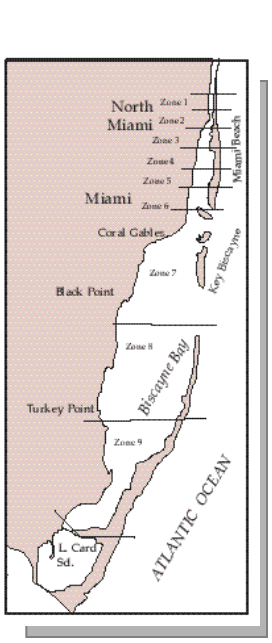
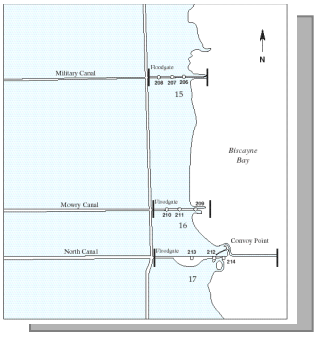
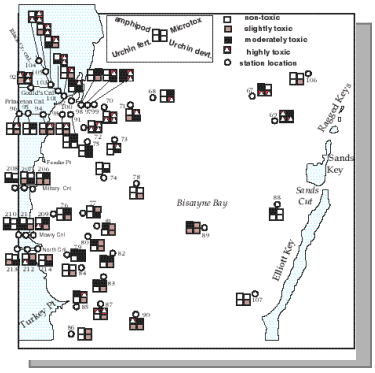
NOAA Technical Memorandum NOS NCCOS CCMA 141

National Status and Trends Program
for Marine Environmental Quality

Magnitude and Extent of Chemical Contamination and Toxicity in Sediments of Biscayne Bay and Vicinity.







Silver Spring, Maryland
December 1999

US Department of Commerce

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Notice

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Magnitude and Extent of Chemical Contamination and Toxicity in Sediments of Biscayne Bay and Vicinity.

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National Oceanic and Atmospheric Administration
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ABSTRACT

The toxicity of sediments in Biscayne Bay and many adjoining tributaries was determined as part of a bioeffects assessments program managed by NOAA's National Status and Trends Program. The objectives of the survey were to determine: (1) the incidence and degree of toxicity of sediments throughout the study area; (2) the spatial patterns (or gradients) in chemical contamination and toxicity, if any, throughout the study area; (3) the spatial extent of chemical contamination and toxicity; and (4) the statistical relationships between measures of toxicity and concentrations of chemicals in the sediments.

The survey was designed to characterize sediment quality throughout the greater Biscayne Bay area. Surficial sediment samples were collected during 1995 and 1996 from 226 randomly-chosen locations throughout nine major regions. Laboratory toxicity tests were performed as indicators of potential ecotoxicological effects in sediments. A battery of tests was performed to generate information from different phases (components) of the sediments. Tests were selected to represent a range in toxicological endpoints from acute to chronic sublethal responses. Toxicological tests were conducted to measure: reduced survival of adult amphipods exposed to solid-phase sediments; impaired fertilization success and abnormal morphological development in gametes and embryos, respectively, of sea urchins exposed to pore waters; reduced metabolic activity of a marine bioluminescent bacteria exposed to organic solvent extracts; induction of a cytochrome P-450 reporter gene system in exposures to solvent extracts; and reduced reproductive success in marine copepods exposed to solid-phase sediments.

Contamination and toxicity were most severe in several peripheral canals and tributaries, including the lower Miami River, adjoining the main axis of the bay. In the open basins of the bay, chemical concentrations and toxicity generally were higher in areas north of the Rickenbacker Causeway than south of it. Sediments from the main basins of the bay generally were less toxic than those from the adjoining tributaries and canals. The different toxicity tests, however, indicated differences in severity, incidence, spatial patterns, and spatial extent in toxicity. The most sensitive test among those performed on all samples, a bioassay of normal morphological development of sea urchin embryos, indicated toxicity was pervasive throughout the entire study area. The least sensitive test, an acute bioassay performed with a benthic amphipod, indicated toxicity was restricted to a very small percentage of the area.

Both the degree and spatial extent of chemical contamination and toxicity in this study area were similar to or less severe than those observed in many other areas in the U.S. The spatial extent of toxicity in all four tests performed throughout the bay were comparable to the "national averages" calculated by NOAA from previous surveys conducted in a similar manner.

Several trace metals occurred in concentrations in excess of those expected in reference sediments. Mixtures of substances, including pesticides, petroleum constituents, trace metals, and ammonia, were associated statistically with the measures of toxicity. Substances most elevated in concentration relative to numerical guidelines and associated with toxicity

included polychlorinated biphenyls, DDT pesticides, polynuclear aromatic hydrocarbons, hexachloro cyclohexanes, lead, and mercury. These (and other) substances occurred in concentrations greater than effects-based guidelines in the samples that were most toxic in one or more of the tests.

EXECUTIVE SUMMARY

The National Status and Trends (NS&T) Program administered by the National Oceanic and Atmospheric Administration (NOAA) conducts a nationwide program of monitoring and bioeffects assessments. As a part of this program, regional surveys are conducted to determine the toxicity of sediments in estuarine and marine environments. Biscayne Bay was selected by NOAA for this survey because data from the NS&T Program Mussel Watch and data from previous surveys of the bay had shown a potential for toxicity and other adverse biological effects. In addition, no bay-wide information had been generated on the toxicological condition of the bay sediments and several agencies had indicated a need for this type of data and a willingness to assist NOAA in collecting them.

The study area was defined as extending from Dumbfoundling Bay at the north end to Little Card Sound at the south end, seaward to the barrier islands or reef, and landward to the shoreline or saltwater control structures. This area was determined to encompass a total of 484 kilometers^2 of the sea floor. During 1995 and 1996, 226 samples were collected from randomly-chosen locations and tested for toxicity and analyzed for chemical concentrations. Data from these tests and analyses are included in this report. Samples for benthic community analyses were collected at one-third of the stations; however, data from those analyses are not included in this report (Tables 1 and 2).

Toxicity in this survey of Biscayne Bay and vicinity was determined using a suite of four laboratory tests done on all 226 samples: (1) percent survival of marine amphipods (*Ampelisca abdita*) in 10-day tests of solid-phase (bulk) sediments; (2) changes in bioluminescent activity of a marine bacterium, *Photobacterium phosphoreum*, in 15-minute Microtox bioassays of organic extracts; (3) fertilization success of the sea urchin *Arbacia punctulata* in one hour tests of the sediment pore water; and (4) normal embryological development of *A. punctulata* in 48-hour tests of the pore water. In addition, a life cycle test of the reproductive success of a meiobenthic copepod was performed on 15 samples and cytochrome P-450 reporter gene system (RGS) assays were performed on 121 samples. The concentrations of trace metals, pesticides, other chlorinated compounds, polynuclear aromatic hydrocarbons, and sedimentological features of the sediments were determined in all samples.

Wide ranges in both chemical concentrations and toxicity were observed throughout the survey area. In the amphipod survival tests, highly significant toxicity was observed in samples that represented 62 km^2, 13% of a total of 484 km^2. This estimate is similar to the average of 10.9% calculated from studies performed throughout other U.S. bays and estuaries. The spatial extent of toxicity in the sea urchin tests of fertilization success in 100% pore waters was 47%, again, similar to the national average of 42.6%. In the Microtox tests, toxicity was apparent over 51% of the area, slightly lower than the national average of 61%. Highly elevated and moderately elevated responses in the P-450 RGS assays occurred in samples collected in 1996 that represented 3.3% and 0.0%, respectively, of the study area.

Table 1. Station locations - 1995.

Zone No.	Strata No.	Sample No.	Station No.	Location	Latitude	Longitude	Depth (m)
2	1	1	1,1	North Bay	25° 54.820 N	80° 08.069 W	4.30
2	1	2	2,1	North Bay	25° 54.593 N	80° 08.162 W	5.50
2	1	3	3,3	North Bay	25° 54.411 N	80° 08.062 W	5.50
2	2	4	1,1	North Bay	25° 55.231 N	80° 07.617 W	2.50
2	2	5	2,1	North Bay	25° 54.245 N	80° 07.564 W	4.00
2	2	6	3,1	North Bay	25° 54.398 N	80° 07.593 W	3.75
2	3	7	1,1	North Bay	25° 53.443 N	80° 08.871 W	2.50
2	3	8	2,1	North Bay	25° 54.144 N	80° 08.272 W	5.00
2	3	9	3,1	North Bay	25° 54.189 N	80° 07.938 W	4.00
6	1	10	1,1	Port of Miami	25° 46.760 N	80° 11.110 W	4.50
6	1	11	2,1	Port of Miami	25° 46.407 N	80° 10.914 W	4.00
6	1	12	3,1	Port of Miami	25° 46.472 N	80° 10.936 W	1.20
6	2	13	1,3	Port of Miami	25° 46.928 N	80° 10.668 W	11.0
6	2	14	2,1	Port of Miami	25° 46.696 N	80° 10.218 W	11.0
6	2	15	3,1	Port of Miami	25° 46.629 N	80° 09.973 W	11.0
6	3	16	1,1	Port of Miami	25° 46.445 N	80° 09.435 W	10.5
6	20	17	1,2	Port of Miami	25° 45.712 N	80° 10.558 W	1.4
6	20	18	2,1	Port of Miami	25° 45.201 N	80° 10.270 W	
6	4	19	1,2	Port of Miami	25° 46.064 N	80° 08.336 W	3.50
6	4	20	2,1	Port of Miami	25° 46.316 N	80° 08.572 W	4.50
6	4	21	3,3	Port of Miami	25° 46.179 N	80° 08.588 W	4.50
6	5	22	1,1	Port of Miami	25° 46.159 N	80° 10.077 W	8.0
6	5	23	2,4	Port of Miami	25° 45.959 N	80° 09.931 W	8.4
6	5	24	3,2	Port of Miami	25° 46.353 N	80° 10.745 W	8.4
6	R6	25	1,3	Port of Miami	25° 45.813 N	80° 09.537 W	2.9
6	R6	26	1,8	Port of Miami	25° 45.403 N	80° 09.376 W	1.2
6	R6	27	3,12	Port of Miami	25° 45.166 N	80° 10.086 W	1.5
6	7	28	1,1	Port of Miami	25° 45.110 N	80° 08.690 W	2.0
6	7	29	2,1	Port of Miami	25° 45.450 N	80° 08.710 W	2.7

Table 1 (continued)

Zone No.	Strata No.	Sample No.	Station No.	Location	Latitude	Longitude	Depth (m)
6	7	30	3,1	Port of Miami	25° 45.536 N	80° 08.853 W	4.6
6	8	31	1,1	Port of Miami	25° 45.645 N	80° 11.163 W	2.40
6	8	32	2,1	Port of Miami	25° 46.235 N	80° 10.990 W	6.00
6	8	33	3,1	Port of Miami	25° 45.749 N	80° 11.222 W	2.00
6	9	34	1,1	Port of Miami	25° 46.180 N	80° 10.780 W	2.50
6	9	35	2,1	Port of Miami	25° 46.010 N	80° 10.643 W	2.25
6	9	36	3,1	Port of Miami	25° 46.166 N	80° 10.433 W	2.25
6	10	37	1,1	Port of Miami	25° 45.307 N	80° 10.268 W	3.00
6	10	38	2,2	Port of Miami	25° 45.814 N	80° 09.963 W	2.50
6	10	39	3,1	Port of Miami	25° 45.908 N	80° 10.046 W	3.00
6	11	40	1,1	Port of Miami	25° 45.184 N	80° 11.400 W	2.80
6	11	41	2,1	Port of Miami	25° 44.957 N	80° 11.826 W	5.00
6	11	42	3,1	Port of Miami	25° 45.045 N	80° 11.313 W	2.40
6	12	43	1,1	Port of Miami	25° 44.654 N	80° 10.005 W	2.80
6	12	44	2,1	Port of Miami	25° 45.010 N	80° 10.643 W	3.00
6	12	45	3,1	Port of Miami	25° 45.117 N	80° 10.506 W	3.30
6	13	46	1,1	Miami River	25° 46.489 N	80° 12.144 W	5.20
6	13	47	2,1	Miami River	25° 46.268 N	80° 11.976 W	3.70
6	13	48	3,1	Miami River	25° 46.219 N	80° 11.507 W	5.30
6	14	49	1,1	Miami River	25° 46.267 N	80° 12.249 W	4.00
6	14	50	2,1	Miami River	25° 46.801 N	80° 12.644 W	4.00
6	14	51	3,1	Miami River	25° 46.938 N	80° 12.848 W	4.50
6	15	52	1,1	Miami River	25° 47.048 N	80° 13.144 W	3.00
6	15	53	2,1	Miami River	25° 47.229 N	80° 13.687 W	3.50
6	15	54	3,1	Miami River	25° 47.419 N	80° 14.164 W	2.25
6	16	55	1,1	Miami River	25° 47.727 N	80° 14.690 W	5.25
6	16	56	2,2	Miami River	25° 47.938 N	80° 14.917 W	4.75
6	16	57	3,1	Miami River	25° 48.084 N	80° 15.106 W	4.50

Table 1 (continued)

Zone No.	Strata No.	Sample No.	Station No.	Location	Latitude	Longitude	Depth (m)
6	17	58	1,1	Miami River	25° 48.324 N	80° 15.437 W	3.50
6	17	59	2,1	Miami River	25° 48.130 N	80° 15.182 W	4.00
6	17	60	3,1	Miami River	25° 48.334 N	80° 15.490 W	4.50
6	18	61	1,1	Seybold Canal	25° 47.036 N	80° 12.571 W	2.25
6	18	62	2,1	Seybold Canal	25° 46.919 N	80° 12.476 W	2.00
6	18	63	3,1	Seybold Canal	25° 46.769 N	80° 12.420 W	1.90
6	19	64	1,1	Tamiani Canal	25° 47.703 N	80° 14.754 W	2.50
6	19	65	2,1	Tamiani Canal	25° 47.669 N	80° 15.253 W	6.00
6	19	66	3,1	Tamiani Canal	25° 47.633 N	80° 15.678 W	2.50
8	1	67	1,1	South Bay	25° 32.587 N	80° 12.719 W	3.0
8	1	68	2,1	South Bay	25° 32.472 N	80° 16.026 W	2.5
8	1	69	3,2	South Bay	25° 31.629 N	80° 12.118 W	2.5
8	2	70	1,1	South Bay	25° 32.047 N	80° 18.192 W	1.4
8	2	71	2,1	South Bay	25° 31.817 N	80° 17.787 W	2.0
8	2	72	3,1	South Bay	25° 31.401 N	80° 19.149 W	1.0
8	3	73	1,1	South Bay	25° 30.955 N	80° 17.690 W	2.0
8	3	74	2,1	South Bay	25° 30.183 N	80° 17.659 W	1.5
8	3	75	3,1	South Bay	25° 30.944 N	80° 18.599 W	1.5
8	4	76	1,1	South Bay	25° 28.886 N	80° 19.707 W	1.5
8	4	77	2,1	South Bay	25° 28.871 N	80° 18.190 W	1.6
8	4	78	3,1	South Bay	25° 28.885 N	80° 17.331 W	2.3
8	5	79	1,1	South Bay	25° 27.719 N	80° 19.389 W	2.0
8	5	80	2,1	South Bay	25° 28.255 N	80° 18.724 W	1.8
8	5	81	3,1	South Bay	25° 28.568 N	80° 18.386 W	2.0
8	6	82	1,1	South Bay	25° 27.275 N	80° 17.901 W	2.0
8	6	83	2,1	South Bay	25° 26.772 N	80° 18.132 W	1.7
8	6	84	3,1	South Bay	25° 27.144 N	80° 19.035 W	1.5
8	7	85	1,1	South Bay	25° 26.006 N	80° 18.753 W	1.5

8	7	86	2,1	South Bay	25° 25.346 N	80° 17.534 W	1.6

Table 1 (continued)

Zone No.	Strata No.	Sample No.	Station No.	Location	Latitude	Longitude	Depth (m)
8	7	87	3,1	South Bay	25° 26.086 N	80° 18.184 W	1.6
8	8	88	1,1	South Bay	25° 28.844 N	80° 12.426 W	3.3
8	8	89	2,1	South Bay	25° 28.399 N	80° 14.890 W	2.6
8	8	90	3,1	South Bay	25° 25.974 N	80° 16.857 W	2.35
8	9	91	1,1	South Bay	25° 31.154 N	80° 19.121 W	1.1
8	14	92	1,1	South Bay	25° 32.229 N	80° 19.860 W	2.0
8	9	93	3,1	South Bay	25° 31.148 N	80° 19.146 W	0.9
8	10	94	1,1	South Bay	25° 31.155 N	80° 20.134 W	2.5
8	10	95	2,1	South Bay	25° 31.150 N	80° 20.530 W	4.3
8	10	96	3,1	South Bay	25° 31.165 N	80° 20.668 W	3.9
8	11	97	1,1	South Bay	25° 31.785 N	80° 18.813 W	
8	11	98	2,1	South Bay	25° 31.846 N	80° 18.958 W	3.6
8	11	99	3,1	South Bay	25° 31.754 N	80° 18.717 W	
8	10	100	3,1	South Bay	25° 31.949 N	80° 19.193 W	3.0
8	12	101	2,1	South Bay	25° 32.054 N	80° 19.441 W	3.4
8	12	102	3,1	South Bay	25° 32.025 N	80° 19.392 W	4.0
8	13	103	1,1	South Bay	25° 32.112 N	80° 19.498 W	4.0
8	13	104	2,1	South Bay	25° 32.279 N	80° 19.611 W	4.5
8	13	105	3,1	South Bay	25° 32.412 N	80° 19.724 W	4.0

Results from Biscayne Bay were comparable to those for northern Puget Sound (2.7% and 0.0%, respectively).

Results from some tests showed relatively good concordance with those from other tests. Overall, the data indicated that the sediments collected in the peripheral tributaries were much more toxic than those from the open water basins of the bay. Samples from the lower Miami River were most toxic in the amphipod survival tests, the least sensitive of the four tests performed bay-wide. Samples from Black Creek Canal also were highly toxic. The cytochrome P-450 RGS assays also indicated higher induction rates in samples from canals and tributaries, indicative of the presence of mixtures of organic compounds. Copepod life cycle assays showed impaired reproductive success in all 15 stations relative to controls - samples from the lower Miami River were the most toxic.

Chemicals of highest concern were those that were elevated relative to numerical guidelines in the most samples, showed strongest concordance with measures of toxicity, and were most elevated in concentrations in samples in which toxicity was most severe. Several substances met these criteria, including copper, lead, mercury, DDTs and PCBs. Concentrations of cadmium, copper, lead, and zinc exceeded reference levels in many samples.

Patterns in chemical contamination generally followed patterns in toxicity, but, there were several exceptions to this overall observation. Some samples with very low chemical concentrations in the southern reaches of the bay were highly toxic and a few samples with high chemical concentrations were not toxic, possibly reflecting heterogeneity within the samples. However, elevated concentrations of mixtures of trace metals, PAHs, PCBs, and other chlorinated substances from samples collected in the lower Miami River were highly correlated with reduced amphipod survival. Many samples from the lower Miami River had relatively high concentrations of these substances and caused very severe toxicity in the amphipod tests. Somewhat different mixtures of substances were highly correlated with toxicity observed in the urchin tests performed on samples from the canals of south bay. Results of the P-450 RGS assays were highly correlated with mixtures of high molecular weight PAHs, PCBs, and other organic compounds.

The spatial extent of elevated chemical concentrations, however, was 2% or less for all substances, indicating that significant contamination was restricted to the small peripheral canals and tributaries of the system. Of the 226 samples analyzed, 33 (14.6%) had at least one chemical concentration that exceeded a mid-range numerical sediment quality guideline. These 33 samples represented about an area of about 3.5 km^2 (0.7% of the total). Both the percentages of samples that exceeded numerical guidelines and the surficial extent of contamination as compared to the guidelines were lower than observed elsewhere in comparable studies performed elsewhere in U. S. estuaries.

Results of this survey indicated that the concentrations of chemical mixtures were sufficiently elevated in some sediments to contribute to acute and sublethal toxicity in laboratory tests. Concentrations of individual chemicals were elevated in only a very small portion of the total survey area - restricted mainly to the narrow canals and tributaries. The toxicity tests confirmed that toxicity, as measured with the acute amphipod survival test, was restricted in surficial extent to a small percentage of the area. However, toxicity as

measured with the sublethal urchin and Microtox tests was much more pervasive. The ecological significance of the elevated chemical concentrations and significant toxicity will be estimated when analyses are completed on the benthic community samples.

INTRODUCTION

Background. As a part of the National Status and Trends (NS&T) Program, NOAA conducts assessments of the adverse biological effects of toxic chemicals in selected regions and estuaries. Studies are performed to determine bioeffects of toxicants in fishes, bivalve molluscs and sediments. This report is one in a series of regional reports on sediment quality. Previous reports have been produced for the Hudson-Raritan estuary, Long Island Sound, Boston Harbor, Tampa Bay, San Diego Bay, San Pedro Bay, southern California estuaries, western Florida panhandle, and South Carolina / Georgia bays and summarized in Long et al. (1996).

Biscayne Bay was selected by NOAA for this survey because data from the NS&T Program Mussel Watch and from previous surveys of the bay (summarized below) had shown a potential for toxicity and other adverse biological effects. In addition, no bay-wide information had been generated on the toxicological condition of the bay sediments and several agencies had indicated a need for this type of data and a willingness to assist NOAA in collecting them. As part of requirement of dredging studies, toxicity tests had been performed on sediments from the lower Miami River; however, there were no data generated for the majority of the Biscayne Bay area.

The study area for this survey extended from Dumfoundling Bay in the north to the Little Card Sound bridge in the south, west to the mainland of the south Florida peninsula and the saltwater control structures of selected canals, and east to Miami Beach and the barrier islands (**Figure 1**). In this report, portions of the area are referred to as north bay, central bay, and south bay, following SFWMD (1994). North bay extends from Dumfoundling Bay to the Rickenbacker Causeway, central bay extends from Rickenbacker Causeway to Black Point, and south bay extends from Black Point to Arsenicker Keys and Mangrove Point.

The study area was divided into nine sampling zones that conformed to the major physiographic basins of the study area **(Figure 1).** Zone 1 was the northern-most region and included Dumbfoundling Bay, Maule Lake, Oleta River, and portion of the Intracoastal Waterway (ICW) **(Figure 2).** Zone 2 extended to study area southward along the ICW to the Broad Ave. Causeway **(Figure 3).** Zone 3 extended from the Broad Ave. Causeway to the 76th St. Causeway and included the lower Biscayne Canal **(Figure 4).** Zone 4 ranged from the 76th St. Causeway south to the Julia Tuttle Causeway and included the Little River and Indian Creek **(Figure 4).** In zone 5, samples were collected between the Julia Tuttle Causeway and the MacArthur Causeway **(Figure 5**). Zone 6 included the Port of Miami from MacArthur Causeway to the Rickenbacker Causeway **(Figure 6)** and the lower Miami River / 'Seybold Canal / Tamiami Canal from Brickell Point to the railroad bridge **(Figure 7)**. Zone 7 extended from the Rickenbacker Causeway south to the 25°35' latitude **(Figure 8**) and included portions of Coral Gables Canal **(Figure 9)** and Snapper Creek Canal **(Figure 10)** seaward of the saltwater control structures. Zone 8 extended from the 25°35' latitude to the vicinity of Turkey Point **(Figure 11)** and included portions of Black Creek / Gould's

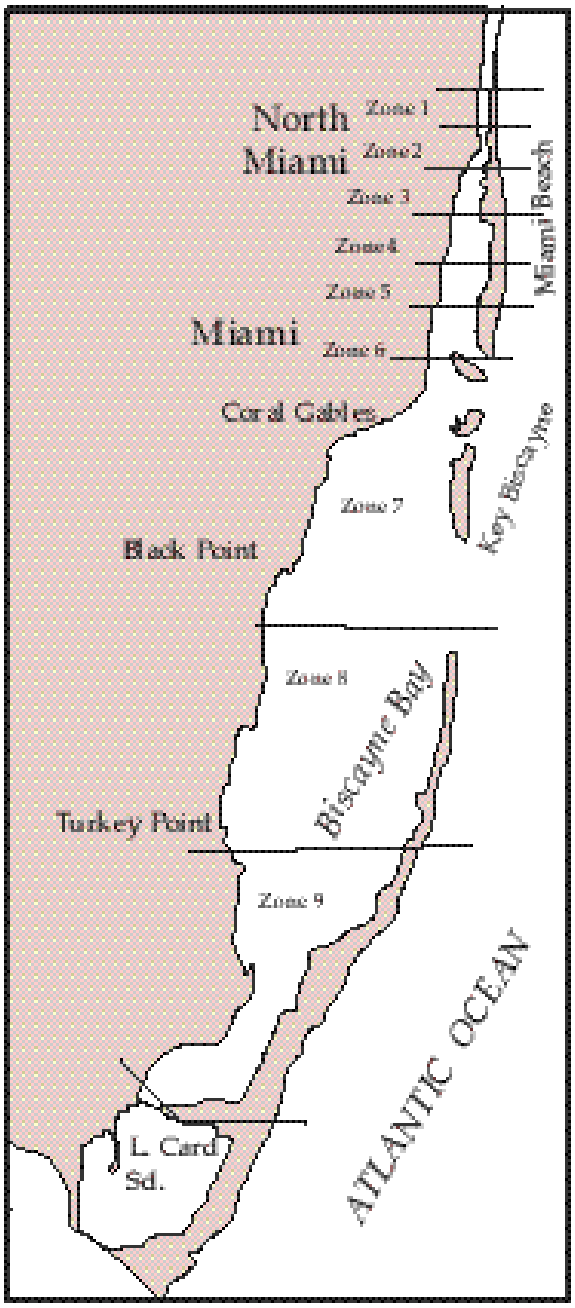


Figure 1. Study area and geographic sampling zones for Biscayne Bay.

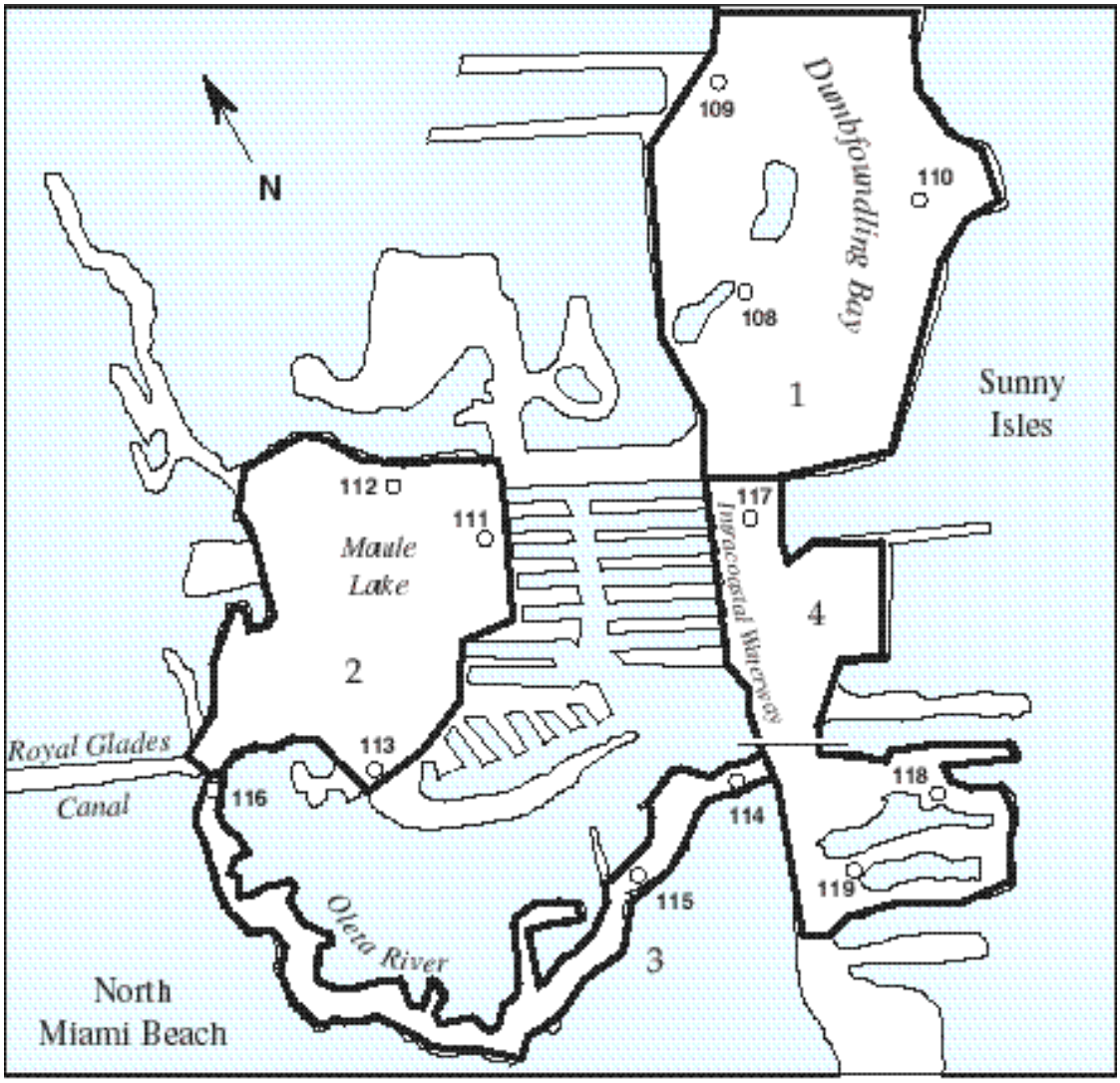


Figure 2. Sampling stations and strata boundaries in zone 1 of Biscayne Bay.

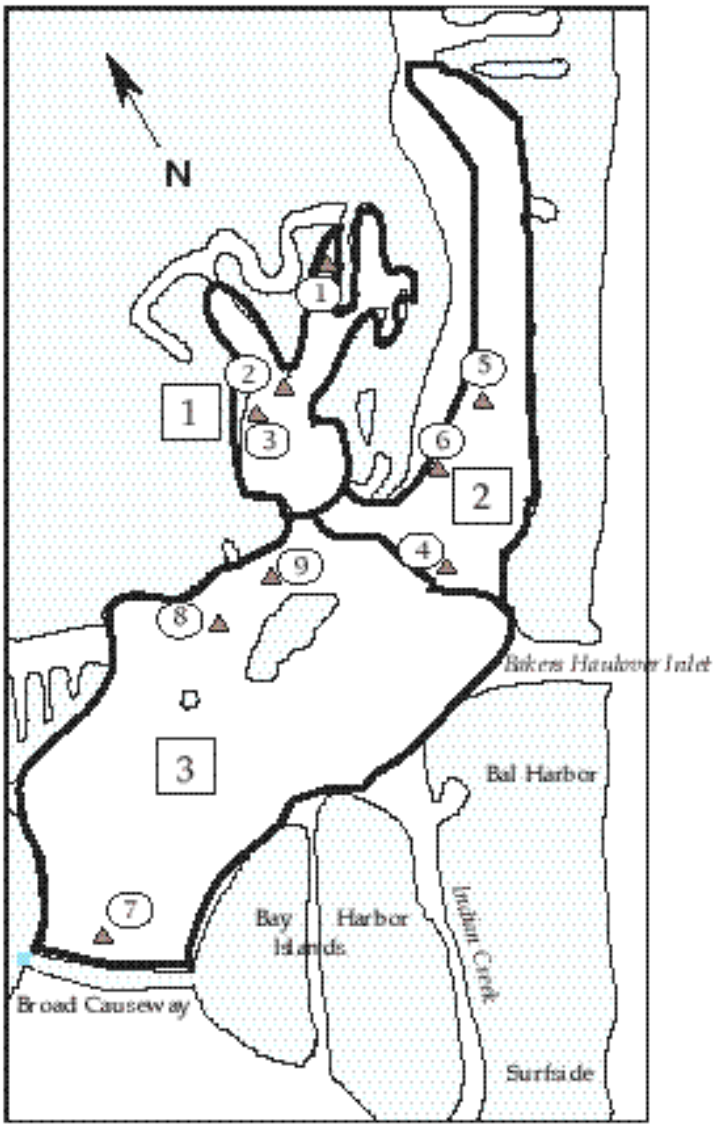


Figure 3. Sampling stations and strata boundaries for zone 2

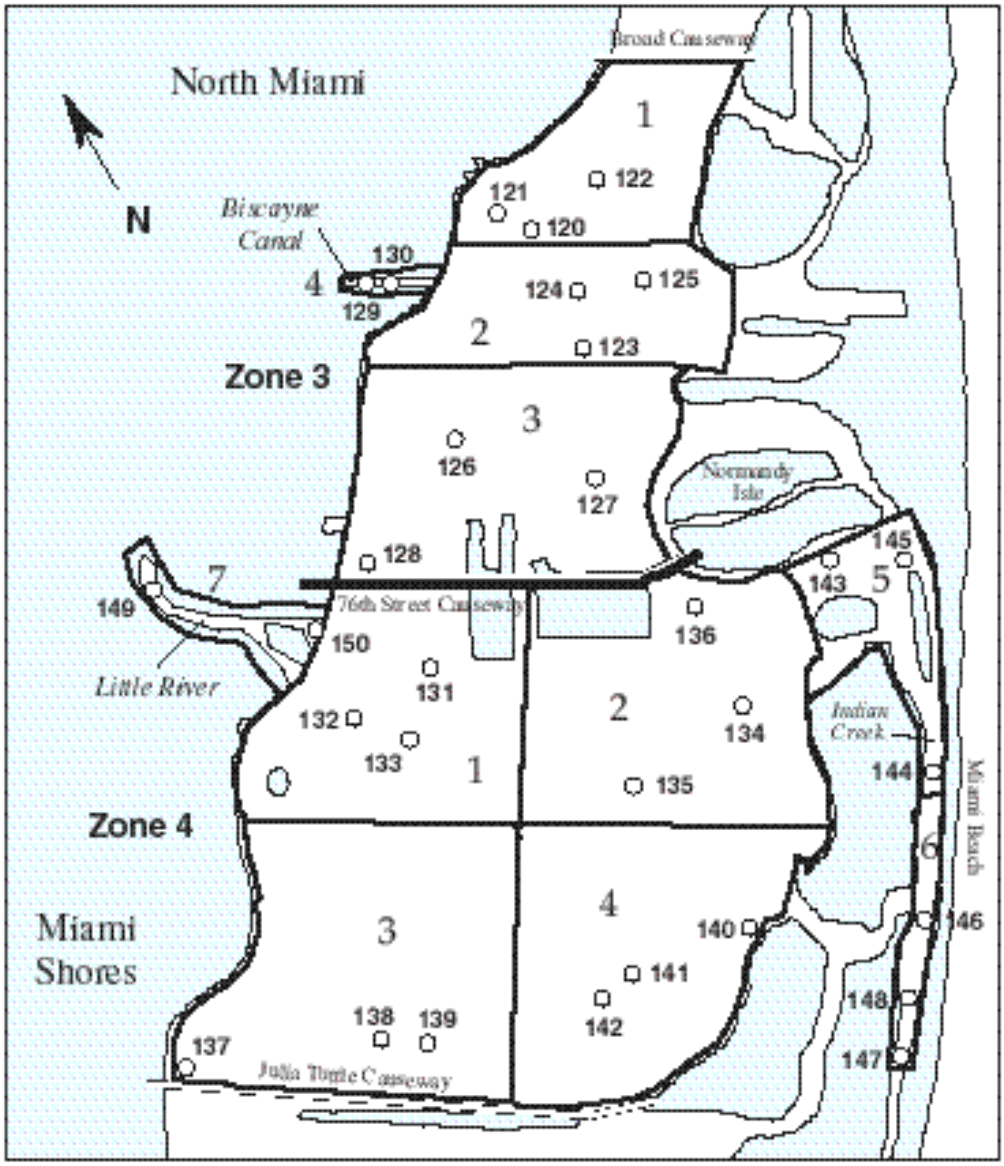


Figure 4. Sampling stations and strata boundaries for zones 3 and 4.

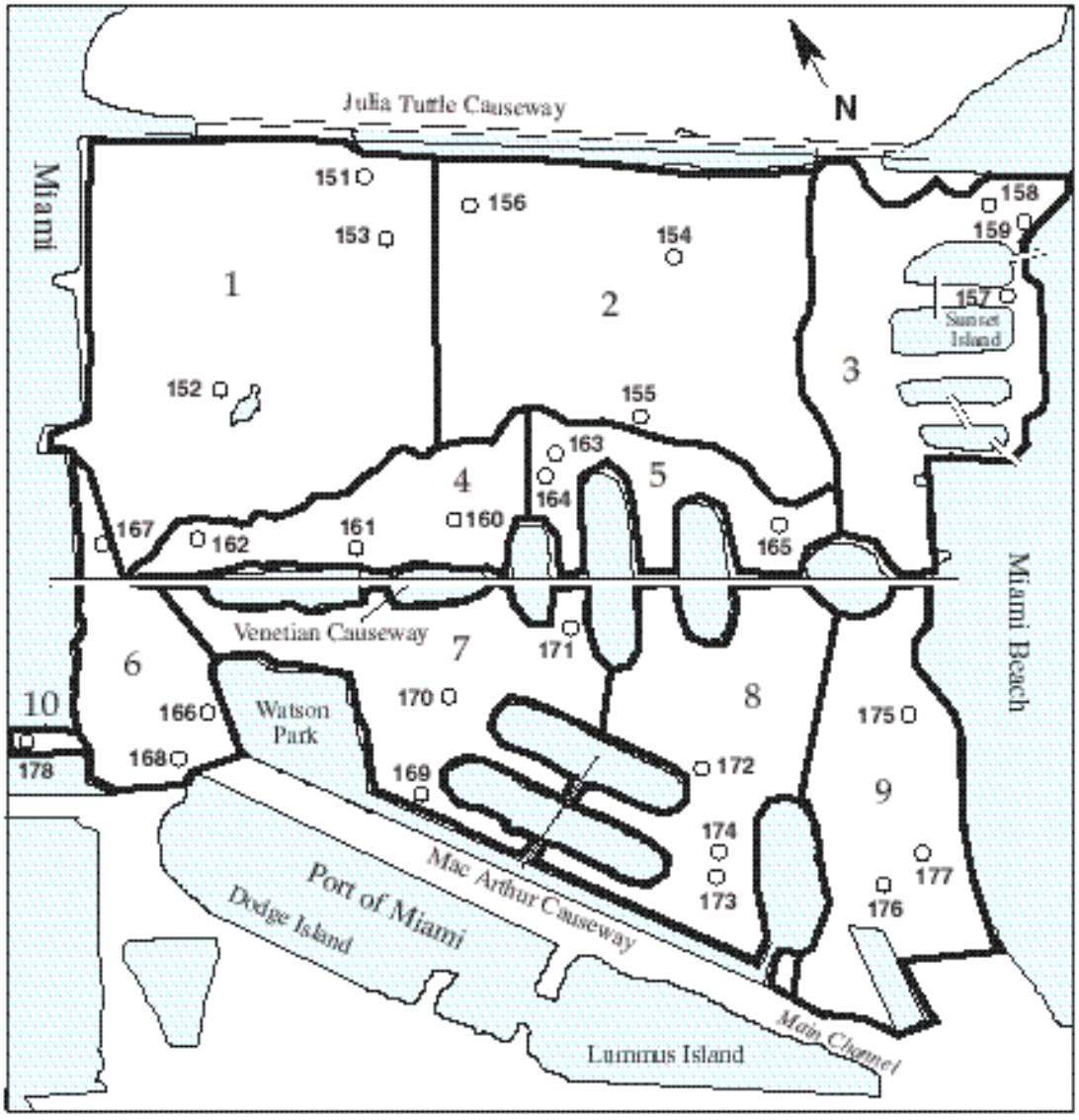


Figure 5. Sampling stations and strata boundaries for zone 5.

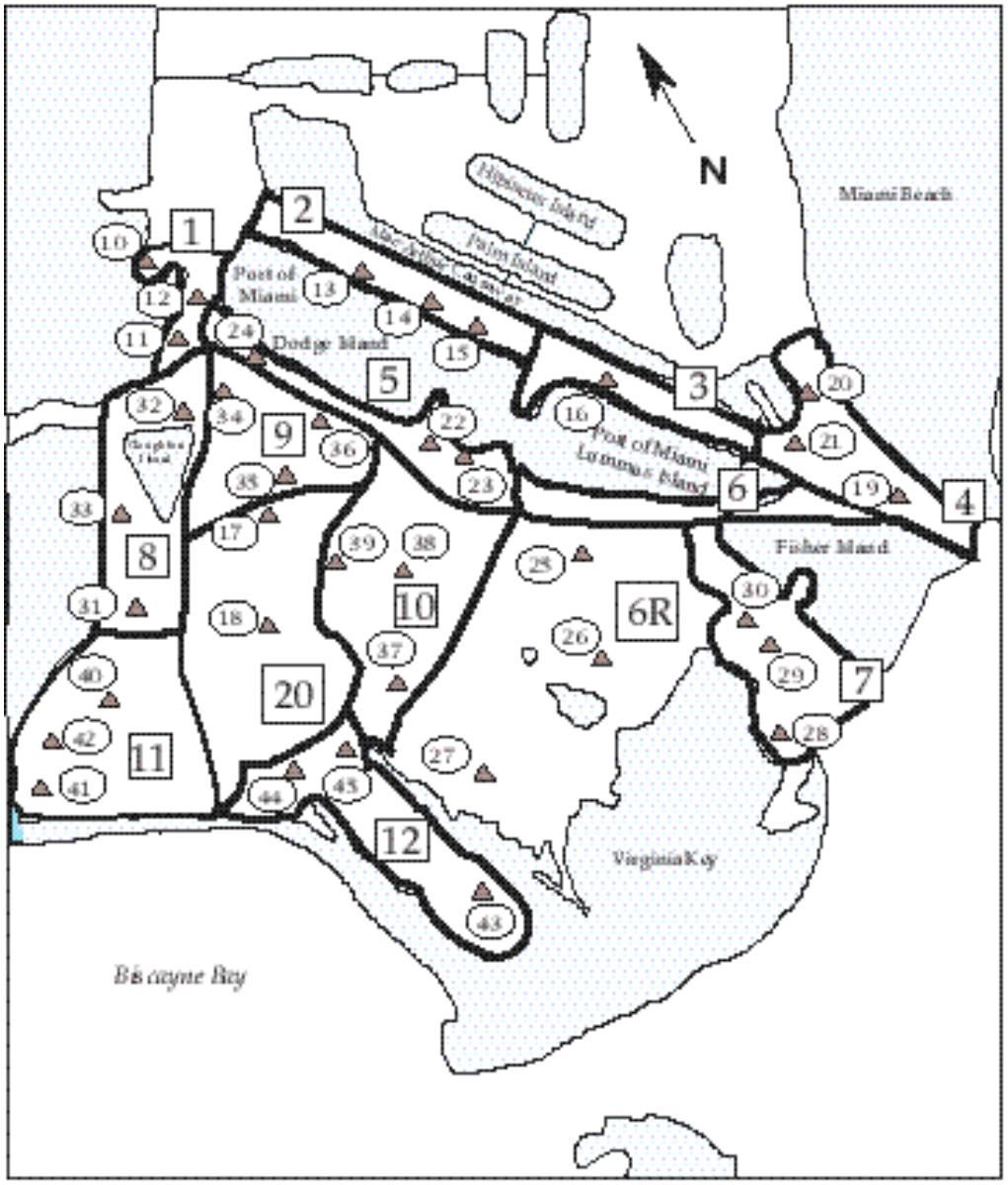


Figure 6. Sampling stations and strata boundaries for zone 6.

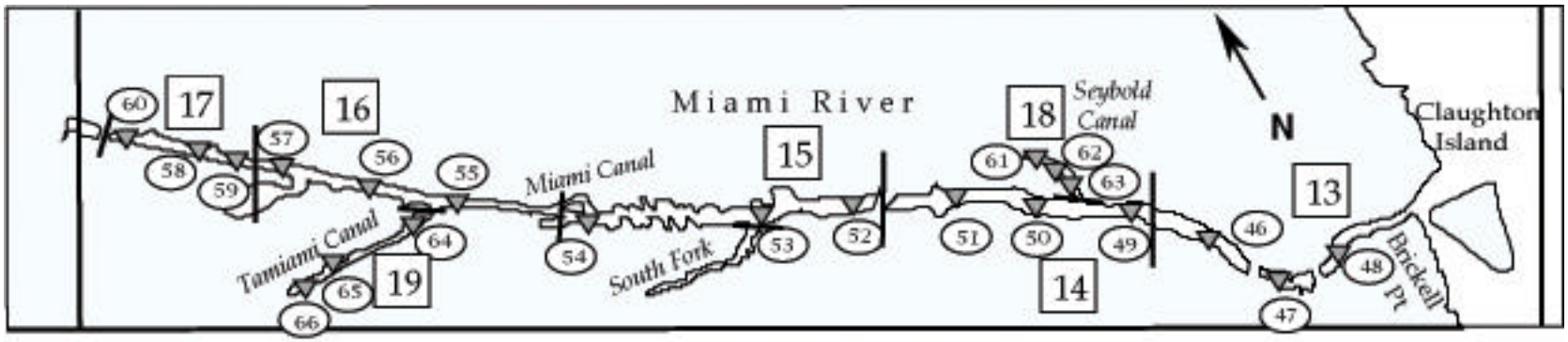


Figure 7. Sampling stations and strata boundaries for the Miami River (zone 6).

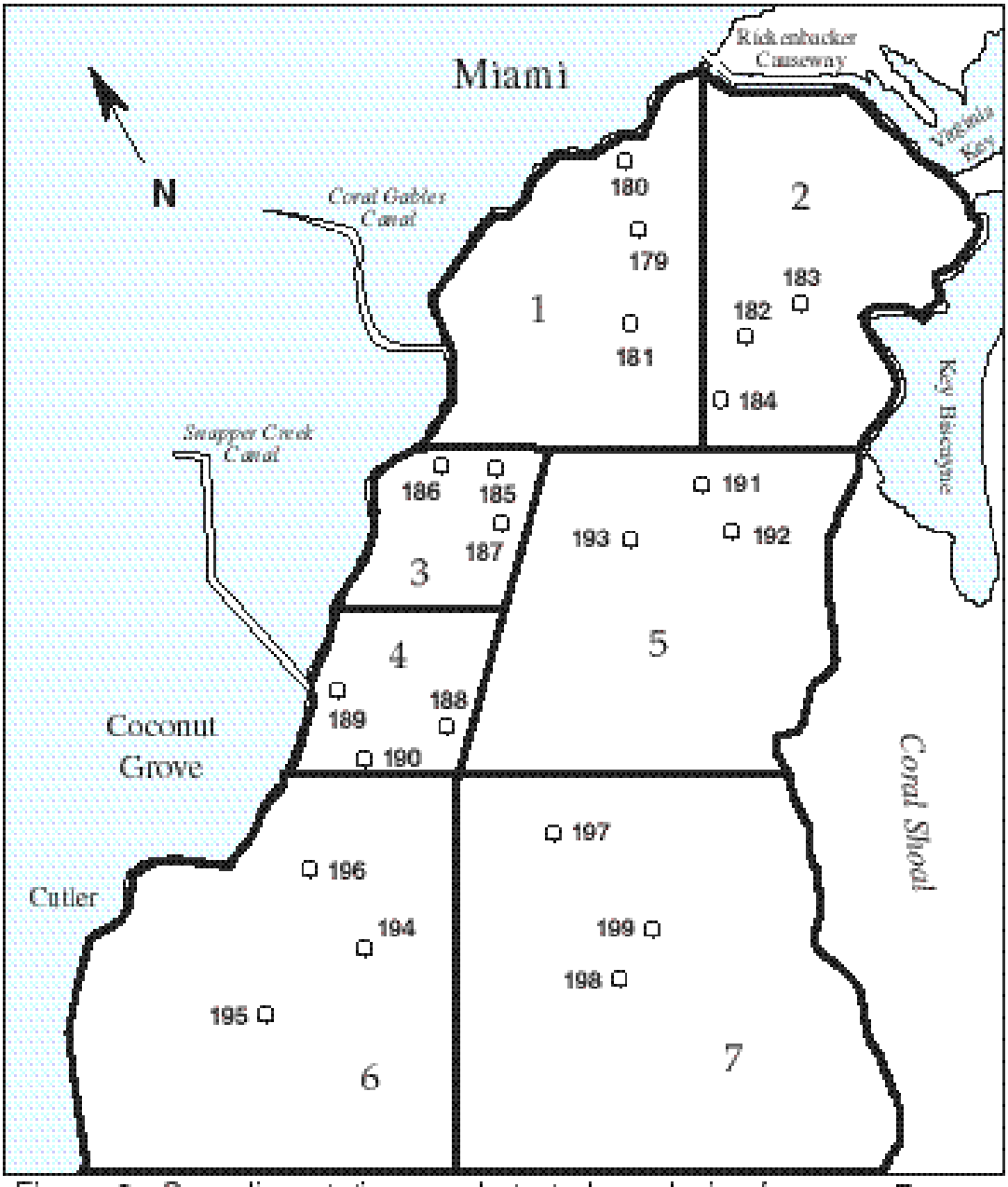


Figure 8. Sampling stations and strata boundaries for zone 7.

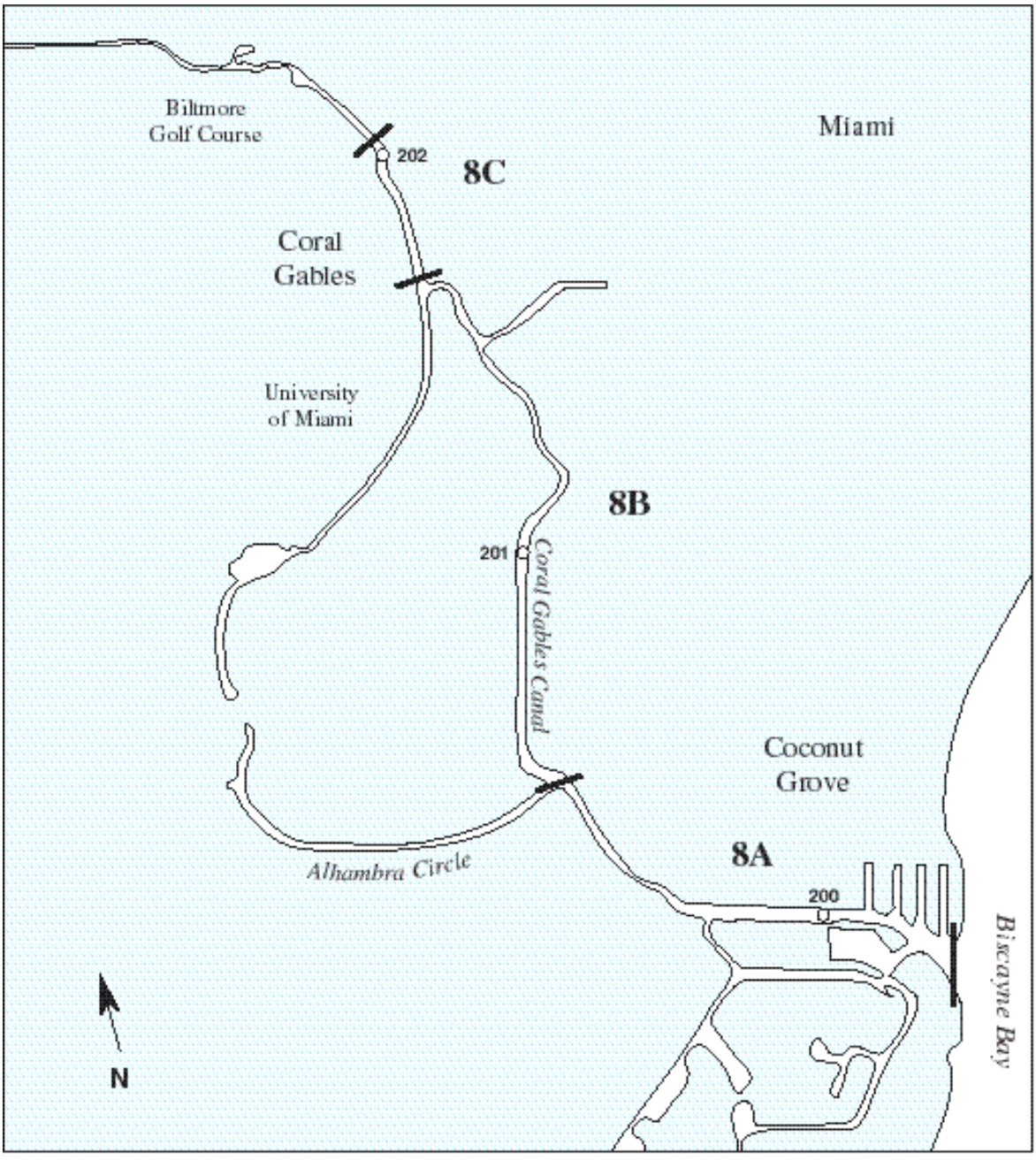


Figure 9. Sampling stations and stratum boundary Coral Gables Canal (zone 7).

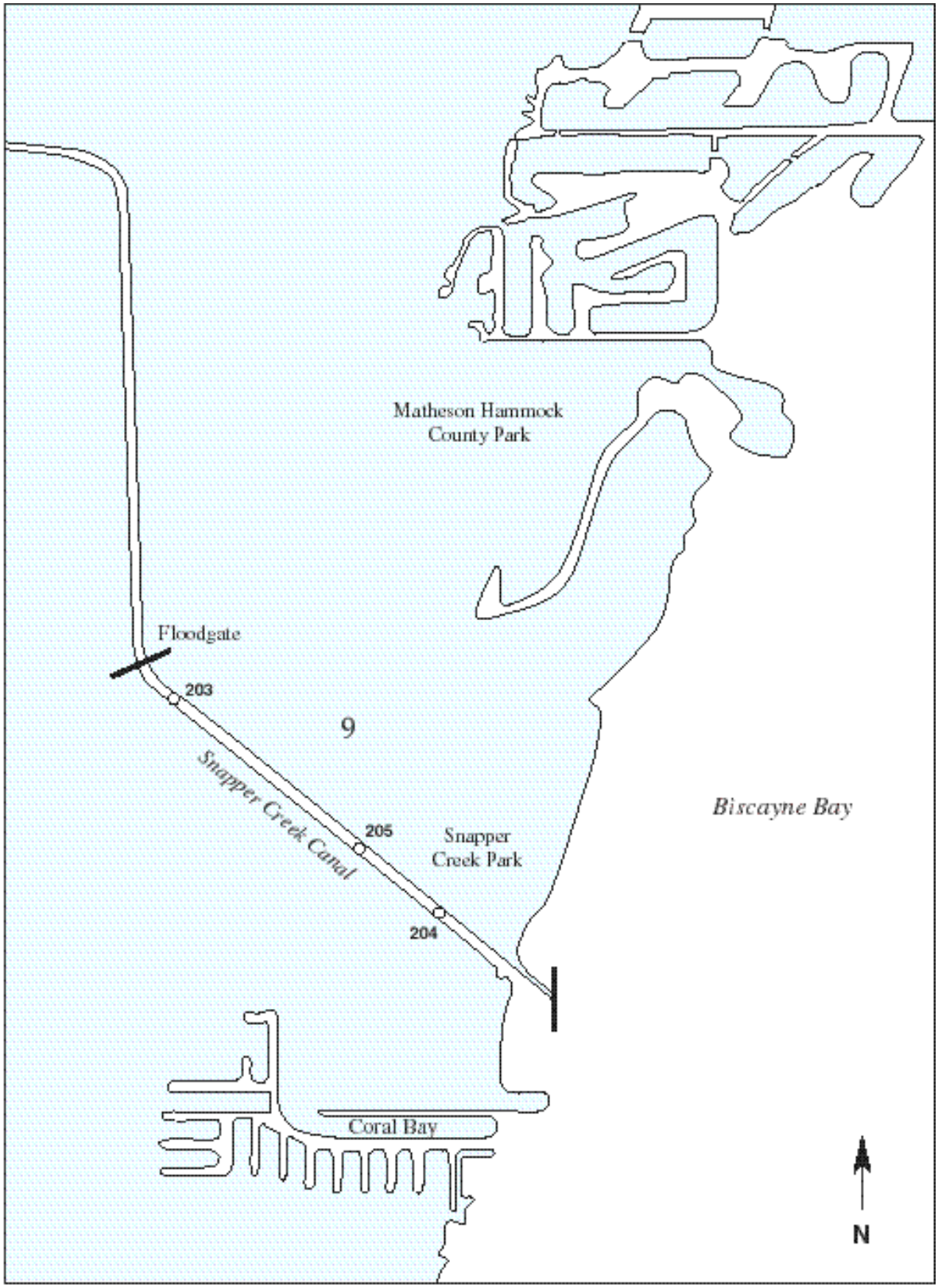


Figure 10. Sampling stations and stratum boundary for Snapper Creek Canal (zone 7).

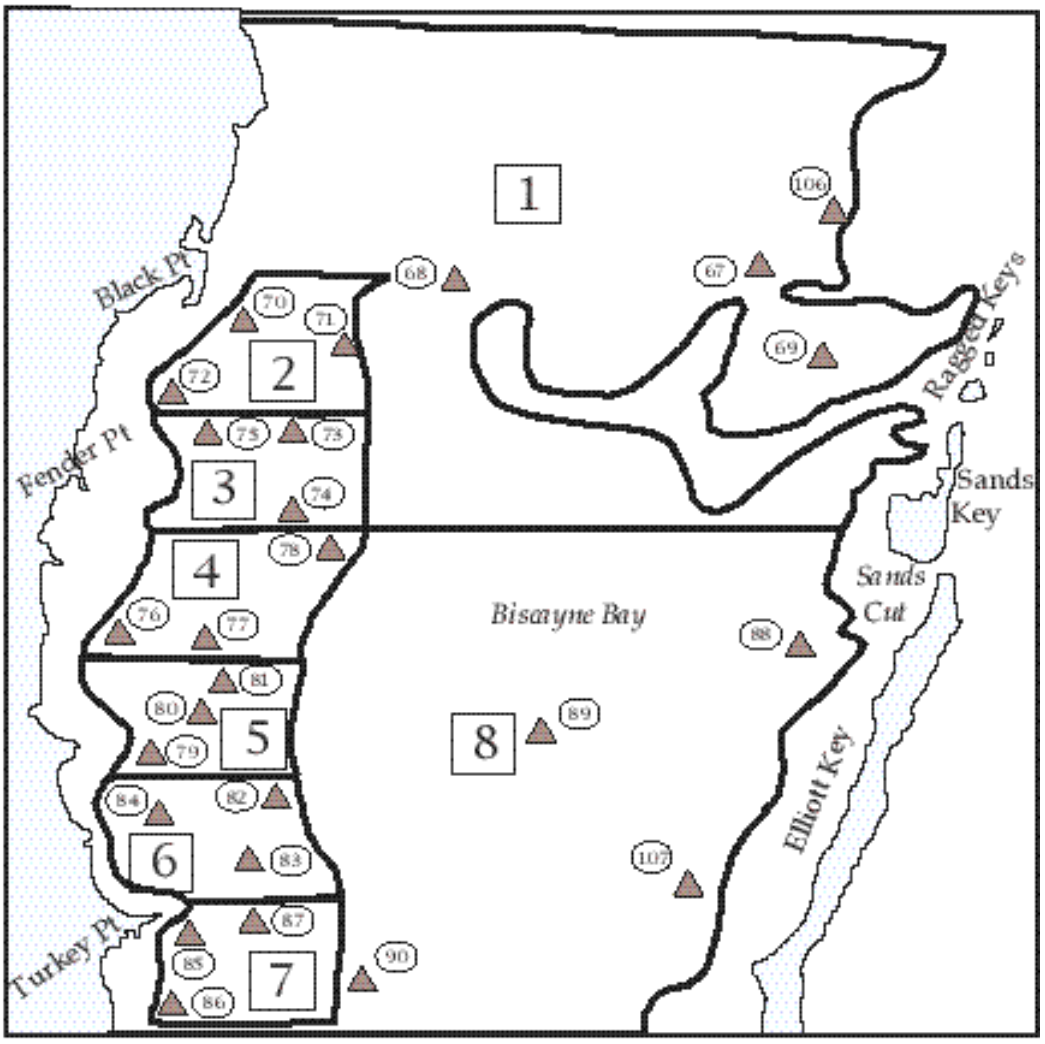


Figure 11. Sampling stations and strata boundaries in zone 8.

Canal, Princeton Canal, Military Canal, Mowry Canal, and North Canal **(Figures 12-13).** In the southernmost area, zone 9 extended from the vicinity of Turkey Point to the Little Card Sound bridge **(Figure 14**).

Historical Data on Contamination. Biscayne Bay has been highly modified by numerous dredge and fill projects, most of which were completed during the 1920's to 1940's (SFWMD, 1994). As early as the 1970's, environmental scientists have recognized that chemical pollutants were entering the bay from the Miami River and other canals and altering the chemistry of the system (Waite, 1976). Many different studies have been conducted in recent years on the concentrations and distributions of potentially toxic chemicals in Biscayne Bay and adjoining canals. The geographic scope and objectives of these studies differed, but, nevertheless, the data from these studies provided a relatively consistent picture of chemical contamination in the surficial sediments of the bay.

The largest of these studies was performed by Corcoran et al. (1983) who collected samples from 205 locations throughout the area. The samples were initially analyzed for hydrocarbons; however, some selected samples were analyzed later for other substances. Their study area was equivalent to that of the NOAA study reported herein; i.e., from Dumfoundling Bay (25°58'N) in the north to Card Sound (25°24'N) in the south. In the first year of their survey, 155 samples were collected at locations scattered throughout the area. All stations locations were carefully selected with criteria intended to provide data to represent conditions in specific areas; none of the stations were randomly chosen. Total hydrocarbon analyses of Soxhlet, organic-solvent, extracts were performed with gas chromatography of core sections from the upper 5 cm. of sediments.

In the samples from the first year, highest hydrocarbon concentrations were found in the lower Miami River, especially at a site near the the monorail bridge (2449 ug total aromatic hydrocarbons / g) and near the railroad bridge (459 ug / g). Other samples with relatively high hydrocarbon concentrations were collected in several other areas, including an area east of Mowry / Military / North canals, near the Miami Beach marina, near the Sunset Beach marina, in lower Little River, near the Sunny Isles Bridge, and several isolated stations in the northern portion of the bay. Lowest concentrations were reported for stations down the north-south axis of the bay and in south bay.

In the second year of this study, Corcoran et al. (1983) collected additional samples as a confirmation step mostly in the areas shown in the first year to have relatively high concentrations. These analyses confirmed that high hydrocarbon concentrations were apparent in samples from the Miami River, Little River, Military Canal, Oleta River, Indian Creek, and Gould's Canal. Concentrations invariably dropped quickly beyond the mouths of these canals. To confirm this observation, they reported an inverse relationship (correlation coefficient of -0.54) between water salinity and hydrocarbon concentrations.

The overall pattern in the concentrations of both total hydrocarbons and aromatic hydrocarbons was one in which the highest concentrations generally occurred in the lower Miami River, followed by concentrations in marinas and other canals mostly in the northern and central regions of the bay. Lowest concentrations were reported for samples collected throughout most of south bay. In addition, although relatively high hydrocarbon concentrations were apparent in many sediment samples, analyses of bulk water and fish tissues at

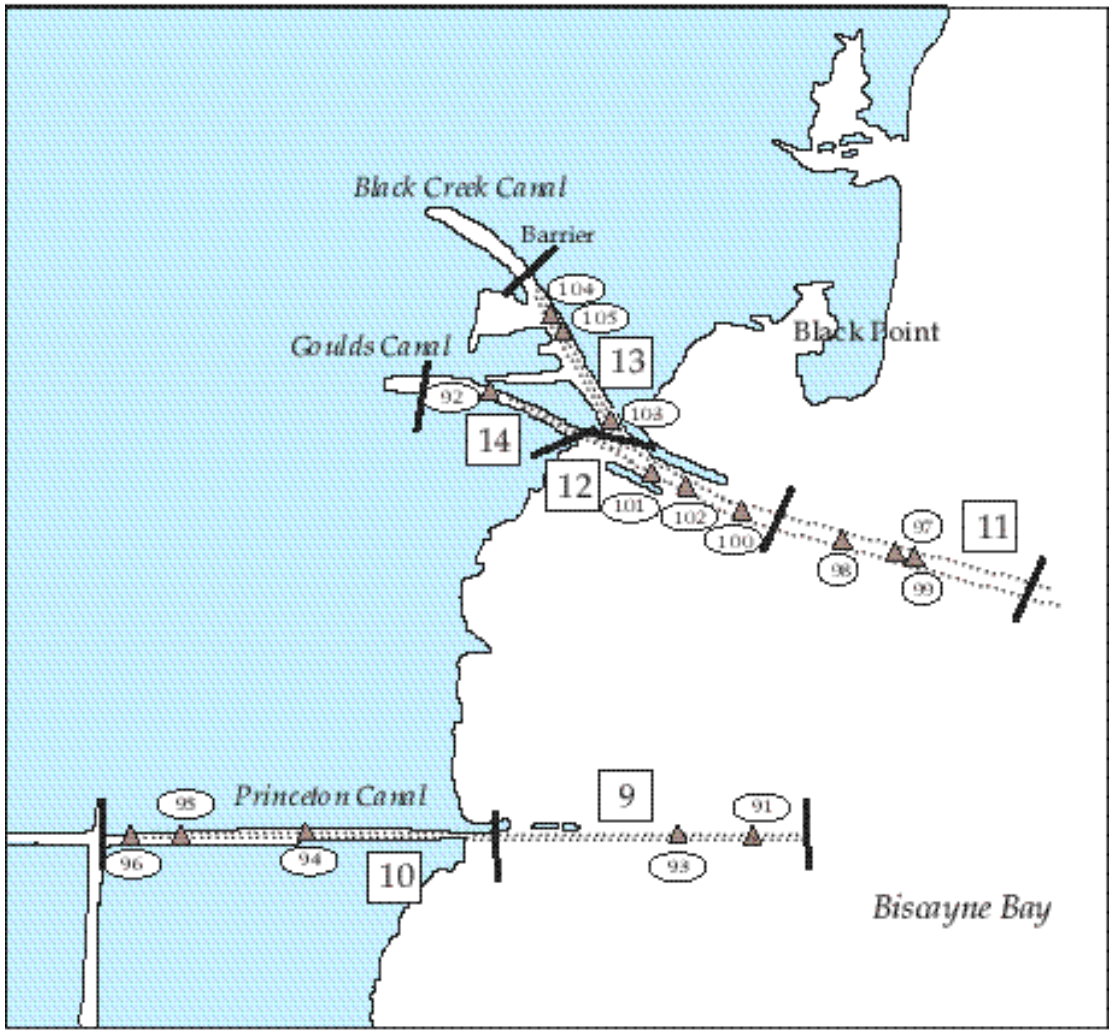


Figure 12. Sampling stations and strata boundaries for Gould's and Princeton canals (zone 8).

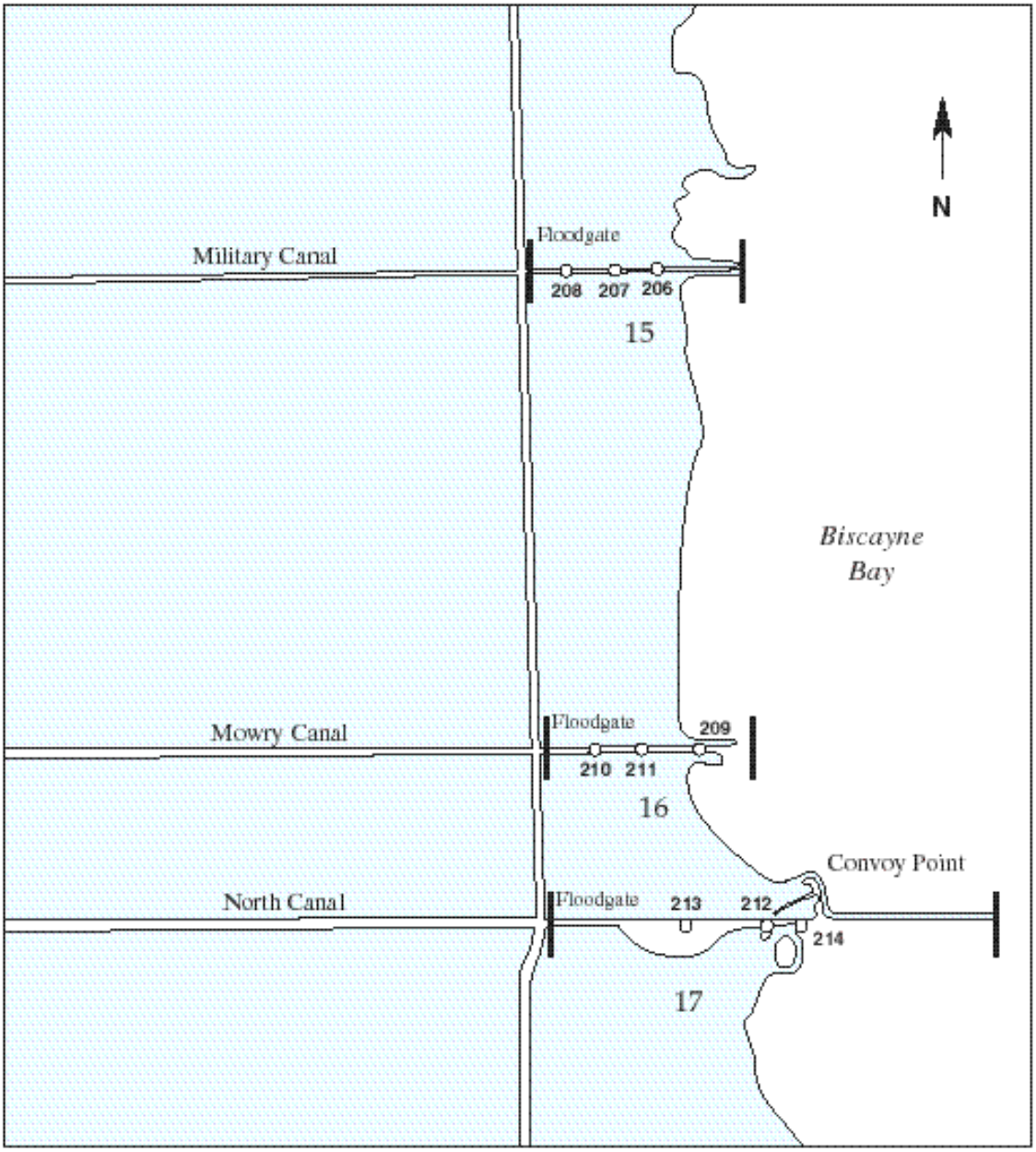


Figure 13. Sampling stations and strata boundaries for Military, Mowry, and North canals (zone 8).

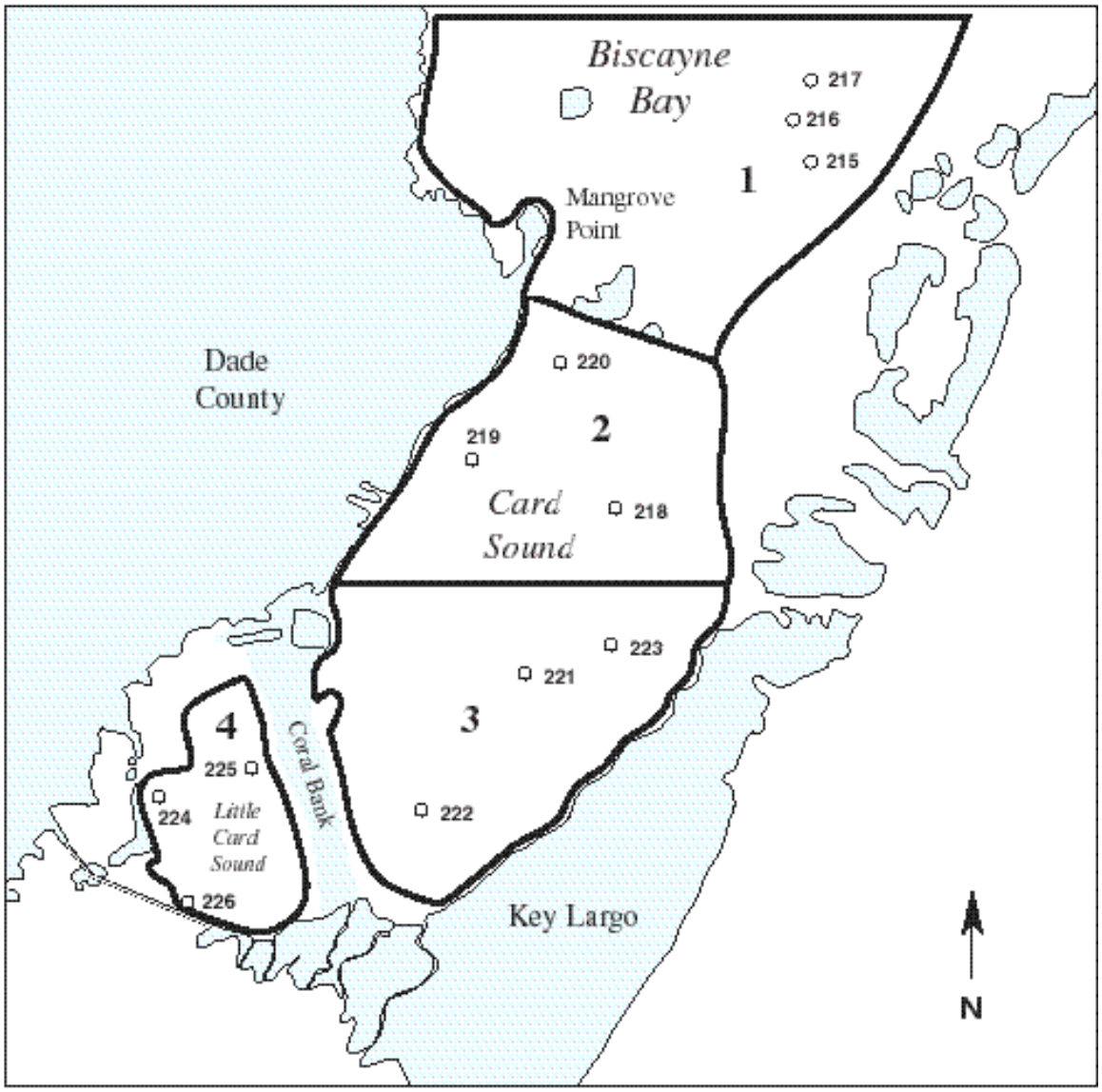


Figure 14. Sampling stations and strata boundaries for zone 9.

many of these locations failed to show elevated concentrations, indicating that these substances were readily sorbed to the sediments (Corcoran et al.,1983).

Corcoran (1983) also analyzed some samples collected during the hydrocarbon study (Corcoran et al.,1983) for pesticides and trace metals. Detectable concentrations of endosulfan (14.5 to 1014.3 ng/g), p,p'+o,p'-DDT (to 52.7 ng/g), and Aroclor 1254 (3.6 to 58.6 ng/g) were reported in the samples. Mercury concentrations ranged from 0.05 to 0.16 ug/g, copper from 2.0 to 7.7 ug/g, lead from 1.0 to 32.0 ug/g, zinc from 4.4 to 72 ug/g, and cadmium concentrations were 0.1 ug/g or less. Highest concentrations of most substances occurred in the sample from the Little River.

In 1984 Corcoran et al. (1984) reported the concentrations of additional substances from 45 of the samples archived from 1983 hydrocarbon survey. Highest concentrations of DDTs (p,p'+o,p') again were reported for the canals: Little River (up to 52.7 ng/g), Oleta River, Gould's Canal/Black Creek, and near Turkey Pt. (2 to 6 ng/g). Concentrations outside the canals ranged from less than 2 to 17.3 ng/g for both total DDTs and DDEs. Phthalate acid esters were found in detectable concentrations in 43 of the 45 samples.

Corcoran et al. (1984) also reported detectable concentrations of endosulfan in the Miami River (124.2 ng/g), C-102 canal, Mowry Canal, Little River (1014.3 ng/g) and Dumfoundling Bay samples. They reported that herbicides (2, 4, 5-T and 2, 4-D, and silvex) were found in 78% of samples and probably occurred with dioxins as impurities. PCBs were detected in 69% of samples with the highest concentrations occurring in samples from the canals; for example 1016 ng/g from a north bay station. PCB concentrations, excluding samples from the canals, ranged from less than 2 ng/g to 307.5 ng/g. The highest concentrations of chromium, cadmium, mercury, lead, and zinc were found in samples from the canals and lakes.

Most of the historical data on chemical concentrations were compiled and summarized by Schmale (1991) to identify large-scale patterns in contamination in the bay. The data showed a familiar pattern: highest concentrations of most substances in peripheral canals, rivers, streams, and marinas and lowest concentrations down the central north-south axis of the bay. Analyses of ethyoxy-resorufin-deethylase (EROD) and glutathione-s-transferase (GST) activities in fish tissues at many locations in the bay showed differences among fish and sampling locations, often coincident with elevated chemical concentrations in the sediments.

Based upon their review of available chemical data, the South Florida Water Management District (SFWMD, 1994) concluded that water and sediment quality degradation were problems in Biscayne Bay. They identified chronic problems with contamination by sewage in portions of Biscayne Bay and identified trace metals, chlorinated hydrocarbons, petroleum hydrocarbons, and tributyl tins as substances which had accumulated in the sediments of the central bay. They cited data showing elevated sediment contamination, occurrence of deformed fish, and elevated liver enzyme activities in fish as evidence of pollution problems. They identified leachates from the Munisport landfill and ammonia in north bay as problems.

SFWMD (1994) recommended the initiation of a sediment monitoring program, monitoring of chemical concentrations in bivalve and fish tissues, and the use of the Florida Department of Environmental Protection (FDEP) sediment quality guidelines in the identification of sites of concern. They identified many different projects which were completed and others that are planned to help improve water and sediment quality. A synopsis of data from analyses of fresh water and sediment performed during 1991-1995 in many south Florida canals indicated the presence of many pesticides, including atrazine, ametryn, bromacil, simazine and norflurazon in water samples and DDE, DDD, and amtetryn in sediments (Miles and Pfeuffer, 1997).

Goals and Objectives. The overall goal of this study was to provide a characterization of the toxicological condition of sediments in Biscayne Bay and vicinity, including saltwater reaches of key tributaries, as a measure, or indicator, of adverse biological effects of toxic chemicals. Based upon chemical analyses of sediments reported in previous studies it appeared that there were relatively high probabilities that concentrations were sufficiently high in some regions of the study area to cause acute toxicity. Data from toxicity tests were intended to provide a means of determining whether toxic conditions actually occurred throughout any of the area.

Several specific technical objectives were established to serve as guides for the sampling designs and analytical plans. The objectives of the study were to:
(1) determine the incidence and degree of toxicity of sediments throughout the study area;
(2) determine the spatial patterns (or gradients) in chemical contamination and toxicity, if any, throughout the study area;
(3) determine the spatial extent of chemical contamination and toxicity;
(4) determine the statistical relationships between measures of toxicity and concentrations of chemical substances in the sediments.

This report includes the data collected to satisfy all four objectives. Data to satisfy an additional objective (to determine if resident benthic populations were adversely affected in contaminated sediments) are not reported in this document. Benthic community data will be reported in a subsequent document.

METHODS

Sampling design. The study area included saltwater portions of the three major components of Biscayne Bay as defined by SFWMD (1994). A stratified -random sampling design similar to those used in previous surveys (Long et al., 1996) was applied in Biscayne Bay. The study area was subdivided into 74 irregular-shaped strata **(Figures 2-14)**. Large strata were established in the open waters of the bay where toxicant concentrations were expected to be uniformly low. This approach provided the least intense sampling effort in areas known or suspected to be relatively homogenous in sediment type, benthic communities, and water depth in regions relatively distant from contaminant sources. In contrast, relatively small strata were established in canals and urban harbors nearer suspected sources in which conditions were expected to be heterogeneous or transitional. As a result, sampling effort was more intense in the smaller strata than in the large strata. The large strata were roughly equivalent in size to each other and the small strata were roughly equivalent in size to each other.

This approach combines the strengths of a stratified design with the random-probabilistic selection of sampling locations. Data generated within each stratum can be attributed to the dimensions of the stratum. Therefore, these data can be used to estimate the spatial extent of toxicity with a quantifiable degree of confidence (Heimbuch, et al., 1995). Strata boundaries were established to coincide with the dimensions of major basins, bayous, waterways, etc. in which hydrographic, bathymetric and sedimentological conditions were expected to be relatively homogeneous.

Within the boundaries of each stratum, all possible latitude/longitude intersections had equal probabilities of being selected as a sampling location. The locations of individual sampling stations within each strata were chosen randomly using GINPRO software developed by NOAA applied to digitized navigation charts. In most cases three samples were collected within each stratum; in a few small strata only one or two stations were sampled. Four samples were collected in two large strata. Usually, four alternate locations were provided for each station in a numbered sequence. The coordinates for each alternate were provided in tables and were plotted on the appropriate navigation chart. In a few cases the coordinates provided were inaccessible by boat; these station locations were rejected and the vessel was moved to the next alternate. In small confined canals, the vessel was occasionally moved out of the center of the channel to avoid collisions with other boat traffic.

A total of 226 samples was collected; 105 during March-May, 1995 and 121 during May-July, 1996. Each location was sampled only once. Nine sampling zones were established within the study area to aid in planning field operations. These zones had no statistical relevance; however, some of the results were plotted within base maps prepared for each zone to aid clarity.

Sample collection. At each station the sampling vessel was piloted to the first alternate location for the sample collection. If the station was inaccessible or if the material at the location was only coarse sand with no mud component, that alternate location was abandoned and the second (third, or fourth, if needed) alternate was sampled. In almost all cases the first or second alternates were acceptable and were sampled. In one very unusual situation, strata 3 and 4 in zone 6 (eastern end of the Port of Miami channel), only hard limestone rock was encountered in numerous trials; therefore, necessitating a change in the size and boundaries of those strata.

Vessel positioning and navigation were aided with a differential-corrected, Trimble NavGraphic XL Global Positioning System (GPS) unit and a compensated LORAN C unit. Both systems generally agreed well with each other when both were operational. Both were calibrated and their accuracy verified each morning at a known location within the study area.

Samples for toxicity and chemical testing were collected with a Kynar-lined $0.1m^2$ modified van Veen grab sampler (also, known as a Young grab) deployed with an electric windless aboard the state of Florida R/V's *Raja* and *Lafiitte*. The grab sampler and sampling utensils were acid washed with 10% HCl at the beginning of each survey, and thoroughly cleaned with site water and acetone before each sample collection. Usually, 3 or 4 deployments of the sampler were required to provide a sufficient volume of material for the toxicity tests

and chemical analyses. The upper 2-3 cm. of the sediment were sampled to ensure the collection of recently-arrived materials. Sediments were removed with a plastic medical scoop and accumulated in a stainless steel pot. The pot was covered with a Teflon plate between deployments of the sampler to minimize sample oxidation and exposure to ship-board contamination. The material was carefully homogenized in the field with a stainless steel spoon before it was distributed to prepared containers for each analysis. At some locations in the south bay region, the grab sampler would not penetrate the firm coarse shell hash and sand. Samples at these locations were collected 2-3 cm. deep by divers pushing one-liter plastic jars horizontally through the sediments. Compositing of these samples was conducted the same way as those collected with the grab.

Samples for benthic community analyses were collected at one station randomly chosen within each stratum. Triplicate samples were collected at each station with a Young-modified, pettite (0.413 cm^2) van Veen grab. Samples for both toxicity / chemistry analyses and the benthic community analyses were collected at the same location. The entire contents of samples that were at least 5 cm. deep were retained and sieved in the field with a 0.5 mm. sieve. Material retained on the sieve was preserved in 10% buffered formalin with Rose Bengal. Samples were rejected if the jaws of the grab were open, if the sample was partly washed out or if the sample was less than 5 cm. deep. A fourth sample was collected at each location and material retained for total organic carbon and grain size analyses.

Sample jars for each toxicity test and chemistry analysis were sealed to prevent leakage and outside contamination and shipped in ice chests packed with frozen water bottles or blue ice to the testing laboratories by overnight courier. Samples for toxicity tests were kept chilled until extractions or tests were initiated. Samples for chemical analyses and cytochrome P-450 tests were kept frozen until thawed for analyses. All samples were accompanied by chain of custody forms which included the date and time of the sample collection, and station designation.

Locations of the individual sampling stations for each sampling zone are summarized in **Tables 1** (for 1995) and **2** (for 1996). Field log notes containing additional information on water column properties, and sediment characteristics at each station during sample collections are listed in Appendices A and B.

Multiple toxicity tests and complete chemical analyses were performed on all 226 sediment samples. Data from samples collected during 1995 and 1996 were merged and treated as equivalent and comparable.

Amphipod survival test. The amphipod tests are the most widely and frequently used assays in evaluations of marine and freshwater sediments performed in North America. In all cases and in this study, they are performed with adult crustaceans exposed to relatively unaltered, bulk sediments. The species *Ampelisca abdita* was chosen as the test species because of several strong attributes. This species has shown relatively little sensitivity to nuisance factors such as grain size, ammonia, and organic carbon in previous surveys. In previous surveys performed by the NS&T Program, this test has provided wide ranges in responses among samples, strong statistical associations with toxicants, and small within-sample variability.

Ampelisca abdita is an euryhaline benthic amphipod that ranges from Newfoundland to south-central Florida, and along the eastern Gulf of Mexico. The amphipod test with *A. abdita* has been routinely used for sediment toxicity tests in support of numerous EPA programs, including the Environmental Monitoring and Assessment Program (EMAP) in the Virginian, Louisianian, and Carolinian provinces (Schimmel et al., 1994).

In the first year of the Biscayne Bay survey, amphipod assays were conducted by Science Applications International Corporation, (SAIC) in Narragansett, R.I. In the second year, these tests were performed by TRAC Laboratories, Inc. in Pensacola, FL. In accordance with NOAA requirements, all tests were initiated within 10 days of the date samples were collected.

In tests performed in 1995, amphipods were collected by SAIC from tidal flats in the Pettaquamscutt (Narrow) River, a small estuary flowing into Narragansett Bay, Rhode Island. Animals were held in the laboratory in pre-sieved uncontaminated ("home") sediments under static conditions. Fifty percent of the water in the holding containers was replaced every second day when the amphipods were fed. During holding, *A. abdita* were fed laboratory cultured diatoms (*Phaeodactylum tricornutum*). Control sediments were collected by SAIC from the Central Long Island Sound (CLIS) reference station of the U.S Army Corps of Engineers, New England Division. These sediments have been tested repeatedly with the amphipod survival test and other assays and found to be non-toxic (amphipod survival has exceeded 90% in 85% of the tests) and un-contaminated. Subsamples of the CLIS sediments were tested along with each series of samples from Biscayne Bay.

In the 1996 tests, test animals were purchased by TRAC Labs. from Brezina and Associates of Dillon Beach, California. They were collected by Brezina in northern San Francisco Bay. Amphipods were packed in native sediment with 8-10 liters of seawater in doubled plastic bags. Oxygen was injected into the bags and shipped via overnight courier to the testing lab at Pensacola. Upon arrival, amphipods were acclimated and maintained at 20(C for one day prior to the initiation of the test. Control sediments for the 1996 testing were collected by TRAC Labs at their site "C-17" in Perdido Bay near Pensacola. These sediments had been tested repeatedly by TRAC Labs in previous research and found to be consistently non-toxic in amphipod tests and uncontaminated.

Amphipod testing performed by both laboratories followed the procedures detailed in the Standard Guide for conducting 10 day Static Sediment Toxicity Tests with Marine and Estuarine Amphipods (ASTM, 1992). Briefly, amphipods were exposed to test and negative control sediments for 10 days with 5 replicates of 20 animals each under static conditions using filtered seawater. Aliquots of 200 mL of test or control sediments were placed in the bottom of the one liter test chambers, and covered with approximately 600 mL of filtered seawater (28-30 ppt). For both sets of tests, air was provided by air pumps and delivered into the water column through a pipette to ensure acceptable oxygen concentrations, but suspended in a manner to ensure that the sediments would not be disturbed. Temperature was maintained at ~20(C by either temperature-controlled room (TRAC) or by water bath (SAIC). Lighting was continuous during the 10 day exposure period to inhibit the swimming behavior of the amphipods. Constant light inhibits emergence of the organisms from

the sediment, thereby maximizing the amphipod's exposure to the test sediments. Information on temperature, salinity, dissolved oxygen, pH and ammonia in test chambers was obtained during tests of each batch of samples.

Twenty healthy, active animals were placed into each test chamber, and monitored to ensure they burrowed into sediments. Non-burrowing animals were replaced, and the test initiated. The jars were checked daily, and records kept for dead animals, and animals on the water surface, emerged on the sediment surface, or in the water column. Those on the water surface were gently freed from the surface film to enable them to burrow, and dead amphipods were removed.

Tests were terminated after ten days. Contents of each of the test chambers were sieved through a 0.5 mm mesh screen. The animals and any other material retained on the screen were examined under a stereomicroscope for the presence of amphipods. Total amphipod mortality was recorded for each test replicate.

A positive control (reference toxicant) test was used to document the sensitivity of each batch of test organisms. The positive control consisted of 96 hr water-only exposures to sodium dodecyl sulfate (SDS) during both years. LC50 values were calculated for each test run. Control charts provided by both SAIC and TRAC Labs. showed consistent results in tests of both the positive and negative controls.

Sea urchin fertilization and embryological development tests. Tests of sea urchin fertilization and embryo development have been used in assessments of ambient water and effluents and in previous NS&T Program surveys of sediment toxicity (Long et al., 1996). Test results have shown wide ranges in responses among test samples, excellent within-sample homogeneity, and strong associations with the concentrations of toxicants in the sediments. The tests, performed with the early life stages of sea urchins (gametes and embryos), have demonstrated high sensitivity. These tests combined the features of testing sediment pore waters, the phase of sediments in which dissolved toxicants are highly bioavailable, and exposures to early life stages of invertebrates which often are more sensitive than adult forms.

Tests of sediment pore waters were conducted with the sea urchin *Arbacia punctulata.* This species is indigenous to the southeast coast, including southern Florida. These tests were performed during both years by the U.S. Geological Survey laboratory in Corpus Christi. Sea urchins used in this study were obtained from Gulf Specimen Company, Inc. (Panacea, Florida) and were acclimated to Port Aransas, TX, laboratory seawater before gametes were collected for testing.

Pore water was extracted from sediments with a pressurized squeeze extraction device (Carr and Chapman, 1992). Sediment samples were held refrigerated (at 4° C) until pore water was extracted. Pore water was extracted as soon as possible after receipt of the samples, but in no event were sediments held longer than 7 days from the time of collection before they were processed. After extraction, pore water samples were centrifuged in polycarbonate bottles (at 4200 g for 15 minutes in year one, and in year two using a new centrifuge - 1200 g for 15 minutes was adequate) to remove any particulate matter, and were then

frozen. Two days before the start of a toxicity test, samples were moved from a freezer to a refrigerator at 4° C, and one day prior to testing, thawed in a tepid water bath. Experiments performed by USGS have demonstrated no effects upon toxicity attributable to freezing of the pore water samples.

Sample temperatures were maintained at 20±1° C. Sample salinity was measured and adjusted to 30±1 ppt, if necessary, using ultrapure sterile water or concentrated brine. Other water quality measurements were made for dissolved oxygen, pH, sulfide and total ammonia. Temperature and dissolved oxygen were measured with YSI meters; salinity was measured with Reichert or American Optical refractometers; pH, sulfide and total ammonia (expressed as total ammonia nitrogen, TAN) were measured with Orion meters and their respective probes. The concentrations of un-ionized ammonia (UAN) were calculated using respective TAN, salinity, temperature, and pH values.

Each of the pore water samples was tested in a dilution series of 100%, 50%, and 25% of the water quality adjusted sample with 5 replicates per treatment. Dilutions were made with clean, filtered (0.45 *u*m), Port Aransas laboratory seawater, which has been shown in many previous trials to be non-toxic.

Tests followed the methods of Carr and Chapman (1992). Pore water from a reference area in Redfish Bay, Texas, an area located near the testing facility and in which sediment pore waters have been determined to be non-toxic in this test, was included with each toxicity test as a negative (non-toxic) control. Adult male and female urchins were stimulated to spawn with a mild electric shock, and gametes collected separately.

For the sea urchin fertilization test, 50 *u*L of appropriately diluted sperm were added to each vial, and incubated at 20±2°C for 30 minutes. One ml of a well mixed dilute egg suspension was added to each vial, and incubated an additional 30 minutes at 20± 2°C. Two mls of a 10% solution of buffered formalin solution was added to stop the test. Fertilization membranes were counted, and fertilization percentages calculated for each replicate test.

For the sea urchin embryological development test, a well mixed dilute egg solution was added to each vial. Then, 50 *u*L of appropriately diluted sperm were added to each vial, and vials were incubated at 20±1°C for 48 hours. At the end of 48 hours, 2 mls of 10% buffered formalin were added to each vial to stop the test. One hundred embryos were counted, and recorded as normal, or as unfertilized, embryological development arrested or otherwise abnormal. The percent of the embryos that were normal was reported for each replicate test.

Microbial bioluminescence (Microtox™) tests. This is a test of the relative toxicity of extracts of the sediments prepared with an organic solvent, and, therefore, it is immune to the effects of nuisance environmental factors, such as grain size, ammonia and organic carbon. Organic toxicants, and to a lesser degree trace metals, that may or may not be readily bioavailable are extracted with the organic solvent. This test can be considered as a test of potential toxicity. In previous NS&T Program surveys, the results of Microtox tests have shown extremely high correlations with the concentrations of mixtures of organic compounds. Microtox tests were run by the National Marine Fisheries Service laboratory in Charleston, SC.

The Microtox® assay was performed with dichloromethane (DCM) extracts of sediments following the basic procedures used in testing Puget Sound sediments (U.S. EPA, 1986, 1990, 1994) and San Fransisco Bay sediments (Long and Markel, 1992). All sediment samples were stored in the dark at 4(C for 5-10 days before processing was initiated. A 3-4 g sediment sample from each station was weighed, recorded, and placed into a DCM rinsed 50 mL centrifuge tube. A 15 g portion of sodium sulfate was added to each sample and mixed. Pesticide grade DCM (30 mL) was added and mixed. The mixture was shaken for 10 seconds, vented and tumbled overnight.

Sediment samples were allowed to warm to room temperature and the overlying water discarded. Samples were then homogenized with a stainless steel spatula, and 15-25 g of sediment were transferred to a centrifuge tube. The tubes were spun at 1000 g for 5 min. and the pore water was removed using a Pasteur pipette. Three replicate 3-4 g sediment subsamples from each station were placed in mortars containing a 15 g portion of sodium sulfate and mixed. After 30 min. subsamples were ground with a pestle until dry. Subsamples were added to 50 mL centrifuge tubes. Then, 30 mL of DCM were added to each tube and shaken to dislodge sediments. Tubes were then shaken overnight on an orbital shaker at a moderate speed. Next, the ubes were centrifuged at 500 g for 5 min and the sediment extracts transferred to Turbovap^{tm} tubes. Then, 20 mL of DCM was added to sediment, shaken by hand for 10 sec and spun at 500 g for 5 min. The previous step was repeated once more and all three extracts were combined in the Turbovap^{tm} tube. Sample extracts were then placed in the Turbovap^{tm} and reduced to a volume of 0.5 mL. The sides of the Turbovap^{tm} tubes were then rinsed down with methylene chloride and again reduced to 0.5 mL. Then, 2.5 mL of dimethylsulfoxide (DMSO) were added to the tubes which were returned to the Turbovap^{tm} for an additional 15 min. Sample extracts were then placed in clean vials and 2.5 mL of DMSO were added to obtain a final volume of 5 mL DMSO.

A suspension of luminescent bacteria, *Vibrio fischeri*, (Azur Environmental, Inc.) was thawed and hydrated with toxicant-free distilled water, covered and stored in a 4°C well on the Microtox analyzer. To determine toxicity, each sample was diluted into four test concentrations. Percent decrease in luminescence of each cuvette relative to the reagent blank was calculated after 15 min. exposures. Based upon these data, the sediment concentrations that caused a 50% decrease in light production (EC50's) were reported.

A negative control (extraction blank) was prepared using DMSO, the test carrier solvent. A phenol standard (45 mg/L phenol) was run after re-constitution of each vial of freeze-dried *V. fischeri*. In addition, a reference sediment was tested from North Inlet - an area shown to be non-toxic in sensitive laboratory tests in previous studies.

Copepod reproduction tests. Fourteen-day, chronic tests of reproductive success of the meiobenthic copepod *Amphiascus tenuiremis* were performed on 15 of the 105 samples collected during 1995. The 15 samples were selected to represent a presumed pollution gradient within Biscayne Bay during the 1995 operations. Analyses followed the standard protocols of Chandler (1990), Chandler and Scott (1991) and Strawbridge et al. (1992). Samples were press-seived (0.125 mm) to remove meiofauna and large particles; 12 gram sieved aliquots were extruded into triplicate beakers filled with clean sterile-filtered artifi-

cial seawater. Then, 35 barren females and 15 males were removed from stock cultures and added to each beaker. Flow-through exposures were conducted for 14 days. Test animals were fed phytoplankton (*Isochrysis galbana* and *Dunaliella tertiolecta*) on days 3, 6, 9, and 12. Barriers consisting of 0.045 mm mesh screens prevented animal losses. After 14 days all males, females, clutch sizes and offspring were counted and compared with North Inlet (S.C.) negative controls.

Tests were run control by the University of South Carolina in Columbia, SC in four consecutive batches consisting in chronological order of three, four, two, and six samples each plus the control. Toxicological end-points included survival of adults at the end of 14 days, naupliar production (no. nauplia per sample), copepodite production (no. copepodites per sample), clutch size (no. eggs per gravid female per sample), and total production (total no. nauplii + copepodites per sample). Results were initially analyzed using SAS ANOVA / GLM (F statistic) and Tukey's Studentized Range Test ($p<0.05$).

Cytochrome p-450 RGS assays. Samples collected during 1996 (n=121) were analyzed by the P-450 reporter gene system (RGS) assay, which uses human liver cells to measure luciferase production in response to activation of CYP1A1 promoter sequences. This assay is responsive to the presence of mixed-function oxidase inducers such as dioxins, furans, high molecular weight PAHs, and co-planar PCBs in tissues and sediments (Anderson et al., 1995). Therefore, the RGS assay provides an estimate of the presence of contaminants bound to sediment that could produce chronic and / or carcinogenic effects in benthic biota and / or demersal fishes that feed in sediments. Results of these tests would be expected to identify regions of the bay in which demersal fish would show enhanced levels of EROD induction and other elevated liver enzyme activities as described by SFWMD (1994) and Schmale (1991). These tests were run by Columbia Analytical Services, Inc. in Carlsbad, CA with solvent extracts prepared by their laboratory in Kelso, WA.

In these tests, standard protocols (Anderson et al., 1996; ASTM, 1997; APHA, 1996) were followed to ensure comparability with data derived for other areas. Approximately, 20 g of sediment from each station were extracted by EPA method 3550 to produce 2 mL of dichloromethane (DCM) extracts. This solvent was exchanged into DMSO, which is less volatile and less toxic to the test cells. Small portions (5 to 15 uL) were applied to approximately one million human liver cells contained in three replicate wells with 2 mL of culture medium. After 16 hours of incubation, the cells were washed, then lysed, and the solution centrifuged. Small portions (50 uL) of the supernatant were used in measures of luminescence. Solvent blanks and the reference toxicant (2, 3, 7, 8 - dioxin and benzo[a[pyrene) were tested with each batch of samples.

Fold induction of the standards and samples was calculated (normalized) by dividing the mean relative light units (RLU) by the mean RLU produced by the solvent blank. The running average fold induction for 10 nM (3.5 ng / mL) of dioxin (TCDD) is approximately 140 and that from 1 ug / mL of benzo(a)pyrene (B[a]P) was 60 fold. The RGS data were converted to ug of B[a]P equivalents (B[a]pEq) by multiplying the fold induction response to 10 uL of the extract by a factor of 200 to represent the total of inducing substances in the 2 mL extract, and then dividing by 60 and the dry weight of the samples.

Chemical analyses - metals. Chemical analyses were performed by the analytical laboratory at Texas A&M University / Geochemical and Environmental Research Group (TAMU / GERG) in College Station, Texas on all 226 samples. All analytical methods conformed with performance-based analytical protocols and employed quality-assurance steps of the NS&T Program (Lauenstein and Cantillo, 1993; 1998).

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

Grain size was determined by the standard pipette method following sieving for the sand and gravel fractions. TOC was determined using a Leco Carbon analyzer. Sediment samples were digested for final analysis by procedures specific to the instrument method used. Various concentrating and trapping techniques were used for selected analytes. The analysis for mercury was performed by cold vapor atomic absorption. Analyses for tin, arsenic, selenium, silver, and cadmium were performed by graphite furnace atomic absorption spectroscopy. All other metals concentrations were determined by flame atomic absorption spectroscopy and reported on a dry weight basis. Method detection limits (MDLs) attained in the analyses are listed in **Table 3**. SEM / AVS analyses were not performed.

Table 3. Trace metals measured in Biscayne Bay sediments and method detection limits (MDLs).

Parameter	Method Detection Limit (ppm, based on dry weight)	Analytical Method *
Aluminum	440	FAA
Iron	40	FAA
Manganese	5.0	FAA
Arsenic	0.3	GFAAS
Cadmium	0.008	GFAAS
Chromium	0.1	GFAAS
Copper	0.44	GFAAS
Lead	0.35	GFAAS
Mercury	0.007	CVAA
Nickel	0.7	GFAAS
Selenium	0.2	GFAAS
Silver	0.03	GFAAS
Tin	0.1	GFAAS
Zinc	2.2	FAA

* FAA = Flame atomic absorbtion spectroscopy;
GFAAS = Graphite furnace atomic absorption spectroscopy
CVAA = Cold vapor atomic absorption.

Chemical analyses - organic compounds. The analytes determined in the organic analyses are listed in **Table 4**, along with some of their representative MDLs. Sediment samples for organic analysis were prepared by $NaSO_4$ drying, methylene chloride extraction, purified by silica gel / alumina chromatography and concentration. Quantification was performed using the internal standards method. Polycyclic aromatic hydrocarbons (PAHs) were analyzed by

gas chromatography with a mass selective detector in the selective ion mode. Sediment samples analyzed for butyltins were dried with $NaSO_4$ and extracted with methylene chloride containing 2% tropolone, hexylated, purified by silica gel chromatography, and concentrated. Butyltins were analyzed by gas chromatography with a tin selective flame photometric detector. Polychlorinated biphenyls and chlorinated pesticides were determined by gas chromatography / electron capture detection. Concentrations of sediment organic compounds are reported on a dry weight basis.

Table 4. Organic compounds measured in Biscayne Bay sediments and method detection limits (MDLs).

Parameter	MDL (ng / g dry)	Parameter	MDL (ng / g dry)
2,4'Dichloro Diphenyl Ethylene (O,P'DDE)	0.28	Naphthalene	0.5
4,4'Dichloro Diphenyl Ethylene (P,P'DDE)	0.85	C1-Naphthalenes	
2,4'Dichloro Diphenyl Dichloroethylene (O,P'DDD)	0.13	C2-Naphthalenes	
4,4'Dichloro Diphenyl Dichloroethylene (P,P'DDD)	0.51	C3-Naphthalenes	
2,4'Dichloro Diphenyl Trichloroethylene (O,P'DDT)	0.25	C4-Naphthalenes	
4,4'Dichloro Diphenyl Trichloroethylene (P,P'DDT)	0.24	1- Methylnaphthalene	0.8
Aldrin	0.25	2- Methylnaphthalene	0.8
Cis-Chlordane	0.66	2,6-Dimethylnaphthalene	2.4
Oxychlordane		2,3,5- Trimethynaphthalene	2.4
Alpha-Chlordane	0.23	Acenaphthalene	3.7
Trans-Nonachlor	0.1	Acenaphthylene	4.5
Cis-Nonachlor		Fluorene	2.5
Dieldrin	0.16	C1-Fluorenes	
Heptachlor	0.2	C2-Fluorenes	
Heptachloro-Epoxide	0.16	C3-Fluorenes	
Hexachlorobenzene	0.37	Phenanthrenes	0.5
Alpha-Benzene Hexachloride (HCH)		C1-Phenanthrenes	
Beta-Benzene Hexachloride (HCH)		C2-Phenanthrenes	
Lindane (Gamma-Benzene Hexachloride-HCH)	0.22	C3-Phenanthrenes	
Delta-Benzene Hexachloride (HCH)	0.17	C4-Phenanthrenes	
Endrin		1- Methylphenanthrene	0.6
Mirex	0.08	Anthracene	4.1
Polychlorinated Biphenyls		Fluoranthene	0.4
PCB#8 (CL2)	0.08	Pyrene	3.1
PCB#18 (CL3)	0.25	Indeno-1,2,3-c,d-Pyrene	1.6
PCB#28 (CL3)	0.09	Dibenzothiophene	
PCB#44 (CL4)	0.09	C1-Dibenzothiophenes	
PCB#52 (CL4)	0.09	C2-Dibenzothiophenes	
PCB#66 (CL4)	0.14	C3-Dibenzothiophenes	
PCB#101 (CL5)	0.13	C1- Fluoranthene Pyrene	
PCB#105 (CL5)	0.1	Benzo-a-Anthracene	1.4
PCB#110 / 77 (CL5 / 4)	*	Chrysene	0.5
PCB#118 / 108 / 149 (CL5 / 5 / 6)	0.12	C1-Chrysenes	
PCB#128 (CL6)	0.13	C2-Chrysenes	
PCB#138 (CL6)	0.18	C3-Chrysenes	
PCB#126 (CL6)	*	C4-Chrysenes	
PCB#153 (CL6)	0.12	Benzo-b-Fluoranthene	1.8
PCB#170 (CL7)	0.81	Benzo-k-Fluoranthene	1.9
PCB#180 (CL7)	0.16	Benzo-a-Pyrene	1.2
PCB#187 / 182 / 159 (CL7 / 7 / 6)	0.14	Benzo-e-Pyrene	2.4
PCB#195 (CL8)	0.25	Perylene	3.3
PCB#206 (CL9)	0.09	Benzo-g,h,i-Perylene	0.3
PCB#209 (CL10)	0.78	Dibenzo-a,h-Anthracene	2.6
Biphenyl	2.4		

Chemistry QA/QC. Quality assurance / quality control (QA / QC) procedures included analyses of duplicates, standard reference materials, and spiked internal standards. In the organic analyses, internal standards were added at the start of the procedure and carried through the extraction, cleanup, and instrumental analysis steps and used to determine the concentrations of analytes. The following specific quality assurance steps were used to insure measurement accuracy and precision:

1. Trace and major metals, including SEM: Two method blanks and three standard reference materials were run with each set of no more than 30 samples.

2. Physical / chemical measurements: Grain size duplicates were run every 20 samples. For TOC, one method blank, one duplicate, and one standard reference material were run every 20 samples.

3. AVS: One sample duplicate and one procedural blank were run with each set of ten samples.

4. Pesticides, PCBs and PAHs: One procedural blank, one matrix spike, one duplicate spike and one standard reference material were run with each batch of no more than 20 samples. Internal standard recoveries were tracked.

Statistical methods.

Amphipod test . Data from each station in which mean percent survival was less than that of the control were compared to the control using a one-way, un-paired t-test (alpha = 0.05) assuming unequal variance. Data from the Central Long Island Sound (CLIS) control site were used as a basis for comparisons in 1995, whereas data from site "C-17" in Perdido Bay, FL were used in tests performed in 1996. Data were not transformed since examination of data from previous tests have shown that *A. abdita* percentage survival data met the requirement for normality.

Significant toxicity for *A. abdita* was defined here as survival statistically less than that in the performance control (alpha = 0.05). In addition, samples in which survival was significantly less than controls and less than 80% of control values were regarded as "highly toxic" . The 80% criterion was based upon statistical power curves created from SAIC's extensive testing database with *A. abdita* (Thursby et al., 1997) that show that the power to detect a 20% difference from the control is 90%. There was considerably more statistical assurance that the differences between test samples and controls are meaningful when mean survival was less than 80% of that in the controls.

Microtox test. Microtox data were analyzed using the computer software package developed by Microbics Corporation to determine concentrations of the extract that inhibit luminescence by 50% (EC50). This value was then converted to mg dry wt. using the calculated dry weight of sediment present in the original extract. To determine significant differences of samples from each station, pair-wise comparisons were made between contaminated samples and results from control sediments using analysis of covariance (ANCOVA). Concentrations tested were expressed as mg dry wt based on the percentage extract in the 1 ml exposure volume and the calculated dry wt of the extracted sediment. Both the concen-

tration and response data were log-transformed before the analysis. ANCOVA was used first to determine if two lines had equal slopes (alpha = 0.05). If the slopes were equal, ANCOVA then determined the quality of the Y-intercepts (alpha = 0.05). A one-sample t-test was used to compare data from each sampling block within each of the bays with the mean of the duplicate performance control data.

Microtox data were analyzed using the computer software package developed by the manufacturer to determine concentrations of the extract that inhibited luminescence by 50% (EC50). This value was then converted to mg dry wt. of sediment / mL of extract (where dry wt. was calculated as the weight of sediment after removal of porewater). To determine significant differences of samples from each station, pair-wise comparisons were made between contaminated samples and results from control sediments (North Inlet) using three different analyses. Following an ANOVA test, a sequence of three increasingly conservative statistical tests were performed to determine significant differences from controls: Mann-Whitney, Dunnett's, and distribution-free. Dunnett's analyses were performed with log-transformed data. These statistical analyses are increasingly conservative when used in sequence; therefore, samples not showing differences from controls in the Mann-Whitney tests were considered non-toxic, those showing differences in only the Mann-Whitney tests were considered slightly toxic; those showing differences in both Mann-Whitney and Dunnett's were considered moderately toxic, and those showing significant differences in all three analyses were considered as highly toxic.

Sea urchin fertilization and morphological development tests. For both the sea urchin fertilization and morphological development tests, statistical comparisons among treatments were made using ANOVA and Dunnett's one-tailed *t*-test (which controls the experiment-wise error rate) on the arcsine square root transformed data with the aid of SAS (SAS, 1989). The trimmed Spearman-Karber method (Hamilton et al., 1977) with Abbott's correction (Morgan, 1992) was used to calculate EC_{50} (50% effective concentration) values for dilution series tests. Prior to statistical analyses, the transformed data sets were screened for outliers (Moser and Stevens, 1992). Outliers were detected by comparing the studentized residuals to a critical value from a t-distribution chosen using a Bonferroni-type adjustment. The adjustment is based on the number of observations (n) so that the overall probability of a type 1 error is at most 5%. The critical value (CV) is given by the following equation: $cv = t(df_{Error}, .05/(2 \times n))$. After omitting outliers but prior to further analyses, the transformed data sets were tested for normality and for homogeneity of variance using SAS / LAB Software (SAS, 1992). Statistical comparisons were made with mean results from the Redfish Bay controls.

Cytochrome P-450 RGS. These tests were performed only on the samples collected during 1996. Procedures to determine the statistical significance of test results are not available thus far. However, based upon analyses of the distributions of the data gathered thus far by NOAA in many regional surveys, two critical values were calculated for the RGS data. The first value, 37.1 ug / g benzo(a)pyrene equivalents, represented the upper 90% prediction limit (UPL) of the entire data set gathered thus far in all NOAA studies (n=530). This value agrees well with 32 ug / g, the RGS induction level equivalent to the ERL value (Long et al., 1995) for high molecular weight PAHs determined in regression analyses of the existing data for this test. Therefore,this value (37.1 ug / g) is viewed as a concentration above which toxicologically significant effects may begin in sediments. The second value, 11.1 ug / g, was

the 80% UPL of the data distribution following elimination of the data above the 90th percentile of the entire data base. This value (11.1 ug / g) is viewed as the upper limit of background RGS responses.

Spatial patterns and extent of toxicity Spatial patterns in toxicity were estimated by plotting data on base maps of each sampling zone. To minimize the number of figures, data were reduced to symbols for each of the four tests reported, and illustrated together on each of the sampling zone base maps.

Estimates of the spatial extent of toxicity were determined with cumulative distribution functions (CDF) in which the toxicity results from each station were weighted to the dimensions (km^2) of the sampling stratum in which the samples were collected (followed procedures of Schimmel et al., 1994 and Long et al., 1996). The size of each stratum (km^2) was determined by use of a planimeter applied to navigation charts, upon which the boundaries of each stratum were outlined.

In the CDF calculations, a critical value of less than 80% of control response was used in the calculations of the spatial extent of toxicity for the amphipod, urchin and Microtox tests as in Long et al., 1996. These critical values were selected following power curve analyses of the data compiled from these tests (as in Thursby et al., 1997 for the amphipod tests) to eliminate inclusion of “slightly toxic” responses in the totals. The totals, however, may ignore some samples in which there were significant differences between results in test samples and controls, but in which mean test results were greater than 80% of the controls. For the RGS data, the two values (37.1 and 11.1 ug / g) described above were used as the critical values.

Chemistry data Similarly, chemical data from the sample analyses were plotted on base maps to identify spatial patterns, if any, in concentrations. Trace metal concentrations were plotted against aluminum concentrations and compared to expected ratios for uncontaminated sediments developed by Schropp et al., 1988. The spatial extent of contamination was determined with CDF calculations in which numerical guidelines (Effects Range-Median, ERM, values from Long et al., 1995) were used as critical values. The sizes of strata in which samples exceeded ERM concentrations were summed.

Chemistry / toxicity relationships Chemistry / toxicity relationships were determined in a multi-step sequence used in previous sediment quality surveys. First, simple Spearman-rank correlations were determined for each toxicity test and each physical / chemical variable. The correlation coefficients and their statistical significance were recorded and compared among chemicals. Second, for those chemicals in which a significant correlation was observed, the data were examined in scatterplots to determine if there was a reasonable pattern of increasing toxicity with increasing chemical concentration and if any chemical in the toxic samples equalled or exceeded published numerical guidelines.

Chemical concentrations expressed in dry wt. were compared with the ERL and ERM values of Long et al. (1995) developed for NOAA and the Threshold Effects Level (TEL) and Probable Effects Level (PEL) values of MacDonald et al (1996) developed for the state of Florida. The concentrations of un-ionized ammonia were compared to Lowest Observable Effects Concentrations (LOEC) determined for the sea urchin tests by Carr et al. (1995) and

No Observable Effects Concentrations (NOEC) determined for amphipod survival tests published by Kohn et al. (1994).

Third, the numbers of samples (from a total of 226) in which either ERL / ERM or TEL / PEL values were exceeded were determined. The results of these steps were compiled to determine which chemical(s), if any, may have contributed to the observed toxicity and which probably had a minor or no role in toxicity.

Correlations were determined for all the substances that were quantified, including total (bulk) trace metals, metalloids, un-ionized ammonia (UAN), percent fines, total organic carbon (TOC), chlorinated organic hydrocarbons (COHs), and polynuclear aromatic hydrocarbons (PAHs). In addition, a chemical index calculated as the sums of quotients formed by dividing the chemical concentrations in the samples by their respective ERM values (from Long et al., 1995) are shown. Those substances that showed significant correlations were indicated with asterisks. In correlation analyses involving a large number of variables, some correlations could appear to be significant by random chance alone. Adjustments (e.g., a Bonferroni correction) often are needed to account for this possibility. Note that in the results tables only those correlations shown with four asterisks would remain significant if the number of variables were taken into account in these analyses.

Availability of Data. Data for all toxicity tests and all chemical analytes from all 226 samples are available from NOAA (301) 713-3034 or on the NOAA / NOS / ORCA web site.

Results

Amphipod survival tests. Amphipod tests were performed in 12 batches in 1995 and 7 batches in 1996 as samples were collected (**Table 5**). Mean survival (n=5 laboratory replicates) ranged from 85% to 100% in the negative controls from either central Long Island Sound (1995) or Perdido Bay (1996). LC50 values calculated from tests of the positive (reference toxicant) controls ranged from 3.67 mg SDS / L to 8.29 mg SDS / L. Except for the seventh test series in 1996, there were no remarkable differences in either amphipod survival in negative controls or the LC50's determined for SDS between the two years (**Table 5**). The performances of both laboratories with regard to both positive and negative controls were within acceptable ranges.

In the amphipod tests performed, survival relative to the controls ranged from 2% in a sample from the lower Miami River to over 100% in many samples (**Table 6**). Mean survival was less than 10% in five samples. Samples in which mean survival was not significantly different from controls (i.e., $p>0.05$) are shown as "ns" (i.e., not significantly toxic); those in which mean survival was significantly different from controls ($p<0.05$), but, exceeded 80% of controls are shown as "*" (i.e., marginally toxic); and those which were significantly different from controls and mean survival was <80% of controls are shown as "**" (i.e., highly toxic). There is considerably more statistical assurance that the differences between test samples and controls are meaningful when mean survival is less than 80% of that in the controls.

Table 5. Summary of amphipod toxicity test conditions for 1995 and 1996 samples.

Test Series	Sample storage time (days)	Mean survival in controls (%)	Reference toxicant (SDS) LC 50 (mg/L)
1995			
401	4 to 6	97	8.19
405	4 to 6	98	5.07
408	6 to 8	95	5.28
415	8	94	5.73
418	9 to 10	99	6.57
428	25*	95	4.76
436	5 to 7	93	4.60
501	8 to 10	95	4.30
506	7 to 9	88	4.74
508	6 to 11	95	6.73
513	9 to 10	99	7.51
517	26 to 29*	98	8.29
1996			
1	7 to 8	97 & 99	6.21
2	7 to 9	94 & 100 & 96	6.21
3	8 to 10	100 & 99 & 98	4.06
4	9 to 11	85 & 100 & 98	4.06
5	8 to 11	99 & 99 & 95	5.17
6	7 to 10	100 & 98 & 100	5.17
7	4 to 7	100 & 99 & 100	3.67

* tests repeated for three samples

None of the results from samples collected in zone 1 were statistically significant (**Table 6**). Similarly, none of the samples from zones 3, 5, and 9 were toxic in these tests. Two samples from zone 2 were marginally toxic and one sample each from zones 4 and 7 was highly toxic. Many of the samples from zone 6 were toxic in these tests; 28 were at least marginally toxic, and 19 were highly toxic. Samples from strata 13-19 within zone 6 (i.e., the Miami River / Tamiami Canal / Seybold Canal region) were the most toxic. Mean survival ranged from 5% to 9% in the three samples from stratum 18 in zone 6 (Seybold Canal); the most toxic of all strata.

Sea urchin fertilization tests. Sea urchin sperm were exposed to100%, 50%, and 25% porewater concentrations after pore waters were adjusted to acceptable salinities for the tests. Similar to the amphipod test results, results are expressed as percentages of the results in the controls. Samples were classified as not toxic (ns), marginally toxic (*), and highly toxic (**) as in the amphipod tests.

In tests of 100% pore water, mean percent fertilization ranged from 0% in five samples from widely scattered stations to 100% or more in many samples (**Table 7**). Fertilization success was less than 10% of controls in 25 samples tested with 100% pore waters. None of the samples from zone 2 were toxic in these tests. Toxic samples were scattered among all other

Table 6. Results of amphipod (A. abdita) toxicity tests, expressed a means of five replicates and as percent of controls.

Zone No.	Strata No.	Station No.	Sample No.	Mean amphipod survival (%)	Amphipod survival as % of controls	Statistical significance
Zone 1						
	1	1,1	108	94	95	ns
	1	2,1	109	99	100	ns
	1	3,1	110	95	96	ns
	2	1,1	111	92	93	ns
	2	2,1	112	98	99	ns
	2	3,2	113	81	82	ns
	3	1,1	114	92	94	ns
	3	2,1	115	91	93	ns
	3	3,4	116	93	95	ns
	4	1,1	117	96	96	ns
	4	2,1	118	93	93	ns
	4	3,1	119	95	95	ns
Zone 2						
	1	1,1	1	84	87	ns
	1	2,1	2	93	98	ns
	1	3,3	3	91	96	ns
	2	1,1	4	93	98	ns
	2	2,1	5	93	98	*
	2	3,1	6	86	91	ns
	3	1,1	7	85	89	ns
	3	2,1	8	91	96	*
	3	3,1	9	94	99	ns
Zone 3						
	1	1,1	120	98	98	ns
	1	2,1	121	99	99	ns
	1	1,1	122	97	97	ns
	2	1,1	123	100	100	ns
	2	2,1	124	99	99	ns
	2	3,1	125	100	100	ns

Table 6. (continued)

Zone No.	Strata No.	Station No.	Sample No.	Mean amphipod survival (%)	survival as % of controls	Statistical significance
	3	1,1	126	97	98	ns
	3	2,1	127	95	99	ns
	3	3,1	128	98	99	ns
	4	1,1	129	89	93	ns
	4	2,1	130	96	100	ns
Zone 4						
	1	1,1	131	94	98	ns
	1	2,1	132	86	91	ns
	1	3,1	133	98	102	ns
	2	1,1	134	89	89	ns
	2	2,1	135	93	93	ns
	2	3,1	136	96	100	ns
	3	1,1	137	95	101	ns
	3	2,1	138	60	64	**
	3	3,1	139	82	87	ns
	4	1,1	140	88	88	ns
	4	2,1	141	93	93	ns
	4	3,1	142	96	96	ns
	5	1,1	143	98	101	ns
	5	2,1	144	99	102	ns
	5	3,1	145	98	101	ns
	6	1,4	146	100	101	ns
	6	2,1	147	100	101	ns
	6	3,1	148	98	99	ns
	7	1,1	149	98	101	ns
	7	2,1	150	97	100	ns
Zone 5						
	1	1,1	151	99	100	ns
	1	2,1	152	93	94	ns
	1	3,1	153	99	101	ns
	2	1,2	154	89	105	ns
	2	2,2	155	95	112	ns
	2	3,1	156	91	107	ns

Table 6. (continued)

Zone No.	Strata No.	Station No.	Sample No.	Mean amphipod survival (%)	Amphipod survival as % of controls	Statistical significance
	3	1,1	157	96	97	ns
	3	2,1	158	94	95	ns
	3	1,1	159	98	99	ns
	4	1,1	160	87	87	ns
	4	2,1	161	90	90	ns
	4	3,2	162	94	94	ns
	5	1,1	163	87	89	ns
	5	2,1	164	90	92	ns
	5	3,4	165	79	81	ns
	6	1,2	166	70	82	ns
	6	2,1	167	96	113	ns
	6	3,1	168	98	115	ns
	7	1,1	169	82	82	ns
	7	2,2	170	81	81	ns
	7	3,1	171	78	78	ns
	8	1,1	172	95	97	ns
	8	2,1	173	99	101	ns
	8	3,1	174	97	99	ns
	9	1,1	175	88	89	ns
	9	3,1	176	100	102	ns
	9	2,1	177	100	102	ns
	10	1,1	178	100	102	ns
Zone 6						
	1	1,1	10	88	91	*
	1	2,1	11	95	98	ns
	1	3,1	12	88	91	*
	2	1,3	13	96	103	ns
	2	2,1	14	94	101	ns
	2	3,1	15	96	103	ns
	3	1,1	16	96	103	ns

Table 6. (continued)

Zone No.	Strata No.	Station No.	Sample No.	Mean amphipod survival (%)	survival as % of controls	Statistical significance
	20	1,2	17	91	96	ns
	20	2,1	18	95	100	ns
	4	1,2	19	88	94	*
	4	2,1	20	72	77	**
	4	3,3	21	89	90	*
	5	1,1	22	99	104	ns
	5	2,4	23	93	100	ns
	5	3,2	24	99	106	ns
	R6	1,3	25	96	103	ns
	R6	1,8	26	89	96	ns
	R6	3,12	27	94	99	ns
	7	1,1	28	90	97	ns
	7	2,1	29	95	102	ns
	7	3,1	30	93	100	ns
	8	1,1	31	94	99	ns
	8	2,1	32	94	99	ns
	8	3,1	33	89	94	ns
	9	1,1	34	94	99	ns
	9	2,1	35	93	98	ns
	9	3,1	36	88	93	*
	10	1,1	37	96	98	ns
	10	2,2	38	93	95	*
	10	3,1	39	89	91	*
	11	1,1	40	96	98	ns
	11	2,1	41	99	101	ns
	11	3,1	42	90	92	ns
	12	1,1	43	96	98	ns
	12	2,1	44	80	82	ns
	12	3,1	45	87	89	ns

Table 6. (continued)

Zone No.	Strata No.	Station No.	Sample No.	Mean amphipod survival (%)	survival as % of controls	Statistical significance
	13	1,1	46	40	41	**
	13	2,1	47	38	39	**
	13	3,1	48	89[a]	94	ns
	14	1,1	49	50	51	**
	14	2,1	50	66	67	**
	14	3,1	51	9	9	**
	15	1,1	52	31	31	**
	15	2,1	53	35	35	**
	15	3,1	54	39	39	**
	16	1,1	55	16	16	**
	16	2,2	56	2	2	**
	16	3,1	57	41	41	**
	17	1,1	58	32	32	**
	17	2,1	59	41	41	**
	17	3,1	60	19	19	**
	18	1,1	61	9	9	**
	18	2,1	62	5	5	**
	18	3,1	63	8	8	**
	19	1,1	64	94	95	*
	19	2,1	65	10	10	**
	19	3,1	66	93	94	*
Zone 7						
	1	1,1	179	93	93	ns
	1	2,3	180	96	96	ns
	1	3,1	181	97	98	ns
	2	1,1	182	99	100	ns
	2	2,1	183	100	101	ns
	2	3,1	184	100	100	ns
	3	1,1	185	83	84	ns
	3	2,1	186	89	94	ns
	3	3,1	187	93	98	ns

Table 6. (continued)

Zone No.	Strata No.	Station No.	Sample No.	Mean amphipod survival (%)	survival as % of controls	Statistical significance
	4	1,1	188	100	105	ns
	4	3,1	189	98	103	ns
	4	2,1	190	92	97	ns
	5	1,1	191	90	91	ns
	5	2,1	192	91	92	ns
	5	3,1	193	82	83	ns
	6	1,3	194	92	92	ns
	6	2,1	195	99	99	ns
	6	3,1	196	92	92	ns
	7	1,1	197	95	97	ns
	7	2,1	198	78	80	**
	7	3,1	199	93	95	ns
	8	1,1	200	88	88	ns
	8	2,1	201	96	96	ns
	8	3,3	202	90	90	ns
	9	1,1	203	95	96	ns
	9	2,1	204	93	94	ns
	9	3,1	205	97	98	ns
Zone 8						
	1	1,2	106	89	110	ns
	1	1,1	67	92[a]	94	*
	1	2,1	68	90	102	ns
	1	3,2	69	39	44	**
	2	1,1	70	82	93	ns
	2	2,1	71	92	105	ns
	2	3,1	72	84	95	ns
	3	1,1	73	91	103	ns
	3	2,1	74	86	98	ns
	3	3,1	75	90	102	ns
	4	1,1	76	90[a]	92	ns
	4	2,1	77	92	105	ns
	4	3,1	78	84	95	ns

Table 6. (continued)

Zone No.	Strata No.	Station No.	Sample No.	Mean amphipod survival (%)	Amphipod survival as % of controls	Statistical significance
	5	1,1	79	79	83	*
	5	2,1	80	77	81	*
	5	3,1	81	85	89	*
	6	1,1	82	78	82	*
	6	2,1	83	77	81	*
	6	3,1	84	89	94	ns
	7	1,1	85	88	93	*
	7	2,1	86	91	96	ns
	7	3,1	87	62	65	**
	8	1,1	88	87	88	*
	8	2,1	89	78	82	*
	8	3,1	90	56	57	**
	8	1,2	107	91	99	ns
	9	1,1	91	95	96	ns
	9	3,1	93	95	96	ns
	10	1,1	94	95	96	ns
	10	2,1	95	98	99	ns
	10	3,1	96	96	97	ns
	11	1,1	97	90	95	ns
	11	2,1	98	91	96	ns
	11	3,1	99	86	91	*
	12	3,1	100	88	93	*
	12	2,1	101	95	100	ns
	12	3,1	102	89	101	ns
	13	1,1	103	91	103	ns
	13	2,1	104	90	102	ns
	13	3,1	105	85	97	ns
	14	1,1	92	68	69	**
	15	1,1	206	90	90	ns
	15	2,1	207	79	79	ns
	15	3,1	208	98	98	ns

Table 6. (continued)

Zone No.	Strata No.	Station No.	Sample No.	Mean amphipod survival (%)	Amphipod survival as % of controls	Statistical significance
	16	1,1	209	95	95	ns
	16	2,1	210	100	100	ns
	16	3,1	211	100	100	ns
	17	1,1	212	95	95	ns
	17	2,1	213	99	99	ns
	17	3,1	214	90	90	ns
Zone 9						
	1	1,1	215	94	96	ns
	1	2,1	216	89	89	ns
	1	3,3	217	91	91	ns
	2	1,1	218	74	74	ns
	2	2,1	219	96	96	ns
	2	3,1	220	95	95	ns
	3	1,1	221	86	87	ns
	3	2,1	222	94	99	ns
	3	3,1	223	94	99	ns
	4	1,1	224	93	98	ns
	4	2,2	225	93	94	ns
	4	3,3	226	83	87	ns

ns = not significant (p>0.05)
* significant (p<0.05, response >80% of control)
** highly significant (p<0.05, response <80% of control)

[a] results of repeated tests shown

zones. In zone 1 five samples were highly toxic in 100% pore water, only one remained toxic in 50% porewater, and none was toxic in 25% pore water. A similar pattern was evident in all zones; the percentages of samples indicated as toxic in tests of 100% pore water was approximately halved in tests of 50% pore water, and decreased considerably again in tests of 25% pore water.

None of the samples from zones 1, 2, 3, and 7 were toxic in tests of 25% pore water and only one from zone 9 was toxic (**Table 7**). In contrast, fertilization success in 25% pore water was lowest (<10%) in samples 135 and 138 in zone 4, sample 156 in zone 5, and samples 67 and 69 in zone 8; indicating these were the most toxic samples in these particular tests. Curiously, the samples that were most toxic in the amphipod tests were not among those that were most toxic in the sea urchin fertilization tests.

Sea urchin embryological development tests. Tests of sea urchin embryo morhological development also were performed with 100%, 50%, and 25% pore water concentrations after pore waters were adjusted to acceptable salinities for the tests. Results are expressed

Table 7. Summary of sea urchin (A. punctulata) fertilization toxicity tests. Results expressed asmeans of five replicates normalized to controls for each of three water-quality adjustedporewater (WQAP) concentrations.

				Percent Fertilization					
Zone No.	Strata No.	Station No.	Sample No.	100% WQAP % of controls	Stat. signif	50% WQAP % of controls	Stat. signif	25% WQAP % of controls	Stat. signif
Zone 1									
	1	1,1	108	50	**	90	ns	105	ns
	1	2,1	109	10	**	33	**	91	ns
	1	3,1	110	78	**	99	ns	104	ns
	2	1,1	111	53	**	95	ns	99	ns
	2	2,1	112	47	**	96	ns	103	ns
	2	3,2	113	98	ns	98	ns	100	ns
	3	1,1	114	93	ns	103	ns	103	ns
	3	2,1	115	94	ns	103	ns	104	ns
	3	3,4	116	97	ns	102	ns	102	ns
	4	1,1	117	97	ns	99	ns	100	ns
	4	2,1	118	100	ns	98	ns	98	ns
	4	3,1	119	96	ns	100	ns	98	ns
Zone 2									
	1	1,1	1	100	ns	104	ns	107	ns
	1	2,1	2	101	ns	91	ns	89	ns
	1	3,3	3	98	ns	100	ns	102	ns
	2	1,1	4	101	ns	105	ns	108	ns
	2	2,1	5	97	ns	104	ns	102	ns
	2	3,1	6	95	ns	102	ns	100	ns
	3	1,1	7	94	ns	101	ns	93	ns
	3	2,1	8	92	ns	91	ns	101	ns
	3	3,1	9	97	ns	100	ns	98	ns
Zone 3									
	1	1,1	120	22	**	90	ns	99	ns
	1	2,1	121	2	**	27	**	100	ns
	1	1,1	122	91	ns	94	ns	105	ns
	2	1,1	123	55	**	89	ns	102	ns
	2	2,1	124	92	ns	93	ns	104	ns
	2	3,1	125	86	*	96	ns	103	ns
	3	1,1	126	76	**	93	ns	103	ns
	3	2,1	127	92	ns	100	ns	102	ns
	3	3,1	128	2	**	63	**	100	ns
	4	1,1	129	97	ns	96	ns	103	ns
	4	2,1	130	91	ns	99	ns	104	ns
Zone 4									
	1	1,1	131	100	ns	98	ns	100	ns
	1	2,1	132	84	*	99	ns	98	ns
	1	3,1	133	82	*	100	ns	103	ns
	2	1,1	134	99	ns	99	ns	103	ns
	2	2,1	135	0	**	0	**	0	**
	2	3,1	136	96	ns	101	ns	97	ns

Table 7 (continued)

Zone No.	Strata No.	Station No.	Sample No.	100% WQAP % of controls	Stat. signif	50% WQAP % of controls	Stat. signif	25% WQAP % of controls	Stat. signif
	3	1,1	137	99	ns	100	ns	93	ns
	3	2,1	138	2	**	2	**	10	**
	3	3,1	139	1	**	43	**	90	ns
	4	1,1	140	95	ns	101	ns	105	ns
	4	2,1	141	9	**	61	**	82	*
	4	3,1	142	95	ns	98	ns	100	ns
	5	1,1	143	54	**	84	*	94	ns
	5	2,1	144	6	**	64	**	86	*
	5	3,1	145	101	ns	98	ns	94	ns
	6	1,4	146	86	*	96	ns	100	ns
	6	2,1	147	88	ns	99	ns	99	ns
	6	3,1	148	71	**	94	ns	100	ns
	7	1,1	149	52	**	99	ns	100	ns
	7	2,1	150	92	ns	100	ns	101	ns
Zone 5									
	1	1,1	151	94	ns	99	ns	102	ns
	1	2,1	152	44	**	79	**	88	ns
	1	3,1	153	47	**	76	**	95	ns
	2	1,2	154	7	**	7	**	15	**
	2	2,2	155	97	ns	98	ns	99	ns
	2	3,1	156	1	**	3	**	4	**
	3	1,1	157	74	ns	90	ns	96	ns
	3	2,1	158	66	**	89	ns	96	ns
	3	1,1	159	63	**	81	*	96	ns
	4	1,1	160	100	ns	99	ns	92	ns
	4	2,1	161	59	**	83	*	101	ns
	4	3,2	162	98	ns	101	ns	101	ns
	5	1,1	163	70	**	96	ns	102	ns
	5	2,1	164	100	ns	101	ns	101	ns
	5	3,4	165	67	**	88	ns	101	ns
	6	1,2	166	71	**	94	ns	97	ns
	6	2,1	167	60	**	87	ns	98	ns
	6	3,1	168	103	ns	100	ns	98	ns
	7	1,1	169	79	**	94	ns	99	ns
	7	2,2	170	94	ns	98	ns	95	ns
	7	3,1	171	69	**	87	*	100	ns
	8	1,1	172	101	ns	99	ns	101	ns
	8	2,1	173	90	ns	96	ns	97	ns
	8	3,1	174	56	**	96	ns	100	ns
	9	1,1	175	103	ns	102	ns	103	ns
	9	3,1	176	82	**	98	ns	102	ns
	9	2,1	177	104	ns	101	ns	101	ns
	10	1,1	178	101	ns	97	ns	94	ns

Table 7 (continued)

Zone No.	Strata No.	Station No.	Sample No.	100% WQAP % of controls	Stat. signif	50% WQAP % of controls	Stat. signif	25% WQAP % of controls	Stat. signif
Zone 6									
	1	1,1	10	83	*	95	ns	91	ns
	1	2,1	11	91	ns	97	ns	96	ns
	1	3,1	12	72	**	88	*	95	ns
	2	1,3	13	75	**	89	ns	92	ns
	2	2,1	14	47	**	95	ns	91	ns
	2	3,1	15	86	*	87	ns	88	ns
	3	1,1	16	86	*	85	*	95	ns
	20	1,2	17	78	**	87	ns	76	**
	20	2,1	18	91	ns	92	ns	98	ns
	4	1,2	19	95	ns	98	ns	96	ns
	4	2,1	20	91	ns	98	ns	99	ns
	4	3,3	21	81	*	94	ns	101	ns
	5	1,1	22	67	**	92	ns	89	ns
	5	2,4	23	91	ns	100	ns	91	ns
	5	3,2	24	94	ns	93	ns	101	ns
	R6	1,3	25	89	ns	99	ns	102	ns
	R6	1,8	26	91	ns	102	ns	107	ns
	R6	3,12	27	97	ns	100	ns	102	ns
	7	1,1	28	97	ns	105	ns	101	ns
	7	2,1	29	96	ns	105	ns	105	ns
	7	3,1	30	83	*	102	ns	100	ns
	8	1,1	31	95	ns	98	ns	101	ns
	8	2,1	32	96	ns	102	ns	103	ns
	8	3,1	33	94	ns	99	ns	104	ns
	9	1,1	34	80.4	*	92	ns	107	ns
	9	2,1	35	68	**	91	ns	99	ns
	9	3,1	36	82	*	100	ns	105	ns
	10	1,1	37	97	ns	103	ns	107	ns
	10	2,2	38	99	ns	103	ns	104	ns
	10	3,1	39	96	ns	104	ns	108	ns
	11	1,1	40	67	**	99	ns	101	ns
	11	2,1	41	2	**	65	**	101	ns
	11	3,1	42	66	**	95	ns	100	ns
	12	1,1	43	62	**	96	ns	104	ns
	12	2,1	44	99	ns	98	ns	106	ns
	12	3,1	45	95	ns	101	ns	103	ns
	13	1,1	46	93	ns	91	ns	86	ns
	13	2,1	47	71	**	86	*	87	ns
	13	3,1	48	95	ns	98	ns	86	ns
	14	1,1	49	48	**	79.9	**	81	*
	14	2,1	50	93	ns	90	ns	91	ns
	14	3,1	51	98	ns	99	ns	95	ns
	15	1,1	52	91	ns	96	ns	93	ns

Table 7 (continued)

Zone No.	Strata No.	Station No.	Sample No.	100% WQAP % of controls	Stat. signif	50% WQAP % of controls	Stat. signif	25% WQAP % of controls	Stat. signif
	15	2,1	53	102	ns	100	ns	88	ns
	15	3,1	54	100	ns	104	ns	100	ns
	16	1,1	55	80.4	*	93	ns	100	ns
	16	2,2	56	98	ns	98	ns	97	ns
	16	3,1	57	99	ns	100	ns	105	ns
	17	1,1	58	95	ns	101	ns	102	ns
	17	2,1	59	92	ns	99	ns	102	ns
	17	3,1	60	104	ns	106	ns	107	ns
	18	1,1	61	88	ns	96	ns	106	ns
	18	2,1	62	96	ns	103	ns	106	ns
	18	3,1	63	14	**	52	**	92	ns
	19	1,1	64	98	ns	98	ns	100	ns
	19	2,1	65	36	**	87	ns	91	ns
	19	3,1	66	99	ns	103	ns	101	ns
Zone 7									
	1	1,1	179	84	*	95	ns	104	ns
	1	2,3	180	74	**	92	ns	102	ns
	1	3,1	181	85	*	97	ns	109	ns
	2	1,1	182	32	**	85	*	96	ns
	2	2,1	183	9	**	68	**	104	ns
	2	3,1	184	11	**	69	**	99	ns
	3	1,1	185	57	**	103	ns	104	ns
	3	2,1	186	69	**	102	ns	108	ns
	3	3,1	187	88	ns	99	ns	106	ns
	4	1,1	188	84	*	99	ns	103	ns
	4	3,1	189	16	**	86	*	100	ns
	4	2,1	190	99	ns	97	ns	108	ns
	5	1,1	191	89	ns	99	ns	107	ns
	5	2,1	192	0	**	37	**	94	ns
	5	3,1	193	95	ns	103	ns	106	ns
	6	1,3	194	55	**	93	ns	102	ns
	6	2,1	195	9	**	49	**	93	ns
	6	3,1	196	87	ns	94	ns	103	ns
	7	1,1	197	100	ns	95	ns	102	ns
	7	2,1	198	95	ns	91	ns	99	ns
	7	3,1	199	101	ns	97	ns	104	ns
	8	1,1	200	87	ns	98	ns	107	ns
	8	2,1	201	95	ns	99	ns	100	ns
	8	3,3	202	98	ns	96	ns	101	ns
	9	1,1	203	95	ns	96	ns	105	ns
	9	2,1	204	101	ns	99	ns	106	ns
	9	3,1	205	98	ns	100	ns	102	ns

Table 7 (continued)

Zone No.	Strata No.	Station No.	Sample No.	100% WQAP % of controls	Stat. signif	50% WQAP % of controls	Stat. signif	25% WQAP % of controls	Stat. signif
Zone 8									
	1	1,2	106	103	ns	102	ns	111	ns
	1	1,1	67	1	**	0	**	1	**
	1	2,1	68	117	ns	111	ns	109	ns
	1	3,2	69	0	**	0	**	1	**
	2	1,1	70	1	**	6	**	10	**
	2	2,1	71	69	**	94	ns	101	ns
	2	3,1	72	0	**	0	**	26	**
	3	1,1	73	112	ns	104	ns	103	ns
	3	2,1	74	111	ns	107	ns	104	ns
	3	3,1	75	108	ns	95	ns	93	ns
	4	1,1	76	108	ns	99	ns	104	ns
	4	2,1	77	114	ns	110	ns	108	ns
	4	3,1	78	117	ns	111	ns	104	ns
	5	1,1	79	115	ns	109	ns	104	ns
	5	2,1	80	115	ns	109	ns	109	ns
	5	3,1	81	114	ns	106	ns	104	ns
	6	1,1	82	114	ns	102	ns	104	ns
	6	2,1	83	110	ns	109	ns	101	ns
	6	3,1	84	114	ns	104	ns	99	ns
	7	1,1	85	110	ns	110	ns	107	ns
	7	2,1	86	106	ns	103	ns	99	ns
	7	3,1	87	110	ns	103	ns	103	ns
	8	1,1	88	105	ns	93	ns	101	ns
	8	2,1	89	59	**	102	ns	99	ns
	8	3,1	90	34	**	100	ns	105	ns
	8	1,2	107	106	ns	102	ns	109	ns
	9	1,1	91	109	ns	107	ns	105	ns
	9	3,1	93	114	ns	108	ns	110	ns
	10	1,1	94	80.05	*	105	ns	106	ns
	10	2,1	95	97	ns	96	ns	94	ns
	10	3,1	96	113	ns	107	ns	107	ns
	11	1,1	97	88	ns	103	ns	102	ns
	11	2,1	98	112	ns	104	ns	104	ns
	11	3,1	99	2	**	79.4	**	99	ns
	12	3,1	100	92	ns	104	ns	99	ns
	12	2,1	101	67	**	81	*	98	ns
	12	3,1	102	112	ns	106	ns	109	ns
	13	1,1	103	7	**	59	**	102	ns
	13	2,1	104	19	**	4	**	12	**
	13	3,1	105	62	**	106	ns	104	ns
	14	1,1	92	37	**	106	ns	105	ns
	15	1,1	206	63	**	93	ns	101	ns
	15	2,1	207	70	**	94	ns	105	ns
	15	3,1	208	58	**	78	**	100	ns

Table 7 (continued)

Zone No.	Strata No.	Station No.	Sample No.	100% WQAP % of controls	Stat. signif	50% WQAP % of controls	Stat. signif	25% WQAP % of controls	Stat. signif
	16	1,1	209	7	**	12	**	52	**
	16	2,1	210	13	**	47	**	92	ns
	16	3,1	211	8	**	43	**	90	ns
	17	1,1	212	96	ns	95	ns	100	ns
	17	2,1	213	53	**	86	*	86	*
	17	3,1	214	67	**	91	ns	99	ns
Zone 9									
	1	1,1	215	67	**	98	ns	104	ns
	1	2,1	216	82	ns	98	ns	105	ns
	1	3,3	217	104	ns	102	ns	105	ns
	2	1,1	218	96	ns	98	ns	107	ns
	2	2,1	219	93	ns	104	ns	110	ns
	2	3,1	220	11	**	87	ns	101	ns
	3	1,1	221	93	ns	95	ns	104	ns
	3	2,1	222	6	**	79.9	**	102	ns
	3	3,1	223	0	**	46	**	93	ns
	4	1,1	224	100	ns	104	ns	108	ns
	4	2,2	225	3	**	32	**	76	**
	4	3,3	226	7	**	90	ns	106	ns

ns - not significant (p>0.05)
* significant (p<0.05)
** significant (p<0.05, mean <80% of controls)

as percentages of the results in the controls. Samples were classified as not toxic (ns), marginally toxic (*), and highly toxic (**) as in the amphipod tests.

The urchin embryological development test was clearly the most sensitive of those performed on all samples. More samples showed significant differences from controls in these tests than in all others. In tests of 100% pore waters, 103 samples showed zero percent normal development of the embryos (**Table 8**). Responses ranged from 0.0% to 105% of negative controls.

Many samples from zones 2 and 6, and samples from several strata in zone 7 were nontoxic in these tests. In contrast, all of the samples from zones 1 and 3, all except one sample each from zones 4 and 9, all except two samples from zone 5, and all except four samples from zone 8 were highly toxic in tests of 100% pore waters. The incidence of toxicity diminished markedly in tests of 50% pore waters and, again, in tests of 25% pore waters. Some samples from zone 8 remained toxic in tests of all pore water concentrations.

In contrast to the results of the amphipod survival tests, samples from the lower Miami River (zone 6, stations 46-66) were not unusually toxic in this test. Many, in fact, were not toxic in all pore water concentrations.

Microbial bioluminescence tests. Expressed as percentages of the response to the North Inlet, SC, reference samples, Microtox results in the 226 samples ranged from 1.1% in

Table 8. Summary of sea urchin (A. punctulata) embryological development toxicity tests. Data expressed as means of five replicates normalized to controls for each of three water-quality adjusted porewater (WQAP) concentrations.

				Percent Normal Urchin Development					
ZONE No.	Strata No.	Station No.	Sample Id. No.	100% WQAP % of controls	Stat. signif	50% WQAP % of controls	Stat. signif	25% WQAP % of controls	Stat. signif
Zone 1									
	1	1,1	108	0	**	1	**	100	ns
	1	2,1	109	0	**	31	**	101	ns
	1	3,1	110	0	**	16	**	100	ns
	2	1,1	111	0	**	51	**	101	ns
	2	2,1	112	0	**	85	ns	101	ns
	2	3,2	113	45	**	101	ns	101	ns
	3	1,1	114	0	**	39	**	101	ns
	3	2,1	115	0	**	44	**	102	ns
	3	3,4	116	7	**	102	ns	101	ns
	4	1,1	117	0	**	98	ns	99	ns
	4	2,1	118	2	**	101	ns	101	ns
	4	3,1	119	0	**	55	**	100	ns
Zone 2									
	1	1,1	1	94	ns	94	ns	92	ns
	1	2,1	2	93.9	ns	89.2	ns	92	ns
	1	3,3	3	99	ns	97	ns	81	*
	2	1,1	4	1	**	106	ns	101	ns
	2	2,1	5	102	ns	102	ns	91	ns
	2	3,1	6	102	ns	103	ns	98	ns
	3	1,1	7	94	ns	102	ns	98	ns
	3	2,1	8	100	ns	98	ns	98	ns
	3	3,1	9	102	ns	105	ns	101	ns
Zone 3									
	1	1,1	120	0	**	39	**	98	ns
	1	2,1	121	0	**	92	ns	100	ns
	1	1,1	122	0	**	100	ns	101	ns
	2	1,1	123	0	**	22	**	100	ns
	2	2,1	124	0	**	102	ns	102	ns
	2	3,1	125	58	**	101	ns	101	ns
	3	1,1	126	0	**	5	**	97	ns
	3	2,1	127	18	**	98	ns	96	ns
	3	3,1	128	0	**	0	**	96	ns
	4	1,1	129	0	**	1	**	99	ns
	4	2,1	130	0	**	7	**	97	ns
Zone 4									
	1	1,1	131	3	**	99	ns	98	ns
	1	2,1	132	0	**	0	**	98	ns
	1	3,1	133	0	**	101	ns	100	ns
	2	1,1	134	0	**	101	ns	100	ns
	2	2,1	135	0	**	3	**	45	**
	2	3,1	136	3	**	100	ns	101	ns
	3	1,1	137	0	**	100	ns	100	ns
	3	2,1	138	0	**	6	**	44	**

Table 8 continued.				Percent Normal Urchin Development					
ZONE No.	Strata No.	Station No.	Sample Id. No.	100% WQAP % of controls	Stat. signif	50% WQAP % of controls	Stat. signif	25% WQAP % of controls	Stat. signif
	3	3,1	139	0	**	79	ns	98	ns
	4	1,1	140	0	**	10	**	100	ns
	4	2,1	141	0	**	85	*	100	ns
	4	3,1	142	101	ns	101	ns	99	ns
	5	1,1	143	1	**	100	ns	100	ns
	5	2,1	144	0	**	0	**	100	ns
	5	3,1	145	5	**	101	ns	101	ns
	6	1,4	146	0	**	24	**	100	ns
	6	2,1	147	1	**	100	ns	101	ns
	6	3,1	148	0	**	25	**	98.6	ns
	7	1,1	149	0	**	0	**	97	ns
	7	2,1	150	0	**	79	**	99	ns
Zone 5									
	1	1,1	151	0	**	36	**	98	ns
	1	2,1	152	0	**	93	ns	98	ns
	1	3,1	153	0	**	99	ns	98	ns
	2	1,2	154	44	**	52	**	54	**
	2	2,2	155	18	**	101	ns	100	ns
	2	3,1	156	0	**	51	**	41	**
	3	1,1	157	83	*	99	ns	94	ns
	3	2,1	158	5	**	100	ns	99	ns
	3	1,1	159	14	**	101	ns	100	ns
	4	1,1	160	102	ns	101	ns	98	ns
	4	2,1	161	0	**	89	ns	99	ns
	4	3,2	162	0	**	77	**	98	ns
	5	1,1	163	0	**	96	ns	96	ns
	5	2,1	164	0	**	96	ns	97	ns
	5	3,4	165	0	**	98	ns	100	ns
	6	1,2	166	0	**	98	ns	96	ns
	6	2,1	167	0	**	75	**	98	ns
	6	3,1	168	26	**	95	ns	98	ns
	7	1,1	169	81	**	99	ns	98	ns
	7	2,2	170	101	ns	99	ns	97	ns
	7	3,1	171	1	**	98	ns	99	ns
	8	1,1	172	1	**	97	ns	97	ns
	8	2,1	173	12	**	100	ns	98	ns
	8	3,1	174	1	**	97	ns	98	ns
	9	1,1	175	0	**	92	ns	97	ns
	9	3,1	176	0	**	21	**	101	ns
	9	2,1	177	0	**	1	**	97	ns
	10	1,1	178	3	**	98	ns	99	ns
Zone 6									
	1	1,1	10	102	ns	102	ns	97	ns
	1	2,1	11	97	ns	103	ns	95	ns
	1	3,1	12	91	ns	109	ns	107	ns

Table 8 continued.				Percent Normal Urchin Development					
ZONE No.	Strata No.	Station No.	Sample Id. No.	100% WQAP % of controls	Stat. signif	50% WQAP % of controls	Stat. signif	25% WQAP % of controls	Stat. signif
	2	1,3	13	1	**	92	ns	102	ns
	2	2,1	14	0	**	89	ns	99	ns
	2	3,1	15	18	**	104	ns	98	ns
	3	1,1	16	12	**	108	ns	101	ns
	20	1,2	17	103	ns	105	ns	98	ns
	20	2,1	18	100	ns	110	ns	103	ns
	4	1,2	19	0	**	100	ns	103	ns
	4	2,1	20	1	**	101	ns	100	ns
	4	3,3	21	56	**	98	ns	92	ns
	5	1,1	22	0	**	45	**	102	ns
	5	2,4	23	99	ns	103	ns	96	ns
	5	3,2	24	90	ns	91	ns	98	ns
	R6	1,3	25	0	**	1	**	102	ns
	R6	1,8	26	100	ns	106	ns	101	ns
	R6	3,12	27	98	ns	102	ns	99	ns
	7	1,1	28	102	ns	105	ns	103	ns
	7	2,1	29	1	**	106	ns	104	ns
	7	3,1	30	96	ns	103	ns	94	ns
	8	1,1	31	101	ns	104	ns	98	ns
	8	2,1	32	99	ns	102	ns	99	ns
	8	3,1	33	95	ns	105	ns	100	ns
	9	1,1	34	89	ns	100	ns	92	ns
	9	2,1	35	82	*	100	ns	87	ns
	9	3,1	36	95	ns	104	ns	97	ns
	10	1,1	37	0	**	108	ns	98	ns
	10	2,2	38	89	ns	103	ns	100	ns
	10	3,1	39	96	ns	105	ns	95	ns
	11	1,1	40	0	**	106	ns	97	ns
	11	2,1	41	0	**	0	**	94	ns
	11	3,1	42	0	**	2	**	101	ns
	12	1,1	43	86	ns	98	ns	98	ns
	12	2,1	44	1	**	81.4	*	106	ns
	12	3,1	45	97	ns	103	ns	102	ns
	13	1,1	46	101	ns	101	ns	97	ns
	13	2,1	47	0	**	101	ns	98	ns
	13	3,1	48	94	ns	102	ns	96	ns
	14	1,1	49	3	**	51	**	103	ns
	14	2,1	50	2	**	74	**	105	ns
	14	3,1	51	78	**	102	ns	104	ns
	15	1,1	52	96	ns	99	ns	97	ns
	15	2,1	53	96	ns	99	ns	99	ns
	15	3,1	54	79.8	*	104	ns	99	ns
	16	1,1	55	97	ns	97	ns	99	ns
	16	2,2	56	97	ns	99	ns	97	ns
	16	3,1	57	97	ns	97	ns	91	ns

Table 8 continued.				Percent Normal Urchin Development					
ZONE No.	Strata No.	Station No.	Sample Id. No.	100% WQAP % of controls	Stat. signif	50% WQAP % of controls	Stat. signif	25% WQAP % of controls	Stat. signif
	2	1,3	13	1	**	92	ns	102	ns
	2	2,1	14	0	**	89	ns	99	ns
	2	3,1	15	18	**	104	ns	98	ns
	3	1,1	16	12	**	108	ns	101	ns
	20	1,2	17	103	ns	105	ns	98	ns
	20	2,1	18	100	ns	110	ns	103	ns
	4	1,2	19	0	**	100	ns	103	ns
	4	2,1	20	1	**	101	ns	100	ns
	4	3,3	21	56	**	98	ns	92	ns
	5	1,1	22	0	**	45	**	102	ns
	5	2,4	23	99	ns	103	ns	96	ns
	5	3,2	24	90	ns	91	ns	98	ns
	R6	1,3	25	0	**	1	**	102	ns
	R6	1,8	26	100	ns	106	ns	101	ns
	R6	3,12	27	98	ns	102	ns	99	ns
	7	1,1	28	102	ns	105	ns	103	ns
	7	2,1	29	1	**	106	ns	104	ns
	7	3,1	30	96	ns	103	ns	94	ns
	8	1,1	31	101	ns	104	ns	98	ns
	8	2,1	32	99	ns	102	ns	99	ns
	8	3,1	33	95	ns	105	ns	100	ns
	9	1,1	34	89	ns	100	ns	92	ns
	9	2,1	35	82	*	100	ns	87	ns
	9	3,1	36	95	ns	104	ns	97	ns
	10	1,1	37	0	**	108	ns	98	ns
	10	2,2	38	89	ns	103	ns	100	ns
	10	3,1	39	96	ns	105	ns	95	ns
	11	1,1	40	0	**	106	ns	97	ns
	11	2,1	41	0	**	0	**	94	ns
	11	3,1	42	0	**	2	**	101	ns
	12	1,1	43	86	ns	98	ns	98	ns
	12	2,1	44	1	**	81.4	*	106	ns
	12	3,1	45	97	ns	103	ns	102	ns
	13	1,1	46	101	ns	101	ns	97	ns
	13	2,1	47	0	**	101	ns	98	ns
	13	3,1	48	94	ns	102	ns	96	ns
	14	1,1	49	3	**	51	**	103	ns
	14	2,1	50	2	**	74	**	105	ns
	14	3,1	51	78	**	102	ns	104	ns
	15	1,1	52	96	ns	99	ns	97	ns
	15	2,1	53	96	ns	99	ns	99	ns
	15	3,1	54	79.8	*	104	ns	99	ns
	16	1,1	55	97	ns	97	ns	99	ns
	16	2,2	56	97	ns	99	ns	97	ns
	16	3,1	57	97	ns	97	ns	91	ns

Table 8 continued.				Percent Normal Urchin Development					
ZONE No.	Strata No.	Station No.	Sample Id. No.	100% WQAP % of controls	Stat. signif	50% WQAP % of controls	Stat. signif	25% WQAP % of controls	Stat. signif
	17	1,1	58	0	**	88	ns	95	ns
	17	2,1	59	1	**	92	ns	97	ns
	17	3,1	60	13	**	100	ns	99	ns
	18	1,1	61	3	**	95	ns	102	ns
	18	2,1	62	0	**	98	ns	103	ns
	18	3,1	63	0	**	78.8	**	96	ns
	19	1,1	64	75	**	98	ns	97	ns
	19	2,1	65	74	**	100	ns	99	ns
	19	3,1	66	103	ns	100	ns	102	ns
Zone 7									
	1	1,1	179	86	ns	98	ns	98	ns
	1	2,3	180	98	ns	99	ns	98	ns
	1	3,1	181	0	**	20	**	100	ns
	2	1,1	182	93	ns	98	ns	98	ns
	2	2,1	183	82	**	99	ns	100	ns
	2	3,1	184	46	**	97	ns	98	ns
	3	1,1	185	0	**	99	ns	100	ns
	3	2,1	186	91	ns	98	ns	96	ns
	3	3,1	187	95	ns	98	ns	97	ns
	4	1,1	188	47	**	99	ns	99	ns
	4	3,1	189	0	**	97	ns	99	ns
	4	2,1	190	84	*	98	ns	101	ns
	5	1,1	191	0	**	99	ns	101	ns
	5	2,1	192	59	**	99	ns	98	ns
	5	3,1	193	0	**	99	ns	99	ns
	6	1,3	194	0	**	0	**	96	ns
	6	2,1	195	0	**	13	**	98	ns
	6	3,1	196	0	**	86	ns	98	ns
	7	1,1	197	0	**	94	ns	97	ns
	7	2,1	198	0	**	6	**	101	ns
	7	3,1	199	4	**	98	ns	98	ns
	8	1,1	200	0	**	0	**	98	ns
	8	2,1	201	0	**	76	**	97	ns
	8	3,3	202	100	ns	97	ns	100	ns
	9	1,1	203	99	ns	97	ns	99	ns
	9	2,1	204	0	**	98	ns	98	ns
	9	3,1	205	0	**	99	ns	99	ns
Zone 8									
	1	1,1	67	0	**	0	**	45	**
	1	2,1	68	0	**	0	**	9	**
	1	3,2	69	0	**	0	**	17	**
	1	1,2	106	1	**	99	ns	101	ns
	2	1,1	70	2	**	0	**	70	**
	2	2,1	71	0	**	65	**	101	ns
	2	3,1	72	0	**	56	**	73	**

Table 8 (continued)				Percent Normal Urchin Development					
ZONE No.	Strata No.	Station No.	Sample Id. No.	100% WQAP % of controls	Stat. signif	50% WQAP % of controls	Stat. signif	25% WQAP % of controls	Stat. signif
	3	1,1	73	0	**	3	**	98	ns
	3	2,1	74	0	**	37	**	98	ns
	3	3,1	75	0	**	0	**	98	ns
	4	1,1	76	0	**	101	ns	97	ns
	4	2,1	77	0	**	48	**	98	ns
	4	3,1	78	2	**	99	ns	100	ns
	5	1,1	79	0	**	42	**	96	ns
	5	2,1	80	45	**	100	ns	97	ns
	5	3,1	81	0	**	100	ns	99	ns
	6	1,1	82	0	**	98	ns	96	ns
	6	2,1	83	3	**	101	ns	98	ns
	6	3,1	84	0	**	97	ns	99	ns
	7	1,1	85	53	**	102	ns	97	ns
	7	2,1	86	1	**	92	ns	99	ns
	7	3,1	87	0	**	99	ns	96	ns
	8	1,1	88	105	ns	102	ns	97	ns
	8	2,1	89	64	**	103	ns	98	ns
	8	3,1	90	13	**	101	ns	98	ns
	8	1,2	107	0	**	101	ns	101	ns
	9	1,1	91	100	ns	104	ns	101	ns
	9	3,1	93	62	**	101	ns	99	ns
	10	1,1	94	85	**	102	ns	98	ns
	10	2,1	95	104	ns	103	ns	99	ns
	10	3,1	96	63	**	103	ns	99	ns
	11	1,1	97	0	**	0	**	99	ns
	11	2,1	98	10	**	103	ns	97	ns
	11	3,1	99	0	**	0	**	0	**
	12	3,1	100	0	**	27	**	98	ns
	12	2,1	101	0	**	0	**	14	**
	12	3,1	102	0	**	96	ns	96	ns
	13	1,1	103	0	**	86	ns	99	ns
	13	2,1	104	0	**	0	**	46	**
	13	3,1	105	0	**	0	**	25	**
	14	1,1	92	0	**	0	**	78	**
	15	1,1	206	0	**	99	ns	98	ns
	15	2,1	207	0	**	0	**	99	ns
	15	3,1	208	0	**	0	**	101	ns
	16	1,1	209	0	**	89	ns	100	ns
	16	2,1	210	88	ns	99	ns	98	ns
	16	3,1	211	3	**	99	ns	98	ns
	17	1,1	212	0	**	11	**	100	ns
	17	2,1	213	0	**	0	**	101	ns
	17	3,1	214	0	**	66	**	99	ns
Zone 9									
	1	1,1	215	0	**	100	ns	101	ns
	1	2,1	216	0	**	1	**	101	ns
	1	3,3	217	0	**	97	ns	98	ns
	2	1,1	218	0	**	97	ns	101	ns
	2	2,1	219	0	**	6	**	100	ns
	2	3,1	220	0	**	99	ns	99	ns
	3	1,1	221	0	**	96	ns	100	ns
	3	2,1	222	3	**	99	ns	97	ns
	3	3,1	223	0	**	94	ns	101	ns
	4	1,1	224	88	ns	96	ns	96	ns
	4	2,2	225	0	**	98	ns	95	ns
	4	3,3	226	0	**	99	ns	98	ns

ns - not significantly different from controls (p<0.05)
* significantly different from controls (p<0.05), but <msd
** significantly different from controls (p<0.05) and >msd

sample 100 from zone 8 to many samples with responses greater than 100% (**Table 9**). In this test low EC50 values signify that a small amount of sample was required to induce at least a 50% reduction in the light production of the microorganisms. It is not unusual to encounter samples that are considerably less toxic than the reference samples. However, statistical analyses are performed only with one-way tests to identify only those samples that are significantly more toxic than reference material. Three statistical analyses were performed with these data to iteratively rank the relative toxicity of samples. Mean results not significantly different from reference in the least conservative test (Mann-Whitney) are shown as "ns", not significantly toxic; those that were significantly different were shown as a single asterisk. Results that were significant in both Mann-Whitney and one-way Dunnetts are shown with double asterisks and those that were significant in those two tests plus the most conservative test, the Distribution-free test, were shown with triple asterisks.

Only three samples from zone 1 were significantly different from North Inlet reference results, whereas all except one sample from the adjacent zone 2 were toxic (**Table 9**). Toxic samples were scattered throughout zones 3, 4, and 5. All except three of the samples from zone 6 were toxic, most of them showing significance in the Distribution-free analysis. In zone 7, results for three tests were significant in Mann-Whitney and another three were significant in Dunnett's. Many of the samples, especially those from strata 9-14 in zone 8 were highly toxic, whereas only one from zone 9 was toxic. Mean EC50's were less than 10% of controls in 55 of the 226 samples.

Region-wide summary of toxicity. Data from each of the four tests performed on all 226 samples are summarized in **Table 10**. All numerical data are listed as percentages of controls. Statistical significance is shown for each test in each sample with symbols used in previous tables for individual tests. In addition, an overall index of toxicity - the "toxicity tally" - is shown for each sample. This index is a sum of the asterisks attributed to each toxicity test endpoint and is based upon the assumption that the least toxic samples would not show significant results in any of the tests and the most toxic samples would be toxic in the majority of tests. Based upon the data from the four tests performed on all 226 samples, the toxicity tally has a possible range in scores from 0 (least toxic) to 17 (most toxic); actual values ranged from 0 to 15.

In zone 1, four stations (113, 116-118) had toxicity tallies of 2 (indicating significant results in only one bioassay); these were among the least toxic samples (**Table 10**). The sample from station 109 had a score of 10; it was toxic in the Microtox and both urchin tests in two porewater concentrations. In zone 2, toxicity tallies ranged from 0 to 4; thus, indicating none of the samples were highly toxic.

Toxicity in samples from zone 3, on average, exceeded that observed in zone 2; many samples had toxicity tallies of 6 to 10 (**Table 10**). Station 128 located near the 76th Street Causeway was the most toxic. Toxicity tally scores ranged from 0 to 14 among the samples from zone 4. The most toxic samples came from stations 135 and 138 located in different strata of the zone. Toxicity was relatively high also in station 144 in the Indian Creek channel.

In zone 5, there were many samples with toxicity tally scores of 0 to 4, indicating relatively low toxicity. Two samples (from stations 154 and 156) were highly toxic - both from the

Table 9. Summary of 15-minute Microtox test results. Data are expressed as mean EC50's and percentages of North Inlet controls.

Zone No.	Strata No.	Station No.	Sample No.	Microtox EC50 EC50 (mg/ml)	Microtox EC50 % of No. Inlet ref.	Stat. signif
Zone 1						
	1	1,1	108	0.2490	81.2	ns
	1	2,1	109	0.0781	25.5	**
	1	3,1	110	0.4366	142.4	ns
	2	1,1	111	0.1089	35.5	**
	2	2,1	112	0.0937	30.6	**
	2	3,2	113	0.1674	54.6	ns
	3	1,1	114	0.7137	232.7	ns
	3	2,1	115	0.9255	301.8	ns
	3	3,4	116	0.4572	149.1	ns
	4	1,1	117	2.8735	937.0	ns
	4	2,1	118	0.1786	58.2	ns
	4	3,1	119	0.2641	86.1	ns
Zone 2	1	1,1	1	0.2560	8.8	***
	1	2,1	2	0.3188	10.8	***
	1	3,3	3	0.2512	8.4	***
	2	1,1	4	0.7819	25.7	**
	2	2,1	5	0.9053	30.3	**
	2	3,1	6	1.1337	37.3	ns
	3	1,1	7	0.3055	10.4	***
	3	2,1	8	0.3599	12.1	**
	3	3,1	9	1.1294	38.1	*
Zone 3						
	1	1,1	120	0.0679	22.2	**
	1	2,1	121	0.2011	65.6	ns
	1	1,1	122	0.2720	88.7	ns
	2	1,1	123	0.1331	43.4	*
	2	2,1	124	0.3787	123.5	ns
	2	3,1	125	2.0272	661.0	ns
	3	1,1	126	0.1562	50.9	*
	3	2,1	127	0.5024	163.8	ns
	3	3,1	128	0.0681	22.2	**

Table 9 (continued)

Zone No.	Strata No.	Station No.	Sample No.	Microtox EC50 EC50 (mg/ml)	Microtox EC50 % of No. Inlet ref.	Stat. signif
	4	1,1	129	0.0807	26.3	**
	4	2,1	130	0.0817	26.7	**
Zone 4						
	1	1,1	131	0.2857	93.2	ns
	1	2,1	132	0.2397	78.2	ns
	1	3,1	133	0.0574	18.7	**
	2	1,1	134	0.7108	231.8	ns
	2	2,1	135	0.0667	21.8	**
	2	3,1	136	0.7465	243.4	ns
	3	1,1	137	0.1840	60.0	ns
	3	2,1	138	0.2419	78.9	ns
	3	3,1	139	0.0626	20.4	**
	4	1,1	140	2.6289	857.3	ns
	4	2,1	141	0.1505	49.1	*
	4	3,1	142	0.2238	73.0	ns
	5	1,1	143	0.1426	46.5	*
	5	2,1	144	0.0491	16.0	**
	5	3,1	145	0.4640	151.3	ns
	6	1,4	146	0.5635	183.8	ns
	6	2,1	147	0.0536	17.5	**
	6	3,1	148	1.0746	350.4	ns
	7	1,1	149	0.0334	10.9	**
	7	2,1	150	0.1123	36.6	**
Zone 5						
	1	1,1	151	3.8522	1256.2	ns
	1	2,1	152	0.1634	53.3	*
	1	3,1	153	0.2043	66.6	ns
	2	1,2	154	0.3167	103.3	ns
	2	2,2	155	0.6005	195.8	ns
	2	3,1	156	0.0991	32.3	**
	3	1,1	157	0.1170	38.2	**
	3	2,1	158	0.1316	42.9	*
	3	1,1	159	0.2207	72.0	ns

Table 9 (continued)

Zone No.	Strata No.	Station No.	Sample No.	Microtox EC50 EC50 (mg/ml)	Microtox EC50 % of No. Inlet ref.	Stat. signif
	4	1,1	160	0.2186	71.3	ns
	4	2,1	161	0.3213	104.8	ns
	4	3,2	162	3.5094	1144.4	ns
	5	1,1	163	0.7574	247.0	ns
	5	2,1	164	3.9304	1281.7	ns
	5	3,4	165	0.2160	70.4	ns
	6	1,2	166	0.1409	46.0	*
	6	2,1	167	0.1138	37.1	**
	6	3,1	168	0.5973	194.8	ns
	7	1,1	169	0.2046	66.7	ns
	7	2,2	170	0.2304	75.1	ns
	7	3,1	171	1.8793	612.8	ns
	8	1,1	172	0.5113	166.7	ns
	8	2,1	173	0.2234	72.8	ns
	8	3,1	174	0.1626	53.0	*
	9	1,1	175	1.1168	364.2	ns
	9	3,1	176	0.2716	88.6	ns
	9	2,1	177	0.6782	221.1	ns
	10	1,1	178	0.1211	39.5	*
Zone 6	1	1,1	10	0.0701	2.4	***
	1	2,1	11	0.2588	8.5	***
	1	3,1	12	0.8262	27.5	**
	2	1,3	13	0.4237	5.5	**
	2	2,1	14	0.2591	3.3	***
	2	3,1	15	0.4519	5.8	**
	3	1,1	16	0.6874	8.9	**
	20	1,2	17	0.2119	2.8	***
	20	2,1	18	0.9758	12.9	**

Table 9 (continued)

Zone No.	Strata No.	Station No.	Sample No.	Microtox EC50 EC50 (mg/ml)	Microtox EC50 % of No. Inlet ref.	Stat. signif
	4	1,2	19	0.9574	32.6	**
	4	2,1	20	1.3239	43.9	*
	4	3,3	21	7.7330	255.6	ns
	5	1,1	22	0.1135	1.4	***
	5	2,4	23	0.6815	8.5	**
	5	3,2	24	0.1751	2.3	***
	R6	1,3	25	0.2712	3.6	***
	R6	1,8	26	0.2122	2.8	***
	R6	3,12	27	0.2398	3.2	***
	7	1,1	28	2.3432	30.3	**
	7	2,1	29	1.1532	14.6	**
	7	3,1	30	0.2963	3.8	***
	8	1,1	31	0.1258	4.2	***
	8	2,1	32	0.6571	22.1	**
	8	3,1	33	0.8354	28	**
	9	1,1	34	0.6202	20.6	**
	9	2,1	35	0.7529	25	**
	9	3,1	36	0.8300	27.3	**
	10	1,1	37	0.5293	17.8	**
	10	2,2	38	0.4369	14.6	**
	10	3,1	39	0.7005	23.1	**
	11	1,1	40	0.0984	3.3	***
	11	2,1	41	0.2243	7.7	***
	11	3,1	42	0.1251	4.2	***
	12	1,1	43	1.3429	44.2	*
	12	2,1	44	5.0850	170.4	ns
	12	3,1	45	5.9180	203.8	ns
	13	1,1	46	0.5388	17.9	**
	13	2,1	47	0.7440	24.6	**
	13	3,1	48	0.4978	17.1	**

Table 9 (continued)

Zone No.	Strata No.	Station No.	Sample No.	Microtox EC50 EC50 (mg/ml)	Microtox EC50 % of No. Inlet ref.	Stat. signif
	14	1,1	49	0.4015	19.2	**
	14	2,1	50	0.8238	28.3	**
	14	3,1	51	0.9557	31.9	**
	15	1,1	52	0.7493	25.7	**
	15	2,1	53	0.8418	27.1	**
	15	3,1	54	0.2143	7.1	***
	16	1,1	55	0.2163	7.3	***
	16	2,2	56	0.3831	12.6	**
	16	3,1	57	0.1199	4	***
	17	1,1	58	0.3395	11.1	***
	17	2,1	59	0.5762	19.2	**
	17	3,1	60	0.2532	8.5	***
	18	1,1	61	0.0509	1.7	***
	18	2,1	62	0.0610	2.1	***
	18	3,1	63	0.0469	1.6	***
	19	1,1	64	5.9503	199.4	ns
	19	2,1	65	0.1640	6.4	***
	19	3,1	66	0.1923	6.5	***
Zone 7						
	1	1,1	179	0.9613	313.5	ns
	1	2,3	180	0.1303	42.5	*
	1	3,1	181	0.7694	250.9	ns
	2	1,1	182	3.8352	1250.6	ns
	2	2,1	183	1.8811	613.4	ns
	2	3,1	184	2.8953	944.1	ns
	3	1,1	185	2.6778	873.2	ns
	3	2,1	186	0.1233	40.2	*
	3	3,1	187	1.7045	555.8	ns
	4	1,1	188	3.9346	1283.0	ns
	4	3,1	189	0.7457	243.2	ns
	4	2,1	190	3.8080	1241.8	ns

Table 9 (continued)

Zone No.	Strata No.	Station No.	Sample No.	Microtox EC50 EC50 (mg/ml)	Microtox EC50 % of No. Inlet ref.	Stat. signif
	5	1,1	191	0.7268	237.0	ns
	5	2,1	192	0.3382	110.3	ns
	5	3,1	193	1.8029	587.9	ns
	6	1,3	194	1.6208	528.5	ns
	6	2,1	195	3.7332	1217.4	ns
	6	3,1	196	1.1980	390.7	ns
	7	1,1	197	3.8590	1258.4	ns
	7	2,1	198	3.8964	1270.6	ns
	7	3,1	199	3.8012	1239.5	ns
	8	1,1	200	0.1124	36.7	**
	8	2,1	201	0.1426	46.5	*
	8	3,3	202	0.6345	206.9	ns
	9	1,1	203	0.1864	60.8	ns
	9	2,1	204	0.0468	15.3	**
	9	3,1	205	0.0705	23.0	**
Zone 8	1	1,1	67	3.6044	47.8	ns
	1	2,1	68	0.6124	8.1	**
	1	3,2	69	0.4983	6.5	**
	1	1,2	106	3.7944	1237.3	ns
	2	1,1	70	0.1256	1.6	***
	2	2,1	71	0.2941	3.8	***
	2	3,1	72	0.2144	2.8	***
	3	1,1	73	0.3172	4.2	**
	3	2,1	74	7.4467	100	ns
	3	3,1	75	0.4512	5.9	**
	4	1,1	76	1.8518	24.4	**
	4	2,1	77	2.9294	38.8	*
	4	3,1	78	5.2947	71.2	ns
	5	1,1	79	1.1436	15.2	**
	5	2,1	80	7.6067	100	ns
	5	3,1	81	3.4723	45.7	*

Table 9 (continued)

Zone No.	Strata No.	Station No.	Sample No.	Microtox EC50 EC50 (mg/ml)	Microtox EC50 % of No. Inlet ref.	Stat. signif
	6	1,1	82	0.7189	9.6	**
	6	2,1	83	0.4385	5.8	**
	6	3,1	84	6.6099	85.9	ns
	7	1,1	85	0.3397	4.4	**
	7	2,1	86	3.4256	45	ns
	7	3,1	87	0.3194	4.1	**
	8	1,1	88	5.5370	75.5	ns
	8	2,1	89	4.2418	55	*
	8	3,1	90	1.5886	21.1	**
	8	1,2	107	3.8290	1248.6	ns
	9	1,1	91	0.4884	6.3	**
	9	3,1	93	0.2607	3.5	***
	10	1,1	94	0.1542	2	***
	10	2,1	95	0.4099	5.5	**
	10	3,1	96	0.2657	3.5	***
	11	1,1	97	0.1219	1.6	***
	11	2,1	98	0.4276	5.5	**
	11	3,1	99	0.1217	1.6	***
	12	3,1	100	0.0869	1.1	***
	12	2,1	101	0.1798	2.3	***
	12	3,1	102	0.2146	2.8	***
	13	1,1	103	0.2296	3	***
	13	2,1	104	0.1030	1.4	***
	13	3,1	105	0.2662	3.6	***
	14	1,1	92	0.1651	3.5	***
	15	1,1	206	0.0837	27.3	**
	15	2,1	207	0.2871	93.6	ns
	15	3,1	208	0.1928	62.9	ns
	16	1,1	209	0.1005	32.8	**
	16	2,1	210	1.2232	398.9	ns
	16	3,1	211	0.3334	108.7	ns

Table 9 (continued)

Zone No.	Strata No.	Station No.	Sample No.	Microtox EC50 EC50 (mg/ml)	Microtox EC50 % of No. Inlet ref.	Stat. signif
	17	1,1	212	0.1528	49.8	*
	17	2,1	213	0.2842	92.7	ns
	17	3,1	214	0.1172	38.2	*
Zone 9						
	1	1,1	215	1.4671	478.4	ns
	1	2,1	216	1.5465	504.3	ns
	1	3,3	217	2.8125	917.1	ns
	2	1,1	218	1.7216	561.4	ns
	2	2,1	219	0.4620	150.6	ns
	2	3,1	220	0.9611	313.4	ns
	3	1,1	221	1.3359	435.6	ns
	3	2,1	222	0.1931	63.0	ns
	3	3,1	223	3.3584	1095.1	ns
	4	1,1	224	2.7190	886.6	ns
	4	2,2	225	0.3612	117.8	ns
	4	3,3	226	0.1507	49.1	*
NIOL ref.	Leg 1	1996		0.4069		
NIOL ref.	Leg 1	1996		0.2064		
NIOL ref.	Leg 2	1996		0.3067		
NIOL ref.	Leg 1	1995		2.0386		
NIOL ref.	Leg 1	1995		4.1346		
NIOL ref.	Leg 2	1995		7.4466		

ns - not significantly different from combined controls (p<0.05)
* significantly different from combined controls (p<0.05) with Mann-Whitney
** significantly different from combined controls with MW and one-way Dunnett's (p<0.05)
*** significantly different from combined controls with MW & Dunnett's &
and Distribution-free (p<0.05)

Table 10. Summary of toxicity test results and overall toxicity tally for each sample.

Zone No.	Sample No.	Amphipod survival	Statistical significance	Microtox EC 50	Statistical significance	Urchin fert'n 100% WQAP[b]	Statistical significance	Urchin fert'n 50% WQAP	Statistical significance	Urchin fert'n 25% WQAP	Statistical significance	Urchin devt 100% WQAP	Statistical significance	Urchin devt 50% WQAP	Statistical significance	Urchin devt 25% WQAP	Statistical significance	Toxicity tally [a]
1																		
	108	95	ns	81.2	ns	50	**	90	ns	105	ns	0	**	1	**	100	ns	6
	109	100	ns	25.5	**	10	**	33	**	91	ns	0	**	31	**	101	ns	10
	110	96	ns	142.4	ns	78	**	99	ns	104	ns	0	**	16	**	100	ns	6
	111	93	ns	35.5	**	53	**	95	ns	99	ns	0	**	51	**	101	ns	8
	112	99	ns	30.6	**	47	**	96	ns	103	ns	0	**	85	ns	101	ns	6
	113	82	ns	54.6	ns	98	ns	98	ns	100	ns	45	**	101	ns	101	ns	2
	114	94	ns	232.7	ns	93	ns	103	ns	103	ns	0	**	39	**	101	ns	4
	115	93	ns	301.8	ns	94	ns	103	ns	104	ns	0	**	44	**	102	ns	4
	116	95	ns	149.1	ns	97	ns	102	ns	102	ns	7	**	102	ns	101	ns	2
	117	96	ns	937.0	ns	97	ns	99	ns	100	ns	0	**	98	ns	99	ns	2
	118	93	ns	58.2	ns	100	ns	98	ns	98	ns	2	**	101	ns	101	ns	2
	119	95	ns	86.1	ns	96	ns	100	ns	98	ns	0	**	55	**	100	ns	4
2																		
	1	87	ns	8.8	***	100	ns	104	ns	107	ns	94	ns	94	ns	92	ns	3
	2	98	ns	10.8	***	101	ns	91	ns	89	ns	93.9	ns	89.2	ns	92	ns	3
	3	96	ns	8.4	***	98	ns	100	ns	102	ns	99	ns	97	ns	81	*	4
	4	98	ns	25.7	**	101	ns	105	ns	108	ns	1	**	106	ns	101	ns	4
	5	98	*	30.3	**	97	ns	104	ns	102	ns	102	ns	102	ns	91	ns	3
	6	91	ns	37.3	ns	95	ns	102	ns	100	ns	102	ns	103	ns	98	ns	0
	7	89	ns	10.4	***	94	ns	101	ns	93	ns	94	ns	102	ns	98	ns	3
	8	96	*	12.1	**	92	ns	91	ns	101	ns	100	ns	98	ns	98	ns	3
	9	99	ns	38.1	*	97	ns	100	ns	98	ns	102	ns	105	ns	101	ns	1
3																		
	120	98	ns	22.2	**	22	**	90	ns	99	ns	0	**	39	**	98	ns	8
	121	99	ns	65.6	ns	2	**	27	**	100	ns	0	**	92	ns	100	ns	6
	122	97	ns	88.7	ns	91	ns	94	ns	105	ns	0	**	100	ns	101	ns	2
	123	100	ns	43.4	*	55	**	89	ns	102	ns	0	**	22	**	100	ns	7
	124	99	ns	123.5	ns	92	ns	93	ns	104	ns	0	**	102	ns	102	ns	2
	125	100	ns	661.0	ns	86	*	96	ns	103	ns	58	**	101	ns	101	ns	3
	126	98	ns	50.9	*	76	**	93	ns	103	ns	0	**	5	**	97	ns	7
	127	99	ns	163.8	ns	92	ns	100	ns	102	ns	18	**	98	ns	96	ns	2
	128	99	ns	22.2	**	2	**	63	**	100	ns	0	**	0	**	96	ns	10
	129	93	ns	26.3	**	97	ns	96	ns	103	ns	0	**	1	**	99	ns	6
	130	100	ns	26.7	**	91	ns	99	ns	104	ns	0	**	7	**	97	ns	6
4																		
	131	98	ns	93.2	ns	100	ns	98	ns	100	ns	3	**	99	ns	98	ns	2
	132	91	ns	78.2	ns	84	*	99	ns	98	ns	0	**	0	**	98	ns	5
	133	102	ns	18.7	**	82	*	100	ns	103	ns	0	**	101	ns	100	ns	5

Table 10 continued.

Zone No.	Sample No.	Amphipod survival	Statistical significance	Microtox EC 50	Statistical significance	Urchin fert'n 100% WQAP[b]	Statistical significance	Urchin fert'n 50% WQAP	Statistical significance	Urchin fert'n 25% WQAP	Statistical significance	Urchin devt 100% WQAP	Statistical significance	Urchin devt 50% WQAP	Statistical significance	Urchin devt 25% WQAP	Statistical significance	Toxicity tally[a]
	134	89	ns	231.8	ns	99	ns	99	ns	103	ns	0	* *	101	ns	100	ns	2
	135	93	ns	21.8	* *	0	* *	0	* *	0	* *	0	* *	3	* *	45	* *	14
	136	100	ns	243.4	ns	96	ns	101	ns	97	ns	3	* *	100	ns	101	ns	2
	137	101	ns	60.0	ns	99	ns	100	ns	93	ns	0	* *	100	ns	100	ns	2
	138	64	* *	78.9	ns	2	* *	2	* *	10	* *	0	* *	6	* *	44	* *	14
	139	87	ns	20.4	* *	1	* *	43	* *	90	ns	0	* *	79	ns	98	ns	8
	140	88	ns	857.3	ns	95	ns	101	ns	105	ns	0	* *	10	* *	100	ns	4
	141	93	ns	49.1	*	9	* *	61	* *	82	*	0	* *	85	*	100	ns	9
	142	96	ns	73.0	ns	95	ns	98	ns	100	ns	101	ns	101	ns	99	ns	0
	143	101	ns	46.5	*	54	* *	84	*	94	ns	1	* *	100	ns	100	ns	6
	144	102	ns	16.0	* *	6	* *	64	* *	86	*	0	* *	0	* *	100	ns	11
	145	101	ns	151.3	ns	101	ns	98	ns	94	ns	5	* *	101	ns	101	ns	2
	146	101	ns	183.8	ns	86	*	96	ns	100	ns	0	* *	24	* *	100	ns	5
	147	101	ns	17.5	* *	88	ns	99	ns	99	ns	1	* *	100	ns	101	ns	4
	148	99	ns	350.4	ns	71	* *	94	ns	100	ns	0	* *	25	* *	98.6	ns	6
	149	101	ns	10.9	* *	52	* *	99	ns	100	ns	0	* *	0	* *	97	ns	8
	150	100	ns	36.6	* *	92	ns	100	ns	101	ns	0	* *	79	* *	99	ns	6
5																		
	151	100	ns	1256.2	ns	94	ns	99	ns	102	ns	0	* *	36	* *	98	ns	4
	152	94	ns	53.3	*	44	* *	79	* *	88	ns	0	* *	93	ns	98	ns	7
	153	101	ns	66.6	ns	47	* *	76	* *	95	ns	0	* *	99	ns	98	ns	6
	154	105	ns	103.3	ns	7	* *	7	* *	15	* *	44	* *	52	* *	54	* *	12
	155	112	ns	195.8	ns	97	ns	98	ns	99	ns	18	* *	101	ns	100	ns	2
	156	107	ns	32.3	* *	1	* *	3	* *	4	* *	0	* *	51	* *	41	* *	14
	157	97	ns	38.2	* *	74	ns	90	ns	96	ns	83	*	99	ns	94	ns	3
	158	95	ns	42.9	*	66	* *	89	ns	96	ns	5	* *	100	ns	99	ns	5
	159	99	ns	72.0	ns	63	* *	81	*	96	ns	14	* *	101	ns	100	ns	5
	160	87	ns	71.3	ns	100	ns	99	ns	92	ns	102	ns	101	ns	98	ns	0
	161	90	ns	104.8	ns	59	* *	83	*	101	ns	0	* *	89	ns	99	ns	5
	162	94	ns	1144.4	ns	98	ns	101	ns	101	ns	0	* *	77	* *	98	ns	4
	163	89	ns	247.0	ns	70	* *	96	ns	102	ns	0	* *	96	ns	96	ns	4
	164	92	ns	1281.7	ns	100	ns	101	ns	101	ns	0	* *	96	ns	97	ns	2
	165	81	ns	70.4	ns	67	* *	88	ns	101	ns	0	* *	98	ns	100	ns	4
	166	82	ns	46.0	*	71	* *	94	ns	97	ns	0	* *	98	ns	96	ns	5
	167	113	ns	37.1	* *	60	* *	87	ns	98	ns	0	* *	75	* *	98	ns	8
	168	115	ns	194.8	ns	103	ns	100	ns	98	ns	26	* *	95	ns	98	ns	2
	169	82	ns	66.7	ns	79	* *	94	ns	99	ns	81	* *	99	ns	98	ns	4
	170	81	ns	75.1	ns	94	ns	98	ns	95	ns	101	ns	99	ns	97	ns	0
	171	78	ns	612.8	ns	69	* *	87	*	100	ns	1	* *	98	ns	99	ns	5
	172	97	ns	166.7	ns	101	ns	99	ns	101	ns	1	* *	97	ns	97	ns	2
	173	101	ns	72.8	ns	90	ns	96	ns	97	ns	12	* *	100	ns	98	ns	2
	174	99	ns	53.0	*	56	* *	96	ns	100	ns	1	* *	97	ns	98	ns	5

Table 10 continued.

Zone	Sample No.	Amphipod survival	Statistical significance	Microtox EC 50	Statistical significance	Urchin fert'n 100% WQAP[b]	Statistical significance	Urchin fert'n 50% WQAP	Statistical significance	Urchin fert'n 25% WQAP	Statistical significance	Urchin devt 100% WQAP	Statistical significance	Urchin devt 50% WQAP	Statistical significance	Urchin devt 25% WQAP	Statistical significance	Toxicity tally [a]
	175	89	ns	364.2	ns	103	ns	102	ns	103	ns	0	**	92	ns	97	ns	2
	176	102	ns	88.6	ns	82	**	98	ns	102	ns	0	**	21	**	101	ns	6
	177	102	ns	221.1	ns	104	ns	101	ns	101	ns	0	**	1	**	97	ns	4
	178	102	ns	39.5	*	101	ns	97	ns	94	ns	3	**	98	ns	99	ns	3
6																		
	10	91	*	2.4	***	83	*	95	ns	91	ns	102	ns	102	ns	97	ns	5
	11	98	ns	8.5	***	91	ns	97	ns	96	ns	97	ns	103	ns	95	ns	3
	12	91	*	27.5	**	72	**	88	*	95	ns	91	ns	109	ns	107	ns	6
	13	103	ns	5.5	**	75	**	89	ns	92	ns	1	**	92	ns	102	ns	6
	14	101	ns	3.3	***	47	**	95	ns	91	ns	0	**	89	ns	99	ns	7
	15	103	ns	5.8	**	86	*	87	ns	88	ns	18	**	104	ns	98	ns	5
	16	103	ns	8.9	**	86	*	85	*	95	ns	12	**	108	ns	101	ns	6
	17	96	ns	2.8	***	78	**	87	ns	76	**	103	ns	105	ns	98	ns	7
	18	100	ns	12.9	**	91	ns	92	ns	98	ns	100	ns	110	ns	103	ns	2
	19	94	*	32.6	**	95	ns	98	ns	96	ns	0	**	100	ns	103	ns	5
	20	77	**	43.9	*	91	ns	98	ns	99	ns	1	**	101	ns	100	ns	5
	21	90	*	255.6	ns	81	*	94	ns	101	ns	56	**	98	ns	92	ns	4
	22	104	ns	1.4	***	67	**	92	ns	89	ns	0	**	45	**	102	ns	9
	23	100	ns	8.5	**	91	ns	100	ns	91	ns	99	ns	103	ns	96	ns	2
	24	106	ns	2.3	***	94	ns	93	ns	101	ns	90	ns	91	ns	98	ns	3
	25	103	ns	3.6	***	89	ns	99	ns	102	ns	0	**	1	**	102	ns	7
	26	96	ns	2.8	***	91	ns	102	ns	107	ns	100	ns	106	ns	101	ns	3
	27	99	ns	3.2	***	97	ns	100	ns	102	ns	98	ns	102	ns	99	ns	3
	28	97	ns	30.3	**	97	ns	105	ns	101	ns	102	ns	105	ns	103	ns	2
	29	102	ns	14.6	**	96	ns	105	ns	105	ns	1	**	106	ns	104	ns	4
	30	100	ns	3.8	***	83	*	102	ns	100	ns	96	ns	103	ns	94	ns	4
	31	99	ns	4.2	***	95	ns	98	ns	101	ns	101	ns	104	ns	98	ns	3
	32	99	ns	22.1	**	96	ns	102	ns	103	ns	99	ns	102	ns	99	ns	2
	33	94	ns	28	**	94	ns	99	ns	104	ns	95	ns	105	ns	100	ns	2
	34	99	ns	20.6	**	80.4	*	92	ns	107	ns	89	ns	100	ns	92	ns	3
	35	98	ns	25	**	68	**	91	ns	99	ns	82	*	100	ns	87	ns	5
	36	93	*	27.3	**	82	*	100	ns	105	ns	95	ns	104	ns	97	ns	4
	37	98	ns	17.8	**	97	ns	103	ns	107	ns	0	**	108	ns	98	ns	4
	38	95	*	14.6	**	99	ns	103	ns	104	ns	89	ns	103	ns	100	ns	3
	39	91	*	23.1	**	96	ns	104	ns	108	ns	96	ns	105	ns	95	ns	3
	40	98	ns	3.3	***	67	**	99	ns	101	ns	0	**	106	ns	97	ns	7
	41	101	ns	7.7	***	2	**	65	**	101	ns	0	**	0	**	94	ns	11
	42	92	ns	4.2	***	66	**	95	ns	100	ns	0	**	2	**	101	ns	9

Table 10 continued.

Zone	Sample No.	Amphipod survival	Statistical significance	Microtox EC 50	Statistical significance	Urchin fert'n 100% WQAP[b]	Statistical significance	Urchin fert'n 50% WQAP	Statistical significance	Urchin fert'n 25% WQAP	Statistical significance	Urchin devt 100% WQAP	Statistical significance	Urchin devt 50% WQAP	Statistical significance	Urchin devt 25% WQAP	Statistical significance	Toxicity tally[a]
	43	98	ns	44.2	*	62	* *	96	ns	104	ns	86	ns	98	ns	98	ns	3
	44	82	ns	170.4	ns	99	ns	98	ns	106	ns	1	* *	81.4	*	106	ns	3
	45	89	ns	203.8	ns	95	ns	101	ns	103	ns	97	ns	103	ns	102	ns	0
	46	41	* *	17.9	* *	93	ns	91	ns	86	ns	101	ns	101	ns	97	ns	4
	47	39	* *	24.6	* *	71	* *	86	*	87	ns	0	* *	101	ns	98	ns	9
	48	94	ns	17.1	* *	95	ns	98	ns	86	ns	94	ns	102	ns	96	ns	2
	49	51	* *	19.2	* *	48	* *	79.9	* *	81	*	3	* *	51	* *	103	ns	13
	50	67	* *	28.3	* *	93	ns	90	ns	91	ns	2	* *	74	* *	105	ns	8
	51	9	* *	31.9	* *	98	ns	99	ns	95	ns	78	* *	102	ns	104	ns	6
	52	31	* *	25.7	* *	91	ns	96	ns	93	ns	96	ns	99	ns	97	ns	4
	53	35	* *	27.1	* *	102	ns	100	ns	88	ns	96	ns	99	ns	99	ns	4
	54	39	* *	7.1	* * *	100	ns	104	ns	100	ns	79.8	*	104	ns	99	ns	6
	55	16	* *	7.3	* * *	80.4	*	93	ns	100	ns	97	ns	97	ns	99	ns	6
	56	2	* *	12.6	* *	98	ns	98	ns	97	ns	97	ns	99	ns	97	ns	4
	57	41	* *	4	* * *	99	ns	100	ns	105	ns	97	ns	97	ns	91	ns	5
	58	32	* *	11.1	* * *	95	ns	101	ns	102	ns	0	* *	88	ns	95	ns	7
	59	41	* *	19.2	* *	92	ns	99	ns	102	ns	1	* *	92	ns	97	ns	6
	60	19	* *	8.5	* * *	104	ns	106	ns	107	ns	13	* *	100	ns	99	ns	7
	61	9	* *	1.7	* * *	88	ns	96	ns	106	ns	3	* *	95	ns	102	ns	7
	62	5	* *	2.1	* * *	96	ns	103	ns	106	ns	0	* *	98	ns	103	ns	7
	63	8	* *	1.6	* * *	14	* *	52	* *	92	ns	0	* *	78.8	* *	96	ns	13
	64	95	*	199.4	ns	98	ns	98	ns	100	ns	75	* *	98	ns	97	ns	3
	65	10	* *	6.4	* * *	36	* *	87	ns	91	ns	74	* *	100	ns	99	ns	9
	66	94	*	6.5	* * *	99	ns	103	ns	101	ns	103	ns	100	ns	102	ns	4
Z																		
	179	93	ns	313.5	ns	84	*	95	ns	104	ns	86	ns	98	ns	98	ns	1
	180	96	ns	42.5	*	74	* *	92	ns	102	ns	98	ns	99	ns	98	ns	3
	181	98	ns	250.9	ns	85	*	97	ns	109	ns	0	* *	20	* *	100	ns	5
	182	100	ns	1250.6	ns	32	* *	85	*	96	ns	93	ns	98	ns	98	ns	3
	183	101	ns	613.4	ns	9	* *	68	* *	104	ns	82	* *	99	ns	100	ns	6
	184	100	ns	944.1	ns	11	* *	69	* *	99	ns	46	* *	97	ns	98	ns	6
	185	84	ns	873.2	ns	57	* *	103	ns	104	ns	0	* *	99	ns	100	ns	4
	186	94	ns	40.2	*	69	* *	102	ns	108	ns	91	ns	98	ns	96	ns	3
	187	98	ns	555.8	ns	88	ns	99	ns	106	ns	95	ns	98	ns	97	ns	0
	188	105	ns	1283.0	ns	84	*	99	ns	103	ns	47	* *	99	ns	99	ns	3
	189	103	ns	243.2	ns	16	* *	86	*	100	ns	0	* *	97	ns	99	ns	5
	190	97	ns	1241.8	ns	99	ns	97	ns	108	ns	84	*	98	ns	101	ns	1
	191	91	ns	237.0	ns	89	ns	99	ns	107	ns	0	* *	99	ns	101	ns	2
	192	92	ns	110.3	ns	0	* *	37	* *	94	ns	59	* *	99	ns	98	ns	6
	193	83	ns	587.9	ns	95	ns	103	ns	106	ns	0	* *	99	ns	99	ns	2

Table 10 continued.

Zone No.	Sample No.	Amphipod survival	Statistical significance	Microtox EC 50	Statistical significance	Urchin fert'n 100% WQAP[b]	Statistical significance	Urchin fert'n 50% WQAP	Statistical significance	Urchin fert'n 25% WQAP	Statistical significance	Urchin devt 100% WQAP	Statistical significance	Urchin devt 50% WQAP	Statistical significance	Urchin devt 25% WQAP	Statistical significance	Toxicity tally [a]
	194	92	ns	528.5	ns	55	* *	93	ns	102	ns	0	* *	0	* *	96	ns	6
	195	99	ns	1217.4	ns	9	* *	49	* *	93	ns	0	* *	13	* *	98	ns	10
	196	92	ns	390.7	ns	87	ns	94	ns	103	ns	0	* *	86	ns	98	ns	2
	197	97	ns	1258.4	ns	100	ns	95	ns	102	ns	0	* *	94	ns	97	ns	2
	198	80	* *	1270.6	ns	95	ns	91	ns	99	ns	0	* *	6	* *	101	ns	6
	199	95	ns	1239.5	ns	101	ns	97	ns	104	ns	4	* *	98	ns	98	ns	2
	200	88	ns	36.7	* *	87	ns	98	ns	107	ns	0	* *	0	* *	98	ns	6
	201	96	ns	46.5	*	95	ns	99	ns	100	ns	0	* *	76	* *	97	ns	5
	202	90	ns	206.9	ns	98	ns	96	ns	101	ns	100	ns	97	ns	100	ns	0
	203	96	ns	60.8	ns	95	ns	96	ns	105	ns	99	ns	97	ns	99	ns	0
	204	94	ns	15.3	* *	101	ns	99	ns	106	ns	0	* *	98	ns	98	ns	4
	205	98	ns	23.0	* *	98	ns	100	ns	102	ns	0	* *	99	ns	99	ns	4
8																		
	106	110	ns	47.8	ns	103	ns	102	ns	111	ns	0	* *	0	* *	45	* *	6
	67	94	*	8.1	* *	1	* *	0	* *	1	* *	0	* *	0	* *	9	* *	15
	68	102	ns	6.5	* *	117	ns	111	ns	109	ns	0	* *	0	* *	17	* *	8
	69	44	* *	1237.3	ns	0	* *	0	* *	1	* *	1	* *	99	ns	101	ns	10
	70	93	ns	1.6	* * *	1	* *	6	* *	10	* *	2	* *	0	* *	70	* *	15
	71	105	ns	3.8	* * *	69	* *	94	ns	101	ns	0	* *	65	* *	101	ns	9
	72	95	ns	2.8	* * *	0	* *	0	* *	26	* *	0	* *	56	* *	73	* *	15
	73	103	ns	4.2	* *	112	ns	104	ns	103	ns	0	* *	3	* *	98	ns	6
	74	98	ns	100	ns	111	ns	107	ns	104	ns	0	* *	37	* *	98	ns	4
	75	102	ns	5.9	* *	108	ns	95	ns	93	ns	0	* *	0	* *	98	ns	6
	76	92	ns	24.4	* *	108	ns	99	ns	104	ns	0	* *	101	ns	97	ns	4
	77	105	ns	38.8	*	114	ns	110	ns	108	ns	0	* *	48	* *	98	ns	5
	78	95	ns	71.2	ns	117	ns	111	ns	104	ns	2	* *	99	ns	100	ns	2
	79	83	*	15.2	* *	115	ns	109	ns	104	ns	0	* *	42	* *	96	ns	7
	80	81	*	100	ns	115	ns	109	ns	109	ns	45	* *	100	ns	97	ns	3
	81	89	*	45.7	*	114	ns	106	ns	104	ns	0	* *	100	ns	99	ns	4
	82	82	*	9.6	* *	114	ns	102	ns	104	ns	0	* *	98	ns	96	ns	5
	83	81	*	5.8	* *	110	ns	109	ns	101	ns	3	* *	101	ns	98	ns	5
	84	94	ns	85.9	ns	114	ns	104	ns	99	ns	0	* *	97	ns	99	ns	2
	85	93	*	4.4	* *	110	ns	110	ns	107	ns	53	* *	102	ns	97	ns	5
	86	96	ns	45	ns	106	ns	103	ns	99	ns	1	* *	92	ns	99	ns	2
	87	65	* *	4.1	* *	110	ns	103	ns	103	ns	0	* *	99	ns	96	ns	6
	88	88	*	75.5	ns	105	ns	93	ns	101	ns	105	ns	102	ns	97	ns	1
	89	82	*	55	*	59	* *	102	ns	99	ns	64	* *	103	ns	98	ns	6
	90	57	* *	21.1	* *	34	* *	100	ns	105	ns	13	* *	101	ns	98	ns	8
	107	99	ns	1248.6	ns	106	ns	102	ns	109	ns	0	* *	101	ns	101	ns	2

Table 10 continued.

Zone No.	Sample No.	Amphipod survival	Statistical significance	Microtox EC 50	Statistical significance	Urchin fert'n 100% WQAP[b]	Statistical significance	Urchin fert'n 50% WQAP	Statistical significance	Urchin fert'n 25% WQAP	Statistical significance	Urchin devt 100% WQAP	Statistical significance	Urchin devt 50% WQAP	Statistical significance	Urchin devt 25% WQAP	Statistical significance	Toxicity tally [a]
	91	96	ns	6.3	* *	109	ns	107	ns	105	ns	100	ns	104	ns	101	ns	2
	93	96	ns	3.5	* * *	114	ns	108	ns	110	ns	62	* *	101	ns	99	ns	5
	94	96	ns	2	* * *	80.05	*	105	ns	106	ns	85	* *	102	ns	98	ns	6
	95	99	ns	5.5	* *	97	ns	96	ns	94	ns	104	ns	103	ns	99	ns	2
	96	97	ns	3.5	* * *	113	ns	107	ns	107	ns	63	* *	103	ns	99	ns	5
	97	95	ns	1.6	* * *	88	ns	103	ns	102	ns	0	* *	0	* *	99	ns	7
	98	96	ns	5.5	* *	112	ns	104	ns	104	ns	10	* *	103	ns	97	ns	4
	99	91	*	1.6	* * *	2	* *	79.4	* *	99	ns	0	* *	0	* *	0	* *	14
	100	93	*	1.1	* * *	92	ns	104	ns	99	ns	0	* *	27	* *	98	ns	8
	101	100	ns	2.3	* * *	67	* *	81	*	98	ns	0	* *	0	* *	14	* *	12
	102	101	ns	2.8	* * *	112	ns	106	ns	109	ns	0	* *	96	ns	96	ns	5
	103	103	ns	3	* * *	7	* *	59	* *	102	ns	0	* *	86	ns	99	ns	9
	104	102	ns	1.4	* * *	19	* *	4	* *	12	* *	0	* *	0	* *	46	* *	15
	105	97	ns	3.6	* * *	62	* *	106	ns	104	ns	0	* *	0	* *	25	* *	11
	92	69	* *	3.5	* * *	37	* *	106	ns	105	ns	0	* *	0	* *	78	* *	13
	206	90	ns	27.3	* *	63	* *	93	ns	101	ns	0	* *	99	ns	98	ns	6
	207	79	ns	93.6	ns	70	* *	94	ns	105	ns	0	* *	0	* *	99	ns	6
	208	98	ns	62.9	ns	58	* *	78	* *	100	ns	0	* *	0	* *	101	ns	8
	209	95	ns	32.8	* *	7	* *	12	* *	52	* *	0	* *	89	ns	100	ns	10
	210	100	ns	398.9	ns	13	* *	47	* *	92	ns	88	ns	99	ns	98	ns	4
	211	100	ns	108.7	ns	8	* *	43	* *	90	ns	3	* *	99	ns	98	ns	6
	212	95	ns	49.8	*	96	ns	95	ns	100	ns	0	* *	11	* *	100	ns	5
	213	99	ns	92.7	ns	53	* *	86	*	86	*	0	* *	0	* *	101	ns	7
	214	90	ns	38.2	*	67	* *	91	ns	99	ns	0	* *	66	* *	99	ns	7
9																		
	215	96	ns	478.4	ns	67	* *	98	ns	104	ns	0	* *	100	ns	101	ns	4
	216	89	ns	504.3	ns	82	ns	98	ns	105	ns	0	* *	1	* *	101	ns	4
	217	91	ns	917.1	ns	104	ns	102	ns	105	ns	0	* *	97	ns	98	ns	2
	218	74	ns	561.4	ns	96	ns	98	ns	107	ns	0	* *	97	ns	101	ns	2
	219	96	ns	150.6	ns	93	ns	104	ns	110	ns	0	* *	6	* *	100	ns	4
	220	95	ns	313.4	ns	11	* *	87	ns	101	ns	0	* *	99	ns	99	ns	4
	221	87	ns	435.6	ns	93	ns	95	ns	104	ns	0	* *	96	ns	100	ns	2
	222	99	ns	63.0	ns	6	* *	79.9	* *	102	ns	3	* *	99	ns	97	ns	6
	223	99	ns	1095.1	ns	0	* *	46	* *	93	ns	0	* *	94	ns	101	ns	6
	224	98	ns	886.6	ns	100	ns	104	ns	108	ns	88	ns	96	ns	96	ns	0
	225	94	ns	117.8	ns	3	* *	32	* *	76	* *	0	* *	98	ns	95	ns	8
	226	87	ns	49.1	*	7	* *	90	ns	106	ns	0	* *	99	ns	98	ns	5

ns = not significant (p>0.05)
* significant (p<0.05, response >80% of control)
** highly significant (p<0.05, response <80% of control)
*** very highly significant in Microtox tests

[a] Toxicity tally calculated as the sum of the asterisks for each of the individual tests.
[b] Water quality-adjusted porewater concentrations.

same stratum. Station 138 in zone 4 and station 156 in zone 5 were located near each other, but separated by the Julia Tuttle Causeway.

Zone 6 samples collected outside the Miami River ranged in toxicity tallies from 2 to 11 (**Table 10**). The sample from station 41 collected near the western shoreline was highly toxic in the Microtox tests and both urchin tests in two porewater concentrations. Samples from stations 13-16 located in the Port of Miami channel were intermediate in toxicity (tallies ranging from 6 to 7). Sediment from station 45 was not toxic in any of the tests. In the lower Miami River, toxicity tallies ranged from 4 to 13. Stations 49 downstream of the confluence with Seybold Canal and 63 in lower Seybold Canal were the most toxic. Relatively high degrees of toxicity were also apparent in samples from stations 65, 47, 50, 58, 60-62.

Most samples from zone 7 had toxicity tally scores of 0 to 4 (**Table 10**); only the sample from station 195 was highly toxic (score of 10). The uppermost stations in Coral Gables and Snapper Creek canals were nontoxic in all tests.

Toxicity was highly variable in zone 8; toxicity tallies ranging from 0 to 15 (**Table 10**). Five samples had toxicity tallies of 14 or 15: station 67 in the northeastern corner of the zone; stations 70 and 72 along the western shoreline; station 99 in the entrance channel to Black Creek Canal; and station 104 in Black Creek Canal. The sample from station 67 was especially curious, given the distance from possible mainland sources, and the fact that it showed significant toxicity in all tests. Toxicity was relatively high in other stations located far from the mainland, including 68, 69, 89, and 90. However, stations 92, 97-105 in Black Creek / Gould's canals and 206-214 in Military, Mowry, and North canals were among the most toxic in this region.

Except for station 225, none of the stations in zone 9 was highly toxic (**Table 10**). The sample from station 225 was toxic in both of the urchin tests. Toxicity tallies in all other stations ranged from 0 to 6, indicating non-toxic to slightly toxic conditions.

Copepod reproduction tests. Ten toxicological end-points were recorded in the copepod tests of reproductive success **(Table 11**). Significant differences between sample means and negative control means are shown with asterisks. The numbers of non-gravid females surviving the exposures to solid-phase sediments were higher relative to controls in samples from stations 11 and 58 and, correspondingly, the numbers of gravid females were significantly lower in those samples. There no significant reductions in numbers of adult males that survived the exposures.

The average numbers of eggs produced (clutch size) were significantly reduced relative to controls in all except two samples (numbers 31, 101). Also, the total numbers of individuals that survived to the naupliar and copepodite stages were significantly reduced in all except two samples (numbers 14, 23). Normalized to the numbers of surviving females, the numbers of total offspring ranged from 0.4 to 12.7, corresponding to 3% to 75% of the mean control responses.

The sum of all eggs (assuming all hatch and survive) + all nauplii + all copepodites divided by the numbers of surviving females represents total potential production from the adults in these tests (**Table 11**). Expressed as percentages of respective controls, results ranged

Table 11. Summary of results of multiple assays of the reproductive success of meiobenthic copepods (A. tenuiremis) in controls and15 selected samples from Biscayne Bay (means ± std. devs. of 4 replicates).

Station No.	Surviving non-gravid females	Surviving gravid females	Surviving adult males	No. eggs per female	Total eggs produced by all females	Juvenile copepodites produced	Nauplii produced	Total nauplii + copepodites	Ratio of offspring to surviving females	Total potential production
Control 1	2.8±2.2	18.8±5.0	19.5±3.1	11.6±1.3	214.5±62.2	40.0±20.9	296.8±160.2	336.8±181.1	14.5±6.6	24.4±7.1
1	11.3±5.4	11.0±6.2	16.5±9.7	6.1±0.8*	67.0±41.0*	1.0±0.8*	80.8±12.9*	81.8±13.4*	3.7±0.9*	6.7±2.0*
11	14.5±7.0*	7.2±6.6*	21.0±2.0	8.5±2.2*	61.5±74.6*	3.0±4.8*	102.0±58.5	105.0±61.9*	4.9±3.0*	7.8±6.4*
48	12.0±1.4	8.0±1.4	20.0±4.1	6.4±1.1*	51.0±9.9*	0.8±1.0*	8.5±6.6*	9.3±7.4*	0.4±0.4*	3.0±0.5*
Control 2	1.0±1.0	21.7±2.1	20.0±2.0	14.0±1.8	304.0±65.1	9.0±6.6	558.3±192.0	567.3±185.7	25.0±8.3	38.4±10.1
4	1.3±1.2	22.0±2.0	20.0±3.6	11.7±0.9*	258.0±39.0	10.0±6.0	228.7±28.6*	238.7±28.4*	10.3±1.6*	21.3±2.5*
8	1.7±0.6	22.7±4.5	18.3±3.5	11.6±1.8*	262.7±90.8	1.3±1.5	244.7±76.3*	246.0±74.8*	10.0±1.7*	20.5±3.6*
31	5.7±4.7	18.7±5.9	21.0±3.0	12.7±1.4	236.7±95.5	2.0±2.0	215.7±34.8*	217.7±36.3*	8.9±1.4*	18.6±4.3*
58	12.3±2.5*	6.0±3.6*	20.3±4.0	5.3±0.6*	32.0±15.7*	0.7±0.6	28.3±18.2*	29.0±17.6*	1.6±1.0*	3.3±0.4*
Control 3	3.8±1.7	21.3±2.5	22.2±1.7	11.2±3.8	237.2±16.3	30.5±19.5	251.5±86.3	282.0±102.7	11.8±5.3	21.4±6.3
14	9.0±2.2	13.0±4.6	23.2±5.2	8.5±2.8*	110.2±48.4	7.8±4.3	180.0±53.2	187.8±57.0	8.5±2.6	13.4±3.2
23	4.8±3.9	14.5±5.5	22.5±2.6	8.9±2.9*	129.8±50.3	7.5±4.2	160.3±38.2	167.8±40.2	8.8±1.8	15.5±4.0
Control 4	1.3±0.6	21.7±0.6	23.0±2.7	13.6±3.1	295.0±21.7	29.7±17.9	360.3±27.9	390.0±13.2	17.0±0.5	29.8±0.3
67	4.0±3.6	17.0±6.1	20.7±1.2	10.6±3.0*	181.0±63.3	3.3±3.2	108.7±13.3*	112.0±11.8*	5.4±0.3*	13.8±1.7*
73	5.0±3.0	17.0±4.6	23.7±2.5	11.2±3.2*	189.7±59.7	2.0±1.0	155.7±40.1*	157.7±41.1*	7.1±1.4*	15.7±2.6*
91	11.3±8.1	13.7±8.1	22.7±5.0	9.3±3.2*	127.3±99.8	3.3±3.1	214.3±12.5*	217.7±10.7*	8.7±0.4*	13.8±3.6*
95	3.7±2.1	18.3±0.6	25.0±0.0	12.1±2.6*	222.3±68	1.7±1.2	252.3±63.3	254.0±62.2*	11.9±4.0	22.1±5.4
101	1.3±1.2	20.0±3.5	25.7±3.2	14.1±3.4	281.7±79	18.7±22.0	247.7±61.0*	266.3±82.9*	12.7±4.7	25.8±2.8
105	5.0±3.0	14.3±3.2	23.3±3.2	10.5±3.5*	150.7±37.6	1.3±0.6	76.7±20.8*	78.0±21.2*	4.0±0.9*	11.8±1.8*

* Significantly different from batch controls (Tukey's studentized range test, $p<0.05$)

from 3.3 (8.6% of control 2) in sample 58 to 25.8 (86.6% of control 4) in sample 101. Total potential production was significantly reduced in 11 of the 15 samples. Samples from stations 48 (lower Miami River) and 58 (upper Miami River) were the most toxic. Samples from stations 95 (Princeton canal) and 101 (lower Gould's / Black Creek canal) were the least toxic. Also, samples from stations 14 (north of Dodge Island) and 23 (south of Dodge Island) were non-toxic.

Cytochrome P-450 RGS bioassays. This test was performed on all of the samples collected during 1996. Data, which express the fold induction attributable to substances such as benzo[a]pyrne and dioxins which attach to the Ah-recepter, were normalized to the degree of induction attributable to exposures to benzo(a)pyrene (**Table 12**). High induction may be caused by the presence of any number of mixed-function oxidase inducing compounds, most notably dioxins, furans, co-planar PCBs, and several high molecular weight polynuclear aromatic hydrocarbons (PAHs). There are no statistical tools available thus far for assigning significance to the results of these tests. Therefore, data are presented on a relative scale by comparing results among each sampling station. However, based upon a review of existing data from many surveys, results greater than 11.1and 37.1 ug B[a]P equivalents / g represent moderate and very high levels of induction, respectively.

Table 12. Summary of results of cytochrome P-450 RGS assays of sediment extracts from Biscayne Bay (as benzo(a)pyrene equivalents, ug/g). These tests were performed only with the 1996 samples.

Station number	B(a)p equiv. (ug/g)	Station number	B(a)p equiv. (ug/g)	Station number	B(a)p equiv. (ug/g)	Station number	B(a)p equiv. (ug/g)	Station number	B(a)p equiv. (ug/g)
106	**1.91**	131	**12.76**	156	**1.95**	181	**0.71**	206	**23.63**
107	**0.75**	132	**1.26**	157	**11.11**	182	**1.45**	207	**20.47**
108	**1.45**	133	**11.04**	158	**12.09**	183	**1.65**	208	**19.10**
109	**2.68**	134	**7.66**	159	**11.90**	184	**3.00**	209	**8.86**
110	**3.77**	135	**3.52**	160	**12.12**	185	**0.41**	210	**6.66**
111	**11.54**	136	**4.10**	161	**9.08**	186	**1.47**	211	**8.61**
112	**12.54**	137	**8.88**	162	**6.23**	187	**0.48**	212	**8.51**
113	**11.01**	138	**4.74**	163	**5.77**	188	**0.54**	213	**35.07**
114	**13.60**	139	**3.08**	164	**3.62**	189	**0.59**	214	**9.29**
115	**7.91**	140	**8.53**	165	**13.10**	190	**0.55**	215	**0.59**
116	**15.60**	141	**1.33**	166	**29.57**	191	**0.87**	216	**0.74**
117	**15.52**	142	**0.78**	167	**17.20**	192	**0.81**	217	**2.42**
118	**7.90**	143	**12.41**	168	**6.22**	193	**0.71**	218	**1.90**
119	**6.70**	144	**28.71**	169	**18.58**	194	**1.18**	219	**2.87**
120	**2.56**	145	**14.81**	170	**16.79**	195	**0.98**	220	**1.34**
121	**5.03**	146	**25.41**	171	**13.55**	196	**2.63**	221	**0.64**
122	**4.19**	147	**36.85**	172	**10.34**	197	**0.87**	222	**0.90**
123	**3.20**	148	**14.29**	173	**15.37**	198	**0.75**	223	**1.50**
124	**2.02**	149	**4.16**	174	**11.27**	199	**1.11**	224	**1.33**
125	**2.86**	150	**29.66**	175	**4.77**	200	**10.73**	225	**1.10**
126	**2.62**	151	**0.49**	176	**4.31**	201	**37.03**	226	**1.34**
127	**0.74**	152	**3.24**	177	**16.42**	202	**8.40**		
128	**16.78**	153	**2.13**	178	**25.37**	203	**8.00**		
129	**21.42**	154	**4.28**	179	**1.42**	204	**18.61**		
130	**21.86**	155	**4.25**	180	**4.56**	205	**8.25**		

The mean response in the P-450 RGS assays among all 121 samples was 8.2 ug B[a]P equivalents / g with a standard deviation of 8.5 and a 99% confidence interval of 2.0. There were 36 samples in which results exceeded 11.1 ug B[a]P equivalents / g and none in which results exceeded 37.1 ug B[a]P equivalents / g. Results ranged from 1 ug B[a]P equivalents / g in many samples collected throughout the bay to 37 ug B[a]P equivalents / g in samples from stations 147 (Indian Creek) and 201 (Coral Gables Canal), both located in peripheral

canals (**Table 12**). Other samples which showed relatively high responses included those from stations 213 (North Canal), 150 (mouth of Little River), and 166 (west of Watson Park and near a marina).

Incidence of toxicity. The percentages of samples that were "toxic", i.e., significantly different from responses in respective control or reference materials in the least conservative statistical test (i.e., assigned at least single asterisks), are listed and compared among toxicity tests in **Table 13**. Data from the samples collected in the1995 and1996 field operations are shown along with the overall totals. Because different regions of the study area were sampled each year, no temporal trends are explicit or implied in these data.

In the amphipod tests, 49 of 226 samples (21.7%) were significantly different from controls (**Table 13**). Based upon the relatively low incidence of toxicity, this was clearly the least sensitive of the bioassays. All except two of the toxic samples were collected in 1995, reflecting the influence of the samples from zone 6 which included the lower Miami River. The distribution of survival results among the 226 samples from Biscayne Bay paralleled that of the combined database from previous NOAA and EMAP studies (n=2630, **Table 14**). That is, the percentages of samples within each each response category were within a few per-

Table 13. Incidence of significant* sediment toxicity in Biscayne Bay in 1995 and 1996 samples.

Toxicity test/end point		1995 toxic/total	1995 percent	1996 toxic/total	1996 percent	Total toxic/total	Total percent
Amphipod survival		47/105	38.8	2/121	1.7	49/226	21.7
Urchin fertilization							
	100% porewater	36/105	34.3	64/121	52.9	100/226	44.2
	50% porewater	14/105	13.3	30/121	24.8	44/226	19.5
	25% porewater	6/105	5.7	8/121	6.6	14/226	6.2
Urchin development							
	100% porewater	66/105	62.9	108/121	89.3	174/226	77.0
	50% porewater	26/105	24.8	43/121	35.5	69/226	30.5
	25% porewater	10/105	9.5	4/121	3.3	14/226	6.2
Microtox		94/105	89.5	37/121	30.6	131/226	58.0

* p<0.05, paired tests relative to controls

Table 14. Comparison of the distribution of results in the amphipod survival tests between Biscayne Bay and those from the combined database from NOAA and EMAP studies nationwide.

Percent control-adjusted amphipod survival	Total (n=2630) number	Total (n=2630) percent	Biscayne Bay (n=226) number	Biscayne Bay (n=226) percent
≥ 100	734	27.9	54	23.9
90-99.9	1237	47.0	116	51.3
80-89.9	330	12.5	29	12.8
70-79.9	112	4.3	4	1.8
60-69.9	55	2.1	4	1.8
50-59.9	30	1.1	2	0.9
40-49.9	24	0.9	4	1.8
30-39.9	27	1.0	5	2.2
20-29.9	19	0.7	0	0.0
10-19.9	25	1.0	3	1.3
0.0-9.9	35	1.3	5	2.2

centage points of each other, suggesting the data from Biscayne Bay followed the pattern elsewhere in U.S. estuaries.

In the sea urchin fertilization tests, 44% of the samples were toxic in 100% pore water, 20% were toxic when samples were diluted by 50%, and only 6% were toxic in tests pf 25% pore water. A slightly higher percentage of the 1996 samples was toxic than the 1995 samples, reflecting the influence mainly of samples from zone 8. In the most sensitive bioassay, 77% of samples were toxic in the urchin embryological development tests performed with 100% pore water.

In the Microtox tests, 58% of samples were toxic. The majority of the toxic samples were collected in 1995, again, reflecting the influence of the Miami River samples on the results.

The copepod tests were performed on selected samples collected during 1995 and P-450 RGS tests were run on samples collected only in 1996. Therefore, these data were not equivalent to those from tests conducted on all 226 samples. Nevertheless, total potential production of copepod offspring was significantly reduced in 11 (73%) of the 15 samples tested. P-450 RGS assay results exceeded 11.1 ug B[a}P equivalents / g in 36 (30%) of the 121 samples tested; however, none exceeded 37.1 ug B[a}P equivalents / g.

Spatial extent of toxicity. Tabulations of the incidence of toxic samples can be highly influenced by the density of sampling effort in polluted regions. To add perspective to the toxicity data, results were weighted to the sizes of the strata within which samples were collected. The weighted sizes of the strata in which "toxic" responses were observed (i.e., responses less than 80% of controls) were summed to provide an estimate of the spatial (or surficial) extent of toxicity in each test. Samples that were toxic from relatively small strata nearest sources, therefore, had a minimal influence on the sum; whereas samples that were toxic in relatively large strata farth from sources where non-toxic conditions were expected made a much larger contribution to the total.

In the amphipod tests, the surficial extent of toxicity was 13%; equivalent to 62 km^2 out of a total of 484 km^2 (**Table 15**). The spatial extent of toxicity in the sea urchin fertilization tests and embryo development tests of 100% pore water were 47% and 84%, respectively. For the Microtox bioluminescence tests, the total for Biscayne Bay was 51%. In the P-450 RGS assays, the samples in which fold induction exceeded 11.1 ug / g B[a]PEq represented about 3.3% of the area tested in 1996; none of the assay responses exceeded 37.1 ug / g.

Concordance among toxicity tests. Tests in this survey were selected to provide complimentary, but not duplicative, information on the toxicity of the sediments. Each test had different degrees of sensitivity to toxicants in the sediments and each was, therefore, expected to show somewhat different regional patterns in toxicity.

The correlations between results of each test are shown in **Table 16**. For all tests, except the cytochrome P-450 test, a positive correlation coefficient indicates the results were in agreement, e. g., amphipod survival decreased as urchin fertilization or microbial bioluminescence decreased. With the cytochrome P-450 data, fold induction would be expected to increase as numerical results of the other tests decreased; therefore, negative correlations would be expected if there was concordance.

Table 15. Spatial extent[a] of sediment toxicity[b] in each test performed during 1995 and 1996.

Toxicity test/end point		1995 Km^2	1995 % of total	1996 Km^2	1996 % of total	Total Km^2	Total % of total
Amphipod survival		52.9	24.8	9.4	3.45	62.3	12.9
Urchin fertilization							
	100% porewater	109.7	51.5	119.8	44.2	229.5	47.4
	50% porewater	54.0	25.4	50.2	21.4	104.2	21.5
	25% porewater	54.1	25.4	5.1	1.9	59.2	12.2
Urchin development							
	100% porewater	176.8	83.1	231.2	85.2	408.0	84.3
	50% porewater	95.5	44.9	75.4	27.8	170.9	35.3
	25% porewater	77.3	36.3	5.2	1.9	82.5	17.0
Microtox EC50		203.8	95.8	44.6	16.4	248.4	51.3
Cytochrome P-450 RGS							
	>11.1 ug BaP/g[c]	no data		8.8	3.3	8.8	3.3
	>37.1 ug BaP/g[c]	no data		0	0	0	0

[a] area sampled: in 1995 = 212.8 km^2, in 1996 = 271.4 km^2 for a total of 484.2km^2

[b] critical value: <80% of controls

[c] critical values of 11.1 and 37.1 ug/g determined from data distribution within national database

Table 16. Spearman-rank correlations (rho) among results of different toxicity tests.

1995

	Amphipod survival	Urchin fertilization	Urchin development
Urchin fertilization	-0.030 ns		
Urchin development	-0.064 ns	+0.112 ns	
Microtox	-0.216 *	+0.309 *	+0.204 *

1996

	Amphipod survival	Urchin fertilization	Urchin development
Urchin fertilization	-0.078 ns		
Urchin development	+0.164 ns	+0.158 ns	
Microtox	-0.079 ns	+0.308 **	+0.134 ns
Cytochrome P-450	+0.052 ns	+0.111 ns	-0.028 ns	-0.521***

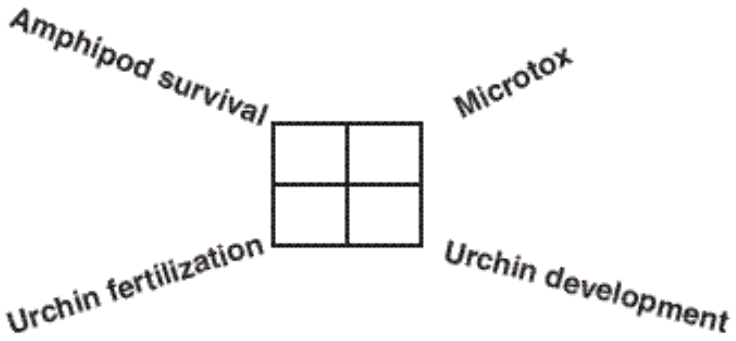
ns = p>0.05 *p<0.05 **p<0.001 ***p<0.0001

In the samples tested during 1995, the results of both the sea urchin tests and the Microtox tests were correlated, indicating they showed similar regional patterns in toxicity. Amphipod survival showed a significant correlation with the Microtox results. In the samples tested during 1996, sea urchin fertilization (100% pore water concentrations), but not embryo development (100% pore water concentrations), was significantly correlated with Microtox results. Microtox and amphipod survival were not correlated. Cytochrome P-450 and Microtox results, both performed on organic solvent extracts of the samples, were highly correlated, indicating fold induction increased as microbial bioluminescent activity decreased.

Spatial patterns in toxicity. Data from each of the tests were plotted on base maps to identify patterns and gradients, if any, in toxicity within the bay and within individual sampling regions. Because of the size and complexity of the study area, data from each of the four tests performed in both years are illustrated as symbols in square 'pie' diagrams on each map. Data from the copepod reproduction tests and cytochrome P-450 tests are shown separately. The legend for the toxicity classifications (**Figure 15**) indicates that white (open) symbols symbolize non-toxic conditions (i.e., not significant relative to controls) in each test. Shaded symbols depict slightly toxic results in the sea urchin and Microtox tests. Black symbols illustrate moderately toxic conditions and black symbols with white triangles indicate highly toxic conditions. The specific criteria for these four classifications are shown in **Figure 15** for each of the four tests that were performed on all 226 samples.

Because the lowest incidence of toxicity was apparent in the amphipod tests, this, was, therefore, the least sensitive test. Consequently, highly toxic results in these tests were regarded as most significant and the classifications of stations were based disproportionately upon results of those tests. However, all four tests plus the cytochrome P-450 and copepod reproduction tests were performed independently and the results of each were taken into consideration in the identification of spatial gradients of toxicity. As indicated in the correlation analyses **(Table 16),** the results of these tests did not parallel or duplicate each other, so perfect agreement or consensus on the least and most toxic stations was neither expected, nor observed. However, some degree of overlap in results was expected in the most contaminated and least contaminated stations.

Several bay-wide and numerous smaller-scale gradients in toxicity were apparent in the results of these tests. First, sediments collected within the lower Miami River were clearly the most toxic among the 226 samples that were tested. Amphipod survival was significantly reduced in all except one of the samples; results were highly toxic in most of the samples; and average amphipod survival was the lowest among all regions. Also, highly significant results were observed in tests of copepod reproductive success and microbial bioluminescence in samples from the Miami River. Toxicity diminished rapidly beyond the mouth of the river. Second, many of the samples from the Black Creek / Gould's canal were moderately to highly toxic in many of the tests. Toxicity generally diminished eastward beyond the entrance channel to this canal. Third, samples collected in an area of the south bay off Turkey Point and in another area off Ragged Keys were surprisingly toxic for areas that were relatively distant from obvious sources and in which concentrations of measured chemicals were uniformly very low.



	Amphipod survival	Urchin fertilization	Urchin development	Microtox
non-toxic	p>0.05	p>0.05 @100%*	p>0.05 @100%*	p>0.05 with Mann-Whitney
slightly toxic	na	p<0.05 @ 100%*	p<0.05 @ 100%*	p<0.05 with Mann-Whitney
moderately toxic	p<0.05, and mean > 80% of control	p<0.05 @50%*	p<0.05 @50%*	p<0.05 with Dunnett's
highly toxic	p<0.05, and mean < 80% of control	p<0.05 @25%*	p<0.05 @25%*	p<0.05 with distribution-free

Figure 15. Legend used to illustrate spatial patterns in toxicity with results from each of the four toxicity tests (*indicates porewater concentrations).

In the northernmost region of the study area (zone 1, **Figure 16**), 12 samples were collected in Dumbfoundling Bay, Maule Lake, Oleta River, and the Intracoastal Waterway. None of the samples was highly toxic in any of the tests. None of the samples was toxic in the amphipod survival tests. Only four showed significant results in the Microtox tests. Despite the proximity to potential toxicant sources in Maule Lake and Oleta River, there were no clear patterns or gradients in toxicity. Surprisingly, because of the very high concentrations of PAHs in the sample, sediments collected near the mouth of the Royal Glade Canal (station 106) were not highly toxic. Among the 12 samples, those from stations 109, 111, and 112 showed the highest toxicity in the sea urchin and Microtox tests.

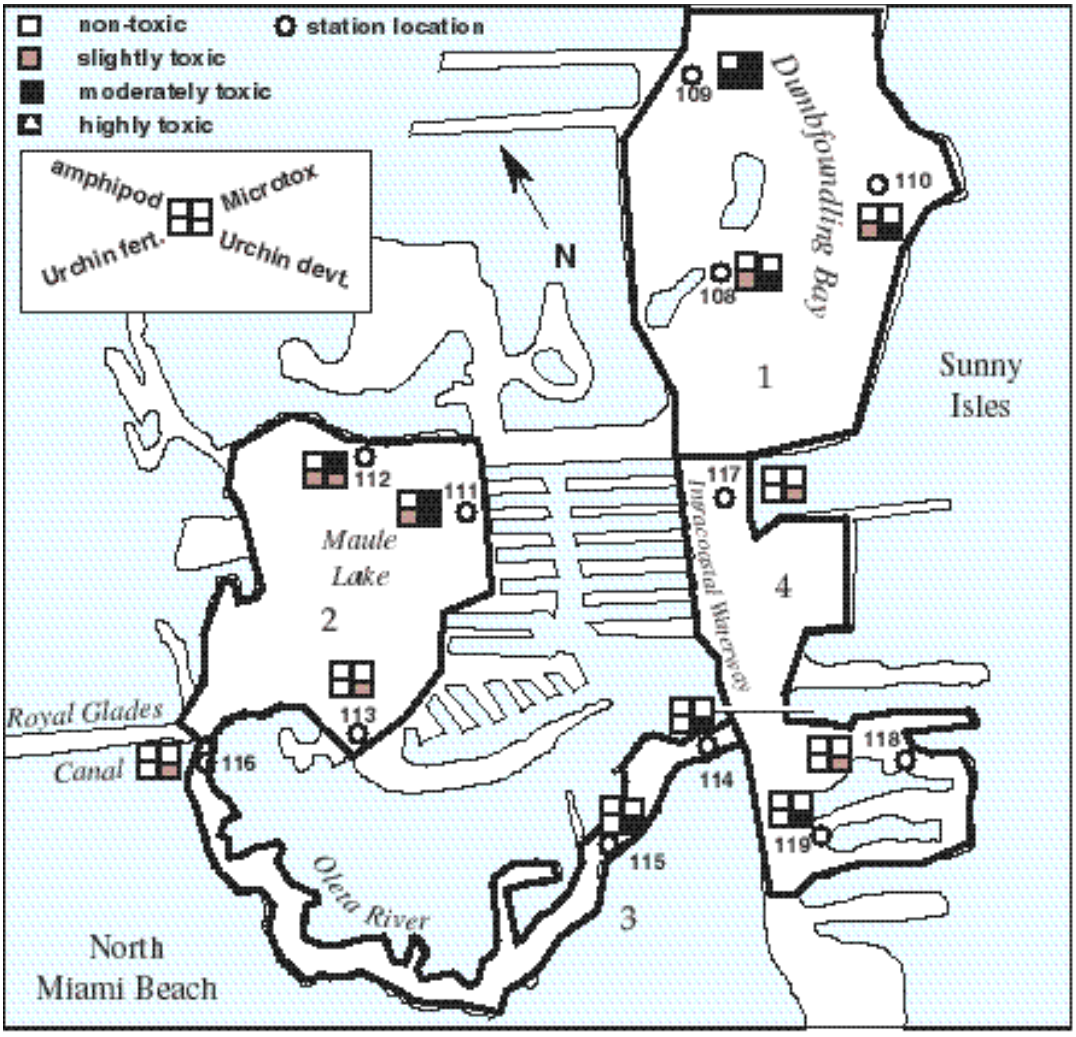


Figure 16. Classifications of the relative degree of toxicity in four sediment tests performed with samples collected within four strata in zone 1.

In zone 2, nine samples were collected near Bal Harbor, Munisport landfill, and north of the Broad Causeway (**Figure 17**). In contrast to zone 1, highly significant results were observed in the Microtox tests in sediments from four of the stations, and moderately toxic results were observed in three other samples. The samples from stations 5 and 8 were moderately toxic in the amphipod test; however, mean survival was relatively high (93% and 91% of controls, respectively) in both samples. Only one significant result (station 4) was apparent in both sea urchin tests; none were moderately or highly toxic. Samples from stations 1-3 were the most toxic in the Microtox tests; otherwise, there were no clear gradients in toxicity within this region.

In zone 3 and 4 in the north-central region of the study area, 31 samples were collected between North Miami and Miami Beach, including strata that encompassed Biscayne

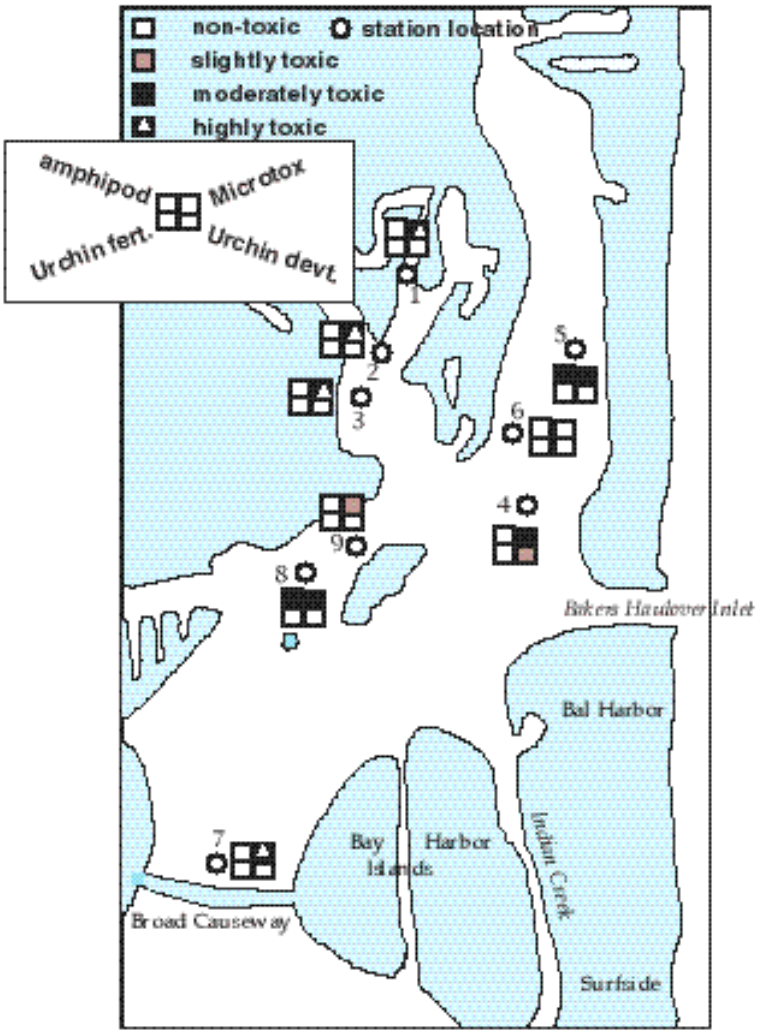


Figure 17. Classifications of the relative degree of toxicity in four sediment tests performed with samples from within three strata in zone 2.

Canal, Little River, and Indian Creek (**Figure 18**). This area was bounded by the Broad Causeway and Julia Tuttle Causeway. Sediments in this area were not remarkably different from those in zone 2. Only one sample (from station 138) was highly toxic in the amphipod tests (mean survival = 64% of controls). None were highly toxic in the Microtox tests; however, many samples were slightly or moderately toxic. All except one sample was at least slightly toxic in at least one of the two urchin tests. The sample from station 138 was noticeably more toxic than the others in three of the four tests. Also, sediments from station 135 were moderately or highly toxic in three tests. Surprisingly, because of their proximity to potential sources, samples from the three peripheral canals were not noticeably more toxic than those from the bay. There were no clear patterns or gradients in toxicity within this region.

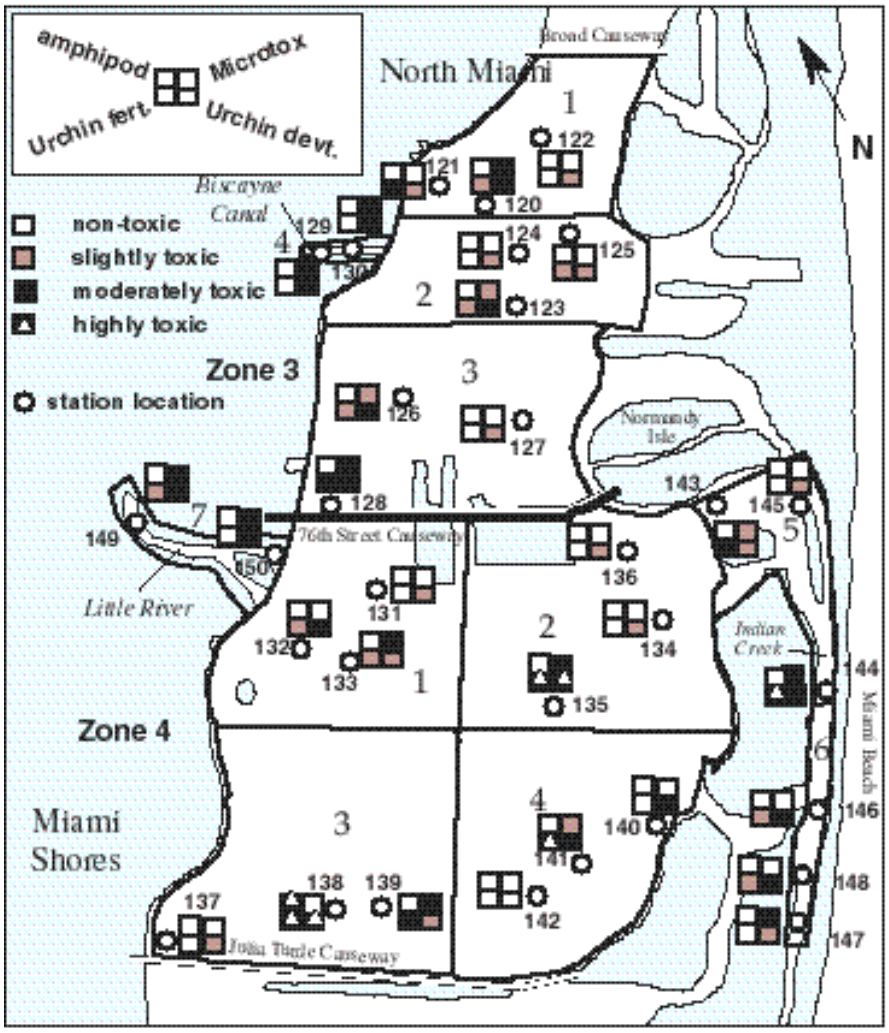


Figure 18. Classifications of the relative degree of toxicity in four sediment tests performed with samples from within 10 strata in zones 3 and 4.

In zone 5, bounded on the north by Julia Tuttle Causeway and on the south by the Port of Miami channel, 28 samples were collected (**Figure 19**). As observed in zones 3 and 4, most of these samples were not highly toxic. None of the results in the amphipod tests were significant. None was highly toxic and only three were moderately toxic in the Microtox tests. Results were highly significant in urchin tests in only two samples (from stations 154 and 156). Curiously, stations 154 and 156 were located near station 138 which was the most toxic station in zone 4; however, these locations were separated by the Julia Tuttle Causeway. Other than the relatively high toxicity in stations 138, 154 and 156; there were no strong toxicity gradients in this region.

In zone 6, samples were collected between the Port of Miami and the Rickenbacker Causeway (35 stations). Twenty-one samples were collected in the lower Miami River, providing

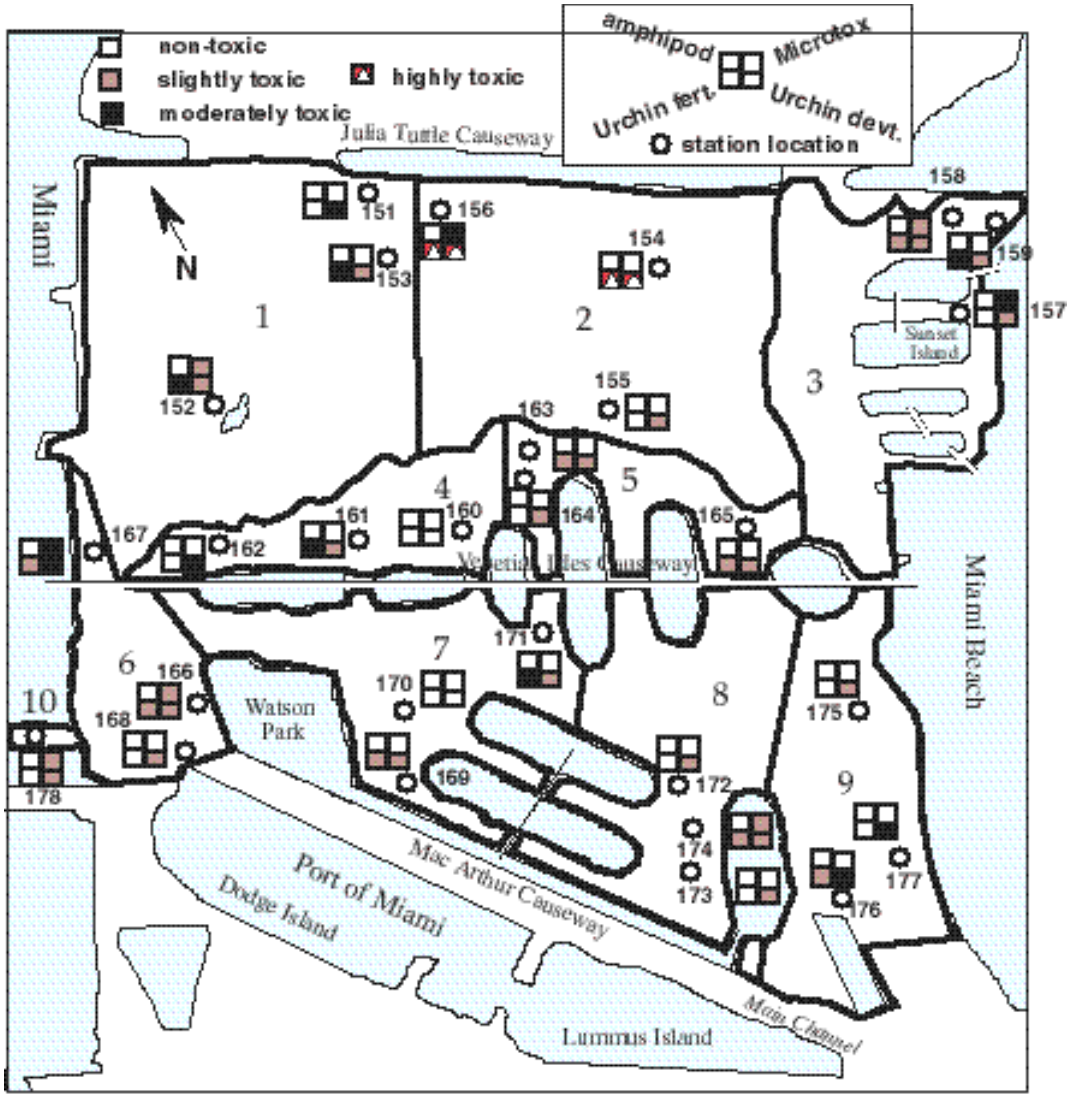


Figure 19. Classifications of the relative degree of toxicity in four sediment tests performed with samples from within ten strata in zone 5.

information from the railroad east to the Brickell Point (**Figures 20, 21**). Sediments could not be collected in the eastern reaches of the Port of Miami channel - only limestone rocks were found in many repeated deployments of the sampler. Therefore, after the sample was collected at station 16, no others were obtained. Stations 17 and 18, originally intended for that stratum, were moved to another stratum within zone 6.

Among the 35 samples collected in the open water of zone 6, two (stations 10 and 12) collected in the northeastern corner indicated moderate toxicity in the amphipod survival tests. An additional three samples (stations 19-21) collected in the eastern end of the Port of Miami entrance channel indicated at least moderate toxicity; the sample from station 20 was highly toxic (mean survival was 77% of that in controls). Many of the samples were moderately or highly toxic in the Microtox tests. Samples collected from stations both north

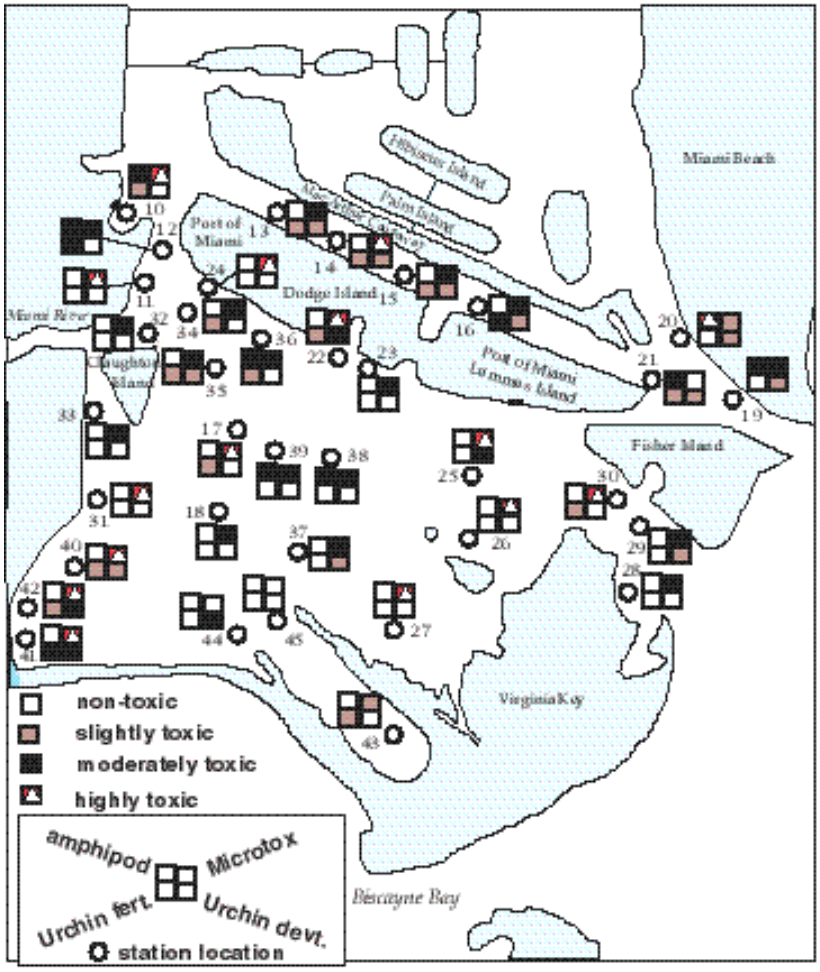


Figure 20. Classifications of the relative degree of toxicity in four sediment tests performed with samples collected within 13 strata in zone 6.

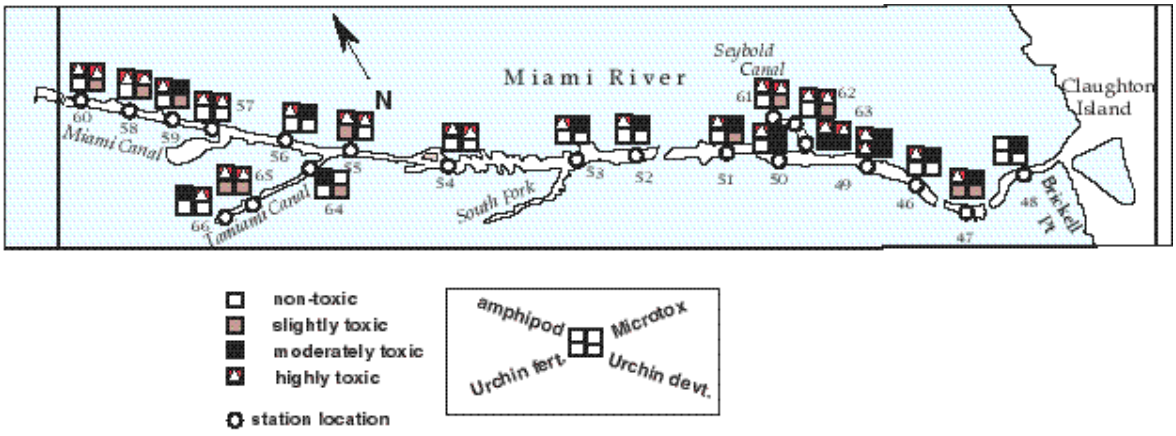


Figure 21. Classifications of the relative degree of toxicity in four sediment tests performed with samples collected within seven strata in zone 6 (Miami River).

and south of the Dodge Island / Lummus Island complex, in the Intracoastal Waterway, and along the shoreline south of the Miami River were relatively toxic in the Microtox tests. Toxicity generally decreased in this test toward the southeast section of the area. In contrast, samples from this region were not highly toxic in either of the sea urchin tests. In the sea urchin tests, toxicity was most apparent among samples collected within the Port of Miami channel, Intracoastal Waterway, and along the southwestern shoreline. The sample from station 41, which was highly toxic in Microtox tests, was moderately toxic in both sea urchin tests.

Among all 226 samples collected, those from sections of the lower Miami River were the most toxic in the amphipod tests (**Figure 21, Table 6**). All except one of the 21 samples was toxic and all except three was highly toxic. In sediments from stations 61-63 (Seybold Canal), mean survival was 9%, 5%, and 8% of controls, respectively. Only 2% of the animals survived in the sample from station 56. In samples from stations 51 and 65, 9% and 10%, respectively, of animals survived. Toxicity diminished abruptly in the most downstream station (station 48) near the mouth of the canal.

Results of the Microtox tests in the Miami River showed a pattern similar to that of the amphipod tests (**Figure 21, Table 9**). All except one of the 21 samples was either moderately or highly toxic. Results were 1.7%, 2.1% and 1.6% of control responses with samples from stations 61-63 (Seybold Canal) - the most toxic samples. Other highly toxic samples included those from stations 54 (7.1% of control response), 57 (4% of controls), 60 (8.5%), and 65-66 (6.4%, 6.5%, respectively). Toxicity generally was highest upstream of the intersection with South Fork and generally diminished somewhat downstream toward the mouth of the river.

In sharp contrast to results of the amphipod and Microtox tests, both tests performed with the sea urchins did not show remarkably high toxicity in the Miami River (**Figure 21, Tables 7 and 8**). In the urchin fertilization tests, toxicity was most apparent in samples from stations 63 and 49 located at and below the mouth of Seybold Canal. All other samples were either non-toxic or only slightly toxic. In the embryo development tests, samples from adjacent stations 50, 63, and 49 were either moderately to highly toxic. Several samples from the upper reaches of the river (stations 58-60), Tamiami Canal (stations 64-65), and upper Seybold Canal (stations 61-62) were slightly toxic.

In zone 7 south of Rickenbacker Causeway, a total of 27 samples was collected, including three each in two tributary canals (**Figure 22**). None of these samples was highly toxic in any of the four tests. The sample from station 198 was moderately toxic (80% survival relative to controls) in the amphipod tests. Two samples from the Snapper Creek Canal and one sample from the Coral Gables Canal were moderately toxic in the Microtox tests and two additional samples were slightly toxic. Nine of the samples collected in the open waters of the bay were moderately toxic in at least one of the urchin tests and most were at least slightly toxic. Moderately toxic conditions in the Microtox tests observed in the lower reaches of the Snapper Creek Canal diminished abruptly beyond the mouth of the canal. Otherwise, there were no clear gradients or patterns in toxicity in this region.

Toxicity tests were performed on 51 samples from zone 8, including 22 samples from six tributary canals (**Figure 23**). Several patterns in toxicity were apparent in this region. First,

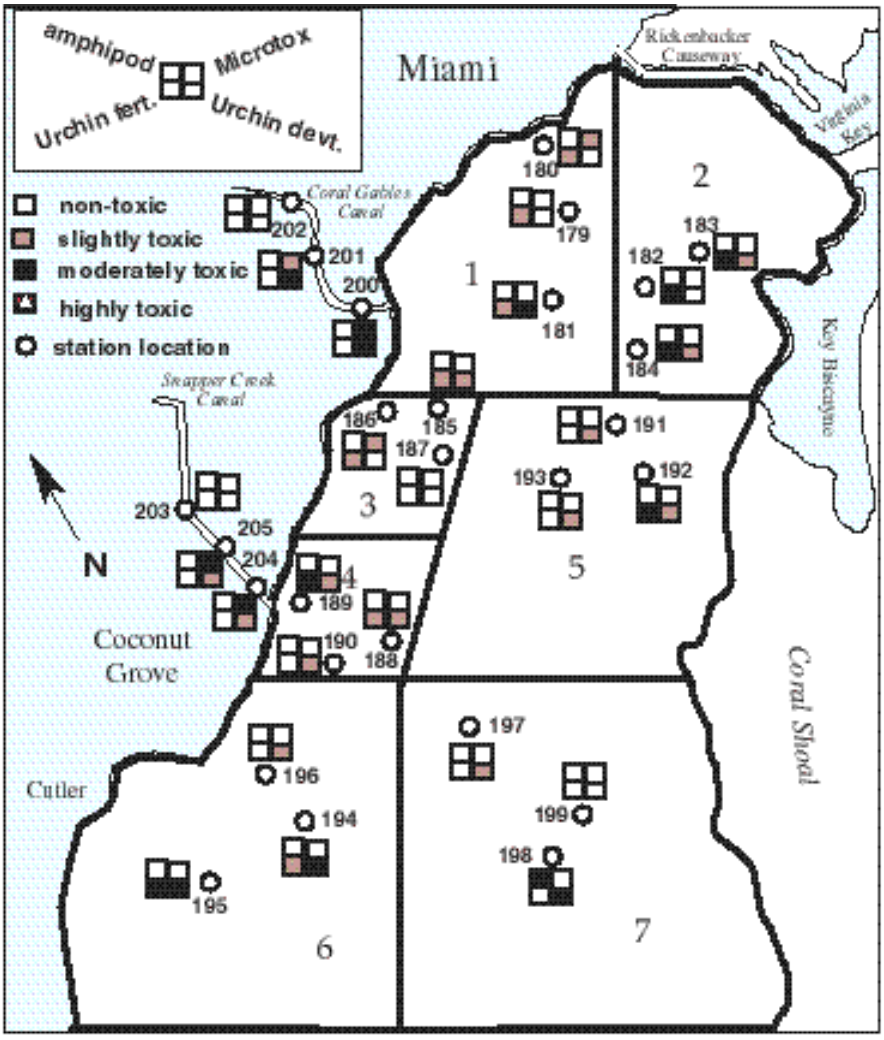


Figure 22. Classifications of the relative degree of toxicity in four sediment tests performed with samples collected within nine strata in zone 7.

Microtox tests, and to a lesser extent, amphipod and sea urchin tests, showed relatively high toxicity in the Black Creek / Gould's Canal. Several samples (i.e., stations 70-72) collected beyond the mouth of this canal also were toxic; thereafter, toxicity generally diminished southeastward into the bay. Second, many samples collected in an area off the mouths of North and Mowry canals and off Turkey Point were relatively toxic in amphipod and Microtox tests, and to a lesser extent, in the urchin tests. Third, and perhaps most curious, samples from stations 67 and 69 which were located far from obvious sources were toxic in the amphipod and both urchin tests. Samples from stations 106, 88, and 107 to the north and south of stations 67 and 69 were considerably less toxic.

Twleve samples were collected in zone 9, the southernmost region of the study area (**Figure 24**). None of these samples was toxic in the amphipod tests and only one was slightly toxic

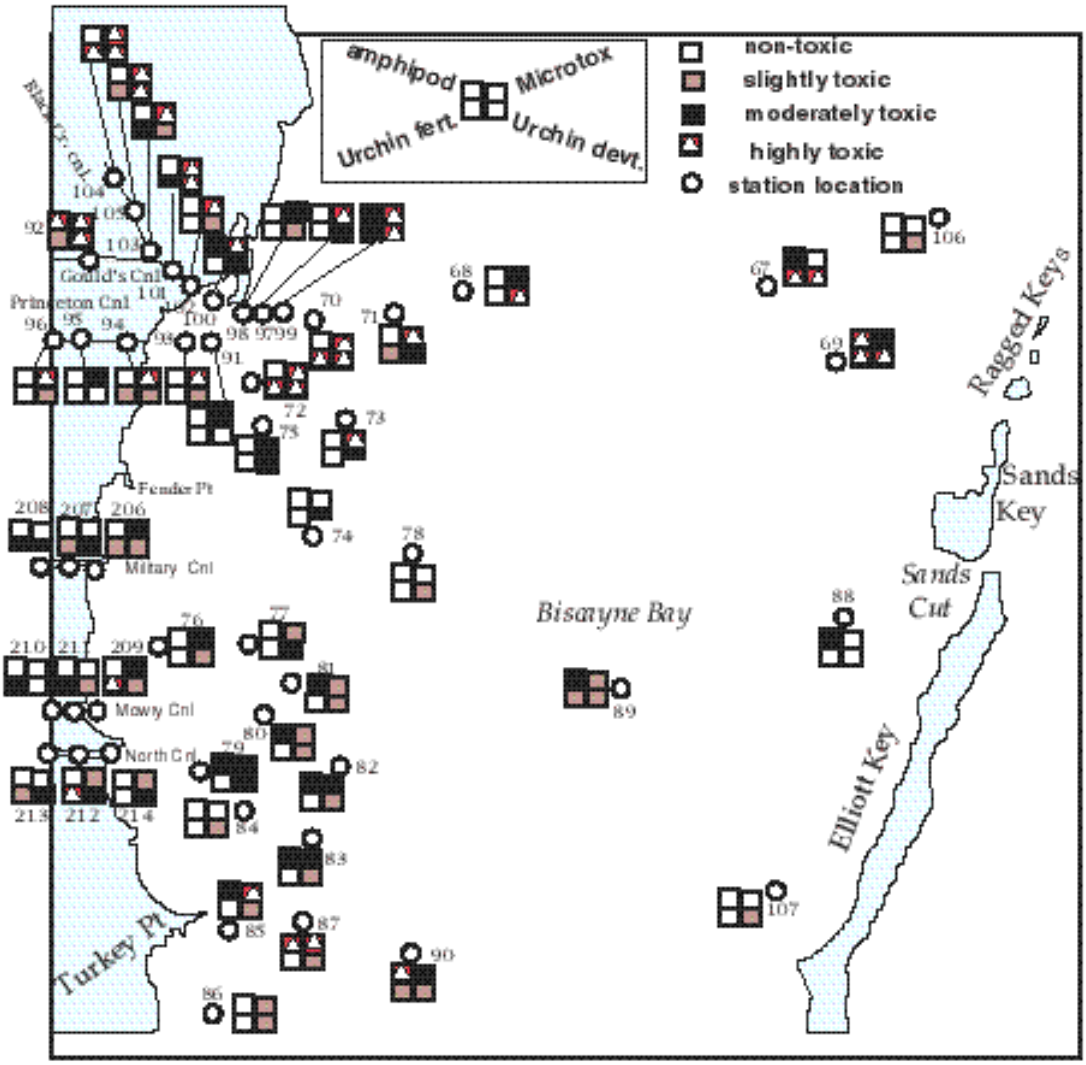


Figure 23. Classifications of the relative degree of toxicity in four sediment tests performed with samples from within seven strata in zone 8.

in Microtox tests. Several samples were either slightly or moderately toxic in either of the urchin tests and one (station 225) was highly toxic in the embryological development test. There were no clear patterns or gradients in toxicity.

In the copepod reproduction tests, samples were collected from 15 stations that were presumed to represent pollution gradients. Station 1 near the Munisport landfill, stations 48 and 58 in the lower Miami River, station 105 in the Black Creek Canal, and station 95 in Princeton Canal were expected to most severely affect reproductive success in these tests. All copepod tests were performed only during 1995. Results of three cumulative endpoints (total numbers of nauplii and copepodites produced, the ratio of total offspring to the numbers of surviving females, and total potential production) as listed in Table 10 are illustrated in **Figure 25**. All data are compared as percentages of batch controls.

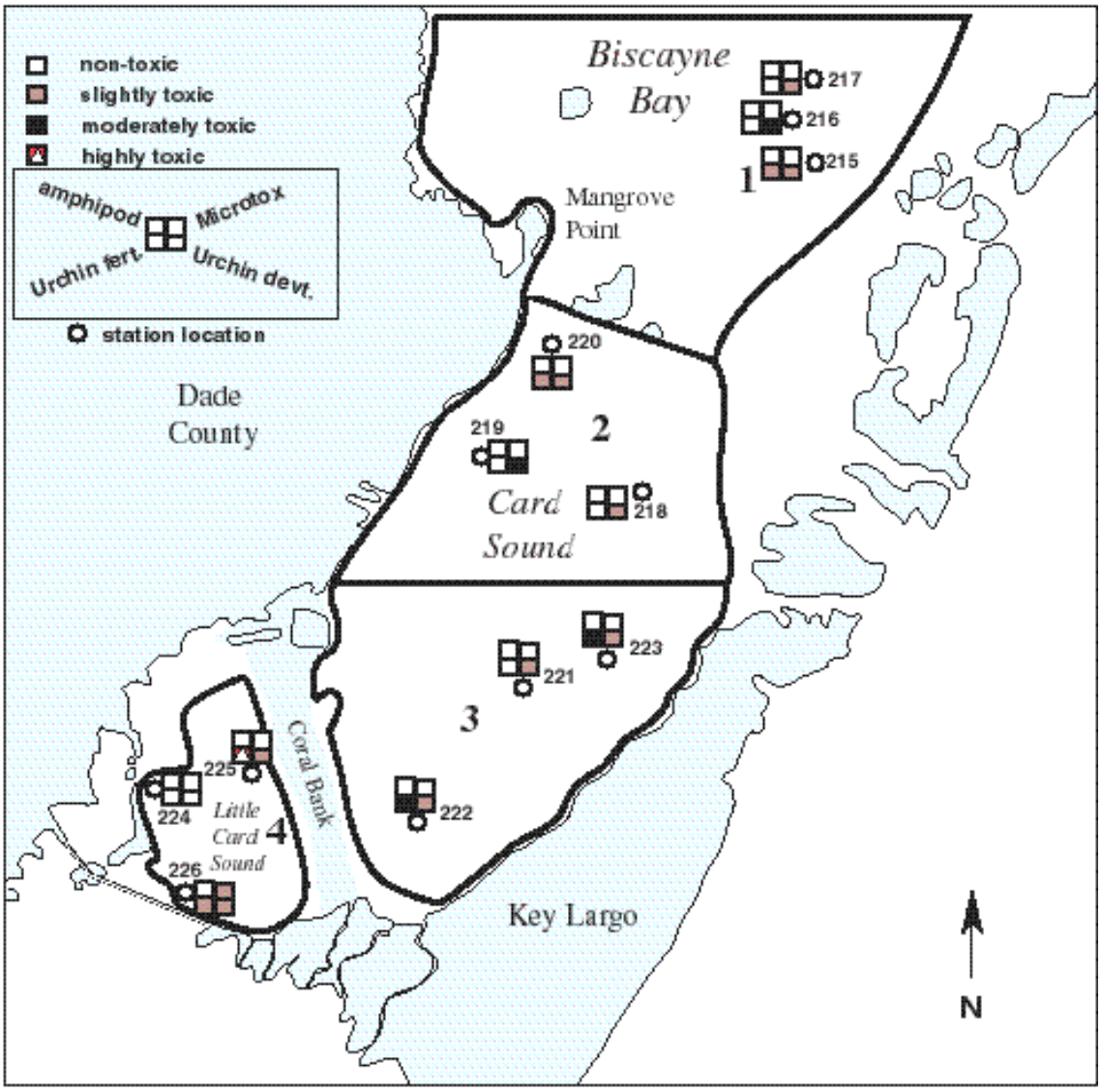


Figure 24. Classifications of the relative degree of toxicity in four sediment tests performed with samples collected within four strata in zone 9.

In the copepod tests, effects were most severe in the samples from stations 48 and 58 in the lower Miami River (**Figure 25**). Results at these two stations ranged from 2.7% to 12.3% of controls for the three endpoints. Reproductive success improved in the samples from stations 11, 14, and 23, which were increasingly distant from the mouth of the Miami River. The samples from stations 1 and 105 also were among the most toxic in these tests; results ranged from 20% to 38% of controls. Effects diminished with increasing distance from both stations. Surprisingly, given the distance from known sources of toxicants, the sample from station 67 in the southern bay was highly toxic in the copepod tests; coinciding with results of the other tests performed on that sample.

Bioassays with the reporter gene system were performed on samples collected during 1996 to detect the presence of substances in organic solvent extracts of the sediments that can

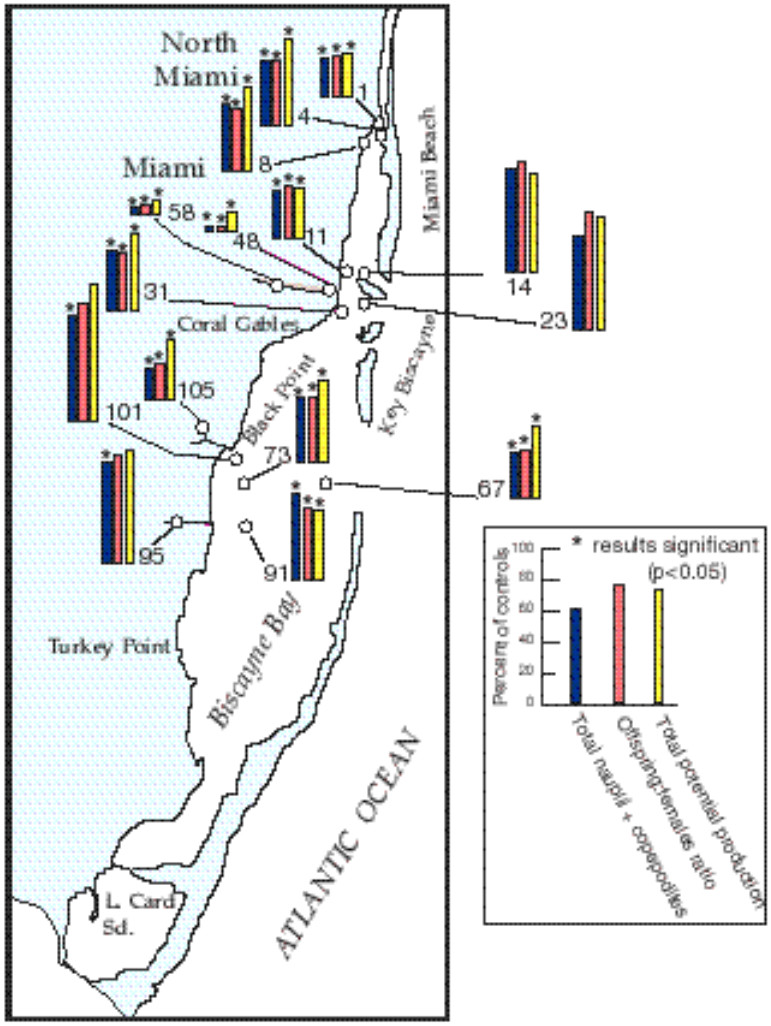


Figure 25. Summary of results (expressed as percentages of controls) of three assays of copepod reproductive success in exposures to sediments from 15 selected stations.

induce cytochrome P-450 activity. Results ranged from <1.0 ug benzo[a]pyrne equivalents / g (B[a]pEq) to over 37 ug B[a]pEq / g (**Table 11).** Spatial patterns in these results are illustrated in **Figures 26-31** for six regions of the survey area. As described in Methods, values greater than 11.1 ug / g and 37.1 ug / g represent responses that are moderate and high, respectively.

In sampling zone 1, bioassay results ranged from 1.5 ug / g in the sample from station 108 to 15.6 ug / g in station 116 (**Figure 26**). In general, P-450 induction was highest in samples

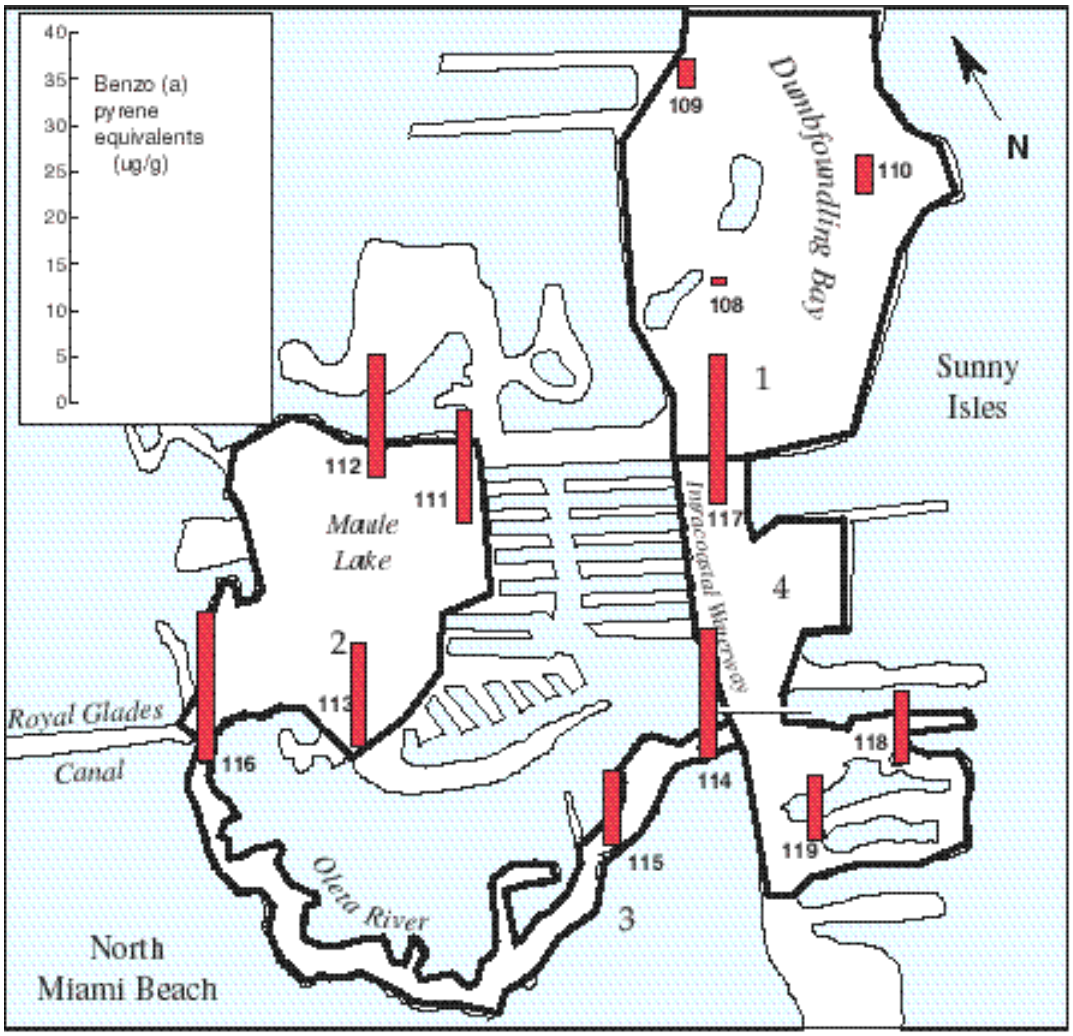


Figure 26. Results of cytochrome P-450 RGS bioassays (expressed as benzo [a] pyrene equivalents) on organic solvent extracts of sediment samples from zone 1.

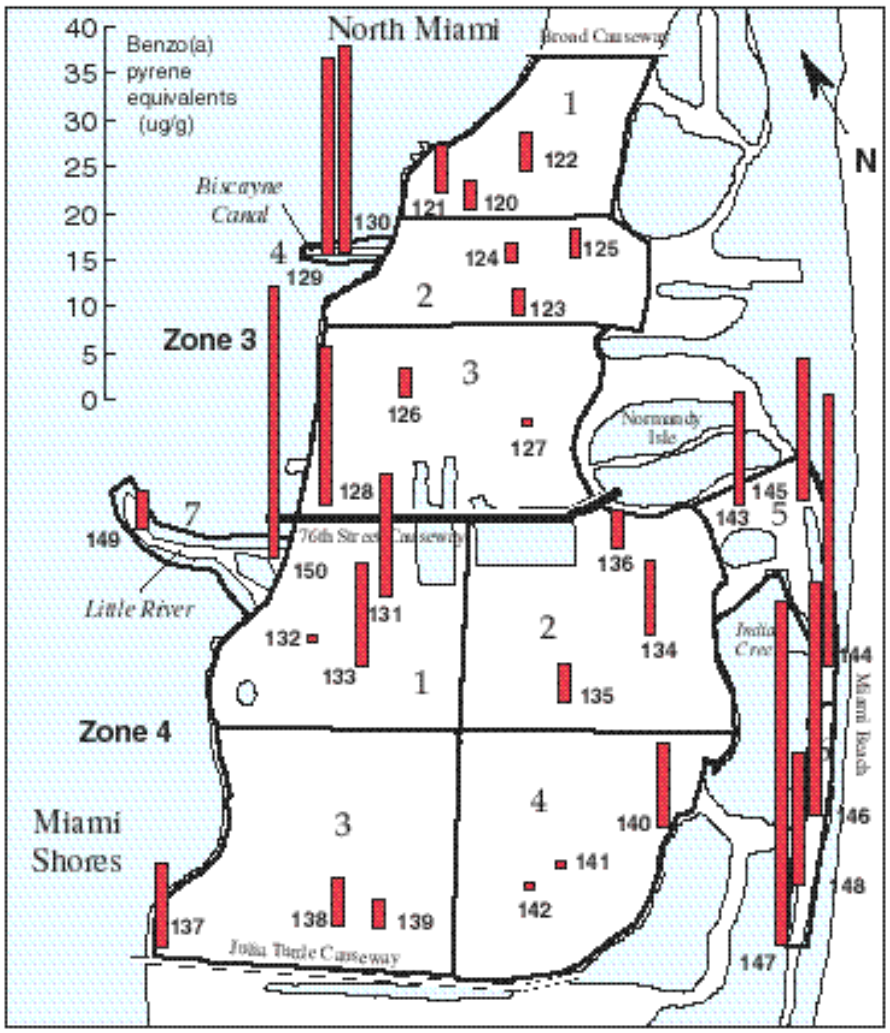


Figure 27. Results of cytochrome P-450 RGS bioassays (expressed as benzo [a] pyrene equivalents) on organic solvent extracts of sediment samples from zones 3 and 4.

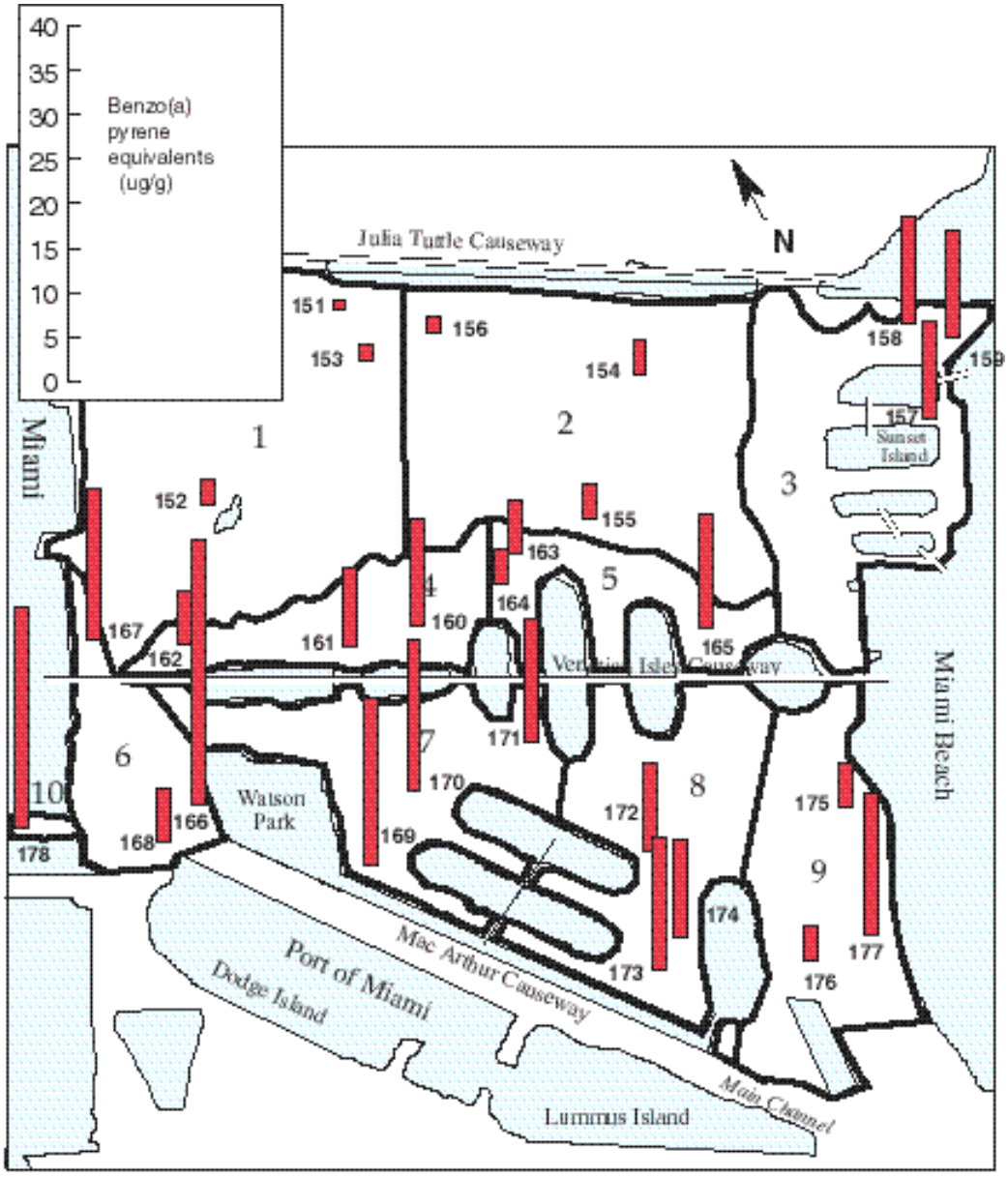


Figure 28. Results of cytochrome P-450 RGS bioassays (expressed as benzo [a] pyrene equivalents) on organic solvent extracts of sediment samples from zone 5.

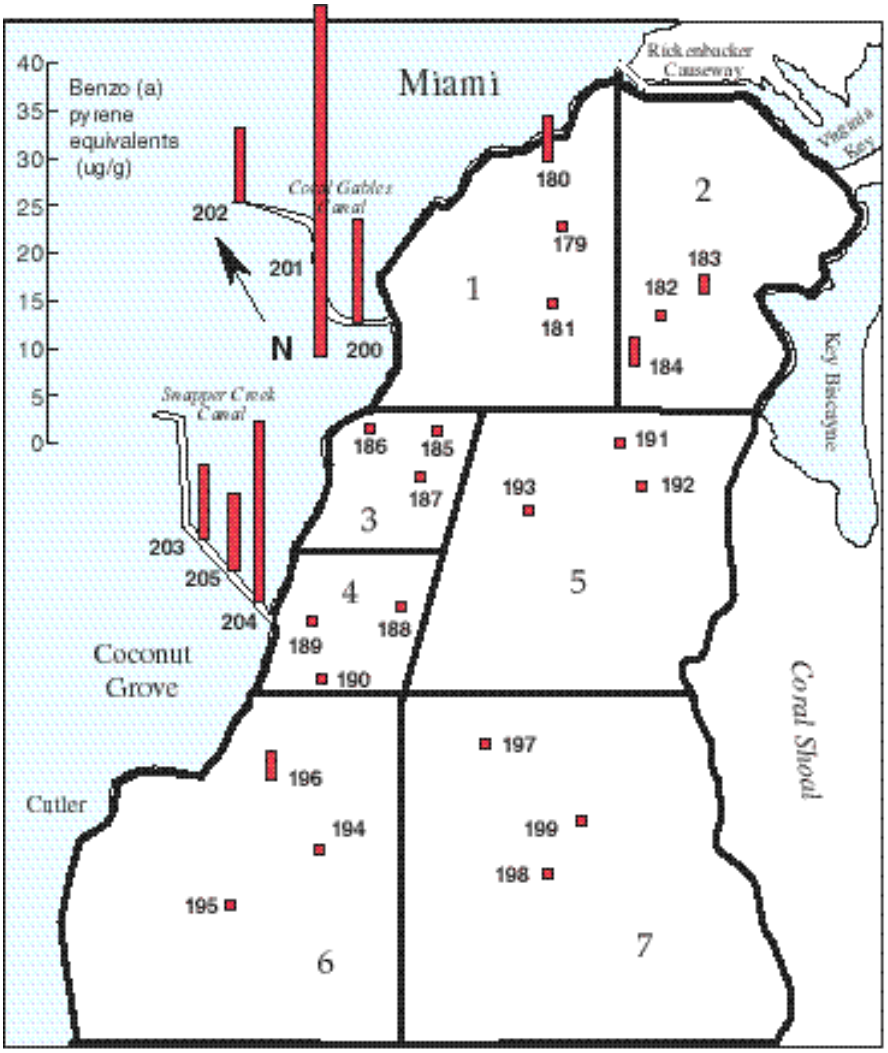


Figure 29. Results of cytochrome P-450 RGS bioassays (expressed as benzo [a] pyrene equivalents) on organic solvent extracts of sediment samples from zone 7.

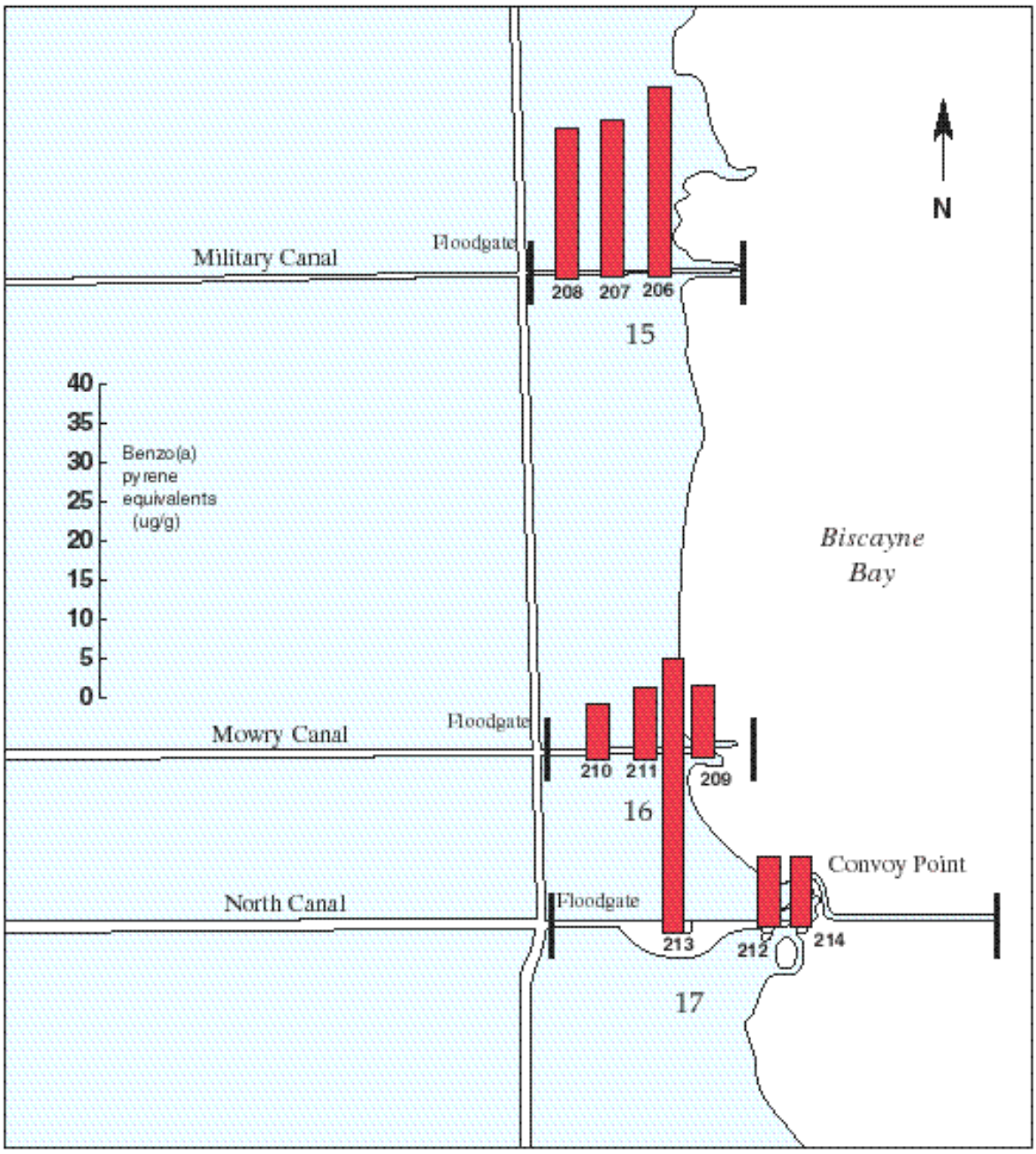


Figure 30. Results of cytochrome P-450 RGS bioassays (expressed as benzo [a] pyrene equivalents) on organic solvent extracts of sediment samples from zone 8 canals.

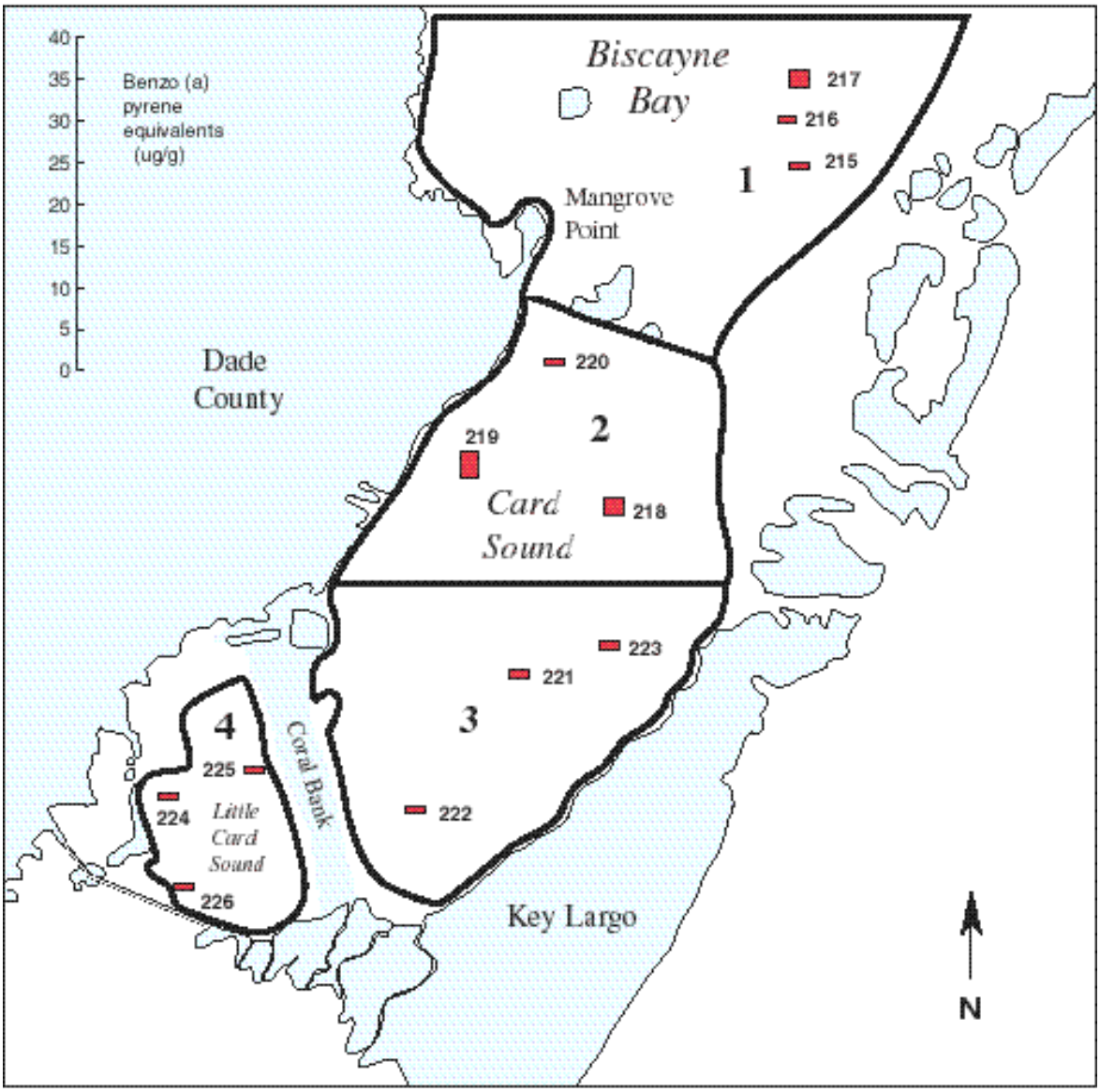


Figure 31. Results of cytochrome P-450 RGS bioassays (expressed as benzo [a] pyrene equivalents) on organic solvent extracts of sediment samples from zone 9.

collected in the Oleta River, Maule Lake, and one reach of the Intracoastal Waterway. However, relative to samples collected elsewhere in the survey, those from zone 1 were only slightly contaminated.

In sampling zones 3 and 4, results ranged from <1.0 ug/g in samples from stations 127 and 142 to over 36 ug/g in sample 147 from Indian Creek (**Figure 27**). In general, samples from the three peripheral tributaries to this region of the bay were most contaminated with substances that induce cytochrome P-450 actitivity. There were only 12 of the 121 samples tested that resulted in responses greater than 20 ug/g; six of which were collected in zones 3 and 4. Furthermore, the sample from station 147 was one of only three that resulted in a response greater than 30 ug/g. Responses exceeded 20 ug/g in samples from the Little River, Biscayne Canal, and Indian Creek and generally diminished steadily with distance from these tributaries.

Results in zone 5 ranged from 0.5 ug/g in the sample from station 151 to 25.4 ug/g and 29.6 ug/g in the samples from stations 178 and 166, respectively (**Figure 28**). Station 178 was located in the Bicentennial Park basin and station 166 was located near a marine fuel dock. Most of the samples collected south of the Venetian Isles were more contaminated that those collected farther north.

The majority of samples from sampling zone 7 showed very low contamination; indicating responses of <1.0 to 3.0 in most samples (**Figure 29**). An exception, the sample from station 201 collected in the Coral Gables Canal, indicated relatively high contamination. The response of 37.0 ug/g in sample 201 was the highest observed among the 121 samples. Other samples from the Coral Gables Canal as well as the Snapper Creek Canal indicated moderate levels of induction. All of the samples from the open waters of the bay showed very low induction.

Similar to results from Coral Gables and Snapper Creek canals, samples from Military, Mowry, and North canals also indicated moderate induction activities (**Figure 30**). The sample from station 213 located near a large marina provided the third highest induction rate among all 121 samples that were tested. The three samples collected in Military Canal (stations 206-208) provided responses of 19.1 ug/g to 23.6 ug/g, much higher on average than induction activities in samples from the other nearby canals.

Bioassay results in all 12 samples collected in sampling zone 9 indicated these samples were not contaminated (**Figure 31**). Induction activity ranged from 0.6 ug/g to 2.9 ug/g.

Spatial patterns in chemical contamination. Because of the size and complexity of the study area and the large number of chemical analytes, data for all substances are not plotted in this report. Instead, the concentrations of four substances - lead, zinc, total PAHs, and total PCBs - are shown to illustrate the spatial gradients and patterns in contamination. These four substances were selected for several reasons. In numerous surveys performed elsewhere in US estuaries, these four substances have been reliable indicators of inputs of anthropogenic toxicants and showed high concordance with measures of toxicity. They showed relatively high correlations with toxicity in Biscayne Bay. Most toxic substances covaried with each other to a high degree in Biscayne Bay, suggesting that the data for these four substances would be representative of the spatial patterns for most other chemicals.

Concentrations are shown as histograms on a sequence of base maps (**Figures 32-40**)**.** Bars representing the concentrations of lead, zinc, the total of 13 PAHs, total PCBs (sum of 20 congeners times 2.0) are shown from left to right for each sampling station. The legend accompanying each illustration includes the respective ERL and ERM (where appropriate) values from Long et al. (1995). Note that the scales are different among the different maps.

In zone 1, chemical conentrations were highest in samples collected in Maule Lake and lowest in the samples from the lower Oleta River and parts of the Intracoastal Waterway **(Figure 32).** Concentrations of lead in stations 111-113 exceeded the ERL value of 46.7 ppm. Concentrations of total PCBs exceeded the ERL value of 22.7 ppb in seven of the stations. The concentration of total PAHs at station 116 near the mouth of Royal Glades Canal was extremely high, exceeding the ERM value of 44,792 ppb.

Chemical concentrations were considerably lower in zone 2 **(Figure 33).** None of the lead, zinc or PAH concentrations equalled or exceeded their respective ERL values. However, the concentrations of PCBs exceeded the ERL in most samples. PCB concentrations were highest in stations 7 and 8 and lowest in station 4.

In zones 3 and 4 chemical data showed a very clear pattern: concentrations were highest in samples from peripheral tributaries to the bay and lowest towards the middle of the bay **(Figure 34).** In this area samples from Biscayne Canal, Little River and Indian Creek had the highest concentrations of the four representative substances. Concentrations in samples from stations 129, 130, 149, and 147 often exceeded their respective ERL values. Concentrations of lead, zinc, and total PCBs in these samples also exceeded the ERM values. Beyond the mouths of these tributaries, chemical concentrations diminished sharply to levels below the ERLs. The sample from station 137 taken near the Julia Tuttle Causeway had intermediate concentrations.

In zone 5, concentrations of lead, zinc, and total PAHs were below the ERL values in most samples; however, the concentrations of PCBs were above the ERL and below the ERM **(Figure 35).** Relative to the other stations within this zone, samples from station 157-159 near Sunset Island and station 178 in a small basin near downtown Miami were the most contaminated. However, these concentrations were considerably lower than those in the Miami River (below). As observed in zones 3 and 4 concentrations often were lowest towards the middle of the bay. Surprisingly, the sample taken at station 166, which was near a fuel dock, did not have an unusually high concentration of PAHs.

All 21 samples from the lower Miami River stations had relatively high concentrations of many chemical substances, including lead, zinc, tPAHs, and tPCBs **(Figure 36).** Concentrations often exceeded respective ERL values and frequently exceeded the ERMs. All of the highest concentrations encountered in the 226 samples analyzed in the study were observed in these samples. Samples in which concentrations were extremely high included those from stations 61-63 (Seybold Canal) and 65 (Tamiami Canal). In the mainstem of the Miami Canal, there was no clear gradient in contamination. All stations from the farthest upstream to the farthest downstream had elevated concentrations. PCB concentrations were slightly higher below the confluence with Seybold Canal than above it, suggesting Seybold Canal may be a source of PCBs to the river. PAH concentrations in sample 65 -

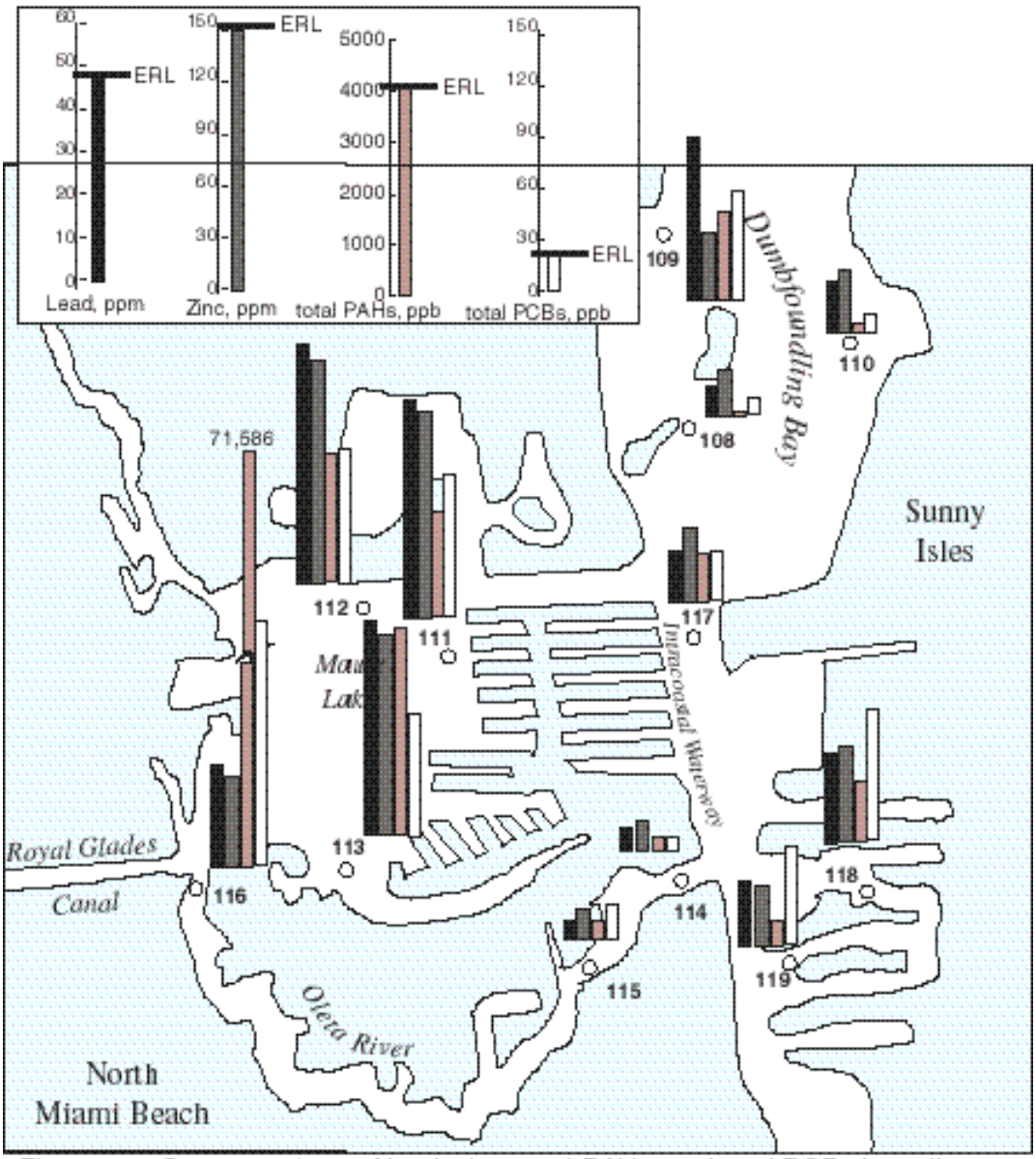


Figure 32. Concentrations of lead, zinc, total PAHs, and total PCBs in sediments from zone 1.

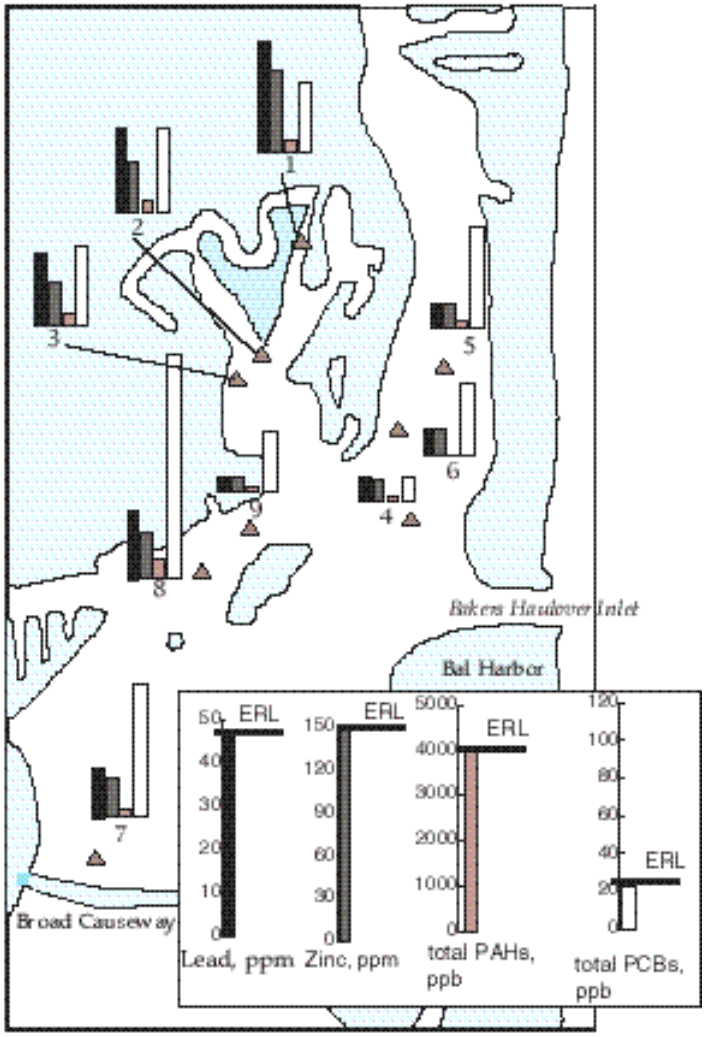


Figure 33. Concentrations of lead, zinc, total PAHs, and total PCBs in sediments from zone 2.

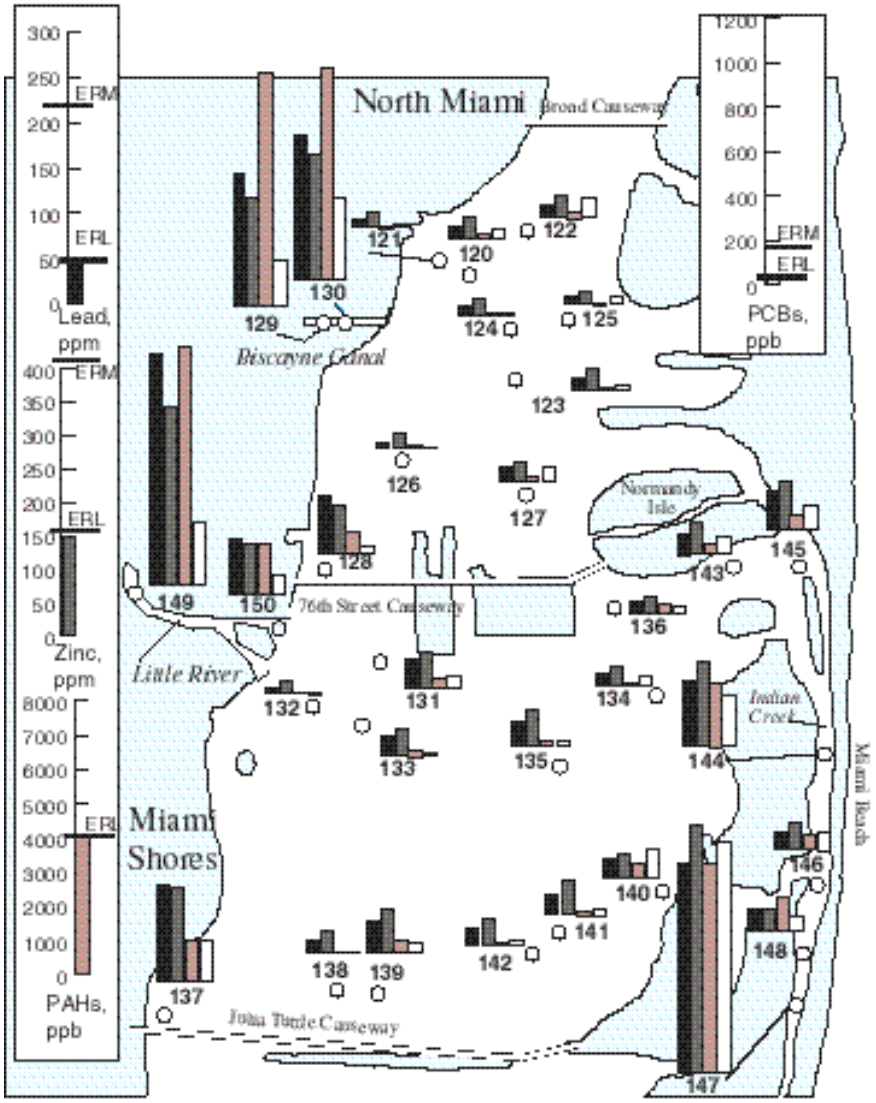


Figure 34. Concentrations of lead, zinc, total PAHs, and total PCBs in sediments from zones 3 and 4.

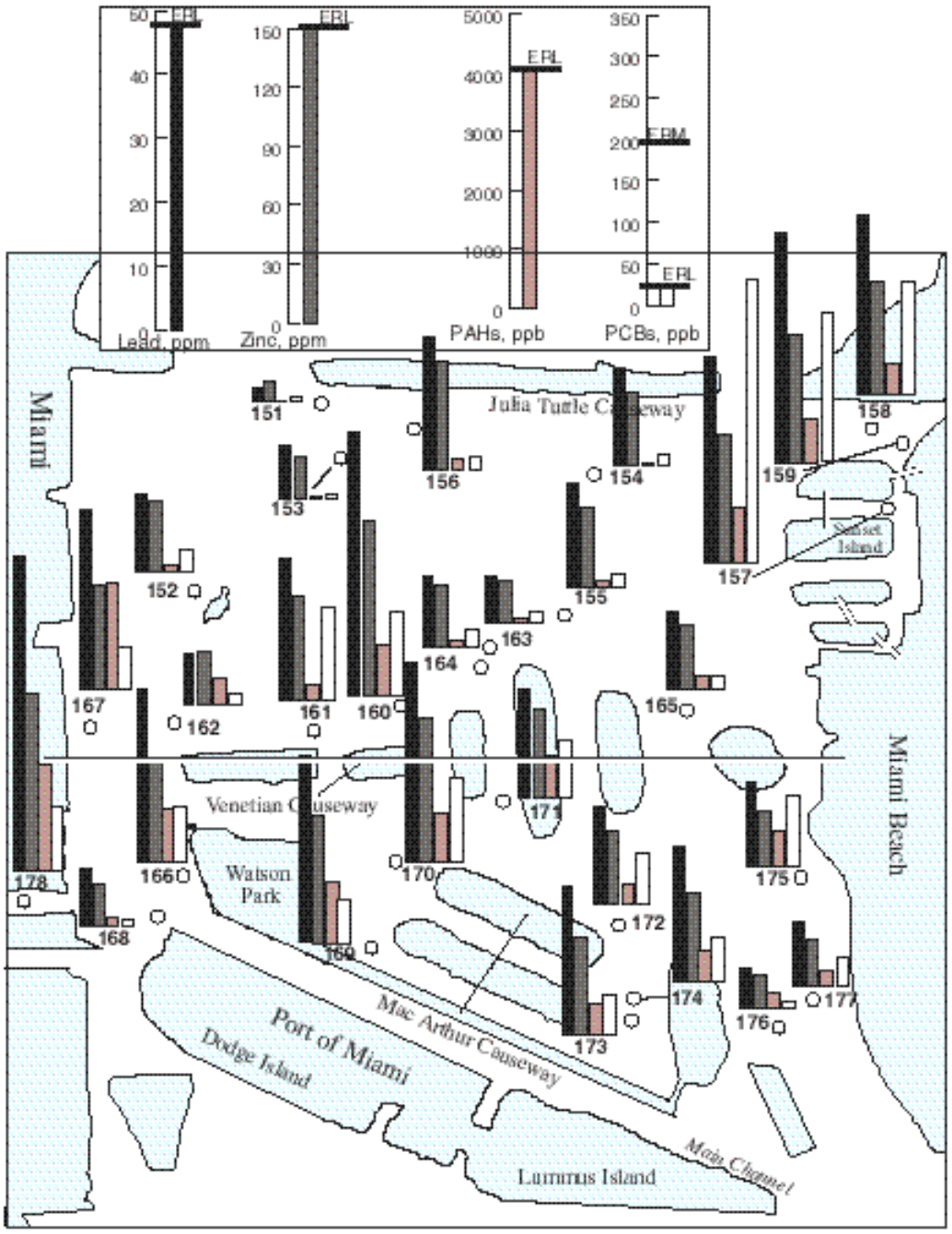


Figure 35. Concentrations of lead, zinc, total PAHs, and total PCBs in sediments from zone 5.

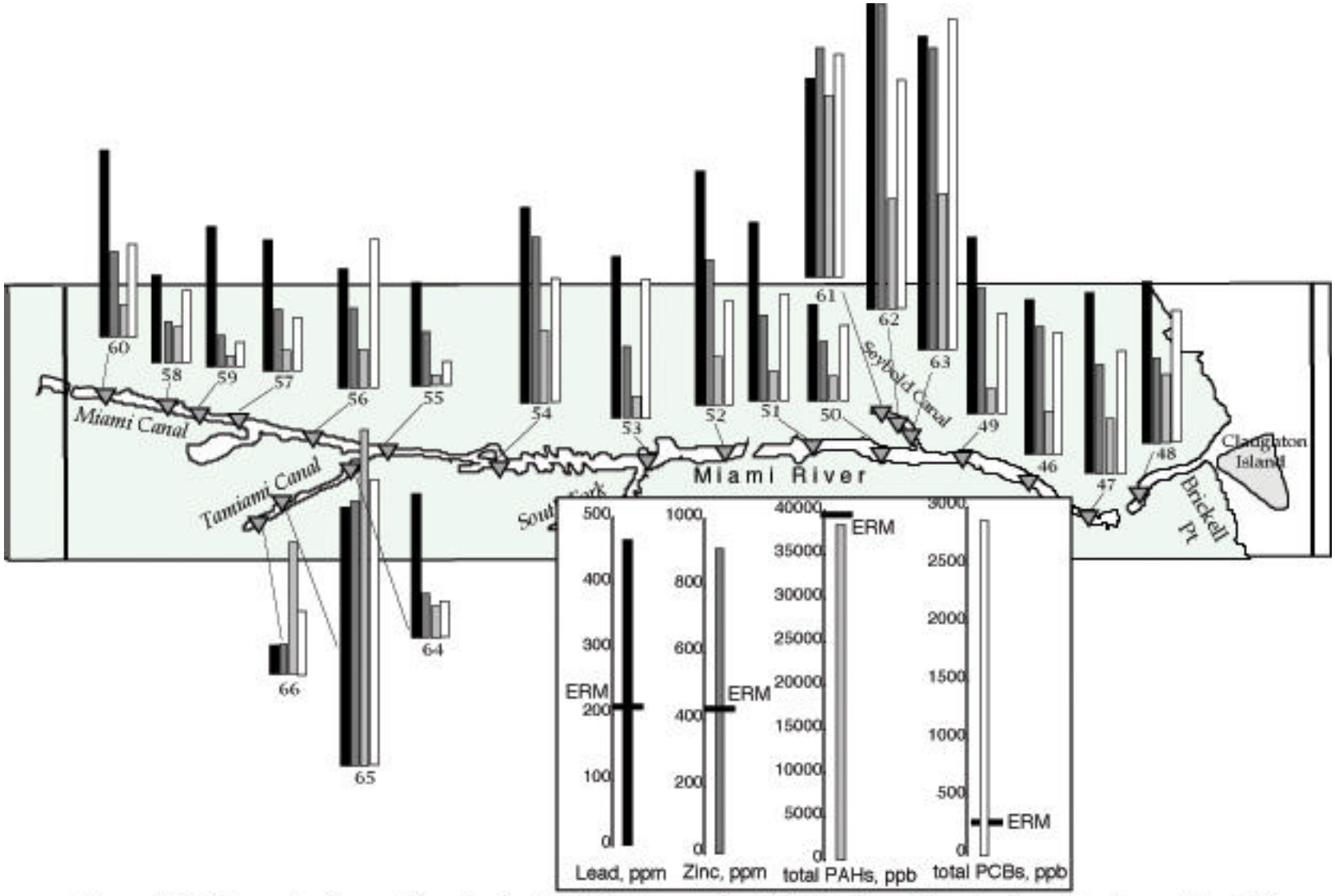


Figure 36. Concentrations of lead, zinc, total PAHs, and total PCBs in sediments from the lower Miami River.

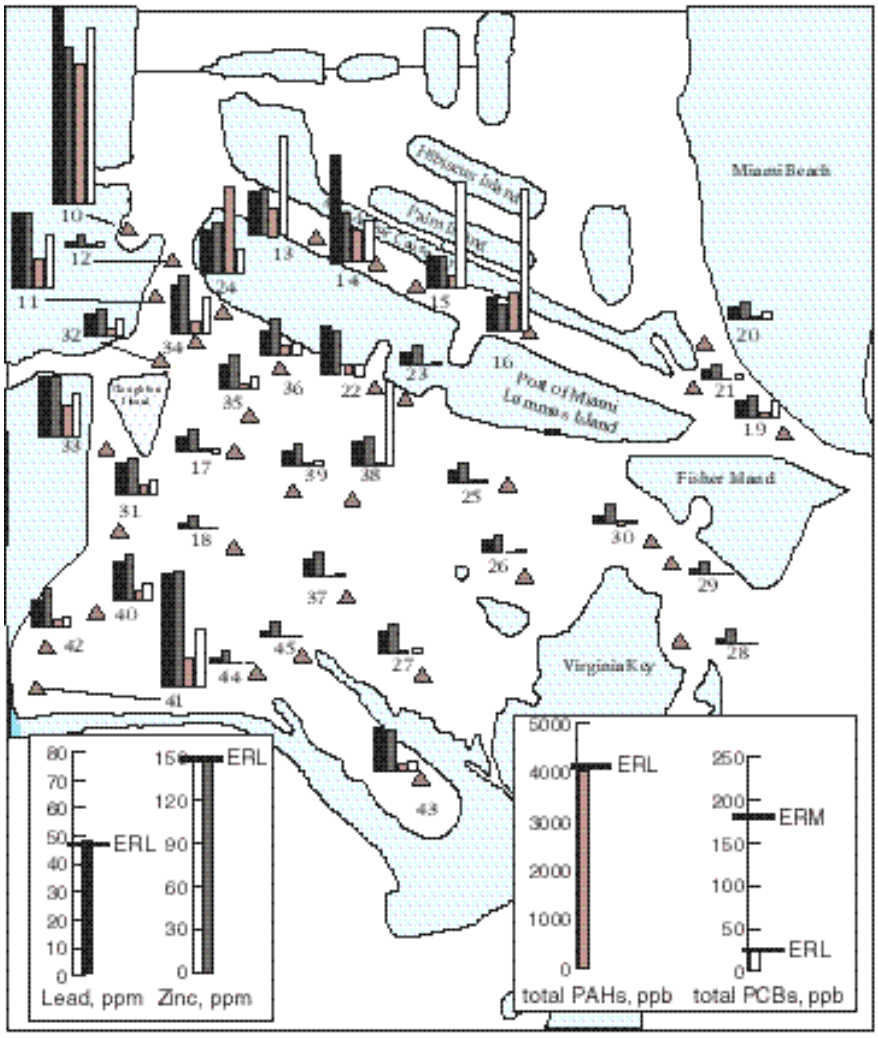


Figure 37. Concentrations of lead, zinc, total PAHs, and total PCBs in sediments from zone 6.

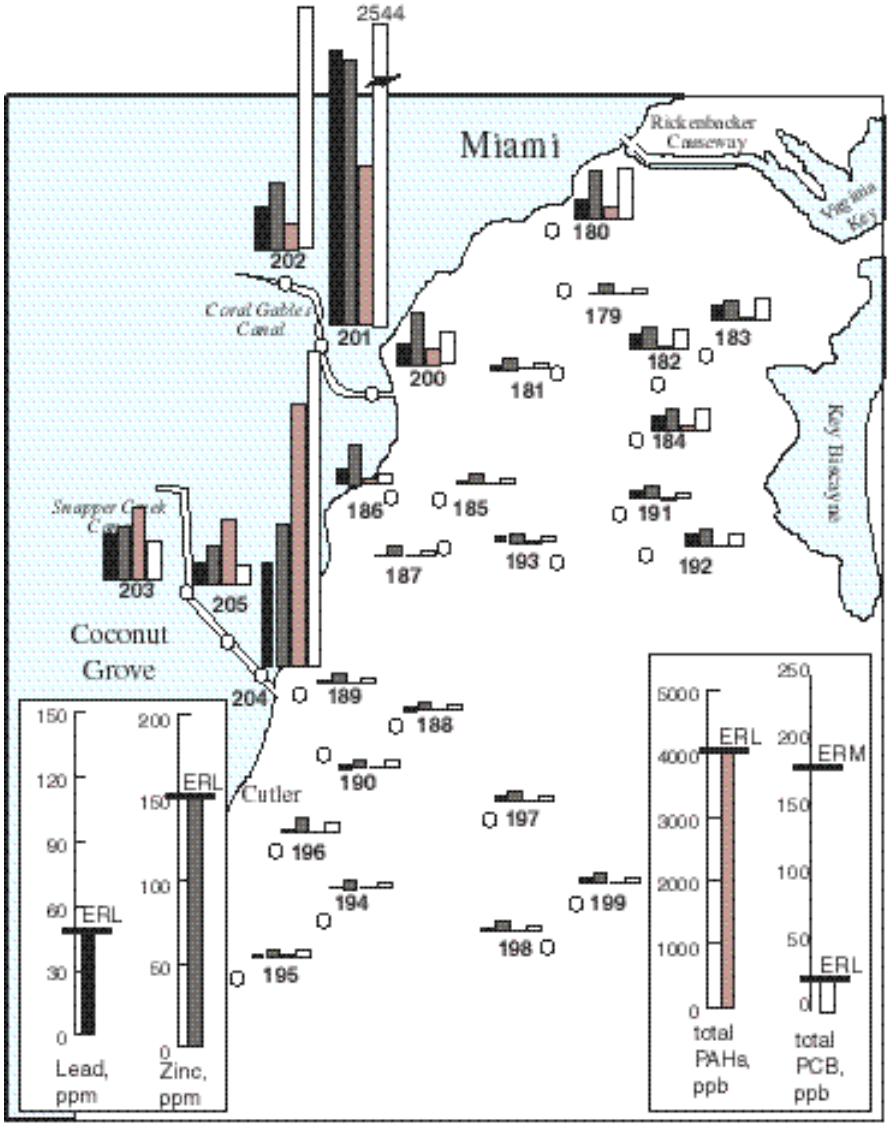


Figure 38. Concentrations of lead, zinc, total PAHs, and total PCBs in sediments from zone 7.

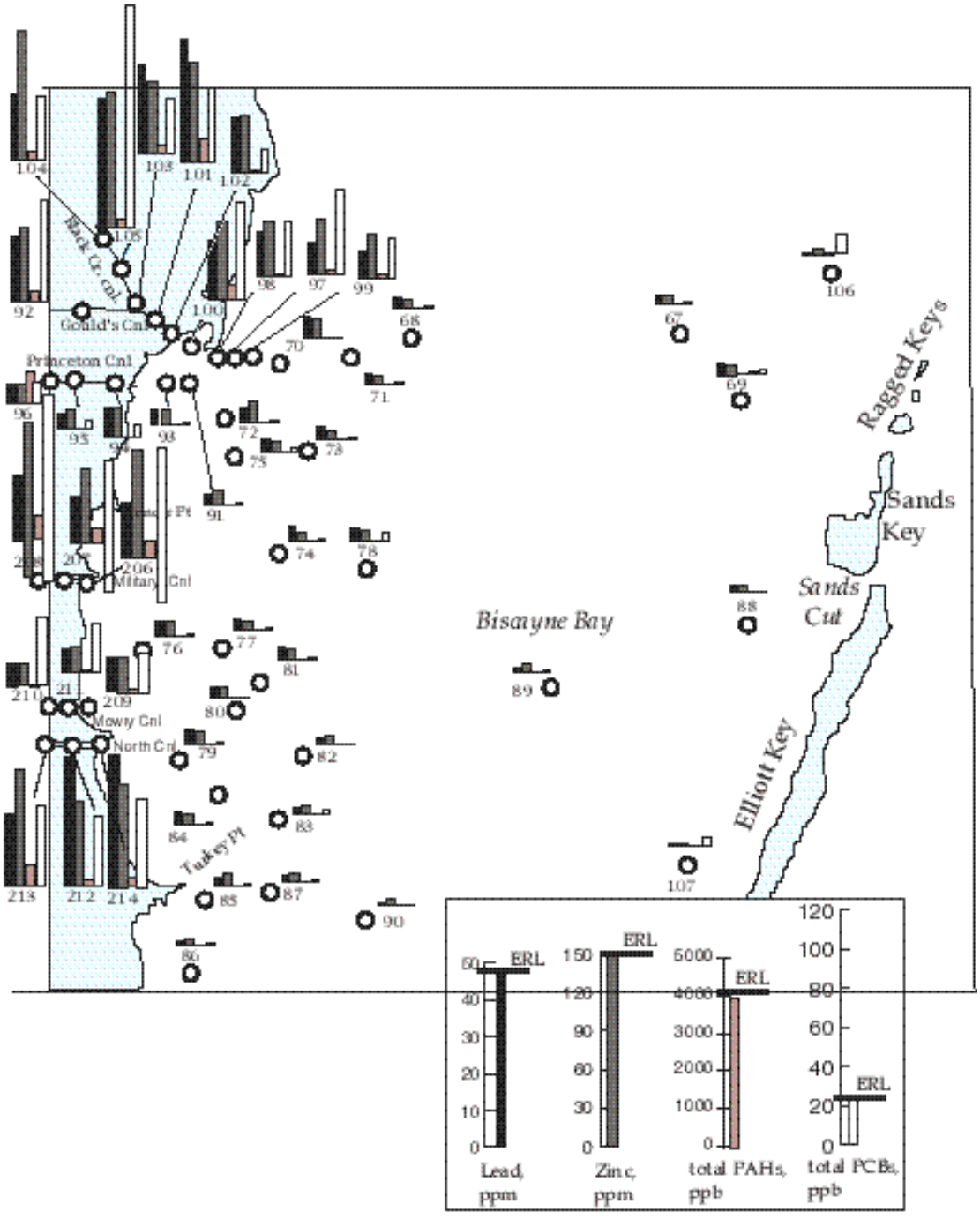


Figure 39. Concentrations of lead, zinc, total PAHs, and total PCBS in sediments from zone 8.

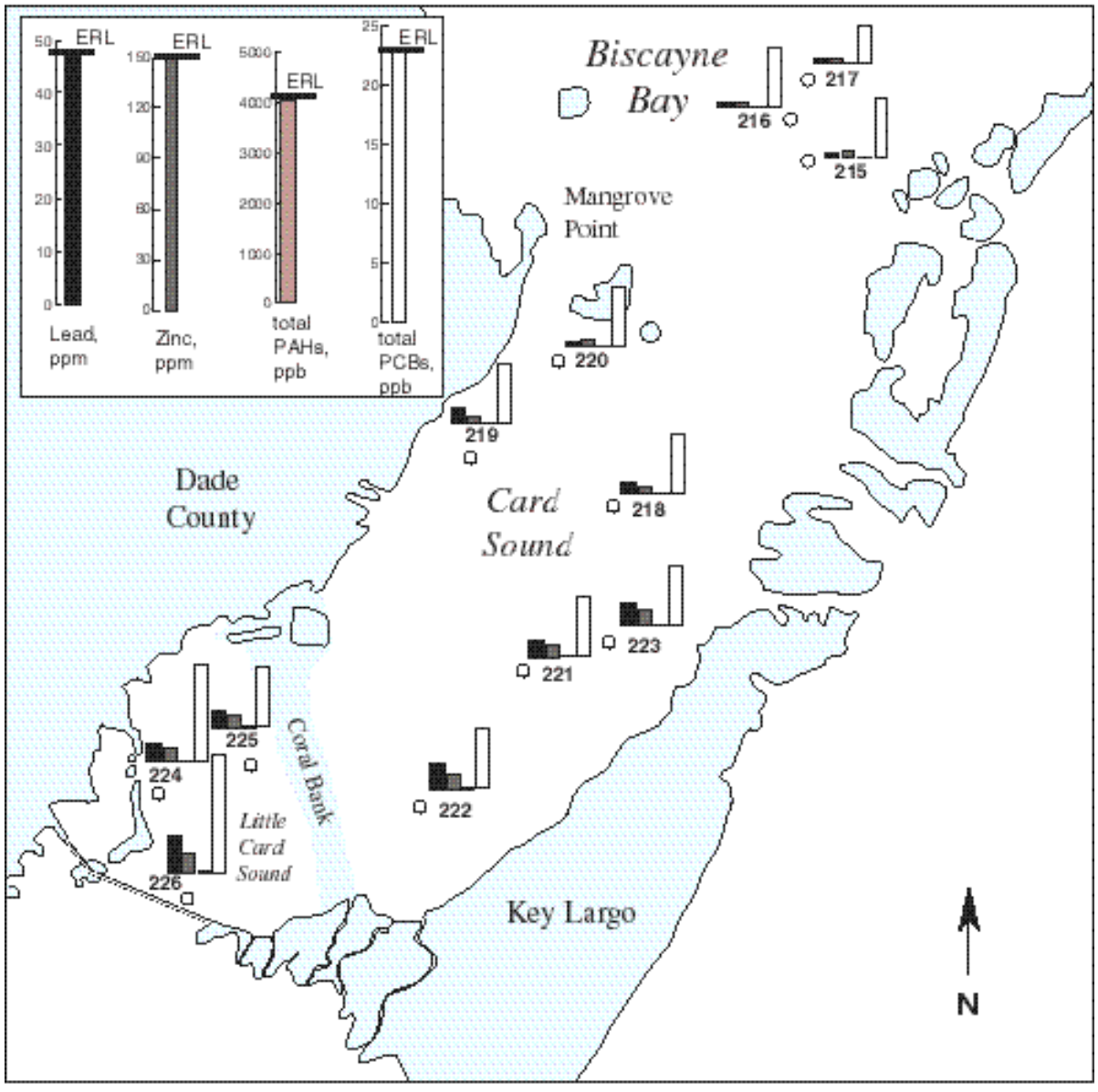


Figure 40. Concentrations of lead, zinc, total PAHs, and total PCBs in sediments from zone 9.

collected near a commerical boat yard - were extremely high, exceeding the ERM value. The high lead concentrations in these samples, especially those from Seybold Canal, suggest stormwater as a potential source of contamination to this region.

Seaward of the mouth of the Miami River, chemical concentrations diminished sharply and continued to gradually decrease eastward toward the ocean **(Figures 36, 37).** None of the samples had zinc or PAH concentrations above the ERL; only one sample (station 10) exceeded the ERL for lead; and most samples from the middle of the bay had relatively low PCB concentrations. Samples from stations 24, 33 and 34 suggested an influence from the Miami River; however, the sample from station 32 had very low chemical levels, suggesting no such influence. Stations 13-16 in the Port of Miami channel had relatively high PCB concentrations; these concentrations diminished sharply near the entrance in stations 19-21. Concentrations also were relatively high in station 10, which was located within the boat basin at a shopping center. Stations 28-30, located nearest the ocean, were clearly the least contaminated, and the most distant from the mainland in this region.

South of the Rickenbacker Causeway **(Figure 38)**, chemical concentrations in the many samples collected in the open waters of Biscayne Bay were very low. In contrast, samples 200-202 from Coral Gables Canal and 203-205 from Snapper Creek Canal had relatively high concentrations. Among these six samples, those from stations 201 and 204 appeared to be the most contaminated. Samples from stations 180, 186, and 200 appeared to show some influence from mainland sources, including Coral Gables Canal. There was a slight pattern of decreasing concentrations of all four substances from northern stations (182-184, 191-192) to southern stations (190, 194-199).

Five tributary canals were sampled in zone 8 to provide information on possible sources of contamination to southern Biscayne Bay **(Figure 39).** The canals included Black Creek / Gould's Canal, Princeton Canal, Military Canal, Mowry Canal, and North Canal. Chemical concentrations often were considerably higher in sediments from these canals than in adjoining regions of the bay. Among the five canals, contamination was most apparent in Black Creek, Military, and North canals; however, this pattern was inconsistent and variable. Although PCB concentrations often exceeded ERL values, concentrations of the other three substances never exceeded their respective ERL values. PAH concentrations were relatively low. Samples taken from strata in the entrance channel to Black Creek Canal clearly showed the influence of the canal. However, beyond the entrances to all canals, chemical concentrations diminished sharply, suggesting that contaminants entering the bay from these canals do not accumulate in bay sediments near the canals.

Thirteen stations (67, 69, 79-83, 85-90) in zone 8 which were moderately to highly toxic in one or more of the bioassays, had very low concentrations of lead, zinc, tPAHs, and tPCBs (**Figure 39**). Data for all metals and organics in these 13 samples were below or near the detection limits for all substances. Concentrations of individual PAHs generally ranged from 1 to 5 ppb and concentrations of all pesticides and PCB congeners were <1ppb. These sediments were sandy (4-17% fines) and had low organic carbon (0.5 to 1.5% TOC). AVS concentrations were relatively low (10-30 ppm). Concentrations of un-ionized ammonia were below the toxicological threshold (LOEC = 800 ug / L) for urchin fertilization; ranging from 32 to 172 ug / L in the porewater test chambers. However, un-ionized ammonia concentrations exceeded the LOEC (90 ug / L) for the embryo development test in some

samples, but not by large amounts. In the amphipod test chambers, un-ionized ammonia concentrations ranged from 50 to 380 ug/L in all except one sample (1030 ug/L in station 87); four samples exceeded the NOEC (236 ug/L for *A. abdita*; Kohn et al., 1994) and one (station 87) exceeded the LOEC (446 ug/L; Kohn et al., 1994). Microtox tests, which were highly significant in many of these samples, were not exposed to ammonia in the organic solvent extracts. Collectively, none of these chemical data alone or in combination provide a possible explanation for the unusual degree of toxicity observed in these 13 samples from the south bay

Concentrations of lead, zinc, tPAHs, and tPCBs were very low in all 12 samples from zone 9 **(Figure 40).** Concentrations in the sample from station 226 were slightly higher than those from the other 11 stations; however, all concentrations were well below ERL levels.

Regions of concern. To provide large-scale patterns or trends in relative sediment quality, regions of the study area were compared with each other based upon summary statistics for both the toxicity tests performed on all 226 samples and the summarized chemical data **(Table 17).** Average toxicity tallies from **Table 10** were calculated for stations located in the open-water basins of each zone, the peripheral canals and tributaries of each zone, and for all stations within all strata of each zone. Highest tallies indicated the highest toxicity responses on the four tests that were performed on all 226 samples.

Table 17. Average toxicity tally scores* based upon results of four toxicity tests and average of mean ERM quotients for stations located within open basins, peripheral canals/tributaries, and all strata of each sampling zone.

	Average toxicity tally scores			Average of mean ERM quotients		
Zone	basin	peripheral	all stations	basin	peripheral	all stations
1	5.00	4.33	4.67	0.054	0.382	0.218
2	2.67	na	2.67	0.036	na	0.036
3, 4	5.43	6.00	5.61	0.049	0.242	0.111
5	4.54	4.00	4.46	0.056	0.134	0.061
6	4.44	6.38	5.16	0.036	0.764	0.304
7	3.71	3.17	3.59	0.010	0.222	0.057
Coral Gables Canal		3.66			0.341	
Snapper Creek Canal		2.66			0.103	
8	6.00	7.73	6.76	0.008	0.068	0.034
Black Creek Canal		9.44			0.055	
Princeton Canal		4.33			0.025	
Military Canal		6.66			0.168	
Mowry Canal		6.66			0.035	
North Canal		6.33			0.074	
9	3.92	na	3.92	0.010	na	0.010

* toxicity tally scores from Table 10

Chemical data were compared as averages of the mean ERM quotients for each station and region. Mean ERM quotients were calculated as mean of the quotients derived by normalizing (dividing) the chemical concentrations for 25 substances by their respective ERM values. The average of the quotients was calculated for each of the regions. Mean ERM quotients of 1.0 or greater signify that the average chemical mixture in the samples is equal to or greater than unity in terms of the ERM values. Data from many previous surveys have indicated that toxicity frequently occurs in samples with mean ERM quotients of 1.0 or greater (Long et al., 1998).

On average, based upon the results of the toxicity tests, the samples from the peripheral canals (especially Black Creek) of zone 8 were the most toxic (average score of 7.73), followed by the Miami River in zone 6 (score of 6.38) and the canals of zones 3 and 4 (score of 6.0). Toxicity in these three zones was higher in the stations located in canals than in stations located offshore in the open waters of the bay. However, in zones 1, 5, and 7 toxicity, on average, was slightly higher in the basins than in the peripheral areas. The least toxic areas, on average, were the strata within zones 2, 7, and 9.

The data from the chemical index calculated as the mean ERM quotients showed a wider range in response than the toxicity tallies **(Table 17).** The area with the highest chemical contamination - the lower Miami River in zone 6 - had an average quotient of 0.764, 21 times higher than the average for the open water stations within zone 6 and 76 times higher than the average for the basins of zones 7, 8, and 9. Chemical concentrations were frequently higher in the peripheral areas of each zone than in the basins. Other canals with high chemical concentrations included Maule Lake / Oleta River in zone 1, Coral Gables, Indian Creek / Biscayne Canal / Little River in zones 3 and 4, and Military Canal in zone 8.

These data indicate a clear difference in chemical concentrations north and south of the Rickenbacker Causeway **(Table 17).** South of the causeway, the mean ERM quotients averaged 0.010, 0.008, and 0.010 in the basins of zones 7, 8, and 9, respectively. North of the causeway (zones 1-6), the averages of the mean ERM quotients in stations sampled in the basins ranged from 0.036 to 0.056 - about 3 to 5 times higher.

Together, the chemical and toxicity data indicated that sediments from the lower Miami River ranked among the most degraded within the study area. Also, the chemical and toxicity data, together, indicated that sediments from the basins of zones 2, 7, and 9 were the least degraded. However, zone 8 peripheral stations, on average, ranked highest in toxicity, but only sixth highest in chemical contamination. In zone 7 peripheral stations, the opposite pattern was apparent: high chemistry, low toxicity. Remarkably, the basin stations in zone 8 ranked highest among the basins (driven by data from 13 stations in south bay), but lowest in chemical concentrations among the basins. The lack of correspondence between the overall indices of chemical contamination and toxicity in the southern portion of zone 8 suggests that results of toxicity tests were probably not driven by the chemicals that were measured.

Chemicals exceeding numerical guidelines. The causes of toxicity observed in the sediment samples could not be determined with the study design used in this survey; nor was this an objective of the survey. Other types of laboratory and field studies would be needed to identify which substances caused toxicity. However, a number of data analyses can be conducted to identify those chemicals that may have contributed to toxicity.

The concentrations of chemicals in the sediments were compared to applicable sediment quality guidelines to provide perspective to the data and to identify which of the substances were most frequently elevated in concentration. TEL and PEL values from MacDonald et al. (1996) and ERL and ERM values from Long et al. (1995) were used as a basis for comparison **(Table 18)**. PEL and ERM values generally were about 10 times higher than respective TEL and ERL values, therefore, more samples would be expected to exceed the latter values than the former. During the derivations of the guidelines, concentrations below the TELs and ERLs were rarely associated with measures of effects, whereas concentrations that exceeded the PELs and ERMs were frequently associated with toxicity and other measures of adverse biological effects.

Arsenic concentrations exceeded the TEL and ERL in 90 and 70 samples, respectively; however, none of the concentrations exceeded either the PEL or ERM **(Table 18)**. Among the nine trace metals, copper, lead and mercury concentrations most frequently exceeded both the TEL/ERL values and the PEL/ERM values; thus, suggesting that these elements could have contributed to toxicity most widely throughout the study area. Concentrations of silver and zinc also were elevated in many samples. In contrast, the concentrations of

Table 18. Numbers of samples among the 226 analyzed in which sediment quality guideline* concentrations were exceeded for each substance and the surficial area (km² and percent of total area) represented by the samples in which the ERMs were exceeded.

Chemical	TEL exceeded	ERL exceeded	PEL exceeded	ERM exceeded	ERM km^2	ERM % of area
arsenic	90	70	0	0	0.00	0.00
cadmium	27	18	3	1	0.03	0.01
chromium	8	4	0	0	0.00	0.00
copper	75	44	18	8	0.08	0.02
lead	52	37	27	19	2.06	0.43
mercury	71	62	15	15	2.12	0.44
nickel	4	1	0	0	0.00	0.00
silver	30	23	10	0	0.00	0.00
zinc	29	24	12	8	0.21	0.04
sum of LPAH	25	19	6	2	0.06	0.01
sum of HPAH	51	30	7	6	0.15	0.03
sum of tPAH	33	19	4	1	0.06	0.01
total chlordane	7	nd	3	nd	nd	nd
dieldrin	19	nd	2	nd	nd	nd
4,4'-DDD	34	nd	17	nd	nd	nd
4,4'-DDE	63	60	0	15	2.03	0.42
4,4'-DDT	32	nd	9	nd	nd	nd
total DDTs	68	99	14	19	2.23	0.46
total PCBs	106	106	30	31	6.37	1.32

* TEL and PEL values from MacDonald et al. (1996) and ERL and ERM values from Long et al. (1995).

nd = no guideline available

chromium and nickel were not particularly high relative to the guidelines. Samples in which trace metals concentrations exceeded guidelines by the greatest amount included those from stations 61-63, 65, 147, 149, 111-113, and 206-208 - scattered among Tamiami Canal, Seybold Canal, Indian Creek, Little River, Maule Lake, and Military Canal, respectively. All of these stations were located in peripheral tributaries to the bay.

PAH concentrations were compared with the guidelines for the sums of 7 low molecular weight compounds (LPAH), 6 high molecular weight compounds (HPAH), and all 13 compounds (total PAH). The high molecular weight compounds exceeded the guideline concentrations more frequently than the low molecular weight compounds **(Table 18)**. The sum of total PAHs exceeded the TEL value in 33 samples and the ERL in 19 samples. These concentrations also exceeded the PEL and ERM in four samples and one sample, respectively. Concentrations were extremely high in the sample from station 116 (Oleta River). The samples from stations 61 and 63 (Seybold Canal) and station 65 (Seybold Canal) also had very high concentrations of PAHs.

Total PCB concentrations (sums of 20 congeners multiplied by a factor of 2.0) were elevated above the TEL and ERL values in 106 of the 226 samples and above the PEL and ERM values in 30 samples and 31 samples, respectively **(Table 18)**. The concentrations of PCBs were highest in samples from stations 61-63 and 65. Concentrations of total DDT and individual isomers were elevated in many samples, especially those from stations 61-63.

To provide perspective as to the spatial scales of contamination with these substances, cumulative distribution functions were prepared with methods similar to those used to calculate estimates of the spatial extent of toxicity. Using the ERM concentrations as critical values, the surficial areas (km ^{2} and percentage of total area) in which concentrations exceeded the ERMs were determined **(Table 18)**. These data indicated that although the ERM concentrations were exceeded in several to many samples, the spatial scales of contamination were relatively small. For example, the ERM concentration for total PCBs was exceeded in 31 samples. However, because many of the samples were collected in relatively small strata in canals, these samples only represented about 6 km^2 or 1.3% of the total. Among all other chemicals, the spatial extent of toxicity ranged from 0% to 0.5% of the total. If the ERLs or TELs, which were not intended to be highly predictive of toxicity, had been used as critical values; the spatial scales of contamination, of course, would be much larger.

Metals occur naturally in sediments, and concentrations of metals vary with sediment type and grain size. The State of Florida established guidance on normalization of metals concentrations to a reference element (Aluminum) to distinguish between anthropogenic and natural levels of metals in estuarine sediments (Schropp et. al, 1990). Trace metal concentrations in samples from clean reference areas were plotted against the concentrations of aluminum in the same samples, and the resulting regression and confidence intervals were plotted. The resulting graph represents the ranges of concentrations that expected as background levels of metals. This tool was developed such that hen new data are collected, they could be plotted on this graph to determine whether the concentration of

metals in the new sample falls within the expected range, or if it exceeds that range (exceeds the 95% C.I.). Concentrations above the upper C.I. are considered to be "enriched", and therefore likely to have been influenced by anthropogenic sources.

The metal-to-aluminum relationships from 226 sediments from Biscayne Bay are compared to the ratios observed by Schropp et al. (1990) in **Figures 41-46.** The upper and lower 95% confidence intervals (C.I.) from Schropp et al. (1990) are shown in each scattergram. Cadmium concentrations in 19 samples from Biscayne Bay exceeded the upper 95% C.I. expected in non-polluted sediments **(Figure 41)**. These data suggest that cadmium concentrations in most samples were well within the expected range; whereas, those in 19 samples were elevated presumably because of anthropogenic (human) inputs. In contrast, chromium and nickel concentrations were elevated above expected levels in only 6 and 4 samples, respectively **(Figure 42).** Copper, lead, and zinc concentrations were very high in many samples relative to expected levels **(Figures 43, 44, 46)**. Concentrations of all three metals were nearly three orders of magnitude above predicted background levels in some samples. Collectively, these data indicated that the concentrations of cadmium, copper, lead, and zinc in many samples were relatively high because of long-term, human inputs to Biscayne Bay.

Overall, these data suggest that concentrations of many substances occurred at or above background levels and concentrations previously associated with toxicity and other adverse biological effects in many of the samples. Furthermore, the data suggest that no single chemical was elevated in concentration; rather, mixtures of many different substances occurred in relatively high concentrations in the samples. Among all substances for which sediment guidelines are available, copper, lead, mercury, DDT isomers, and PCBs appear to be the contaminants of most concern in Biscayne Bay. PAHs also occurred in elevated concentrations in several samples. It is important to recognize, however, that the spatial scales of elevated contamination are relatively small, reflecting the fact that contaminant concentrations were highest among the small strata sampled in peripheral canals and tributaries to the bay.

Chemistry/toxicity correlations: baywide. To determine which, if any, of the chemical substances in the samples were associated with measures of toxicity, a series of correlation analyses were performed. All correlations were performed with non-parametric, Spearman-rank analyses as in previous surveys of this kind. Correlation coefficients (rho, corrected for ties) were determined with Statview software and reported along with probability (p) values. In these analyses, correlations that were statistically significant could occur as a result of random chance alone, because many independent variables were considered. In the data from Biscayne Bay, correlations were determined for 54 individual chemicals and classes of chemicals. Probability (p) values of less than 0.0001 would not remain significant if the number of variables were taken into account. Therefore, in the accompanying tables, coefficients assigned less than four asterisks would not remain significant.

Correlative relationships must not be confused with causality. That is, although there appear to be many interesting associations between measures of toxicity and chemical concentrations, these associations do not describe causative relationships. Other chemicals not measured could have contributed to or been solely responsible for the toxicity. Substances

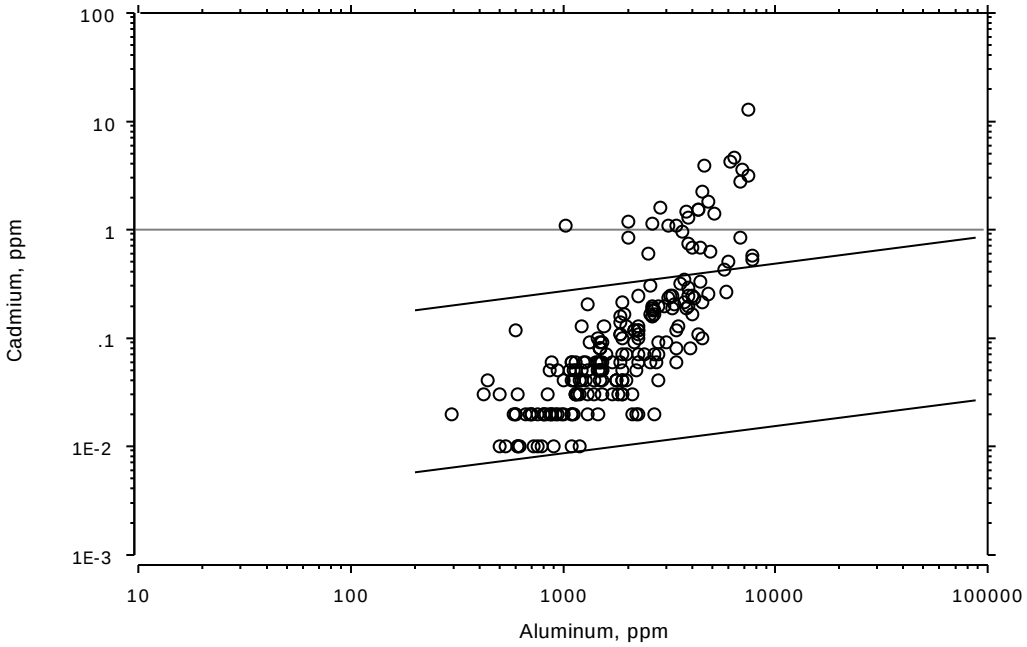


Figure 41. Relationship between concentrations of cadmium and aliminum in sediments from Biscayne Bay relative to upper and lower 95% confidence limits of cadmium:aluminum ratios in sediments from reference areas (Schropp et al., 1990).

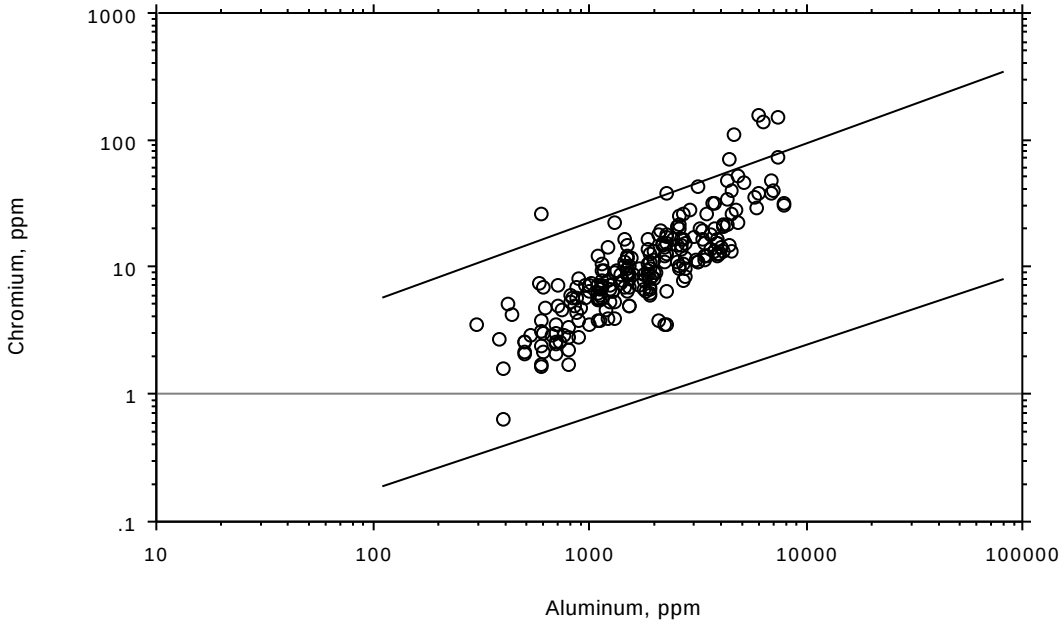


Figure 42. Relationship between the concentrations of chromium and aluminum in sediments from Biscayne Bay relative to upper and lower 95% confidence limits of chromium:aluminum ratios in sediments from reference areas (from Schropp et al., 1990).

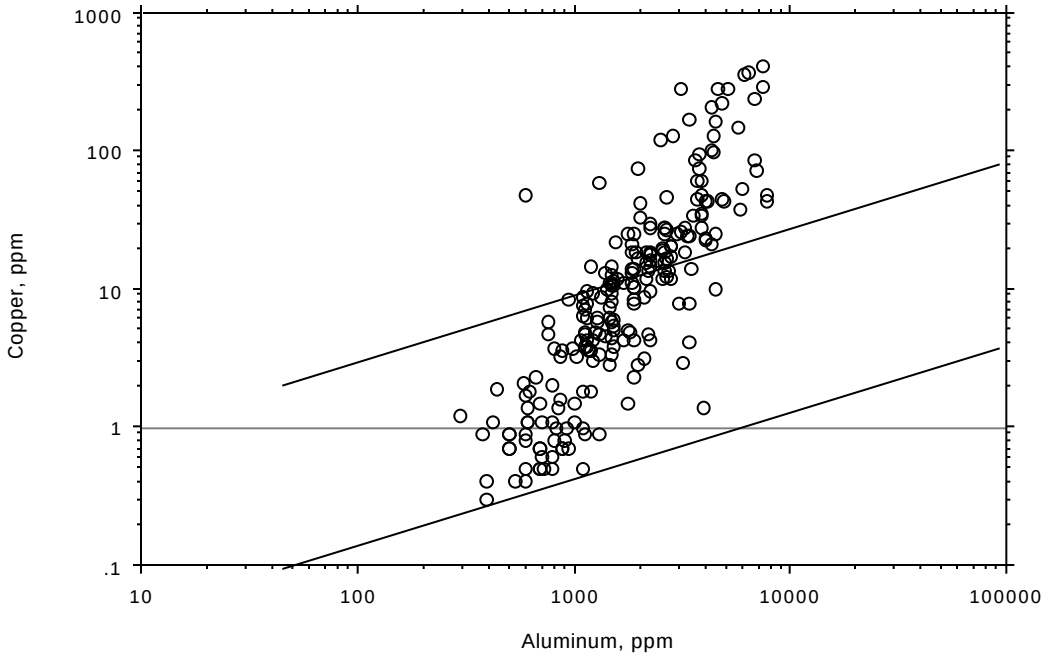


Figure 43. Relationship between concentrations of copper and aluminum in sediments from Biscayne Bay relative to upper and lower 95% confidence limits of copper:aluminum ratios in sediments from reference areas (from Schropp et al., 1990).

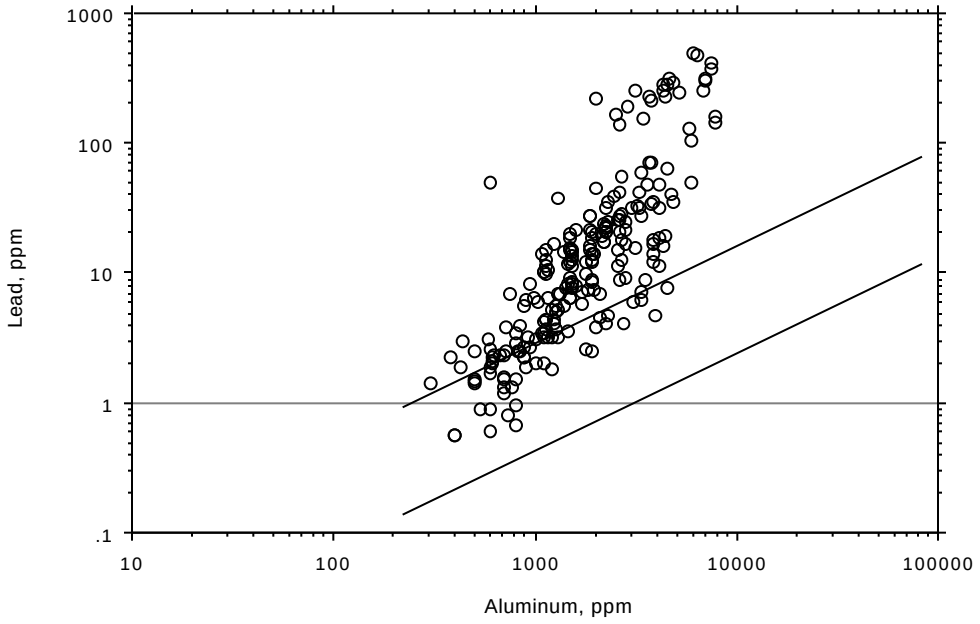


Figure 44. Relationship between concentrations of lead and aluminum in sediments from Biscayne Bay relative to upper and lower 95% confidence limits of lead:aluminum ratios in sediments from reference areas (from Schropp et al., 1990).

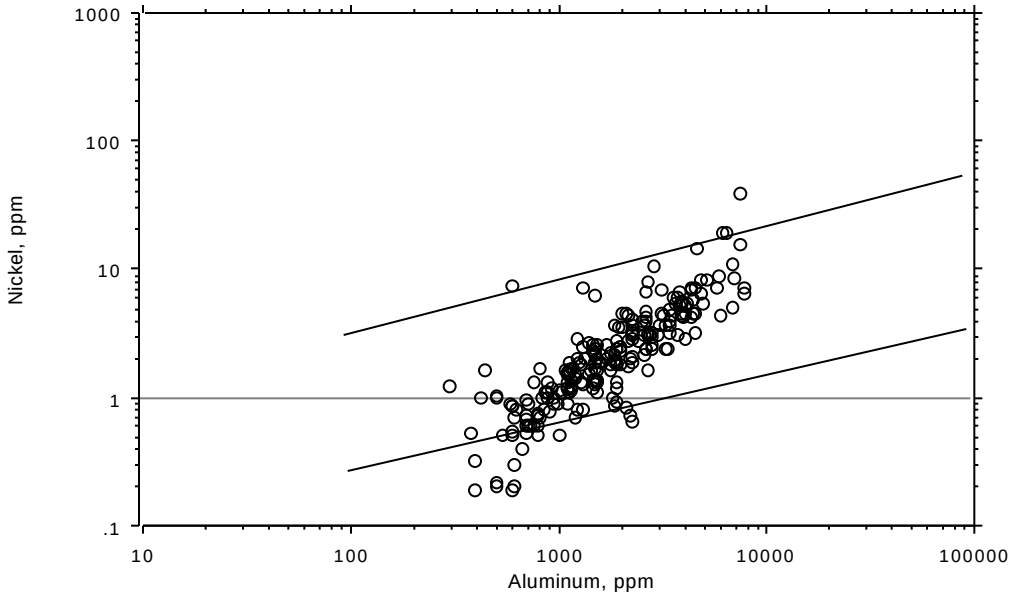


Figure 45. Relationship between concentrations of nickel and aluminum in sediments from Biscayne Bay relative to upper and lower 95% confidence limits of nickel:aluminum ratios in sediments from reference areas (from Schropp et al., 1990).

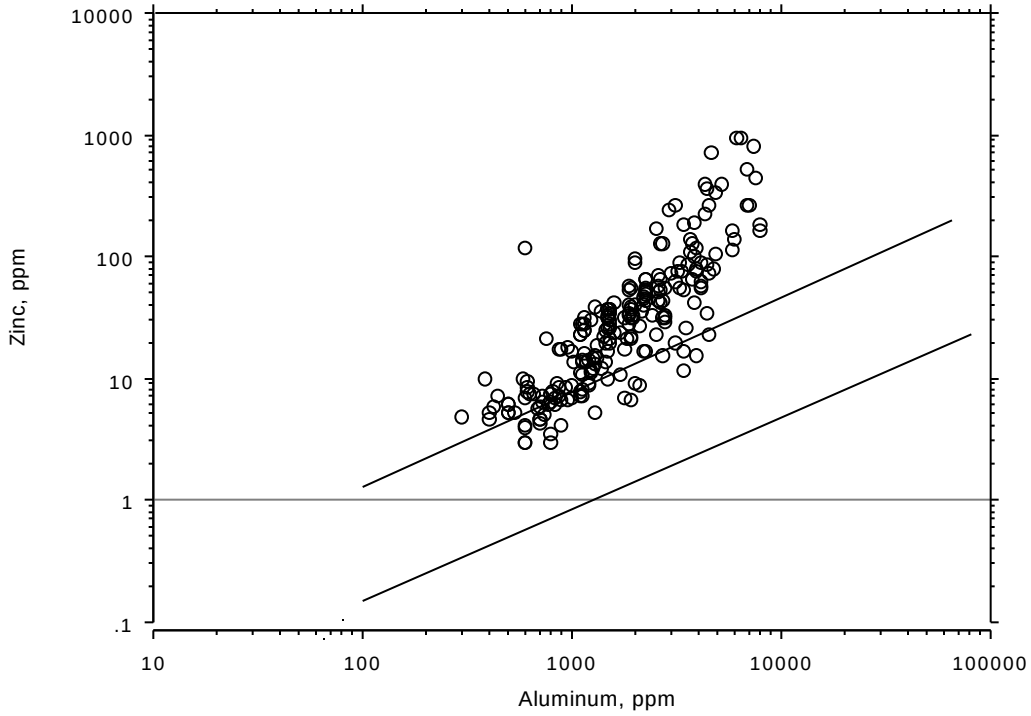


Figure 46. Relationship between concentrations of zinc and aluminum in sediments from Biscayne Bay relative to upper and lower 95% confidence limits of zinc:aluminum ratios in from reference areas (from Schropp et al., 1990).

co-varying with each other in mixtures probably were responsible for the toxicity, but the absolute nature of these mixtures is unknown. Causality must be determine in laboratory tests such as toxixity identification evaluations and spiked sediment bioassays.

Correlation coefficients should have negative signs to indicate that the endpoints (e.g., survival) measured in these tests decreased as chemical concentrations increased. Correlations with positive signs indicate spurious, meaningless relationships. Correlations are shown for the following substances: un-ionized form of ammonia in either the porewaters of amphipod test chambers or urchin test chambers; 17 metals and metalloids; percentages of the sediments composed of different grain sizes; total organic carbon (TOC); acid-volatile sulfides (AVS); seven low molecular weight PAH (LPAHs) for which ERM values were derived; all parent and substituted LPAHs; six high molecular weight PAHs (HPAHs) for which ERMs were derived; all parent and substituted HPAHs; all thirteen PAHs for which ERMs exist; all parent and substituted PAHs; many different chlorinated organic hydrocarbons (COHs), including hexachlorocyclohexanes (HCHs); six isomers of DDT; total DDTs; five representative PCB congeners; total of 20 PCB congeners times a factor of 2.0; and sums of quotients calculated by normalizing chemical concentrations by their respective ERM values.

Correlations were initially performed with all data from the 226 stations sampled during both years **(Table 19)**. In the amphipod survival tests, correlations were most significant for helptachlor, aldrin, trans-nonachlor, oxychlordane, and PCB congener 209. These correlations would remain significant if the number of variables were taken into account. Other less significant correlations were apparent for the concentrations of cadmium, percent clay, and o, p' - DDD. Weaker correlations were apparent for nickel, tin, zinc, sum of all LPAHs, and many different kinds of COHs. Overall, these data suggest relative strong relationships between amphipod survival and complex mixtures of chlorinated hydrocarbons and either weak or no significant relationships with trace metals, PAHs, ammonia or grain size. However, none of the ERM-normalized indices of contamination showed significant correlations with amphipod survival in the bay-wide data set.

In contrast to the amphipod survival tests, results of the sea urchin fertilization tests (done with results from the tests of 100% pore waters) showed no significant correlations with the same classes of chlorinated organics **(Table 19).** In this test correlations were most significant for selenium, percent clay, percent fines (clay + silt), AVS, and the sum of HCHs. Less significant were correlations with ammonia, aluminum, nickel, percent silt, and percent TOC. The correlations with several trace metals were relatively weak. Overall, these data suggest that urchin fertilization was depressed in samples with high percent fines, TOC, aluminum, and AVS concentrations - all of which would be expected to co-occur with each other. Among potential toxicants, the correlations suggested a strong relationship with both selenium and total HCHs.

In the urchin embryological development tests with 100% pore waters, correlations were very strong with the concentrations of ammonia, and to a lesser extent, total HCHs, and AVS **(Table 19).** The correlation with ammonia (rho = -0.573, $p<0.0001$) was the most significant observed among all variables.

Table 19. Spearman-rank correlation coefficients (rho, corrected for ties) and probable significance levels for results of four toxicity tests and chemical concentrations in 226 sediment samples from Biscayne Bay.

Chemical	Amphipod survival		Urchin fertilization		Urchin development		Microbial bioluminescence	
Un-ionized ammonia	-0.129	ns	-0.195	**	-0.573	****	na	
aluminum	-0.075	ns	-0.189	**	0.024	ns	-0.368	****
antimony	-0.118	ns	-0.077	ns	-0.095	ns	-0.082	ns
arsenic	0.025	ns	-0.033	ns	-0.043	ns	-0.159	*
cadmium	-0.191	**	-0.096	ns	0.093	ns	-0.460	****
chromium	-0.048	ns	-0.169	*	0.129	ns	-0.415	****
copper	-0.124	ns	-0.161	*	0.083	ns	-0.391	****
iron	-0.111	ns	-0.046	ns	0.063	ns	-0.337	****
lead	-0.095	ns	-0.132	*	0.049	ns	-0.329	****
manganese	-0.023	ns	-0.108	ns	-0.123	ns	-0.304	****
mercury	-0.108	ns	-0.083	ns	0.080	ns	-0.191	**
nickel	-0.131	*	-0.179	**	0.087	ns	0.438	****
selenium	0.028	ns	-0.260	****	-0.048	ns	-0.333	****
silver	-0.079	ns	-0.104	ns	0.102	ns	-0.339	****
thallium	-0.059	ns	0.078	ns	0.068	ns	-0.172	*
tin	-0.149	*	-0.165	*	0.001	ns	-0.235	***
zinc	-0.132	*	-0.135	*	0.038	ns	-0.362	****
percent sand	-0.098	ns	0.265	****	-0.001	ns	0.226	***
percent silt	0.061	ns	-0.250	***	0.053	ns	-0.276	****
percent clay	0.196	**	-0.277	****	-0.108	ns	-0.065	ns
percent fines	0.098	ns	-0.267	****	0.001	ns	-0.229	***
percent TOC	-0.048	ns	-0.232	***	-0.001	ns	-0.306	****
AVS	-0.035	ns	-0.371	****	-0.138	*	-0.458	****
sum 7 LPAHs	-0.093	ns	-0.102	ns	0.019	ns	-0.255	****
sum all LPAHs	-0.142	*	-0.093	ns	0.024	ns	-0.331	****
sum 6 HPAHs	-0.088	ns	-0.078	ns	0.091	ns	-0.296	****
sum all HPAHs	0.086	ns	-0.083	ns	0.082	ns	-0.292	****
sum 13 PAHs	-0.079	ns	-0.092	ns	0.075	ns	-0.291	****
sum all PAHs	-0.105	ns	-0.088	ns	0.056	ns	-0.315	****
hexachlorobenzene	-0.158	*	0.093	ns	0.010	ns	-0.123	ns
sum of HCHs	-0.115	ns	-0.259	****	-0.244	***	0.147	ns
heptachlor	-0.298	****	0.033	ns	0.217	ns	-0.148	*
heptachlor epoxide	-0.187	*	0.015	ns	0.033	ns	-0.149	*
aldrin	-0.293	****	0.078	ns	0.129	ns	-0.245	***
total chlordanes	-0.155	*	-0.128	ns	0.051	ns	-0.277	****
trans-nonachlor	-0.257	****	-0.023	ns	-0.051	ns	-0.154	*
cis-nonachlor	-0.180	*	-0.061	ns	0.069	ns	-0.281	****
dieldrin	-0.139	*	-0.040	ns	0.120	ns	-0.298	****
o, p'-DDE	-0.188	*	-0.114	ns	-0.018	ns	-0.189	*
p, p'-DDE	-0.119	ns	-0.096	ns	0.097	ns	-0.367	****
o, p'-DDD	-0.234	***	-0.039	ns	0.001	ns	-0.235	***
o, p'-DDT	-0.055	ns	-0.027	ns	0.115	ns	-0.124	ns
p, p'-DDT	-0.186	*	0.001	ns	0.148	ns	-0.311	****
total DDTs	-0.135	*	-0.097	ns	0.082	ns	-0.281	****

Table 19 (continued)

Chemical	Amphipod survival		Urchin fertilization		Urchin development		Microbial bioluminescence	
mirex	-0.153	*	-0.049	ns	0.001	ns	-0.104	ns
oxychlordane	-0.281	****	-0.001	ns	0.021	ns	-0.109	ns
endosulfan	-0.194	*	-0.012	ns	0.132	ns	-0.081	ns
endrin	0.055	ns	-0.069	ns	-0.037	ns	-0.066	ns
PCBs 5 + 8	-0.201	*	0.042	ns	-0.049	ns	0.048	ns
PCB 105	-0.114	ns	-0.022	ns	0.125	ns	-0.264	****
PCBs 153 + 132	-0.117	ns	-0.038	ns	0.157	ns	-0.274	****
PCB 206	-0.156	*	0.001	ns	0.043	ns	-0.220	**
PCB 209	-0.363	****	0.135	ns	0.114	ns	-0.147	*
total PCBs	-0.127	ns	-0.070	ns	0.136	ns	-0.247	***
Sums of chemical:ERM quotients								
• 9 metals	-0.119	ns	-0.114	ns	0.058	ns	-0.319	****
• 13 PAHs	-0.080	ns	-0.097	ns	0.060	ns	-0.280	****
• 3 COHs	-0.133	ns	-0.084	ns	0.080	ns	-0.312	****
• 25 chemicals	-0.110	ns	-0.084	ns	-0.080	ns	-0.313	****

* $p < 0.05$
** $p < 0.01$
*** $p < 0.001$
**** $p < 0.0001$

Microbial bioluminescence activity, as measured in the Microtox tests, was highly correlated with numerous toxicants, including nearly all metals, all classes of PAHs, and many classes and compounds of chlorinated organics **(Table 19).** The strong statistical correlations with the three classes of ERM-normalized chemicals further substantiates the associations with mixtures of substances. As in the urchin fertilization test, the positive correlation with percent sand and the negative correlations with percent fines, percent TOC, and AVS content, suggests that toxicity was most severe in fine-grained, organically-enriched sediments. Correlation coefficients were among the highest for cadmium, chromium, and nickel. This test, because it is conducted with an organic solvent extract of the sediments, is intended to identify samples in which organic substances pose a potential toxicological threat. Therefore, it is likely that trace metals co-varied in concentrations with organic compounds eluted with the solvents.

The cytochrome P-450 assays have been shown in laboratory tests of clean materials spiked with known substances to be responsive to the presence of dioxins, furans, PAHs, and likely to some co-planar PCBs (ASTM, 1996). Analyses were performed on the 1996 samples for some of the parent PAH compounds for which there are toxicity data from spiked tests. However, no analyses were performed for the dioxins, furans, or co-planar PCBs. Correlation coefficients for the individual PAHs, classes of PAHs, and total PCBs ranged from 0.772 ($p<0.0001$) for total PCBs to 0.852 ($p<0.0001$) for the sum of all PAHs. The correlation with the mean ERM quotients was highly significant (rho = +0.837, $p<0.0001$). These data indicate that this test was highly responsive - as expected - to the PAHs, and, possibly, additively to the PCBs in the sediments.

The three diagrams in **Figure 47** display the patterns in response in the P-450 RGS assays with the concentrations of total 13 PAHs, total PCBs, and the mean ERM quotients. In all cases, there were many samples with the lowest chemical concentrations in which the P-450 induction responses were lowest. As chemical concentrations increased, there was a general but variable pattern of increasing P-450 induction responses, and a few samples in which chemical concentrations and P-450 responses were among the highest. One sample in which PAH concentrations were very high did not cause a large P-450 response, probably because of heterogeneity within the sample.

Chemistry/toxicity correlations: zone 6. Toxicity in different regions of the bay could have been caused by different substances. Also, because of their differential sensitivities to toxicants, each of the tests may have been affected by different substances in the sediments. Acute mortality to the amphipods, for example, may have been caused by one mixture of chemicals in the Miami River and another mixture in the canals of south bay. In previous surveys of this type, correlations have often improved when performed with a subset of the data focused upon the most toxic and contaminated regions. Because many of the samples from the lower Miami River were highly contaminated with many substances and highly toxic in the amphipod tests, chemistry / toxicity correlations were calculated for the samples from only zone 6 to clarify these associations **(Table 20).**

In the amphipod tests, many of the correlations that were not significant or indicated weak associations in the entire, baywide data set were highly significant in the samples from zone 6. These correlations would remain significant if the numbers of variables were taken into account. Amphipod survival was highly correlated with nearly all of the trace metals, PAHs, and chlorinated organics; many coefficients ranged from rho = -0.500 to rho = -0.759. Many of the chlorinated substances (aldrin, chlordanes, PCBs) showed the highest correlations with toxicity observed in this study.

In contrast, most of the highly significant correlations observed baywide in the sea urchin fertilization tests disappeared in the analysis of data from zone 6 **(Table 20).** Only the measures of grain size showed weak correlations with urchin fertilization success. Results of the sea urchin development tests were highly correlated with the concentrations of the un-ionized form of ammonia in the zone 6 samples; the correlation coefficient increased considerably over that for the entire data set.

As with the urchin fertilization tests, the correlations between microbial bioluminescence and chemical concentrations observed baywide nearly disappeared with the data for only zone 6 **(Table 20).** Only a few trace metals and several measures of sediment grain size were correlated with these test results in zone 6.

To further examine the relationships between measures of toxicity and chemical concentrations, scatterplots were prepared for substances that showed the strongest correlations with toxicity. These scatterplots were intended to further verify the pattern in co-variance suggested by the correlations and to determine if the samples that were most toxic also had the highest chemical concentrations. Again, as with the correlation coefficients, the scatterplots do not provide information on causality; they simply offer further evidence that some chemicals were strongly associated with measures of toxicity.

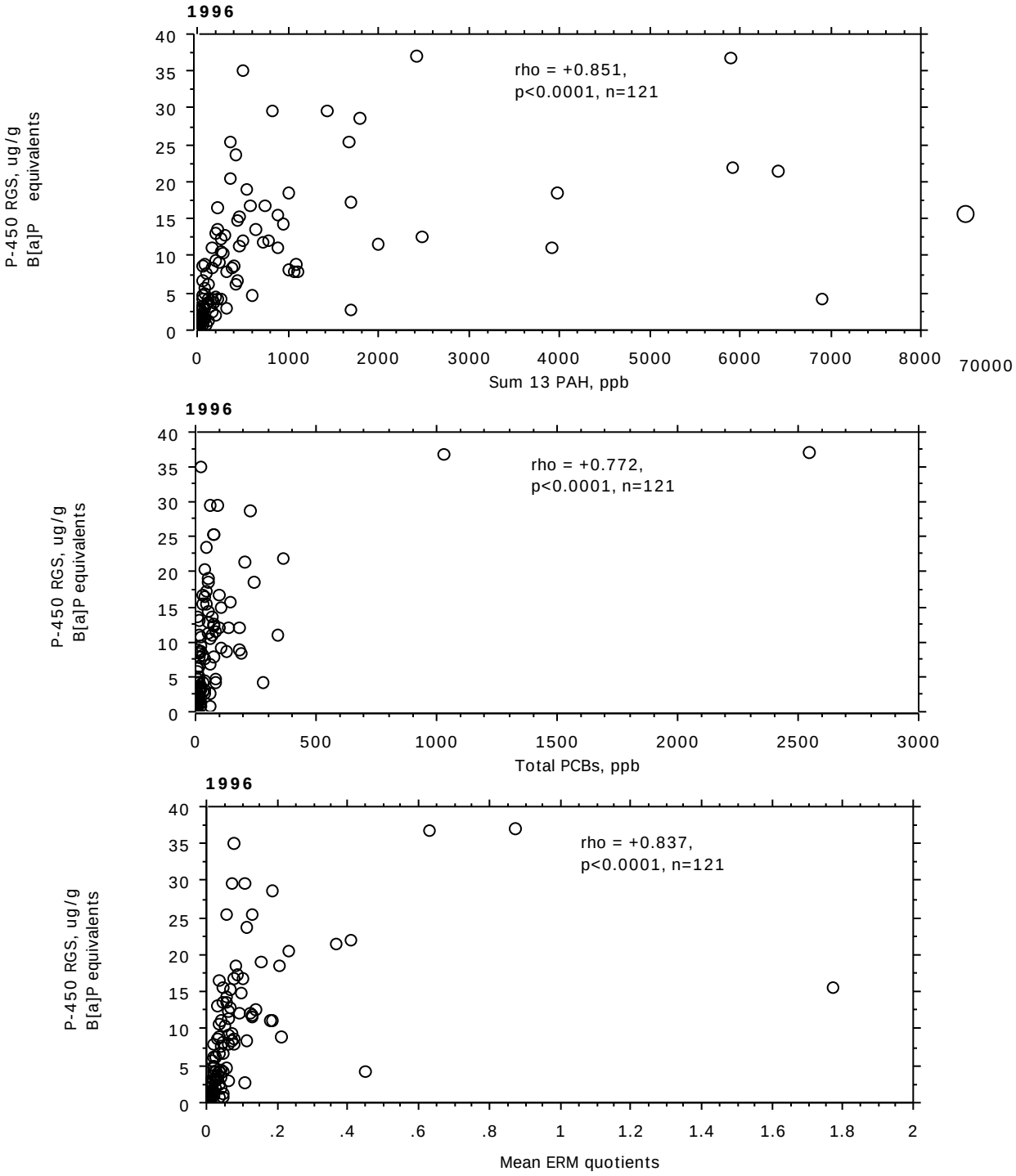


Figure 47. Relationships between results of P-450 RGS assays and the concentrations of sum 13 PAHs, total PCBs, and mean ERM quotients in Biscayne Bay .

Table 20. Spearman-rank correlation coefficients (rho, corrected for ties) and probable significance levels for results of four toxicity tests and chemical concentrations in 57 sediment samples from zone 6.

Chemical	Amphipod survival		Urchin fertilization		Urchin development		Microbial bioluminescence	
Un-ionized ammonia	-0.055	ns	-0.140	ns	-0.690	****	na	
aluminum	-0.471	***	-0.088	ns	-0.174	ns	-0.273	*
antimony	-0.561	****	0.163	ns	-0.197	ns	-0.045	ns
arsenic	-0.240	ns	-0.139	ns	-0.260	ns	.-193	ns
cadmium	-0.646	****	0.061	ns	-0.166	ns	-0.172	ns
chromium	-0.496	***	-0.074	ns	-0.189	ns	-0.276	*
copper	-0.559	****	-0.049	ns	-0.122	ns	-0.244	ns
iron	-0.526	****	0.014	ns	-0.124	ns	-0.241	ns
lead	-0.585	****	-0.001	ns	-0.189	ns	-0.215	ns
manganese	-0.548	****	0.010	ns	-0.144	ns	-0.166	ns
mercury	-0.564	****	0.023	ns	-0.044	ns	-0.114	ns
nickel	-0.535	****	-0.013	ns	-0.142	ns	-0.298	*
selenium	-0.206	ns	-0.200	ns	-0.186	ns	-0.408	**
silver	-0.479	***	-0.063	ns	-0.088	ns	-0.231	ns
thallium	-0.323	*	0.013	ns	-0.059	ns	0.001	ns
tin	-0.600	****	0.022	ns	-0.133	ns	-0.130	ns
zinc	-0.600	****	0.002	ns	-0.147	ns	.-229	ns
percent sand	0.098	ns	0.270	*	0.198	ns	0.384	**
percent silt	-0.154	ns	-0.233	ns	-0.191	ns	-0.396	**
percent clay	0.144	ns	-0.297	*	-0.134	ns	-0.319	*
percent fines	-0.098	ns	-0.270	*	-0.198	ns	-0.384	**
percent TOC	-0.429	**	-0.061	ns	-0.163	ns	-0.362	**
sum 7 LPAHs	-0.518	****	0.025	ns	-0.107	ns	-0.241	ns
sum 6 HPAHs	-0.538	****	0.007	ns	-0.133	ns	-0.247	ns
sum 13 PAHs	-0.538	****	0.004	ns	-0.128	ns	-0.247	ns
hexachlorobenzene	-0.458	***	-0.061	ns	-0.166	ns	-0.244	ns
sum of HCHs	-0.331	*	0.191	ns	0.011	ns	-0.235	ns
heptachlor	-0.537	****	0.264	ns	0.045	ns	-0.025	ns
heptachlor epoxide	-0.441	***	0.060	ns	-0.093	ns	0.177	ns
aldrin	-0.728	****	0.246	ns	0.095	ns	0.036	ns
total chlordanes	-0.578	****	0.019	ns	-0.112	ns	-0.241	ns
trans-nonachlor	-0.696	****	0.142	ns	-0.001	ns	-0.031	ns
cis-nonachlor	-0.600	****	0.083	ns	-0.180	ns	-0.141	ns
dieldrin	-0.426	***	-0.078	ns	-0.076	ns	-0.203	ns
o, p'-DDE	-0.525	****	0.158	ns	-0.100	ns	-0.059	ns
p, p'-DDE	-0.599	****	0.044	ns	-0.119	ns	-0.215	ns
o, p'-DDD	-0.603	****	0.076	ns	-0.151	ns	-0.108	ns
p, p'-DDD	-0.587	****	-0.003	ns	-0.158	ns	-0.210	ns
o, p'-DDT	-0.497	***	0.104	ns	-0.157	ns	-0.122	ns
p, p'-DDT	-0.515	****	0.037	ns	-0.062	ns	-0.106	ns
total DDTs	-0.555	****	-0.005	ns	-0.113	ns	-0.239	ns

Table 20 (continued)

Chemical	Amphipod survival		Urchin fertilization		Urchin development		Microbial bioluminescence	
mirex	-0.513	****	0.251	ns	-0.024	ns	0.138	ns
oxychlordane	-0.759	****	0.129	ns	0.001	ns	0.001	ns
endosulfan	-0.489	***	0.094	ns	-0.088	ns	-0.191	ns
endrin	0.001	ns	0.003	ns	-0.130	ns	-0.207	ns
PCBs 5 + 8	-0.602	****	0.306	ns	-0.020	ns	0.035	ns
PCB 105	-0.596	****	0.078	ns	-0.195	ns	-0.099	ns
PCBs 153 + 132	-0.566	****	0.026	ns	-0.152	ns	-0.200	ns
PCB 206	-0.613	****	0.018	ns	-0.116	ns	-0.129	ns
PCB 209	-0.748	****	0.051	ns	-0.162	ns	-0.170	ns
total PCBs	-0.607	****	0.051	ns	-0.162	ns	-0.170	ns
Sums of chemical:ERM quotients								
• 9 metals	-0.575	****	0.005	ns	-0.132	ns	-0.200	ns
• 13 PAHs	-0.535	****	0.004	ns	-0.129	ns	-0.249	ns
• 3 COHs	-0.592	****	0.047	ns	-0.149	ns	-0.196	ns
• 25 chemicals	-0.561	****	0.030	ns	-0.125	ns	-0.233	ns

* $p < 0.05$
** $p < 0.01$
*** $p < 0.001$
**** $p < 0.0001$

In **Figure 48** percent amphipod survival was plotted against the mean ERM quotient indices. The mean ERM quotients are indicative of the presence of elevated concentrations of mixtures of 25 substances. A value of 1.0 is equivalent to unity, or an average ERM value. Toxicity has been shown to occur frequently in samples with mean ERM quotients of 1.0 or greater (Long et al., 1998). The scatterplot indicates that the correlation between amphipod survival and the mean ERM quotients was highly significant. All except one of the samples with mean ERM quotients less than 0.1 were nontoxic (i.e., survival >80%). Among the 18 samples with mean ERM quotients of 0.1 to 1.0, 15 (83%) were toxic. All four of the samples with mean ERM quotients >1.0 were highly toxic (i.e., amphipod survival was <10%). The station numbers of those samples with the highest chemical concentrations are shown on the scatterplot. Stations 61-63 and 65 were clearly the most contaminated and most toxic.

As indicated on **Table 20,** numerous substances were highly correlated with amphipod survival in zone 6. In many cases the concentrations in the most toxic samples exceeded applicable numerical guidelines. In the following scatterplots, examples of these patterns are shown for lead, PAHs, PCBs, chlordane, and ammonia.

Amphipod survival exceeded 80% (indicating nontoxicity) in all except one of the samples in which lead concentrations were less than the PEL value of 112 ppm **(Figure 49).** Generally, as lead concentrations increased above the PEL and ERM concentrations, amphipod survival decreased sharply. All except two of the samples with lead concentrations above the PEL value were toxic (i.e., survival <80%). Sediments from stations 52, 62, 63, and 65 had the highest concentrations and were among the most toxic in this test.

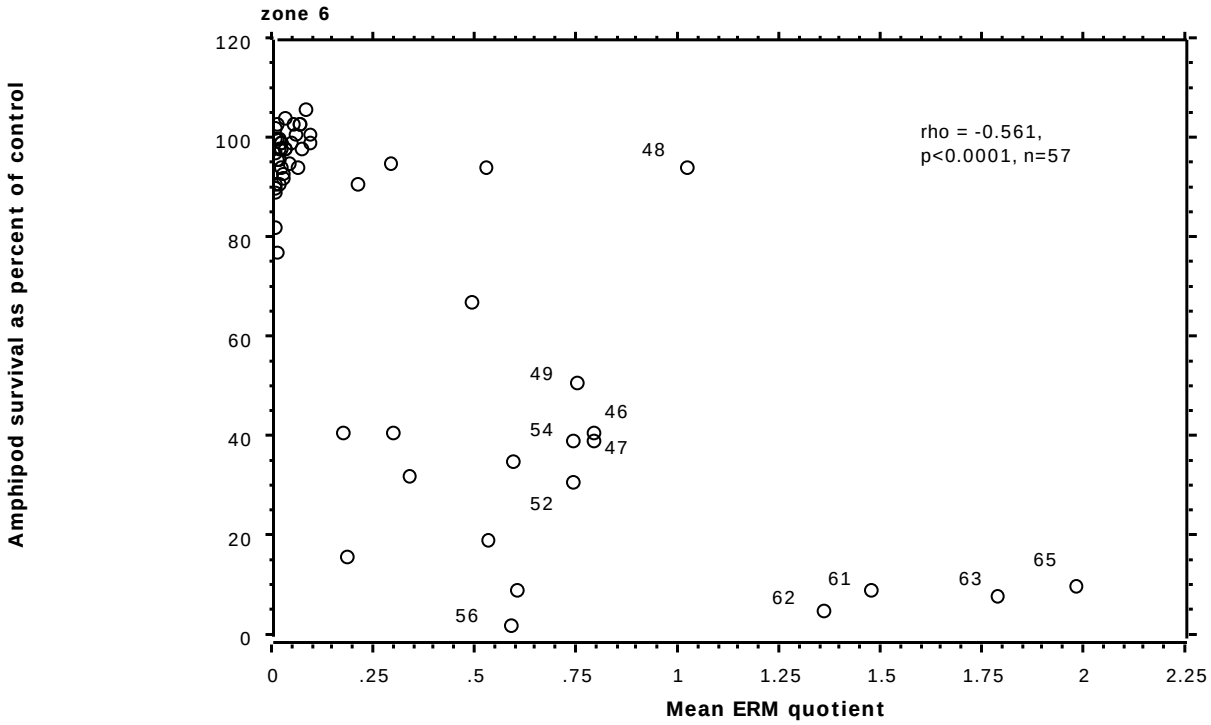


Figure 48. Relationship between amphipod survival and mean ERM quotients in 57 sediment samples from zone 6.

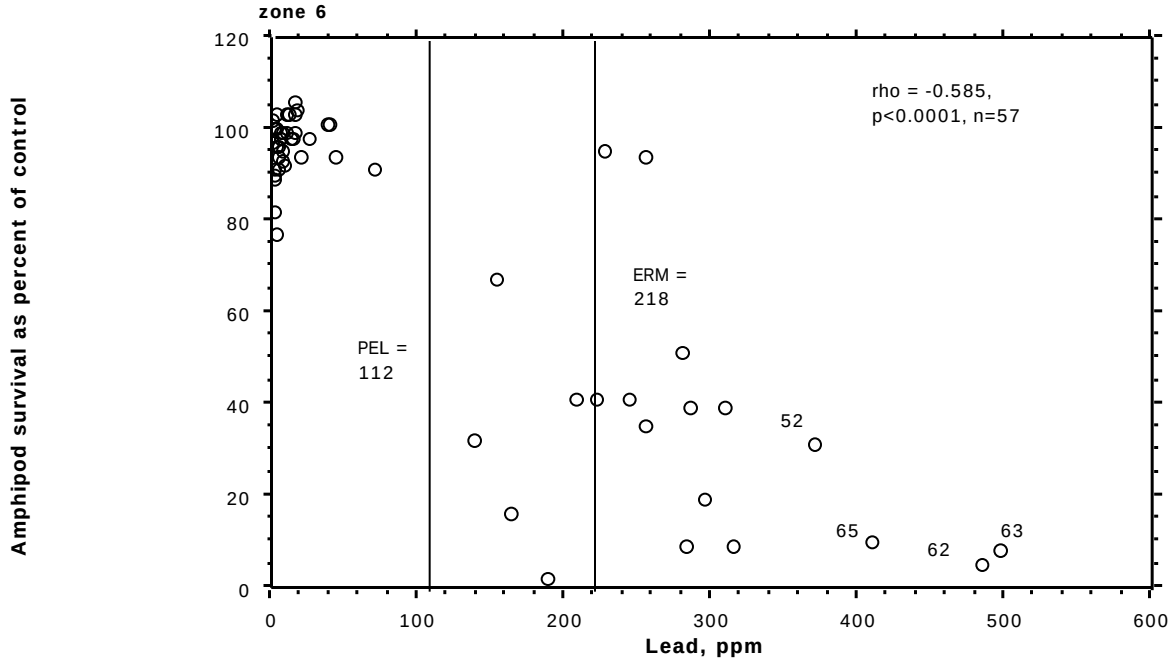


Figure 49. Relationship between amphipod survival and concentrations of lead in 57 sediment samples from zone 6.

The concentrations of high molecular weight PAHs exceeded the PEL value in eight samples and the ERM value in four samples; all except two of which were toxic in the amphipod tests **(Figure 50).** Generally, amphipod survival decreased with increasing concentrations of these substances. Amphipod survival was very low (<10%) in samples from stations 61-63, and 65 in which HPAH concentrations were elevated above the ERM value. An outlier, the sample from station 66, had a high concentration of HPAHs, but was not toxic. The sample from station 66 had very high sand content (96.7%), which was unusual for the Miami River and unexpectedly had a TOC content of 3.7%. While not unusual, TOC content of 3.7% is very high for a sample made up primarily of sand. However, it is possible that the relatively high PAH concentrations were not readily bioavailable because of the high organic content in this sample. Alternatively, the portion of the sample analyzed for PAHs may have had a tar ball within it that was not included in the portion tested for toxicity.

Amphipod survival showed a very strong association with the concentrations of PCBs **(Figure 51).** Most samples with low PCB concentrations were not toxic and as these concentrations increased, amphipod survival sharply decreased. Sixteen of the nineteen samples (84%) with PCB concentrations above the PEL and ERM values were highly toxic in the amphipod tests. Samples with the highest concentrations came from stations 61-63 and 65.

Another class of substances that showed a strong correlation with toxicity was the chlordanes (total of the alpha and gamma isomers) **(Figure 52).** As with the concentrations of lead, PAHs, and PCBs, amphipod survival diminished markedly as chlordane concentrations increased above the PEL and ERM levels. Samples from stations 55, and 61-63 with the highest chlordane concentrations were highly toxic (survival <20%).

None of the concentrations of un-ionized ammonia in the porewaters from either the amphipod test chambers or the urchin tests exceeded toxicity thresholds for *Ampelisca abdita* survival or *Arbacia punctulata* fertilization success and the correlations were either non-significant or weak. However, results of the urchin embryological tests showed a strong correlation with ammonia **(Table 20, Figure 53).** Many of the samples with relatively low ammonia concentrations were not toxic, while those with concentrations that exceeded the lowest observable effects concentration (LOEC = 90 ug/L) were highly toxic. These data suggest that this test was primarily responsive to the presence of high ammonia concentrations in the porewaters.

Chemistry/toxicity correlations: zone 8. Relative to the sediments from the lower Miami River, those from the zone 8 canals were less contaminated and less toxic in the amphipod tests. Therefore, the correlations between amphipod survival and chemical concentrations were not significant in zone 8 for all except one compound - PCB congener 209 **(Table 21).** These data suggest that chemical concentrations generally were not sufficient to cause highly toxic conditions to this, the least sensitive bioassay performed.

In contrast to the amphipod tests, the two urchin tests and the Microtox tests indicated that many samples in zone 8 were toxic **(Table 21).** Sea urchin fertilization success was not significantly correlated with the concentrations of ammonia in the porewaters, but was highly correlated with the presence of fine-grained, organically-enriched sediments indica-

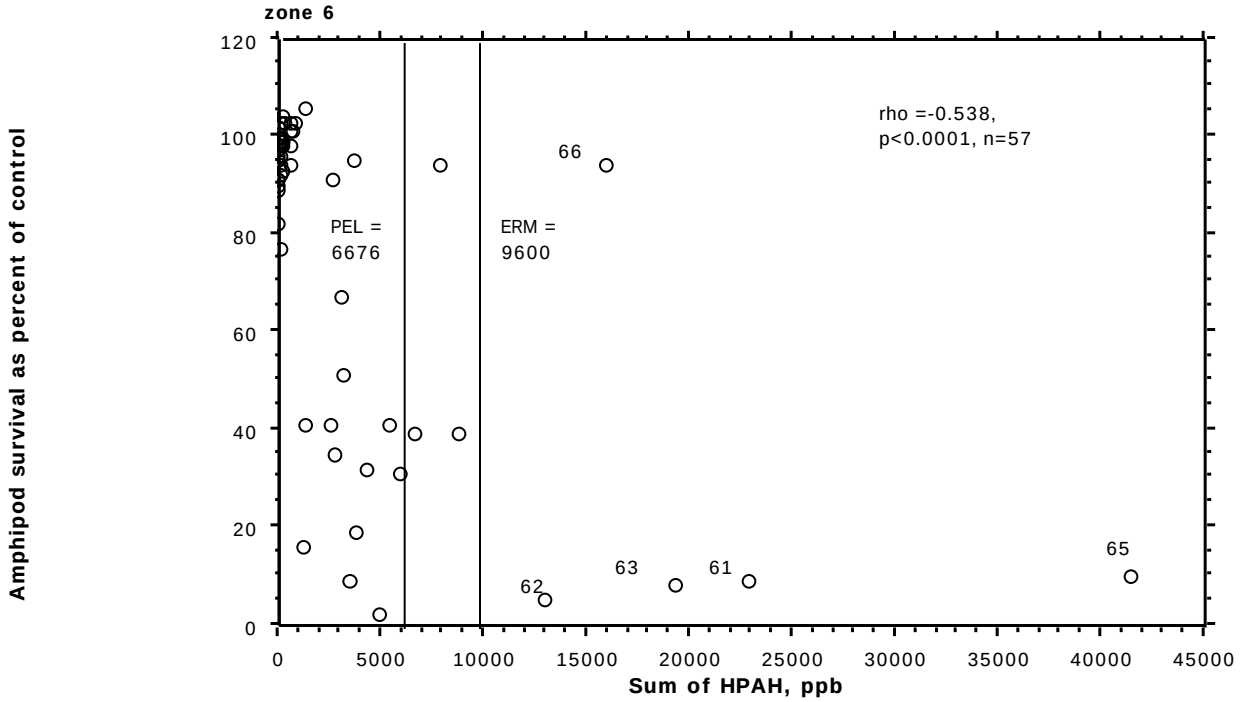


Figure 50. Relationship between amphipod survival and concentrations of high molecular weight PAHs in 57 sediment samples from zone 6.

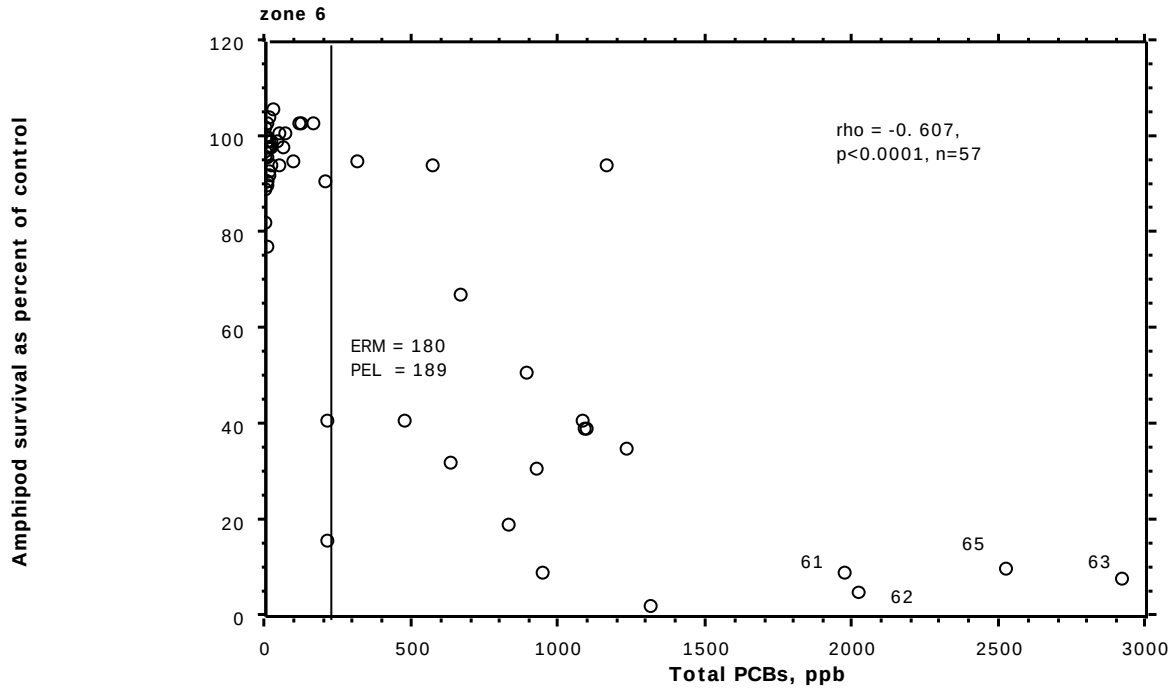


Figure 51. Relationship between amphipod survival and concentrations of total PCBs in 57 sediment samples from zone 6.

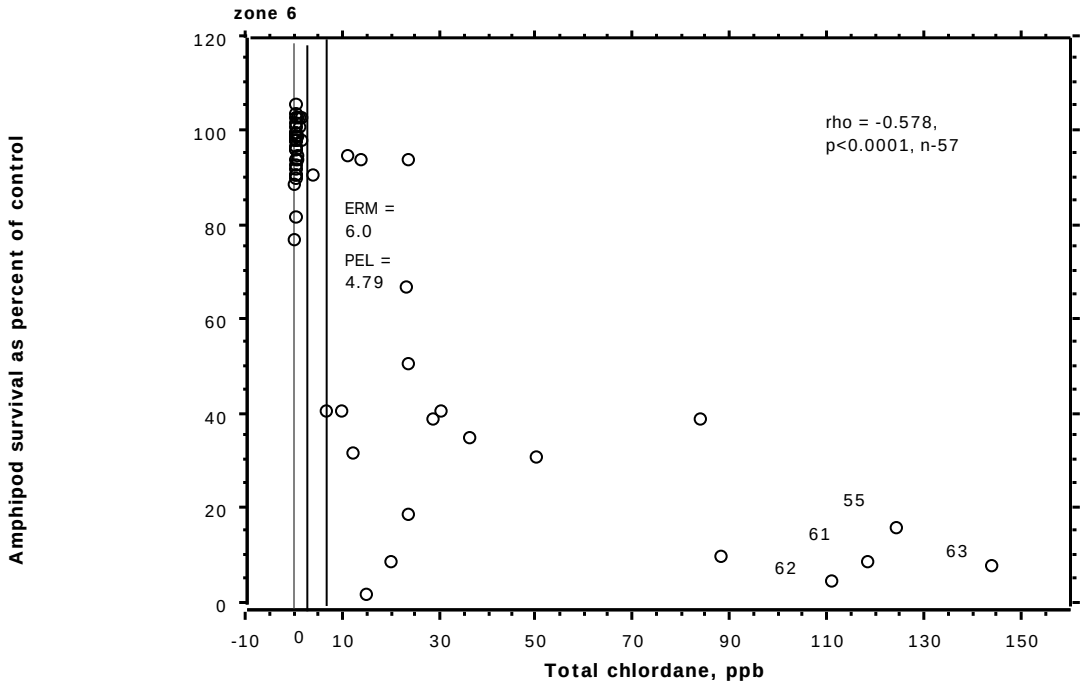


Figure 52. Relationship between amphipod survival and concentrations of total chlordane (alpha + gamma) in 57 sediment samples from zone 6.

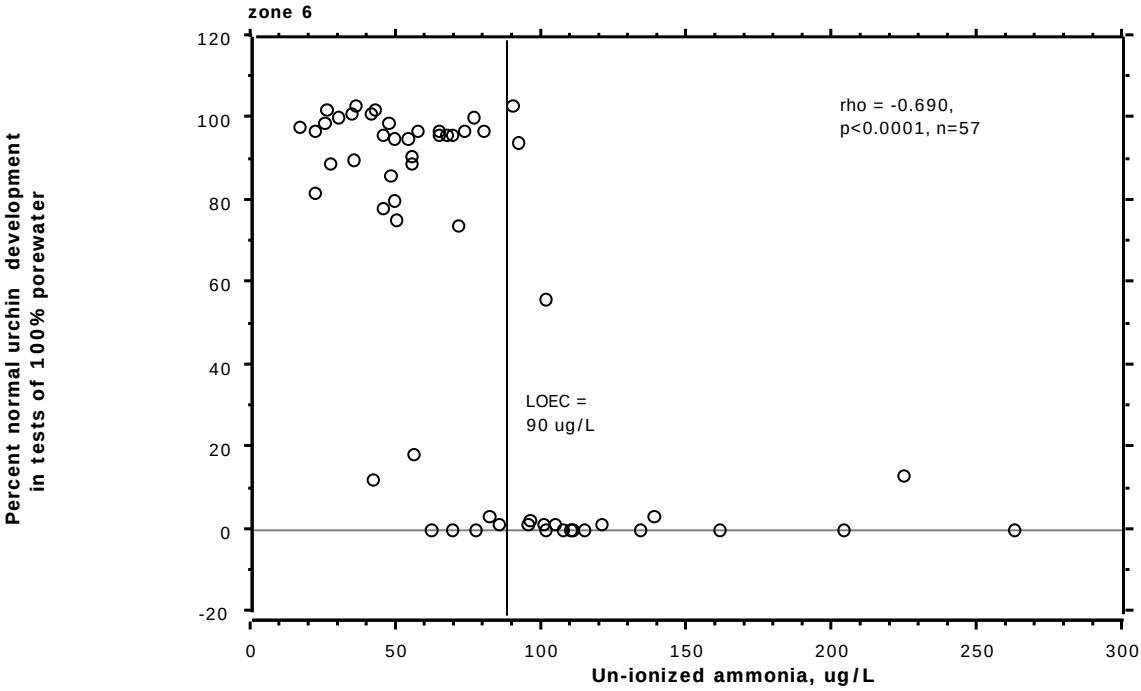


Figure 53. Relationship between normal sea urchin embryological development and concentrations of un-ionized ammonia in pore waters from 57 sediment samples from zone 6.

tive of depositional areas. Urchin fertilization success was significantly correlated in zone 8 with the concentrations of many trace metals, PAHs, and chlorinated organics. These associations were strongest (rho > -0.5, p<0.001) for classes of PAHs and HCHs in the samples. Slightly less significant correlations were apparent for concentrations of antimony, cadmium, copper, nickel, tin, several isomers of chlordane, and several isomers of DDT. A significant correlation was apparent for the presence of 25 substances normalized to their respective ERM values, suggesting that mixtures of different substances may have contributed to diminished fertilization success.

As in the baywide data set and the data from zone 6, urchin development was significantly correlated with ammonia concentrations in zone 8 **(Table 21).** This was the highest correlation coefficient (rho = -0.681, p<0.0001) encountered in the zone 8 data set. However, urchin development also was significantly correlated with the concentrations of arsenic, mercury, silver, tin, percent clay, and to a lesser degree, with many other anthropogenic substances (including classes of PAHs and chlorinated organics).

Surprisingly, results of the Microtox tests were not highly correlated (p<0.001) with any anthropogenic substances in zone 8 - only the concentrations of AVS **(Table 21).** Relatively weak, but statistically significant, correlations were apparent for many trace metals, two classes of PAHs, and several chlorinated organics.

Scatterplots were prepared to illustrate and clarify some of the more interesting correlations in zone 8. The correlation between urchin fertilization and the mean ERM quotients was significant (rho = -0.311, p<0.05). The scatterplot **(Figure 54)** indicates very high fertilization success in most samples with very low chemical concentrations as indicated with mean ERM quotients of less than 0.025. Fertilization success generally diminished as the quotients increased from 0.025 to 0.1. All four samples with quotients greater than 0.1 were significantly toxic (percent fertilization < 70%). These four samples with the highest con-

Table 21. Spearman-rank correlation coefficients (rho, corrected for ties) and probable significance levels for results of four toxicity tests and chemical concentrations in 50 sediment samples from zone 8.

Chemical	Amphipod survival		Urchin fertilization		Urchin development		Microbial bioluminescence	
Un-ionized ammonia	-0.255	ns	-0.260	ns	-0.681	****	na	
aluminum	0.072	ns	-0.258	ns	-0.087	ns	-0.319	*
antimony	0.209	ns	-0.371	**	-0.224	ns	-0.012	ns
arsenic	0.107	ns	0.246	ns	-0.474	***	-0.063	ns
cadmium	0.103	ns	-0.447	**	-0.210	ns	-0.338	*
chromium	0.243	ns	-0.250	ns	-0.157	ns	-0.206	ns
copper	0.108	ns	-0.455	**	-0.199	ns	-0.325	*
iron	0.121	ns	0.017	ns	-0.263	ns	-0.301	*
lead	0.147	ns	-0.348	*	-0.325	*	-0.330	*
manganese	0.160	ns	-0.159	ns	-0.169	ns	-0.369	**
mercury	0.056	ns	-0.313	*	-0.397	**	-0.120	ns
nickel	0.022	ns	-0.381	**	-0.150	ns	-0.259	ns
selenium	0.157	ns	-0.389	*	-0.343	*	-0.262	ns
silver	0.039	ns	-0.332	*	-0.452	**	-0.253	ns
thallium	0.001	ns	0.165	ns	-0.324	*	0.137	ns
tin	0.053	ns	-0.461	**	-0.373	**	-0.071	ns
zinc	0.101	ns	-0.367	*	-0.273	ns	-0.377	**

Table 21 (continued)

Chemical	Amphipod survival		Urchin fertilization		Urchin development		Microbial bioluminescence	
percent sand	-0.161	ns	0.503	***	0.297	*	0.091	ns
percent silt	0.114	ns	-0.506	***	-0.233	ns	-0.136	ns
percent clay	0.239	ns	-0.481	***	-0.380	**	0.022	ns
percent fines	0.161	ns	-0.503	***	-0.297	*	-0.091	ns
percent TOC	0.195	ns	-0.546	****	-0.163	ns	-0.195	ns
AVS	0.170	ns	-0.469	***	-0.282	*	-0.572	****
sum 7 LPAHs	0.189	ns	-0.515	***	-0.332	*	-0.249	ns
sum 6 HPAHs	0.148	ns	-0.448	**	-0.280	*	-0.341	*
sum 13 PAHs	0.217	ns	-0.477	***	-0.313	*	-0.319	*
hexachlorobenzene	-0.250	ns	-0.066	ns	-0.358	*	-0.140	ns
sum of HCHs	-0.018	ns	-0.556	****	-0.325	*	-0.048	ns
heptachlor	0.147	ns	-0.253	ns	-0.064	ns	0.383	ns
heptachlor epoxide	0.069	ns	-0.094	ns	-0.104	ns	-0.114	ns
aldrin	0.092	ns	-0.169	ns	-0.089	ns	0.065	ns
total chlordanes	0.117	ns	-0.334	*	-0.253	ns	-0.211	ns
trans-nonachlor	0.196	ns	-0.430	**	-0.271	ns	0.063	ns
cis-nonachlor	0.047	ns	-0.455	**	-0.233	ns	-0.246	ns
dieldrin	-0.098	ns	-0.186	ns	-0.082	ns	0.128	ns
o, p'-DDE	-0.042	ns	-0.364	*	-0.179	ns	-0.039	ns
p, p'-DDE	0.082	ns	-0.423	**	-0.138	ns	-0.135	ns
o, p'-DDD	0.042	ns	-0.478	***	-0.251	ns	0.060	ns
p, p'-DDD	0.071	ns	-0.437	**	-0.220	ns	-0.044	ns
o, p'-DDT	0.405	ns	-0.181	ns	-0.130	ns	-0.123	ns
p, p'-DDT	-0.069	ns	-0.232	ns	0.001	ns	-0.078	ns
total DDTs	0.041	ns	-0.278	*	-0.161	ns	-0.070	ns
mirex	0.062	ns	-0.309	*	-0.256	ns	0.100	ns
oxychlordane	0.154	ns	-0.174	ns	-0.056	ns	-0.352	*
endosulfan	-0.001	ns	-0.204	ns	-0.072	ns	0.206	ns
endrin	0.212	ns	-0.097	ns	-0.001	ns	-0.171	ns
PCBs 5 + 8	-0.049	ns	-0.111	ns	-0.275	ns	0.114	ns
PCB 105	0.048	ns	-0.285	*	-0.348	ns	-0.428	**
PCBs 153 + 132	0.041	ns	-0.415	**	-0.284	*	-0.177	ns
PCB 206	0.113	ns	-0.088	ns	-0.021	ns	-0.096	ns
PCB 209	-0.283	*	0.256	ns	0.033	ns	-0.141	ns
total PCBs	0.092	ns	-0.360	*	-0.294	*	-0.224	ns
Sums of chemical:ERM quotients								
• 9 metals	0.078	ns	-0.268	ns	-0.299	*	-0.185	ns
• 13 PAHs	0.233	ns	-0.495	***	-0.309	*	-0.290	*
• 3 COHs	0.074	ns	-0.331	*	-0.232	ns	-0.111	ns
• 25 chemicals	0.091	ns	-0.311	*	-0.269	ns	-0.200	ns

* $p < 0.05$
** $p < 0.01$
*** $p < 0.001$
**** $p < 0.0001$

centrations of chemical mixtures were collected from station 105 in Black Creek Canal and stations 206-208 in Military Canal. However, it is curious that fertilization success was less than 20% in many samples with lower contaminant levels, indicating that non-measured substances played a major role in contributing to toxicity in these samples.

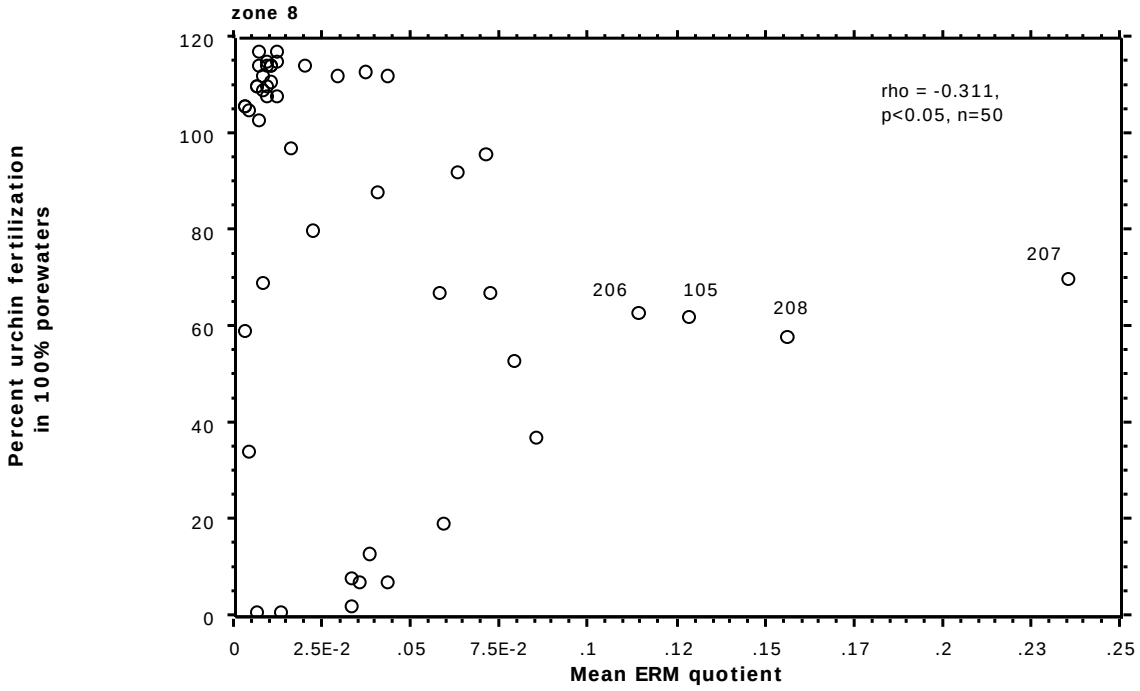


Figure 54. Relationship between urchin fertilization success and mean ERM quotients for 50 sediment samples from zone 8.

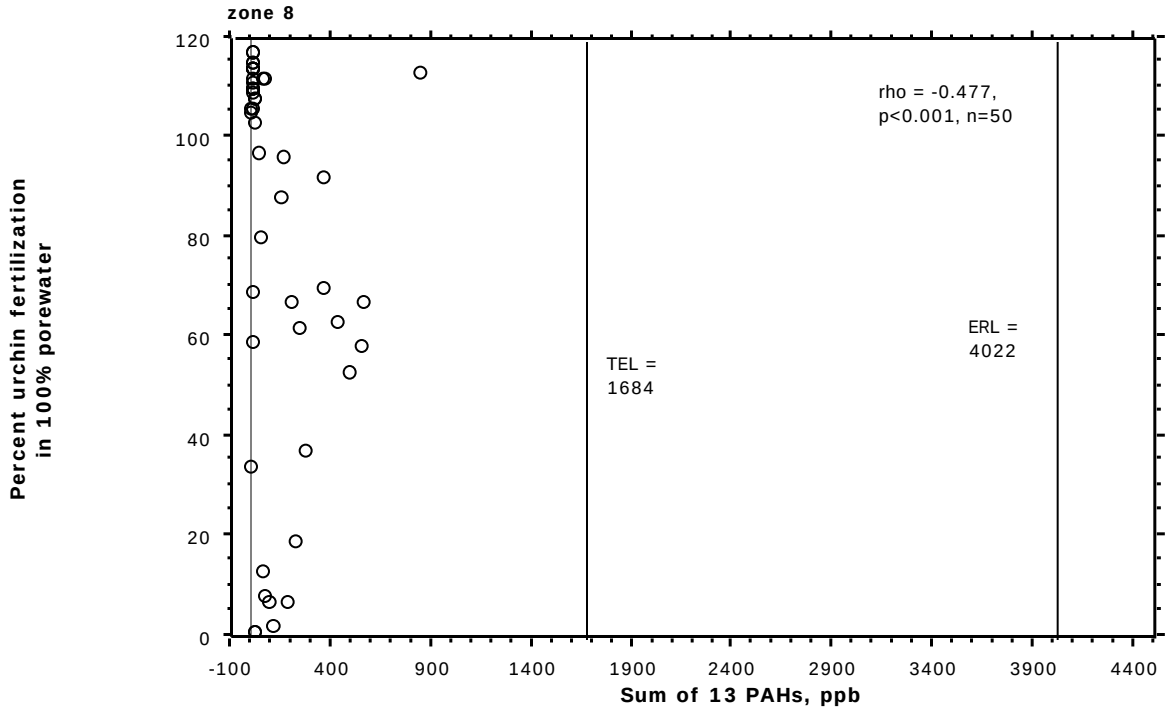


Figure 55. Relationship between urchin fertilization success and concentrations of total PAHs (13 parent compounds) in 50 sediment samples from zone 8.

The PAHs (sum of 13 parent compounds) were among the classes of chemicals that showed significant correlations with fertilization success. Percent fertilization was highest among samples with the lowest total PAH concentrations **(Figure 55).** In many samples with total PAH concentrations of 200 ppb to 600 ppb, fertilization success was 50% to 70%; however, percent fertilization was much higher among samples with lower concentrations. None of the concentrations equalled or exceeded the TEL or ERL values for total PAHs. These data suggest that, although the correlations indicated a statistical association between fertilization success and total PAHs, these chemicals probably had a minor role in contributing to toxicity in this test.

PCB concentrations in most samples from zone 8 were very low **(Figure 56),** and the association with percent fertilization was relatively weak. Furthermore, PCB concentrations in some of the samples that were most toxic (fertilization < 20%) were not elevated (< 20 ppb). However, in contrast to the PAHs, the concentrations of total PCBs in many samples that were toxic (fertilization < 80%) exceeded both the TEL and ERL values.

The correlation between percent normal embryological development and the mean ERM quotients was not significant (rho = -0.269, p=0.06, n=50). Many samples were highly toxic that had very low chemical concentrations. However, there were some samples also with low chemical concentrations that were non-toxic and the scatterplot shows that all samples with mean ERM quotients > 0.05 were highly toxic (0.0% percent normal development) **(Figure 57).** The three samples from Military Canal and one from Black Creek Canal that were most contaminated were also highly toxic in this test.

The correlation between percent normal development and ammonia concentration was highly significant and the scatterplot verifies this strong association **(Figure 58).** All samples with concentrations of un-ionized ammonia above 70 ug/L or the LOEC value of 90 ug/L were highly toxic. Based upon the correlations calculated for zone 8 **(Table 21),** it was also apparent that substances in addition to ammonia may have contributed to toxicity. For example, the concentrations of arsenic and silver in the sediments were significantly correlated with percent normal development and the scatterplots indicated that samples in which these elements exceeded the TEL and ERL values were highly toxic **(Figures 59, 60).** The concentrations of silver were especially high (but did not exceed the ERM value of 3.7 ppm) in the samples from stations 105 (Black Creek canal), and 206-208 (Military canal).

Cytochrome P-450 RGS assays were performed on 11 of the samples from zone 8 during 1996. This test indicated relatively high induction rates among some of the samples from the zone 8 canals; thus providing a relatively large gradient in response with which to compare the chemical data. Correlations between induction (as ug/g, benzo[a]pyrene equivalents) and concentrations of PAHs and PCBs were extremely high **(Figure 61)**. Correlation coefficients and p values were: total PCBs (rho = +0.800, p=0.011); seven parent LPAHs (rho = +0.900, p=0.004); six parent HPAHs (rho = +0.918, p=0.004); sum of 13 parent PAHs (rho = +0.918, p=0.004); all quantified parent and substituted PAHs (rho = +0.909, p=0.004); and mean ERM quotients for 25 substances (rho = +0.845, p=0.008).

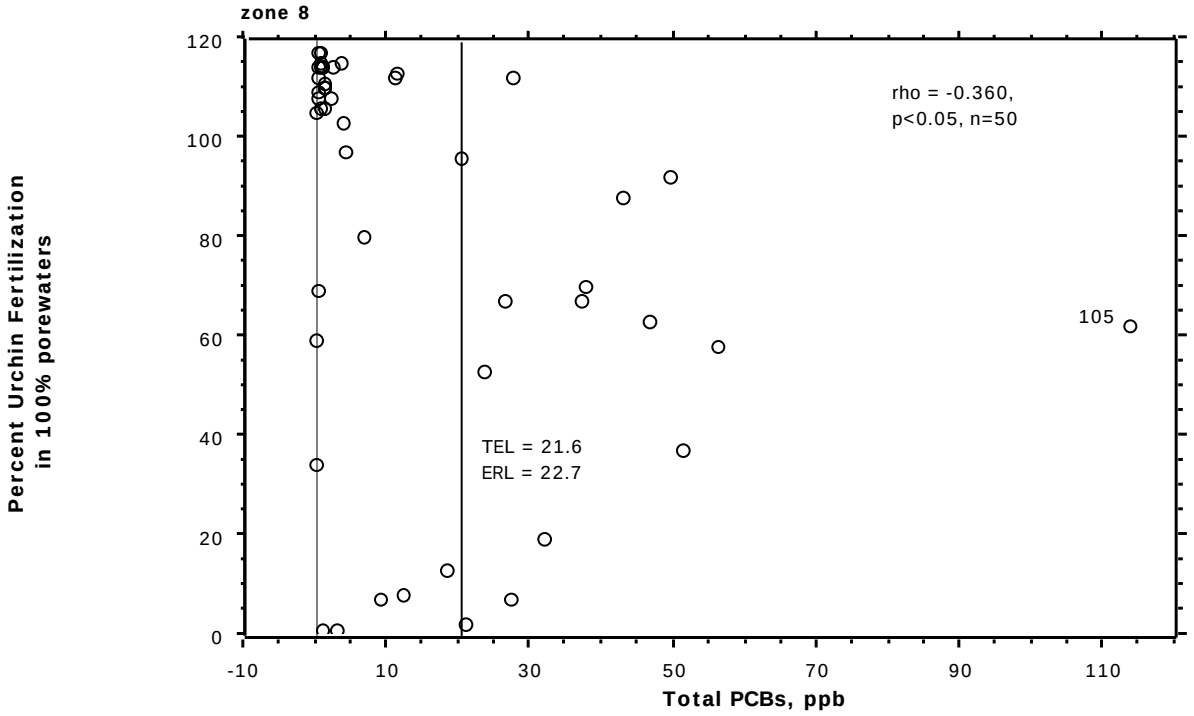


Figure 56. Relationship between urchin fertilization success and concentrations to total PCBs in 50 sediment samples from zone 8.

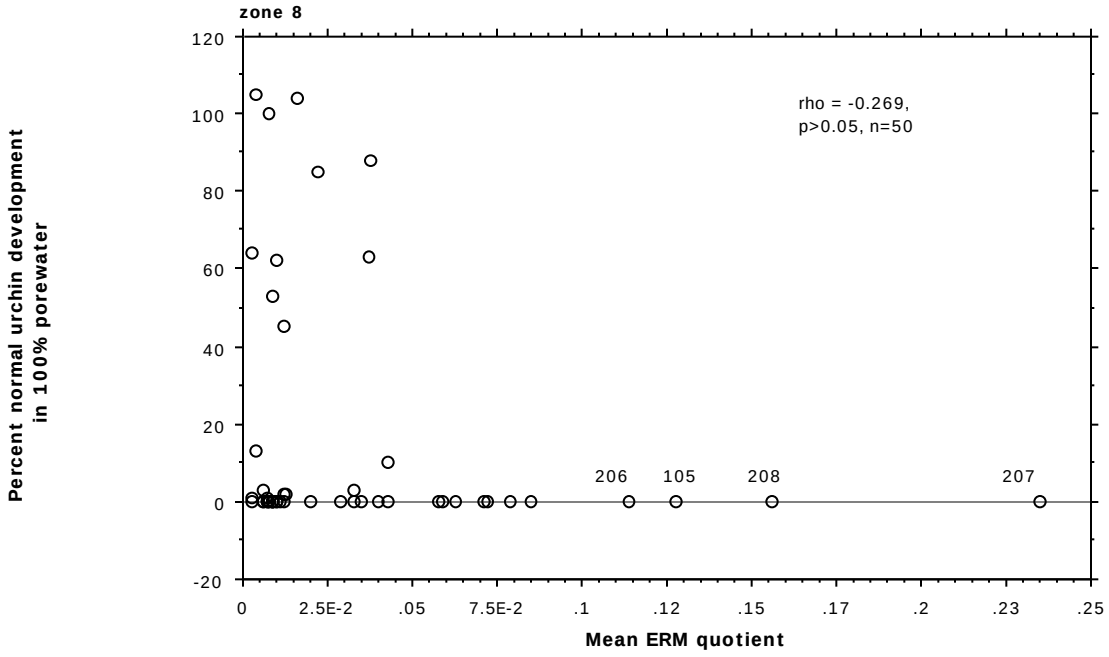


Figure 57. Relationship between percent normal embryological development in 100% pore water and mean ERM quotients in 50 sediment samples from zone 8.

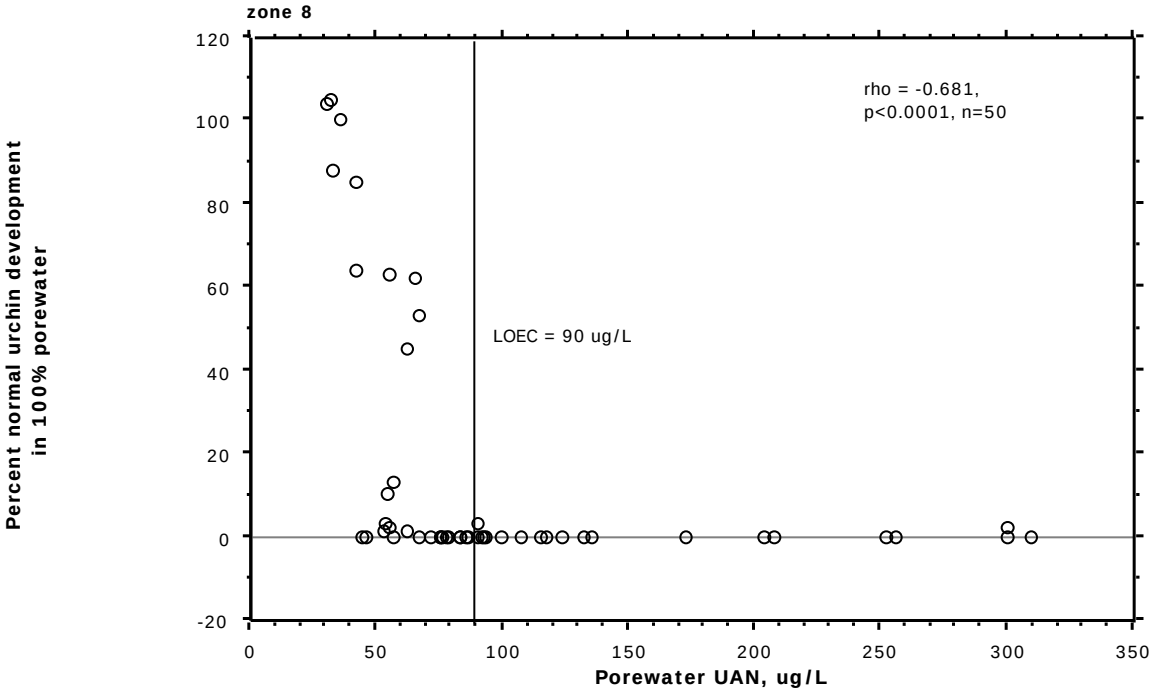


Figure 58. Relationship between percent normal embryological development in 100% pore water and concentrations of un-ionized ammonia in pore water of 50 sediment samples from zone 8.

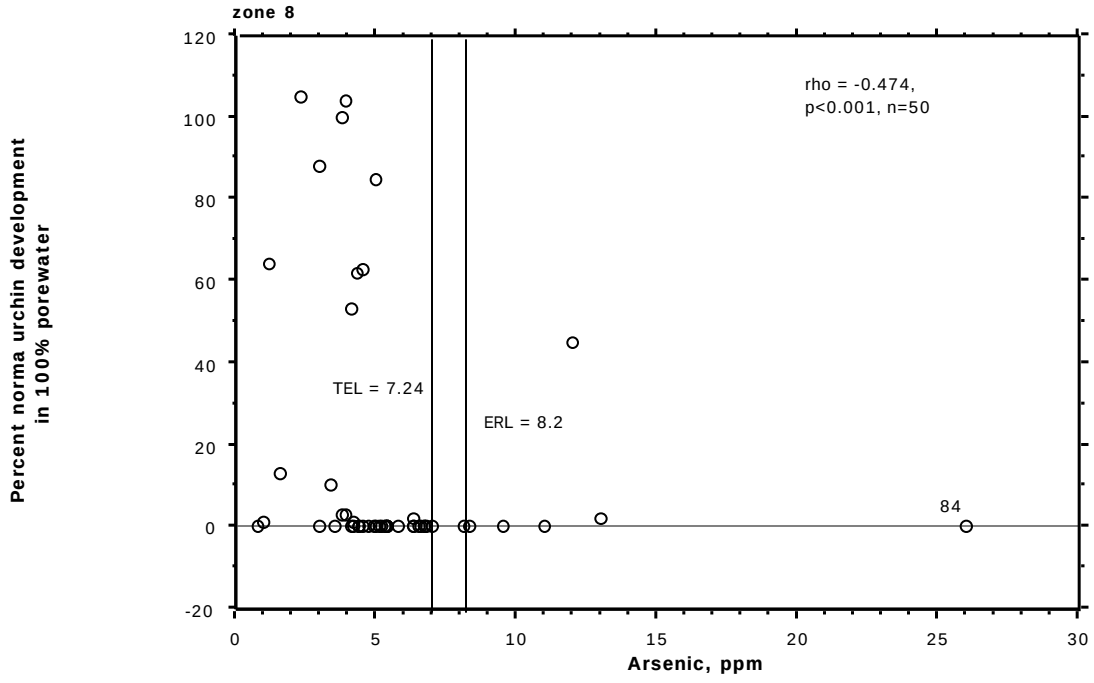


Figure 59. Relationship between percent normal embryological development in tests of 100% pore water and concentrations of arsenic in 50 sediment samples from zone 8.

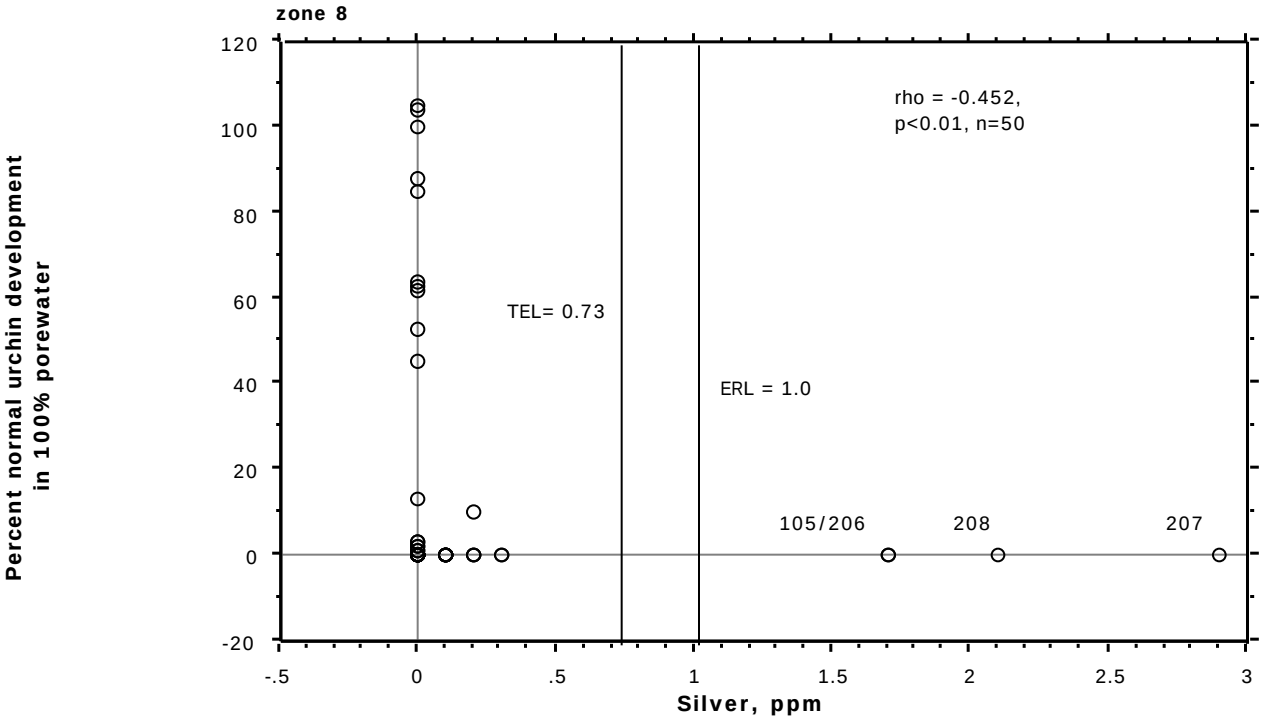


Figure 60. Relationship between normal embryological development in tests of 100% pore waters and concentrations of silver in 50 sediment samples from zone 8.

The patterns in response in the P-450 RGS assays with the concentrations of total 13 PAHs, total PCBs, and mean ERM quotients are displayed in **Figure 61**. These scatterplots demonstrate a very strong association between the concentrations of these substances and the P-450 induction response. The regression of RGS response against total PAHs is nearly linear. These data suggest that the physiological response to toxicants measured with the RGS assays most likely responded to a mixture of PAH, co-planar PCBs, and, perhaps, other substances in the samples.

Overall, the data from zone 8 indicated several interesting patterns in which sublethal measures of toxicity co-varied with the concentrations of many different potentially toxic substances. Sediments from the zone 8 canals, in which chemical concentrations were much higher than in the adjoining open-water basin of south bay, were clearly less contaminated than those from the lower Miami River in zone 6. As a consequence, the correlations between amphipod survival and chemical concentrations were not very significant. However, it appears that these concentrations were sufficiently high to contribute to toxicity in the other, sublethal - and more sensitive - tests with urchins and P-450 RGS. Induction of the cytochrome P-450 RGS assay was highly correlated with the presence of PAHs and PCBs are known to induce a response in this test. As observed in zone 6 and throughout the entire survey area, mixtures of ammonia, trace metals, PAHs, and chlorinated organics were sufficiently elevated in many samples and they probably contributed to or were responsible for the toxicity observed in the sublethal tests.

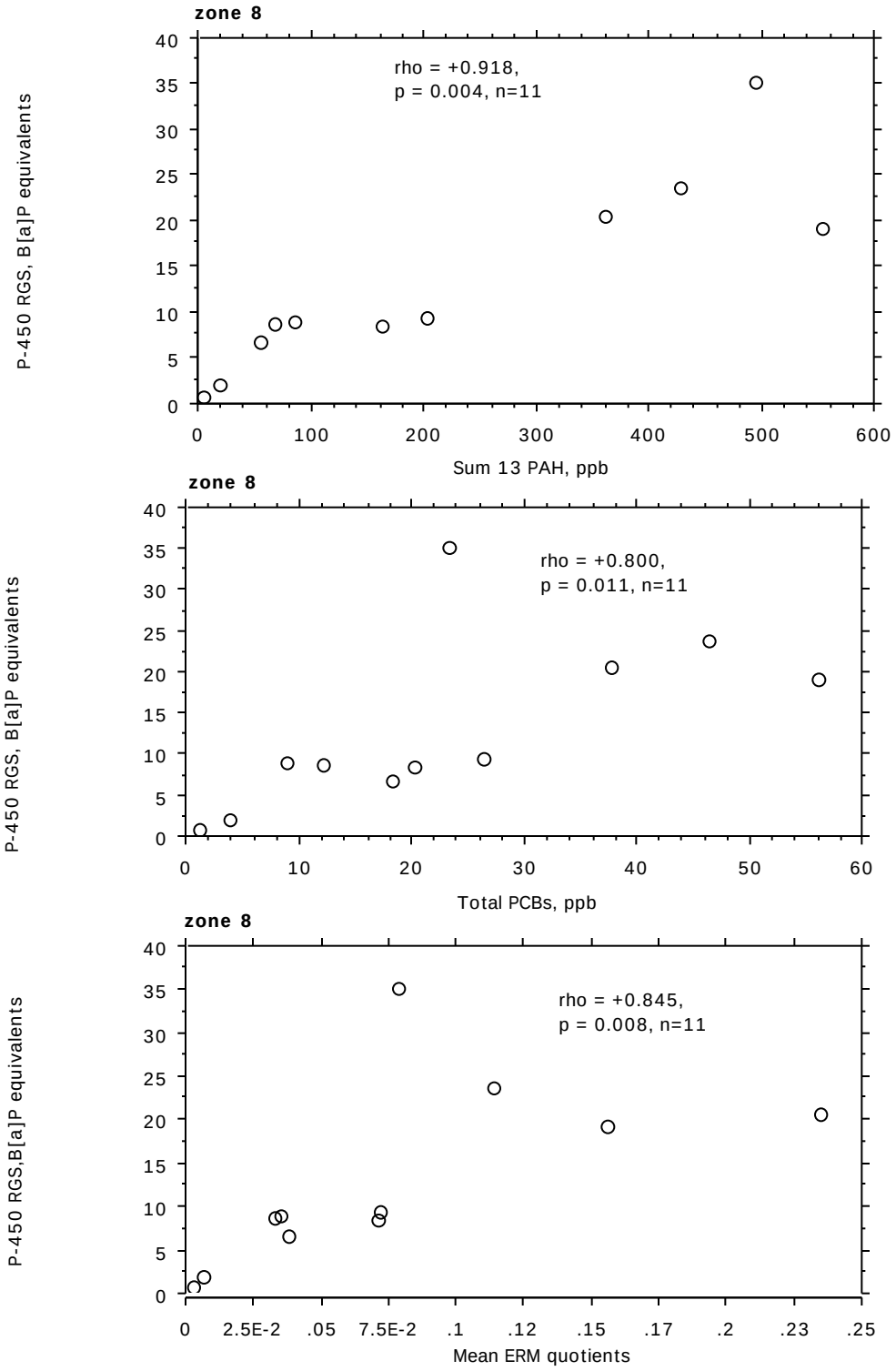


Figure 61. Relationship between results of P-450 RGS assays and the concentrations of total PAHs, total PCBs, and mean ERM quotients in Zone 8.

In the southern reaches of zone 8, there were 13 samples that formed a ribbon or band of toxicity from the shoreline across the bay to the ocean. These samples were highly toxic in one or more tests, often including the amphipod survival test. Samples collected to the north and south of this band were not toxic in the amphipod test. The data from the chemical analyses indicated these samples were not highly contaminated. Except for a few samples with slightly elevated ammonia levels, concentrations of chemicals for which analyses were performed were below or near the detection limits. The lack of correspondence between measures of toxicity and chemical concentrations in the 13 samples suggests that other substances for which analyses were not performed were present at toxicologically significant concentrations.

DISCUSSION

The survey of sediment toxicity in Biscayne Bay was similar in intent and design to those performed elsewhere by NOAA in many different bays and estuaries using comparable methods. Data have been generated for areas along the Atlantic, Gulf of Mexico, and Pacific coasts to determine the presence, severity, regional patterns and spatial scales of toxicity (Long et al., 1996). Spatial extent of toxicity in other regions ranged from 0.0% of the area to 100% of the area, depending upon the toxicity test.

The intent of this survey of Biscayne Bay was to provide information on toxicity throughout all regions of the Biscayne Bay system, including a number of tributary streams and canals. The survey area, therefore, was very large and complex. This survey was not intended to focus upon any potential discharger or other source of toxicants. The survey was not designed to provide evidence to be used to identify or regulate any source of pollution. Temporal trends in chemical contamination and/or toxicity were not determined. Bioaccumulation of toxicants in tissues was not determined.

Rather, the data from the laboratory bioassays were intended to represent the toxicological condition of the survey area, using a battery of complimentary tests, as a measure of the potential biological effects of toxicants. The primary objectives were to estimate the severity, spatial patterns, and spatial extent of toxicity and chemical contamination. A stratified-random design was followed to ensure that unbiased sampling was conducted and, therefore, the data could be attributed to the strata within which samples were collected.

Amphipod survival tests. This test was performed with relatively unaltered, bulk sediments and with an adult crustacean exposed to the sediments for 10 days. The endpoint was survival. Amphipod survival tests are the most commonly applied bioassays in dredging and hazardous waste site assessments in North America. Standardized protocols are widely used in many regions of the U.S. Data from several field surveys conducted along portions of the Pacific, Atlantic, and Gulf of Mexico coasts have shown that significantly diminished survival of these animals often is coincident with decreases in total abundance of benthos, abundance of crustaceans including amphipods, total species richness, and other metrics of benthic community structure (Long et al., 1996).

The amphipod tests proved to be the least sensitive of the tests performed baywide. Of the 226 samples tested, survival was significantly different from controls in 49 (22%). With the results of the amphipod tests weighted to the sizes of the sampling strata within which samples were collected, the spatial scales of toxicity could be estimated. The strata within which decreased amphipod survival was highly significant (i.e., <80% of controls) totalled about 62km^2 or 13% of the total survey area. The estimate for the spatial extent of toxicity in the amphipod tests was similar to the "national average" (11%; Long et al., 1996) compiled for the other regions sampled by NOAA **(Table 22).**

The observation that survival was significantly reduced in 22% of samples and that the strata in which toxicity was apparent represented only 13% of the total area highlights the importance of normalizing the toxicity data to the sizes of the strata. Most of the samples in which amphipod survival was reduced were collected in relatively small strata such as those in the Miami River and Black Creek. Fewer samples that were toxic were collected in the relatively large strata of zones 6 and 8, etc.

In surveys of 24 U. S. regions, estimates of the spatial extent of toxicity ranged from 0.0% in many areas to 85% in Newark Bay, NJ **(Table 22).** Biscayne Bay ranked towards the middle of this range, slightly above the "national average" calculated with data collected nationwide through 1995 (11%). Toxicity was not observed in many other bays of the southeastern U.S., particularly along the South Carolina / Georgia coastline and the western Florida panhandle. Regions in which toxicity was most pervasive were mainly in the northeastern U. S. and Southern California. The data from the samples collected in Biscayne Bay and Galveston Bay in 1996 had the affect of lowering the "national average" from 11% to about 7%.

Sea urchin tests. In the tests performed with sea urchin sperm to determine fertilization success, early life stages (the gametes) of the animals were used in the exposures. Early life stages of invertebrates often are more sensitive to toxicants than adult forms. Fewer defense mechanisms are developed in the gametes than in the adults. The endpoint of the tests was fertilization success and normal morphological development of the embryos, sublethal endpoints expected to be more sensitive than mortality. The gametes were exposed to the pore waters extracted from the samples; the phase in which toxicants are expected to be highly bioavailable. This test was adapted from bioassays originally performed to test wastewater effluents and has had wide application throughout North America in tests of both effluents and sediment porewaters. The combined effects of these features was to develop a relatively sensitive test - much more sensitive than that performed with the adult amphipods.

In Biscayne Bay 44% of the samples were significantly toxic in the fertilization tests relative to controls in tests of 100% (undiluted) pore waters; about twice the number of samples identified as toxic in the amphipod tests. In tests of 50% and 25% porewater concentrations, the frequency of toxicity decreased to 19% and 6% of the samples, respectively. The strata in which toxicity was highly significant (i.e., <80% of controls) totalled about 47%, 22%, and 12% of the survey area in tests with 100%, 50%, and 25% porewater concentrations, respectively.

NOAA has estimated the spatial extent of toxicity in urchin fertilization or equivalent bioassays in many other regions of the U. S. (Long et al., 1996). These estimates ranged from 98% in San Pedro Bay, CA, to 0.0% in Leadenwah Creek, SC **(Table 23).** As in the amphipod tests, Biscayne Bay ranked near the middle of this range, slightly above the "national average" calculated with data collected through 1995. Many areas in Southern California were highly toxic in these tests, whereas Boston Harbor, Sabine Lake, northern Puget Sound, and several estuaries of the southeastern U. S. were not toxic in most samples.

The urchin embryological development test was developed by the USGS laboratory as a companion to the fertilization test. This is an exposure of the fertilized embryos to the pore waters and the percent of the embryos that develop a "normal" morphology are counted as the toxicity endpoint. This test has proven in previous surveys to be highly sensitive to the presence of ammonia in the pore waters. The toxicity threshold to ammonia is about an order of magnitude lower than that for fertilization success. It has also shown strong statistical associations with the presence of anthropogenic toxicants in samples from some areas such as Boston Harbor.

Among the four tests performed with all 226 samples in the Biscayne Bay survey, the embryo development test was the most sensitive test performed, indicating 77%, 31%, and 6% of samples were toxic in tests of 100%, 50%, and 25% porewater concentrations, respectively. Highly significant results (i.e., <80% normal development) in the samples represented about 84%, 35%, and 17% of the survey area, respectively, in the three porewater concentrations. Comparable data available from other regions illustrate the pervasiveness of toxicity in this test in Biscayne Bay **(Table 24).** Biscayne Bay ranked nearly highest and well above the "national average" among seven bays for which comparable data are available.

Microbial bioluminescence tests. The Microtox tests were performed with an organic solvent extract intended to elute all potentially toxic organic substances from the sediments regardless of their bioavailability. The tests, therefore, provide an estimate of the potential for toxicity attributable to complex mixtures of toxicants associated with the sediment particles, and, not normally available to benthic infauna. The test endpoint is a measure of metabolic activity of a cultured bacteria, not acute mortality. These features combined to provide a relatively sensitive test - usually the most sensitive test performed nationwide in the NOAA surveys (Long et al., 1996).

In Biscayne Bay 58% of the samples were significantly toxic, representing about 51% of the total area. Comparable data are available from 16 other regions in the U. S. **(Table 25).** Spatial extent of toxicity in these regions ranged from 0.1% in Tampa Bay to 100% in two bays of the western Florida panhandle. As observed in the amphipod and urchin fertilization tests, the estimate for Biscayne Bay ranked towards the middle of the range, slightly below the "national averages" calculated for data collected through 1995 and 1996.

Cytochrome P-450 RGS assays: These tests have been performed for NOAA thus far in: Charleston Harbor (SC) and vicinity; San Diego Bay (CA); coastal California estuaries; Sabine Lake (TX); Galveston Bay (TX); Biscayne Bay; and northern Puget Sound (WA). The

overall running mean of responses among 528 samples is 17.4 ug B[a]P equivalents / g with an upper 99% confidence limit of 23 ug B[a]P equivalents / g. There were 15 samples (12%) among the 121 from Biscayne Bay that were tested in which the response exceeded 17.4 ug B[a]P equivalents / g and 9 in which the response exceeded 23 ug B[a]P equivalents / g

Using the two critical values developed as a part of the Biscayne Bay and northern Puget Sound studies, the spatial extent of toxic responses can be compared between these two areas. In northern Puget Sound, the samples in which RGS assay responses exceeded 11.1 ug B[a]P equivalents / g and 37.1 ug B[a]P equivalents / g represented about 2.5% and 0.03% of the study area, respectively. These results, therefore, were similar to those for the 1996 Biscayne Bay samples (i.e., 3.3% and 0.0%, respectively). The estimated area sampled in 1996 in which the P-450 RGS response exceeded 11.1 ug B[a]P equivalents / g and the area sampled during both years in which at least one ERM value was exceeded (see text below) showed remarkable agreement (3.3% vs. 0.7%, respectively) in Biscayne Bay.

In analyses of 30 samples from Charleston Harbor and vicinity, results ranged from 1.8 ug B[a]P equivalents / g to 86.3 ug B[a]P equivalents / g. In the 121 samples from Biscayne Bay, results ranged from 0.4 to 37. ug B[a]P equivalents / g. In Charleston Harbor, nine samples produced results greater than 30 ug / g and three gave results greater than 70 ug B[a]P equivalents / g; whereas in Biscayne Bay only three samples produced results greater than 30 ug B[a]P equivalents / g and none exceeded 70 ug B[a]P equivalents / g. On average it appears that the induction rates produced by samples from Biscayne Bay were lower than those from Charleston Harbor.

In northern Puget Sound, responses ranged from 0.3 ug B[a]P equivalents / g to 104.6 ug B[a]P equivalents / g and five samples had responses greater than 30 ug B[a]P equivalents / g - comparble to results for Biscayne Bay. Induction responses in 30 samples from San Diego Bay were considerably higher than those from the other three areas. Assay results in San Diego Bay samples ranged from 5 ug B[a]P equivalents / g to 110 ug B[a]P equivalents / g and results from 19 samples exceeded 30 ug B[a]P equivalents / g. Responses in eight samples exceeded 80 ug B[a]P equivalents / g.

These data suggest that CYP1A inducing substances in the 1996 Biscayne Bay samples occurred at concentrations similar to those observed in northern Puget Sound and Charleston Harbor. However, the levels of response were well below those encountered in San Diego Bay.

Copepod reproduction tests. The tests of reproductive success among copepods were not conducted on all samples because of the lack of funding. Therefore, the spatial extent of toxicity in the tests of reproductive success could not be estimated. Rather, the tests were run to provide an opportunity for a field validation of this promising bioassay. More important, this test was performed on selected samples to determine if a toxicological response that is highly relevant to the abundance of resident sensitive taxa, i.e, the ability of progeny to survive, was significantly diminished in samples that may have proved to be not toxic in acute tests of survival.

The University of South Carolina conducted assays similar to those performed in Biscayne Bay in a survey of Charleston Harbor and vicinity for NOAA. Results in both areas were overlapping; total naupliar + copepodite production ranged from 9.3 to 567 in Biscayne Bay and from 95 to 494 in Charleston Harbor. In the majority of samples from both areas, total production ranged from 200 to 300 offspring. However, the statistical significance of the results was quite different between the two areas. None of the sample means for total production in Charleston Harbor were significantly different from controls, whereas 13 of 15 were significant in Biscayne Bay. Also, total production was below 100 in only one of the samples from Charleston Harbor; whereas it was below 100 in three Biscayne Bay samples, ranging as low as 29 and 9 in samples from stations 58 and 48, respectively.

These data suggest that indicators of sublethal reproductive success were triggered to a much greater degree in Biscayne Bay samples than in those from Charleston Harbor. If these bioassays are reliable indicators of the toxicological significance of sediment-associated contaminants to the reproductive success of infaunal invertebrates in Biscayne Bay, the data would suggest that populations of these biota could experience declines in abundance.

Levels of chemical contamination. In Biscayne Bay, 6 of 226 samples (2.7%) had mean ERM quotients exceeding 1.0; whereas in a database compiled from samples taken nationwide in many bays and estuaries (Long et al., 1998), 51 of 1068 samples (4.8%) had equivalent chemical concentrations. Similarly, 45 of 226 Biscayne Bay samples (20%) had mean ERM quotients of 0.11 or greater , whereas, 415 of the 1068 national database samples (39%) had equivalent concentrations.

Of the 226 samples analyzed, 33 (14.6%) had chemical concentrations that exceeded one or more ERM values by any amount. In comparison, 27% of the 1068 samples compiled in the NOAA national database had chemical concentrations that exceeded at least one ERM value (Long et al., 1998). Also, 26% of samples from over 21,000 locations sampled nationwide had at least one chemical concentration that exceeded an ERM, or PEL, or apparent effects threshold (AET) value (U. S. EPA, 1996).

The 33 samples from Biscayne Bay in which at least one ERM was exceeded represented stations that totalled an area of about 3.5 km^2 or 0.7% of the total survey area of 484.2 km^2. This estimate is considerably lower than the surficial area (16%) in the Carolinian province in which at least one chemical concentration exceeded an ERM or PEL or in which at least three substances exceeded the ERL or TEL values (Hyland et al., 1996).

These comparisons between the chemical concentrations observed in Biscayne Bay and those reported for other areas indicate that, on average, contaminant levels in the bay were relatively low throughout much of the area. The incidence and spatial extent of contaminated conditions, as compared to the ERM and PEL values as benchmarks, were relatively low. The regions of the bay in which chemical concentrations were highest and exceeded numerical guidelines were mostly the peripheral tributaries and canals on the mainland, and, thus, were relatively small in size. Contaminant levels often were much lower in the open basin south of the Rickenbacker Causeway through Little Card Sound than in areas farther north.

However, it is important to note the percentages of samples in which ERL and TEL values were exceeded in Biscayne Bay. Among all 226 samples analyzed, 47%, 44%, 27%, and 8% of them had concentrations of total PCBs, total DDTs, mercury, and total PAHs, respectively, that exceeded the ERL values. These data suggest that, although relatively small percentages of samples had high chemical concentrations, many of them had intermediate concentrations.

Determinations of temporal trends in contaminant concentrations and toxicity were not a part of this study. Furthermore, data from previous studies of chemical contamination (e.g., Corcoran, 1983) were generated with different sampling and analytical methods and, therefore, probably are not comparable with the data from this survey. However, the general patterns reported by Corcoran (1983) and others in chemical concentrations (highest in the Miami River and other tributary canals, lowest in the open waters of south bay) were also observed in the present survey.

CONCLUSIONS

• A total of 226 sediment samples were collected, tested for toxicity testing and analyzed for chemical contaminants during 1995 and 1996. Samples were collected all majors regions of Biscayne Bay. All sampling locations were chosen with a stratified-random sampling design.

• A battery of toxicity tests were performed to provide a comprehensive assessment of the toxicological condition of the sediments. Chemical analyses were performed for a wide variety of trace metals, aromatic hydrocarbons, chlorinated organic hydrocarbons, and other ancillary measures.

• The different tests indicated overlapping patterns or gradients in toxicity. The least sensitive test indicated severe toxicity (high mortality) in tests of sediments from the lower Miami River. Results from four different tests, overall, indicated highest toxicity in samples from the lower Miami River, Black Creek Canal, other canals adjoining the south bay, and canals and tributaries adjoining the bay near Miami and Miami Beach. Samples that were least toxic were collected from the far north and far south ends of the study area.

• Tests performed in 1995 on the reproductive success of a meiobenthic copepod showed significant results in all samples. Impaired reproductive success was most severe in tests of samples from the lower Miami River.

• P-450 RGS tests of the induction of CYP1A1 activity in 1996 indicated a clear pattern in which highest chemical concentrations occurred in sediments from peripheral tributaries and canals and background levels were observed elsewhere in the open basins of the bay. Induction was highly correlated with the presence of mixtures of organic substances, especially the PAHs and PCBs.

• Chemical analyses indicated the presence of complex mixtures of chemical substances in the most toxic samples. Overall, contamination was highest by a considerable amount in the lower Miami River, intermediate in Military Canal and several other tributaries and canals, and lowest in the open basin south of Rickenbacker Causeway.

• The spatial extent of toxicity was estimated by weighting the results of each test to the sizes of the sampling strata. The area in which highly significant toxicity occurred totalled 13% of the total area in the amphipod survival test - the least sensitive test; 47% of the area in urchin fertilization tests; 84% of the area in urchin embryo development tests; and 51% of the area in microbial bioluminescence tests

• The estimates of the spatial extent of toxicity measured in four tests in Biscayne Bay were similar to the "national average" estimates compiled from many other surveys previously conducted by NOAA, suggesting that Biscayne Bay sediments are not unusually toxic relative to sediments from other areas. These data also agreed well with observations made by the U. S. Environmental Protection Agency (EPA) of the surficial extent of toxicity in large estuarine provinces. In the Louisianian, Virginian, and Carolinian provinces, EPA estimated that 8.4%, 10%, and 2%, respectively, of these survey areas were toxic in tests of amphipod survival (Long et al., 1996).

• The surficial area in which chemical concentrations exceeded numerical guidelines was very small; ranging from 0.0% of the area for several substances to 1.3% for total PCBs. Of the 226 samples analyzed, 33 (14.6%) had at least one chemical concentration that exceeded a mid-range, numerical guideline. These 33 samples represented about 3.5 km^2 (0.7% of the total). Both the percentages of samples that exceeded numerical guidelines and the surficial extent of contamination as compared to the guidelines were lower than observed elsewhere in comparable studies performed nationwide.

• Statistical analyses of the data indicated that complex mixtures of substances were associated with and possibly contributed to the toxicity observed in the tests. These mixtures consisted of several trace metals, ammonia, PAHs, PCBs, and other chlorinated substances. The chemical nature of the mixtures differed among regions of the study area. PCBs, DDT isomers, lead, mercury, and zinc were most often elevated in concentration above numerical guidelines. Several other classes of substances (notably the hexachlorocyclohexanes - HCHs) for which there are no widely-applicable numerical guidelines were significantly associated with some measures of toxicity. Several trace metals occurred in concentrations in excess of those expected from reference sediments.

• The causes of toxicity could not be determined in this study and determinations of causality were not among the objectives. However, the weight of evidence strongly suggests that in the lower Miami River, toxicity as measured in the amphipod survival tests could have been caused, at least in part, by mixtures of PAHs, PCBs, chlordane pesticides, lead, and HCHs. In the canals of the south bay, both toxicity and contamination were less severe and the identities of chemicals that most probably contributed to toxicity were less clear. Concentrations of PAHs, PCBs, and several trace metals, however, may have been sufficient to contribute to toxicity in the sensitive sublethal urchin tests. Throughout the entire area, ammonia appeared to be a major contributor to toxicity observed in the urchin embryological development tests, but not to the other tests.

• A section of the southern Biscayne Bay showed remarkably high toxicity that could not be explained with the chemical data. Results of many of the toxicity tests were highly significant in the samples from this section of the bay, yet they were surrounded by many stations

in which there was little or no toxicity. Concentrations of chemicals for which analyses were performed were uniformly low, usually near or below detection limits. Therefore, the data suggest that chemical substances other than those for which analyses were performed likely caused or contributed to the toxic conditions in these samples.

• In previous studies performed elsewhere in the U. S., significant toxicity observed in laboratory tests has been associated with and statistically linked to measures of degraded resident benthic communities. Often high percent mortalities in acute tests are accompanied by loss of sensitive species in the resident infauna. The ecological significance of the toxicity observed in the Biscayne Bay survey will be estimated after the benthic community analyses are completed.

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The National Marine Fisheries Service laboratory in Charleston, SC performed the Microtox tests on all samples (Dr. Geoffrey Scott, P.I.). The U. S. Geological Survey laboratory in Corpus Christi, TX performed the sea urchin tests (Dr. R. Scott Carr, P.I.). The Geochemical and Environmental Research Group (GERG) of the University of Texas A & M conducted the chemical analyses (Drs. Terry Wade and Bobby Presley, P.I.'s). Science Applications International Corporation in Narragansett, RI (Dr. K. John Scott, P.I.) and TRAC Laboratories, Inc. in Pensacola, FL (Ms. Geri Brecken-Fols, P.I.) completed the amphipod survival tests. Columbia Analytical Services, Inc. in Carlsbad, CA. performed the cytochrome P-450 RGS assays (Dr. Jack Anderson, P.I.). The University of South Carolina conducted the copepod life cycle tests (Dr. G. Thomas Chandler, P.I.).

EVS Environment Consultants, LTD. in Seattle, WA provided assistance in data base management and graphics (Ms. Corinne Severn, P.I.). Mari Nord (NOAA) reviewed a draft version of this report and provided helpful comments and Kevin McMahon (NOAA) formatted and prepared the final camera-ready version of the manuscript.

Appendix A. 1995 field notes.

Zone	Strata	Sample	Station	Station Location	Date	Time	Latitude	Longitude
#	#	#	#					
2	1	1	1,1	North Miami Bay	3/29/95	12:50	25° 54.820 N	80° 08.069 W
2	1	2	2,1	North Miami Bay	4/4/95	9:40	25° 54.593 N	80° 08.162 W
2	1	3	3,3	North Miami Bay	4/4/95	10:45	25° 54.411 N	80° 08.062 W
2	2	4	1,1	North Miami Bay	4/4/95	11:25	25° 55.231 N	80° 07.617 W
2	2	5	2,1	North Miami Bay	4/4/95	12:05	25° 54.245 N	80° 07.564 W
2	2	6	3,1	North Miami Bay	4/4/95	13:12	25° 54.398 N	80° 07.593 W
2	3	7	1,1		4/4/95	14:55	25° 53.443 N	80° 08.871 W
2	3	8	2,1		4/4/95	14:15	25° 54.144 N	80° 08.272 W
2	3	9	3,1		4/4/95	13:45	25° 54.189 N	80° 07.938 W
6	1	10	1,1	Inside of Bayside-behind Hard Rock Cafe	3/31/95	9:45	25° 46.760 N	80° 11.110 W
6	1	11	2,1	Inside Channel	3/31/95	10:25	25° 46.407 N	80° 10.914 W
6	1	12	3,1	West of Dodge Island	3/31/95	11:30	25° 46.472 N	80° 10.936 W
6	4	19	1,2		4/6/95	9:25	25° 46.064 N	80° 08.336 W
6	4	20	2,1		4/6/95	9:55	25° 46.316 N	80° 08.572 W
6	4	21	3,3	Just off Coast Guard Station	4/8/95	10:05	25° 46.179 N	80° 08.588 W
6	8	31	1,1		4/5/95	9:15	25° 45.645 N	80° 11.163 W
6	8	32	2,1		4/5/95	10:15	25° 46.235 N	80° 10.990 W
6	8	33	3,1		4/5/95	9:45	25° 45.749 N	80° 11.222 W
6	9	34	1,1		4/5/95	11:00	25° 46.180 N	80° 10.780 W
6	9	35	2,1		4/5/95	12:05	25° 46.010 N	80° 10.643 W
6	9	36	3,1		4/5/95	11:35	25° 46.166 N	80° 10.433 W
6	10	37	1,1	North of Virginia Key	4/3/95	9:45	25° 45.307 N	80° 10.268 W
6	10	38	2,2	South of Dodge Island	4/3/95	10:55	25° 45.814 N	80° 09.963 W
6	10	39	3,1	South of Dodge Island	4/3/95	11:20	25° 45.908 N	80° 10.046 W
6	11	40	1,1	North of Rickenbacker Causeway	4/1/95	9:20	25° 45.184 N	80° 11.400 W
6	11	41	2,1	North of Rickenbacker Causeway	4/1/95	9:45	25° 44.957 N	80° 11.826 W
6	11	42	3,1	North of Rickenbacker Causeway	4/1/95	10:30	25° 45.045 N	80° 11.313 W
6	12	43	1,1	East of Intercoastal Waterway;in front of stadiu	4/1/95	11:30	25° 44.654 N	80° 10.005 W
6	12	44	2,1	North of Rickenbacker Causeway	4/3/95	9:06	25° 45.010 N	80° 10.643 W

Zone	Strata	Sample	Station	Station Location	Date	Time	Latitude	Longitude
#	#	#	#					
6	12	45	3,1	East of Intercoastal Waterway	4/1/95	12:00	25° 45.117 N	80° 10.506 W
6	13	46	1,1	Miami River	3/30/95	11:55	25° 46.489 N	80° 12.144 W
6	13	47	2,1	Miami River	3/30/95	11:00	25° 46.268 N	80° 11.976 W
6	13	48	3,1	Miami River	3/30/95	9:35	25° 46.219 N	80° 11.507 W
6	14	49	1,1	Miami River	4/3/95	12:20	25° 46.267 N	80° 12.249 W
6	14	50	2,1	Miami River	4/3/95	13:05	25° 46.801 N	80° 12.644 W
6	14	51	3,1	Miami River	4/3/95	13:30	25° 46.938 N	80° 12.848 W
6	15	52	1,1	Miami River	4/9/95	15:25	25° 47.048 N	80° 13.144 W
6	15	53	2,1	Miami River	4/9/95	2:40	25° 47.229 N	80° 13.687 W
6	15	54	3,1	Miami River; outside of Florida Yacht Club	4/8/95	17:50	25° 47.419 N	80° 14.164 W
6	16	55	1,1	Miami River	4/8/95	17:05	25° 47.727 N	80° 14.690 W
6	16	56	2,2	Miami River	4/8/95	16:30	25° 47.938 N	80° 14.917 W
6	16	57	3,1	Miami River	4/8/95	15:40	25° 48.084 N	80° 15.106 W
6	17	58	1,1	Miami River by Railroad tracks	4/8/95	12:20	25° 48.324 N	80° 15.437 W
6	17	59	2,1	Miami River	4/8/95	14:10	25° 48.130 N	80° 15.182 W
6	17	60	3,1	Miami River by Railroad tracks	4/8/95	13:25	25° 48.334 N	80° 15.490 W
6	18	61	1,1		4/9/95	16:00	25° 47.036 N	80° 12.571 W
6	18	62	2,1		4/9/95	16:25	25° 46.919 N	80° 12.476 W
6	18	63	3,1		4/9/95	16:50	25° 46.769 N	80° 12.420 W
6	19	64	1,1	Tamiani Canal	4/9/95	12:50	25° 47.703 N	80° 14.754 W
6	19	65	2,1	Tamiani Canal	4/9/95	12:10	25° 47.669 N	80° 15.253 W
6	19	66	3,1	Tamiani Canal	4/9/95	11:30	25° 47.633 N	80° 15.678 W

Depth meters	Surface Temp. °C	Btm Temp. °C	Surface Salinity ppt	Bottom Salinity ppt	Surface D.O. mg/L	Btm. D.O. mg/L	Surface Conductivity micro moles	Bottom Conductivity micro moles
4.30	26.15	24.8	36.8	37.8	6.02	5.67	55,600	56,600
5.50	25.0	25.0	29.0	31.0	6.20	5.10	49,000	50000+ (off scale)
5.50	25.0	24.0	30.0	30.5	6.10	5.90	50,000	50000+ (off scale)
2.50	25.0	25.0	29.0	30.0	5.80	5.70	49,000	50000+ (off scale)
4.00	25.0	25.0	31.0	31.0	5.80	5.80	50000+ (off scale)	50000+ (off scale)
3.75	25.0	25.0	30.5	31.0	5.50	5.50	50000+ (off scale)	50000+ (off scale)
2.50	25.0	25.0	29.9	30.5	5.50	5.60	49,500	50000+ (off scale)
5.00	25.0	25.0	30.5	31.0	5.40	5.50	50000+ (off scale)	50000+ (off scale)
4.00	25.0	25.0	30.0	31.0	5.40	5.30	50,000	50000+ (off scale)
4.50	26.5	26.0	32.0	33.5	5.20	5.50	49,900	50000+ (off scale)
4.00	26.5	26.0	31.5	33.0	5.70	5.60	49,200	50000+ (off scale)
1.20	26.5	26.5	31.0	31.5	5.50	5.50	48,700	49,100
3.50	25.0	25.0	33.0	33.0	5.60	5.40	49,900	49,900
4.50	25.0	25.0	33.0	33.0	5.90	5.70	49,900	50,000
4.50	25.0	25.0	31.50	33.00	6.00	5.80	49,000	50000+ (off scale)
2.40	24.0	24.5	32.0	32.2	7.10	6.60	48,300	48,300
6.00	25.0	24.5	31.2	32.0	6.30	6.10	47,900	48,500
2.00	24.5	24.5	32.0	31.8	7.20	6.80	48,100	48,100
2.50	25.9	24.0	32.0	31.9	6.00	5.70	49,000	49,000
2.25	24.5	25.0	33.0	32.5	6.30	6.00	49,900	49,900
2.25	25.0	24.0	32.0	32.0	6.60	5.90	49,000	49,000
3.00	24.0	24.0	31.0	29.5	7.20	7.20	49,050	49,050
2.50	25.0	24.0	31.0	31.0	7.35	7.50	50000+ (off scale)	50000+ (off scale)
3.00	24.9	25.0	31.5	31.5	6.30	6.30	50000+ (off scale)	50000+ (off scale)
2.80	26.5	26.5	31.5	31.5	5.60	5.60	49,000	49,200
5.00	27.0	26.5	31.5	32.0	5.10	5.30	49,100	49,800
2.40	27.0	27.0	31.0	31.0	5.70	5.70	49,500	49,400
2.80	27.0	27.0	32.1	32.2	5.20	5.00	50000+ (off scale)	50000+ (off scale)
3.00	24.0	24.0	31.0	31.0	7.30	7.20	49,000	49,000

Depth meters	Surface Temp. °C	Btm Temp. °C	Surface Salinity ppt	Bottom Salinity ppt	Surface D.O. mg/L	Btm. D.O. mg/L	Surface Conductivity micro moles	Bottom Conductivity micro moles
3.30	27.0	26.5	31.5	32.1	5.85	5.65	49,900	50000+ (off scale)
5.20	26.5	26.0	9.5	24.0	4.40	4.90	15,900	38,900
3.70	26.0	26.0	12.0	22.0	4.40	5.20	21,000	37,000
5.30	26.0	26.0	14.0	31.5	5.10	6.00	24,100	49,000
4.00	25.5	25.0	7.5	29.0	4.20	5.30	14,000	49,000
4.00	26.0	26.0	5.5	29.0	4.70	5.00	10,050	49,000
4.50	26.0	26.0	5.0	29.0	5.10	5.20	9,500	49,000
3.00	26.5	26.0	1.00	3.50	4.50	4.70	2,000	6,000
3.50	26.0	25.0	0.0	3.0	4.00	2.40	1,000	6,000
2.25	25.0	25.0	0.20	0.20	4.50	4.50	1,000	1,100
5.25	25.0	25.0	0.10	9.50	2.70	1.50	500	16,500
4.75	26.0	26.0	0.00	3.80	2.50	1.00	0.0	7,000
4.50	26.0	26.0	0.00	2.50	2.70	1.10	250	5,000
3.50	25.0	25.0	0.0	0.0	2.70	2.50	500	500
4.00	26.5	26.0	0.00	0.50	2.60	2.00	820	1,450
4.50	25.0	25.0	0.00	0.00	2.65	2.60	250	250
2.25	27.0	26.0	1.50	3.00	5.20	5.00	2,000	5,000
2.00	27.0	26.0	2.30	3.30	6.00	3.70	4,510	6,000
1.90	27.0	26.0	1.50	3.50	3.20	3.80	3,200	5,800
2.50	25.0	25.0	0.00	0.00	5.40	5.40	0.0	0.0
6.00	25.0	25.0	0.0	0.0	5.80	5.50	0.0	0.0
2.50	25.0	25.0	0.00	0.00	6.00	5.90	550	550

Field notes from Leg 1 - Biscayne Ba

Biscayne Bay

Sample #	Zone #	Strata #	Station #
1	2	1	1,1
2	2	1	2,1
3	2	1	3,3
4	2	2	1,1
5	2	2	2,1
6	2	2	3,1
7	2	3	1,1
8	2	3	2,1
9	2	3	3,1
10	6	1	1,1
11	6	1	2,1
12	6	1	3,1
19	6	4	1,2
21	6	4	3,3
20	6	4	2,1
21	2	1	1,3
31	6	8	1,1
32	6	8	2,1
33	6	8	3,1
34	6	9	1,1
35	6	9	2,1
36	6	9	3,1
37	6	10	1,1
38	6	10	2,2
39	6	10	3,1
40	6	11	1,1
41	6	11	2,1
42	6	11	3,1

Sample	Zone	Strata	Station
#	#	#	#
43	6	12	1,1
44	6	12	2,1
45	6	12	3,1
46	6	13	1,1
47	6	13	2,1
48	6	13	3,1
49	6	14	1,1
50	6	14	2,1
51	6	14	3,1
52	6	15	1,1
53	6	15	2,1
54	6	15	3,1
55	6	16	1,1
56	6	16	2,2
57	6	16	3,1
58	6	17	1,1
59	6	17	2,1
60	6	17	3,1
61	6	18	1,1
62	6	18	2,1
63	6	18	3,1
64	6	19	1,1
65	6	19	2,1
66	6	19	3,1

Biscayne Bay

Sediment Description	Sample #	Zone #	Strata #
Lt. Brwn silt - large. invert tubes; slight sulfurous odor pine needles; population of diatoms; baby fish	13	6	2
Lt. brwn soft silty clay; no noticeable sulfites	14	6	2
Flecks on top of lt. brwn and gold soft silty clay, no sand; organic matter; clam tubes and clam holes	15	6	2
Drk. brwn muddy sand w/shell hash, algae on top - lots of algae; a live Gastropod!!!	16	6	3
Muddy lt. brwn sand with darker sand below; clam tubes	17	6	20
Lt. brwn sandy mud over gray sandy mud w/black shell hash; a little crab; polychaete	18	6	20
Drk. brwn sandy clay over gray sandy clay; sea grass; shell debris; plant and animal organisms	22	6	5
Lt. brwn silty clay w/ tiny amounts of sand; algae on surface; soft clam tubes	23	6	5
Lt. tan fine sandy mud; polychaete; G-3 Soft sand w/some lt. brn mud; G-4 grass on surface of grab	24	6	5
Lt. brwn on top with dark grey-black below; silty clay; gooey and sticky; very consistent	25	6	R6
Lt. brwn soft silty clay w/small amount of sand; diatoms on top; a fish, shrimp and other crustaceans	26	6	R6
Top 1cm lt. brn. w/lt. gray below; fine sandy mud, shell hash, algae, sea grass, manatee grass, mysids,	27	6	R6
and thallasia; G-3 Sandy no grass, huge shrimp	28	6	7
Top 1cm lt. brown with lt. gray below; some muddy, fine sand with shell hash, polychaetes, diatoms, mysids,	29	6	7
shrimp, sea grass, and baby fish	30	6	7
Top 1cm lt. brn then gray; slightly muddy sand; shell debris, diatom scum,polycheate, sea grass,amphipod, clam	67	8	1
Top 2cm brown sand then gray silty/clay sand; shell hash, amphipods, worm tubes; G-3 All brown sand no clay	68	8	1
Top 1cm drk. brown then dark gray below; sandy mud, shell debris, green plants, sponges	69	8	1
Lt. brwn w/ lt. gray below; mix of mud, sand, gravel, shell debris; chunky; amphipods	70	8	2
Top 1cm drk. brn w/drk gray below; sandy mud, leafy gr. plants, fine shell debris; polychaetes, lt. blue sponge	71	8	2
Top 1cm lt. brown over gray; muddy, silty, sand; clam tubes, amphipods, blue sponge, polychaete, gastropod	72	8	2
Lt. brown over lt. gray muddy sand, fine shell hash: G-3 Jelly fish	73	8	3
2 cm of light brown sandy mud over light gray sandy mud; phalaciea, sea grass and other plants, shell hash	74	8	3
Soft fine light brown muddy sand, algae on surface, sea grass, shell hash, live shell, polychaete and hydroids	75	8	3
Light brown, soft, fine, muddy sand, shell hash, dead gastropod shell	76	8	4
Top 1cm lt. brn over lt. gray, fine to coarse, muddy sand, shell debris, shrimp, fish, sea grass, G-4 was sandier	77	8	4
Top 1cm lt. brn over lt. gray, slight sandy mud some clay, lt. shell debris, sea grass, amphipods, soupy sea grass plates	78	8	4
Top 0.5cm lt. brwn over lt. gray, runny silty clay, strong sulfur smell, one fish	79	8	5
Lt. brn sandy silt w/lighter brown-gray below, fine shell hash, diatoms on surface, living sponge, red algae, flat worm	80	8	5

Sediment Description	Sample	Zone	Strata
	#	#	#
Carbonate, no RPD, no layering, lt. brown, consistent in color, slight fine sandy clay, runny-gooey, sea grasses	81	8	5
Lt brown sandy silty muddy shell hash, sea grasses	82	8	6
Lt. brwn sand, a lot of shell hash, G-3 Top 1 to 2cm Lt brwn over lt gray, muddy fine, med, & coarse sand, a worm tube	83	8	6
Brwn-gray slight sandy clay, gooey, blue paint chips, paper, slight oil sheen, G-2 lt. brwn sandy mud	84	8	6
Brown silty, petro sheen, tar ball, larval fish, crab, rock, sulfur smell, G-8 was sandier	85	8	7
Lt. brn-gray sandy mud/clay; no odor; G-2 petro sheen; a lot of debris; G-3 sandy shell hash; 1cm of	86	8	7
lt.brwn w/black below; sulfur and petro smell; G-4 gooey clay; very patchy area	87	8	7
Dark brown soft sandy silt, worm tubes, petro sheen, plant debris, rocks	88	8	8
Top 1 cm chocolate brown over dark gray, sandy clay, shrimp, mysids, petroleum sheen	89	8	8
Dark brown over dark gray, dead plant debris, tar ball, petroleum sheen, petroleum odor after homogenized	90	8	8
Top 1 cm light brown over dark gray, sandy silt, oil sheen, tar ball	91	8	9
Dark chocolate brown over black, sandy clay, petroleum odor, bivalves, petroleum sheen, shell debris	92	8	14
Olivine green over gray, slimy, oil blobs, worm or leech?, rocks, organic debris throughout	93	8	9
Light brown on top of dark gray, petroleum sheen	94	8	10
Thin layer of lt brn fine sand over drk gray sandy clay, sticky, creosote odor, limestone, shell hash, petro odor	95	8	10
Dark brown, sandy mud some clay, slick oily sheen, slight petroleum odor	96	8	10
Dark chocolate brown sandy silt, organic debris, petroleum sheen, sticks-twigs	97	8	11
Lt brn muddy fine sand;G-3 Drk brn muddy fine sand, petro sheen/blobs;G-7 drk choc. brn mud w/lt tan sand, petro odor	98	8	11
Top 2cm drk brn over gravel and rocks,sandy ,peaty clay,petro sheen and smell, lots of organics, some shell hash, rocks	99	8	11
Black runny mayo-like, organic matter, hydrogen sulfide odor, algae, polychaete	100	8	10
Black runny silty goo, sulfurous smell, black glop of petroleum, petroleum sheen, organic matter	101	8	12
Runny black mayo, sulfur smell, organic matter, garbage;G-3 some clay, A LOT of oil, black muddy, gooey sticky mass	102	8	12
Drk brn,muddy,sandy,silty,shell debris;G-2 Drk brn muddy sand fine & coarse,algae mat on surface of grab;G-5 sm. fish	103	8	13
100% blk plant debris,ceosote odor; G-2 sandier, drk brn silt, creosote, plant debris, soft runny; G-4 silty, petro sheen	104	8	13
Dark gray sandy mud, organic matter, aquatic plants; G-4 petroleum sheen; G-5 med-coarse brown sand with shell debris, algae mat on top of sediment in grab	105	8	13

/ne Bay

Station #	Station Location	Date	Time	Latitude	Longitude	Depth meters	Surface Temp. °C
1,3	West of Port of Miami	4/21/95	11:30	25° 46.928 N	80° 10.668 W	11.0	25.0
2,1	West of Port of Miami	4/21/95	12:45	25° 46.696 N	80° 10.218 W	11.0	27.0
3,1	West of Port of Miami	4/21/95	13:30	25° 46.629 N	80° 09.973 W	11.0	26.5
1,1	South of Mc Arthur Causeway	4/23/95	11:30	25° 46.445 N	80° 09.435 W	10.5	27.0
1,2	South East of Claughton Island	4/24/95	11:10	25° 45.712 N	80° 10.558 W	1.4	28.0
2,1	North of Rickenbacker Causeway	4/24/95	11:45	25° 45.201 N	80° 10.270 W		28.5
1,1	South of Port of Miami	4/22/95	15:25	25° 46.159 N	80° 10.077 W	8.0	27.0
2,4		4/22/95	16:50	25° 45.959 N	80° 09.931 W	8.4	27.5
3,2	East side of Dodge Island	4/23/95	10:25	25° 46.353 N	80° 10.745 W	8.4	27.0
1,3		4/23/95	14:30	25° 45.813 N	80° 09.537 W	2.9	28.0
1,8		4/23/95	15:55	25° 45.403 N	80° 09.376 W	1.2	28.0
3,12	South of Port of Miami, North of Marine Stadium	4/24/95	13:10	25° 45.166 N	80° 10.086 W	1.5	27.5
1,1	East side of Norris Cut	4/22/95	11:40	25° 45.110 N	80° 08.690 W	2.0	27.0
2,1	Norris Cut	4/22/95	12:10	25° 45.450 N	80° 08.710 W	2.7	27.0
3,1	East side of Norris Cut	4/22/95	13:35	25° 45.536 N	80° 08.853 W	4.6	27.0
1,1	Mid/South Biscayne Bay	4/26/95	11:10	25° 32.587 N	80° 12.719 W	3.0	27.0
2,1	East of Black Point	4/26/95	12:50	25° 32.472 N	80° 16.026 W	2.5	26.5
3,2	West of Bocco Chica Key	4/23/95	14:55	25° 31.629 N	80° 12.118 W	2.5	27.0
1,1	East of Black Point, North of Goulds Canal	4/26/95	16:15	25° 32.047 N	80° 18.192 W	1.4	27.0
2,1	East of Black Point, North of Goulds Canal	4/27/95	9:45	25° 31.817 N	80° 17.787 W	2.0	27.0
3,1	South of Goulds Canal and Black Point	4/27/95	11:37	25° 31.401 N	80° 19.149 W	1.0	28.0
1,1	South of Black Point	4/27/95	12:00	25° 30.955 N	80° 17.690 W	2.0	26.5
2,1	East of Fender Point	4/27/95	13:12	25° 30.183 N	80° 17.659 W	1.5	28.0
3,1	North East of Fender Point, South of Goulds Canal	4/27/95	14:00	25° 30.944 N	80° 18.599 W	1.5	27.5
1,1	South of Fender Point	4/29/95	9:40	25° 28.886 N	80° 19.707 W	1.5	26.0
2,1		4/27/95	15:10	25° 28.871 N	80° 18.190 W	1.6	27.5
3,1	Between Black Point and Turkey Point	4/29/95	10:25	25° 28.885 N	80° 17.331 W	2.3	26.5
1,1	Entrance from bay to North Canal	4/29/95	11:10	25° 27.719 N	80° 19.389 W	2.0	26.5
2,1	North East of Convoy Point	4/29/95	11:55	25° 28.255 N	80° 18.724 W	1.8	26.1

Station #	Station Location	Date	Time	Latitude	Longitude	Depth meters	Surface Temp. °C
3,1	North East of Convoy Point	4/29/95	12:50	25° 28.568 N	80° 18.386 W	2.0	26.0
1,1	South of channel entrance to Turkey Point	4/29/95	13:26	25° 27.275 N	80° 17.901 W	2.0	26.5
2,1	South of channel entrance to Turkey Point	4/29/95	14:00	25° 26.772 N	80° 18.132 W	1.7	26.5
3,1		4/29/95	14:35	25° 27.144 N	80° 19.035 W	1.5	26.2
1,1	South East of Turkey Point	4/30/95	15:35	25° 26.006 N	80° 18.753 W	1.5	26.5
2,1	South East of Turkey Point	4/29/95	15:30	25° 25.346 N	80° 17.534 W	1.6	27.0
3,1	East of Turkey Point	4/29/95	16:00	25° 26.086 N	80° 18.184 W	1.6	27.0
1,1	Southern Biscayne Bay	5/2/95	13:15	25° 28.844 N	80° 12.426 W	3.3	27.5
2,1	West of Elliot Key, Mid/South Bay	4/30/95	16:45	25° 28.399 N	80° 14.890 W	2.6	26.5
3,1	Between Turkey Point and Elliot Key	5/2/95	12:15	25° 25.974 N	80° 16.857 W	2.35	27.5
1,1	East of entrance to Princeton Canal	5/2/95	11:20	25° 31.154 N	80° 19.121 W	1.1	27.5
1,1	Goulds Canal	5/2/95	10:25	25° 32.229 N	80° 19.860 W	2.0	27.0
3,1	Off mouth of Princeton Canal	5/1/95	16:40	25° 31.148 N	80° 19.146 W	0.9	29.0
1,1	Princeton Canal	5/1/95	14:40	25° 31.155 N	80° 20.134 W	2.5	26.5
2,1	Princeton Canal	5/1/95	13:20	25° 31.150 N	80° 20.530 W	4.3	26.5
3,1	Princeton Canal, East of flood control gate	5/1/95	11:30	25° 31.165 N	80° 20.668 W	3.9	26.5
1,1	Goulds canal entrance	4/30/95	13:50	25° 31.785 N	80° 18.813 W		
2,1	In channel to Goulds canal	4/30/95	12:20	25° 31.846 N	80° 18.958 W	3.6	25.5
3,1	Goulds canal entrance	4/30/95	14:30	25° 31.754 N	80° 18.717 W		
3,1	South side of entrance to Goulds canal	4/30/95	11:20	25° 31.949 N	80° 19.193 W	3.0	25.5
2,1	Goulds canal entrance	4/30/95	10:35	25° 32.054 N	80° 19.441 W	3.4	26.5
3,1	Goulds canal entrance	4/28/95	12:27	25° 32.025 N	80° 19.392 W	4.0	27.0
1,1	Black Creek Canal	4/28/95	11:45	25° 32.112 N	80° 19.498 W	4.0	27.1
2,1	Black Creek Canal	4/28/95	11:10	25° 32.279 N	80° 19.611 W	4.5	27.5
3,1	Black Creek Canal	4/28/95	10:10	25° 32.412 N	80° 19.724 W	4.0	27.5

Field notes from Leg 1 - B

Biscayne Bay

Bottom Temperature ºC	Surface Salinity ppt	Bottom Salinity ppt	Surface D.O. mg/L	Btm. D.O. mg/L	Surface Conductivity micro moles	Bottom Conductivity micro moles	Sample #	Zone #	Strata #
26.0	26.0	28.5	5.80	5.70	42,200	45,900	13	6	2
26.0	27.5	28.0	6.00	5.70	44,800	45,100	14	6	2
27.0	29.0	29.8	5.90	5.80	46,200	47,500	15	6	2
27.0	29.0	31.0	6.00	5.70	46,000	48,770	16	6	3
28.0	27.5	27.5	7.20	7.20	47,000	47,000	17	6	20
27.5	29.0	29.0	6.40	6.20	48,000	48,000	18	6	20
27.5	29.5	30.5	5.80	5.80	47,200	48,600	22	6	5
27.0	31.5	32.0	6.50	6.10	50,000	50,000+ off scale	23	6	5
27.0	28.0	31.0	6.00	5.80	45,000	49,100	24	6	5
28.0	31.0	31.0	7.30	7.10	49,000	49,100	25	6	R6
28.0	32.0	32.0	6.70	6.70	50,000+ off scale	50,000+ off scale	26	6	R6
27.5	30.0	30.0	6.20	6.20	48,600	48,600	27	6	R6
27.0	29.0	30.5	6.00	7.20	46,500	48,900	28	6	7
27.0	30.5	30.5	6.20	6.20	48,900	48,900	29	6	7
27.0	31.5	32.0	6.90	6.40	49,900	50,000+ off scale	30	6	7
27.0	31.5	32.0	6.10	5.80	50,000+ off scale	50,000+ off scale	67	8	1
27.0	32.0	32.5	5.90	5.70	50,000+ off scale	50,000+ off scale	68	8	1
27.0	33.1	33.3	5.60	5.40	50,000+ off scale	50,000+ off scale	69	8	1
27.0	28.0	28.0	5.50	5.20	45,100	45,100	70	8	2
27.0	29.2	29.5	4.50	5.20	47,500	48,000	71	8	2
27.5	25.5	25.5	4.40	4.80	42,200	42,200	72	8	2
27.5	31.0	31.0	5.10	5.00	49,600	49,600			
28.0	30.8	30.8	5.30	5.40	49,800	49,800	73	8	3
28.5	30.0	30.0	6.35	6.50	48,900	49,000	74	8	3
26.5	28.0	28.0	4.40	4.00	44,500	45,000	75	8	3
28.0	31.2	31.4	5.50	5.30	50,000+ off scale	50,000+ off scale	76	8	4
26.0	29.0	29.0	5.80	5.40	46,500	46,500	77	8	4
26.0	22.0	29.0	5.20	5.40	34,900	46,000	78	8	4
26.0	29.1	29.2	5.10	5.25	47,000	47,000	79	8	5

Bottom Temperature °C	Surface Salinity ppt	Bottom Salinity ppt	Surface D.O. mg/L	Btm. D.O. mg/L	Surface Conductivity micro moles	Bottom Conductivity micro moles	Sample #	Zone #	Strata #
26.0	30.0	30.0	5.20	5.10	47,400	47,500	80	8	5
26.5	29.8	29.8	5.60	5.80	47,200	47,200	81	8	5
26.5	29.1	29.1	5.60	5.60	46,500	46,800	82	8	6
26.1	29.3	29.3	6.50	6.60	46,800	46,900	83	8	6
26.5	29.9	29.9	6.70	6.40	47,000	47,000	84	8	6
26.5	29.5	29.5	6.10	5.70	47,500	47,500	85	8	7
27.0	29.1	29.1	6.20	6.20	47,900	47,000	86	8	7
27.5	31.5	31.5	6.60	6.60	50,000+ off scale	50,000+ off scale	87	8	7
26.5	31.0	31.0	6.60	6.50	48,800	48,900	88	8	8
27.5	30.1	30.1	6.80	6.70	48,500	48,800	89	8	8
27.5	23.9	24.1	7.60	7.70	39,300	40,000	90	8	8
27.5	8.0	15.0	5.70	1.30	19,600	25,900	91	8	9
29.6	24.1	23.7	12.80	12.90	41,100	41,100	92	8	14
27.0	2.2	18.2	5.60	6.10	4,100	30,900	93	8	9
27.0	6.5	19.1	5.40	5.20	9,900	31,800	94	8	10
26.5	3.2	18.4	4.60	5.10	5,700	30,400	95	8	10
							96	8	10
26.0	21.9	22.1	5.60	5.70	35,200	35,900	97	8	11
							98	8	11
25.5	21.5	21.5	5.40	4.80	34,800	34,900	99	8	11
25.5	12.1	21.9	4.60	4.30	18,500	35,100			
26.5	12.2	24.3	5.60	3.40	22,000	40,000	100	8	10
26.5	11.9	24.2	5.80	2.80	20,300	39,700			
27.5	11.6	24.5	5.90	1.90	20,000	40,800	101	8	12
27.5	10.7	23.5	6.10	3.10	19,100	39,200			
							102	8	12
							103	8	13
							104	8	13
							105	8	13

Biscayne Bay

Station #	Sediment Description
1,3	Top 2 cm. sticky, light brown, sandy clay over gray sandy clay; diatom scum on top, very consistent sediment
2,1	Top 2 cm. light brown fine sandy clay over light gray; sulfur odor, amphipod tubes
3,1	Top 3 cm. light brown, fine, sandy clay over dark gray sandy clay; G-2: rocks, gravel, sandy clay
1,1	Light brown coarse sandy mud, sponges, shrimp, limestone rocks, baby fish, amphipod tubes
1,2	Top 2 cm. light brown sandy, silty, clay over dark gray; sea grasses, shrimp, polychaete
2,1	Top 1 cm. light brown sandy mud over light gray, diatom scum, sea grasses G-5: slightly muddy sand
1,1	Top 1 cm. light brown soft sticky silty clay over dark gray; sulfur odor, amphipods
2,4	Light brown muddy sand, shell debris, gravel rocks
3,2	Lt. brown sandy, sticky, clay with limestone rocks, gravel, shrimp;G-3: sticky mud, brown clay, sulfur odor
1,3	Light brown, muddy coarse sand, gravel, epifauna, shell hash, hard shell, gravel, crab
1,8	Light brown slightly fine sandy silty clay, sea grasses, hydro sulfide smell
3,12	Light brown sticky sandy clay, shell hash, tube worms, amphipods, baby fish
1,1	Salt and pepper sand with a little mud, shell debris, gastropods
2,1	Black and white coarse sand, sea grass shell debris, amphipods, crabs, hermit crabs
3,1	Top 2 cm. light brown soft, sticky sandy clay over light gray; shell debris, mollusk shells, shrimp, turtle grass
1,1	Light cream colored soft sandy silt; shell hash, mollusk shells, sponges, vascular plants
2,1	Top 5 cm. lt. brown sand and shell debris over grey muddy fine sand; epifauna, algae vascular plants, bivalves
3,2	Light brown silty, fine to coarse sand, algae, sea grass, sponges, shell debris
1,1	Gray, sticky sandy clay, mollusk shells, sea grasses
2,1	Coarse black and gray sand with a bit of silt, infauna and epifauna, ASV
3,1	Brown to black, silty fine sand with shell hash, sea grass, acetabularia, bristle brush plants, lots of baby fish more algae than vascular plants, blue crabs
1,1	Light brown, silty fine to coarse sand, grass beds, crab burrows, algae, sponges
2,1	Black and tan slightly silty coarse sand, sponges, gorgonians, saw a lobster
3,1	Light brown layer of coarse sand and shell hash over slightly silty medium to coarse dark gray sand
1,1	Top 1cm lt brn coarse sand & shell hash over drk brn-gray muddy sand, amphipods, baby fish & crab,gastrpods,bivalves
2,1	Lt. brown layer of coarse sand & shell hash over slightly silty med to coarse dark gray sand, sponges, sea grass
3,1	Dark gray to black coarse sand, some silt, brown shell hash on top; worm holes, sponges, soft corals, sea grass
1,1	Shell hash with light brown silt, sea grass, sponges, rocks

Station #	Sediment Description
2,1	Thin light brown surface over dark gray, slightly silty coarse sand and shell hash
3,1	Thin light brown surface over dark gray, slightly silty coarse sand and shell hash
1,1	Thin light brown surface over drk gray, slightly silty coarse sand and shell hash, sponges, soft corals, sea grass
2,1	Thin light brown surface over drk gray, slightly silty coarse sand and shell hash, sponges, soft corals, sea grass
3,1	Thin light brown surface over drk gray, slightly silty coarse sand and shell hash, sponges, soft corals, sea grass
1,1	Top 2 cm. silty sand over rock; sponge, algae, tubillarid worms, blue crabs
2,1	Soft silty sand with some shell hash, tube worms, bivalves, plants, soft corals
3,1	Soft silty sand with some shell hash, tube worms, bivalves, plants, soft corals
1,1	White top layer w/gray below, soft fine sand, lt. gray, w/coarse sand & shell hash, SAV, plants, inverts, soft corals
2,1	Top 0.5 cm. carbonate, fine silty sand over fine, light gray, silty sand, shell hash
3,1	Very thin light brown carbonate silty sand layer over gray coarse to medium sand, shell hash
1,1	Fine to coarse brown silty sand, shell hash; blue crab, gastropods, red algae, SAV
1,1	Soft runny, olivine chocolate clayey silt, shell debris, sand, plant debris, oil sheen, hydrogen sulfide odor, oyster shells
3,1	Light gray coarse silty sand, shell hash, infaunal, epifauna
1,1	Top 1cm choc. brn fine silt on tan clay, thin veneer of brn silt over coarse limestone gravel, silt in pocket between rocks
2,1	Top 2-3cm choc. brn silty sand w/limestone gravel, shell debris, plant matter, hydrogen sulfide odor over, lt. brn clay
3,1	Light brown, silty, sandy, clay with gravel, faint sulfur odor
1,1	Soft silty olivine brown clay, plant debris, shell debris, strong sulfur odor
2,1	Sticky sandy light brown clay, under layer of shell hash; oyster shells, gastropods, hermit crabs, sulfur odor
3,1	G-1 gray, silty coarse sand, shell debris, plants;G-2 soft, silty mud w/shell hash, plants;G-3 silty fine lt brn sand, fine shell hash, dead sea grass blades; G-4 silty runny mud, plant debris; all have sulfur odor.
3,1	Olivine sandy silty clay organic debris; G-2 no sand, mat of vegetative debris on top, red algae, petro sheen, sulfur and petroleum hydrocarbons smell
2,1	G-2:Silty sand, gravel, shell hash, petro odor, amphipod, oyster shell; G-6: Olivine silty, fine, runny, clay, oil sheen strong sulfur odor, G-7: Brown diatom scum on surface
3,1	Muddy, coarse sand, gravel, lots of shell debris, rag, pipe
1,1	Dark brown, fine, sandy, silty mud, slight shell and plant debris, sulfur odor
2,1	Top 2-3 cm. olivine, soft runny silty clay, over sand, sulfur odor, petroleum sheen
3,1	Top 1-2 cm. dark brown, soft, olivine, silty clay over firm clay, sulfurous odor; G-3 muddy sand

Appendix B. Field notes from 1996 stations.

Zone #	Strata #	Sample #	Station #	Station Location	Date	Time	Latitude
8	1	106	1,2	NW of Ragged Keys	6/26/96	11:05	25° 33.065 N
8	8	107	1,2	W of Elliot Key	6/26/96	9:47	25° 26.699 N
1	1	108	1,1	NE of Maule Lake	6/21/96	10:05	25° 56.624 N
1	1	109	2,1	NE of Maule Lake	6/21/96	11:30	25° 57.020 N
1	1	110	3,1	E lobe of basin N Dade County	6/21/96	12:30	25° 56.702 N
1	2	111	1,1	NE corner Maule lake	6/21/96	13:42	25° 55.167 N
1	2	112	2,1	Maule lake	6/21/96	14:45	25° 56.280 N
1	2	113	3,2	Maule lake	6/21/96	15:32	25° 55.667 N
1	3	114	1,1	Oleta river	6/9/96	10:20	25° 55.710 N
1	3	115	2,1	Oleta river	6/9/96	12:40	25° 55.660 N
1	3	116	3,4	Upper Oleta River	6/9/96	13:50	25° 55.760 N
1	4	117	1,1	N of sunny isles bridge	6/28/96	10:15	25° 55.530 N
1	4	118	2,1	S of sunny isles bridge	6/28/96	10:55	25° 55.670 N
1	4	119	3,1	In ICW	6/28/96	11:25	25° 55.486 N
3	1	120	1,1		6/4/96	9:45	25° 52.488 N
3	1	121	2,1		6/4/96	10:05	25° 52.644 N
3	1	122	1,1		6/4/96	9:00	25° 52.790 N
3	2	123	1,1	Spoil Isles	6/4/96	11:05	25° 52.039 N
3	2	124	2,1	N of Spoil isles	6/4/96	12:05	25° 52.281 N
3	2	125	3,1		6/4/96	12:43	25° 52.205 N
3	3	126	1,1	Btwn Miami shores & beach	05/31/96	13:50	25° 51.619 N
3	3	127	2,1	W of Normandy Isle	6/2/96	2:40	25° 51.642 N
3	3	128	3,1	East of Miami shores	05/31/96	13:00	25° 50.999 N
3	4	129	1,1	Biscayne canal- E station	6/3/96	9:50	25° 52.322 N
3	4	130	2,1	Biscayne canal - mid channel	6/3/96	9:15	25° 52.274 N
4	1	131	1,1	Btwn North Bay & Treasure Isle	6/1/96	9:31	25° 50.612 N
4	1	132	2,1		6/1/96	10:40	25° 50.357 N
4	1	133	3,1	E of Bird island	6/1/96	10:00	25° 50.399 N
4	2	134	1,1	N of Miami city	6/2/96	10:25	25° 50.502 N
4	2	135	2,1	W of Miami beach	6/2/96	11:00	25° 50.140 N
4	2	136	3,1		6/2/96	9:30	25° 50.815 N
4	3	137	1,1	N of W sea wall of Julia Tuttle	6/1/96	2:25	25° 48.751 N
4	3	138	2,1	E of Spoil Isle	6/1/96	12:25	25° 49.077 N
4	3	139	3,1		6/1/96	1:30	25° 48.941 N
4	4	140	1,1	S of Surprise lake	6/2/96	12:05	25° 49.497 N
4	4	141	2,1		6/2/96	1:00	25° 49.237 N
4	4	142	3,1	W of Mt. Siria Medical Center	6/2/96	1:50	25° 49.153 N
4	5	143	1,1	Btwn Normandy & La Garce Isle	05/31/96	9:44	25° 51.111 N
4	5	144	2,1	East Bank	05/30/96	2:15	25° 50.384 N
4	5	145	3,1	North Miami	05/31/96	9:15	25° 51.038 N
4	6	146	1,4	Indian Creek	05/30/96	1:20	25° 49.537 N
4	6	147	2,1	Indian Creek	05/30/96	12:10	25° 48.826 N
4	6	148	3,1	Inidian Creek	05/30/96	10:55	25° 49.125 N
4	7	149	1,1	Little river	05/31/96	10:40	25° 50.786 N
4	7	150	2,1	Little river	05/31/96	11:56	25° 50.705 N
5	1	151	1,1	NW of Julia Tuttle Causewy	6/4/96	1:45	25° 48.503 N
5	1	152	2,1		6/4/96	2:25	25° 47.996 N
5	1	153	3,1	E of Channel & Spoil islands	6/6/96	9:25	25° 48.277 N
5	5	154	1,2		6/7/96	12:55	25° 48.289 N

5	2	155	2,2		6/7/96	12:20	25° 47.932 N
5	2	156	3,1	S of Julia Tuttle Causeway	6/7/96	10:50	25° 48.505 N
5	3	157	1,1		6/5/96	9:26	25° 48.254 N
5	3	158	2,1	Embayment of Canal system	6/5/96	10:25	25° 48.543 N
5	3	159	1,1	Near Sunset Isle	6/5/96	10:00	25° 48.486 N
5	4	160	1,1	Nea E Venetian Bridge	6/7/96	1:35	25° 47.545 N
5	4	161	2,1	W top of San Marco Isle	6/7/96	2:00	25° 47.503 N
5	4	162	3,2	N of Venetian Causeway w brid	6/7/96	2:46	25° 47.551 N
5	5	163	1,1		6/8/96	12:00	25° 47.790 N
5	5	164	2,1		6/8/96	1:05	25° 47.730 N
5	5	165	3,4	N of E Venetian bridge	6/8/96	1:47	25° 47.611 N
5	6	166	1,2		6/7/96	8:37	25° 47.049 N
5	6	167	2,1		6/7/96	8:45	25° 47.565 N
5	6	168	3,1	N of Port of Miami bridge	6/7/96	9:10	25° 46.888 N
5	7	169	1,1	N of MacArthur Causeway	6/8/96	9:47	25° 46.872 N
5	7	170	2,2	Btwn MacArthur & Venetian cau	6/8/96	10:30	25° 47.170 N
5	7	171	3,1	Btwn San Marino & Dilido Isles	6/8/96	11:02	25° 47.322 N
5	8	172	1,1	NE of Hibiscus Isle	6/5/96	1:30	25° 47.028 N
5	8	173	2,1		6/5/96	2:00	25° 46.687 N
5	8	174	3,1	W of Star Island	6/6/96	8:34	25° 46.896 N
5	9	175	1,1		6/5/96	11:15	25° 47.143 N
5	9	176	3,1	Mid basin	6/5/96	13:05	25° 46.713 N
5	9	177	2,1	Channel entrance	6/5/96	12:30	25° 46.824 N
5	10	178	1,1		6/6/96	10:30	25° 46.962 N
7	1	179	1,1	Central Biscayne bay	6/27/96	11:46	25° 42.890 N
7	1	180	2,3	Central Biscayne bay	6/27/96	12:55	25° 43.610 N
7	1	181	3,1	Central Biscayne bay	6/29/96	11:04	25° 42.661 N
7	2	182	1,1	Central Biscayne bay	6/29/96	12:23	25° 42.568 N
7	2	183	2,1	Central Biscayne bay	6/29/96	12:58	25° 41.835 N
7	2	184	3,1	W coast of Key Biscayne	6/29/96	14:00	25° 42.221 N
7	3	185	1,1	S Biscayne bay	6/22/96	13:48	25° 41.292 N
7	3	186	2,1	SE of Tahiti Beach	6/24/96	9:10	25° 41.444 N
7	3	187	3,1	E of Tahiti Beach	6/24/96	8:23	25° 40.878 N
7	4	188	1,1	E of Coral Bay	6/24/96	10:04	25° 36.359 N
7	4	189	3,1	NE of Snapper Creek	6/24/96	12:16	25° 38.858 N
7	4	190	2,1	NE of Shoal Pt.	6/24/96	11:13	25° 38.523 N
7	5	191	1,1	S Biscayne bay	6/22/96	10:48	25° 41.042 N
7	5	191	2,1	S Biscayne bay	6/22/96	11:30	25° 40.945 N
7	5	193	3,1	S Biscayne bay	6/22/96	12:35	25° 40.890 N
7	6	194	1,3	Biscayne Bay NE	6/30/96	16:33	25° 37.396 N
7	6	195	2,1	S Biscayne bay	6/29/96	15:45	25° 36.686 N
7	5	196	3,1	S Biscayne bay	6/29/96	17:15	25° 37.720 N
7	7	197	1,1	S Biscayne bay	6/26/96	14:25	25° 38.190 N
7	7	198	2,1	S Biscayne bay	6/26/96	12:20	25° 36.729 N
7	7	199	3,1	S Biscayne bay	6/26/96	13:31	25° 37.350 N
7	8	200	1,1	Coral gables canal	6/28/96	16:18	25° 42.293 N
7	8	201	2,1	Coral gables canal	6/28/96	15:34	25° 43.252 N
7	8	202	3,3	Coral gables canal	6/28/96	14:25	25° 44.132 N
7	9	203	1,1	Snapper Creek Canal	7/1/96	13:38	25° 40.093 N
7	9	204	2,1	Snapper Creek Canal	7/1/96	15:31	25° 39.651 N
7	9	205	3,1	Snapper Creek Canal	7/1/96	14:43	25° 39.746 N
8	15	206	1,1	Military Canal	6/30/96	14:55	25° 29.374 N
8	15	207	2,1	Military Canal	6/30/96	14:30	25° 29.370 N

8	15	208	3,1	Military Canal	6/30/96	13:33	25° 29.370 N
8	16	209	1,1	Mowry Canal	6/30/96	12:35	25° 28.226 N
8	16	210	2,1	N of Convoy point	6/30/96	10:35	25° 28.217 N
8	16	211	3,1	Mowry Canal	6/30/96	11:12	25° 28.217 N
8	17	212	1,1	North Canal	7/1/96	10:30	25° 27.786 N
8	17	213	2,1	North Canal	7/1/96	10:00	25° 27.769 N
8	17	214	3,1	North Canal	7/1/96	11:04	25° 27.793 N
9	1	215	1,1	SE Biscayne Bay	6/25/96	16:07	25° 24.038 N
9	1	216	2,1	E of W Arsenicker	6/25/96	15:10	25° 24.222 N
9	1	217	3,3	NE of W Arsenicker	6/25/96	14:34	25° 24.607 N
9	2	218	1,1	N Central Card Sound	6/25/96	10:55	25° 20.527 N
9	2	219	2,1	Western Card Sound	6/25/96	11:58	25° 21.071 N
9	2	220	3,1	NW Card Sound	6/25/96	13:17	25° 22.146 N
9	3	221	1,1	Lower Central Card Sound	6/23/96	14:17	25° 19.120 N
9	3	222	2,1	Little Card Sound	6/23/96	13:42	25° 18.022 N
9	3	223	3,1	East Central Card Sound	6/23/96	15:00	25° 19.449 N
9	4	224	1,1	Little Card Sound	6/23/96	11:42	25° 18.074 N
9	4	225	2,2	Little Card Sound	6/23/96	12:45	25° 18.614 N
9	4	226	3,3	Little Card Sound	6/23/96	10:55	25° 17.437 N

Longitude	Depth meters	Surface Temp. °C	Btm. Temp °C	Salinity ppt	Surface Salinity ppt	Bottom Surface D.O mg/L	Btm D.O. mg/L
80° 11.947 W	1.98	30.0	30.0	33.0	33.0	6.2	6.4
80° 13.570 W	2.75	29.5	29.5	32.0	32.0	6.1	6.2
80° 07.905 W	1.40	27.5	28.0	8.0	11.5	6.9	5.7
80° 07.904 W	8.00	28.5	27.0	8.5	31.0	6.7	0.0
80° 07.595 W	1.83	28.5	29.0	7.0	20.0	6.4	3.1
80° 08.591 W	5.94	28.0	28.5	3.0	27.0	3.6	1.9
80° 08.605 W	5.64	28.0	28.0	3.0	27.1	4.2	0.8
80° 08.649 W	3.35	28.1	28.1	3.2	21.0	4.5	0.2
80° 07.900 W	2.20	28.5	29.0	15.5	23.8	3.9	4.3
80° 08.050 W	1.20	29.0	29.0	15.0	16.0	4.1	4.2
80° 08.940 W	2.20	29.0	29.0	9.0	8.5	4.5	4.0
80° 07.270 W	6.10	28.0	28.0	6.0	30.0	4.0	4.8
80° 07.510 W	2.50	29.0	29.0	14.0	28.5	4.7	4.6
80° 07.737 W	1.60	29.0	30.0	15.0	22.0	4.6	5.1
80° 09.510 W	2.50	26.0	26.0	31.5	30.5	4.6	4.6
80° 09.604 W	7.00	26.5	26.5	30.0	30.0	5.5	5.5
80° 08.964 W	2.50	26.0	24.0	29.0	34.0	5.8	4.6
80° 09.533 W	7.50	27.0	26.0	30.0	31.0	5.8	5.3
80° 09.198 W	7.50	27.0	26.5	30.0	31.0	5.6	5.4
80° 08.696 W	3.00	26.0	27.5	31.5	31.5	5.3	4.9
80° 09.818 W	1.90	30.0	30.0	27.9	30.5	7.1	10.0
80° 08.991 W	7.50	27.0	27.0	28.0	28.5	6.4	6.8
80° 10.262 W	3.50	30.0	27.5	28.0	31.5	6.5	5.8
80° 10.091 W	4.50	26.0	26.0	1.9	31.0	4.0	5.1
80° 10.153 W	5.60	26.0	26.0	1.5	31.0	4.2	5.6
80° 09.706 W	2.44	28.0	28.0	25.0	27.0	5.3	4.6
80° 10.269 W	0.91	28.0	27.5	24.0	26.0	5.6	6.0
80° 09.930 W	2.44	27.0	27.0	24.0	26.0	5.0	4.0
80° 08.083 W	3.05	27.0	27.0	28.0	28.0	6.7	6.6
80° 08.652 W	0.75	27.0	26.5	27.0	27.0	10+	10+
80° 08.588 W	9.50	27.0	27.0	27.0	27.5	5.7	5.2
80° 11.031 W	3.66	29.0	28.0	27.0	28.0	6.2	5.0
80° 10.028 W	1.22	28.0	28.0	28.0	28.0	6.5	6.3
80° 09.824 W	1.52	28.0	28.0	28.0	28.0	7.1	6.9
80° 08.119 W	9.00	27.0	27.0	29.0	29.0	10+	10+
80° 08.784 W	0.75	27.0	27.0	28.0	28.0	9.8	9.8
80° 08.941 W	1.00	27.0	27.0	28.0	27.0	10.0	10+
80° 07.843 W	3.75	28.5	29.5	29.0	32.0	6.1	2.8
80° 07.377 W	3.96	30.0	31.0	33.0	37.0	6.0	2.9
80° 07.648 W	3.50	28.5	29.0	28.9	32.0	6.1	3.3
80° 07.360 W	3.35	30.0	29.0	34.0	36.5	6.2	5.1
80° 07.462 W	4.11	29.0	28.5	33.5	37.0	5.3	1.9
80° 07.432 W	2.74	29.0	28.5	34.0	35.0	5.6	4.3
80° 11.037 W	3.40	27.5	29.0	9.0	28.5	3.0	5.5
80° 10.423 W	2.50	28.5	29.0	13.0	28.8	3.8	5.6
80° 10.333 W	2.40	27.0	27.0	29.0	29.5	5.8	5.8
80° 10.670 W	1.22	27.0	27.0	29.5	29.5	5.8	5.5
80° 10.309 W	1.80	28.0	29.0	28.5	28.1	7.1	6.8
80° 09.343 W	1.22	29.0	29.0	30.0	30.0	6.7	6.9

80° 10.000 W	2.50	28.0	28.5	30.0	31.0	5.6	5.6
80° 09.833 W	1.83	28.5	28.0	30.0	31.0	6.0	4.9
80° 08.478 W	2.50	27.5	27.0	31.0	31.0	5.0	4.7
80° 08.499 W	1.70	28.0	28.0	30.0	30.5	5.1	4.9
80° 08.380 W	2.29	27.0	27.0	31.0	31.1	4.5	4.6
80° 10.033 W	2.59	29.0	28.0	30.0	30.5	5.6	6.0
80° 10.258 W	2.90	28.9	28.0	30.0	30.0	5.7	5.7
80° 10.799 W	4.57	28.0	28.0	32.0	34.0	5.4	5.0
80° 09.713 W	2.50	29.0	29.0	30.0	29.9	5.3	5.4
80° 09.651 W	2.59	29.0	29.0	30.5	30.5	5.7	5.5
80° 09.108 W	3.50	29.0	29.0	31.0	31.0	5.4	5.9
80° 10.721 W	10.72	27.0	27.0	27.0	31.5	5.1	5.1
80° 11.080 W	2.25	29.0	28.0	29.0	30.0	5.1	5.1
80° 10.923 W	2.10	28.0	28.0	29.0	30.5	5.1	5.2
80° 10.257 W	2.40	28.5	28.5	30.5	30.4	5.8	5.5
80° 10.156 W	2.60	29.0	29.0	30.0	29.9	5.6	5.6
80° 09.623 W	3.00	29.0	29.0	29.5	29.5	5.4	5.4
80° 09.291 W	3.20	28.0	27.5	30.0	33.0	5.6	5.7
80° 09.242 W	2.74	28.0	28.0	31.5	33.0	5.7	6.0
80° 09.199 W	3.00	28.0	29.0	29.6	32.0	6.7	6.5
80° 08.816 W	4.00	27.0	26.5	32.0	33.0	5.6	5.9
80° 08.788 W	3.70	28.0	27.5	33.2	33.5	6.1	6.3
80° 08.642 W	3.50	28.0	27.0	33.0	34.0	5.8	6.1
80° 11.260 W	7.30	28.5	28.0	29.0	31.0	4.1	3.2
80° 12.200 W	2.00	30.0	29.5	27.5	28.8	6.4	6.4
80° 12.200 W	2.70	30.0	29.5	28.5	29.0	6.9	6.5
80° 12.829 W	2.75	30.0	29.0	27.0	28.0	5.7	6.5
80° 11.672 W	3.50	30.5	30.0	28.5	29.5	6.3	6.8
80° 11.919 W	3.50	30.0	30.0	28.0	29.0	5.9	6.7
80° 11.366 W	3.70	30.0	30.0	28.2	29.5	6.5	6.7
80° 14.267 W	2.29	32.0	31.0	24.5	25.5	5.4	6.1
80° 14.818 W	2.29	29.0	28.9	24.9	26.0	5.6	4.5
80° 14.463 W	2.13	29.0	28.9	25.8	26.2	5.5	5.8
80° 13.491 W	2.74	30.0	30.0	24.9	27.0	5.7	6.0
80° 15.218 W		31.0	30.8	24.0	25.0	7.1	7.0
80° 13.625 W	3.20	30.5	30.0	23.9	26.5	6.0	6.4
80° 12.360 W	3.05	29.5	29.5	25.0	28.0	6.0	6.2
80° 12.181 W	3.20	30.0	31.0	25.5	27.5	6.0	6.1
80° 13.157 W	3.60	31.0	30.5	24.5	26.3	7.8	6.6
80° 15.709 W			27.5		23.8		
80° 15.663 W	2.50	30.0	30.0	25.0	25.0	7.5	7.5
80° 16.222 W	2.00	29.0	31.0	23.0	23.0	9.0	9.0
80° 14.268 W	2.50	30.0	30.0	27.0	28.5	6.6	8.7
80° 13.540 W	2.44	30.0	29.8	29.0	29.0	6.5	7.6
80° 13.417 W	2.90	30.1	29.9	27.9	29.3	6.8	7.8
80° 15.069 W	2.10	30.5	31.0	15.0	25.0	4.9	4.7
80° 16.002 W	2.25	29.0	31.0	5.9	20.0	4.1	3.5
80° 16.507 W	0.95	29.5	29.5	0.5	0.7	5.8	5.6
80° 16.959 W	4.25	28.0	28.0	0.2	18.0	1.8	1.9
80° 16.343 W	3.40	28.0	28.5	1.5	21.5	2.3	2.9
80° 16.468 W	3.75	28.0	26.5	1.5	21.7	2.1	0.1
80° 20.501 W	2.74		26.5		14.5		
80° 20.596 W	2.74		27.0		11.0		

80° 20.742 W	2.29		27.0		12.1		
80° 20.313 W	3.66		27.0		15.0		
80° 20.639 W	4.57		27.0		15.8		
80° 20.569 W	4.27		26.5		8.0		
80° 20.069 W	3.10	27.0	29.0	11.8	20.5	5.8	1.4
80° 20.385 W	3.00	27.0	29.0	13.0	21.0	5.9	0.5
80° 20.038 W	2.25	28.0	29.5	11.0	19.5	5.9	2.3
80° 15.896 W	2.40	32.1	32.0	28.2	28.1	7.1	7.1
80° 16.111 W	1.52	32.0	28.0	32.0	28.0	7.1	7.1
80° 15.341 W	5.00	32.0	32.0	28.4	28.6	6.7	6.7
80° 17.990 W	2.44	31.0	31.0	26.9	28.5	6.2	5.4
80° 19.135 W	2.44	31.5	31.0	24.9	27.0	6.0	6.3
80° 18.397 W	1.37	31.8	31.8	26.4	26.2	6.9	6.9
80° 19.216 W	9.50	30.0	31.0	25.5	28.0	6.3	6.4
80° 19.860 W	2.74	30.0	30.5	24.5	27.0	6.4	6.3
80° 17.995 W	2.74	30.0	30.0	25.5	27.5	6.2	7.2
80° 22.548 W	1.22	30.0	30.0	24.0	24.0	6.6	6.4
80° 21.511 W	1.83	30.0	30.0	23.0	26.0	6.2	6.8
80° 22.186 W	1.68	29.0	29.0	19.5	23.0	5.1	5.8

Conductivity micro moles	Surface Conductivity micro moles
50000+	50000+ (off scale)
50000+	50000+ (off scale)
14,100	15,300
15,100	50,000
149,000	33,800
5,100	45,000
5,500	45,000
6,000	36,000
27,000	41,000
27,000	28,000
16,000	16,000
10,000	48,200
25,000	47,800
27,500	39,000
47,500	47,500
47,000	47,000
46,200	50,000
4,700	48,500
48,000	48,200
49,200	50,500
47,800	500000+ (off scale)
48,000	48,500
47,800	500000+ (off scale)
3,500	48,000
2,410	48,100
43,500	46,000
42,000	45,000
41,500	46,000
48,000	48,500
46,000	46,000
46,500	47,000
47,000	47,500
48,000	48,000
480,000	48,000
49,500	49,500
4,850	48,000
47,500	47,500
48,500	500000+ (off scale)
39,000	500000+ (off scale)
48,000	500000+ (off scale)
500000+	500000+ (off scale)
49,500	500000+ (off scale)
500000+	500000+ (off scale)
17,000	48,000
23,100	48,900
48,200	47,000
47,700	47,300
47,000	47,000
48,000	50,000

49,200	50,000
49,000	50,000
49,500	50,000
49,000	49,500
49,500	50,000
50,000	50000+ (off scale)
29,000	50,000
50,000	50,000
50,000	50,000
50000+	50000+ (off scale)
50000+	50000+ (off scale)
47,000	51,000
48,500	48,000
46,000	49,200
49,900	50,000
49,900	50000+ (off scale)
50,000	50,000
49,200	50000+ (off scale)
50000+	50000+ (off scale)
48,500	51,500
51,000	52,000
50000+	50000+ (off scale)
52,000	52,000
47,100	50000+ (off scale)
48,100	48,300
48,300	48,900
47,000	47,500
49,000	50000+ (off scale)
48,000	49,600
48,400	50000+ (off scale)
44,100	45,000
42,200	43,600
43,900	44,800
42,800	46,400
43,600	4,400
43,500	45,000
43,000	48,000
44,000	47,500
43,500	46,200
	39,100
43,000	43,000
39,000	39,000
46,000	48,000
49,600	49,900
47,900	50,000
27,500	44,900
11,000	36,200
1,190	1,200
6,000	31,000
2,550	31,800
2,510	35,000
	24,700
	19,100

	21,100
	20,000
	28,500
	13,900
19,900	35,900
22,000	35,900
19,500	35,000
50,000	50,000
50,000	50,000
50000+	50000+ (off scale)
46,500	49,000
44,000	47,000
47,100	47,100
44,800	47,500
42,900	46,000
44,800	47,200
42,000	42,000
41,000	45,000
35,500	40,000

Sediment Description

Lt. brwn to tan, silty fine to coarse sand, shell hash, no odor, Thallassia nearly covering substrate
Lt brwn to lt gry fine to coarse, sand w/ shell hash
Upper cm dk brwn, dk brwn below, lots of shell debris (same material all 4 grabs); no odor; SAV, polychaetes tubes
1,2, & 3rd grbs- dk gry, soft runny, silty clay oliven no visible benth orgs., eel grass degree, strong sulfur
1st & 2nd grb-gry,some blk, sandy mix, SAV, red algae, bivalves; 3rd -lt. brwn over lt gray, silty sand, bivalves; 4th -lt brwn over lt gry, snails
all 3 grbs - soft silty caly, oozy, runny, shiny, silty; top 2mm - blk, then olivene soft brwn clay, some decaying vegetation
Soft, runny, silty clay, dk. brwn-black, 1 mm black flock layer on surface, slight sulfur odor; no visible signs of life
all 3 grbs - soft, olivein, greenish-brwn, clay-silt; snails, polychaetes, lots of org matter
Lt brwn & dk gray silty sand, some dk brwn, shell hash, detritus, firm; SAV, snails, clams, hermit crab
Dk brwn, sandy silty, soft, some shell hash; SAV, green algae, amphipods
Dk. brwn, green on surface, darker below, silty sand w/ detritus & shell hash; tannic brown odor; no benthic orgs.
Dk. chocolate brwn, sandy-silt, some clay; plant debris, sponges, polychaete tubes, some shell hash
Dk. brwn, slightly sandy silty clay, flock layer over dk brown; no visible life, plant debris, some shell debris
all 3 grabs - dk. choc. brwn, sandy clay-silt, soft; 2nd grb - silty, coarse sand; 1st -plants; 2nd -gastopods, green plants
Lt. brwn floc over dk.- med. grey clay; sandy silty clay; organic odor; variety of inverts - brittlestar, algae - green, brwn
Brwn layer over med. gry; silty sand; grn algae had odor; inverts., algae, med. shell hash, SAV
Brwn, coarse shell hash; 3rd grb brwn floc, silty; last grb-floc lt. brwn & gry clay- silty less shell; polychaetes
Lt. brwn, shell hash @ surface, dk. gry, silt below; lots of benth. - single-celled algae, crab, jellyfish, Halodule, mysids
Lt. brwn above, gray below; silty fine to med. sand, shell hash in 2nd grb; algae fans, sea grass, syridium
Lt. brwn , gray below; firm silty sand; SAV
lt. brwn surface - abundant benth., dk brwn; silty fine med. sand; SAV, syrigodium, polychaete tubes, seahorse
Lt. brwn over gry; mostly clay w/sand; polychaetes, no SAV
Lt. oliveen-gry over med/dk. gry; sticky silty clay; diaton scum lt. filamentons,red algae, clam holes
Dk. gry; soft organic enriched silt/clay; leaves & other plant debris some shell; sulfur; oyster shells
Dk. gry; soft and smooth silt; sulfur; fecial castings
Md. brwn floc layer, md gry soft silt; vegetation
Gray; silty sand, shell hash; Syrigodium, hydroids
Lt. brwn over lt gry with nephords; silt w/ fine sand; plant debris, green coralline algae
Firm, lt. brwn, dkr material 1 cm down; silty sand w/ shell hash; polychaetes, blue sponge, some SAV
Md. brwn to lt. brwn, slighty sandy silt; lt sulfur; Haodul, Thalassia, lots of benth, gelatenous eggs
Lt. brwn, firm black sand throughout; silty clay sand, fine shell hash; polychaetes, crab, small SAV
Lt. brwn; silt/clay
Dk. brwn; fine silty; sulfur; coraline algae - tons
Dk. brwn floc to lt. brwn or lt gry; silty w/ fine shell hash, some sand; diatom scum, some SAV, gastropod
Lt. brwn; shell hash, sand; Epiphytic growth
Lt. gry, lots of floc; soft silt, some shell; Gyrium godium, huge grass beds covering sm. areas
Dk. brwn; shell hash, fine sandy silt; Halodule grassbed, coralline algae, gastropods
Fine grain sandy silty clay; med brwn; Polychaete tubes, 1
Dk. gry silty clay, 2nd - fine shell hash, coarse sand; strong sulfur; 3rd jur. fish
Sft. lt. brwn-gry silty clay some sand; lt brwn layer over gry layer; bivalves
Lt. brwn; fine shell hash to coarse sand, 3rd-fine to silty sand; amphipods, worm tube
Dk.gry, olive silty clay; sulfur; diatoms
Lt. Tan coarse sandy w/ shell hash over; med. to lt. brwn silty clay; 2nd grab- anoxic
Dk. brwn sandy silt, thin lt. brwn; gravel shell debris; petroleum odor; hydrilla, floating sav.
Brwn sandy over md. brwn sandy silty clay, som gravel, rocks, coral; SAV, sponges, sea grasses
Tan w/ orange & white shell hash; sand w/shell hash; crusty algae
Brwn above, gry below; soft silty sand; slight sulfur odor; mostly Syringodium, crustacea, hydroid
Lt brwn silty sand - 2mm, over dk. gry sandy silt; sulfur odor; in grass bed; polychaetes, amphipods, syringodium
Dk. gry, fine sandy silt; sulfur odor; calcareous algae, sea grasses

Brwn, sticky sandy silty clay; shell debris, small algae (brown)

Dk. brwn silt w/ calcareous inclusions - algae abundant 1st core; strong sulfur odor; Syringodium dense, grass beds, fish

Lt. brwn, soft gooey silty clay; no odor; green plants, SAV, polychaete tubes

Lt. brwn over dk. gry over blk sandy clay; soft silt - 2mm surface; 2nd grb- sandy clay; Syringodium, SAV, mysids

Lt. brwn; soft silty clay, no odor; worm tubes, SAV

Lt. brwn 1st cm, grey below, soft silt; moluscs, diatoms

Dk. brwn; clay sity sand, mainly coarse sand; abundant animals and plants

Lt brwn upper 1cm; gray below; silty sandy fine and med grain sands; sponge and invertebrates

Lt. brwn upper 1-2 cm, dk gry below, lots of shell hash, slightly silty coarse to fine sand; sponges, polychaetes

Lt brwn, silty sand w/lots of shell hash; polychaete tubes, SAV, brown algae

Lt brwn, lt gray below; sandy silty clay upper cm, same material below; polychaetes, SAV

Lt. brwn, slighty sandy w/ soft clay over 2cm of lt gry; crab, few worm tubes, clam

Lt brwn upper 2 cm over gry sand below; soft sandy silty sand, SAV, plants, polychaete tubes

Lt. brwn over lt gry, silty sand firm; algae, diatom scum, worm tubes

Med. brwn soft silty sand w/ some shell hash, floc surface, diatom scum; mollusk hole, worm tubes on surface; SAV, halophite grass

Med. brwn color over med. gry, soft clayey silt, mollusk holes, polych. worm tubes, no sand.

Med. brwn silty sand w/ shell hash & fine & med. sand over gry silty sand, green algae; 4th grab - thin brwn 2mm surface over gry, brown algae; SAV

Tan, lt brwn silty sand over gry silty sand; worm tubes, polychaete & amphipod tubes

Lt. brwn over lt gry, soft, sticky silt over fine sandy silt; polychaetes, amphipods

Lt. brwn soft sticky silty clay - 1 cm over gry soft sticky silty clay; several inverts - "feather" SAV, diatomes, small shells

Lt. brwn; fairly firm silty sand; variety of inverts - SAV

Lt. thin brwn over grey, firm fine silty sandy; dense Halodule, gastropods, mysids, harpactacoids

Lt. brwn silty sand over gry silty sand; some worm tubes, diatom scum, marine spider

Brwn soft silt w/ floc surface, some blk silty streaks & gry below; odor ?, no benthic, fish - 2nd grab

Thin (2mm) layer of dk. brwn sandy silt over dk. black silty sand; sulfur odor; polychaete tubes, fishes, sm. brwn algae, numerous benth. orgs.

Dk. brwn slightly sandy silty clay, sticky; no odor; green algae, seagrass

Lt. brwn, lt gry; silty sand; seagrass, thalassia, Halodule, SAV, sponges, gastropods, green algae, polychaete tubes

Lt. tan, cream color, silty-clay; polychaetes, diatoms, molluscs

Lt. brwn, tan over lt gry, silty-clay, some sand, soft; Syrengodium, seagrass, diatoms, polychaete tubes, algae

Lt. brwn tan over lt. gry, slightly sandy silty-clay; conch, Halophila, diatom layer; 3rd grb - distinct algal layer

Dk gry, silty sand, fine to coarse sand; sponges, grazed seagrass, small fish

Soft, dk brwn over dk gry, slightly sandy, clayey silt; slight sulfur odor; polychaete tubes, green algae, grabs 1,2,3 same

Grey silty sand with shell hash, scattered Thalassia beds

Lt. gry, shell fragments; sandy silt w/ shell hash; lt tan to lt gry, no odorous sheen, mollusks, algae, SAV

Tan to lt brwn silty sand w/ shell hash; numerous SAV, Thalassia, soft corals, bivalves, snails, worms, sponges

Tan to lt brwn over lt gry, silty sand w/ shell debris; numerous animal & plants - worms, SAV, Thallassia, soft corals, etc.

1st - soft, white, silty fine sand; 2nd - diatom scum, tan on surface; 3rd - silty, sandy clay, tan, thin veneer of gry, 4th -same as 2 & 3; Lots of benth orgs- marine algae, etc.

tan to lt gry, silty sandy clay, then veneer (2 mm) of brow over gry; polychaete tubes; soft sticky calcar. algae scum on surface; 3rd -live shaving brush algae

Lt. tan soft silty sand, carbonate over grey soft silty carbonate sand; Thalassia seagrass bed

Gry, sandy w/ shell hash; bivalves, seagrass, Terrebellid worms, Gorgonians, various sponges

Lt. brwn to tan over lt gry, silty sand; sulfur odor; complex community of SAV, soft corals, sponges, terebellids

Dk. brwn silty sand; abundant grasses, gastropods, fish, green & brwn algae

Lt. tan/gry, silty sand, shell hash; dense SAV, Thallassia, and algae, many inverts.

Lt tan thin surface over gry silty sand fine shell hash; dense Thallassia, gastropods, cacareous epiphytes

Lt tan over dk gry, silty sand, shell hash; Thallasia beds thick, sone crabs, sponges, barracuda, terribellid worms, Lima, fecal casts

Dk. brwn, soft sandy silt, 2nd - gravel, lg oyster shells, hermit crabs; strong sulfur; shell hash, seagrass, brown & red algae

Lt. brwn, soft, runny silt; no visible life; 2nd grab - mudfish

Dk. brwn-blk & greenish, silty-sand; gastropods, organic debris, fresh water grasses, hydrila

Dk. brwn over white clay, sandy clayey silt w/ rocks and trees; oyster shells, other shells, gravel

Dk. brwn - blk, soft runny mayo, rocks, sticks, petroleum sheen, sulfur odor; amphipods, fishes, oysters

Blk mayonnaise over silty sand over dk. gry-blk; 2nd - blk mayo (1cm thick) over blk silty-sand, soft runny; sulfur odor

Dk. brwn sandy silt w/ some clay; sulfur odor; organic detritius, mangrove roots

Dk. brwn sandy clayey silt; sulfur odor; abundant plant debris, pine needles, shell hash debris, gravel, floc. surface

Dk. brwn w/ flocky surface, shell hash, soft, oozy slightly sandy silt; sulfur odor; lots of org mat., shell hash, Hydrilla, green algae

Dk. brwn, thin brwn flocky surface layer; soft, slightly sandy-silt, gravel, rocks, sulfur odor; plant debris; 3rd -gravel, shell hash

Lt. brwn, med.brwn flock surface, clay, solid, dk. brwn below; 2nd,3rd grbs - sulfur odor; org mat mixed, worm tubes, pine needles, fish

Dk. brwn, med. brwn, silty sandy-clay, lots of limerock; strong sulfur odor; green algae

Dk. brwn, soft, slightly sandy, clay-silt, rocks & gravel, green slime layer; sulfur odor; plant debris, oyster shells, mangrove leaves

Ochre, olivene surface over dk. brwn silty clay over clay; 2nd - thin dk. green mat of slime, strong sulfur odor

Slimy green layer (1-2mm); sulfur odor, dk brwn & olivene silty sand; some rock, mangrove, plant debris

Lt. brwn 2mm thick over lt gry, silty sand; worms, snails, clams

Lt. brwn over dk.gry silty gry silty san floc 2mm thick on surf very floc shell hash; light sulfur odor; Thalassia with epifatics, hermit crabs, tube worms

1st & 2nd -thin tan 2mm surface over md. gry soft silty sand, shell hash, slight sulfur odor, polychaetes, mollusks, Thalassia blades, gastropods, hermit crabs

Lt gry & tan silty fine sand, soft w/ shell hash; Thalassia beds & halameda; no odor; mollusks, shallow grabs

Lt. brwn layer of sand 2mm thick over dk. gry silty sand; slight sulfur odor; numerous plants & animals- hydroids, etc.

Lt. tan shell/sand layer over dk. gry, silty sand w/ shell hash; comm'y of worms, sponges, etc.

Lt brwn silty sand over dk grey silty sand; Inverts and plants abundant - shellfish, green algae, hydroids, amphipods, sea spider

Lt. brwn, soft sandy silty clay over lt gry soft silty clay; shells, no visible life

Lt. brwn & gry fine sandy silt, abundant shell debris, live halodule grass, halameda calc. algae, shrimp; sulfur odor when homogenizing.

Lt. brwn, sandy-silt, layer of peat 2-3cm below surface, shell hash; wide variety of plants $& animals, notably Halamedea

Dk. brwn, sandy-silt, soft, shell debris; sulfur odor; Thalassia abundant

all 5 grbs -dk. brwn silty-mud, soft, runny, slightly sandy; SAV, plants, polychaetes, dead thalassia blades, brittle star

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