***	-0.527***	-0.601*
PCB 101	-0.285*	-0.551***	-0.523***	-0.535***	-0.590*
PCB 77[a]	-0.146	-0.631***	-0.615***	-0.618***	-0.699*

Table 26 continued.

Chemical	Percent amphipod survival	Percent sea urchin fertilization @100%	@50%	@25%	Microtox™ bioluminescence EC50
PCB 110	-0.704*	-0.476	-0.229	-0.371	-0.604*
PCB 118[b]	-0.026	-0.513**	-0.497**	-0.498*	nd
PCB 153[c]	-0.191	-0.641***	-0.627***	-0.622***	-0.728*
PCB 105[b]	-0.140	-0.608***	-0.565***	-0.552**	-0.464
PCB 138[c]	-0.192	-0.626***	-0.597***	-0.586***	-0.685*
PCB 126[a]	-0.210	-0.569***	-0.567***	-0.527***	-0.381
PCB 187	-0.032	-0.576***	-0.604***	-0.558***	-0.461
PCB 128[c]	-0.082	-0.579***	-0.576***	-0.558***	-0.277
PCB 180[c]	-0.194	-0.637***	-0.626***	-0.611***	-0.589*
PCB 170[c]	+0.087	-0.474**	-0.507***	-0.489**	-0.425
PCB 195	-0.211	-0.465**	-0.414**	-0.392*	-0.653*
PCB 206	-0.271*	-0.462**	-0.403*	-0.411*	-0.241
PCB 209	-0.321*	-0.513**	-0.330*	-0.265*	-0.493

[a]Co-planar PCB congeners
[b]Mono-ortho co-planar congeners
[c]Di-ortho co-planar congeners
*P<0.05; **P<0.001; ***P<0.0001; (unadjusted for multiple comparisons).
nd = no data; not analyzed in Phase 1.

The correlations between sea urchin fertilization and the concentrations of most PCB congeners were highly significant. The correlation between fertilization success and the sum of the 23 congeners was highly significant (Rho = -0.605 to -0.678). The correlations between total PCBs and sea urchin fertilization were significant for all three pore water dilutions. The correlation coefficients ranged up to -0.663 for the individual congeners. All congeners, except 29 and 110, were significantly correlated with fertilization success in at least one of the pore water concentrations. Both of the co-planar congeners (77 and 126) were significantly correlated with fertilization success.

The correlations between Microtox™ bioluminescence and the concentrations of most PCB congeners were marginally significant. The highest correlations were apparent for congeners 28, 52, 77, 153, 138, and 195. The correlation between the sum of total congeners and bioluminescence was significant (Rho=-0.683). Microtox™ tests were not performed in Phase 2, therefore, there were no data for congeners 29 and 118 since they were quantified only in Phase 2. Many of the congeners with the highest correlations with bioluminescence toxicity (18, 52, 77, 153, 138, and 195) were among the least concentrated and abundant congeners.

The correlations between toxicity and PCB concentrations normalized to TOC content are summarized in Table 27. As with the PAH data, TOC normalization generally strengthened the correlations of PCB with amphipod survival, and reduced the correlations with both urchin fertilization success and Microtox™ fertilization EC50. However, a pattern of consistent negative correlations was retained for both these tests in the TOC normalized data. Many of the congeners, expressed on a dry weight basis, that were highly correlated with toxicity to amphipods and sea urchin fertilization, remained significantly toxic when expressed in units of organic carbon. These data indicate that the TOC content did not explain fully the relationships between PCB concentrations and these measures of toxicity. Overall, some of the concordance between toxicity and PCB concentrations could be attributed to covariance with TOC content, but it remains plausible that PCB could be responsible for some of the observed toxic responses, especially in the amphipod test.

Table 27. Spearman rank correlations (Rho, corrected for ties) between sediment toxicity and the concentrations of PCB congeners and the sum of total PCBs normalized to TOC content.

Chemical	Percent amphipod survival	Percent sea urchin fertilization @100%	@50%	@25%	Microtox™ bioluminescence EC50
Sum of 23 PCBs	-0.474**	-0.419*	-0.376*	-0.329*	-0.568*
PCB 8	-0.612***	-0.107	-0.024	+0.016	-0.472
PCB 18	-0.640*	-0.662**	-0.369	-0.337	-0.422
PCB 28	-0.781*	-0.523*	-0.258	-0.380	-0.450
PCB 29	+0.094	+0.119	-0.0005	-0.037	nd
PCB 50	-0.536*	-0.286	-0.109	-0.205	-0.265
PCB 52	-0.464**	-0.247	-0.160	-0.136	-0.421
PCB 44	-0.298*	-0.045	-0.022	-0.033	+0.204
PCB 66	-0.450**	-0.189	-0.192	-0.230	-0.322
PCB 101	-0.379*	-0.347*	-0.323*	-0.312*	-0.184
PCB 77[a]	-0.261*	-0.442**	-0.446**	-0.433**	-0.501
PCB 110	-0.669**	-0.310	-0.106	-0.215	-0.489
PCB 118[b]	-0.210	-0.261	-0.263	-0.245	nd
PCB 153[c]	-0.332*	-0.471**	-0.472**	-0.457**	-0.637*
PCB 105[b]	-0.233	-0.415*	-0.361*	-0.315*	-0.314
PCB 138[c]	-0.330*	-0.468**	-0.451**	-0.427**	-0.609*
PCB 126[a]	-0.252*	-0.421*	-0.456**	-0.387*	-0.275
PCB 187	-0.130	-0.348*	-0.405*	-0.342*	-0.280
PCB 128[c]	-0.144	-0.324*	-0.366*	-0.333*	-0.161
PCB 180[c]	-0.313*	-0.469**	-0.474**	-0.461**	-0.459
PCB 170[c]	+0.001	-0.192	-0.261*	-0.235	-0.089
PCB 195	-0.276*	-0.254*	-0.242	-0.215	-0.439
PCB 206	-0.309*	-0.4284*	-0.243	-0.245	-0.019
PCB 209	-0.358*	-0.185	-0.093	-0.015	-0.073

[a]Coplanar PCB congeners
[b]Mono-ortho coplanar congeners
[c]Di-ortho coplanar congeners
*P<0.05; **P<0.001; ***P<0.0001; (unadjusted for multiple comparisons).
nd = no data; not analyzed in phase 1.

The relationship between sea urchin fertilization and total PCB concentration is illustrated in a scattergram (Figure 29). In this plot, the sum of the 23 congeners that were quantified were doubled to estimate the concentrations of total PCBs, following the methods of NOAA (1989). Sea urchin fertilization generally decreased as PCB concentrations increased. At total PCB concentrations below the ERM value (180 ppb) of Long et al. (in press), fertilization success ranged from 0.0% to over 90%. In contrast, fertilization success generally was less than 30% (often less than 10%) in samples with total PCB concentrations that exceeded the ERM value. The two samples with the highest total PCB concentrations caused zero fertilization success.

The Spearman rank correlations between toxicity and pesticides concentrations were determined for 61 samples from Phases 1 and 2 (Table 28). The concentrations of the butyl tins were determined only in Phase 1 (n=16) and the concentratio/*ns of 2,4-DDD and 4,4-DDE were determined only in Phase 2 (n=29 and n=45, respectively). The Dunn-Sidak (Sokal and Rohlf 1981) adjustment would eliminate those results marked with "*" from significance at the 0.05 level. The correlations between measures of toxicity and the concentrations of many pesticides were highly significant.

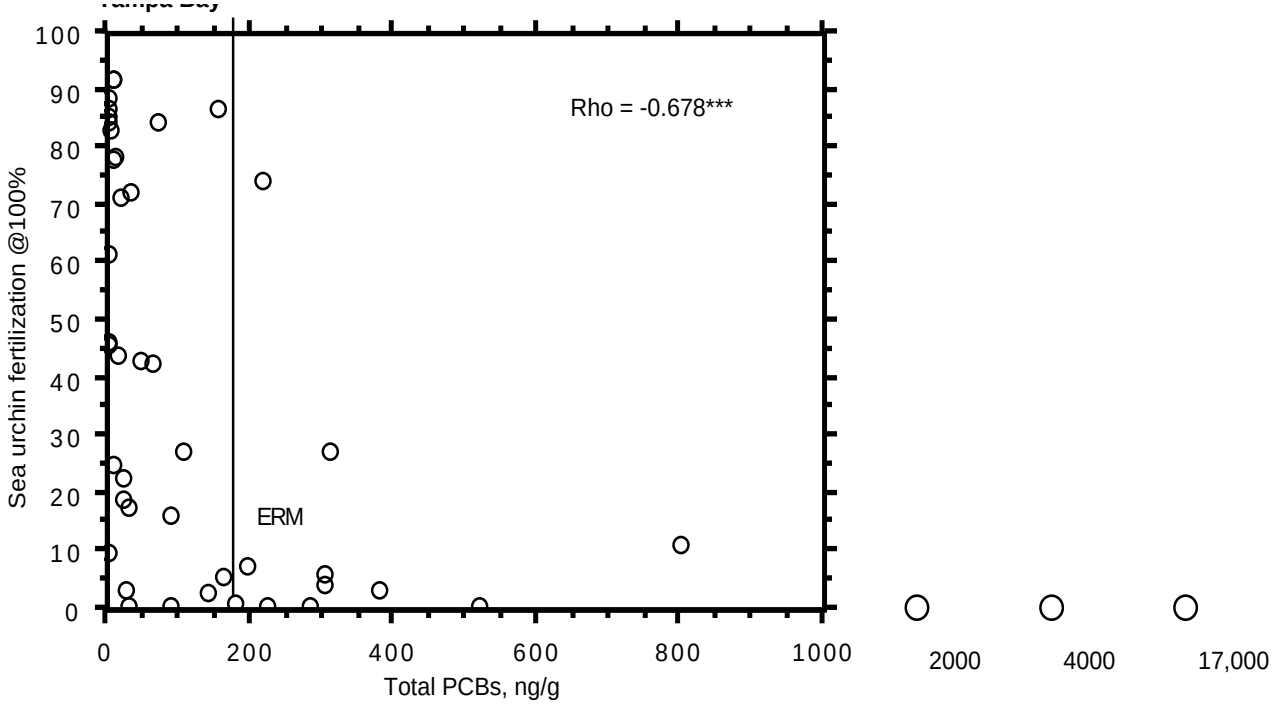

Figure 29. Relationship between sea urchin fertilization in 100% pore water and the concentrations (ng/g) of total PCB in sediments.

Table 28. Spearman rank correlations (Rho, corrected for ties) between sediment toxicity and the concentrations of pesticides and butyl tins (ng/g dry wt.).

	Percent amphipod	Percent sea urchin fertilization			Microtox™ bioluminescence
Chemical	**survival**	**@100%**	**@50%**	**@25%**	**EC50**
chlordane	-0.421*	-0.714***	-0.690***	-0.636***	-0.669*
trans-nonachlor	-0.326*	-0.665***	-0.617***	-0.612***	-0.683*
dieldrin	-0.396*	-0.667***	-0.628***	-0.564***	-0.724*
endrin	-0.433**	-0.631***	-0.557***	-0.479**	-0.647*
HCB	-0.383*	-0.198	-0.155	-0.105	-0.292
lindane	+0.0003	-0.478**	-0.511***	-0.512***	-0.278
heptachlor	-0.247	-0.232	-0.173	-0.208	+0.200
aldrin	-0.296*	-0.291*	-0.291*	-0.264*	+0.0003
heptachlor epox.	-0.498***	-0.490***	-0.327*	-0.241	-0.531*
Total pesticides	-0.449**	-0.739***	-0.689***	-0.636***	-0.703*
mirex	-0.403*	-0.350*	-0.339*	-0.274*	nd
total butyl tins	-0.670*	-0.443	-0.082	-0.147	-0.538
2,4-DDD	+0.064	-0.612***	-0.656***	-0.637***	nd
4,4-DDD	-0.370*	-0.704***	-0.682***	-0.659***	-0.684*
2,4-DDT	-0.449**	-0.420*	-0.322*	-0.234	-0.679*
4,4-DDT	-0.353*	-0.642***	-0.652***	-0.622***	-0.658*
2,4-DDE	-0.440**	-0.643***	-0.521***	-0.428**	-0.556*
4,4-DDE	+0.0009	-0.570**	-0.648***	-0.635***	nd
total DDTs	-0.292*	-0.671***	-0.693***	-0.684***	-0.647*

*P<0.05; **P<0.001; ***P<0.0001; (unadjusted for multiple comparisons).
nd = no data

In the amphipod tests, many of the correlation coefficents that were significant with the pesticides expressed in units of dry weight increased when the concentrations were normalized to organic carbon content (Table 29). Most notably, the correlations with chlordane, total pesticides, and total DDTs increased with TOC normalization. Conversely, the correlations with butyl tins changed from negative to positive in all cases. In the sea urchin tests, many of the correlations (e.g., those for chlordane and the DDT isomers) decreased with TOC-normalization. In the Microtox™ tests, many of the correlations decreased slightly with TOC-normalization. In summary, as with the PAHs and PCBs, TOC concentrations apparently accounted for some of the variability in the pesticide concentrations, but did not fully explain all of the variability. The pattern of negative correlations was retained for both the urchin and Microtox™ tests, and many of the correlations remained significant (unadjusted) with the TOC-normalized data, most notably for the DDT compounds.

Table 29. Spearman rank correlations (Rho, corrected for ties) between sediment toxicity and the concentrations of pesticides and butyl tins normalized to organic carbon content (μg/goc normalized to TOC).

	Percent amphipod	Percent sea urchin fertilization			Microtox™ bioluminescence
Chemical	survival	@100%	@50%	@25%	EC50
chlordane	-0.652***	-0.286*	-0.285*	-0.240	-0.567*
trans-nonachlor	-0.406*	-0.187	-0.173	-0.141	-0.694*
dieldrin	-0.560***	-0.261*	-0.257*	-0.197	-0.729*
endrin	-0.430**	-0.484**	-0.421*	-0.312*	-0.505*
HCB	-0.386*	-0.058	-0.018	+0.060	+0.206
lindane	-0.118	+0.298	+0.281	+0.317	+0.0003
heptachlor	_0.287*	-0.167	-0.104	-0.132	+0.312
aldrin	-0.282*	-0.184	-0.178	-0.141	+0.227
heptachlor epox.	-0.514***	-0.456**	-0.286*	-0.196	-0.324
total pesticides	-0.664***	-0.183	-0.161	-0.092	-0.505*
mirex	-0.369*	-0.216	-0.207	-0.137	+0.564
total butyl tins	+0.130	+0.219	+0.209	+0.312	+0.342
2,4-DDD	-0.139	-0.126	-0.285	-0.281	nd
4,4-DDD	-0.439**	-0.419*	-0.445**	-0.408*	-0.529*
2,4-DDT	-0.468**	-0.384*	-0.289*	-0.193	-0.575*
4,4-DDT	-0.374*	-0.442**	-0.460**	-0.439**	-0.583*
2,4-DDE	-0.407*	-0.586***	-0.456**	-0.359*	-0.340
4,4-DDE	-0.186	-0.279	-0.395*	-0.373*	nd
Total DDTs	-0.406*	-0.372*	-0.440**	-0.435**	-0.532*

*P<0.05; **P<0.001; ***P<0.0001; (unadjusted for multiple comparisons).
nd = no data

One of the strongest correlations was that between sea urchin fertilization and total DDT concentrations. This relationship is illustrated in Figure 30. Percent fertilization generally decreased as total DDT concentrations increased, especially at concentrations that approached and exceeded the ERM value of Long et al. (in press). At concentrations below the ERM value of 46 ng/g, percent fertilization success ranged widely from zero to over 90%. At concentrations above the ERM value, all but one sample caused 10% fertilization success or less.

Average concentrations of PCBs and pesticides in the samples that were toxic to the amphipods greatly exceeded these in the nontoxic samples (Table 30). The concentrations of PCBs, endrin, heptachlor, and heptachlor epoxide were particularly elevated in the toxic samples. The average concentrations of total DDTs and total PCBs in the toxic samples (596 and 3191 ng/g, respectively) greatly exceeded the corresponding ERM values (46.1 and 180 ng/g, respectively) of Long et al. (in press).

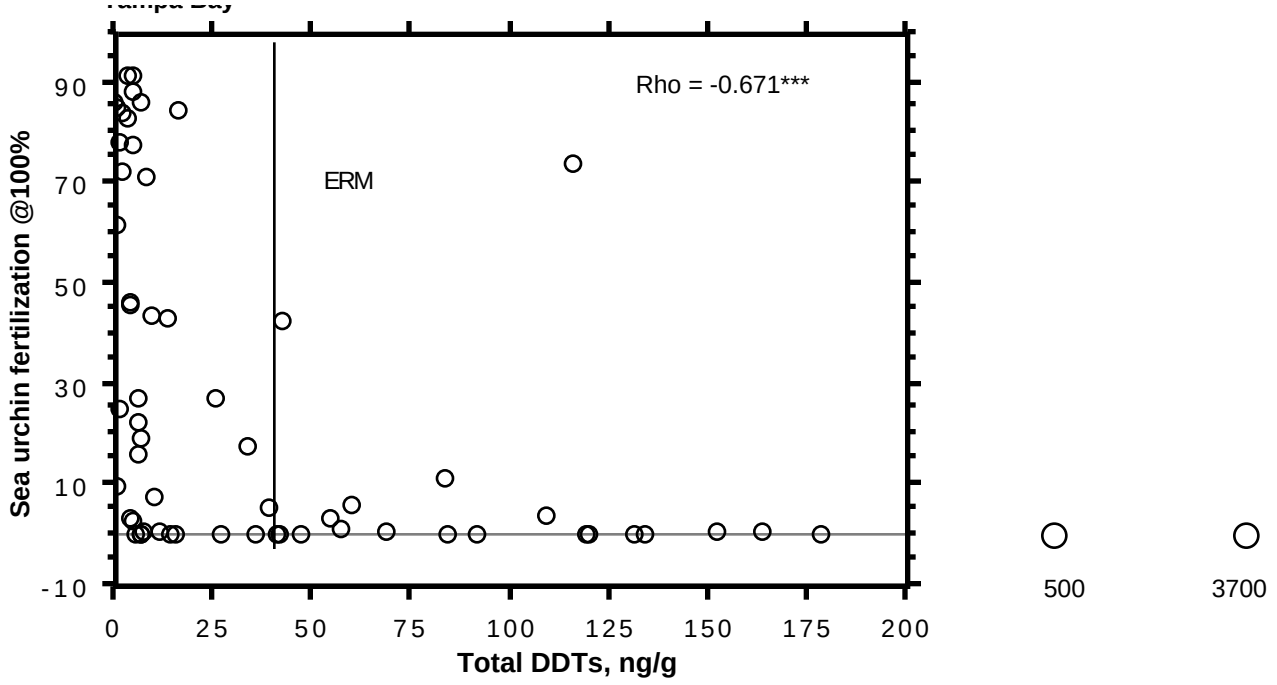

Figure 30. The relationship between total DDT concentrations (ng/g) and percent sea urchin fertilization in 100% pore water (n=61).

Table 30. Average concentrations (ng/g dry wt.) of pesticides and PCBs in toxic and non-toxic samples in the amphipod survival tests and ratios between the average concentrations (n=61).

	Not Toxic (Ave. 87.5±5.2% survival, n=53)	Significantly Toxic (Ave. 64.8±17.5% survival, n=8)	Ratio (Toxic/ non-toxic)
Sum of 23 PCBs	60.3 ± 66.7	1595.8 ± 2776.6	26.6
Total PCBs	120.6 ±133.3	3191.6 ± 5553.2	26.6
"a"-chlordane	4.2 ± 6.2	59.2 ± 106.1	14.1
trans-nonachlor	1.3 ± 1.3	30.5 ± 51.5	23.5
dieldrin	2.5 ± 3.8	59.8 ± 105.7	23.9
endrin	1.5 ± 1.5	67.6 ± 132.4	45.1
hexachlorobenzene	0.7 ± 1.5	3.6 ± 2.5	5.1
indane	1.9 ± 1.6	26.9 ± 55.1	14.2
heptachlor	0.7 ± 1.4	30.9 ± 74.1	44.1
aldrin	1.0 ± 1.8	4.8 ± 6.6	4.8
heptachlor epoxide	0.2 ± 0.5	6.3 ± 8.2	31.5
Total DDTs	33.0 ± 45.8	596.1 ± 1302.5	18.1
TOC	2.3 ± 1.5	63.5 ± 1.35	1.5

In the amphipod tests, the average concentrations of total DDTs, normalized to the organic carbon content, were 19.4 µg/goc in the toxic samples and 1.39 µg/goc in the non-toxic samples (a 14-fold difference) (Table 31). Swartz et al. (1994) reported LC50 values for total DDT of 2500 µg/goc 1040 µg/goc, based upon toxicity tests of field-collected samples performed with the amphipods, *Eohaustorius estuarius* and *Rhepoxynius abronius*, respectively). The average concentration of total PCBs in the toxic samples (100.8 µg/goc) differed by a factor of 17 from the average concentration in the nontoxic samples (5.91 µg/goc).

Table 31. Average concentrations (μg/goc) of pesticides and PCBs, normalized to organic carbon, in toxic and non-toxic samples in the amphipod survival tests and ratios between the average concentrations (n=61).

	Not Toxic (Ave. 87.5±5.2% survival, n=53)	Significantly Toxic (Ave. 64.8±17.5% survival, n=8)	Ratio (Toxic/ non-toxic)
Sum of 23 PCBs	2.96 ± 3.00	850.44 ± 87.79	17.1
Total PCBs	5.91 ± 6.16	100.87 ± 175.58	17.1
"a"-chlordane	0.19 ± 0.21	1.88 ± 3.56	9.8
trans-nonachlor	0.07 ± 0.09	0.95 ± 1.63	13.2
dieldrin	0.12 ± 0.15	1.82 ± 3.55	15.5
endrin	0.07 ± 0.08	2.19 ± 4.18	31.3
hexachlorobenzene	0.05 ± 0.10	0.11 ± 0.08	2.3
lindane	0.29 ± 0.94	0.83 ± 1.72	2.9
heptachlor	0.04 ± 0.08	1.05 ± 2.33	26.8
aldrin	0.05 ± 0.07	0.14 ± 0.15	2.9
heptachlor epoxide	0.01 ± 0.02	0.20 ± 0.26	20.9
Total DDTs	1.39 ± 1.51	19.40 ± 41.15	14.0

The average concentrations of dieldrin, normalized to the organic carbon content, were 1.82 μg/goc in the samples that were toxic to amphipods and 0.12 μg/goc in the nontoxic samples (a 15-fold difference). The average concentration in the toxic samples was lower than the proposed National criterion (U.S. EPA, 1991d) of 20 μg/goc (confidence limits: 9.5-44 μg/goc), and lower than the LC50 for dieldrin (25 μg/goc) reported by Swartz et al. (1994).

In the amphipod tests, the average concentrations of endrin were 2.19 μg/goc in the toxic samples and 0.07 μg/goc in the nontoxic samples (a 31-fold difference). The average concentration in the toxic samples exceeded the proposed National criterion of 0.73 μg/goc (confidence limits of 0.35 to 1.6 μg/goc, U.S. EPA, 1993e) by a factor of 3.0.

The average concentrations of pesticides and PCBs were very high in samples that were toxic to sea urchin fertilization as compared to the concentrations in nontoxic samples (Table 32). The samples that were toxic in all three pore water concentrations had considerably higher chemical concentrations than those that were toxic in only the 100% pore water or in 100% and 50% pore water. In the 32 samples that were toxic in all three pore water concentrations, the average concentrations of endrin, total DDTs, dieldrin, and total PCBs were elevated by factors of 60x, 43x, 44x, and 35x, respectively, over the average concentrations in nontoxic samples. The average concentrations of both total DDTs and total PCBs in the toxic samples exceeded the respective ERM values of Long et al. (in press). By contrast, the ratio for TOC in toxic/nontoxic samples was 1.5, illustrating again that many of these organic toxicants were present in the toxic samples in excess.

In the sea urchin tests the average concentrations of total DDTs were 6.05 μg/goc in the samples that were toxic in 100%, 50%, and 25% pore water and 1.22 μg/goc in the nontoxic samples (a 5-fold difference) (Table 33). The average concentration in the toxic samples was considerably lower than the LC50 of 2500 μg/goc reported by Swartz et al. (1994) for amphipods. The average concentrations of total PCBs were 29.24 μg/goc in the toxic samples and 5.82 μg/goc in the nontoxic samples (a 5-fold difference). The average concentration of dieldrin in the toxic samples (0.55 μg/goc) was considerably lower than the proposed National criterion of 17 μg/goc (U.S. EPA, 1991d). The average concentration of endrin in the toxic samples (0.59 μg/goc) was 17 times higher than the average concentration in the nontoxic samples (0.03 μg/goc) and nearly equalled the proposed national criterion of 0.73 μg/goc (U.S. EPA, 1991e).

The average concentrations of total PCBs, total DDTs, and other pesticides in samples that were nontoxic and in samples that were significantly toxic in the Microtox™ bioluminescence tests are compared in Table 34. These data were collected only in Phase 1. The ratios between the average concentrations, expressed in dry wt., in the nontoxic and toxic samples ranged from 1.4 to 30.4. Relative to the other substances, the concentrations of dieldrin and total DDTs were most elevated in the toxic samples. Also, the concentrations of total PCBs, "a"-chlordane, trans-nonachlor, endrin, and lindane were relatively high in the toxic samples. The average concentration of total PCBs in the toxic samples (3546.6 ng/g) exceeded the ERM value (180 ng/g) of Long et al. (in

Table 32. Average PCB and pesticide concentrations (ng/g ± standard deviations) in sediment samples that were not toxic to sea urchin fertilization in 100% pore water, or were significantly toxic in different pore water dilutions, and ratios between the average concentrations. Phases 1 and 2. A value of one-half the method detection limit (MDL) was used for concentrations below MDLs.

	Non-toxic @ 100% (85.2±4.5% fertilization, n=11)	Toxic @ 100% (48.9±24.6% fertilization[a], n=8)	Ratio of toxic to non-toxic averages	Toxic @ 100 & 50% (16.9±20.2% fertilization[a], n=10)	Ratio of toxic to non-toxic averages	Toxic @ 100 & 50 & 25% (4.8±9.5% fertilization[a], n=32)	Ratio of toxic to non-toxic averages
Sum of 23 PCBs	13.3 ± 23.8	93.6 ± 136.3	7.0	34.5 ± 30.0	2.6	460.0 ± 1478.5	34.6
Total PCB	26.7 ± 47.5	187.3 ± 272.5	7.0	69.1 ± 59.9	2.6	920.1 ± 2957.0	34.6
chlordane	0.7 ± 0.6	3.4 ± 3.9	4.9	2.4 ± 2.3	3.4	19.8 ± 56.0	28.3
trans-nonachlor	0.3 ± 0.2	1.3 ± 1.5	4.3	0.7 ± 0.5	2.3	8.9 ± 27.6	29.7
dieldrin	0.4 ± 0.3	2.1 ± 2.4	5.3	1.4 ± 1.6	3.5	17.8 ± 56.1	44.5
endrin	0.3 ± 0.5	2.5 ± 4.2	8.3	1.5 ± 1.3	5.0	17.9 ± 69.3	59.7
hexachlorobenzene	0.5 ± 1.3	1.0 ± 1.7	2.0	0.7 ± 1.3	1.4	1.4 ± 2.2	2.8
lindane	1.1 ± 0.5	1.7 ± 1.1	1.5	1.1 ± 0.5	1.0	8.7 ± 28.4	7.9
heptachlor	0.3 ± 0.7	1.8 ± 2.8	6.0	0.6 ± 1.5	2.0	8.2 ± 37.7	27.3
aldrin	0.2 ± 0.4	2.2 ± 2.8	11.0	0.4 ± 0.6	2.0	2.1 ± 3.9	10.5
heptachlor epoxide	0.1 ± 0.2	0.4 ± 0.7	4.0	0.2 ± 0.3	2.0	1.8 ± 4.7	18.0
total DDTs	4.4 ± 4.4	30.7 ± 44.1	7.0	14.0 ± 15.0	3.2	190.1 ± 664.8	43.2

[a] average percent fertilization measured in 100% pore water

Table 33. Average PCB and pesticide concentrations, normalized to organic carbon, (μg/goc ± standard deviations) in sediment samples that were not toxic to sea urchin fertilization in 100% pore water, or were significantly toxic in different pore water dilutions, and ratios between the average concentrations. Phases 1 and 2. A value of one-half the method detection limit (MDL) was used for concentrations below MDLs.

	Non-toxic @ 100% (85.2±4.5% fertilization, n=11)	Toxic @ 100% (48.9±24.6% fertilization[a], n=8)	Ratio of toxic to non-toxic averages	Toxic @ 100 & 50% (16.9±20.2% fertilization[a], n=10)	Ratio of toxic to non-toxic averages	Toxic @ 100 & 50 & 25% (4.8±9.5% fertilization[a], n=32)	Ratio of toxic to non-toxic averages
Sum of 23 PCBs	2.91 ± 4.14	4.89 ± 7.38	1.7	2.15 ± 2.26	0.7	14.61 ± 48.46	5.0
Total PCB	5.82 ± 8.28	9.78 ± 14.77	1.7	4.30 ± 4.52	0.7	29.23 ± 96.91	5.0
chlordane	0.18 ± 0.17	0.21 ± 0.21	1.2	0.13 ± 0.08	0.7	0.63 ± 1.84	3.5
trans-nonachlor	0.09 ± 0.08	0.12 ± 0.16	1.4	0.05 ± 0.03	0.6	0.28 ± 0.91	3.2
dieldrin	0.10 ± 0.09	0.16 ± 0.18	1.7	0.09 ± 0.07	0.9	0.55 ± 1.83	5.8
endrin	0.03 ± 0.06	0.13 ± 0.23	4.0	0.10 ± 0.09	3.1	0.58 ± 2.29	17.5
hexachlorobenzene	0.05 ± 0.12	0.05 ± 0.07	1.0	0.05 ± 0.07	0.9	0.06 ± 0.10	1.1
lindane	0.36 ± 0.29	0.23 ± 0.40	0.7	0.09 ± 0.07	0.3	0.48 ± 0.146	1.3
heptachlor	0.06 ± 0.09	0.08 ± 0.15	1.5	0.05 ± 0.12	0.9	0.27 ± 1.25	4.9
aldrin	0.04 ± 0.07	0.10 ± 0.12	2.4	0.02 ± 0.04	0.5	0.06 ± 0.09	1.5
heptachlor epoxide	0.005 ± 0.02	0.02 ± 0.03	3.6	0.01 ± 0.01	2.0	0.06 ± 0.15	10.3
total DDTs	1.22 ± 1.76	1.55 ± 1.97	1.3	0.92 ± 1.22	0.8	6.05 ± 21.99	5.0

[a] average percent fertilization measured in 100% pore water

press) by a factor of 19.7. The average concentration of total DDTs in the toxic samples (664.9 ng/g) exceeded the ERM value (46.1 ng/g) of Long et al. (in press) by a factor of 14.4. Sediment guidelines for the other pesticides listed in Table 32 are not available from Long et al. (in press).

Table 34. Average concentrations (ng/g dry wt.) of pesticides and PCBs in toxic and nontoxic samples in the Microtox™ bioluminescence tests and the ratios between the averages (n=16).

	Not Toxic (Ave. EC50 = 0.066±0.033, n=9)	Significantly Toxic (Ave. EC50 = 0.017±0.012, n=7)	Ratio (Toxic/ non-toxic)
Sum of 23 PCBs	130.7 ± 123.8	1773.3 ± 2948.5	13.6
Total PCBs	261.3 ± 247.5	3546.6 ± 5896.9	13.6
"a"-chlordane	4.2 ± 3.5	65.6 ± 112.9	15.5
trans-nonachlor	2.0 ± 1.9	33.7 ± 54.7	17.3
dieldrin	2.2 ± 2.2	67.5 ± 111.7	30.4
endrin	4.8 ± 3.8	75.7 ± 141.4	15.7
hexachlorobenzene	2.8 ± 1.7	4.0 ± 2.7	1.4
lindane	1.7 ± 1.1	30.6 ± 58.5	18.0
heptachlor	3.3 ± 3.6	33.4 ± 79.7	10.2
aldrin	1.8 ± 1.4	4.9 ± 7.1	2.7
heptachlor epoxide	0.8 ± 1.0	6.8 ± 8.6	8.1
Total DDTs	22.5 ± 25.9	664.9 ± 1391.3	29.5

The average concentrations of total DDTs, normalized to the organic carbon content, were 1.85 μg/goc in the nontoxic samples and 24.9 μg/goc in the toxic samples (a difference of a factor of 13.5) (Table 35). The 10-day LC50 for total DDT in field-collected sediments tested with the amphipod *Eohaustorius estuarius* was 2500 μg/goc (Swartz et al., 1994), roughly two orders of magnitude higher than the average concentration of DDT in the samples that were toxic to Microtox™ bioluminescence.

Table 35. Average concentrations, normalized to total organic carbon, (μg/goc.) of pesticides and PCBs in toxic and nontoxic samples in the Microtox™ bioluminescence tests and the ratios between the averages (n=16).

	Not Toxic (Ave. EC50 = 0.066±0.033, n=9)	Significantly Toxic (Ave. EC50 = 0.017±0.012, n=7)	Ratio (Toxic/ non-toxic)
Sum of 23 PCBs	9.65 ± 7.54	63.78 ± 97.57	6.6
Total PCBs	19.31 ± 15.09	127.57 ± 195.13	6.6
"a"-chlordane	0.32 ± 0.16	2.38 ± 3.74	7.4
trans-nonachlor	0.15 ± 0.08	1.20 ± 1.82	7.9
dieldrin	0.18 ± 0.15	2.37 ± 3.70	13.2
endrin	0.34 ± 0.21	2.78 ± 4.68	8.1
hexachlorobenzene	0.15 ± 0.11	0.17 ± 0.11	1.1
lindane	0.08 ± 0.6	1.10 ± 1.91	13.3
heptachlor	0.19 ± 0.176	1.28 ± 2.65	6.6
aldrin	1.1 ± 0.10	0.12 ± 0.16	1.1
heptachlor epoxide	0.05 ± 0.03	0.23 ± 0.29	4.2
Total DDTs	1.85 ± 1.63	24.94 ± 46.19	13.5

The average concentrations of dieldrin, normalized to the organic carbon content, were 0.18 μg/goc in the nontoxic samples and 2.37 μg/goc in the toxic samples (a 13-fold difference). Swartz et al. (1994) reported an LC50 for dieldrin of 25-35 μg/goc, based upon toxicity tests of field-collected samples with *Eohaustorius estuarius*. The proposed National sediment quality criterion for dieldrin is 17 μg/goc (confidence limits of 7.7 to 36.0 μg/goc) for salt water (U.S. EPA, 1991d). The average concentration in the toxic samples was roughly an order of magnitude lower than both of these guideline values.

The average concentrations of TOC-normalized endrin were 0.34 µg/goc in the nontoxic samples and 2.78 µg/goc in the toxic samples (an 8-fold difference). The proposed National sediment quality criterion is 0.73 µg/goc (confidence limits of 0.34 to 1.60 µg/goc) for saltwater (U.S EPA, 1991e). The average concentrations of endrin in the toxic samples exceed the endrin criterion by a factor of 3.8 and the upper 95% confidence limit by a factor of 1.7.

Summary of Toxicity/Chemistry Relationships. Numerous substances have the potential to cause toxicity in sediments, including toxic chemicals and naturally-occurring properties. In the preceeding section the relationships between three measures of toxicity and a broad range of physical-chemical variables were discussed. The results of all three toxicity tests were strongly correlated with a number of physical and chemical properties of the sediments. These correlations demonstrate patterns in covariance between toxicity and these properties of the sediments, however, they do not establish cause-effect relationships. Considerably more research would be needed to establish the causes of the observed toxicity.

Based upon the data generated in this survey, it is apparent that toxicity co-varied with a number of potentially toxic chemicals. Often, these chemicals, in turn, co-varied in concentration with each other. That is, the samples that were the most toxic frequently contained high concentrations of mixtures of substances, any one of which could have caused or contributed to the toxicity. The mixtures of chemicals and their absolute concentrations differed among samples and among regions of Tampa Bay. The bioavailability of the chemicals undoubtedly differed among the regions of the bay in response to differences in the physical properties of the sediments. Also, the three toxicity tests differed in relative sensitivity and probably differed in the substances to which they were sensitive. Given these conditions it is difficult, if not impossible, to tease out of these data any definitive statements as to the cause(s) of toxicity.

However, it is possible to identify which chemicals, among those that were measured, co-varied most closely with toxicity. Also, it is possible to identify which of those chemicals also exceeded known toxicity standards, and, therefore, may have contributed to the toxicity. Based upon the correlation analyses, a number of chlorinated hydrocarbons (notably the PCBs, the DDT isomers, endrin, and other pesticides), numerous aromatic hydrocarbons, a number of trace metals, and ammonia were most strongly correlated with toxicity. However, only a relatively small proportion of these substances exceeded concentrations that have been previously associated with toxicity.

Table 36 summarizes the exceedances of the guideline values proposed by Long et al. (in press), Swartz et al. (1994), or U.S. EPA (1991a-e). The exceedances are listed as toxicity units, derived as the product of dividing the average concentration in the significantly toxic samples by the guideline concentration. The average concentrations of all other substances in the toxic samples failed to equal or exceed the respective guidelines. Specifically, the average concentrations of ammonia in the toxic samples were lower than the EC50 or LC50 values for the invertebrate tests. The average concentrations of all the metals in the toxic samples, except those listed in Table 33, were below the respective ERM values. The average concentrations of PAHs and other organic compounds not listed in Table 33, whether expressed in units of dry wt. or organic carbon, were lower than the respective guideline values.

Table 36. Toxicity unit concentrations for those substances in which the average concentrations in the significantly toxic samples equaled or exceeded the respective guideline values*.

	Amphipod survival	Sea urchin fertilization	Microtox™ bioluminescence
Lead[a]	3.55	<1.0	<1.0
Zinc[a]	1.13	<1.0	<1.0
Pyrene[a]	1.51	1.01	1.60
HPAH[a]	1.95	1.27	2.05
Phenanthrene[a]	<1.0	<1.0	1.04
Dibenzo(a,h)anthracene[a]	1.0	<1.0	1.08
Total PCBs[a]	17.73	8.21	19.71
Total DDTs[a]	12.96	4.13	14.43
Endrin (µg/goc)[b]	3.0	<1.0	3.81

* Average concentrations in significantly toxic samples divided by the respective SQC, ERM, EC50, or LC50 values.
[a] Based upon the ERM values (dry wt.) of Long et al. (in press).
[b] Based upon the proposed National sediment quality criterion (SQC) of U.S. EPA (1991e).

The average concentrations of total PCBs and total DDTs in the toxic samples exceeded their respective ERM values by the greatest degree (Table 33). However, the degree of confidence in the reliability of the guidelines for total PCBs and total DDTs is relatively low (Long et al., in press). When normalized to organic carbon content, the average concentration of total DDTs were considerably lower than the suggested guideline values of Swartz et al. (1994). The average concentration of endrin, expressed in units of organic carbon, was elevated considerably in the samples that were toxic to amphipod survival and Microtox™ bioluminescence. Also, the concentrations of lead and endrin were relatively high in samples that were toxic to the amphipods and Microtox™ tests. Finally, three individual aromatic hydrocarbons and the sum of total high molecular weight PAH occurred in relatively high concentrations in the toxic samples.

Among the chemicals that were measured, those listed in Table 33 most likely contributed to the observed toxicity. These chemicals were highly correlated with toxicity and they occurred at concentrations previously associated with adverse biological effects. However, many other substances could have contributed to toxicity, including many that were not measured. Also, the analysis summarized in Table 33 was based upon the averages among a group of toxic samples collected at different locations in the bay. Any one of these chemicals could have caused toxicity in any of the individual samples. Most likely, many different mixtures of chemicals caused the toxicity or contributed to it.

V. Conclusions

• The toxicity of 165 sediment samples collected throughout the Tampa Bay estuary was determined with a battery of complementary toxicity tests performed under controlled laboratory conditions.

• Approximately 79% of the 165 sediment pore water samples from Tampa Bay tested with sea urchin fertilization tests were significantly toxic in laboratory tests when the salinity-adjusted pore water was tested at full strength.

• Approximately 6% of the 165 sediment samples from Tampa Bay tested with the solid-phase amphipod toxicity tests were significantly toxic in laboratory tests. Approximately 12.8% of the 90 Phase 1 samples were toxic with the amphipod test; however, when the test was repeated (with a different stock of test animals and different control sediments) in Phase 2, none of the 75 sediments was significantly toxic. Sediments collected in Phase 2 had a substantially coarser grain size composition on the average than those in Phase 1, which could also have contributed to the observed differences with this test.

• Approximately 27% of the 90 organic extracts of sediments from Tampa Bay tested with Microtox™ bioluminescence tests were significantly toxic in laboratory tests.

• Toxicity was most severe in the northern Hillsborough Bay samples, especially those from upper Ybor Channel and adjoining industrial waterways.

• Also, toxicity was apparent in other areas around the perimeter of the estuary, including Allen Creek, Cross Bayou Canal, Bayboro Harbor, St. Petersburg yacht basins, lower Boca Ciega Bay, and Bear Creek.

• Among the areas that were sampled, sediments from Safety Harbor, central and eastern Old Tampa Bay, Big Bayou, Little Bayou, and Bayou Grande were among the least toxic.

• The three toxicity tests provided overlapping and complementary estimates of the spatial patterns and extent of toxicity. Collectively, the amphipod test, the Microtox™ test, and the sea urchin test performed with the most diluted pore water concentration indicated that about 0.5 - 0.6 km^2 of Tampa Bay were highly toxic. In contrast, the area in which sediments were toxic to sea urchin egg fertilization with undiluted pore water covered over 464 $kilometer^2$ within the Tampa Bay estuary. Dilution series on the pore water confirmed the patterns and extent of relative toxicity indicated by the Microtox™ and amphipod tests.

• Numerous trace metals, pesticides, other synthetic compounds, and polynuclear aromatic hydrocarbons were found in elevated concentrations and were highly correlated with the results of the toxicity tests.

• Among the trace metals that were quantified, the concentrations of cadmium, copper, lead, mercury, and zinc often were highly correlated with the measures of toxicity.

• The concentrations of cadmium, copper, lead, and zinc in samples that were significantly toxic to amphipods often exceeded the expected background levels based upon the aluminum content; however, molar ratios of metals to AVS were generally less than 1.0, and toxicity was not significantly correlated to these ratios.

• The concentrations of most PCB congeners and total DDT were very highly correlated with toxicity to amphipod survival, sea urchin fertilization, and Microtox™ bioluminescence.

• Among the PAHs that were quantified, the concentrations of numerous low and high molecular weight compounds were highly correlated with toxicity in all three tests.

• Normalization of the organic contaminants (PAH, PCB, and chlorinated pesticides) to TOC generally enhanced the correlation with amphipod toxicity. Urchin fertilization and Microtox™ EC50 remained correlated with these organic contaminants after TOC normalization.

• Ratios of contaminants in toxic/nontoxic samples were greatest for the chlorinated organic contaminants and less for PAHs and metals.

• The concentrations of lead, zinc, several PAHs, endrin, total PCBs, and total DDT in toxic samples equalled or exceeded sediment quality guidelines that were based on concentrations in associated with toxicity in previous studies.

• The concentrations of unionized ammonia in the amphipod toxicity test chambers were far below the levels previously associated with toxicity, whereas the unionized ammonia concentrations in the pore water tests were sufficiently high in a few samples to contribute possibly to toxicity.

• The concentrations of some toxicants and the severity and frequency of toxicity may warn of adverse effects among resident benthic organisms.

VI. References

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Appendices

APPENDIX A1. Field notes from Phase 1 sites.

SITE No.	STATION	DATE	SITE LOCATION	LATITUDE, °N	LONGITUDE, °W	DEPTH (m)	SEDIMENT DESCRIPTION
1	A	9/5/91	Hillsborough Bay	27°56'26"	82°27'25"	7.5	Dark black runny mud with thick dark flocculent surface layer. Strong sulfur odor with some shell fragments.
1	B	9/5/91		27°56'26"	82°27'32"	8.1	Black oozy/runny mud with dark surface flocculent. Very strong sulfur odor with some shell fragments.
1	C	9/5/91		27°56'22"	82°27'29"	9.4	Black runny mud with dark flocculent surface layer. Strong sulfur odor with shell fragments.
2	A	9/5/91	Hillsborough Bay	27°57'11"	82°26'34"	9.7	Dark black oozy mud with oil sheen. Very strong sulfur & oily smell. Dark flocculent layer at surface.
2	B	9/5/91		27°57'11"	82°26'34"	11.3	Same composition as in 2A, but with less sand in the grabs.
2	C	9/5/91		27°57'08"	82°26'33"	10	Uniformly soupy & firmer silty sand at 2 cm. depth. Dark brown/black detrital flocculent on surface.
3	A	9/4/91	Hillsborough Bay	27°56'07"	82°25'47"	1	Dark grey/black silty mud, strong sulfur smell & shell fragments. Amphipod tubes present with some worms & organic matter.
3	B	9/4/91		27°56'15"	82°25'43"	1	Thin green algal mat on surface of dark grey/black silty mud. Strong sulfur smell, snail & amphipod tubes present.
3	C	9/4/91		27°56'06"	82°25'37"	1	Same as 3B with brown and green algal mat on surface.

APPENDIX A1. Field notes from Phase 1 sites (contd.).

SITE No.	STATION	DATE	SITE LOCATION	LATITUDE, °N	LONGITUDE, °W	DEPTH (m)	SEDIMENT DESCRIPTION
4	A	9/4/91	Hillsborough Bay	27°56'31"	82°24'59"	1.6	Dark oozy/soupy silt w/ strong sulfur smell. Some worm tubes present & some algal film on surface w/ hairlike structures.
4	B	9/4/91		27°56'28"	82°24'51"	3.9	Same as 4A, but has a thicker layer of detrital flocculent.
4	C	9/4/91		27°56'31"	82°24'48"	1.6	Dark grey/black soupy/silty sediment similar to 4A, with green mat on surface. Some amphipod tubes present.
5	A	9/4/91	Hillsborough Bay	27°55'11"	82°25'39"	11	Dark grey runny mud w/ the consistency of cottage cheese. Strong sulfur smell & fluffy silty upper layer 1 cm. deep.
5	B	9/4/91		27°55'13"	82°25'34"	11	Same as 5A.
5	C	9/4/91		27°55'16"	82°25"39"	10	Similar to 5A, but soupier mud, more homogenous silt without cottage cheese consistency. Mud on deck stains the paint.
6	A	9/5/91	Hillsborough Bay	27°54'14"	82°26'29"	3.9	Soft brownish green silty sand with shell fragments.
6	B	9/5/91		27°54'17"	82°26'27"	4.8	Brown/green silty sandy mud with more shell fragments than 6A. Large snail present.
6	C	9/5/91		27°54'11"	82°26'25"	3.9	Similar to 6A. Grey brown silty mud w/some sand & shell fragment. Light layer of flocculent on surface. Worms present.
7	A	9/5/91	Hillsborough Bay	27°55'27"	82°26'56"	11.3	Drk gry/brn flocculent surface layer with light gry brn mud underneath. Strong sulfur smell.
7	B	9/5/91		27°55'28"	82°26'52"	11.3	Same as 7A.

APPENDIX A1. Field notes from Phase 1 sites (contd.).

SITE No.	STATION	DATE	SITE LOCATION	LATITUDE, °N	LONGITUDE, °W	DEPTH (m)	SEDIMENT DESCRIPTION
7	C	9/5/91		27°55'32"	82°26'52"	7.4	Firmer & slightly more sand than A or B. Some silty sand present at approximately 1.5 cm.
8	A	9/3/91	Hillsborough Bay	27°55'09"	82°28'35"	1.6	Dark grey silty mud with some sand and shells. Very strong sulfur & oil smell. Green algal film on surface.
8	B	9/3/91		27°54'54"	82°28'22"	1.6	Blk silty mud w/ some sand (more than A or C). Shell fragments, strong sulfur smell, some tubes present,& algal film on surface.
8	C	9/3/91		27°54'56"	82°28'35"	1.6	Silty dark black mud w/ some sand & a dark flocculent layer. Very strong sulfur smell w/ some green algae on surface.
9	A	9/3/91	Hillsborough Bay	27°53'59"	82°27'35"	1.6	Grey silty sandy mud, a dark flocculent layer & some green algae on surface. Worm tubes & some snails present. Strong sulfur odor.
9	B	9/3/91		27°54'01"	82°27'40"	1.3	Dark grey/black silty sand. Strong sulfur smell. Snails, worm tubes & green algae present on surface.
9	C	9/3/91		27°53'57"	82°27'40"	1.3	Same general description as 9B.
10	A	9/3/91	Hillsborough Bay	27°52'46"	82°27'19"	3.5	Dark grey oozy silty mud. Strong sulfur smell. Flocculent layer w/ grey clumps of mud on surface.
10	B	9/3/91		27°52'48"	82°27'24"	3.5	Similar to 10 A, but slightly more soupy with thicker layer of flocculent.
10	C	9/3/91		27°52'43"	82°27'22"	3.2	Same general description as 10B.

APPENDIX A1. Field notes from Phase 1 sites (contd.).

SITE No.	STATION	DATE	SITE LOCATION	LATITUDE, °N	LONGITUDE, °W	DEPTH (m)	SEDIMENT DESCRIPTION
11	A	9/3/91	Hillsborough Bay	27°51'45"	82°25'20"	2.6	Grey oozy mud, strong sulfur odor, light silty flocculent layer on surface. Hairlike structures and 1 worm seen.
11	B	9/3/91		27°51'43"	82°25'28"	2.6	Same general description as 11A.
11	C	9/3/91		27°51'36"	82°25'21"	2.6	Same as 11A, but contains more shell fragments and some small dark black flecks of various sizes in sediment.
12	A	8/23/91	Hillsborough Bay	27°50'11"	82°27'35"	4.2	Oozy brown green mud. Some dark streaks & bubbles. Light layer of flocculent. 1 bivalve, amphipods & tubes
12	B	8/23/91		27°49'51"	82°27'32"	4.2	Same general description as 12A.
12	C	8/23/91		27°49'59"	82°27'39"	4.2	Similar to 12A. Some amphipods & worms present. Samples had a higher frequency of black oily deposits.
13	A	8/23/91	Hillsborough Bay	27°48'43"	82°25'13"	3.2	Dark silty sand with dark detrital flocculent. Lg amphipod tubes and some snails present.
13	B	8/23/91		27°48'57"	82°25'08"	3.2	Dark grey, silty muddy sand. Very strong sulfur odor. Some algal layer with dark flocculent Amphipod & worm tubes present
13	C	8/23/91		27°48'48"	82°25'06"	3.5	Dark brown/black silty mud w/ some sand. More soupy than 1st 2 station. Stronger sulfur odor. No tubes, some snails.
14	A	8/21/91	Old Tampa Bay	28°00'17"	82°40'18"	3.2	Dark grey soft silty sand, no odor. Worm tubes and some worms present, one spider crab & tiny amphipods.

APPENDIX A1. Field notes from Phase 1 sites (contd.).

SITE No.	STATION	DATE	SITE LOCATION	LATITUDE, °N	LONGITUDE, °W	DEPTH (m)	SEDIMENT DESCRIPTION
14	B	8/21/91		28°00'30"	82°40'16"	3.2	Fine black silty sand & a bit sandier than 14A. No odor, snails and tiny amphipods floating on surface of grab.
14	C	8/21/91		28°00'29"	82°40'11"	1.9	Brownish grey silty sand with shell fragments. Same as 14A, numerous gastropods & worms. No odor.
15	A	8/21/91	Old Tampa Bay	27°56'38"	82°42'28"	3.9	Black soupy mud with a strong sulfur odor. Some polychaetes & numerous Ampelisca & amphipod tubes.
15	B	8/21/91		27°56'21"	82°42'13"	3.9	Strong sulfur odor. Black soupy mud w/some brown sand. Ampelisca and amphipod tubes present.
15	C	8/21/91		27°56'21"	82°42'34"	3.9	Grayish black mud w/ some sand. Finer grain size than 15A or B. A few ampelisca & amphipod tubes.
16	A	8/21/91	Old Tampa Bay	27°56'26"	82°38'58"	3.2	Gray sand with some black silt and shell fragments. Silt lenses through sediment. Snails & 1 sand lance present.
16	B	8/21/91		27°56'13"	82°39'11"	2.9	Brown sand w/dark grey silt, black silty lenses throughout. Algal or detrital floc on surface, gastropods & 1 sand lance.
16	C	8/21/91		27°56'29"	82°39'06"	2.9	Similar description of sediment as 16A & 16B. Sediment very homogenous throughout site.
17	A	8/21-22/91	Old Tampa Bay	27°57'11"	82°35'05"	5.2	Grey/brown mud, some grey sand w/darker silt. No odor & a layer of flocculent. Worms & amphipod tubes present.

APPENDIX A1. Field notes from Phase 1 sites (contd.).

SITE No.	STATION	DATE	SITE LOCATION	LATITUDE, °N	LONGITUDE, °W	DEPTH (m)	SEDIMENT DESCRIPTION
17	B	8/21-22/91		27°57'05"	82°35'08"	4.5	Soft grayish sandy silt w/ a dark flocculent layer on surface. No odor, few worms or tubes. 1 seastar-some ampelisca.
17	C	8/21-22/91		27°57'08"	82°35'22"	4.5	Grayish sandy silt w/ a dark flocculent layer. No odor, worms, worm tubes, polychaetes & Ampelesca seen.
18	A	8/22/91	Old Tampa Bay	27°55'27"	82°33'31"	3.2	Grey sand w/ dark grey lenses of silt. Dark detrital flocculent on surface, 1 nudibranch, 1 seastar, worm tubes & Ampelisca.
18	B	8/22/91		27°55'41"	82°33'23"	3.2	Grey sand w/ darker lenses of silt & dark flocculent layer. 1 sand lance, worm tubes, amphipod tubes & Ampelisca.
18	C	8/22/91		27°55'28"	82°33'11"	3.2	Same general description of sediment as 18B. 1 seastar, worm tubes and some Ampelisca.
19	A	8/20/91	Old Tampa Bay	27°51'31"	82°33'10"	9	Black/brown sticky silty sand with sm. shell fragments. Brown flocculent, oil sheen, & a strong sulfur odor.
19	B	8/20/91		27°51'30"	82°33'20"	9	Light brown sand w/ black silt. No odor, algal debris. Some young clams and worms present.
19	C	8/20/91		27°51'26"	82°33'13"	4.5	Brown sand w/ black silt. Higher sand content than 19A or B. Oil sheen, strong sulfur odor. Worms, sm. clams, & snails.
20	A	8/20/91	Middle Tampa Bay	27°49'33"	82°36'20"	3.2	Very sandy, brown in color w/ silt & shell fragments. Light brown flocculent. Lg. amphipod, baby shrimp, tubes & worms.

APPENDIX A1. Field notes from Phase 1 sites (contd.).

SITE No.	STATION	DATE	SITE LOCATION	LATITUDE, °N	LONGITUDE, °W	DEPTH (m)	SEDIMENT DESCRIPTION
20	B	8/22/91		27°49'33"	82°36'15"	3.2	Same general description as 20A.
20	C	8/22/91		27°49'33"	82°36'13"	2.6	Same general description as 20 A.
21	A	8/22/91	Middle Tampa Bay	27°48'13"	82°31'14"	4.8	Brown silty mud w/ some sand. Slight sulfur odor. Diverse biology; various gastropods, worms, amphipods, and tubes.
21	B	8/23/91		27°48'15"	82°31'00"	4.2	Similar to 21A, but softer sediment and detrital flocculent. Many worms w/some amphipods. Slight sulfur odor.
21	C	8/23/91		27°48'06"	82°30'50"	4.5	Similar general description as 21A with stronger sulfur odor, more sand and more shell fragments.
22	A	8/23/91	Middle Tampa Bay	27°45'34"	82°37'46"	6.5	Oozy black silty mud on top of fine grained grey. Sand thick layer of black flocculent, light grey lenses, strong sulfur odor, no visible life.
22	B	8/23/91		27°45'34"	82°37'41"	6.5	Soupy, almost liquid, black mud w/ very strong sulfur/sewage odor. No biology visible.
22	C	8/23/91		27°45'31"	82°37'42"	7.7	Oozy black mud w/ strong sulfur odor on top of grey sand & shells approx. 1-2 cm deep.
23	A	9/6/91	Middle Tampa Bay	27°44'10"	82°30'41"	3.5	Greenish brown silty sand w/ dark swirls in mud. Light brown flocculent layer, slight sulfur odor.
23	B	9/6/91		27°44'08"	82°30'41"	3.5	Similar to 23A, but with more shell fragments & sand content. Slight sulfur odor. Worms & tubes present.

APPENDIX A1. Field notes from Phase 1 sites (contd.).

SITE No.	STATION	DATE	SITE LOCATION	LATITUDE, °N	LONGITUDE, °W	DEPTH (m)	SEDIMENT DESCRIPTION
23	C	9/6/91		27°44'09"	82°30'43"	3.9	Similar to 23B but with a higher sand content & shell content & with less visible biology. Some worms & tubes
24	A	9/24/91	Lower Tampa Bay	27°41'57"	82°40'11"	2.9	Fine grained silty sand. Layer of detrital flocculent. Very thin hair-like structure, slight sulfur odor.
24	B	9/24/91		27°41'49"	82°40'13"	3.2	Grey silty sandy mud w/ some fine shell fragments. Slight sulfur odor, more silt than 24A or C.
24	C	9/24/91		27°41'57"	82°40'26"	2.6	Same general description of sediment as 24A with a noticeable large population of amphipods present.
25	A	9/26/91	Boca Ciega Bay	27°43'58"	82°42'55"	3.2	Non homogenous area. Some grabs homogenous dark grey oozy silt others firmer sandier silt w/ shell fragments.
25	B	9/26/91		27°43'59"	82°42'56"	3.5	Grey oozy mud w/ some shell fragments a strong sulfur odor. A thick detrital flocculent & sm. hair-like structures.
25	C	9/26/91		27°43'51"	82°42'51"	3.2	Oozy grey mud with a strong sulfur odor. One grab had more sand and shells.
26	A	9/26/91	Boca Ciega Bay	27°47'52"	82°45'56"	1.9	Sandy mud with silt, light layer of flocculent. Slight sulfur odor, numerous snails, crabs and worm tubes.
26	B	9/26/91		27°47'54"	82°45'58"	1.3	Same general description as 26A, but slightly higher sand content.

APPENDIX A1. Field notes from Phase 1 sites (contd.).

SITE No.	STATION	DATE	SITE LOCATION	LATITUDE, °N	LONGITUDE, °W	DEPTH (m)	SEDIMENT DESCRIPTION
26	C	9/26/91		27°47'58"	82°45'59"	2.2	Softer sediment than 26A or B w/ more silt. Strong sulfur odor, snails crabs, worm tubes & baby shrimp.
27	A	9/26/91	Cockroach Bay	24°40'40"	82°30'50"	1	Soft light brown silty sand with a slight sulfur odor. Agal film on surface. Brittle stars, worms, eel grass.
27	B	9/24/91		27°40'43"	82°30'47"	0.5	Soft light brown silty sand w/ slight odor. Eel grass and thin grass. Agal film, shrimp, worms, amphipods & mites.
27	C	9/24/91		27°40'41"	82°30'44"	0.5	Black silty sand w/ strong sulfur odor. Dark detrital flocculent, agal mat , red mites, worms, thin grass & amphipods
28	A	9/25/91	Terra Ciea Bay	27°32'50"	82°39'15"	3.2	Light brown soft silty sand w/ few shell fragments. Brownish/god agal flocculent, snails, amphipods & worms.
28	B	9/25/91		27°32'53"	82°39'03"	3.2	Same general description of sediment as station 28A.
28	C	9/25/91		27°32'47"	82°39'10"	3.2	Same general description of sediment as station 28A and 28B.
29	A	9/25/91	Manatee River	27°30'53"	82°35'42"	1.6	Black grey sandy mud w/ some shell fragments. Agal flocculent , lg. amphipods, lg. tubes and snails present.
29	B	9/25/91		27°30'50"	82°35'37"	1.6	Same general description of sediment as station 29A.
29	C	9/25/91		27°30'45"	82°35'36"	1.3	Same description of biology as station 29A but noticeably more sandy.

APPENDIX A1. Field notes from Phase 1 sites (contd.).

SITE No.	STATION	DATE	SITE LOCATION	LATITUDE, °N	LONGITUDE, °W	DEPTH (m)	SEDIMENT DESCRIPTION
30	A	9/25/91	Anna Maria Sound	27°30'20"	82°41'20"	1	Dark grey/black silty mud w/ some sand & strong sulfur odor. Dark flocculent, lots of grass, clams, shrimp, & worms.
30	B	9/25/91		27°30'15"	82°41'17"	1	Similar description of sediment as 30A w/ brownish red algal patches & sandy lenses. Grass w/ egg masses.
30	C	9/25/91		27°30'10"	82°41'16"	1.3	Same general description of sediment and biology as station 30B.

APPENDIX A2. Field notes from Phase 2 sites.

SITE No.	STATION	DATE	SITE LOCATION	LATITUDE,°N	LONGITUDE, °W	DEPTH (m.)	SEDIMENT DESCRIPTION
1	A	8/29/92	Head of Ybor Channel	27°57'13.8"	82°26'33"	12	Black anoxic silt with petroleum odor and sheen. H_2S odor. Garbage & plant debris on surface.
1	B	8/29/92		27°57'12"	82°26'35.4"	11	Black soft silty clay, black surficial scum. H_2S.
1	C	8/29/92		27°57'10.2"	82°26'32.4"	11.6	Black consolidated silt, leaf detritus, strong H_2S odor.
2	A	8/29/92	Ybor Ch./Banana Docks	27°56'58.8"	82°26'31.2"	5.5	Oily greenish black silty clay, H_2S odor.
2	B	8/29/92		27°56'59.4"	82°26'34.8"	11.4	Black anoxic clayey silt, H_2S .
2	C	8/29/92		27°57'0.6"	82°26'32.4"	12	Anoxic black, silty clay, H_2S odor. Distinct petroleum sheen.
3	A	8/29/92	Ybor Turning Basin	27°56'24"	82°26'45.6"	9.9	Black silty anoxic, hint of sand. Sand, shell frags. Petroleum distillate odor and sheen.
3	B	8/29/92		27°56'21.6"	82°26'45"	8.9	Greyish black silty clay, anoxic, azooic. H_2S, petroleum sheen and odor.
3	C	8/29/92		27°56'17.4"	82°26'42.6"	11	Clayey silt. Anoxic below, thin oxic layer on surface. No notable sheen, or odor.
4	A	8/28/92	Sparkman Channel	27°56'0"	82°26'49.2"	13	Medium grey consolidated silt with small fraction of sand. Strong H_2S odor.
4	B	8/28/92		27°56'3.6"	82°26'49.2"	9.5	Silt, clay, sand, grey and brown. Small shell frags. Sandy silt with clay below. Slight H_2S .
4	C	8/28/92		27°55'57"	82°26'50.4"	11.8	Silty black clay, little sand. Anoxic, H_2S . Petroleum sheen.
5	C	8/28/92	"Cut "D"" Ch./airport	27°55'4.8"	82°26'48.6"	14.5	Brown silt (runny) over clay. No noticeable odor.

APPENDIX A2. Field notes from Phase 2 sites (contd.).

SITE No.	STATION	DATE	SITE LOCATION	LATITUDE,°N	LONGITUDE, °W	DEPTH (m.)	SEDIMENT DESCRIPTION
5	A	8/28/92		27°54'58.2"	82°26'43.8"	14.5	Grey green clayey/silt. Fine light brown lens on surface. Anoxic, azooic. Uniformly gooey. Strong H_2S.
5	B	8/28/92		27°55'0.6"	82°26'0"	7.3	Sandy silt, anoxic, H_2S odor. Clay beneath. Some shell hash. Ghost shrimp. Small ampelisca tubes.
6	A	8/28/92	N. Hillsborough Bay	27°53'56.4"	82°26'40.2"	4.3	Sandy silty mud and shell fragments. No odor, polychaete tubes, shrimp, sm. Fish, crustaceans.
6	B	8/28/92		27°53'52.8"	82°26'42"	4.5	Silty mud, no odor, shell hash on surface. Unidentified polychaete tubes, juv. Crabs, ampelisca tubes.
6	C	8/28/92		27°53'53.4"	82°26'36"	4.5	Fine grain mud, lt. Brown shell hash. Bivalve mollusk tubes, crab larvae, juv. Shrimp. Oxic. Gelatinous.
7	A	8/27/92	W. Old Tampa Bay	27°57'6.6"	82°43'3"	3.1	Silty mud, greenish brown. More brown than black. Very few shell fragments.
7	B	8/27/92		27°57'6"	82°43'6"	2.8	Light brown silt, wormtubes. No H_2S. Fine grained material. Gastropods, sm. Fish.
7	C	8/27/92		27°57'3"	82°43'5.4"	3.1	Light & dark brown mottled floc on top,poorly consolidated.
8	A	8/27/92	W. Old Tampa Bay	27°57'6"	82°42'3"	3.1	Soft grey silt, light brown on top. Copepods, crustaceans (possibly, ghost shrimp)
8	B	8/27/92		27°57'11.4"	82°42'4.8"	3.3	Black/grey fine silt. Gobies on surface, crustacean.
8	C	8/27/92		27°57'3"	82°42'4.2"	3.4	Black/grey fine silt. Ghost shrimp.
9	A	8/27/92	W. Old Tampa Bay/airport	27°56'27.6"	82°41'14.4"	3.4	Dark grey clay, light H2S odor. Crab larvae.

APPENDIX A2. Field notes from Phase 2 sites (contd.).

SITE No.	STATION	DATE	SITE LOCATION	LATITUDE,°N	LONGITUDE, °W	DEPTH (m.)	SEDIMENT DESCRIPTION
9	B	8/27/92		27°56'25.2"	82°41'19.2"	3.8	Organically enriched grey silt, chocolate jello. Slight H_2S. Fine oxic lt. Brown silt layer on top.
9	C	8/27/92		27°56'22.2"	82°41'15"	3.5	Organically enriched dk. Grey silt. No odor. Thin oxic lt. Brown silt layer & copepods on surface.
10	A	8/27/92	Mouth of Allan Creek	27°56'11.4"	82°43'36"	2.9	Black anoxic silt, oil sheen, strong H_2S. V.Thin oxic layer on surface with copepods. Plant debris, sticks.
10	B	8/27/92		27°56'12"	82°43'28.8"	2.7	Black silty floc layer on top. H_2S. Copepods, snail, polychaete tubes. Ampelisca. Some plant debris.
10	C	8/27/92		27°56'16.8"	82°43'25.8"	3	Black organic silt, strong H_2S. Mats of ampelisca tubes on surface. Gastropods, shrimp.
11	A	8/27/92	MouthCross Bayou Canal	27°55'19.2"	82°41'42.6"	2.5	Silt, anoxic, H_2S. Grey brown color. Fine grained with some sand.
11	B	8/27/92		27°55'7.2"	82°41'47.4"	2	Brown sandy silt, sticky, some clay, faint sulphur odor. Gastropod.
11	C	8/27/92		27°55'24"	82°41'39.6"	2.5	Silty sand, shell fragments, some clay (sticky). Brown, muddy.
12	A	8/11/92	Smacks Bayou	27°48'18.6"	82°36'34.2"	3.4	Silty sand, top 2cm. Oxic. Light brown. Diatom scum. Ampelisca tubes, juv. Shrimp, gastropod.
12	B	8/11/92		27°48'19.8"	82°36'36"	4.4	Buff grey, predominantly sandy. Amphipods and algal debris.
12	C	8/11/92		27°48'17.4"	82°36'36.6"	5.9	Sediments oxic, light brown. Ampelisca abundant.

APPENDIX A2. Field notes from Phase 2 sites (contd.).

SITE No.	STATION	DATE	SITE LOCATION	LATITUDE,°N	LONGITUDE, °W	DEPTH (m.)	SEDIMENT DESCRIPTION
13	A	8/29/92	Garrison Channel	27°56'21.6"	82°27'10.2"	8.4	Greyish black anoxic silt. Uniform vertically, & horizontally. No vis. Signs of life. No petro sheen. Strong H_2S.
13	B	8/29/92		27°56'23.4"	82°27'6"	6.9	Anoxic black goo. Uniform. No visible life. One sample had one spot of sheen.
13	C	8/29/92		27°56'25.2"	82°27'1.2"	6.5	Black anoxic clayey silt, more clay rich.
14	A	8/11/92	Lower Coffeepot Bayou	27°47'31.8"	82°37'30.6"	3	Soft organic-rich anoxic with sand and organic matter. No H_2S, 1cm. Dark clayey layer over sand.
14	B	8/11/92		27°47'31.8"	82°37'32.4"	3.2	Gastropod, some worm tubes.
14	C	8/11/92		27°47'27.6"	82°37'31.2"	3.6	Much sandier than 14a, shell debris, more oxic in appearance, sea grass debris, worm tube (2 cm. Diameter)
15	A	8/11/92	No. St. Pete Marina	27°46'36"	82°37'44.4"	4	Sandy, dark brown, seagrass debris. Worm tubes. Polychaetes, brittle stars, red worms.
15	B	8/11/92		27°46'29.4"	82°37'42"	4	Oxic surface, 1cm. Fine silty sand over black clayey silt. Faint H_2S odor, dense ampelisca community. Seagrass debris.
15	C	8/12/92		27°46'32.4"	82°37'44.4"	4.2	Silty fine sand with a few worm tubes.
16	A	8/12/92	St. Pete Marina-Cent.Basin	27°46'4.2"	82°37'42"	6	Black silt with black film on top. Highly sulphurous. Worm tubes on bottom of sample.
16	B	8/12/92		27°46'1.8"	82°37'46.2"	5.2	Black anoxic goo. H_2S strong, silty. No visible life. Petroleum sheen.Black goo, high H_2S. Green hue to sediment. Oozy. No visible life.
16	C	8/12/92		27°46'8.4"	82°37'34.8"	6.2	Anoxic, oozy dark fine silt, no life visible. Dk. Brown blackish green with very few plant fragments.

APPENDIX A2. Field notes from Phase 2 sites (contd.).

SITE No.	STATION	DATE	SITE LOCATION	LATITUDE,°N	LONGITUDE, °W	DEPTH (m.)	SEDIMENT DESCRIPTION
17	A	8/12/92	St. Pete Marina-Chnl. mouth	27°46'16.2"	82°37'16.2"	4.9	Light brown fine sand, few amphipod tubes, & a few polychaetes. Oxic sediments, shell fragments.
17	B	8/12/92		27°46'15.6"	82°37'19.8"	8	Charcoal color, gelatinous silty ooze. Polychaetes, larval crabs. Sulfur odor.
17	C	8/12/92		27°46'13.8"	82°37'16.8"	5.2	Light brown sand, polychaetes, juv. Fish, sparse shell hash.
18	A	8/12/92	Bayboro Harbor	27°45'41.4"	82°38'6.6"	3.3	Grey black silt with abundant floc on surface. Small amt. Petroleum sheen, live gastropod worm tubes. H_2S.
18	B	8/12/92		27°45'41.4"	82°38'9.6"	3	Grey, tan sand. Sulphurous odor, abundant petroleum sheen. High organic matter content-leaves, plant debris.
18	C	8/12/92		27°45'37.8"	82°38'8.4"	3.95	Black ooze, petroleum sheen. No visible life, some plant debris. Silty sand anoxic, at surface.
19	A	8/12/92	Entrance of Bayboro Harbor	27°45'31.8"	82°37'32.4"	8	Greenish black silty ooze. Mantis shrimp in one grab.
19	B	8/12/92		27°45'31.2"	82°37'29.4"	7.2	Anoxic black silt topped by 1/4 cm. Light brown oxic layer. Holes-from biota?
19	C	8/12/92		27°45'31.2"	82°37'34.8"	6.8	Anoxic, sulphurous dark ooze, under silty thin oxic layer, about 1/4 cm. Thick
20	A	8/14/92	Big Bayou	27°43'51"	82°38'12"	6	Light tan silty sand. Organic floc on surface. V.Few shell frags. Seagrass-live amphipods, gastropods.
20	B	8/14/92		27°44'9"	82°38'16.2"	4.75	Light tan silty sand; mottled appearance, light org. Debris floc on surface. Tan/grey mottling. Gastropods, polychaetes, oxic.
20	C	8/14/92		27°44'19.8"	82°38'10.8"	4.1	Light brown mottled sand, live gastropods, oxic, similar to a and b replicates.

APPENDIX A2. Field notes from Phase 2 sites (contd.).

SITE No.	STATION	DATE	SITE LOCATION	LATITUDE,°N	LONGITUDE, °W	DEPTH (m.)	SEDIMENT DESCRIPTION
21	A	8/13/92	Little Bayou	27°43'12"	82°37'55.8"	2	Muddy sand. Amphipods. Polychaete tubes abundant. Gastropods, oxic, laminated.
21	B	8/13/92		27°43'19.8"	82°37'52.2"	-1	Light brown muddy sand. Polychaetes, gastropods. Oxic. Laminated. Amphipods.
21	C	8/13/92		27°43'21"	82°37'52.8"	5.5	Oxic brownish grey mud layer 1 cm. Over grey brown sandy mud. Polychaete tubes, juvenile brittle stars.
22	A	8/13/92	Gulfport	27°43'55.2"	82°41'43.2"	2.2	Dark tan to grey silty sand, fine shell fragments. Oxic, black mottling, polychaetes, H_2S.
22	B	8/13/92		27°44'0"	82°41'49.8"	2.3	Dark brown silty sand. Polychaete, gastropod, sculpin.
22	C	8/13/92		27°44'4.8"	82°41'46.2"	2.4	Tan sand, less silt than a and b replicates. Shell fragments. Large worm tube.
23	A	8/13/92	Inner Bear Creek	27°45'17.4"	82°43'56.4"	2.9	Dark grey/black ooze, H_2S odor, anoxic, abundant organic material. At 2cm. Dark grey silt, no biota.
23	B	8/13/92		27°45'12.6"	82°43'57.6"	2.3	Similar to a replicate, black ooze, no biota, high H_2S , anoxic, plant remains, few worm tubes.
23	C	8/13/92		27°45'7.2"	82°43'58.2"	2.4	Black ooze, sulfur smell, organic rich silty mud, anoxic, small shell fragments.
24	A	8/13/92	Outer Bear Creek	27°44'55.8"	82°43'55.2"	4	Black grey silty clayey ooze, slight sulfur smell, diatom scum upper 2 mm., Sediment not totally anoxic.
24	B	8/13/92		27°44'51"	82°43'58.2"	2.5	Grey silty muddy sand with shell fragments, more oxic than 24-a.
24	C	8/13/92		27°44'54"	82°44'1.2"	2.1	Muddy sand, light brown at top, dark grey beneath. Oxic sediments with worm tubes, shell fragments, live worm.

APPENDIX A2. Field notes from Phase 2 sites (contd.).

SITE No.	STATION	DATE	SITE LOCATION	LATITUDE,°N	LONGITUDE, °W	DEPTH (m.)	SEDIMENT DESCRIPTION
25	A	8/13/92	Boca Ciega Bay	27°44'54"	82°44'19.2"	3.5	Light greyish green silt, thin patchy diatom scum.
25	B	8/13/92		27°45'1.2"	82°44'19.8"	3.5	Light grey silt with sticky clay component, very fine shell fragments.
25	C	8/13/92		27°44'52.2"	82°44'22.2"	5	Light grey silt, gelatinous. Gastropods.
26	A	8/26/92	Charlotte Harbor Ref.	26°47'24.6"	82°6' 9"	6.1	Dark grey sticky mud, with silt component & mollusk shell fragments.
26	B	8/26/92		26°47'23.4"	82°6'6.6"	6.1	Stratified brown oxic sediments mud on top over black silty mud. Live worm.
26	C	8/26/92		26°47'21"	82°6'9.6"	6	Brown fluffy floc layer over clay. No sand. Trace of silt & shell fragments.

APPENDIX A3. Field notes from Phase 2 sites.

SITE No.	TEMP Sfc.°C	TEMP Btm.°C	SAL. Sfc. ppt	SAL. Btm. ppt	"D.O. Sfc., mg/l"	"D.O. Btm., mg/l"	COND. Sfc.	COND. Btm.
1	28	30.5	7	28.2	5.8	0.1	12500	41500
1	28	30	9.3	24.9	5.4	0.1	18000	42800
1	28	33	12	24	7.6	0.1	23300	42900
2	31.5	32.3	14.6	24	2.7	0.7	25400	39800
2	30	30.5	15	23.5	7	0.1	28100	41900
2	29	31.5	13.2	23.2	4.5	0.1	24900	41300
3	30.3	32	14.8	25.1	6	0.2	25400	41800
3	31.2	32.2	15.1	24.9	7.4	0.5	26100	41000
3	32	33.8	15.7	25.2	7.5	0.5	26900	41900
4	31	30.5	18.5	24	8.5	0.2	32500	41500
4	31	30.5	18.2	24	7.6	0.3	32900	42000
4	30.2	31	18	24.1	8.3	0.2	32300	43000
5	31	31	18	23	6.2	1.4	33400	40900
5	30	30	18	23.4	5.8	1.3	32500	42000
5	31	31	18	23	6.2	1.4	33400	40900
6	30	30.5	21	22.5	7.8	1.4	37100	39900
6	31	30.5	20.5	22	7.3	1.4	37500	39900
6	31	31	20.5	21.5	7.3	1.8	38000	38000
7	30.2	29.3	26.5	24.8	8.6	5.3	35100	33000
7	30.2	29.5	26.5	26.2	8.8	5.5	35100	35000
7	30.5	29.2	26.5	26.3	8.6	4.5	35500	35100
8	29.6	29.1	26.5	26	8.6	5.5	35700	34900
8	30.2	29	27	26.4	8.7	5.9	36100	35100
8	30.1	29.1	27.1	26.8	8.6	6	36000	35300
9	29	28.8	27	26.7	7.8	5.3	35900	35800
9	29.5	29	26.5	26.9	7.3	5.7	35800	35600
9	29.8	28.9	26.2	25	7.4	5.2	35200	35000
10	31.5	29.9	26.8	26.2	7.5	4.2	35800	34900
10	31.9	29.8	27.3	26.2	9.5	3	36500	34800
10	31	29.5	26.9	26	8.2	3.6	35800	34800
11	31	30	26.9	26.5	8.4	6	35900	35100
11	31.8	30.2	27	26.6	8.4	6.6	35900	35700
11	31.5	30.1	26.9	26.2	9.5	6.8	36000	35000
12	30	29.5	25.9	25.5	5.6	4.7	44300	43900
12	31	29.7	26	25.8	5.7	4.8	44200	44000
12	30	29.1	25.8	25.9	5.6	4.4	43900	43900
13	30	32	12.3	25	6.1	0	20700	41100

APPENDIX A3. Field notes from Phase 2 sites (contd.).

SITE No.	TEMP Sfc.°C	TEMP Btm.°C	SAL. Sfc. ppt	SAL. Btm. ppt	"D.O. Sfc., mg/l"	"D.O. Btm., mg/l"	COND. Sfc.	COND. Btm.
13	31.8	31.9	17.6	24.6	4.3	0	30100	40900
13	30.1	32	11.7	24.8	4.3	0	20300	40900
14	29	28	24	25	4.2	3.3	40500	41500
14	29	28.5	24.5	24.5	4.1	3	42100	42100
14	29.4	28.8	24.7	25	3.9	3.8	42800	43000
15	30.8	29.9	27.1	26.2	6.5	5.4	45900	44500
15	31	29.9	26.5	25.2	6.8	4.6	45200	43000
15	28.5	29	25.7	25.8	6.2	4.4	44100	44600
16	29.5	29	26	25.9	6.2	5	44700	44500
16	29	29.2	26	25.2	7.1	6.5	44600	43600
16	30	29.6	26	23	7	3.8	44600	39800
17	28.5	28.5	26	25.9	5.5	5.4	44800	44700
17	29	29	26	25.8	5.6	5.4	44300	44000
17	29	28.8	26	26	5.6	5.4	44700	44300
18	30	29.5	16.2	20	11	4.8	29500	44200
18	30	29.5	26.5	25.9	7.2	4.9	45100	44300
18	30	29	21.5	25.9	8.3	4.9	37800	44100
19	30	29	24	26	7.8	7.8	41500	44500
19	30	29	23.7	26.2	7.9	6.4	41000	44900
19	30.1	29.5	22.8	25	8.3	6.2	39600	43000
20	30	30	27	27	4.3	4.2	46000	46000
20	30	30.4	27	26.3	4.2	4.2	45500	43100
20	30	30	27	27	4.2	3.6	46300	46100
21	29.9	29.3	27.1	26.4	6.6	6.3	46900	45600
21	30	29.8	27	26.9	6.6	6.3	46100	46000
21	30	29	27	26	6.5	4.3	45600	43000
22	29.5	29.5	30	29.5	5.4	5.1	50000	50000
22	29.5	30	29.9	28.5	5.1	5	50000	50000
22	30	29.9	29.5	28.5	5.6	5.1	50000	50000
23	28.1	29.7	22	29.8	3.6	3.5	39000	50000
23	29	29	23	29	4.4	5.1	41000	50000
23	29.5	29.5	26	29.5	5.4	5.7	44200	50000
24	30	29	29.9	30	5.9	5.4	50000	50000
24	30	29.5	30	29.5	5.7	5.8	50000	49500
24	30	30	30	30	6	6.5	50000	50000
25	25.5	24	31	29.5	6.4	4.5	50000	49000
25	30	30	30.5	30	5.8	5.6	50000	50000
25	30	30	30.5	27	6.1	4	50000	50000
26	28	28	17.5	27	5.9	3.8	30000	44000
26	28	28.5	15	22.5	6.2	3.8	27100	37000
26	29	29	18	28	6	3.6	30500	46500

Appendix B. Areas of blocks used to estimate areal extent of toxicity in Tampa Bay.

Block No.	Phase	Station	Location	Area (km2)
1	1	1	Hillsborough R.	0.12
2	2	1	Head of Ybor chl.	0.45
3	1	2	off Banana docks	0.45
4	2	2	lower Ybor chl.	0.45
5	2	3	Ybor turning basin	0.16
6	2	13	Garrison channel	0.08
7	2	4	Sparkman channel	0.24
8	1	7	Seddon channel	0.12
9	2	15	Cut D channel	0.3
10	1	4	Palm River	1.09
11	1	3	McKay Bay	1.09
12	1	5	East Bay	1.54
13	1	6	Port Sutton channel	0.26
14	1	8	E. of Davis Isls.	4.78
15	1	9	Ballast Pt.	5.18
16	2	6	Pendola Pt.	3.68
17	1	10	Nw Hillsborough Bay	14.88
18	1	11	Ne Hillsborough Bay	14.88
19	1	12	Sw Hillsborough Bay	7.08
20	1	13	Se Hillsborough Bay	15.59
21	1	14	Safety Harbor	3.65
22	nd	nd	N. Old Tampa Bay	nd
23	2	10	Allen Creek	0.12
24	2	11	Cross Bayou Canal	0.19
25	2	7	Bayview	1.71
27	2	9	St. Pete/Clearwater	4.88
28	1	16	C. Old Tampa Bay	30.8
29	1	17	E. Old Tampa Bay	30.8
30	1	18	Gandy Bridge	40.94
31	1	19	So. Old Tampa Bay	21.73
32	1	20	Bayou Grande	0.75
33	2	12	Smacks Bayou	0.52
34	2	14	Coffeepot Bayou	0.32
35	2	15	No. St. Pete Marina	0.09
36	2	16	Cen St. Pete marina	0.22
37	2	17	St. Pete entrance	0.22
38	2	18	Inner Bayboro	0.12
39	1	22	Outer Bayboro	0.18
40	2	19	Bayboro entrance	0.18
41	1	21	middle Tampa Bay	187.6
42	1	23	off St. Pete	54.6
43	1	24	Pinellas	54.6
44	nd	nd	mouth of bay	nd
45	1	26	upper Boca Ciega	7.19
46	1	25	lower Boca Ciega 1	5.11
47	2	22	lower Boca Ciega 2	5.11
48	2	25	causeway	0.06

"nd" = no data.

Appendix B. Areas of blocks used to estimate areal extent of toxicity in Tampa Bay (contd.).

Block No.	Phase	Station	Location	Area (km2)
49	2	23	Inner Bear Cr.	0.16
50	2	24	outer Bear Cr.	0.16
51	1	29	Manatee River	11.52
52	1	30	Anna Maria Sd.	4.58
53	1	28	Terra Ceia Bay	3.57
54	1	27	Cockroach Bay	1.98
55	2	20	Big Bayou	0.64
56	2	21	Little Bayou	0.21
26a	2	8	Clearwater STP	1.69
26b	1	15	Long Branch	1.41
Total				550.031

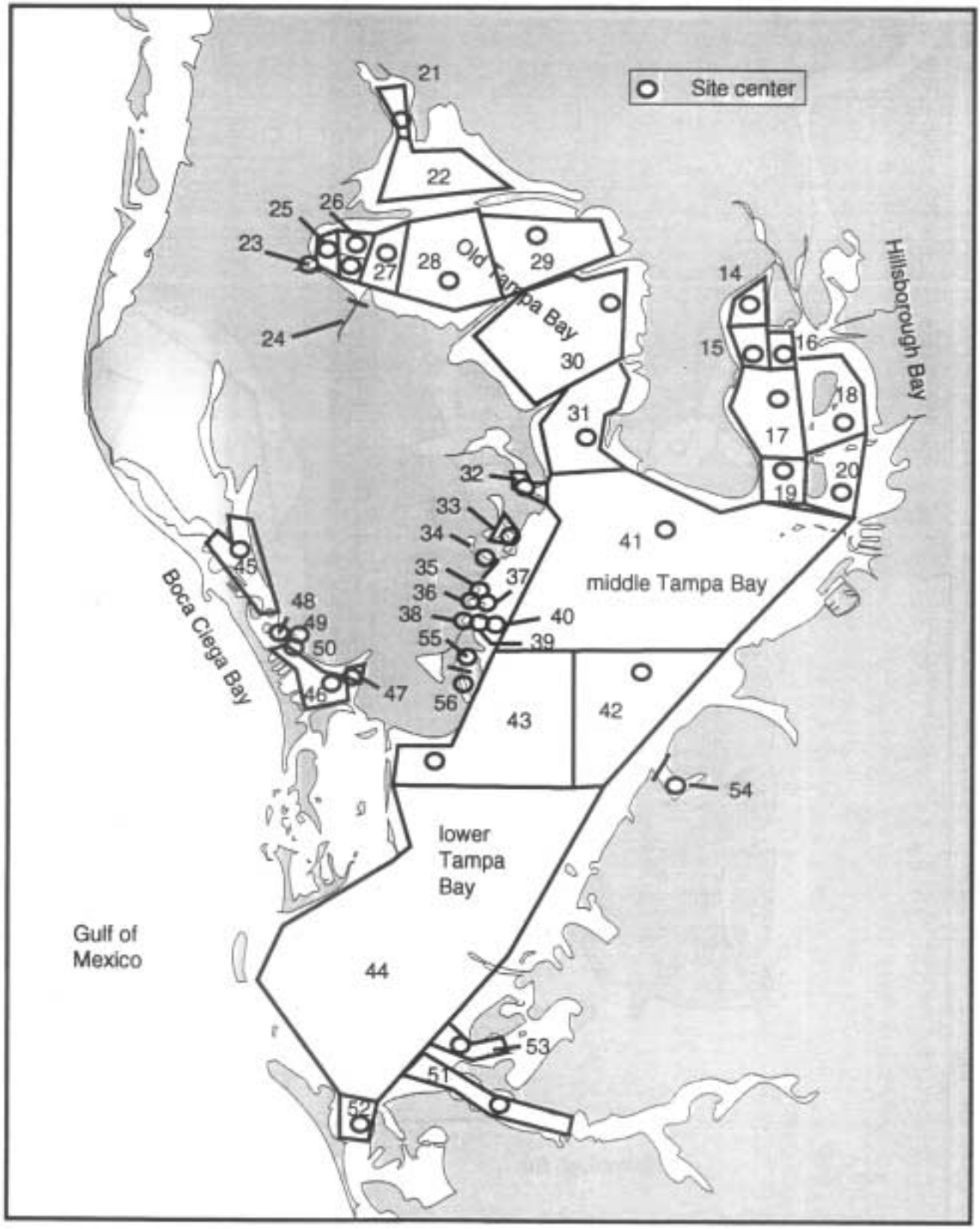

Figure B.1. Locations and boundaries of sampling blocks 14-56 in Tampa Bay and the positions of the site centers within each block.

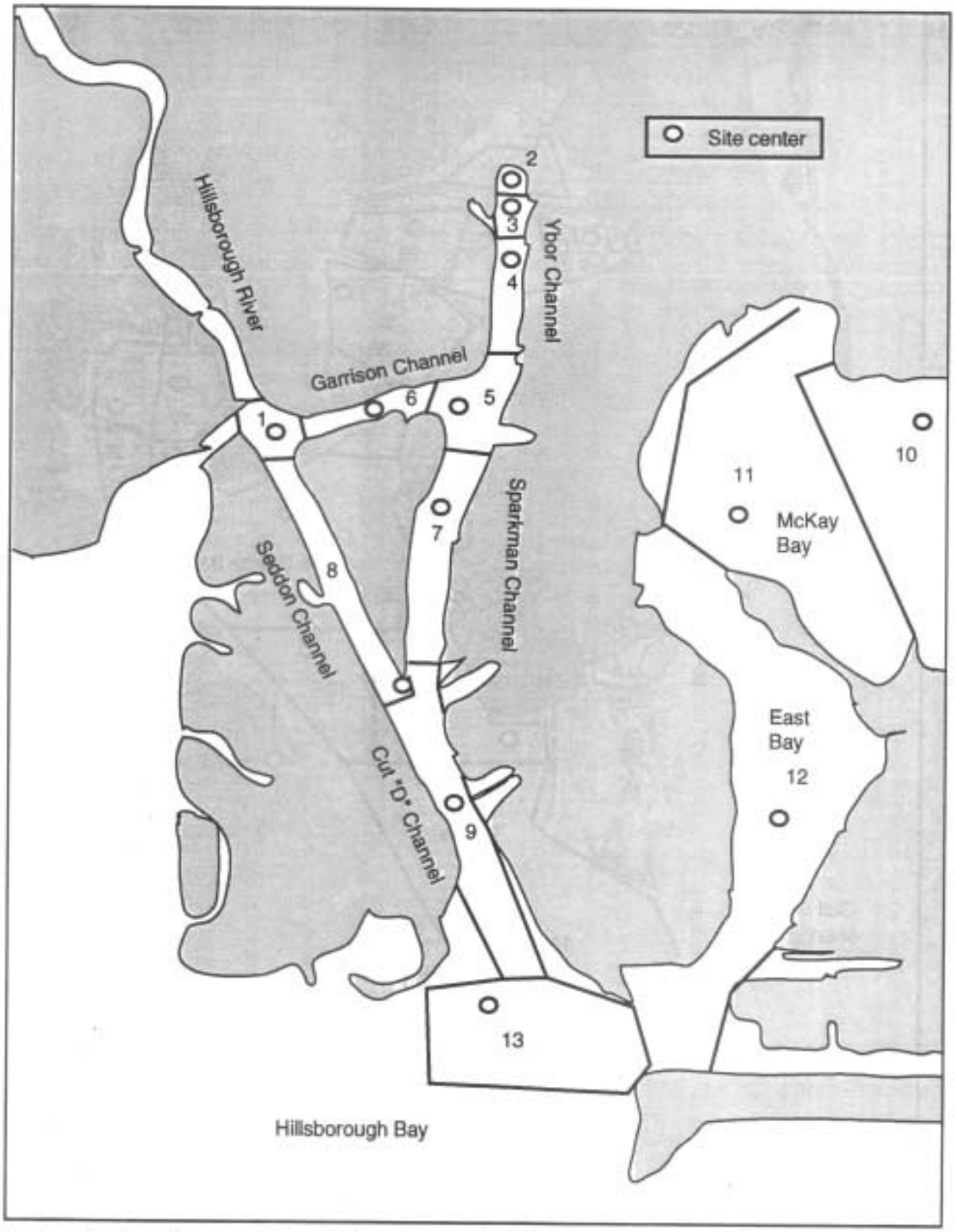

Figure B.2. Locations and boundaries of sampling blocks 1-13 in Tampa Bay (Upper Hillsborough Bay) and the positions of the site centers within each block.

Appendix C1. Phase 1 and Phase 2 for metals (Aluminum through Lithium) in Tampa Bay sediments.

Phase	Station No.	Aluminum %	Arsenic ppm	Barium ppm	Cadmium ppm	Chromium ppm	Copper ppm	Iron %	Lead ppm	Lithium ppm
1	01A	5.03	5.91	110	3.12	133	112	2.6	193	44.5
1	01B	5.43	8.32	106	3.06	141	112	2.84	192	44
1	01C	5.48	10.5	109	2.91	149	113	2.93	185	44.6
1	02A	2.37	3.07	98.2	2.52	62.6	125	1.87	223	16.5
1	02B	3.45	6.75	174	4.33	94.2	206	2.77	346	25.1
1	02C	3.55	6.62	193	3.53	77.5	158	2.96	204	25.3
1	03A	1.75	2.8	85.7	1.12	42.5	16.3	0.8	51	13
1	03B	1.52	4.11	94.7	1.22	39	14.8	0.71	45	11.7
1	03C	0.88	1	84.5	0.42	21.9	8.16	0.39	25	6.5
1	04A	3.85	4.76	129	7.58	133	74.1	1.72	342	28.7
1	04B	4.52	5.77	109	4.98	136	72.7	2.02	201	35
1	04C	4.11	5.48	119	6.43	130	75.6	1.76	298	29.7
1	06A	1.03	1.41	65.5	0.419	28.3	8.36	0.7	15	9.1
1	06B	1.4	2.29	58.9	0.666	33.7	9.19	0.83	16	10.6
1	06C	1.71	3.83	83.6	0.783	41.8	12.4	1.08	21	13.9
1	07A	3.57	4.02	91.4	1.8	89.4	101	1.91	51	30.8
1	07B	4.17	4	104	2.53	105	126	2.12	54	37.1
1	07C	3.42	4.58	108	1.7	88.9	117	1.86	57	28.2
1	08A	1.28	3.57	68.5	0.225	31.1	9.06	0.71	20	10.7
1	08B	0.78	2.05	46.7	0.13	19.7	5.75	0.4	13	7.3
1	08C	1.13	3.45	59	0.083	28.2	8.27	0.63	18	11.3
1	11A	3.11	2.51	87.5	1.2	74.1	12.1	1.69	23	26.9
1	11B	2.83	4.58	74.8	0.535	68.1	11.2	1.5	22	23.4
1	11C	2.34	1.85	77.5	0.547	57	9.58	1.29	20	20.5
1	12A	3.74	3.33	104	1.74	95.2	21	2.2	38	33.5
1	12B	3.31	4.07	96.8	1.38	87	18.1	1.97	34	32.9
1	12C	3.56	5.64	101	1.41	95	20.2	2.1	38	32.6
1	13A	0.58	1.12	21	0.082	9.03	2.13	0.2	3.4	4.3
1	13B	1.25	1.98	32.1	0.165	12.7	2.95	0.22	4	5.8
1	13C	1.2	1.41	44.3	0.146	22.9	5.2	0.48	8.2	10.5
1	15B	0.32	2.7	52.6	0.25	95.4	8.6	1.28	21	53.6
1	16A	0.54	1	10.5	0.14	14.9	1.5	0.16	3.9	9.6
1	16B	0.55	0.8	11.2	0.06	15.2	1.8	0.18	3.9	10.5
1	16C	0.63	1.4	14.9	0.14	16.2	1.8	0.19	4.8	11.4
1	17A	0.55	0.39	41.8	0.059	11.7	3.03	0.17	4.8	5.1
1	17B	0.58	1.9	36.3	0.082	12.9	2.83	0.2	5	5.6
1	17C	0.66	2.68	39.3	0.115	13.4	3.1	0.23	5.7	6.4

Appendix C1. Phase 1 and Phase 2 for metals (Aluminum through Lithium) in Tampa Bay sediments (contd.).

Phase	Station No.	Aluminum %	Arsenic ppm	Barium ppm	Cadmium ppm	Chromium ppm	Copper ppm	Iron %	Lead ppm	Lithium ppm
1	18A	0.54	3	18.8	0.16	15.4	3.2	0.17	5.5	4
1	18B	0.62	3.7	24.9	0.12	16.6	2.6	0.2	6	7.7
1	18C	0.47	2.4	15.2	0.08	14.2	30.3	0.14	4.4	6.8
1	19B	0.27	2	12.2	0.19	9.6	1.6	0.03	1.9	3.3
1	19C	0.62	3.7	29	0.19	17.2	4.8	0.2	5.2	7.8
1	21A	0.39	1.22	23.4	0.139	9.31	2.27	0.17	3.9	4.4
1	21B	0.43	1.14	16.9	0.067	8.06	2.77	0.14	3.1	4.4
1	21C	0.23	1.59	11.1	0.115	6.27	2.78	0.11	2.9	3.2
1	22A	2	5.8	41.3	0.66	44.2	29.5	0.74	36	24.3
1	22B	1.9	5.6	39.2	0.47	45.8	27.5	0.74	37	22
1	22C	0.78	5.1	17.6	0.4	20.7	13.8	0.31	17	11.8
1	23A	0.47	1.93	15.7	0.115	9.78	2.61	0.2	3.1	5.2
1	23B	0.43	2.16	14.3	0.123	9.24	2.38	0.17	3.2	4.6
1	23C	0.43	0.87	17.2	0.123	9.81	2.49	0.17	3	4.9
1	24A	0.41	1.7	21.5	0.12	10.6	3.4	0.14	4.4	6.1
1	24B	0.83	0.8	52.5	0.22	21.9	7.1	0.36	9	13.7
1	24C	0.23	1.7	15.2	0.22	5.1	2.2	0.09	2.4	5
1	25A	1.62	4.3	43.9	0.48	40	17.4	0.76	19	18.8
1	25B	2.26	8	60.4	0.49	68.1	27.6	1.06	28	30.5
1	25C	1.57	6.2	40.7	0.49	44.7	18.1	0.76	18	18.5
1	27A	0.2	4.3	4.5	0.14	6.5	1.3	0.08	1.3	3.3
1	27B	0.19	3	5.6	0.15	5.1	1.8	0.08	1.3	4.3
1	27C	0.31	3.4	6.7	0.16	7.6	2.9	0.08	1.6	4.6
1	29A	0.27	1.6	14.6	0.08	6.4	3.3	0.12	3.3	5.7
1	29B	0.26	0.5	13.7	0.16	6.8	2.9	0.11	3.2	5.9
1	29C	0.18	1.4	13.3	0.07	4.2	2.1	0.06	2.1	4.7
1	30A	0.31	4.4	15.7	0.15	8.8	3.1	0.08	2.9	4.8
1	30B	0.31	3.8	21.3	0.27	13.3	4.8	0.2	4	6.5
1	30C	0.54	3.4	17	0.12	9.9	1.4	0.11	2.5	5.2
2	01A	1.94	4.3	110	2.27	55.9	208	1.65	241	18.7
2	01B	2.9	13.3	140	3.16	88.3	275	2.25	297	28.6
2	01C	2.62	6.7	142	3.42	78.5	272	2.22	309	26.6
2	02A	2.94	8.9	127	2.63	83.5	255	2.02	192	31
2	02B	3.64	9.3	147	3.64	99.6	348	2.51	203	37.7
2	02C	3.32	5.7	129	3.26	89.9	279	2.24	190	33.6
2	03A	3.27	5.5	122	2.14	91	167	2.04	112	36.5
2	03B	3.16	4.6	120	1.6	88.4	162	1.93	109	35.2

Appendix C1. Phase 1 and Phase 2 for metals (Aluminum through Lithium) in Tampa Bay sediments (contd.).

Phase	Station No.	Aluminum %	Arsenic ppm	Barium ppm	Cadmium ppm	Chromium ppm	Copper ppm	Iron %	Lead ppm	Lithium ppm
2	03C	3.13	4.3	111	1.88	84.7	129	1.95	87	34.4
2	04A	2.74	2.9	97.3	1.43	71.6	71	1.54	57	28.5
2	04B	0.88	1.1	54.4	0.44	21.9	19.7	0.56	20	8.5
2	04C	2.71	1.5	109	1.12	66.2	73.6	1.51	56	27.6
2	05A	3.94	0.08	96.8	1.67	102	42	1.92	57	45
2	05B	3.01	0.08	79	1.26	75.9	31.9	1.42	40	34.6
2	05C	3.6	0.08	99.2	1.67	95.4	42.5	1.77	51	42
2	06A	2.14	4.2	113	0.96	50.8	12.8	1.31	30	23.3
2	06B	2.17	2.1	107	0.96	50.8	13.1	1.32	30	23.5
2	06C	1.61	3.7	88.2	0.77	36.9	9.9	1.03	22	17.3
2	07A	4.12	4.3	140	0.86	117	15.1	1.69	39	46.7
2	07B	3.12	3.7	127	0.44	86.8	10.8	1.25	31	35.2
2	07C	3.21	3.6	158	0.57	84.7	10.5	1.27	30	34.8
2	08A	4.83	7.5	152	0.63	127	13.4	2.11	38	56.4
2	08B	4.85	5	147	0.81	131	13.5	2.1	36	56.3
2	08C	4.57	5.2	142	0.59	126	12.5	1.96	33	52.4
2	09A	5.87	7	125	0.8	167	15.2	2.52	44	72
2	09B	5.09	5.3	120	0.63	139	13.1	2.14	39	60.2
2	09C	5.14	7.1	127	0.85	146	14.4	2.25	39	61.3
2	10A	4.72	5.5	96.1	1.1	132	30.9	1.85	52	55.5
2	10B	5.29	6.9	115	0.82	154	25.4	2.07	48	62.9
2	10C	5.85	1.2	104	1.11	143	26.1	2.36	51	64.9
2	11A	5.03	5.6	107	1.1	120	20.7	2.33	43	58.6
2	11B	4.97	2.8	105	1.27	119	20.9	2.28	40	57.8
2	11C	4.26	2.2	101	0.79	98.9	16.7	1.92	33	50
2	12A	0.19	0.3	5.3	0.05	4.2	1	0.06	3.4	3.3
2	12B	0.27	0.6	10.2	0.05	5.7	2.1	0.09	4.5	4.4
2	12C	0.26	0.5	5.7	0.03	4.8	1.2	0.09	3.6	3.6
2	13A	4.71	9.6	154	2.68	118	162	2.66	163	49.4
2	13B	4.59	4.1	114	2.91	116	169	2.61	157	46.4
2	13C	4.22	2.9	113	2.87	107	168	2.46	149	41.5
2	14A	0.7	0.9	17	0.27	14	6.4	0.25	21	11.3
2	14B	0.26	0.5	8.7	0.12	5.7	33.2	0.16	11	5.7
2	14C	0.3	0.7	6.9	0.13	5.2	2	0.08	7.8	5.9
2	15A	1.13	2.1	32.9	0.79	26.6	14.1	0.38	32	12.9
2	15B	0.56	0.9	26.2	0.22	14.4	6.7	0.18	16	6.2
2	15C	4.39	8.7	123	3.12	116	59.8	1.64	140	54.8

Appendix C2. Phase 1 and Phase 2 metals data (contd.).

Phase	Station No.	Aluminum %	Arsenic ppm	Barium ppm	Cadmium ppm	Chromium ppm	Copper ppm	Iron %	Lead ppm	Lithium ppm
2	16A	3.64	3	74.4	2.6	102	138	1.51	124	47.1
2	16B	3.34	6.5	72.8	2.34	97.3	156	1.36	138	42.2
2	16C	2.1	4.3	41	1.37	55.3	69.2	0.93	61	26.4
2	17A	0.21	0.1	9.3	0.04	5.2	1.5	0.09	3.6	3.4
2	17B	1.46	2.3	41.5	0.56	35.4	12.6	0.58	23	17.9
2	17C	0.21	0.5	8.6	0.05	5.3	2.2	0.08	3.3	3.6
2	18A	0.84	2.9	40.9	1.46	26.4	51.7	0.44	146	9.6
2	18B	0.19	0.7	13.3	0.28	4.6	11.3	0.1	30	3.5
2	18C	0.54	5.2	48.4	2.15	41.5	67.4	0.65	158	16.6
2	19A	2.17	3.5	59.3	0.94	57.2	23.1	0.85	38	28.7
2	19B	0.71	1.6	36.4	0.42	16.9	8.2	0.27	23	9
2	19C	1.1	2.1	36.1	0.49	26.1	16.2	0.42	33	14
2	20A	0.26	0.5	20.4	0.11	5	2.8	0.09	6	4.1
2	20B	0.25	0.1	12.6	0.08	5.3	2.9	0.09	3.9	4.2
2	20C	0.09	0.2	4	0.03	1.9	0.7	0.03	1.4	2.1
2	21A	0.16	0.1	23.4	0.05	2.8	1.2	0.05	2.5	2.3
2	21B	0.16	0.5	16.8	0.04	2.8	1.1	0.05	2.9	2.5
2	21C	0.42	0.7	34.6	0.14	9.3	4.5	0.15	7.8	6
2	22A	0.22	1.2	37.2	0.21	9.1	5.2	0.11	11	5.4
2	22B	0.27	0.7	36.7	0.16	5.6	3.7	0.11	8.6	3.7
2	22C	0.29	1.2	39.2	0.14	6.1	3.5	0.12	7.8	4.2
2	23A	2.6	6.4	58.5	1.52	72	98.5	1.43	124	39.7
2	23B	1.88	3.4	44.1	1.11	46.3	48.8	0.93	97	25.6
2	23C	0.84	2.6	28.8	0.38	20.1	15.8	0.4	23	11.6
2	24A	2.13	6.5	61.3	0.74	55.6	32.3	1.18	34	31.1
2	24B	0.16	0.5	14.3	0.16	6.2	10.3	0.07	4.2	2.7
2	24C	0.15	0.1	14.7	0.14	4.2	1.9	0.06	3.1	2.4
2	25A	2.65	4.6	64.4	1.06	63.3	35.9	1.3	47	32.5
2	25B	0.35	3.1	31.4	0.14	9.5	6.4	0.2	9.3	5.5
2	25C	1.72	8.2	58.5	0.84	44.4	24.6	0.93	30	23.2
	MDL	0.001	0.08	0.02	0.02	0.99	0.13	0.001	0.04	0.58

AVS = Acid volatile sulfides.
Porewater UAN=Un-ionized ammonia in porewater test chambers.

Amph. Term. UAN=Un-ionized ammonia in overlying water in amphipod test chambers after 10 days.

Appendix C2. Phase 1 and Phase 2 data for metals (Manganese through Zinc) in Tampa Bay sediments.

Phase	Station No.	Manganese ppm	Mercury ppb	Phosphorus ppm	Nickel ppm	Silver ppm	Titanium ppm	Vanadium ppm	Zinc ppm
1	01A	141	347	4270	24.7	1.16	2030	108	369
1	01B	157	364	4750	25.8	1.19	2390	116	366
1	01C	152	369	5160	27.2	1.07	2270	124	365
1	02A	216	281	6370	18.4	0.94	800	65.9	487
1	02B	223	491	7840	25.7	1.19	1280	96.5	863
1	02C	56.4	247	6360	29.5	0.79	1340	95.6	1260
1	03A	52.3	51.5	2000	9.29	0.24	1110	44.2	107
1	03B	35.8	121	1890	6.87	0.15	980	38.1	98.4
1	03C	131	45.7	1290	4.67	0.16	850	20.8	59.5
1	04A	129	194	4530	24.1	1.31	2250	107	620
1	04B	128	264	5070	24.4	0.91	1970	127	423
1	04C	128	263	4280	23.7	1.11	1470	110	559
1	06A	51.5	110	2230	5.48	0.27	720	23.4	50.9
1	06B	64.5	93.9	1930	7.7	0.28	680	29.4	50
1	06C	80.4	115	2750	9.51	0.44	980	36.8	68.1
1	07A	161	165	3640	19.7	0.84	1160	93.3	226
1	07B	176	187	4680	22.8	0.66	1650	107	254
1	07C	135	153	3510	20	0.78	1030	88.3	269
1	08A	36	94	1780	6.24	0.25	920	24.2	51.9
1	08B	20.1	70.9	1170	4.2	0.19	490	15.5	35.6
1	08C	28.1	91.7	1510	5.17	0.2	610	21.6	46.9
1	11A	105	123	4230	15.2	0.33	1040	68.8	67.9
1	11B	80.1	114	3890	13.4	0.24	670	63	65
1	11C	76.7	114	3660	11.5	0.31	980	53.1	57.1
1	12A	160	149	5720	19.7	0.84	1580	74.7	104
1	12B	149	155	5110	18.2	0.72	1230	72.1	101
1	12C	156	167	5520	20	0.85	910	76.1	105
1	13A	12.1	59.6	945	2.9	0.03	60	7.7	18.8
1	13B	15.6	23.8	1110	3.5	0.07	240	10.4	21.4
1	13C	40.2	34.3	1590	6.23	0.09	310	20.2	32.2
1	15B	81.1	80.8	2040	13.7	0.18	1540	69.5	42.4
1	16A	14.1	21.4	384	2.2	0.02	240	10.9	6.6
1	16B	12.5	20.7	340	2.2	0.05	120	10.7	5.6
1	16C	14.4	21.3	560	3	0.02	180	12.4	7.8
1	17A	8.1	27.3	599	3.15	0.03	490	10	19
1	17B	8	30.7	707	2.96	0.03	310	10.2	19.9
1	17C	12.1	33.6	719	2.99	0.03	310	10.6	21

Appendix C2. Phase 1 and Phase 2 data for metals (Manganese through Zinc) in Tampa Bay sediments (contd.).

Phase	Station No.	Manganese ppm	Mercury ppb	Phosphorus ppm	Nickel ppm	Silver ppm	Titanium ppm	Vanadium ppm	Zinc ppm
1	18A	13.4	24.2	287	4.3	0.01	490	12.7	19.4
1	18B	15.8	25.5	342	3.5	0.06	680	13.9	15.1
1	18C	11.7	22.6	310	3.4	0.04	430	11.3	16.8
1	19B	13.7	17.5	554	2.9	0.04	240	8.1	15.6
1	19C	17.3	27.6	910	4.1	0.04	370	13.8	19.3
1	21A	12.1	31.7	927	2.61	0.05	310	7.5	20.5
1	21B	4	24.2	576	2.47	0.04	120	6.6	16.7
1	21C	12	26.5	512	2.24	0.02	370	5	17.7
1	22A	33.1	205	1440	11.9	0.83	790	41.9	67.5
1	22B	33.9	233	1510	11.7	0.94	740	40.9	68.6
1	22C	15.9	131	683	6.2	0.38	120	22.3	38.2
1	23A	16	34.6	924	2.9	0.01	50	7.7	17.3
1	23B	8	31.7	947	3.81	0.07	50	7	19.5
1	23C	8	28.2	906	3.85	0.01	50	7.9	19
1	24A	10.1	20.5	565	1.3	0.05	50	7.6	8.1
1	24B	22.7	33.5	846	4.6	0.06	120	15.2	14.8
1	24C	6.6	15.6	774	1.1	0.02	50	4.2	5.2
1	25A	42.3	55.6	1040	9.9	0.16	610	28.6	40.6
1	25B	69	68.4	1450	13.5	0.11	550	48.5	60.3
1	25C	47.2	65.1	1110	10.4	0.09	600	32.1	42.4
1	27A	5.3	32.2	130	1.8	0.07	50	5.2	12.4
1	27B	5.6	18.1	69	1.9	0.02	120	4	10.2
1	27C	7.5	24.9	60	1.9	0.02	60	6.3	11.9
1	29A	6.7	35.9	1060	1.4	0.04	50	4.6	6.2
1	29B	9.8	33.7	713	1.1	0.04	50	3.7	7.5
1	29C	5.9	53.1	1810	0.4	0.02	50	2.8	6.2
1	30A	8.9	13.2	754	2.7	0.05	50	6.1	11.8
1	30B	11.5	15.7	987	3.4	0.07	50	10.9	16.3
1	30C	8.2	15.6	590	1.9	0.01	50	6.6	13.3
2	01A	140	417	3100	21.1	0.67	1250	60.3	646
2	01B	154	532	4840	27.8	0.95	1620	95.7	699
2	01C	178	423	4580	27.5	0.95	1500	90.7	733
2	02A	154	493	3830	28.5	0.94	1550	98	510
2	02B	174	502	4620	30.8	1.09	1810	118	610
2	02C	154	602	4390	28.4	1.04	1680	106	521
2	03A	182	312	3850	29.3	0.78	1660	117	372
2	03B	178	400	3560	27.9	0.73	1440	111	367

Appendix C2. Phase 1 and Phase 2 data for metals (Manganese through Zinc) in Tampa Bay sediments (contd.).

Phase	Station No.	Manganese ppm	Mercury ppb	Phosphorus ppm	Nickel ppm	Silver ppm	Titanium ppm	Vanadium ppm	Zinc ppm
2	03C	141	296	3360	26.6	0.7	1420	102	297
2	04A	151	180	2730	20.1	0.53	1430	79.4	204
2	04B	42.6	27	910	9	0.17	810	28	60.6
2	04C	161	581	2730	17.4	0.54	1460	74.8	210
2	05A	174	210	4080	24.2	0.69	1840	102	169
2	05B	146	125	3290	17.8	0.52	1480	83.6	130
2	05C	160	208	3950	23.5	0.68	1670	98.8	164
2	06A	67.1	174	2940	13.3	0.3	1120	45.2	70.9
2	06B	67.1	146	3080	13.3	0.44	1430	45.9	70.4
2	06C	55.1	103	2610	13.2	0.27	1420	33.5	39.9
2	07A	106	102	3060	18.2	0.26	2620	89.3	52.9
2	07B	76.3	66	2540	13.3	0.22	2310	64.3	45.4
2	07C	84.2	92	2540	12.4	0.31	2360	65.2	43
2	08A	116	153	3570	20.9	0.18	3180	103	57.5
2	08B	112	124	3480	20.7	0.32	3170	105	56.5
2	08C	111	123	3340	19.7	0.3	2930	98.1	53.9
2	09A	131	151	3830	27.1	0.29	3280	137	68.2
2	09B	110	126	3290	22.6	0.29	2680	114	58.5
2	09C	117	132	3380	23.9	0.32	3120	119	59.4
2	10A	100	156	3130	20.7	0.37	2800	108	91.8
2	10B	104	159	3610	23.4	0.46	2870	122	84.6
2	10C	111	165	2710	24.9	0.39	3180	117	87.1
2	11A	92.1	154	2190	22.2	0.83	2830	97.7	87.3
2	11B	91.1	160	2180	22	0.86	3050	96.5	86.5
2	11C	71.3	122	1830	18.3	0.6	2800	81.2	70.4
2	12A	2.5	9	84	0.9	0.02	500	4.4	4.1
2	12B	4.5	13	122	0.8	0.04	640	4.9	5.9
2	12C	3.4	11	57	1	0.02	560	3.6	6.2
2	13A	143	439	4490	30.6	1	2280	125	390
2	13B	151	474	4450	30.7	1.12	2490	128	387
2	13C	142	447	4330	31.6	0.92	2200	119	397
2	14A	8.6	81	311	3.3	0.14	940	11.2	27.3
2	14B	5.4	16	162	1.9	0.06	610	5.4	25.3
2	14C	3.5	15	58	1.2	0.02	620	4.5	9.6
2	15A	16	164	1100	5.2	0.22	1050	22.7	60.2
2	15B	7.2	66	803	2.1	0.1	750	10.4	32
2	15C	72.4	635	3920	22.6	1.3	2370	94.6	251

Appendix C2. Phase 1 and Phase 2 data for metals (Manganese through Zinc) in Tampa Bay sediments (contd.).

Phase	Station No.	Manganese ppm	Mercury ppb	Phosphorus ppm	Nickel ppm	Silver ppm	Titanium ppm	Vanadium ppm	Zinc ppm
2	16A	64.6	445	2660	26.1	3.49	2040	80	252
2	16B	60.7	429	2520	24.4	3.7	2120	76.5	276
2	16C	36.5	302	1710	16.1	1.55	1560	48.9	136
2	17A	6.1	13	171	1	0.07	670	5	5.1
2	17B	27.5	151	1340	7.9	0.41	1370	32.4	43.1
2	17C	4.5	14	172	1	0.06	680	4.8	5.1
2	18A	21.6	419	723	7.7	0.27	1220	20.7	199
2	18B	12.4	52	180	3.6	0.03	680	3.9	85.2
2	18C	34.7	356	1350	10.8	0.45	1680	33.6	315
2	19A	39	256	1900	12.9	0.64	1740	51.5	68.8
2	19B	14.8	115	786	4.1	0.21	1050	15.3	33.3
2	19C	17.9	149	1050	5.8	0.21	1190	23.8	43.1
2	20A	4.3	16	68	1	0.04	860	4.7	13.5
2	20B	3.6	13	49	0.7	0.03	740	3.9	6.8
2	20C	1.8	7	10	0.3	0.02	620	1.7	2.1
2	21A	4.1	7	168	0.5	0.02	870	2.1	3.7
2	21B	2.5	8	247	0.6	0.02	750	2.2	3.4
2	21C	7.2	35	410	1.8	0.07	870	7.6	12.1
2	22A	11.4	13	446	1.9	0.02	1000	5.5	14.7
2	22B	8.1	14	302	1.6	0.02	980	3.9	16.2
2	22C	9.1	13	206	1.8	0.03	990	3.6	10.7
2	23A	54.6	227	1700	21.5	0.27	2060	55.4	184
2	23B	34.7	141	1120	14.3	0.18	1810	37	131
2	23C	17.8	45	486	6.8	0.08	1240	15.1	36.7
2	24A	51.4	94	1440	21.9	0.2	1820	44.3	62.8
2	24B	4.6	7	154	1.9	0.02	810	3	5.7
2	24C	3.5	7	132	2.1	0.02	720	2.5	4.9
2	25A	65.2	156	1700	28.4	0.2	1620	45.2	81.2
2	25B	11.7	36	539	4.2	0.02	1000	6.9	20.1
2	25C	48.6	107	1350	19.8	0.18	1620	32.4	58.5
	MDL	1	0.007	5.1	0.25	0.001	5	0.005	0.38

Appendix C3. Phase 1 and Phase 2 data for physico-chemical characteristics of Tampa Bay sediments.

Phase	Station No.	Carbon %	Nitrogen %	Carbonate %	Grain size phi	AVS mg/g	Porewater "UAN, ug/l"	Amph. Term. "UAN, ug/l"	Sulfide mg/l
1	01A	5	0.42	23.38	7.72	13.5	684	-	0.29
1	01B	6.29	0.54	28.07	8.6	33.5	357.6	-	0.33
1	01C	4.47	0.44	26.02	7.65	11.8	1350.4	-	0.05
1	02A	2.83	0.14	22.46	8.8	8.49	437.6	-	0.34
1	02B	4.38	0.25	30.13	8.2	4.21	386.4	-	0.47
1	02C	2.97	0.14	19.15	8.1	2.6	432	-	0.05
1	03A	1.59	0.23	9.59	8.4	1.22	400	-	0.05
1	03B	1.65	0.19	8.39	8.2	1.32	256.8	-	0.05
1	03C	0.51	0.03	5.98	8.6	0.67	60	-	0.05
1	04A	3.3	0.22	22.49	7.9	2.92	376.8	-	0.05
1	04B	3.29	0.19	32.38	7.8	5.84	347.2	-	3.01
1	04C	2.9	0.22	25.37	7.88	7.02	580.8	-	1.92
1	06A	0.64	0.06	10.74	8.42	0.08	217.6	-	0.05
1	06B	1.03	0.05	15.47	8.2	0.43	181.6	-	0.05
1	06C	1.19	0.08	14.2	7.9	0.23	196	-	0.05
1	07A	1.96	0.2	30.64	7.98	4.14	434.4	-	0.05
1	07B	2.79	0.29	33.8	7.87	6.69	747.2	-	0.05
1	07C	1.68	0.13	20.9	7.2	8.37	291.2	-	0.05
1	08A	0.82	0.05	6.26	8.4	1.39	140.8	-	0.05
1	08B	0.7	0.03	4.01	7.6	1.47	156.8	-	0.05
1	08C	0.81	0.09	5.54	7.4	0.13	125.6	-	0.05
1	11A	1.44	0.14	26.4	8.06	2.54	240.8	-	0.05
1	11B	1.54	0.16	19.21	8.11	2.85	330.4	-	0.05
1	11C	1.3	0.16	19.12	7.5	0.91	271.2	-	0.05
1	12A	0.47	0.41	35.56	7.7	3.77	264	-	0.05
1	12B	1.86	0.18	32.78	7.5	2.84	220	-	0.05
1	12C	2.95	0.23	33.72	8	2.56	129.6	-	0.05
1	13A	0.53	0.01	8.2	8.6	0.49	183.2	-	0.05
1	13B	0.33	0.04	5.68	8.38	0.03	385.6	-	0.05
1	13C	0.68	0.08	15.84	8.39	0.21	88	-	0.05
1	15B	1.72	0.22	7.64	8.54	3.4	207.2	-	0.05
1	16A	0.27	0.03	2.35	8.51	0.03	107.2	-	0.05
1	16B	0.27	0.03	2.3	8.5	0.03	186.4	-	0.05
1	16C	0.32	0.04	3.37	8.49	0.03	93.6	-	0.05
1	17A	0.32	0.04	3.38	8.5	0.49	164	-	0.05
1	17B	0.34	0.01	3.21	8.8	0.11	153.6	-	0.05
1	17C	0.41	0.08	4.14	8.6	0.14	211.2	-	0.05

Appendix C3. Phase 1 and Phase 2 data for physico-chemical characteristics of Tampa Bay sediments (contd.).

Phase	Station No.	Carbon %	Nitrogen %	Carbonate %	Grain size phi	AVS mg/g	Porewater "UAN, ug/l"	Amph. Term. "UAN, ug/l"	Sulfide mg/l
1	18A	0.44	0.15	3.55	8.5	0.02	187.2	-	0.05
1	18B	0.38	0.13	3.44	9.2	0.37	300	-	0.05
1	18C	0.31	0.04	3.25	8.52	0.03	246.4	-	0.05
1	19B	0.08	0.02	40.38	8.1	0.04	484	-	0.05
1	19C	0.84	0.22	5.26	8.7	0.06	364.8	-	0.05
1	21A	0.23	0.03	5.78	8.53	0.03	145.6	-	0.05
1	21B	0.28	0.08	3.59	8.8	0.09	148.8	-	0.05
1	21C	0.29	0.03	3.68	8.56	0.03	108.8	-	0.05
1	22A	1.47	0.19	15.61	8.5	2.73	1547.2	-	19.9
1	22B	2.14	0.29	19.87	8.27	4.69	1089.6	-	16.7
1	22C	0.78	0.17	8.73	8.2	0.94	1263.2	-	14.7
1	23A	0.38	0.12	5.4	9.2	0.16	232	-	0.05
1	23B	0.29	0.03	5.89	8.53	0.03	205.6	-	0.05
1	23C	0.33	0.04	5.69	8.53	0.03	193.6	-	0.05
1	24A	1.6	0.18	12.48	8.53	3.03	132	-	0.05
1	24B	1.07	0.12	21.77	8.46	1.4	228	-	0.05
1	24C	0.33	0.04	7.05	8.56	0.03	240.8	-	0.05
1	25A	2.51	0.27	33.3	8.32	5.83	404.8	-	0.05
1	25B	3.52	0.3	47.96	8.6	2.26	506.4	-	0.29
1	25C	2.1	0.24	37.38	8.33	4.57	534.4	-	0.05
1	27A	0.51	0.21	1.82	9	0.03	487.2	-	0.05
1	27B	0.35	0.04	2.94	8.57	0.03	163.2	-	0.05
1	27C	0.74	0.07	1.92	8.55	0.39	120	-	0.05
1	29A	0.28	0.03	3.9	8.55	0.03	256	-	0.05
1	29B	0.27	0.03	3.31	8.55	0.03	446.4	-	0.05
1	29C	0.16	0.02	2.84	8.57	0.03	232.8	-	0.05
1	30A	0.46	0.16	4.25	8.8	0.03	387.2	-	0.22
1	30B	0.63	0.06	5.97	8.55	0.05	503.2	-	0.25
1	30C	0.63	0.06	4.37	8.51	0.05	372.8	-	0.05
2	01A	6.14	0.47	26.4	4.79	5.05	2244	114	2.08
2	01B	6.08	0.39	38.8	6.13	3.05	861	37	5.96
2	01C	4.67	0.28	27.5	5.85	1.75	1143	68	3.31
2	02A	2.93	0.21	31.7	5.86	3.25	526	33	1.28
2	02B	3.62	0.28	38.2	7.14	3.32	684	27	1.86
2	02C	2.53	0.19	35.5	6.93	4.11	421	11	0.13
2	03A	2.61	0.25	38.2	7.13	3.9	307	7	0.01
2	03B	2.9	0.23	37.6	6.76	2.66	146	9	0.03

"-" = No data.

Appendix C3. Phase 1 and Phase 2 data for physico-chemical characteristics of Tampa Bay sediments (contd.).

Phase	Station No.	Carbon %	Nitrogen %	Carbonate %	Grain size phi	AVS mg/g	Porewater "UAN, ug/l"	Amph. Term. "UAN, ug/l"	Sulfide mg/l
2	03C	2.62	0.23	41	7.11	2.89	185	7	0.01
2	04A	1.7	0.17	18.7	5.77	0.56	82	6	0.02
2	04B	2.02	0.18	10.4	3.63	0.38	30	4	0.005
2	04C	1.92	0.19	33.6	5.87	0.54	60	5	0.005
2	05A	2.81	0.3	28.6	7.93	1.29	200	6	0.02
2	05B	1.22	0.14	15.6	5.04	0.6	85	9	0.01
2	05C	2.13	0.21	27.4	6.91	1.41	38	5	0.01
2	06A	1.52	0.14	15.8	5.84	0.08	16	3	0.04
2	06B	1.09	0.11	14.8	6.05	0.05	20	3	0.005
2	06C	0.89	0.1	12.7	5.29	0.11	20	2	0.005
2	07A	1.89	0.22	8.4	6.81	0.17	23	3	0.005
2	07B	1.05	0.11	7.7	5.52	0.26	28	3	0.005
2	07C	1.71	0.2	7.6	6.28	0.02	20	3	0.005
2	08A	2.76	0.32	11.4	7.78	0.29	73	2	0.005
2	08B	2.97	0.34	11.2	7.88	0.27	80	3	0.005
2	08C	2.45	0.32	10	7.41	0.01	88	3	0.005
2	09A	3.24	0.39	16.1	8.8	0.8	160	3	0.005
2	09B	2.85	0.32	12.4	7.86	0.76	161	3	0.005
2	09C	2.45	0.29	12.4	8	0.57	116	3	0.005
2	10A	4.63	0.41	14.7	7.34	0.71	910	15	0.02
2	10B	4.44	0.45	14.2	7.97	0.68	221	13	0.01
2	10C	4.63	0.47	22.5	9.08	1.07	211	6	0.01
2	11A	2.74	0.28	11.1	8.48	0.4	157	4	0.005
2	11B	2.7	0.28	12	7.91	0.88	276	8	0.01
2	11C	1.72	0.18	6.3	6.57	0.09	133	6	0.005
2	12A	0.19	0.02	1.8	4.42	0.01	24	29.6	0.005
2	12B	0.24	0.03	2.5	2.82	0.01	26	29.3	0.005
2	12C	0.35	0.04	2.1	2.77	0.01	22	35.9	0.005
2	13A	4.58	0.38	32.5	8.51	0.61	916	24	4.21
2	13B	3.93	0.36	34	9.03	0.09	576	17	0.88
2	13C	3.99	0.36	35.4	8.64	1.38	302	4	0.09
2	14A	1.08	0.09	3.1	3.39	0.05	19	13	0.005
2	14B	0.25	0.03	5.4	2.33	0.01	33	22.1	0.005
2	14C	0.26	0.03	1.5	2.75	0.01	25	20.5	0.005
2	15A	0.95	0.09	4.9	3.51	0.04	25	15.2	0.005
2	15B	0.48	0.05	3.6	2.63	0.05	20	8	0.005
2	15C	5.03	0.46	20	7.58	0.14	22	1.6	0.005

Appendix C3. Phase 1 and Phase 2 data for physico-chemical characteristics of Tampa Bay sediments (contd.).

Phase	Station No.	Carbon %	Nitrogen %	Carbonate %	Grain size phi	AVS mg/g	Porewater "UAN, ug/l"	Amph. Term. "UAN, ug/l"	Sulfide mg/l
2	16A	5.31	0.6	34.4	4.56	0.28	714	14.9	1.69
2	16B	5.94	0.65	34.2	5.9	1.03	176	15.7	7.61
2	16C	2.61	0.28	22.9	5.1	0.16	243	17.9	1.46
2	17A	0.21	0.03	2.3	2.69	0.01	18	12.9	0.02
2	17B	1.17	0.13	9.6	4	0.08	15	6.5	0.005
2	17C	0.2	0.03	2.6	2.74	0.01	15	12.7	0.005
2	18A	2.36	0.14	9.2	3.56	0.06	85	20.5	0.81
2	18B	1.21	0.06	3.1	2.56	0.04	251	22.5	0.04
2	18C	3.58	0.25	14.7	4.34	0.1	267	24.6	1.52
2	19A	2.34	0.27	16.9	5.62	0.04	308	19.6	0.8
2	19B	0.84	0.09	6.5	3.9	0.02	93	15.8	0.01
2	19C	1.67	0.14	8.9	4.32	0.05	243	9.5	0.99
2	20A	0.31	0.03	2.1	2.85	0.02	75	4.7	0.005
2	20B	0.26	0.03	2.1	2.77	0.01	63	9.8	0.005
2	20C	0.09	0.01	1.7	2.48	0.01	53	5.6	0.005
2	21A	0.12	0.02	2	2.86	0.01	28	12.7	0.005
2	21B	0.14	0.02	1.9	2.71	0.01	23	8.4	0.005
2	21C	0.78	0.08	3.7	2.87	0.08	53	13.7	0.005
2	22A	0.43	0.05	9.1	2.73	0.06	60	28.2	0.005
2	22B	0.47	0.04	11.4	3.33	0.07	60	15	0.005
2	22C	0.35	0.04	12.5	2.93	0.02	55	19.5	0.005
2	23A	2.34	0.23	42.1	4.67	1.28	812	11.9	3.72
2	23B	4.34	0.34	20	5.28	0.58	135	10.1	2.07
2	23C	3.66	0.3	13.1	3.86	0.04	119	3.8	1.26
2	24A	3.23	0.36	44.1	4.93	0.45	86	3.6	2.98
2	24B	0.24	0.02	4.9	3.08	0.01	66	16.9	0.005
2	24C	0.18	0.02	4.9		0.01	40	31.7	0.005
2	25A	3.72	0.41	56.4	4.46	0.13	223	2.1	0.005
2	25B	7.86	0.83	10.1	2.92	0.02	75	13.5	0.005
2	25C	2.69	0.3	37.5	6.46	0.32	81	2.1	0.005

[a]Unionized ammonia nitrogen

Appendix C4. Phase 1 and Phase 2 data for PAH (naphthalene to chrysene) in Tampa Bay Sediments.

Phase	Station No.	naphthalene ug/g	acenaphthylene ug/g	acenaphthene ug/g	fluorene ug/g	phenenanthrene ug/g	anthracene ug/g	fluoranthene ug/g	pyrene ug/g	benz(a)anthracene ug/g	chrysen ug/g
1	01B	0.07	0.1	0.08	0.3	0.81	0.16	3.22	3.25	0.82	1.72
1	02B	0.37	0.62	0.67	0.66	3.34	0.81	7.17	7.75	2.63	3.19
1	O2A	0.14	0.38	0.31	0.44	2.17	0.54	5.2	5.4	1.99	2.65
1	O2C	0.17	0.39	0.3	0.49	3.98	0.93	10.33	9.84	3.3	3.74
1	O3A	0.07	0.08	0.08	0.09	0.09	0.09	0.23	0.41	0.13	0.13
1	O3B	0.07	0.08	0.08	0.09	0.09	0.09	0.16	0.3	0.13	0.13
1	O4A	0.07	0.12	0.08	0.09	0.41	0.09	1.48	1.87	0.37	0.8
1	O4B	0.07	0.12	0.08	0.16	0.4	0.11	1.52	1.96	0.39	0.81
1	O6B	0.07	0.08	0.08	0.09	0.09	0.09	0.11	0.27	0.13	0.13
1	O6C	0.07	0.08	0.08	0.09	0.09	0.09	0.15	0.2	0.13	0.13
1	O7C	0.07	0.08	0.08	0.09	0.28	0.09	0.87	1.06	0.35	0.53
1	11C	0.07	0.08	0.08	0.09	0.09	0.09	0.11	0.18	0.13	0.13
1	12B	0.07	0.08	0.08	0.09	0.09	0.09	0.11	0.34	0.13	0.13
1	12C	0.07	0.08	0.08	0.09	0.17	0.09	0.2	0.53	0.13	0.13
1	22A	0.07	0.08	0.08	0.09	0.09	0.09	0.51	0.92	0.13	0.4
1	25B	0.07	0.08	0.08	0.09	0.09	0.09	0.11	0.32	0.13	0.13
2	1a	0.07	0.08	0.3	0.24	2.37	0.91	6.91	6.52	1.43	3.32
2	1b	0.1	0.08	0.34	0.21	1.69	0.46	5.59	6.11	1.91	3.2
2	1c	0.16	0.08	0.34	0.25	1.84	0.43	5.77	5.92	1.81	3.2
2	2a	0.07	0.08	0.14	0.17	1.03	0.32	2.78	3.97	0.97	1.82
2	2b	0.07	0.08	0.1	0.09	0.99	0.23	3.31	4.6	1.33	2.23
2	2c	0.07	0.08	0.1	0.13	0.96	0.32	3.31	4.36	1.6	2.51
2	3a	0.07	0.08	0.08	0.09	0.35	0.09	1.19	1.42	0.65	0.8
2	3b	0.07	0.08	0.08	0.09	0.35	0.09	0.99	1.25	0.36	0.69
2	3c	0.07	0.08	0.08	0.09	0.29	0.09	0.94	1.22	0.32	0.57
2	4b	0.07	0.08	0.08	0.09	0.09	0.09	0.11	0.12	0.13	0.13
2	4c	0.07	0.08	0.08	0.09	0.1	0.09	0.32	0.42	0.13	0.34
2	5c	0.07	0.08	0.08	0.09	0.09	0.09	0.23	0.34	0.13	0.16
2	6a	0.07	0.08	0.08	0.09	0.09	0.09	0.11	0.12	0.13	0.13
2	6c	0.07	0.08	0.08	0.09	0.09	0.09	0.11	0.12	0.13	0.13
2	7c	0.07	0.08	0.08	0.09	0.09	0.09	0.51	0.51	0.13	0.36
2	8c	0.07	0.08	0.08	0.09	0.09	0.09	0.11	0.12	0.13	0.13
2	9b	0.07	0.08	0.08	0.09	0.09	0.09	0.11	0.12	0.13	0.13
2	10b	0.07	0.08	0.08	0.09	0.09	0.09	0.31	0.28	0.13	0.43
2	10c	0.07	0.08	0.08	0.09	0.09	0.09	0.43	0.42	0.13	0.37
2	11a	0.07	0.08	0.08	0.09	0.09	0.09	0.11	0.12	0.13	0.13
2	11b	0.07	0.08	0.08	0.09	0.09	0.09	0.11	0.12	0.13	0.13

Appendix C4. Phase 1 and Phase 2 data for PAH (naphthalene to chrysene) in Tampa Bay Sediments (contd.).

Phase	Station No.	naphthalene ug/g	acenaphthylene ug/g	acenaphthene ug/g	fluorene ug/g	phenenanthrene ug/g	anthracene ug/g	fluoranthene ug/g	pyrene ug/g	benz(a)anthracene ug/g	chrysene ug/g
2	11c	0.07	0.08	0.08	0.09	0.09	0.09	0.11	0.12	0.13	0.13
2	12a	0.07	0.08	0.08	0.09	0.09	0.09	0.11	0.12	0.13	0.13
2	12c	0.07	0.08	0.08	0.09	0.09	0.09	0.11	0.12	0.13	0.13
2	13a	0.07	0.08	0.08	0.09	0.38	0.13	2.15	2.5	0.49	1.26
2	13b	0.07	0.08	0.08	0.09	0.36	0.09	1.64	2.26	0.42	0.94
2	13c	0.07	0.08	0.08	0.09	0.46	0.13	1.57	1.97	0.62	1.16
2	14a	0.07	0.08	0.08	0.09	0.09	0.09	0.16	0.21	0.13	0.13
2	14b	0.07	0.08	0.08	0.09	0.09	0.09	0.11	0.12	0.13	0.13
2	15a	0.07	0.08	0.08	0.09	0.09	0.09	0.6	0.68	0.13	0.36
2	16a	0.07	0.08	0.08	0.09	0.61	0.25	4.17	5.17	0.98	2.85
2	17c	0.07	0.08	0.08	0.09	0.09	0.09	0.11	0.12	0.13	0.13
2	18a	0.07	0.08	0.08	0.09	0.6	0.18	2.15	2.53	0.57	1.42
2	18c	0.07	0.08	0.08	0.09	0.86	0.34	4.45	4.48	0.13	0.13
2	19a	0.07	0.08	0.08	0.09	0.09	0.09	0.26	0.55	0.13	0.28
2	20a	0.07	0.08	0.08	0.09	0.09	0.09	0.11	0.14	0.13	0.13
2	20c	0.07	0.08	0.08	0.09	0.09	0.09	0.11	0.12	0.13	0.13
2	21b	0.07	0.08	0.08	0.09	0.09	0.09	0.11	0.12	0.13	0.13
2	22b	0.07	0.08	0.08	0.09	0.09	0.09	0.11	0.12	0.13	0.13
2	22c	0.07	0.08	0.08	0.09	0.09	0.09	0.11	0.12	0.13	0.13
2	23a	0.07	0.08	0.08	0.09	0.67	0.22	4	3.58	0.85	0.13
2	23c	0.07	0.08	0.08	0.09	0.09	0.09	0.48	0.46	0.13	0.37
2	24a	0.07	0.08	0.08	0.09	0.09	0.09	0.33	0.31	0.13	0.22
2	24b	0.07	0.08	0.08	0.09	0.09	0.09	0.11	0.12	0.13	0.13
2	24c	0.07	0.08	0.08	0.09	0.09	0.09	0.11	0.12	0.13	0.13
	MDL	0.07	0.08	0.08	0.09	0.09	0.09	0.11	0.12	0.13	0.13

% TOC = Percent total organic carbon

LPAH = 2 and 3 ring PAH

HPAH = 4 and 5 ring PAH

Appendix C5. Phase 1 and Phase 2 data for PAH (benzo(b,k)flouranthene to benzo(g,h,i)perylene) in Tampa Bay sediments.

Phase	Station No.	benzo(b,k)fluoranthene ug/g	benzo(e)pyrene ug/g	benzo(a)pyrene ug/g	perylene ug/g	indeno(1,2,3-cd)pyrene ug/g	benzo(g,h,i)perylene ug/g
1	01B	3.2	1.17	0.96	0.27	1.04	1.09
1	02B	5.43	2	2.31	0.49	2.41	2.61
1	O2A	4.97	1.78	1.8	0.35	1.78	1.8
1	O2C	6.08	2.23	2.59	0.83	2.46	2.59
1	O3A	0.27	0.17	0.17	0.17	0.23	0.23
1	O3B	0.17	0.17	0.17	0.17	0.23	0.23
1	O4A	1.31	0.52	0.5	0.17	0.44	0.56
1	O4B	1.54	0.6	0.5	0.17	0.53	0.62
1	O6B	0.17	0.17	0.17	0.17	0.23	0.23
1	O6C	0.17	0.17	0.17	0.17	0.23	0.23
1	O7C	1.05	0.37	0.31	0.17	0.34	0.37
1	11C	0.17	0.17	0.17	0.17	0.23	0.23
1	12B	0.17	0.17	0.17	0.17	0.23	0.23
1	12C	0.17	0.17	0.17	0.17	0.23	0.23
1	22A	0.63	0.17	0.17	0.17	0.23	0.23
1	25B	0.17	0.17	0.17	0.17	0.23	0.23
2	1a	4.69	0.87	2.38	1.32	1.88	1.83
2	1b	5.45	2.09	2.71	1.05	1.75	1.92
2	1c	5.15	1.89	2.54	0.97	1.7	1.85
2	2a	2.99	1.21	1.64	0.82	0.91	0.92
2	2b	4.63	1.72	2.22	0.79	1.37	1.36
2	2c	4.17	1.65	2.18	0.91	1.28	1.36
2	3a	1.43	0.57	0.67	0.28	0.45	0.47
2	3b	1.45	0.58	0.68	0.31	0.41	0.46
2	3c	1.28	0.5	0.55	0.26	0.4	0.44
2	4b	0.17	0.17	0.17	0.17	0.23	0.23
2	4c	0.52	0.23	0.23	0.17	0.23	0.23
2	5c	0.23	0.17	0.17	0.17	0.23	0.23
2	6a	0.17	0.17	0.17	0.17	0.23	0.23
2	6c	0.17	0.17	0.17	0.17	0.27	0.23
2	7c	0.96	0.38	0.31	0.18	0.23	0.31
2	8c	0.17	0.17	0.17	0.17	0.23	0.23
2	9b	0.17	0.17	0.17	0.17	0.23	0.23
2	10b	0.68	0.26	0.23	0.22	0.23	0.32
2	10c	0.55	0.2	0.17	0.17	0.23	0.23
2	11a	0.17	0.17	0.17	0.17	0.23	0.23
2	11b	0.17	0.17	0.17	0.17	0.23	0.23

Appendix C5. Phase 1 and Phase 2 data for PAH (benzo(b,k)flouranthene to benzo(g,h,i)perylene) in Tampa Bay sediments (contd.).

Phase No.	Station	benzo(b,k)fluoranthene ug/g	benzo(e)pyrene ug/g	benzo(a)pyrene ug/g	perylene ug/g	indeno(1,2,3-cd)pyrene ug/g	benzo(g,h,i)perylene ug/g
2	11c	0.17	0.17	0.17	0.17	0.23	0.23
2	12a	0.17	0.17	0.17	0.17	0.23	0.23
2	12c	0.17	0.17	0.17	0.17	0.23	0.23
2	13a	2.84	1.08	1.05	0.56	0.79	0.85
2	13b	2.14	0.82	0.79	0.37	0.47	0.53
2	13c	2.59	0.99	1.13	0.5	0.82	0.92
2	14a	0.17	0.17	0.17	0.17	0.23	0.23
2	14b	0.17	0.17	0.17	0.17	0.23	0.23
2	15a	0.34	0.17	0.17	0.17	0.23	0.23
2	16a	6.57	2.31	2.63	1.36	2.08	2.04
2	17c	0.17	0.17	0.17	0.17	0.23	0.23
2	18a	2.51	0.93	1.29	0.59	0.73	0.82
2	18c	4.59	1.72	2.06	0.99	1.41	1.6
2	19a	0.4	0.18	0.24	0.17	0.23	0.23
2	20a	0.17	0.17	0.17	0.17	0.23	0.23
2	20c	0.17	0.17	0.17	0.17	0.23	0.23
2	21b	0.17	0.17	0.17	0.17	0.23	0.23
2	22b	0.17	0.17	0.17	0.17	0.23	0.23
2	22c	0.17	0.17	0.17	0.17	0.23	0.23
2	23a	5.71	1.97	2.06	0.71	1.74	1.83
2	23c	0.49	0.17	0.17	0.17	0.23	0.23
2	24a	0.37	0.17	0.17	0.17	0.23	0.23
2	24b	0.17	0.17	0.17	0.17	0.23	0.23
2	24c	0.17	0.17	0.17	0.17	0.23	0.23
	MDL	0.17	0.17	0.17	0.17	0.23	0.23

Appendix C6. Phase 1and Phase 2 data for PAH and TOC in Tampa Bay sediments.

Phase	Station No.	Total LPAH ug/g	Total HPAH ug/g	Total PAH ug/g	TOC %/100
1	01B	2.52	18.97	21.49	0.0629
1	02B	7.47	38.51	45.98	0.0438
1	O2A	4.98	30.05	35.03	0.0283
1	O2C	7.26	46.64	53.9	0.0297
1	O3A	1.5	4.37	5.87	0.0159
1	O3B	1.5	4.09	5.59	0.0165
1	O4A	1.86	10.25	12.11	0.033
1	O4B	1.94	10.87	12.81	0.0329
1	O6B	1.5	4.01	5.51	0.0103
1	O6C	1.5	3.98	5.48	0.0119
1	O7C	1.69	7.65	9.34	0.0168
1	11C	1.5	3.92	5.42	0.013
1	12B	1.5	4.08	5.58	0.0186
1	12C	1.58	4.36	5.94	0.0295
1	22A	1.5	5.79	7.29	0.0147
1	25B	1.5	4.06	5.56	0.0352
2	1a	5.97	35.61	41.58	0.0614
2	1b	4.88	36.45	41.33	0.0608
2	1c	5.1	35.53	40.63	0.0467
2	2a	3.81	22.29	26.1	0.0293
2	2b	3.56	27.93	31.49	0.0362
2	2c	3.66	27.83	31.49	0.0253
2	3a	2.76	12.16	14.92	0.0261
2	3b	2.76	11.41	14.17	0.029
2	3c	2.7	10.71	13.41	0.0262
2	4b	2.5	5.86	8.36	0.0202
2	4c	2.51	7.05	9.56	0.0192
2	5c	2.5	6.29	8.79	0.0213
2	6a	2.5	5.86	8.36	0.0152
2	6c	2.5	5.9	8.4	0.0089
2	7c	2.5	8.11	10.61	0.0171
2	8c	2.5	5.86	8.36	0.0245
2	9b	2.5	5.86	8.36	0.0285
2	10b	2.5	7.32	9.82	0.0444
2	10c	2.5	7.13	9.63	0.0463
2	11a	2.5	5.86	8.36	0.0274
2	11b	2.5	5.86	8.36	0.027

Appendix C6. Phase 1and Phase 2 data for PAH and TOC in Tampa Bay sediments (contd.).

Phase	Station No.	Total LPAH ug/g	Total HPAH ug/g	Total PAH ug/g	TOC %/100
2	11c	2.5	5.86	8.36	0.0172
2	12a	2.5	5.86	8.36	0.0019
2	12c	2.5	5.86	8.36	0.0035
2	13a	2.83	17.8	20.63	0.0458
2	13b	2.77	14.61	17.38	0.0393
2	13c	2.91	16.51	19.42	0.0399
2	14a	2.5	6	8.5	0.0108
2	14b	2.5	5.86	8.36	0.0025
2	15a	2.5	7.31	9.81	0.0095
2	16a	3.18	34.65	37.83	0.0531
2	17c	2.5	5.86	8.36	0.002
2	18a	3.1	17.75	20.85	0.0236
2	18c	3.52	25.91	29.43	0.0358
2	19a	2.5	6.9	9.4	0.0234
2	20a	2.5	5.88	8.38	0.0031
2	20c	2.5	5.86	8.36	0.0009
2	21b	2.5	5.86	8.36	0.0014
2	22b	2.5	5.86	8.36	0.0047
2	22c	2.5	5.86	8.36	0.0035
2	23a	3.21	26.99	30.2	0.0234
2	23c	2.5	7.13	9.63	0.0366
2	24a	2.5	6.56	9.06	0.0323
2	24b	2.5	5.86	8.36	0.024
2	24c	2.5	5.86	8.36	0.0018
	MDL				0.001

Appendix C7. Phase 1 and 2 data for PCBs (8 through 118) in Tampa Bay sediments.

Phase	Station No.	TOC %/100	PCB 8 ng/g	PCB 18 ng/g	PCB 28 ng/g	PCB -29 ng/g	PCB 50 ng/g	PCB 52 ng/g	PCB 44 ng/g	PCB 66 ng/g	PCB 101 ng/g	PCB 77,154 ng/g	PCB 110 ng/g	PCB 118 ng/g
1	01B	0.0629	49.2	33.2	11.5	-	11.7	36	52.7	27.8	25.7	9	33.6	-
1	02B	0.0438	121.5	95.8	54.5	-	53.7	189.3	267.3	51.7	41.2	43.1	89.4	-
1	02A	0.0283	49.3	33.9	23.6	-	23.2	38.2	0.5	13.4	7.1	15.9	27.6	-
1	02C	0.0297	426	394.3	364.2	-	0.1	996	0.5	269.4	238.1	267.2	420.8	-
1	03A	0.0159	21.3	20.4	18.5	-	13	52.2	0.5	10.7	6.8	3.5	4.2	-
1	03B	0.0165	19.2	24.1	6.8	-	5.6	19.3	19	10.5	7.6	3.2	3.8	-
1	04A	0.033	47.3	28.9	22.4	-	17.9	31.2	20.2	22.7	10.4	4.5	6.8	-
1	04B	0.0329	41.8	41.1	43.2	-	26.6	81.6	73.4	70	53.4	23.4	60	-
1	06B	0.0103	11.8	10.7	4	-	3.8	8.6	11.7	6.2	4.8	1.4	3.9	-
1	06C	0.0119	3.7	0.5	6.2	-	4.9	35.4	0.5	3.8	5.8	3	4.9	-
1	07C	0.0168	0.5	0.5	12.6	-	9.9	36.5	43.7	15.8	24.9	11.7	39.5	-
1	11C	0.013	7.7	0.5	0.5	-	3	7.2	6.1	4.5	3.5	1.2	2.6	-
1	12B	0.0186	0.5	0.5	3.1	-	2.7	0.1	0.5	0.1	0.1	1	2	-
1	12C	0.0295	0.5	0.5	7.3	-	8.6	34.2	12.7	20.7	28.1	5.3	9.4	-
1	22A	0.0147	10.9	12.1	4.4	-	4.1	9.6	1.3	6.2	5.8	3.2	4.3	-
1	25B	0.0352	14.6	0.5	6.3	-	0.1	10.8	2.8	0.4	0.1	2.4	4.8	-
2	1A	0.0614	1.07	1.91	-	6.21	-	6.25	6.23	27.84	9.47	19.15	-	6.23
2	1B	0.0608	0.7	5.1	-	8.42	-	8.16	6.94	40.14	20.45	30.29	-	24.99
2	1C	0.0467	0.79	5.5	-	4.88	-	5.49	7.56	14.88	16.25	26.46	-	14.92
2	2A	0.0293	0.01	2.71	-	4.85	-	1.87	1.84	11.49	14.6	28.09	-	10.22
2	2B	0.0362	0.01	2.68	-	0.01	-	6.25	4.59	39	12.92	22.99	-	9.59
2	2C	0.0253	0.01	2.37	-	3.26	-	5.38	4.13	10.17	11.67	20.84	-	7.74
2	3A	0.0261	0.01	3.95	-	6.21	-	6.56	3.76	11.69	16.95	17.62	-	0.01
2	3B	0.029	0.01	5.78	-	8.78	-	7.85	4.83	17.66	16.2	19.89	-	10.45
2	3C	0.0262	0.01	4.63	-	5.3	-	4.88	3.18	8.05	8.05	1.45	-	0.01
2	4B	0.0202	0.01	0.01	-	0.46	-	0.61	0.48	1.41	1.17	2.7	-	0.01
2	4C	0.0192	0.01	0.82	-	2.59	-	2.5	1.51	4.45	5.91	9.91	-	0.01
2	5C	0.0213	0.01	0.01	-	2.39	-	1.59	1.31	6.45	3.25	7.87	-	3.63
2	6A	0.0152	0.01	0.01	-	0.59	-	0.45	0.32	1.5	1.11	1.58	-	1.1
2	6C	0.0089	0.01	0.01	-	0.01	-	0.01	0.01	0.46	0.73	0.25	-	0.09
2	9B	0.0285	0.01	0.01	-	0.01	-	1.35	0.97	1.04	0.95	1.42	-	0.66
2	10B	0.0444	0.01	0.01	-	0.01	-	0.01	0.01	11.76	0.01	1.21	-	0.62
2	10C	0.0463	0.01	0.01	-	0.22	-	0.34	0.01	14.37	0.48	0.51	-	0.58
2	11A	0.0274	0.01	0.06	-	0.31	-	0.35	0.34	5.45	0.58	0.89	-	0.76
2	15A	0.0095	0.01	0.01	-	1.1	-	1.45	1.87	1.07	3.27	3.83	-	2.65
2	16A	0.0531	0.01	0.01	-	0.01	-	1.76	1.42	1.06	4.8	3.88	-	9.52
2	17c	0.002	0.01	0.15	-	0.05	-	0.24	0.12	0.08	0.07	0.11	-	0.08

"-" = No data.

Appendix C7. Phase 1 and Phase 2 data for PCBs (8 through 118) in Tampa Bay sediments (contd.).

Phase	Station No.	TOC %/100	PCB 8 ng/g	PCB 18 ng/g	PCB 28 ng/g	PCB -29 ng/g	PCB 50 ng/g	PCB 52 ng/g	PCB 44 ng/g	PCB 66 ng/g	PCB 101 ng/g	PCB 77,154 ng/g	PCB 110 ng/g	PCB 118 ng/g
2	18A	0.0236	0.01	0.01	-	0.01	-	7.33	6.01	11.53	9.34	12.78	-	6.26
2	18c	0.0358	0.01	0.01	-	0.01	-	0.01	0.01	1.56	2.9	0.01	-	0.24
2	21B	0.0014	0.01	0.01	-	0.06	-	0.11	0.1	0.56	0.08	0.12	-	0.04
2	22C	0.0035	0.01	0.01	-	0.01	-	0.51	0.43	1.54	0.61	0.69	-	0.47
2	7C	0.017	0.01	0.01	-	0.28	-	0.3	0.39	1.75	0.44	0.56	-	0.36
2	8C	0.0245	0.01	0.01	-	0.11	-	0.09	0.2	0.47	0.31	0.3	-	0.21
2	11B	0.027	0.01	0.18	-	0.29	-	0.24	0.3	7.08	0.82	1.31	-	1.18
2	11C	0.0172	0.01	0.01	-	0.01	-	0.01	0.01	0.01	0.01	0.01	-	0.01
2	12A	0.0019	0.01	0.01	-	0.16	-	0.17	0.39	3.65	0.16	0.19	-	0.15
2	12C	0.0035	0.01	0.07	-	0.12	-	0.17	0.13	0.42	0.21	0.21	-	0.14
2	13A	0.0458	0.01	0.01	-	0.01	-	0.01	0.01	0.58	1.29	10.79	-	0.61
2	13B	0.0393	0.01	0.01	-	0.01	-	0.01	0.01	3.83	0.01	7.03	-	3.95
2	13C	0.0399	0.01	0.01	-	0.01	-	0.01	0.01	13.32	8.49	13.8	-	10.38
2	14A	0.0108	0.01	0.01	-	0.02	-	0.01	0.11	7.55	1.15	1.22	-	1.23
2	14B	0.0025	0.01	0.01	-	0.02	-	0.01	0.01	34.37	0.01	0.27	-	0.25
2	19A	0.0234	0.01	0.01	-	0.01	-	0.01	0.01	45.58	0.5	0.82	-	1.03
2	20A	0.0031	0.08	0.01	-	0.29	-	0.23	0.33	1.2	1.26	0.36	-	0.28
2	20C	0.0009	0.02	0.01	-	0.09	-	0.06	0.1	0.7	0.1	0.11	-	0.08
2	22B	0.0047	0.01	0.01	-	0.06	-	0.14	0.12	0.56	0.21	0.21	-	0.14
2	23a	0.0234	0.01	0.01	-	0.01	-	0.01	0.01	78.29	28.75	7.59	-	7.61
2	23C	0.0366	0.01	0.01	-	0.1	-	0.25	0.53	17.77	1.92	0.64	-	0.81
2	24A	0.0323	0.16	0.24	-	0.36	-	0.57	0.62	1.98	2.11	0.83	-	0.4
2	24B	0.024	0.01	0.01	-	0.1	-	0.29	0.28	4.9	0.25	0.23	-	0.13
2	24C	0.0018	0.01	0.01	-	0.01	-	0.15	0.13	1.41	0.18	0.15	-	0.08
	MDL	-	0.19	0.13	-	0.24	-	0.2	0.23	0.24	0.21	0.26	-	0.27

"-" = No data.

Appendix C8. Phase 1 and Phase 2 for PCBs (105 through 209) in Tampa Bay sediments.

Phase No.	Station	PCB 153 ng/g	PCB105 ng/g	PCB 138 ng/g	PCB 126 ng/g	PCB 187 ng/g	PCB 128 ng/g	PCB 180 ng/g	PCB 170 ng/g	PCB 195 ng/g	PCB 206 ng/g	PCB 209 ng/g	Sum of 23 PCBs ng/g	Total PCBs ng/g
1	01B	261.6	1.1	48.6	35.7	24.5	3.6	43.1	13.4	21	16.2	41.4	800.6	1601.2
1	02B	82.4	54.9	98	78.3	34	17	41.2	58.3	188.9	105.7	22.1	1788.3	3576.6
1	02A	14	12.5	15.6	0.1	0.1	0.1	4.2	0.1	68.2	0.3	0.3	348.2	696.4
1	02C	570.9	696.9	706.4	791.6	186.3	238.5	288.2	0.1	0.1	0.3	1482.5	8338.4	16676.8
1	03A	2.9	6.9	3.8	0.4	0.1	0.1	1	0.1	16.2	9.7	0.3	192.6	385.2
1	03B	2.3	4.8	2.4	1.2	0.1	0.3	1.4	0.1	0.1	8	0.3	140.1	280.2
1	04A	2.5	2.3	6.6	0.1	0.1	0.1	4.1	0.1	0.1	28.7	0.3	257.3	514.6
1	04B	49.5	21.6	52	17.4	9.3	4.5	26.2	5.8	55.1	32.6	0.3	788.8	1577.6
1	06B	1	3.3	1.4	0.2	0.1	0.4	0.6	0.1	0.1	4.2	0.3	78.6	157.2
1	06C	4.9	3.7	5.6	0.1	0.8	0.8	1.2	0.1	0.1	0.3	11.9	98.2	196.4
1	07C	33.4	23.1	40.7	25.2	11.9	14.1	20.6	5.4	18.6	11.8	0.3	400.7	801.4
1	11C	0.1	1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.3	0.3	39.2	78.4
1	12B	0.1	4.5	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.3	0.3	16.5	33
1	12C	3.4	19.5	4.8	0.1	0.1	0.1	0.1	0.1	0.1	0.3	0.3	156.2	312.4
1	22A	6.4	8.2	7.9	5.9	1.1	0.9	1.2	0.1	0.1	7	0.3	101	202
1	25B	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.3	0.3	44.3	88.6
2	1A	7.35	8.17	14.3	3.25	4.94	3.67	5.89	7.12	1.03	1.23	0.68	141.99	283.98
2	1B	17.85	12.27	29.8	6.19	12.06	5.97	14.03	10.89	2.69	2.47	1.33	260.74	521.48
2	1C	7.91	10.24	21.72	4.63	4.88	5.72	6.76	9.12	1.79	0.64	0.01	170.15	340.3
2	2A	10.88	9.33	20.27	4.27	6.34	5.33	8.85	9.43	1.71	1.33	0.01	153.43	306.86
2	2B	9.84	10.66	17.07	4.36	7.47	4.85	8.58	8.37	2.46	3.29	1.23	176.22	352.44
2	2C	7.83	9.16	1.5	2.88	6.47	4.19	4.46	7.37	2.14	1.18	0.18	112.93	225.86
2	3A	13.59	6.96	16.01	4.11	12.39	4.25	12.82	8.7	3.27	3.05	0.19	152.1	304.2
2	3B	16.83	8.45	19.86	4.96	12.81	4.24	15.02	10.81	3.59	2.62	0.01	190.65	381.3
2	3C	5.45	5.56	11.81	1.99	4.82	2.55	5.13	6.32	1.51	0.53	0.01	81.24	162.48
2	4B	0.29	1.41	1.63	0.69	1.18	0.54	0.19	0.64	0.05	0.01	0.01	13.5	27
2	4C	7.43	3.97	9.22	2.28	5.56	2.15	6.25	4.65	1.1	0.94	0.27	71.53	143.06
2	5C	2.86	2.28	5.05	0.84	1.83	1.15	1.84	1.93	0.31	0.26	0.01	44.87	89.74
2	6A	1.07	0.73	1.47	0.26	0.64	0.33	0.63	0.51	0.1	0.1	0.06	12.57	25.14
2	6C	0.24	0.61	0.15	0.01	0.01	0.1	0.01	0.01	0.01	0.01	0.01	2.75	5.5
2	9B	0.38	0.26	0.43	0.07	0.18	0.1	1.09	0.1	0.01	0.93	0.01	9.98	19.96
2	10B	0.39	0.22	1	0.01	0.49	0.07	0.2	0.15	0.01	0.01	0.01	16.21	32.42
2	10C	0.42	0.19	0.49	0.01	0.24	0.1	0.27	0.15	0.01	0.01	0.01	18.43	36.86
2	11A	0.4	0.36	0.83	0.12	0.26	0.22	0.3	0.19	0.03	0.05	0.22	11.73	23.46
2	15A	2.65	2.03	4.85	0.99	1.72	1.2	1.99	2.41	0.42	0.17	0.01	33.7	67.4
2	16A	5.42	4.19	9.62	1.96	4.61	1.97	5.49	6.78	1.75	3.94	0.01	68.21	136.42
2	17c	0.07	0.06	0.07	0.12	0.14	0.07	0.06	0.05	0.02	0.01	0.01	1.59	3.18

Appendix C8. Phase 1 and Phase 2 for PCBs (105 through 209) in Tampa Bay sediments (contd.).

Phase No.	Station	PCB 153 ng/g	PCB105 ng/g	PCB 138 ng/g	PCB 126 ng/g	PCB 187 ng/g	PCB 128 ng/g	PCB 180 ng/g	PCB 170 ng/g	PCB 195 ng/g	PCB 206 ng/g	PCB 209 ng/g	Sum of 23 PCBs ng/g	Total PCBs ng/g
2	18A	7.94	5.89	10.91	3.35	6.87	2.6	7.6	6.2	1.85	2.2	0.01	108.7	217.4
2	18c	1.26	1.98	0.79	7.04	0.87	0.7	0.32	1.39	0.01	0.01	0.01	19.14	38.28
2	21B	0.04	0.05	0.01	0.03	0.01	0.02	0.01	0.05	0.01	0.01	0.01	1.34	2.68
2	22C	0.25	0.23	0.38	0.1	0.15	0.11	0.15	0.11	0.01	0.01	0.01	5.79	11.58
2	7C	0.14	0.23	0.32	0.06	0.09	0.09	0.07	0.11	0.02	0.01	0.01	5.25	10.5
2	8C	0.12	0.11	0.21	0.04	0.07	0.06	0.05	0.04	0.01	0.01	0.01	2.44	4.88
2	11B	0.71	0.51	1.07	0.25	0.39	0.27	0.36	0.18	0.19	0.09	0.84	16.27	32.54
2	11C	0.01	0.35	0.25	0.01	0.01	0.1	0.01	0.01	0.01	0.01	0.01	0.87	1.74
2	12A	0.06	0.05	0.1	0.02	0.03	0.02	0.04	0.04	0.01	0.01	0.02	5.29	10.58
2	12C	0.07	0.06	0.12	0.02	0.04	0.03	0.03	0.03	0.01	0.01	0.01	1.91	3.82
2	13A	1.99	5.05	1.16	10.81	1.37	1.57	0.64	0.01	0.01	0.01	0.01	35.95	71.9
2	13B	2.22	2.47	4.48	0.01	1.47	1.04	1.94	2.03	0.01	0.01	0.01	30.56	61.12
2	13C	6.86	4.95	10.37	2.15	5.27	2.25	5.33	4.7	1.1	0.5	0.01	89.53	179.06
2	14A	0.91	0.65	1.27	0.24	0.45	0.31	0.51	0.33	0.06	0.1	0.01	16.15	32.3
2	14B	0.14	0.08	0.19	0.01	0.07	0.04	0.08	0.05	0.01	0.01	0.01	35.65	71.3
2	19A	0.96	0.37	1.22	0.49	0.94	0.27	0.95	0.47	0.26	0.55	0.11	54.57	109.14
2	20A	0.21	0.16	0.27	0.07	0.15	0.06	0.18	0.11	0.04	0.07	0.01	5.37	10.74
2	20C	0.05	0.03	0.07	0.02	0.04	0.02	0.03	0.02	0.01	0.01	0.01	1.58	3.16
2	22B	0.07	0.08	0.14	0.03	0.05	0.03	0.06	0.06	0.01	0.01	0.01	2.01	4.02
2	23a	3.58	4.89	8.54	2.55	2.39	1.45	1.74	1.35	0.01	0.01	0.01	148.81	297.62
2	23C	0.26	0.52	0.59	0.23	0.17	0.12	0.13	0.15	0.01	0.01	0.01	24.24	48.48
2	24A	0.08	0.39	0.34	0.1	0.06	0.14	0.04	0.07	0.02	0.01	0.01	8.53	17.06
2	24B	0.05	0.05	0.08	0.01	0.02	0.01	0.02	0.02	0.01	0.01	0.01	6.49	12.98
2	24C	0.04	0.04	0.06	0.01	0.02	0.01	0.02	0.01	0.01	0.01	0.01	2.37	4.74
	MDL	0.21	0.23	0.25	0.22	0.24	0.23	0.22	0.21	0.19	0.2	0.19		

Appendix C9. Phase 1 and Phase 2 for Pesticides data in Tampa Bay sediments.

Phase	Station No.	dieldrin+4,4'-DDE ng/g	dieldrin ng/g	endrin ng/g	hexachloro benzene ng/g	lindane ng/g	heptachlor ng/g	aldrin ng/g	heptachlor epoxide ng/g	Total pesticides	mirex
1	01B	62.3	-	11.7	4.1	3.2	0.1	5.5	2.5	127.8	0.5
1	02B	49.1	-	60.6	0.3	50.6	0.1	20.5	7.4	282.8	0.5
1	02A	16.9	-	23.2	5.2	1	0.1	1	1.8	78.5	0.5
1	02C	315.5	-	392.3	6	156.5	213.8	1	24.9	1583.3	0.5
1	03A	2.2	-	4.4	5.5	1	0.1	1	0.1	18.5	0.5
1	03B	1.8	-	4.1	4.8	2.2	3.3	1	1	23.9	0.5
1	04A	3.1	-	9.2	3.1	1	10.2	3.2	3.3	48.6	0.5
1	04B	24.5	-	26.9	6.8	1	15.2	1	9.4	133.2	0.5
1	06B	0.6	-	1.5	4.5	1.5	2.2	1.4	0.6	14.6	0.5
1	06C	2.4	-	3.6	0.5	1	4.8	1	0.3	15.8	0.5
1	07C	6.5	-	12.5	0.1	1	7.5	5.1	1.1	47.7	0.5
1	11C	0.4	-	2.1	3.3	1	1.2	1.5	0.4	12.6	0.5
1	12B	0.2	-	1	1.8	4.2	0.1	1	0.1	9	0.5
1	12C	1.9	-	3.7	0.1	1	4.5	4.4	1.8	24.8	0.5
1	22A	4.8	-	4.9	4.2	2.4	0.1	1	0.7	26.9	0.5
1	25B	0.2	-	4	3	1	0.1	1	0.1	13.5	0.5
2	1A	-	7.61	5.38	1.43	2.71	0	3.44	1.3	42.54	1.46
2	1B	-	8.47	5.9	1.83	3.04	4.89	4.69	0	51.05	0
2	1C	-	6.65	2.31	0	2.05	2.97	0	0.24	32.06	0
2	2A	-	2.48	2.34	0	1.84	0	0	0	11.84	0
2	2B	-	2.8	2.04	0.65	2.26	3.75	5.81	1.84	27.87	1.12
2	2C	-	0	3.08	1.28	1.54	0	4.62	0	18.23	0
2	3A	-	1.75	1.25	0.15	2.2	2.96	4.74	0	17.18	1.32
2	3B	-	1.46	1.2	0	2.15	2.58	5.59	0	16.75	1.14
2	3C	-	1.51	0.65	0	2.01	0	0	0	7.79	0
2	4B	-	0.94	0.71	0	0.74	0	0	0	3.84	0
2	4C	-	0.84	2.34	0	1.95	0.95	1.93	0	10.11	0
2	5C	-	0.6	0.71	0	2.11	0	0	0	5.49	0
2	6A	-	0.94	0.71	0.15	1.31	0	0.2	0	4.84	0
2	6C	-	0.94	0	0	1.45	0	0	0	4.07	0
2	9B	-	0.94	0	0.57	1.25	1.98	0	0	6.07	0
2	10B	-	1.65	0	0	1.99	1.04	0	0	8.22	0
2	10C	-	1.73	0.71	0	1.75	0	0	0.44	8.44	0
2	11A	-	0.94	0	0	1.53	0.28	0.37	0	4.94	0
2	15A	-	1.52	2.34	0	1.08	0	0	0.44	9.11	1.32
2	16A	-	5.24	2.34	0	2.39	0	0	0.94	20.49	1.06
2	17c	-	0	0	0.11	0.82	0.32	0.3	0	2.35	0

"-" = No data.

Appendix C9. Phase 1 and Phase 2 for Pesticides data in Tampa Bay sediments (contd.).

Phase No.	Station	dieldrin+4,4'-DDE ng/g	dieldrin ng/g	endrin ng/g	hexachloro benzene ng/g	lindane ng/g	heptachlor ng/g	aldrin ng/g	heptachlor epoxide ng/g	Total pesticides	mirex
2	18A	-	5.07	1.09	5	1.07	0	6.92	0.45	30.47	0.8
2	18c	-	19.27	2.67	0	2.37	0	0	0	55.82	1.92
2	21B	-	0	0	0.15	1.12	0	0	0	1.54	0
2	22C	-	0.94	0	0.17	0.82	0	0	0	2.76	0
2	7C	-	0.37	0.71	0	0	0.29	0	0	3.03	0
2	8C	-	0	0	0.16	1.31	0	0	0	2.27	0
2	11B	-	0.94	0.71	0.23	1.72	0	0	0	4.7	0
2	11C	-	0.94	0.71	0.2	1.56	0	0	0	4.06	0
2	12A	-	0.94	0	0.02	1.67	0.43	0	0	4.74	0
2	12C	-	0.94	0.71	0.15	0.78	0	0	0	3.81	0
2	13A	-	1.77	2.34	0	2.87	0	0	0	13.36	0.4
2	13B	-	3.26	0	0	3.18	0	0	0	14.18	0
2	13C	-	3.48	0.71	0	1.87	0	0	0.48	11.62	1.32
2	14A	-	1.63	0.71	0	0.85	0	0	0	6.62	0
2	14B	-	0.6	0	0	1.16	0	0	0	3.72	0
2	19A	-	1.41	0.88	0	1.95	0	0	0	6.84	0.48
2	20A	-	0.64	0.55	0.07	0.72	0	0.56	0	4.11	0
2	20C	-	0.94	0	0.06	1.16	0	0	0	3.84	0
2	22B	-	0.94	0	0	0.78	0	0	0	3.47	0.4
2	23a	-	18.44	2.2	0	2.36	0	0	0.94	60.03	1.4
2	23C	-	2.38	2.34	0	1.1	0	0	0.44	11.55	1.32
2	24A	-	1.6	2.34	0.12	1.71	0	0	0	9.46	1.32
2	24B	-	0.28	0	0.15	1.51	0	0	0	2.74	0
2	24C	-	0.29	0	0	12.27	0	0.22	0	13.58	0
	MDL	-	0.29	0.71	0.15	0.25	0.13	0.2	0.13	0.4	5

"-" = No data.

Appendix C10. Phase 1 and Phase 2 data for butyl tins and DDT in Tampa Bay sediments.

Phase	Station No.	tributyl ng/g	dibutyl tin ng/g	butyl tin ng/g	Total butyl tins ng/g	2,4-DDD ng/g	4,4'-DDD ng/g	2,4'-DDT ng/g	4,4'-DDT ng/g	2,4'-DDE ng/g	4,4-DDE ng/g	Total DDTs ng/g
1	01B	6	6	6	18	-	19.3	15.6	74.2	10.2	-	119.3
1	02B	12	8	9	29	-	141.6	76.1	182	57.2	-	456.9
1	02A	8	6	6	20	-	41.8	24.6	35.4	18.2	-	120
1	02C	31	12	28	71	-	783.8	553.6	2117.9	346.5	-	3801.8
1	03A	6	6	6	18	-	5.5	2.7	3.1	4.5	-	15.8
1	03B	6	6	6	18	-	4.9	2.4	2.1	4.8	-	14.2
1	04A	6	6	6	18	-	17.9	5.4	5.4	13.2	-	41.9
1	04B	6	6	6	18	-	48.2	18.2	40.7	27.1	-	134.2
1	06B	6	6	6	18	-	1.9	0.9	1.4	2.8	-	7
1	06C	6	6	6	18	-	2.9	1.8	2.7	2.5	-	9.9
1	07C	6	6	6	18	-	13.8	13.6	47.9	8	-	83.3
1	11C	6	6	6	18	-	1.9	1	0.1	2.5	-	5.5
1	12B	6	6	6	18	-	1	0.1	0.1	1	-	2.2
1	12C	6	6	6	18	-	2.5	1.3	1.5	1	-	6.3
1	22A	6	6	6	18	-	7.4	6.2	8.5	4.9	-	27
1	25B	6	6	6	18	-	3.9	2.7	0.8	4.2	-	11.6
2	1A	-	-	-	-	6.93	15.89	10.21	20.4	0.76	97.7	151.89
2	1B	-	-	-	-	21.71	26.35	0	18.24	1.1	96.25	163.65
2	1C	-	-	-	-	7.86	18.6	0	12.33	1.1	138.49	178.38
2	2A	-	-	-	-	3.06	6.47	0	17.7	1.1	80.88	109.21
2	2B	-	-	-	-	3.76	9.37	0	6.59	1.1	63.37	84.19
2	2C	-	-	-	-	3.74	6.78	0	4.68	0	53.37	68.57
2	3A	-	-	-	-	3	5.82	0.94	3.63	1.1	45.3	59.79
2	3B	-	-	-	-	3.27	5.85	1.18	3.55	1.1	39.54	54.49
2	3C	-	-	-	-	2.89	5.2	0	5.32	0	25.75	39.16
2	4B	-	-	-	-	-	0.58	1.03	0.51	0.76	0.95	3.83
2	4C	-	-	-	-	-	1.19	2.73	0	0.01	0.95	4.88
2	5C	-	-	-	-	-	1.25	2.06	0	1.63	0.95	5.89
2	6A	-	-	-	-	0.72	0.78	0	0	0	5.1	6.6
2	6C	-	-	-	-	0.97	1.14	0	0.51	0	0.52	3.14
2	9B	-	-	-	-	0.97	1.14	0	0	0	5.83	7.94
2	10B	-	-	-	-	0.97	0.76	0	1.68	0	4.21	7.62
2	10C	-	-	-	-	0.59	1.25	0	1.68	0	3.45	6.97
2	11A	-	-	-	-	0.97	1.14	0	0	0	3.65	5.76
2	15A	-	-	-	-	0.81	2.32	3.12	2.13	0	33.9	42.28
2	16A	-	-	-	-	3.12	6.88	7.29	4.57	1.1	18.05	41.01
2	17c	-	-	-	-	0	0	0	0	0	0.12	0.12

"-" = No data.

Appendix C10. Phase 1 and Phase 2 data for butyl tins and DDT in Tampa Bay sediments (contd.).

Phase	Station No.	tributyl ng/g	dibutyl tin ng/g	butyl tin ng/g	Total butyl tins ng/g	2,4-DDD ng/g	4,4'-DDD ng/g	2,4'-DDT ng/g	4,4'-DDT ng/g	2,4'-DDE ng/g	4,4-DDE ng/g	Total DTs ng/g
2	18A	-	-	-	-	4.51	10.25	9.14	4.99	0.18	86.77	115.84
2	18c	-	-	-	-	9.82	20.52	19.86	17.95	0.5	22.82	91.47
2	21B	-	-	-	-	0	0	0.14	0.28	0	0	0.42
2	22C	-	-	-	-	0	0	0.4	0.65	0	0	1.05
2	7C	-	-	-	-	0.97	1.14	0	0	0	2.58	4.69
2	8C	-	-	-	-	0	0.35	0	0.51	0	1.48	2.34
2	11B	-	-	-	-	0.97	1.14	0	0	0	4.96	7.07
2	11C	-	-	-	-	0.97	1.14	0	0	0	1.61	3.72
2	12A	-	-	-	-	0.97	1.14	0	0	0	1.4	3.51
2	12C	-	-	-	-	0.97	1.14	0	0	0	2.24	4.35
2	13A	-	-	-	-	3.01	4.82	0	3.81	1.1	22.87	35.61
2	13B	-	-	-	-	4.63	12.14	0	9.92	1.1	19.33	47.12
2	13C	-	-	-	-	3.09	6.96	4.71	4.71	0.33	37.35	57.15
2	14A	-	-	-	-	0.83	2.17	0	2.21	0	28.38	33.59
2	14B	-	-	-	-	0.65	1.57	0	1.68	0	12.35	16.25
2	19A	-	-	-	-	1.92	3.35	2.24	7.91	1.1	8.95	25.47
2	20A	-	-	-	-	0.69	1.04	0	0	0	3	4.73
2	20C	-	-	-	-	0	0	0	0	0	0.57	0.57
2	22B	-	-	-	-	0.97	1.14	0	1.68	0	1.26	5.05
2	23a	-	-	-	-	7.24	12.36	0	10.51	1.1	99.82	131.03
2	23C	-	-	-	-	0.86	2.1	0	2.29	0	7.96	13.21
2	24A	-	-	-	-	0.77	1.95	0	1.2	0	5.75	9.67
2	24B	-	-	-	-	0.97	0	0	0	0	0.66	1.63
2	24C	-	-	-	-	0	0	0	0	0	0.41	0.41
	MDL	-	-	-	-	0.29	0.35	0.36	0.51	0.34	0.29	-

"-" = No data.

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