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A Pilot Study for Ambient Toxicity Testing in Chesapeake Bay

Year 4 Report

Chesapeake Bay Program

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A Pilot Study for Ambient Toxicity Testing in Chesapeake Bay

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FOREWORD

This study was designed to evaluate ambient toxicity in the Chesapeake Bay watershed by using a battery of water column and sediment toxicity tests. A team of scientists from two Chesapeake Bay research laboratories and Maryland Department of the Environment worked jointly to complete this goal. Water column toxicity studies and overall project management was directed by the University of Maryland's Agricultural Experiment Station. Sediment toxicity tests and selected sediment chemistry was managed by Old Dominion University Applied Marine Research Laboratory. Maryland Department of the Environment was responsible for selected sediment chemistry. This report summarizes data from the fourth year of a four-year ambient toxicity testing program. The following government agencies were responsible for supporting and/or managing this research: U.S. Environmental Protection Agency and Maryland Department of the Environment.

ABSTRACT

Data presented in this report were collected during the fourth year of a research program designed to assess ambient toxicity of living resource habitats in Chesapeake Bay for the purpose of identifying defined regions where ambient toxicity levels warrant further investigation. The goals of this study were to identify toxic ambient areas in the Chesapeake Bay watershed by using a battery of standardized, directly modified, or recently developed water column and sediment toxicity tests. The toxicity of ambient estuarine water and sediment was evaluated during the fall of 1994 at six stations in Baltimore Harbor (Patapsco River) and two stations each in the Sassafras, Magothy and Severn Rivers. The toxicity of ambient estuarine water was assessed at all stations by using the following estuarine tests: 8 day larval sheepshead minnow, *Cyprinodon variegatus*, survival and growth test; 8 day larval grass shrimp, *Palaemonetes pugio*, survival and growth test; 8 day *Eurytemora affinis* life cycle test and two different 48 hour coot clam, *Mulinia lateralis* embryo/larval tests. Toxicity of ambient estuarine sediment was determined by using the following tests: 10 day sheepshead minnow embryo-larval test; 20 day survival, growth and reburial test with the amphipods *Leptacheirus plumulosus* and *Lepidactylus dytiscus* and 20 day polychaete worm, *Streblospio benedicti* survival and growth test. Both inorganic and organic contaminants were assessed in ambient sediment and inorganic contaminants were measured in ambient water concurrently with toxicity testing to assess "possible" causes of toxicity.

Both univariate and multivariate (using all endpoints) statistical techniques were used to analyze the water column and sediment toxicity data. Results from univariate water column tests with sheepshead minnows, grass shrimp and *Eurytemora* showed that survival was not significantly reduced at any of the stations when compared with the controls. Growth of sheepshead minnows was significantly reduced at the Sassafras-Betterton site but there were no effects on growth at any of the other 11 stations. Growth of grass shrimp and reproductive endpoints for *Eurytemora* were not significantly reduced at any of the stations. Percent normal shell development of the coot clam was significantly reduced at the following stations during the first test: Sassafras River-Betterton, Sassafras River-Turner Creek, Baltimore Harbor-Bear Creek, Baltimore Harbor-Curtis Bay, Baltimore Harbor- Middle Branch, Baltimore Harbor-Northwest Branch, Baltimore Harbor-Outer Harbor, Magothy River-Gibson Island, Severn River-50\301 Bridge and

Severn River-Annapolis Sailing School. During test 2, percent normal shell development was significantly reduced at only the Magothy River-South Ferry station. Results from multivariate analysis using endpoints (survival, growth and reproduction) for all water column tests combined showed significant differences between the control and test conditions at all sites except the Magothy River-South Ferry and the Baltimore Harbor-Curtis Bay site. In most cases, however, the toxicity at these ten sites was judged to be low to moderate from an ecological perspective. Metals measured at all stations were generally low; only a copper value of 3.85 ug/L at Baltimore Harbor-Bear Creek exceeded the U. S. EPA marine water quality criteria. The Maryland estuarine criteria of 6.1 ug/L was not exceeded.

Results from univariate analysis of sediment toxicity data showed that sites within Baltimore Harbor (Patapsco River) produced the greatest toxicological effects of the 1994 sites. All of the Baltimore Harbor sediments exceeded the Effects Range-Median (ER-Ms) for dibenzo (a,h) anthracene as well as the metals, lead, zinc and chromium. Nearly 100 percent mortality occurred in some test organisms at the Northwest Harbor and Bear Creek sites. The Sassafras River sites showed moderate toxicity, with the Betterton site sediments resulting in significant effects in both the *L. dytiscus* and *S. benedicti* tests. The ER-Ms were exceeded at the Betterton site for nickel and lead. In the Magothy River, moderate toxic effects were observed at both sites, however Gibson Island resulted in slightly greater mortality. Gibson Island sediment also exceeded the ER-M for lead by nearly 25 times. South Ferry also exceeded the Effects Range Low (ER-Ls) for several metals. The Severn River sites showed toxicity at the Annapolis site in two species, while only *S. benedicti* produced significant toxicity at the Route 50 site. The Annapolis sediment exceeded the ER-M for dibenzo(a,h)anthracene. The multivariate analysis of the 1994 sediment data indicated that the Sassafras River displayed no significant overall toxic effect. The Magothy sites exhibited slight to moderate toxicity, particularly at the South River site. The Annapolis site on the Severn River also displayed significant but moderately low toxicity. The Baltimore Harbor sites showed various degrees of toxicity from slight (Outer Harbor) to quite high (Bear Creek, Northwest Harbor), with moderate toxicity at Sparrows Point, Middle Branch and Curtis Bay.

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SECTION 1

INTRODUCTION

The unique physical, chemical and biological characteristics of the Chesapeake Bay watershed provides habitat for numerous aquatic species. Decline of various living resources such as submerged aquatic vegetation, anadromous fish and the American oyster has been an area of concern in recent years (Majumdar et al., 1987). Possible causes of these declining resources are fishing pressure, nutrient enrichment, disease and pollution. The link between contaminants (including adverse water quality such as reduced dissolved oxygen) and biological effects has been of concern in critical Chesapeake Bay habitat areas. Information derived from the loading of toxic chemicals and/or chemical monitoring studies are not adequate for assessing the biological effects resulting from numerous sources such as multiple point source effluents, nonpoint source runoff from agriculture, silviculture and urban sites, atmospheric deposition, groundwater contamination, and release of toxic chemicals from sediments. The most realistic approach for evaluating the adverse effects of toxic conditions on living resources is by direct measurement of biological responses in the ambient environment. For the purposes of this report, the ambient environment is defined as aquatic areas located outside of mixing zones of point source discharges.

Research efforts designed to address the link between contaminants and adverse effects on living aquatic resources have been supported by various state and federal agencies in the Chesapeake Bay watershed. For example, the Chesapeake Bay Basinwide Toxics Reduction Strategy has a commitment to develop and implement a plan for Baywide assessment and monitoring of the effects of toxic substances, within natural habitats, on selected commercially, recreationally and ecologically important species of living resources (CEC, 1989). This commitment is consistent with the recommendations of the Chesapeake Bay Living Resource Monitoring Plan (CEC, 1988).

The idea for an Ambient Toxicity Testing Program was discussed at an Ambient Toxicity Assessment Workshop held in Annapolis, Maryland in July of 1989 (Chesapeake Bay Program, 1990). The goals of this workshop were to provide a forum on how to use biological indicators to monitor the effects of toxic contaminants on living resources in Chesapeake Bay. Recommendations from this workshop were used to develop an ongoing ambient toxicity monitoring program

(1990-1994). Objectives from the first three years of this effort have been completed and reports have been published (Hall et al., 1991; Hall et al., 1992; Hall et al., 1994).

Results from our first year of this study demonstrated that ambient toxic conditions were present in the Elizabeth River and Patapsco River based on water column, sediment and suborganismal tests (Hall et al., 1991). Data from sediment and suborganismal tests also suggested that toxic conditions were present at the proposed reference site in the Wye River; water column tests did not demonstrate the presence of toxic conditions at this reference site. Several ambient stations in the Potomac River also had toxic conditions based on water column and sediment tests. The need for multispecies testing was supported by the water column tests as no significant ranking of sensitivity among species was reported. Results from the sediment tests showed that the amphipod test was most sensitive, followed by the polychaete worm test and the grass shrimp test. The need for integrated water column, sediment and suborganismal testing was confirmed during our first year of testing as a spectrum of tests was needed to maximize our ability to identify toxic conditions in the ambient environment of the Chesapeake Bay watershed. Suborganismal testing was not continued after the frist two years.

Ambient toxicity tests were conducted twice in the following locations during the second year of this study: Potomac River-Morgantown, Potomac River-Dahlgren, Patapsco River and Wye River (Hall et al., 1992). Significant biological effects (statistically different from controls) were demonstrated from water column tests during at least one sampling period for all stations except the Patapsco River. The most persistent biological effects in the water column were reported from the Wye River station as significant mortality from two different test species was reported from both the first and second test. Sediment tests demonstrated significant biological effects for both tests at the Dahlgren, Morgantown, and Patapsco River stations. Significant biological effects were reported in sediment during the first Wye River test but not the second.

Ambient toxicity tests for year three were conducted at the following locations during the fall of 1992 and the spring of 1993: Wye River - Manor House, Wye River - Quarter Creek, Nanticoke River - Sandy Hill Beach, Nanticoke River - Bivalve Harbor, Middle River - Frog Mortar and Middle River - Wilson Point. Results from water column testing with the coot clam showed consistent toxicity at both Middle River stations during the fall and spring tests.

Concentrations of copper, lead, nickel and zinc were reported to exceed the EPA recommended chronic marine water quality criteria at one of the stations (Wilson Point). The concentration of copper at Frog Mortar Creek was below Maryland's acute estuarine criteria but exceeded EPA's recommended marine acute criteria. In addition, the concentration of nickel at Frog Mortar Creek exceeded EPA's recommended marine chronic criteria. The only other water column test showing significant effects was the *E. affinis* test (reduced survival) conducted at the Wye River (Quarter Creek) site during the spring test. Potentially toxic concentrations of contaminants were not reported concurrently with toxicity. Significant biological effects likely related to either adverse water quality or elevated contaminants were not reported at any of the other sites with the water column tests.

Results from sediment toxicity testing during year three showed a significant reduction in growth for *L. plumulosus* at the Nanticoke - Sandy Hill Beach site during the fall of 1992. Three times the Effects Range-Low (ER-L) for mercury was found at this site. Although below sediment ER-Ls, several organics and pesticides were also confirmed at this site. Elevated levels of unionized ammonia were present at both Bivalve and Sandy Hill Beach sites. Wye River Manor House produced significantly reduced survival of *L. dytiscus* and Wye River Quarter Creek sediment significantly reduced growth of *L. plumulosus* during the fall. Concentrations of metals were low at both sites, however 4,4 -DDT was detected at Manor House during the fall sampling. Spring toxicity data revealed significant reduction in survival in *L. dytiscus* at day 10 at the Manor House site when mortality was adjusted for particle size effects. Organic data indicated the presence of 4-methylphenol. Neither survival or growth effects were observed at the Middle River sites for either sampling period. Frog Mortar and Wilson Point showed elevated levels (above ER-Ls) of some metals including lead, zinc, mercury, and copper during the spring sampling. AVS/SEM (acid volitile sulfides/simultaneous extractable metals)data indicated the lack of bioavailability of these metals. The contaminant 4,4-DDE was also detected at the Frog Mortar site during the fall sampling. The purpose of this report is to present data from the fourth year of testing and summarize all information collected over the four year period using a composite index approach (multivariate analysis) based upon that of the sediment quality triad (Alden, 1992). Many of the test procedures described in the first year report were used for the fourth year of testing; therefore, the first year report by Hall et al. (1991) should be used to provide details on specific procedures. One new water column test (coot clam, *Mulinia lateralis*) and two new sediment tests (*Cyprinodon variegatus*, sheepshead minnow embryo-larval and amphipod, *Leptocheirus plumulosus*) were used in the third year. Descriptions of the testing procedures are provided in detail in Hall et al. (1994). The goals of this study were to conduct four water column and four sediment toxicity tests on a broader spatial scale than the previous efforts. Water column and sediment toxicity tests were conducted at six stations in the Patapsco River and two stations each in the Sassafras, Magothy and Severn Rivers. Inorganic contaminants were evaluated in water and both organic and inorganic contaminants were evaluated in sediment during these experiments.

SECTION 2

OBJECTIVES

This ambient toxicity study was a continuation of a research effort previously conducted for three years in the Chesapeake Bay watershed. The major goal of this program was to assess and determine the toxicity of ambient water and sediment in selected areas of the Chesapeake Bay watershed by using a battery of standardized, directly modified, or recently developed water column and sediment toxicity tests.

The specific objectives of the fourth year of this study were to:

- assess the toxicity of ambient estuarine water and sediment during the fall of 1994 at six stations in the Patapsco River and two stations each in the Sassafras, Magothy and Severn Rivers of the Chesapeake Bay;

- determine the toxicity of ambient estuarine water described in the first objective by using the following estuarine tests: 8 day larval sheepshead minnow, *Cyprinodon variegatus* survival and growth test; 8 day larval grass shrimp, *Palaemonetes pugio* survival and growth test, 8 day *Eurytemora affinis* life cycle test and 48 hour coot clam, *Mulinia lateralis* embryo-larval tests;

- evaluate the toxicity of ambient sediment described in the first objective by using the following estuarine tests: 10 day sheepshead minnow embryo-larval test; 20 day amphipod, *Lepidactylus dytiscus* and *Leptocheirus plumulosus* survival, growth and reburial test and 20 day polychaete worm, *Streblospio benedicti* survival and growth test;

- measure inorganic contaminants in ambient water and organic and inorganic contaminants in sediment concurrently with toxicity testing to determine "possible" causes of toxicity;

- determine the relative sensitivity of test species for each type of test and compare between test methods to identify regions where ambient toxicity exists;

- identify longer term test methods development or follow up survey design needs (if any) to support baywide assessment of ambient toxicity; and

- summarize water column and sediment toxicity data over four years using a composite index approach for each site.

SECTION 3

METHODS

3.1 Study Areas

Study areas were selected to represent either historically impacted locations, locations of unknown impact or ecologically important areas (Figures 3.1 and 3.2). These figures show the relationship of these 12 sites with other areas in the Chesapeake Bay. The Sassafras River was selected because it is an ecologically important environment (e.g. spawning area for striped bass) with some documented potentially toxic organic conditions in the sediments (Eskin et al., 1996). Specific sites selected were Betterton (SASBT) (39° 22 27 N x 76° 03 01 W) and Turner Creek (SASTC) (39° 21 47 N x 75° 59 03 W).

The Magothy River was selected to represent a highly urbanized area with very few point sources. Potentially toxic organics have also been reported in this river by Eskin et al. (1996). However, due to limited background data the possible influence of contaminants on this system is unknown. Specific locations were near Gibson Island (MAGGI) (39° 03 36 N x 76° 26 06 W) and North of South Ferry Point (MAGSF) (39° 04 36 N x 76° 30 05 W).

The Severn River was selected because it has a few point sources and potentially toxic orgnic compounds have been reported in the sediment of this river (Eskin et al. 1996). Limited background data are available in this river to determine if contaminant problems exist. Locations selected for ambient testing in this river were near the 50/301 Bridge (SEV50) (39° 00 20 N x 76° 30 24 W) and near the Eastport sailing school in Annapolis (SEVAP) (38° 58 01 N x 76° 28 18 W).

The six sites in the Patapsco River (Baltimore Harbor) were selected due to previous contaminant problems reported during our first and second year of ambient toxicity testing (Hall et al. 1991; Hall et al., 1992). Five of these sites were used by Maryland Department of the Environment for their benthic monitoring program. Therefore, our ambient data can be compared with the benthic community data to provide an overall assessment of the ecological status of these sites. Specific sites used for ambient toxicity testing were as follows: Sparrows Point (BHSPT) (39° 12 29 N x 76° 30 27 W), Outer Harbor (BHOTH) (39° 12 32 N x 76° 31 29 W), Bear Creek (BHBCR) (39° 14 09 N x 76° 29 46 W), Curtis Bay (BHCUB) (39° 12 23 N x 76° 34 49 W), Lower Middle Branch (BHMBR) (39° 15 10 N x 76° 35 18 W) and Northwest Branch (BHNWB) (39° 16 36 N x 76° 34 27 W).

Figure 3.1 Sampling locations were Sassafras River-Betterton, Sassafras River-Turner Creek, Magothy River-South Ferry, Magothy River-Gibson Island, Severn River-Annapolis and Severn River-Route 50.

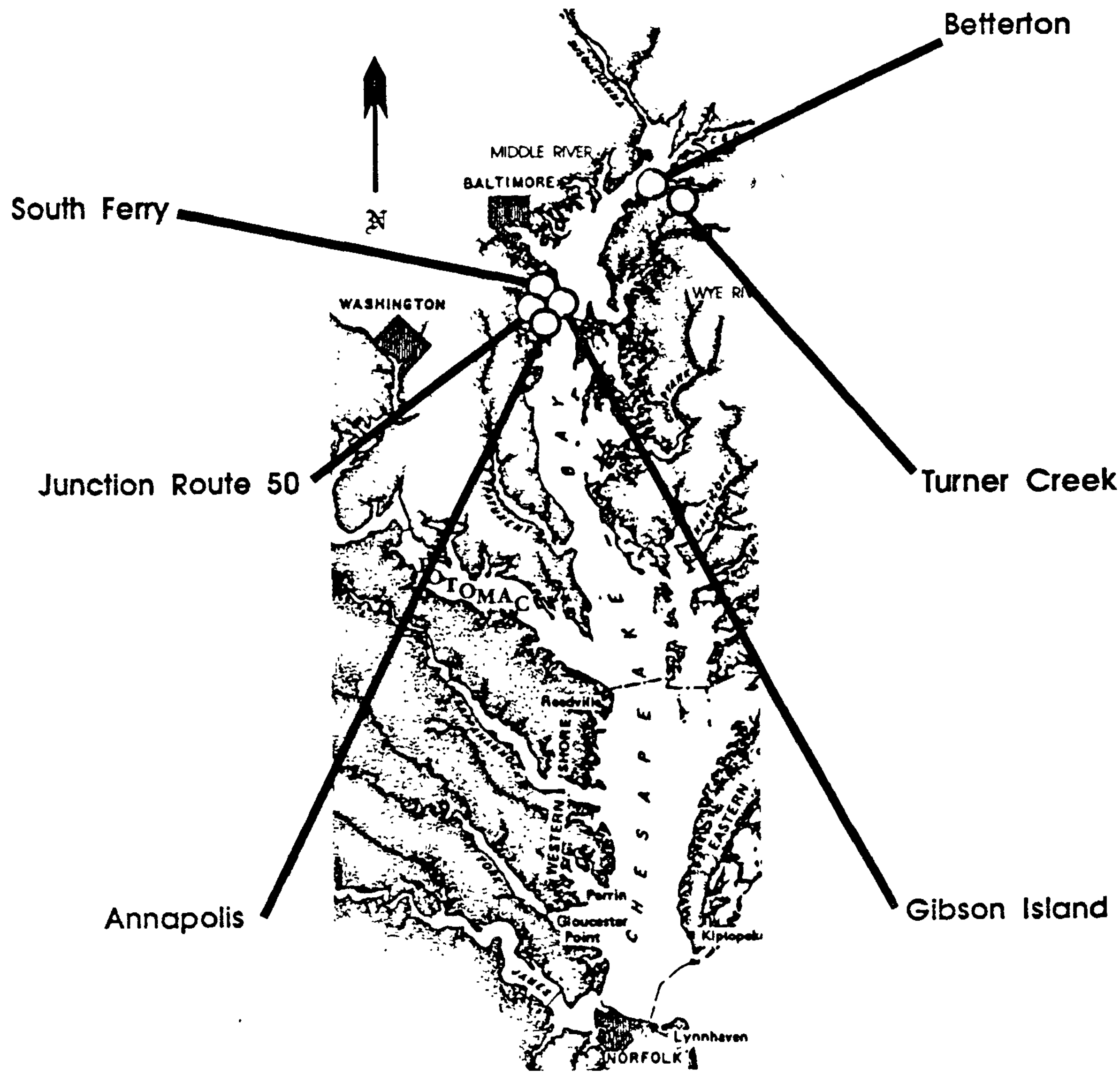
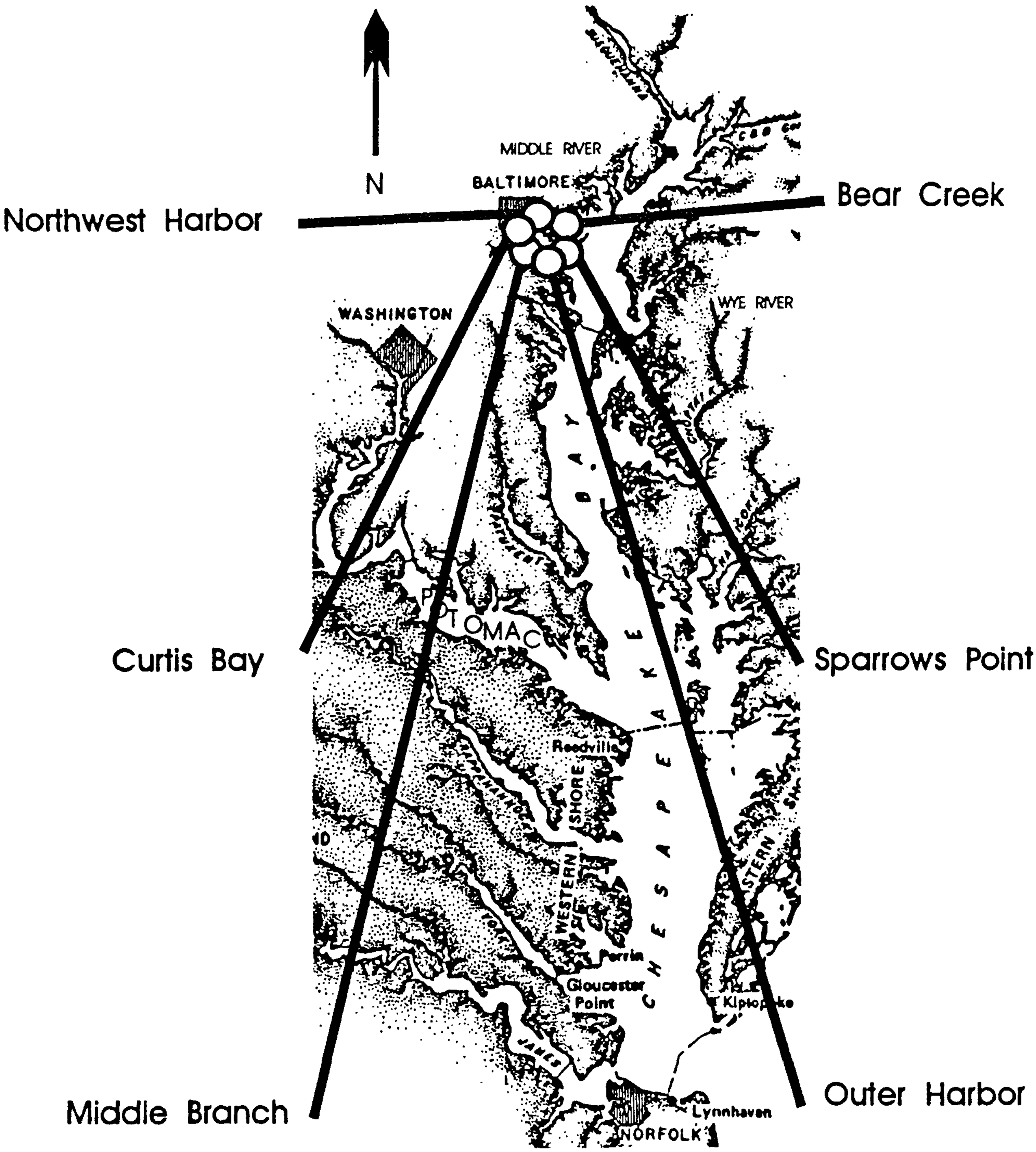


Figure 3.2 Sampling locations in the Patapsco River (Baltimore Harbor) were: Northwest Harbor, Bear Creek, Curtis Bay, Sparrows Point, Middle Branch and Outer Habor.



3.2 Water Column Toxicity Tests

The objectives of the water column toxicity tests were to determine the toxicity of ambient water at the 12 stations described above. The following tests were conducted at these stations during the fall of 1994: 8 day larval sheepshead minnow survival and growth test; 8 day larval grass shrimp survival and growth test; 8 day *E. affinis* life cycle test and two 48 hour coot clam embryo/larval tests. A suite of metals and organics was also measured in ambient water used for these tests.

3.2.1 Test species

Larval sheepshead minnows, larval grass shrimp and the copepoda *E. affinis* have been used in the previous three years of ambient toxicity testing. These test species were selected because they meet most of the following criteria: (1) resident Chesapeake Bay species, (2) sensitive to contaminants in short time period (less than 10 d) and (3) standard test organism that does not require additional research. Both larval sheepshead minnows and larval grass shrimp are highly abundant, resident Chesapeake Bay organisms used extensively in standard tests. Sheepshead minnows have demonstrated moderate sensitivity in subchronic tests. Juvenile and adult grass shrimp are generally considered resistant species, however, larvae have been used to report biological effects in previous ambient tests (Hall et al. 1994). Both sheepshead minnows and grass shrimp are commonly used in EPA's and MDE's Whole Effluent Toxicity Testing Program. *E. affinis* is an extremely abundant, resident Chesapeake Bay zooplankton species that is sensitive to contaminants. We recently developed a Standard Operating Procedure for this species that was used for these tests (Ziegenfuss and Hall, 1994).

The coot clam, *M. lateralis*, was a new species added to the suite of test organisms during the third year of ambient toxicity testing. This clam is a small (< 2 cm length) euryhaline bivalve. It is a numerically dominant species in the mesohaline areas of the Chesapeake Bay as well as numerous tributaries (Shaughnessy et al., 1990). Embryo/larval development occurs in the water column in approximately 6-8 days. It is, therefore, suitable for water column testing because the sensitive life stage occurs in the water column. The coot clam adds another dimension to the suite of test organisms because it represents a class of organisms (bivalves) not presently represented. This clam is not a standard test organism, however, the U.S. EPA has written a draft test method for estimating toxicity of effluents using *Mulinia* (Morrison and

Petrocelli, 1990a; 1990b).

3.2.2 Test Procedures

Test procedures and culture methods previously described in the year 1 report for the 8 day larval sheepshead minnow survival and growth test, 8 day larval grass shrimp survival and growth test and 8 day *E. affinis* life cycle test were used for this study (Hall et al., 1991). The test procedures for the coot clam described in the year 3 report were also used for these experiments (Hall et al. 1994). The sources for the four species were as follows: sheepshead minnows, Aquatic Biosystems, Denver, Colorado; grass shrimp, S.P. Engineering and Technology, Salem, Massachusetts; *E. affinis*, in-house cultures (orginally from University of Maryland - Chesapeake Biological Laboratory) and coot clams (U. S. EPA Laboratory in Narragansett, Rhode Island).

3.2.3 Statistical Analysis

Univariate statistical tests described in Fisher et al. (1988) were used for each test species when appropriate. The goal of this study was not to generate typical LC50 data with various dilutions of ambient water. For each test species response, control and test conditions (100 percent ambient water) were compared using a one-way Analysis of Variance (ANOVA). A statistical difference between the response of a species exposed to a control condition and an ambient condition was used to determine toxicity. Dunnett's (parametric) or Dunn's (non-parametric) mean testing procedures were used in cases where comparisons of a species response on a spatial scale was necessary.

3.2.4 Sample Collection, Handling and Storage

Sample collection, handling and storage procedures used in the previous pilot study were implemented (Hall et al., 1991). Ambient water was collected from all study areas and taken to our toxicity testing facility at the Wye Research and Education Center, Queenstown, Maryland for testing.

Grab samples were used because they are easier to collect, require minimum equipment (no composite samplers), instantaneous toxicity is evaluated, and toxicity spikes are not masked by dilution. Grab samples collected from each station represented a composite of the water column (top, mid-depth and bottom). A metering pump with teflon line was used to collect samples in 13.25 L glass containers.

The time lapsed from the collection of a grab sample and the initiation of the test or renewal did not exceed 72 hours. Samples were collected on days 0, 3 and 6 during the 8 day tests. All samples were chilled after collection and maintained at 4°C until used. The temperature of the ambient water used for testing was 25°C. Salinity adjustments (increase) were performed on samples collected from less saline sites to obtain a standard test salinity of 15 ppt.

3.2.5 Quality Assurance

A copy of our Standard Operating Procedures (SOP) Manual was submitted and approved by the sponsor prior to the study (Fisher et al., 1988). Standard Quality Assurance (QA) procedures used in our laboratory for The State of Maryland's Effluent Toxicity Testing Program were followed (Fisher et al., 1988). These QA procedures were used during the previous three years of ambient toxicity testing study. The control water used for these experiments was obtained from a pristine area of the Choptank River. The water was autoclaved and filtered with a 1 um filter. Hawaiian (HW) Marine sea salts were used to salinity adjust samples to 15 ppt. The pH was also adjusted to 7.5 to 8.0 after salinity adjustment.

Acute reference toxicant tests with cadmium chloride were conducted with the same stocks of species used for ambient toxicity tests. Cadmium chloride was selected as the reference toxicant because there is an established data base with this chemical for all of the proposed tests. Reference toxicity tests were used to establish the validity of ambient toxicity data generated from toxicity tests by ensuring that the test species showed the expected toxic response to cadmium chloride (Fisher et al., 1988). The reference toxicant tests were conducted on each test species and source (of species) once during this study using procedures described in Hall et al., 1991.

3.2.6 Contaminant Analysis and Water Quality Evaluations

The contaminant analyses used for these studies provided limited information on selected contaminants that may be present in the study areas. It was not our intention to suggest that the proposed analysis for inorganic contaminants would provide an absolute "cause and effect relationship" between contaminants and biological effects if effects were reported. Information on suspected contaminants in the study areas may, however, provide valuable insights if high potentially toxic concentrations of inorganic contaminants were reported in conjunction with biological effects.

Aqueous samples for analysis of inorganic contaminants listed in Table 3.1 were collected during the ambient toxicity tests. These contaminants and methods for their measurement have been evaluated in our previous ambient toxicity testing study (Hall et al., 1991). Analytical procedures and references for analysis of these samples are presented in Table 3.1. Total inorganic contaminant analysis were conducted on filtered samples using 0.40 um polycarbonate membranes. The Applied Marine Research Laboratory of Old Dominion University was responsible for inorganic analysis.

Standard water quality conditions of temperature, salinity, dissolved oxygen, pH and conductivity was evaluated at each site after sample collection. These conditions were evaluated every 24 hours at all test conditions during the tests.

3.3 Sediment Toxicity Tests

All tests and analyses were conducted according to the SOPs and QA plans previously submitted to the sponsor. The methods described in this report are general summaries of those protocols.

3.3.1 Test Species

Sediment samples (100 percent ambient sediment samples) from twelve stations were tested using four organisms: eggs of the sheepshead minnow *Cyprinodon variegatus*, the amphipods *Lepidactylus dytiscus* and *Leptocheirus plumulosus*, and the polychaete worm *Streblospio benedicti*.

3.3.2 Test Procedures

All tests were conducted for 10 days at 25°C and monitored daily. Daily monitoring in the sheepshead test included the assessment of egg and larval mortality, hatching success and water quality parameters (Hall et al., 1991) until the end of the test. On day 10 of the *S. benedicti*, *L. plumulosus*, and *L. dytiscus* tests, mortalities were recorded, and the animals were returned to the original test containers. The organisms were then monitored daily for an additional 10 days. Numbers of live animals were recorded on day 20. Any living organisms were preserved for length and weight measurements.

The sediment samples were collected from six sites in the Patapsco River (Bear Creek, Curtis Creek, Middle Branch, Northwest Harbor, Outer Harbor and Sparrows Point), two sites in the Sassafras River (Betterton, Turner Creek), two sites in the Magothy

Table 3.1 Analytical methods used for inorganic analysis in water samples. The following abbreviations are used: Atomic Emission - ICP (AE-ICP), AA-H (Atomic Absorption - Hydride), AA-F (Atomic Absorption - Furnace) and AA-DA (Atomic Absorption - Direct Aspiration) and AA-CV (Atomic Absorption - Cold Vapor).

Contaminant	Method	Method #	Reference
Arsenic	AA-H	206.3	U.S. EPA, 1979
Cadmium	AA-F	213.2	U.S. EPA, 1979
Chromium, Total	AA-F	218.2	U.S. EPA, 1979
Copper	AA-F	220.2	U.S. EPA, 1979
Lead	AA-F	239.2	U.S. EPA, 1979
Mercury	AA-CV	245.1	U.S. EPA, 1979
Nickel	AA-F	249.2	U.S. EPA, 1979
Selenium	AA-H	270.3	U.S. EPA, 1979
Zinc	AA-DA	200.7	U.S. EPA, 1979

River (South Ferry, Gibson Island), and two sites from the Severn River (Junction Route 50, Annapolis). Control sediments for each species consisted of native sediments from the area in which the test organisms were collected or naturally occur. Control and reference sediments (see below) were tested with each set of test samples. Reference sediments were employed to assist in determining any possible naturally occurring geochemical and physical conditions inherent to the sediment being tested which may influence mortality.

Because of the large range in particle size between test sites observed in past studies, two reference sediments were used with each organism per test. These reference sediments bracketed the sediment particle sizes found at the selected test sites. For example, one reference sediment most closely matched the test site with highest sand proportion and one reference most closely matched the test site with highest silt/clay proportion. Reference and control sediments were designated as follows: (1) Lynnhaven sand, (2) Lynnhaven mud, and (3) Poropatank sediment. Lynnhaven mud was used as the control sediment for *S. benedicti* and *C. variegatus* eggs, Lynnhaven sand was used as the control for *L. dytiscus*, and Poropatank sediment was used as the control for *L. plumulosus*. Lynnhaven sand (97.55 percent sand) and Poropatank sediment (1.14 percent sand) bracket the particle size of all test samples and were therefore considered suitable as reference sediments as well. The test sediment samples were also analyzed for sand, silt, and clay content, and the particle size/composition of the test sediments (Table 3.2) were quite variable even between replicates at the same site.

The culture and maintenance procedures used for *the polychaete S. benedicti* the amphipod *Lepidactylus dytiscus* are described in Hall et al. (1991). *Leptocheirus plumulosus* and the sheepshead minnow egg tests are described in Hall et al. 1994.

3.3.3 Statistical Analysis of Sediment Data

The goal of this study was not to generate LC50 data from dilution series tests. The main objective was to evaluate for each test species, the response (mortality, growth, etc.) when tested in 100 percent ambient sediment, as compared to a control. Statistical differences between the responses of species exposed to control and ambient sediments were used to determine the toxicity. Evaluations relative to particle size effects were made based on the response seen in the reference sediments. Sheepshead egg data were evaluated using ANOVA contrasts and compared to the

Table 3.2 Particle size analysis of sediments from Twelve stations and references and controls used in toxicity tests. Samples collected 10/6-10/7/94.

Station	% Sand	% Silt	% Clay
Annapolis R1	42.80	35.61	21.60
Annapolis R2	26.74	46.62	26.63
Annapolis R3	18.56	52.75	28.69
Annapolis R4	38.64	37.72	23.63
Annapolis R5	21.62	49.57	28.81
Betterton R1	9.16	65.92	24.91
Betterton R2	4.74	66.52	28.72
Betterton R3	8.85	65.30	25.85
Betterton R4	7.70	66.46	25.84
Betterton R5	4.18	69.93	25.89
Bear Creek R1	81.66	11.40	6.93
Bear Creek R2	23.06	53.84	23.10
Bear Creek R3	10.99	56.50	32.52
Bear Creek R4	8.66	63.48	27.86
Bear Creek R5	2.59	74.25	23.17
Curtis Bay R1	16.53	50.54	32.92
Curtis Bay R2	33.21	40.51	26.27
Curtis Bay R3	3.02	65.50	31.48
Curtis Bay R4	8.46	54.68	36.86
Curtis Bay R5	2.06	64.40	33.54
Gibson Island R1	94.61	3.00	2.39
Gibson Island R2	94.34	3.04	2.62
Gibson Island R3	30.95	43.60	25.45
Gibson Island R4	24.75	47.42	27.83
Gibson Island R5	15.72	53.36	30.93
Junction Rt 50 R1	45.57	33.65	20.78
Junction Rt 50 R2	10.02	54.59	35.38
Junction Rt 50 R3	8.22	55.42	36.35
Junction Rt 50 R4	5.93	56.16	37.90
Junction Rt 50 R5	6.69	55.66	37.65
Outer Harbor R1	2.90	57.57	39.53
Outer Harbor R2	2.32	58.89	38.79
Outer Harbor R3	7.03	54.69	38.28
Outer Harbor R4	1.67	60.39	37.94
Outer Harbor R5	2.85	55.95	41.20
Middle Branch R1	7.33	63.59	29.08
Middle Branch R2	6.98	64.39	28.62

Table 3.2(con't) Particle size analysis of sediments from Twelve stations and references and controls used in toxicity tests. Samples collected 10/6-10/7/94.

Station	% Sand	% Silt	% Clay
Middle Branch R3	7.73	63.55	28.72
Middle Branch R4	0.14	4.88	94.98
Middle Branch R5	3.47	67.90	28.63
Northwest Harbor R1	70.04	19.97	9.99
Northwest Harbor R2	40.71	39.62	19.67
Northwest Harbor R3	9.97	58.01	32.02
Northwest Harbor R4	12.82	54.73	32.45
Northwest Harbor R5	1.37	59.97	38.66
South Ferry R1	74.34	15.87	9.79
South Ferry R2	13.50	52.94	33.56
South Ferry R3	11.49	53.53	34.98
South Ferry R4	8.59	54.54	36.87
South Ferry R5	13.77	0.18	86.05
Sparrows Point R1	0.77	61.57	37.67
Sparrows Point R2	2.19	66.04	31.77
Sparrows Point R3	3.36	60.72	35.92
Sparrows Point R4	2.90	64.24	32.86
Sparrows Point R5	0.55	64.90	34.55
Turner's Creek R1	74.79	17.71	7.50
Turner's Creek R2	43.96	38.47	17.57
Turner's Creek R3	37.93	47.09	14.98
Turner's Creek R4	39.51	44.82	15.67
Turner's Creek R5	44.92	39.10	15.98
Poropatank	1.14	63.77	35.09
Lynnhaven Mud	37.86	48.97	13.17
Lynnhaven Sand	97.55	1.18	1.27

controls. Evaluation of total mortality was assessed by combining egg mortality, larval mortality, and unhatched eggs remaining at the termination of the test. Unhatched eggs were included as mortality based upon previous observations and the assumption that probability of hatching and thus survival decreases essentially to zero by test termination.

For all other tests, the statistical approaches that were employed in the first two years of the study (Hall et al., 1992) were again utilized in the fourth year. Basically, the analyses consisted of analysis of variance (ANOVA) models with *a priori* tests of each treatment contrasted to the controls. Arcsine transformations were used for the percent mortality data. Mortality was corrected for particle size effects using the regression equations presented in year 2 of the study. Length and weight were expressed as percentage of change from the initial length and weight measurements.

3.3.4 Sample Collection, Handling and Storage

The general sediment sample collection, handling, and storage procedures described in Hall et al. 1991 were used in this study. Sediment samples were collected at each site by Applied Marine Research Laboratory (AMRL) personnel and returned to the laboratory for testing. The sediments were collected October 7-8, 1994 by petite ponar grab. True field replicates were maintained separately for transport to the laboratory. Sediment was collected at each site by first randomly identifying 5 grab sample locations along a 100 meter square grid. At each site a discrete field subsample was collected for bioassays and stored on ice. A separate subset from the same ponar grab series was placed into a handling container. Subsamples from all 5 sites within a station were serially placed into the same handling container. When all 5 sites within the station had been sampled, the entire batch was homogenized and distributed into the sample containers designated for chemical analyses. All samples were transported on ice, out of direct sunlight. Bioassay samples were held in refrigerators at 4°C until initiation of the toxicity tests. Samples for chemical analysis were frozen and stored until tested. All samples were analyzed within EPA recommended holding times.

3.3.5 Quality Assurance

All quality assurance procedures submitted previously to the sponsoring agency were implemented following the testing protocols and associated SOP's. Laboratory quality assurance procedures for sediment and pore water and inorganic and organic chemical analyses followed standard EPA quality assurance guidelines.

Toxicity test sediment controls consisted of sediment from sites where either the animals were collected, or the animals are naturally resident. Reference sediments were used to compare the effects non-toxicity related parameters such as sediment particle size, ammonia, nitrate, and total organic carbon (TOC) had on the test animals. Because of the apparent notable effect particle size has upon survival, and the large heterogeneity of particle size at the sites, two references sediments (high percent sand, high percent silt/clay) were used for *C. variegatus* and *S. benedicti* to bracket the particle sizes encountered at the test sites. Only one reference was used for each of the amphipods. It was necessary to use only one reference because the control sediment for each animal represented one end of the particle size scale in each case. The control for the *L. dytiscus* was at the high end of the sand scale, while the control for *L. plumulosus* represented the high end of the silt/clay scale. Other physico-chemical parameters were measured for comparison, but not controlled for in the references.

Static acute non-renewal water-only reference toxicant tests were performed for each species during each sampling period. Cadmium chloride was used as a reference toxicant for each animal because the existing laboratory data base is available for this chemical. Reference toxicant information was used to establish the validity and sensitivity of the populations of animals used in the sediment test. Seasonal changes in sensitivity have been observed previously in *L. dytiscus* (Deaver and Adolphson, 1990), therefore consideration of this QA reference data is paramount to proper interpretation.

3.3.6 Contaminant and Sediment Quality Evaluations

Contaminants were evaluated concurrently with toxicity tests. It was not our intention to suggest that the presence of inorganic and organic contaminants provide an absolute "cause and effect" relationship between contaminants and any observed biological effects. Information on suspected contaminants does however, provide valuable insights if high concentrations of potentially toxic contaminants were reported in conjunction with biological effects.

Sediment samples for organic contaminants analysis were collected in conjunction with bioassay sediment samples. The contaminants assayed are listed in Tables 3.3 and 3.4. Organic analytical procedures used were in accordance with a modified AOAC (Association Official Analytical Chemists) method 970.52M with EPA

Table 3.3 Concentrations for "Effects Range-Medium" levels for selected polynuclear aromatic hydrocarbons, as defined by Long and Morgan, 1990). NA=Not available.

Compound	ER-M Concentration (ug/g)
Naphthalene	2.100
Acenaphthene	0.650
Fluorene	0.640
Phenanthrene	1.380
Anthracene	0.960
Fluoranthene	3.600
Pyrene	2.200
Benzo (a) anthracene	1.600
Chrysene	2.800
Benzo (a) pyrene	2.500
Indeno (1,2,3-cd) pyrene	NA
Dibenzo (a,h) anthracene	0.260
Benzo (g,h,i) perylene	NA

Table 3.4 Pesticides analyzed, utilizing a user-created calibration library. Sediment method detection limits (MDL) are reported in μg/kg dry weight.

COMPOUND	SEDIMENT MDL
Hexachlorobenzene	0.0035
Aldrin	0.0041
Alpha-BHC	0.0061
Beta-BHC	0.0058
DDD	0.0034
DDE	0.0027
DDT	0.0023
Dieldrin	0.0093
Endrin	0.0076
Heptachlor	0.0030
Heptachlor Epoxide	0.0015
Alpha-Chlordane	0.0007
Gamma-Chlordane	0.0016
Alachlor	0.0050
Metolachlor	0.0065
Trifluralin	0.0038
Chlorpyrifos	0.0016
Fenvalerate	0.0017
Lindane	0.0043
Permethrin	0.0077
2,3',5-Trichlorobiphenyl	0.0031
2,4,4'-Trichlorobiphenyl	0.0012
2,2',4,4'-Trichlorobiphenyl	0.0013
Methoxychlor	0.0026

clean-up 3660A for sulphur. Organophosphorus compounds were analyzed by GC/FPD; organochlorine compounds by GC/FCD using EPA 508 GC conditions. PAH's were analyzed using EPA method 550 HPLC conditions.

All sediment samples were analyzed for acid volatile sulfides (AVS) and Total Organic Carbon (TOC). Samples were frozen until analysis, at which time they were thawed, then homogenized by gently stirring. Sediment samples were analyzed for AVS using the method of DiToro et al., (1990). Details of the analytical procedures for both AVS and TOC are described in Hall et al., 1991. Pore water samples were removed from all sediment samples by squeezing with a nitrogen press. All pore water samples were filtered then frozen until analyses of ammonia, nitrite and sulfides were conducted. These analyses were conducted on all samples. Details of the methods are described in Hall et al., 1991.

All sediment samples were analyzed for the following bulk metals: aluminum, cadmium, chromium, copper, lead, nickel, tin and zinc, using an ICP (inductively coupled plasma atomic emission spectroscopy) following USEPA/SW-846, Method 6010 (see Hall et al., 1991). In addition, a Simultaneously Extractable Metals (SEM) analysis was conducted on all samples to use with the AVS data to determine the potential toxicity of the sediment due to metals. The sample for the SEM analysis was obtained from a step in the AVS procedure. The AVS method was detailed in Hall et al. 1991. The SEM sample was the sediment suspension remaining in the generation flask after the cold acid extraction had been completed. The sediment suspension was filtered through a 0.2 micron membrane filter into a 250 ml volumetric flask. The sample was then diluted to volume with deionized water. The concentrations of the SEM were determined by EPA-600/4-79-020 Methods for Chemical Analysis of Water and Wastes (U.S. EPA, 1979). Cadmium, lead, copper, nickel, and zinc were determined by ICP following U.S.EPA method number 200.7. Mercury was determined by cold vapor generation following USEPA method number 245.1. The concentrations were then converted to micromoles per gram dry sediment and were added together to give total SEM.

3.4 Analysis of Four Year Data Base

A series of summary statistical analyses were conducted in order to provide environmental managers with summary information concerning the relative toxicity of water and sediments from the collection areas. These analyses also provide quantitative indicators of the degree of confidence which may be given to differences between responses observed for "clean" ("reference") conditions and those seen for test media (water or sediments) of unknown quality. These analyses are based upon the summary composite indices first developed for the toxicity axis of the "sediment quality triad" (Long and Chapman, 1985; Chapman, 1986; Chapman et al. 1987, Chapman 1990). This approach has been modified to provide confidence limits on composite indices designated as "ratio-to-reference mean" (RTRM) indices (Alden, 1992). Details of the calculation of the RTRM indices for the Ambient Toxicity Program are presented in the Year 3 report (Hall et al., 1994).

In order to make the RTRM indices more meaningful to managers, a method was developed to scale the values, so that they range between a "best case" (uncontaminated) condition, represented by a score of 0 and a "worst case" (highly contaminated and toxic) condition, represented by a score of 100. A value of 0 would represent the median response of a reference test of uncontaminated water or sediment, while a value of 100 would represent a condition producing the maximum detrimental responses in all of the endpoints (e.g. no growth, reproduction, or survival of all test populations). Not only does this sort of scaling provide a "frame of reference" to address the question of "how bad is this site?", but it allows scores of RTRM indices from different years (which may have had different numbers of endpoints) to be evaluated on the same scale. This well-defined scaling system is much more readily interpreted than the sediment quality triad RTR values or the RTRM indices, which have a reference value of 1, but have an open-ended scale for toxic conditions, the maximum value of which depends upon the number of endpoints, the magnitude of the test responses, and the reference response values used in the calculations.

The scaled RTRM index, hereafter designated as "toxicity index" or TOX-INDEX, was calculated as follows. The RTRM values and confidence limits were calculated as in previous years (Hall et al., 1994). The reference median for any given site was subtracted from all reference and test values (medians, lower and upper confidence limits). This step scales the reference median to 0. The values are then divided by a "worst case" constant for each test data set. This "worst case" constant is calculated by taking the test data set and setting the values to the maximum detrimental responses for each endpoint (e.g. no survival, growth, reproduction, hatching of eggs, etc.), calculating the RTRM values for these "worst case" conditions by dividing by the appropriate reference means (i.e.,for the sediment data set, each sample was matched to the reference data set that most closely matched the sediment characteristics) and calculating the "worst case" constant as the mean of RTRM values for all endpoints. The division by the "worst case" constant makes all values (medians and confidence limits) a fraction of the "worst case" condition. The TOX-INDEX values are converted to a percentage scale by multiplying by 100. The TOX-INDEX medians and confidence limits for test and reference conditions of each site are plotted on maps of the Bay to indicate the relative toxicity of various geographic locations. For graphical purposes, the lower confidence limits of the reference data are not shown, unless the test confidence limits overlap those of the reference conditions (i.e. a portion of the confidence limits for both the test and reference conditions are less than zero).

In order to provide more information to the TOX-INDEX maps, pie charts are included to indicate the relative percentage of endpoints that were shown to be different between the test and reference data sets in the RTRM simulations. Therefore, a highly toxic site would not only be shown to have high TOX-INDEX values which display a low degree of uncertainty (i.e., to have narrow confidence bands that are well separated from reference conditions), but it would also be shown to have a high percentage of endpoints that were adversely affected by the toxic conditions.

This type of presentation should provide managers with a tool to evaluate the relative ecological risk of the sites in comparison to each other. A site with TOX-INDEX confidence limits that overlap those of a reference site, and which displays few statistically significant endpoints, would be expected to pose little ecological risk with respect to ambient toxicity. On the other hand, a site displaying a large TOX-INDEX value, with confidence limits that are well separated for the reference condition and with many significantly impacted endpoints would be expected to pose a much greater ecological risk. The ecological significance of toxicity at sites with intermediate TOX-INDEX scores would have to be interpreted through the best professional judgement of scientists and managers, although the relative magnitude of the values does provide information on the relative degree of toxicity with respect to other sites. Although absolute ecological risk assessments would require much more intensive biological evaluations of long-term population and community level effects, TOX-INDEX provides a screening system that indicated the relative ranking by which regions can be prioritized for management actions related to toxicity. Thus, the maps provide quantitative indications of the magnitude, certainty and consistency of toxic effects.

The site location symbols in the TOX-INDEX maps indicate the degree to which water or sediment benchmarks (water quality criteria or ER-M values, respectively) were exceeded. Thus, the maps also display the qualitative degree of chemical contamination.

SECTION 4

RESULTS

4.1 Water Column Tests

The following results from water column tests are presented below: toxicity data, contaminants data, water quality data and toxicity data from reference toxicant tests.

4.1.1 Toxicity Data

Survival, growth, reproduction and percent normal shell development from the four estuarine tests conducted from 10/11/94 to 10/19/94 (or 10/12/94 to 10/20/94) are presented in Tables 4.1 - 4.6. Survival of sheepshead minnows, grass shrimp, and *Eurytemora* in the controls was not significantly different after 8 days of exposure when compared with the 12 ambient test conditions. However, growth of sheepshead minnows was significantly lower at the Sassafras River-Betterton station when compared with the controls. There were no significant differences in growth of sheepshead minnnows at the other 11 stations when compared with the controls. Growth of grass shrimp was not significantly different in ambient water from the 12 stations when compared with the controls. Reproductive endpoints for *Eurytemora* (mean % gravid females and mean % immatures) at all the ambient stations were not significantly different than the controls.

Percent normal shell development for the coot clam was significantly reduced at the following stations during the first test: Sassafras River - Betterton, Sassafras River - Turner Creek, Baltimore Harbor - Bear Creek, Baltimore Harbor - Curtis Bay, Baltimore Harbor - Middle Branch, Baltimore Harbor - Northwest Branch, Baltimore Harbor - Outer Harbor, Magothy River - Gibson Island, Severn River - 50/301 Bridge and Severn River - Annapolis Sailing School (Table 4.6). For test 2, percent normal shell development was significantly reduced at the Magothy River - South Ferry. There were no significant effects at any of the other stations.

4.1.2 Contaminants Data

Inorganic contaminants data from the 12 sites are presented in Table 4.7. Metals were generally low at all location based on the one grab sample collected at each station during the study. Only one metal (copper value of 3.85 ug/L at the Baltimore Harbor - Bear Creek station) exceeded the U.S. EPA marine water quality

Table 4.1 Survival data for sheepshead minnow larvae after 8 d tests at 12 stations from 10/11/94 to 10/19/94.

	Cumulative Percent Survival Per Day							
Station	1	2	3	4	5	6	7	8
CONTROL	100	100	100	100	100	100	100	100
SASBT(Sassafras-Betterton)	100	100	100	100	100	100	100	100
SASTC(Sassafras-Turner C.)	100	100	100	100	100	100	100	100
BHBCR(Bal Harb-Bear Cr.)	100	100	100	100	100	100	100	100
BHCUB(Bal Harb-Curtis B.)	100	100	100	100	100	100	100	100
BHMBR(Bal Harb-Middle B.)	100	100	100	100	100	100	100	100
BHNWB(Bal Harb-NW Br.)	100	100	100	100	100	100	100	100
BHOTH(Bal Harb-Outer H.)	100	100	100	100	100	100	100	100
BHSPT(Bal Harb-Sparrows P)	100	100	100	100	100	100	100	100
MAGGI(Magothy-Gibson I.)	100	100	100	100	100	100	100	100
MAGSF(Magothy-South F.)	100	100	100	100	100	100	100	100
SEV50(Severn-Rt.50)	100	100	100	100	100	100	100	100
SEVAP(Severn-Annapolis)	100	100	100	100	100	100	100	100

Table 4.2 Survival data for grass shrimp larvae after 8 d tests at 12 stations from 10/12/94 to 10/20/94.

	Cumulative Percent Survival Per Day							
Station	1	2	3	4	5	6	7	8
CONTROL	100	96	96	96	92	92	92	88
SASBT	100	96	96	96	96	96	92	92
SASTC	100	96	96	96	92	92	92	92
BHBCR	100	100	100	100	100	100	100	96
BHCUB	100	100	100	100	100	100	96	84
BHMBR	96	96	96	96	96	96	96	92
BHNWB	96	96	96	96	96	96	96	96
BHOTH	100	100	100	100	100	100	100	96
BHSPT	100	100	100	100	96	96	96	96
MAGGI	100	96	96	96	96	96	92	88
MAGSF	100	100	100	100	100	100	100	100
SEV50	100	100	100	100	100	100	96	96
SEVAP	100	100	100	100	100	100	100	100

Table 4.3 Survival data for *Eurytemora* after 8 d tests at 12 stations from 10/12/94 to 10/20/94.

Station	Mean Percent Survival	±S.E.	Mean Percent Gravid Female	±S.E.	Mean Percent Immature	±S.E.
CONTROL	93.2	7.2	55.2	3.1	6.8	2.5
SASBT	81.8	4.2	37.9	5.9	5.1	2.9
SASTC	76.7	10.6	41.8	5.9	2.8	2.8
BHBCR	72.6	10.0	43.2	6.8	1.7	1.7
BHCUB	94.8	8.5	43.4	8.1	12.9	3.7
BHMBR	96.3	13.6	53.7	7.3	1.6	1.6
BHNWB	89.7	6.5	44.4	8.8	4.1	2.5
BHOTH	83.4	5.6	43.6	6.2	0.0	0.0
BHSPT	69.2	22.5	23.2	7.9	0.0	0.0
MAGGI	66.1	4.3	41.2	6.1	0.0	0.0
MAGSF	88.0	7.0	58.1	10.8	4.2	2.5
SEV50	61.5	18.6	42.4	4.0	1.6	1.6
SEVAP	52.5	7.5	43.9	2.4	3.1	3.1

Table 4.4 Growth data for sheepshead minnow larvae from the 10/11/94 to 10/19/94 experiment. Growth data are the mean final weight per individual at day 8.

Sheepshead larvae dry weight (initial weight at day 0=0.16 mg)			
Station	n	Mean Wt. (Mg)	±S.E.
CONTROL	38	1.44	0.064
SASBT	40	1.13[a]	0.036
SASTC	29	1.36	0.038
BHBCR	39	1.42	0.092
BHCUB	29	1.39	0.064
BHMBR	38	1.59	0.046
BHNWB	40	1.33	0.154
BHOTH	30	1.52	0.056
BHSPT	39	1.18	0.076
MAGGI	38	1.48	0.068
MAGSF	40	1.47	0.044
SEV50	40	1.34	0.024
SEVAP	39	1.37	0.024

[a]Significantly different at P<0.05 using Dunnett's test.

Table 4.5 Growth data for grass shrimp larvae from the 10/12/94 to 10/20/94 experiment. Growth data are the mean final weight per individual at day 8.

Sheepshead larvae dry weight (initial weight at day 0=0.14 mg)			
Station	n	Mean Wt. (mg)	±S.E.
CONTROL	22	0.81	0.047
SASBT	23	0.80	0.025
SASTC	21	0.76	0.041
BHBCR	24	0.88	0.050
BHCUB	22	0.82	0.070
BHMBR	23	0.80	0.023
BHNWB	24	0.73	0.039
BHOTH	24	0.78	0.042
BHSPT	24	0.77	0.034
MAGGI	22	0.80	0.037
MAGSF	24	0.82	0.054
SEV50	14	0.81	0.046
SEVAP	25	0.76	0.039

Table 4.6. Percent normal shell development from two 48 h coot clam embyro/larval tests conducted from 10/14/94 (Test 1) and from 10/17/94 to 10/19/94 (Test 2).

	Test 1		Test 2	
Station	Percent Normal	±S.E.	Percent Normal	±S.E.
CONTROL	98.0	0.68	95.2	0.94
SASBT	87.2[a]	0.74	92.5	1.72
SASTC	89.0[a]	3.91	93.7	1.26
BHBCR	91.8[a]	3.61	96.5	1.01
BHCUB	92.3[a]	1.57	93.5	0.68
BHMBR	91.7[a]	1.34	94.3	1.87
BHNWB	92.6[a]	2.00	95.7	0.82
BHOTH	89.3[a]	0.54	96.7	1.45
BHSPT	94.4	1.18	93.3	1.74
MAGGI	90.3[a]	2.03	93.6	1.22
MAGSF	95.7	1.13	86.9[a]	0.28
SEV50	91.1[a]	0.86	95.4	1.20
SEVAP	93.0[a]	0.95	93.7	1.03

[a]Significantly different at $P<0.05$ using Dunnett's test.

Table 4.7 Inorganic contaminants data from the 12 stations sampled during the fall of 1994 (10/12/94 - 10/20/94). Marine U.S. EPA acute water quality criteria (WQC) are listed beside each metal. All values exceeding the criteria are underlined.

Metals & WQC $\mu g/L$)	Stations											
	SASBT	SASTC	BHBCR	BHCUB	BHMBR	BHNWB	BHOTH	BHSPT	MAGGI	MAGSF	SEV50	SEVAP
As (-)	1.25	1.01	1.13	1.55	1.49	1.90	2.2	1.37	1.37	1.49	1.25	1.49
Cd (9.3)	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
Cr (50)	<0.50	<0.50	<0.50	1.30	<0.50	1.2	<0.50	1.40	0.60	<0.50	1.30	2.3
Cu (2.9)	1.35	2.26	3.85*	2.47	2.40	2.17	1.90	2.08	2.66	1.38	1.39	2.12
Pb (5.6)	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Hg (0.025)	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25
Ni (8.3)	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	6.62	<5.0	<5.0	<5.0
Sc (54)	0.59	<0.25	<0.25	0.59	0.65	<0.85	0.25	<0.72	<0.25	<0.25	<0.25	<0.25
Zn (86)	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0

* Maryland estuarine acute copper criteria of 6.1 ug/L was not exceeded.

criteria.

4.1.3 Water Quality Data

Water quality parameters reported from grab samples collected three times at all stations are presented in Table 4.8. The temperature and salinity of ambient water collected from all sites was adjusted to 25°C and 15 ppt before testing. Ambient water quality conditions appeared adequate for survival of test species. Water quality conditions reported in test containers during testing are reported in Appendix A. All parameters appeared adequate for survival of test species.

4.1.4 Reference Toxicant Data

Forty-eight hour LC or EC50 values for the four test species exposed to cadmium chloride during reference toxicant tests are presented in Table 4.9. These toxicity values were compared with the values from the previous three years for all species except the coot clam where only year 3 data were available. Toxicity values for grass shrimp, sheepshead minnows and *Eurytemora* in this study were similar to values reported during the first three years. In all cases the fourth year values were between the low and high values for the first three years (except for *E. affinis*) Data from the reference toxicant tests indicate that test species from the various sources are healthy and ambient toxicity data were valid.

4.2 Sediment Tests

The following results from sediment toxicity tests are presented below: toxicity data, contaminants data, and data from reference toxicant tests.

4.2.1 Toxicity Data

Survival results from toxicity tests of the twelve estuarine sediments from the Patapsco, Sassafras, Magothy, and Severn Rivers for amphipods, worms and sheepshead minnow eggs are included in Tables 4.10 through 4.16. Those stations that were significantly different from the controls are so indicated. Growth data (mean length and dry weight) for amphipods and worms after 20 day exposure to sediments are included in Tables 4.14 through 4.16.

Survival in controls was greater than 84 percent and 74 percent at day 10 and day 20, respectively, for both amphipods and the polychaete worm. Survival data are summarized in Tables 4.10-4.13. Significant mortality was observed in all species compared with controls. Both *S. benedicti* and *L. dytiscus* showed the

Table 4.8 Water quality parameters reported in the field during water sample collection for the Fall of 1994.

Date	Station	Temp (C)	Salinity (ppt)	Cond umhos/cm	DO	pH
10-11-94	SASTC	16.0	1.5	2200	9.6	7.23
	SASBT	16.0	1.0	1750	10.1	8.23
	MAGSF	17.0	10.0	13000	7.2	7.42
	MAGGI	17.0	11.5	14500	7.8	7.74
	SEVAP	18.0	12.5	15500	7.8	7.93
	SEV50	17.5	11.0	14000	7.6	7.80
	BHCUB	17.0	11.5	15500	7.6	7.81
	BHNWB	18.5	12.0	17000	6.7	7.62
	BHMBR	18.0	11.5	16000	7.8	7.93
	BHBCR	17.5	11.0	15000	7.8	7.98
	BHSPT	18.0	11.5	16000	7.2	7.88
	BHOTH	16.0	11.0	15000	8.2	7.80
10-14-94	SASTC	16.3	2.0	2200	9.1	7.37
	SASBT	16.5	2.5	2750	8.6	7.76
	MAGSF	17.0	10.0	13500	8.2	7.68
	MAGGI	17.0	11.0	14000	8.4	7.80
	SEVAP	16.5	12.0	15000	8.6	7.95
	SEV50	17.0	11.0	14000	8.0	7.88
	BHCUB	16.0	12.5	15000	6.7	7.81
	BHNWB	16.5	13.0	17500	5.9	7.62
	BHMBR	16.0	12.5	16500	7.7	8.02
	BHBCR	16.0	12.0	15000	6.1	7.60
	BHSPT	16.5	12.0	15500	6.9	7.86
	BHOTH	15.0	12.0	15500	7.5	7.84
10-17-94	SASTC	15.5	2.0	--	8.5	7.40
	SASBT	16.0	2.5	--	9.3	7.67
	MAGSF	16.0	10.5	14200	8.6	7.55
	MAGGI	15.0	10.5	14000	8.8	7.76
	SEVAP	15.0	12.0	16000	9.0	8.05
	SEV50	16.0	11.5	15000	8.8	7.94
	BHCUB	14.0	12.5	15500	6.6	7.61
	BHNWB	15.5	13.0	17000	7.3	7.44
	BHMBR	14.5	11.5	14500	8.6	8.01
	BHBCR	16.0	11.5	15000	8.3	7.97
	BHSPT	15.5	12.0	15500	6.7	7.63
	BHOTH	14.0	12.0	15000	7.2	7.65

Table 4.9 Toxicity data (48 h LC50s or EC50s mg/L) from reference toxicant tests conducted with cadmium chloride for the four test species. Previous values from year 1, 2 and 3 are reported.

Date	Species	48 h LC50 (95% Conf Int)	Previous 48 h LC50 values Yr.1	Yr. 2	Yr. 3
09/23/94	Grass shrimp	0.723 (0.594-0.882)	0.502	0.230	1.340
09/29/94	Sheepshead minnow	0.710 (0.610-0.830)	0.510	1.540	1.180
09/09/94	*E. affinis*	0.143 (0.111-0.184)	0.021	0.095	0.120
11/10/94	Coot clam	0.008[a] (0.008-0.009)	-----	-----	0.005[a]

[a] Value is an EC50 (percent normal shell development is the endpoint).

Table 4.10 Survival data from *L. dytiscus* at the twelve stations. Tests were conducted from 10/11/94 to 11/1/94. "(R)" = Reference, "(C)"= Control. "SE" = Standard Error (n = 5).

Species	% Survival							
	Day 10				Day 20			
L. dytiscus	**Unadjusted**	**SE**	**Adjusted**	**SE**	**Unadjusted**	**SE**	**Adjusted**	**SE**
Station								
Annapolis	66.00*	6.00	87.32	4.99	13.00*	3.74	72.55	10.24
Betterton	51.00*	1.87	77.53*	2.79	12.00*	3.74	59.74*	4.77
Bear Creek	20.00*	7.42	25.97*	8.07	0.00*	0.00	7.84*	2.20
Curtis Bay	33.00*	3.75	48.47*	4.90	9.00*	2.92	30.32*	4.99
Gibson Island	70.00*	11.40	82.98*	7.20	30.00*	12.74	59.94*	7.29
Junction Rt 50	59.00*	26.78	83.19	8.25	9.00*	29.16	70.03	13.28
Outer Harbor	50.00*	6.52	77.34*	10.20	11.00*	4.00	66.05	12.58
Middle Branch	51.00*	4.00	78.22*	5.86	6.00*	1.87	60.84*	7.82
Northwest Harbor	1.00*	1.00	1.57*	1.57	0.00*	0.00	5.97*	0.60
South Ferry	53.00*	16.48	62.77*	14.64	33.00*	15.05	50.94	14.24
Sparrows Point	49.00*	3.67	76.47*	5.58	9.00*	1.87	59.99*	5.77
Turner's Creek	77.00	9.43	88.30	7.55	35.00*	10.49	75.01	10.76
Poropatank (R)	54.00*	6.78	82.75*	9.61	9.00*	5.34	71.70	12.74
Lynnhaven Sand (C)	99.00	1.00	99.47	0.52	89.00	3.67	90.90	2.93

NOTE 1: *Significantly different from controls ($p<0.05$).

NOTE 2: Adjusted *L. dytiscus* and *S. benedicti* survival is percent survival adjusted for predicted particle size effects.

Table 4.11 Survival data from *L. plumulosus* at the twelve stations. Tests were conducted from 10/1/94 to 11/1/94. "(R)" = Reference, "(C)"= Control. "SE" = Standard Error.

Species		% Survival			
		Day 10		Day 20	
L. plumulosus		**Unadjusted**	**SE**	**Unadjusted**	**SE**
	Station				
	Annapolis	73.00	5.15	65.00	3.54
	Betterton	81.00	9.14	58.00	12.31
	Bear Creek	0.00*	0.00	0.00*	0.00
	Curtis Bay	76.00	7.48	61.25	13.29
	Gibson Island	62.00*	10.07	54.00	10.00
	Junction Rt 50	67.00	11.02	58.00	12.90
	Outer Harbor	82.00	4.63	64.00	62.04
	Middle Branch	68.00	7.52	67.00	7.35
	Northwest Harbor	1.00*	1.00	0.00*	0.00
	South Ferry	76.00	6.00	70.00	5.70
	Sparrows Point	80.00	6.52	76.00	7.31
	Turner's Creek	91.00	4.30	89.00	4.30
	Poropatank (C)	84.00	7.31	74.00	8.86
	Lynnhaven Sand (R)	42.00	10.56	6.00*	2.45

NOTE 1: *Significantly different from controls ($p<0.05$).

Table 4.12 Survival data from *S. benedicti* at the twelve stations. Tests were conducted from 10/11/94 to 11/1/94. "(R)" = Reference, "(C)"= Control. "SE" = Standard Error.

Species	% Survival							
	Day 10				Day 20			
S. benedicti	**Unadjusted**	**SE**	**Adjusted**	**SE**	**Unadjusted**	**SE**	**Adjusted**	**SE**
Station								
Annapolis	33.33*	15.63	33.33*	15.63	26.67*	15.06	26.67*	15.06
Betterton	48.00*	12.36	48.00*	12.36	46.67*	12.82	46.67*	12.82
Bear Creek	50.67*	12.93	53.38*	14.64	37.33*	10.87	43.67*	14.45
Curtis Bay	49.33*	15.86	49.33*	15.86	33.33*	11.93	33.33*	11.93
Gibson Island	41.00*	11.04	48.96*	13.50	28.00*	8.27	46.48*	14.20
Junction Rt 50	41.33*	6.46	41.33*	6.46	29.33*	10.02	29.33*	1.00
Outer Harbor	74.66*	10.41	74.67*	10.41	62.67	15.14	62.67	15.14
Middle Branch	33.33*	13.50	33.33*	13.50	14.67*	8.00	14.67*	8.00
Northwest Harbor	42.67*	12.04	43.31*	12.01	8.00*	2.49	7.67*	3.15
South Ferry	60.00*	8.43	61.49*	8.85	53.33	13.50	56.02	13.10
Sparrows Point	46.67*	12.82	46.67*	12.82	37.33*	12.93	37.33*	12.93
Turner's Creek	49.33*	19.28	49.33*	19.28	37.33*	15.29	32.00*	17.05
Poropatank (R)	61.33*	7.42	62.66*	9.09	62.67	9.09	61.33	7.42
Lynnhaven Mud (C)	100.00	0.00	100.00	0.00	82.67	11.85	82.67	11.85
Lynnhaven Sand (R)	58.67*	6.46	77.34*	8.52	46.67	6.99	75.38	7.55

NOTE 1: *Significantly different from controls ($p<0.05$).

NOTE 2: Adjusted *L. dytiscus* and *S. benedicti* survival is percent survival adjusted for predicted particle size effects.

Table 4.13 Survival data from *C. variegatus* at the twelve stations. Tests were conducted from 10/11/94 to 11/1/94. "(R)" = Reference, "(C)"= Control.

Species	Station	% Survival	%Hatched	%dead fish	%dead eggs
C. variegatus					
	Annapolis	40.00*	42.00*	6.66	38.00*
	Betterton	80.00	80.00	0.00	10.00
	Bear Creek	4.00*	4.00*	0.00	14.00
	Curtis Bay	16.00*	26.00*	48.61*	24.00
	Gibson Island	76.00	86.00	10.22	10.00
	Junction Rt.50	70.00	70.00	0.00	12.00
	Outer Harbor	40.00*	42.00*	4.16	18.00
	Middle Banch	38.00*	42.00*	22.86	22.00
	Northwest Harbor	0.00*	2.00*	100.00*	18.00
	South Ferry	50.00*	64.00*	37.94*	22.00
	Sparrows Point	2.00*	6.00*	75.00*	28.00*
	Turner's Creek	70.00	72.00	3.13	10.00
	Poropatank (R)	88.00	90.00	2.22	8.00
	Lynnhaven Mud (C)	94.00	94.00	0.00	6.00
	Lynnhaven Sand (R)	100.00	100.00	0.00	0.00

Note: * indicates significantly different from control (α=0.05).
% Survival =1-[(Dead fish + dead eggs at test termination)/(# eggs exposed)]*100.
% Dead fish = (Dead fish)/(# hatched)*100
% Dead eggs = (Dead eggs)/(# exposed)*100
% Hatched = (# hatched)/(# eggs exposed)*100

Table 4.14 Growth data (dry weight and length) for *L. dytiscus* after 20-day exposure to sediments. Initial weight and length represent the mean and SE of 5 replicates of 20 animals each species at the start of the test. Data for each replicate is the mean of the surviving animals from each. Tests were conducted 10/11/94 through 11/1/94. "(R)" = Reference, "(C)"= Control.

Site	Number of True Replicates**	Weight(mg)	S.E.	Length(mm)	S.E.
L. dytiscus					
Initial	5	0.282	0.021	4.050	0.079
Annapolis	5	0.599	0.109	5.194	0.494
Betterton	5	0.469	0.105	4.837	0.361
Bear Creek	0	0.000	0.000	0.000	0.000
Curtis Bay	5	0.591	0.149	5.813	0.429
Gibson Island	4	0.504	0.103	5.168	0.338
Junction Rt.50	4	0.430	0.041	4.993	0.208
Outer Harbor	4	0.625	0.115	5.764	0.486
Middle Banch	4	0.746	0.204	5.878	0.523
Northwest Harbor	0	0.000	0.000	0.000	0.000
South Ferry	5	0.670	0.142	5.383	0.356
Sparrows Point	5	0.462	0.098	5.336	0.332
Turner's Creek	5	0.396	0.058	0.364	0.163
Poropatank (R)	4	0.460	0.438	5.034	0.248
Lynnhaven Sand (C)	5	0.372	0.102	4.341	0.050

*Significantly less than controls ($p < 0.05$).

Table 4.15 Growth data (dry weight and length) for *L. plumulosus* after 20-day exposure to sediments. Initial weight and length represent the mean and SD of 5 replicates of 20 animals each species at the start of the test. Data for each replicate is the mean of the surviving animals from each. Tests were conducted 10/11/94 through 11/1/94. "(R)" = Reference, "(C)"= Control.

Site	Number of True Replicates**	Weight(mg)	S.E.	Length(mm)	S.E.
L. plumulosus					
Initial	5	0.068	0.004	4.000	0.074
Annapolis	5	0.403	0.042	6.338	0.169
Betterton	5	0.390	0.094	6.611	0.437
Bear Creek	0	0.000	0.000	0.000	0.000
Curtis Bay	4	0.262*	0.061	5.884	0.453
Gibson Island	5	0.472	0.090	7.327	0.202
Junction Rt.50	5	0.581	0.061	7.395	0.189
Outer Harbor	5	0.433	0.110	6.795	0.327
Middle Banch	5	0.428	0.052	6.593	0.281
Northwest Harbor	0	0.000	0.000	0.000	0.000
South Ferry	5	0.438	0.063	6.941	0.259
Sparrows Point	5	0.343	0.048	6.229	0.221
Turner's Creek	5	0.794	0.063	8.050	0.375
Poropatank (C)	5	0.487	0.054	6.514	0.190
Lynnhaven Sand (R)	4	0.106*	0.027	4.891	0.393

*Significantly less than controls ($p < 0.05$).

Table 4.16 Growth data (dry weight and length) for *S. benedicti* after 20-day exposure to sediments. Initial weight and length represent the mean and SE of 5 replicates of 15 animals each species at the start of the test. Data for each replicate is the mean of the surviving animals from each. Tests were conducted 10/11/94 through 11/1/94. "(R)" = Reference, "(C)"= Control.

Site	Number of True Replicates**	Weight(mg)	S.E.	Length(mm)	S.E.
S. benedicti					
Initial	5	0.027	0.006	4.39	0.294
Annapolis	3	0.094	0.024	5.921	0.554
Betterton	5	0.015	0.004	3.909*	0.279
Bear Creek	4	0.021	0.004	3.478*	0.229
Curtis Bay	4	0.032	0.010	3.423*	0.552
Gibson Island	4	0.020	0.003	3.667*	0.397
Junction Rt.50	5	0.036	0.009	4.201*	0.173
Outer Harbor	5	0.037	0.008	4.973	0.112
Middle Banch	3	0.088	0.070	4.491	0.238
Northwest Harbor	2	0.080	0.040	2.364*	0.279
South Ferry	5	0.017	0.009	4.284*	0.064
Sparrows Point	5	0.008	0.002	3.676*	0.524
Turner's Creek	5	0.041	0.008	5.079	0.532
Poropatank (R)	5	0.038	0.004	4.904	0.266
Lynnhaven Mud (C)	5	0.030	0.006	5.364	0.239
Lynnhaven Sand (R)	5	0.015	0.001	3.382*	0.199

* Significantly less than controls ($p < 0.05$).

greatest number of sites with significant mortality effects. Bear Creek and Northwest Harbor (Patapsco River) sites showed the lowest survival for both *L. dytiscus* and *L. plumulosus* on both day 10 and day 20, while *S. benedicti* demonstrated the lowest survival at the Middle Branch (Patapsco River) and Annapolis (Severn River) sites. In the *Cyprinodon variegatus* egg tests, Bear Creek, Northwest Harbor, Sparrows Point and Curtis Bay sites resulted in the lowest survival (Table 4.13). On day 20, significantly reduced survival in the *L. dytiscus* was only observed in the Baltimore Harbor (Patapsco) sites with the exception of Betterton and Gibson Island when adjusting for particle size effects. Taking into consideration all potential significant survival effects after particle size adjustment, Patapsco river sites had 83% "hits", Sassafras River 50%, Magothy River 66% and Severn 41%. Those sites with the least number of "hits" were Turners Creek and Junction Route 50 with 2 hits each, both with *S. benedicti*.

Significant reduction in growth of *L. plumulosus* was reported in the Curtis Bay sediment. It should be noted that there were no survivors in the Bear Creek and Northwest Harbor sites: therefore, no growth data could be analyzed for these sites. Lynnhaven sand also caused decreased growth as compared with controls, however it is suspected that this was caused by insufficient food as indicated by the relatively low TOC (see Table 4.7) and not by toxicity. Particle size in the Lynnhaven Sand reference is nearly 100% sand. It is expected that food sources become limited during the test for *L. plumulosus*. The natural control sediment for *L. plumulosus* is only approximately 2% sand. For this reason it is expected that survival in this reference would be low after 20 days of exposure to uncontaminated but highly sand-laden sediments.

A number of sediments resulted in significantly reduced length in *S. benedicti* (Table 4.16). Only four of the twelve sites failed to demonstrate reduced lengths; Annapolis, Outer Harbor, Middle Branch, and Turners Creek.

4.2.2 Contaminants Data

Toxicity of chemicals in sediments is determined by the extent to which chemicals bind to the sediments. There are many factors that influence the binding capabilities of a particular sediment. The toxicity of non-ionic organic chemicals is related to the organic content of the sediments, and it appears that the bioavailability of many sediment-associated metals is related to the concentration of Acid Volatile Sulfides (AVS) present in the sediment (DiToro, 1990). Sediment samples from the twelve stations and the controls were analyzed for Total Organic Carbon (TOC) and Acid Volatile Sulfides (AVS). The results are shown in Tables 4.17 and 4.18. At present, there is no readily accessible data base for comparison of TOC normalized data, therefore the TOC analysis from this study was included to allow for future comparisons.

The AVS approach to sediment contaminants evaluation is still developmental (DiToro, 1990) and has yet to be incorporated into a standarized method for determining sediment quality criteria. To appropriately interpret the AVS data, simultaneously extractable metals (SEM) must also be analyzed. The data for SEM are presented in Table 4.19. In evaluating the AVS values, a ratio of the sum of the SEM to the total AVS is calculated. If the ratio is greater than one (1), toxicity is predicted, although if the total concentration of metals is very low, toxic effects may not be observed. If the SEM:AVS ratio produces a value less than one, it is assumed that there is sufficient AVS present in the sediment to bind with the metals, rendering them non-bioavailable and therefore non-toxic. Evaluation of the SEM to AVS ratio is included in Table 4.18. All stations had ratios much less than one, therefore toxicity due to metals would not normally be indicated. AVS in both the Bear Creek and Curtis Bay sediments is greatly elevated, therefore some consideration of the formation of sulfuric and other acids in the anoxic zones must be considered as a potential natural "toxicants", and may lead to mortality. Additionally, because the SEM value in the Bear Creek sediments is relatively high when compared to the other sites, the potential exists for toxicity to occur when these sediments are exposed to oxidizing conditions, whether in an aerated toxicity test or during winter storm events in the field.

Inorganic contaminants data from the twelve stations are presented in Table 4.20. All test sites had concentrations above the detection limits for ten of the eleven metals analyzed. The eleventh metal, tin, was below detection limit at several sites. The Lynnhaven sand and Lynnhaven mud sites had concentrations below detection limits for mercury, and tin, while the Poropotank sediment was below the detection limit for mercury. Sediment-sorbed contaminants have been extensively studied by Long and Morgan (1990). They have established a table of concentrations at which biological effects would be expected if these contaminants were present in the sediment. The lower ten percentile of data for which biological effects were observed was established as the "Effects Range-Low" (ER-L); and median concentrations for which biological effects were observed were identified as the "Effects Range-Median" (ER-M). Long and Morgan (1990) indicate that the ER-L

Table 4.17 Chemical data (TOC) for sediment samples from the six stations and the controls. All data are on a dry weight basis.

Station	Total Organic Carbon (%)
Annapolis	1.94
Betterton	2.89
Bear Creek	6.23
Curtis Bay	3.75
Gibson Island	1.07
Junction Rt.50	2.37
Outer Harbor	3.97
Middle Banch	2.97
Northwest Harbor	8.59
South Ferry	2.45
Sparrows Point	4.60
Turner's Creek	2.21
Poropatank (R)	3.53
Lynnhaven Mud (C)	1.39
Lynnhaven Sand (R)	<0.36

Table 4.18 Average SEM and AVS values and the SEM:AVS ratio for sediment samples tested in 1994.

	Mean AVS	Mean SEM	Ratio
Annapolis	8.97	4.476	0.499
Betterton	21.96	3.249	0.148
Bear Creek	294.00	39.872	0.136
Curtis Bay	136.44	8.213	0.060
Gibson Island	7.12	2.258	0.317
Junction Rt.50	11.49	4.057	0.353
Middle Banch	21.48	5.682	0.265
Northwest Harbor	77.69	7.837	0.101
Outer Harbor	69.51	11.441	0.165
South Ferry	22.44	2.771	0.123
Sparrows Point	59.69	15.412	0.258
Turner's Creek	25.20	2.657	0.105
Lynnhaven Sand	5.19	0.000	0.000
Lynnhaven Mud	4.85	0.947	0.195
Poropatank	25.76	1.189	0.046

Table 4.19 SEM analysis for sediments for sediments collected 10/7-10/8/94. Concentrations for each metal are expressed in umol per gram of sediment.

Site	Cadmium Mean	Copper Mean	Lead Mean	Nickel Mean	Zinc Mean	Sum Mean
Annapolis	0.045	0.576	0.214	0.271	3.371	4.476
Betterton	0.052	0.000	0.201	0.705	2.291	3.249
Bear Creek	0.268	0.000	0.872	0.516	38.216	39.872
Curts Bay	0.203	0.696	0.917	0.765	5.633	8.213
Gibson Island	0.000	0.156	0.115	0.187	1.800	2.258
Outer Harbor	0.154	1.175	0.676	0.443	8.993	11.441
Junction Rt. 50	0.060	0.390	0.272	0.359	2.976	4.057
Middle Branch	0.000	0.876	0.512	0.246	4.049	5.682
Northwest Harbor	0.000	0.178	1.608	0.225	5.826	7.837
South Ferry	.0.000	0.000	0.169	0.104	2.498	2.771
Sparrows Point	0.154	1.198	1.135	0.621	12.304	15.412
Turner's Creek	0.056	0.179	0.170	0.364	1.876	2.646
Detection Limits	0.0003	0.0050	0.0006	0.0004	0.0005	

NOTE:*All Mercury values were below detection limits of 0.00005 at all sites.

Table 4.19 (cont'):

SEM analysis for sediments collected 10/7-10/8/94. Concentrations for each metal are expressed in umol per gram of sediment.

	Cadmium	Copper	Lead	Nickel	Zinc	Sum
	Mean	Mean	Mean	Mean	Mean	Mean
Lynnhaven Sand	0.000	0.000	0.000	0.000	0.000	0.000
Lynnhaven Mud	0.000	0.089	0.047	0.000	0.810	0.947
Proropotank Mud	0.000	0.000	0.046	0.000	1.143	1.189
Detection Limits	0.0003	0.0050	0.0006	0.0004	0.0005	

NOTE: All Mercury values were below detection limits of 0.00005 in both sets for all sites.

Table 4.20 Inorganic contaminants for sediment samples from the Twelve stations and the controls. (Note: single underlined values represent concentrations exceeding "Effects Range-Low", and double underlined values represent concentrations exceeding "Effects Range-Median" levels listed below as defined in Long and Morgan, 1990). NA = not available; -- = not listed; < = values were less than those listed.

Site	Contaminant (ug/g dry weight)										
	Al	As	Cd	Cr	Cu	Pb	Hg	Ni	Se	Sn	Zn
Annapolis	22300.	59.2	0.83	189.	50.6	55.6	0.260	42.8	1.10	0.808	306
Bear Creek	8210.	52.6	12.3	1340.	207.	267.	0.380	44.5	5.19	537	2420
Betterton	33600.	47.2	1.52	64.0	59.4	67.5	0.202	93.3	1.80	0.882	358
Curtis Bay	18700.	127.	2.44	181.	264.	243.	0.603	37.2	9.10	3.93	461
Gibson Island	10100.	23.3	0.42	56.9	14.5	25.58	0.099	18.3	0.720	0.320	137
Junction Rt.50	25500.	57.4	1.09	125.	43.1	66.1	0.254	47.5	2.75	<0.301	276
Middle Banch	26400.	41.6	1.44	152.	150.	132.	0.394	47.3	2.10	1.06	339
Northwest Harbor	16200.	68.2	2.76	296.	599.	710.	0.482	40.8	24.6	1.86	497
Outer Harbor	24500.	93.5	1.47	362.	144.	118.	0.414	47.3	7.15	3.77	557
South Ferry	9240.	43.3	1.09	29.4	38.7	43.9	0.161	23.1	1.40	<0.301	199
Sparrows Point	30400.	64.0	2.19	396.	154.	178.	0.441	56.0	3.98	16.0	695
Turner's Creek	18200.	49.9	0.63	126.	17.9	35.3	0.095	34.3	0.926	0.466	143
Lynnhaven Sand	348.	11.0	0.148	0.691	0.150	1.20	<0.030	0.360	0.042	<0.301	2.16
Lynnhaven Mud	11400.	24.1	1.80	22.2	12.7	12.8	<0.030	11.8	0.204	<0.301	72.0
Poropatank	30000.	42.7	0.41	51.7	18.3	19.1	<0.030	23.0	0.680	.573	111
Detection Limit	0.301	0.015	0.030	0.003	0.003	0.003	0.030	0.006	0.015	0.301	0.003
Effects range:											
LOW	--	33	5	80	70	35	0.15	30	--	NA	120
MEDIAN	--	85	9	145	390	110	1.3	50	--	NA	270

and ER-M values can be used for comparisons between sites. The concentrations of toxicants in the sediments of the sites are compared with the ER-L or ER-M values, which are used simply as "benchmarks" for the relative degree of contamination. Those contaminants with concentrations exceeding the ER-L fall into a category that Long and Morgan (1990) consider to be the "possible" effects range for toxic effects. Contaminant concentrations above the ER-M fall in the category of "probable" toxic effects. Of course, many biogeochemical factors influence biological availability of contaminants in sediments, so comparisons of "bulk" chemical concentrations against these benchmark values represent rough attempts at ranking the relative potential of various sediments for toxicity. These comparisons are believed to be overly conservative in many cases, so theoretically-based approaches such as the SEM/AVS method described above should be given more weight in the interpretation of the data.

Inorganic analysis revealed one site (Bear Creek) exceeded the ER-M values for cadmium. Lead and zinc were found to exceed either the ER-L or ER-M at every test site, while chromium exceeded either one or the other of these levels at all but Betterton, Gibson Island and South Ferry. Similarly, mercury values exceeded either ER-L or ER-Ms at all but Turner Creek and Gibson Island. Arsenic exceeded these values at all but Gibson Island. Copper was not as widespread, however concentrations measuring nearly 3 times the ER-L were observed in Bear Creek sediments, and the Sparrows Point and Outer Harbor sites had values approaching twice to three times the ER-Ls.

The results of organic pesticides and semi-volatile compound analyses in sediment samples are presented in Appendix B. No pesticides exceeded either the ER-L or ER-M for these compounds (Long and Morgan 1990). Contamination by semi-volatile organic compounds was widespread, and exceeded the ER-Ms at a number of Baltimore Harbor (Patapsco River) sites. Most notably were the high concentration of both pyrene and dibenzo(a,h)anthracene. Some of the values reached nearly five times the ER-M for pyrene and over 22 times the ER-M for dibenzo(a,h)anthracene. Both of these values were observed at the Northwest Harbor site in the Patapsco River.

4.2.3 Pore Water Data

Sediment pore water was analyzed for sulfide, ammonia, and nitrite for all stations and the controls. The pore water data are shown in Table 4.21. Ammonia concentrations were converted to percent unionized ammonia for comparison with EPA criteria for

Table 4.21 Chemical data for pore water samples from the twelve stations and the references and controls.

Site:	Total Ammonia (mg/L)	Nitrite (mg/L)	Sulfide (mg/L)	Unionized Ammonia (mg/L)	Unionized Toxicity Limits (mg/L)
Annapolis	4.34	0.0142	0.0043	0.0350	0.0130
Bear Creek	8.69	0.0029	0.0154	0.2724	0.0517
Betterton	3.98	0.0029	0.0056	0.0796	0.0326
Curtis Bay	17.55	0.0110	0.0117	0.4398	0.0410
Gibson Island	6.56	0.0049	0.0043	0.0834	0.0206
Junction Rt.50	3.12	0.0055	0.0043	0.0397	0.0206
Middle Banch	4.16	0.0119	0.0105	0.0529	0.0206
Northwest Harbor	14.78	0.0006	0.0289	0.3704	0.0411
Outer Harbor	4.13	0.0156	0.0056	0.0525	0.0411
South Ferry	12.16	0.0032	0.0179	0.2433	0.0326
Sparrows Point	5.65	0.0119	0.0056	0.0456	0.0130
Turner's Creek	6.52	0.0090	0.0105	0.0526	0.0130
Lynnhaven Sand	3.67	0.0462	0.0400	0.0920	0.0082
Lynnhaven Mud	6.10	0.0225	0.0228	0.0311	0.0326
Poropatank	2.51	0.0095	0.0092	0.0502	0.0326

continuous concentrations for saltwater aquatic life. Values for sediment exposure concentrations have not been determined. Therefore these "comparison" values should be extremely conservative, as it is suspected that sediment organisms have developed either a greater tolerance for ammonia, or exhibit behaviors or physiological responses which enable them to live in high ammonia environments.

4.2.4 Reference Toxicant Data

The relative sensitivities of each set of test organisms was evaluated with reference toxicant tests. The results of each reference toxicant test conducted with each batch of amphipod, worms and Sheepshead minnows are shown in Table 4.22. All organisms were tested using cadmium chloride ($CdCl_2$). All test LC50's were within the range of the previous reference toxicant tests conducted, with the exception of the *L. plumulosus* data which exhibited higher sensitivity to cadmium than previous reference tests. Because the survival in the control sediment was 84 percent at day ten, the increased sensitivity was attributed to the slight reduction in initial size of the animals used in the tests as compared to the previous tests. This increased sensitivity in reference tests did seem to decrease overall negative control survival when compared with previous data.

Table 4.22 Reference toxicant data results from 96-hr, water only, reference toxicant tests for the fourth year of the ambient toxicity project. Cadmium chloride ($CdCl_2$) was used for all organisms.

Organism	Chemical	LC50 & CIs (mg/L)	Historical Mean
L. plumulosus	$CdCl_2$	0.25 (0.128-0.494)	1.06
L. dytiscus	$CdCl_2$	2.40 (1.78-3.23)	3.76
S. benedicti	$CdCl_2$	2.07 (1.65-2.60)	4.26
C. variegatus	$CdCl_2$	0.94 (0.730-1.21)	0.697

SECTION 5

DISCUSSION

5.1 Patapsco River

The Patapsco River (Baltimore Harbor) area has historical contaminant problems that have been documented during our previous ambient toxicity testing programs (Hall et al., 1991; Hall et al., 1992) and other studies (Eskin et al., 1994). Most of the contaminant problems have been reported in sediment and not the water column. Results from the 1994 effort were somewhat consistent with this trend except for the toxicity observed with the coot clam. During the first test with this bivalve species, reduced shell development was reported at all Baltimore Harbor sites (5 sites) except Sparrows Point. However, during the second test no biological effects were reported at any of the 6 sites. These results suggest that occasional toxicity can be observed in the water column at the various Baltimore Harbor sites. Possible causes of toxicity cannot be identified. The metals data available from these tests do not generally suggest that high, potentially toxic concentrations are available although copper did exceed the marine water quality criteria at the Bear Creek station. Due to the lack of organics data from this study, the role of organic contaminants cannot be assessed.

The sediment data obtained from the fall 1994 sampling period indicated significant decrease in survival in all of the Baltimore Harbor sites. *Streblospio benedicti* and *L. dytiscus* tests indicated significant differences in survival at day ten after adjustment for particle size at all sites. At day 20, only Outer Harbor failed to produce significant mortality for both species. *Leptocheirus plumulosus* resulted in high significant mortality at both the Bear Creek and Northwest Harbor sites. Growth reduction was seen only at the Curtis Bay site in the *L. plumulosus* test, however, *S. benedicti* revealed length reductions in all but Outer Harbor and Middle Branch. Inorganic contaminants were particularly high at Bear Creek, exceeding the ER-Ms for Cd, Cr, Pb, and Zn and ER-Ls for As, Cu, Hg and Ni. All of these sites exceeded the ER-Ms for Pb, Zn and Cr. Although the AVS/SEM values were all below one, it is believed that because of the presence of excessive metals concentrations in the sediment, sufficient oxidation takes place at the sediment water interface to oxidize the sulfide-metal complexes, produce bioavailable forms of these metals, and induce toxicity. The TOC at several of these sites (Bear Creek, Curtis Bay, Outer Harbor, Northwest Harbor, and Sparrows point) exceeded those found in the Poropotank control and reference sediment suggesting much greater inputs of carbon sources than would occur naturally. It is currently unclear if the major source of this input is point-source or non-point urban run-off. Ammonia levels were also elevated at the Bear Creek, Curtis Bay and Northwest Harbor sites. The unionized ammonia toxicity limits were exceeded at every Patapsco river site, sometimes by as much as 10 times (Curtis Bay).

Pesticide analysis indicated the presence of metolachlor at five of the six harbor sites. In addition, DDD, was found at the Outer Harbor site, and the Bear Creek sediments contained alachlor, methoxychlor and trichlorbiphenyls. None of these, however, exceeded the ER-Ls. Every site in the Patapsco River exceeded the ER-Ms of at least one semi-volatile compound. The most prevalent of these was dibenzo(a,h)anthracene, which exceeded the ER-M at every site. Pyrene was also present above the ER-Ms at multiple sites. Naphthalene, phenanthrene, benzo(a)pyrene, fluoranthene were also found above the ER-Ms in the Patapsco River (Appendix B).

The above sediment toxicity data can be compared with Long-term benthic (LTB) monitoring data collected during the Maryland Department of Environment Chesapeake Bay Water Quality Monitoring Program. The LTB data for August 1994 from Ranasinghe et al. (1995) showed that the benthic index of biotic integrity (B-IBI) indicated either degraded or severely degraded conditions were present in 5 of the Baltimore Harbor sites evaluated during our ambient toxicity study (Outer Harbor, Bear Creek, Curtis Bay, Middle River and Northwest Branch). The Sparrows Point ambient toxicity site was not evaluated during the LTB sampling. The results from LTB sampling are in general agreement with the data from our ambient toxicity testing.

5.2 Sassafras River

The Sassafras River is an ecologically important ecosystem (e.g., spawning area for striped bass) with some documented contaminants present in the sediment (Eskin et al. 1994). Toxicity data from ambient water column tests are not available from previous studies for comparison. Results from water column tests at the Betterton site, located at the mouth of the river, did suggest the presence of toxicity from both the *Eurytemora* and coot clam test. This was the most significant water column toxicity reported from any of the 12 stations tested during 1994. Significant reduced shell development from the coot clam test at Turner Creek (test 1) also suggested the presence of water column toxicity. The limited contaminants data available (metals data only) did not provide any insight on possible causes of toxicity.

Betterton and Turners Creek sediment resulted in fewer significant toxicity results compared with those of the Baltimore Harbor sites. While Betterton demonstrated toxic responses in both *L. dytiscus* and *S. benedicti,* Turner Creek showed toxicity only in the *S. benedicti* tests. Particle size results indicated that the Turner Creek site was substantially more sandy than the Betterton site, possibly affecting survival of the *S. benedicti*. There were no growth effects in the Turners Creek sediment, however reduction in the *S. benedicti* length was reduced in the Betterton sediment. TOC was not notably increased compared with controls at either site. The SEM data for both sites was low relative to most of the other tests sites, but still elevated in comparison to reference and control sites (Table 4.18). Bulk metals may have been partially responsible for toxicity at both sites, as nickel and zinc were greater than the Median Effect Range at the Betterton site, and arsenic, lead and mercury were greater than the ER-L at Betterton. (Long and Morgan, 1990). Turner Creek sediment also exceeded the ER-Ls for arsenic, chromium, lead, nickel and zinc. Ammonia concentrations were above the continuous water column toxicity limits, however they were relatively consistent with the control and reference sediment concentrations. Pesticides were found only in trace mounts at both sites. No semi-volatile organic compounds exceeded the ER-M's in the Sassafras River sediments.

5.3 Magothy River

The Magothy River is located in a highly urbanized area with very few point sources. Potentially toxic organic contaminants have been reported in sediments of this river (Eskin et al., 1994). This was the first year of ambient toxicity testing in this river; therefore background data are not available for comparison. The water column results from at least one coot clam test at both the Gibson Island and South Ferry station suggested toxicity; biological effects were not reported from any of the other water column tests. Concentrations of metals in the water column were not high or potentially toxic and organics data were not reported. Therefore, potential causes of toxicity can not be identified during the coot clam tests.

The South Ferry site exhibited sediment toxicity in all species except *L. plumulosus*. At day 20 neither *L. dytiscus* or *S. benedicti* demonstrated the same significance toxicological effects compared with controls as they had at day 10 when adjusting for particle size effects. The Gibson Island site showed a similar pattern, however mortality was still significant at day 20 in both *L. dytiscus* and *L. plumulosus*. No statistically significant mortality was observed in the *C. variegatus* egg tests. Reduction in growth was observed at both sites in the *S. benedicti* tests, while no other growth effects were observed. TOC was relatively low in the Gibson Island sediment and is probably related to the relatively high sand content at the site. Total SEM was also relatively low at both Gibson Island and South Ferry test sites when compared with the other tests sites, but was above those for the reference and control sites. Bulk metals analyses revealed lead concentration exceeding the ER-M by nearly 25 times at Gibson Island. This elevated lead content was not observed when SEM was measured, but could account for toxicity observed at the Gibson Island site. The source of this contamination is currently unknown. South Ferry was contaminated with levels of arsenic, lead, mercury and zinc which exceeded the ER-Ls. South Ferry sediments contained measurable levels of gamma-chlordane while Gibson Island sediment had trace levels. No semi-volatile organic compounds exceeded the ER-M's in the Magothy River sediments.

5.4 Severn River

The Severn River is an ecologically important river (e.g. blue crabs, key bay fish species) with few point sources. Eskin et al. (1994) have reported the presence of toxic compounds in the sediment of this river. Background water column toxicity data are not available for comparison with our data. Our results from the first coot clam test suggest the presence of toxic conditions in the water column from both the Annapolis and Route 50 stations. No effects were reported during the second coot clam test or any of the other water column tests. These results suggest that occasional toxicity can occur in this river. Possible causes of toxicity can not be identified although the metals that were measured during this study can likely be eliminated due to the low concentrations reported.

The Route 50 sediment caused significant mortality only in *S. benedicti* at both day 10 and 20 when adjusting for particle size effects. *Lepidactylus dytiscus* showed significant mortality only prior to particle size adjustment. *Cyprinodon variegatus* and *L. plumulosus* revealed no increased mortality over controls. Annapolis sediment caused increased mortality in *S. benedicti* as well as in *C. variegatus* tests. When adjusting for particle size, no significant mortality was observed in the *L. dytiscus* test, and

L. plumulosus also did not indicate increased toxicity. The only growth effects observed were for *S. benedicti* at the Route 50 site. Total organic carbon at both sites was moderate with respect to the other test sites, and was lower than that found at the Poropotank reference/control site. Carbon loading was therefore not considered a concern at these sites. The particle size at the Annapolis site was shifted more toward the sand end of the spectrum when compared with the other test sites. Only Gibson Island and Turner Creek appeared to be more heavily sand-laden. Of all the test sites, Annapolis had the highest SEM/AVS ratio value, 0.499 (Table 4.18). This may have resulted from the low AVS which may be somewhat correlated to the high sand content of the sediment. The Route 50 site had the second highest ratio of all the tests sites at 0.353. The bulk metals at Annapolis show chromium and zinc above the ER-M, and arsenic, lead, mercury and nickel above the ER-L. Junction Route 50 resulted in a similar pattern, except that only zinc was above the ER-M (Table 4.20). Pesticide analysis showed the presence of trifluralin in the Annapolis sediment. Additionally, the semi-volatile compound dibenzo(a,h)anthracene was present above the ER-M at the Annapolis site(Appendix B).

SECTION 6

ANALYSIS OF THE FOUR YEAR DATA BASE

6.1 Water Column Toxicity

The results of multivariate composite index calculations for water column toxicity for the 1990, 1991, 1992-93, and 1994 experiments are summarized in Figures 6.1, 6.2, 6.3, 6.4a and 6.4b respectively. The species tested and the number of endpoints used varied slightly from year to year (i.e., five water column tests for 1990, four tests for 1991, 1992-93 and 1994). Therefore, comparisons of index values within the figures for same year are more comparable than those of different years. The composite index calculations generated for each station and year from concurrent reference (control value) and test conditions, therefore, provide interpretation on the relative magnitude of the toxic response of the various sites. This analysis also provided a degree of confidence that could be given to differences between reference and test values. A summary of comparison of TOX-INDEX values for control (or reference) and test sites is presented in Table 6.1.

The TOX-INDEX analysis for the 1990 data in Figure 6.1 showed that the Elizabeth River was clearly the most toxic site tested, as the median for the index of the test condition was clearly greater than the reference (control). The confidence limits for the reference and test condition did not overlap at this location. Nearly half of the endpoints displayed significant differences between the reference and test conditions. The results from the Elizabeth River are not surprising since significant mortality was observed in two of the three estuarine tests that were conducted. The second most toxic area identified with the TOX-INDEX analysis was the Patapsco River as significant mortality was reported in one out of three tests. However, the confidence interval was fairly wide (indicating variability) for this station and there was no difference in the median values for the reference and test site. The results from the Indian Head, Freestone Point, Possum Point, Morgantown, Dahlgren and Wye River stations indicated no significant difference with index values between the reference and test conditions for the 1990 tests. Both Morgantown and Dahlgren stations did show limited biological effects with one of the tests (significant mortality with the sheepshead minnow test). However, these results from the test condition were not significantly different than the reference when all endpoints from all tests were combined for the final index calculations.

The multivariate composite index calculations for the 1991

Figure 6.1 TOX-INDEX results for the 1990 water column data. (See Section 3.4 for a detailed description of presentation).

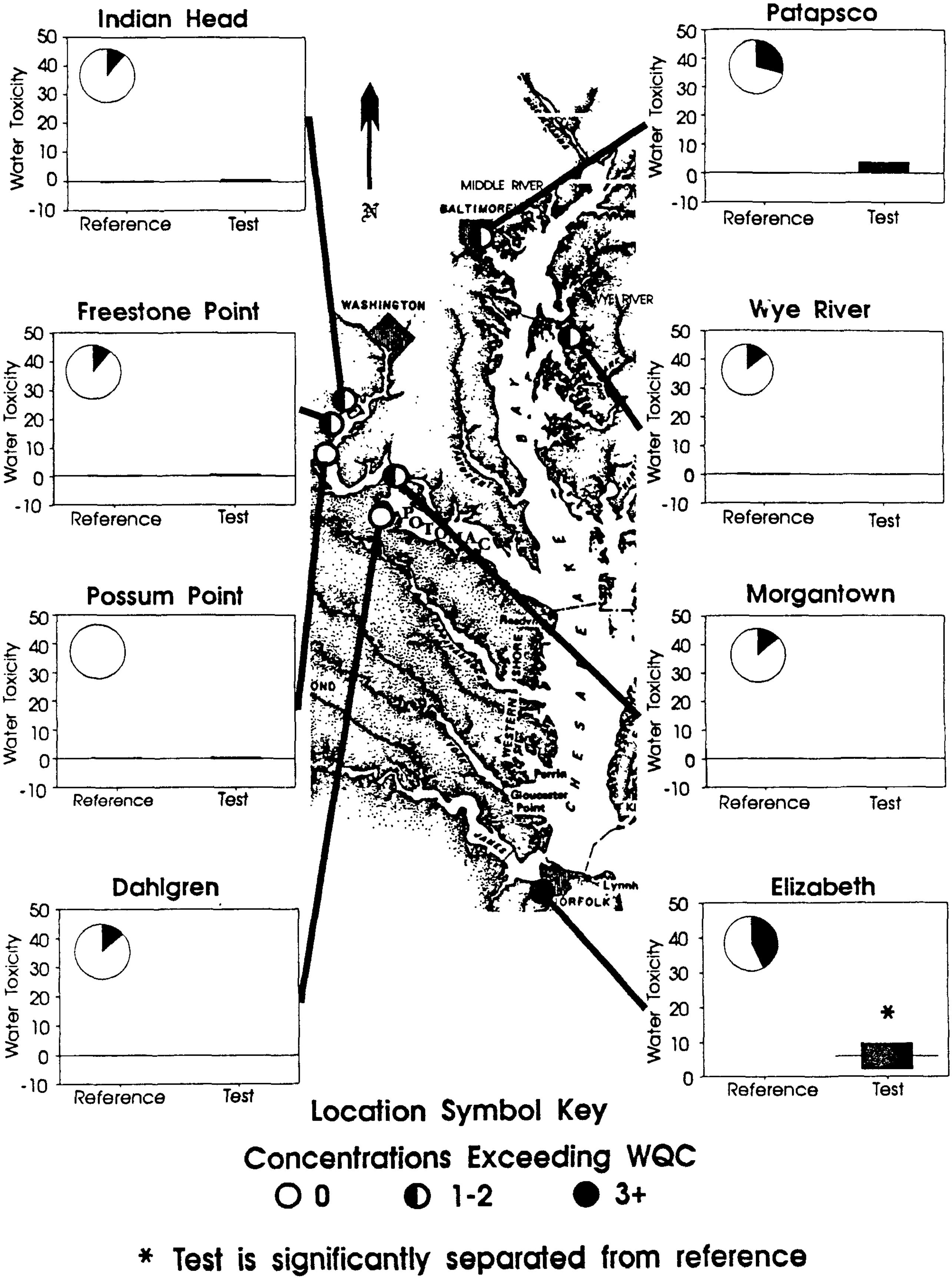


Figure 6.2 TOX-INDEX results for the 1991 water column data. (See Section 3.4 for a detailed description of presentation).

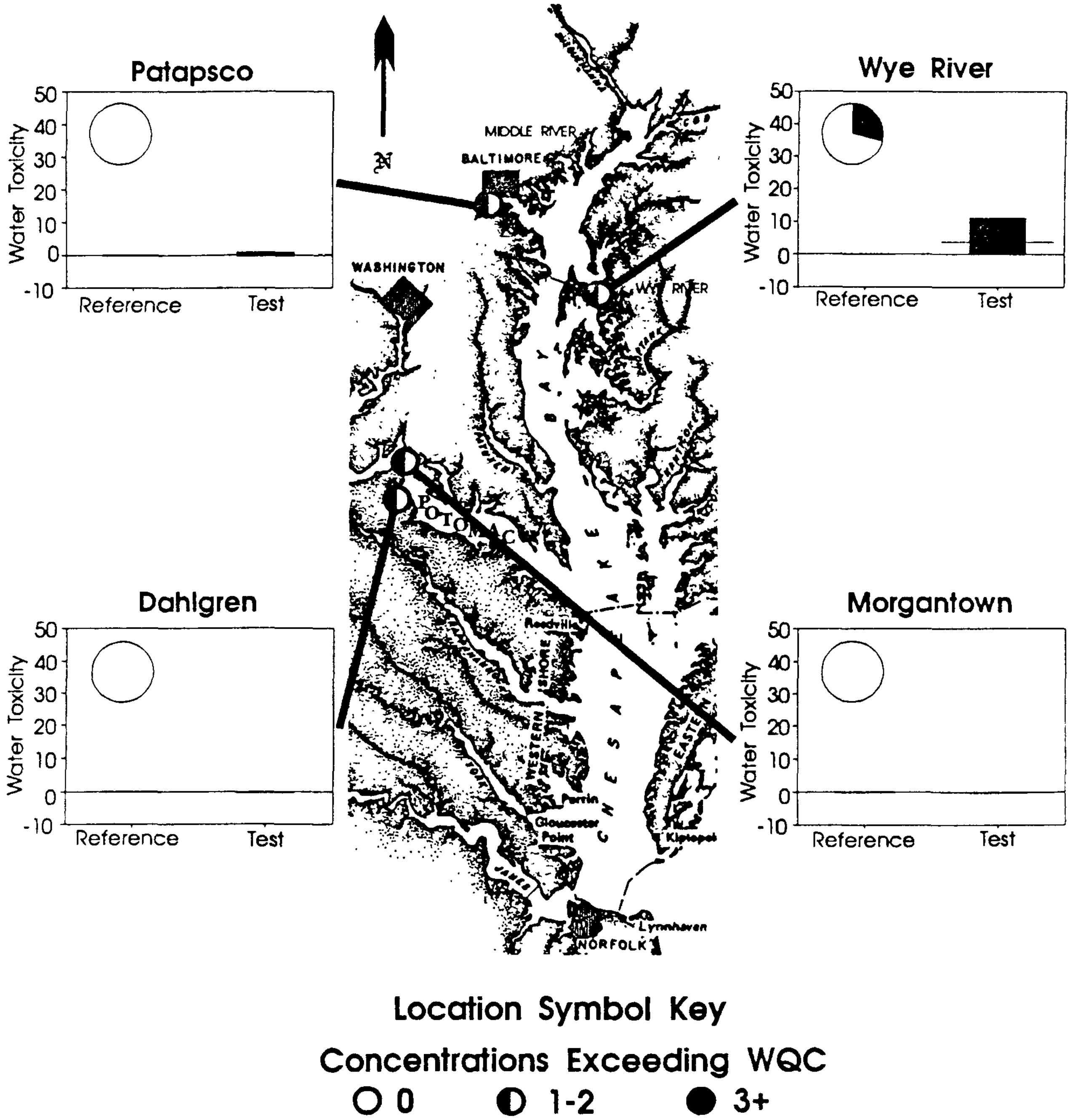


Figure 6.3 TOX-INDEX results for the 1992-3 water column data. (See Section 3.4 for a detailed description of presentation).

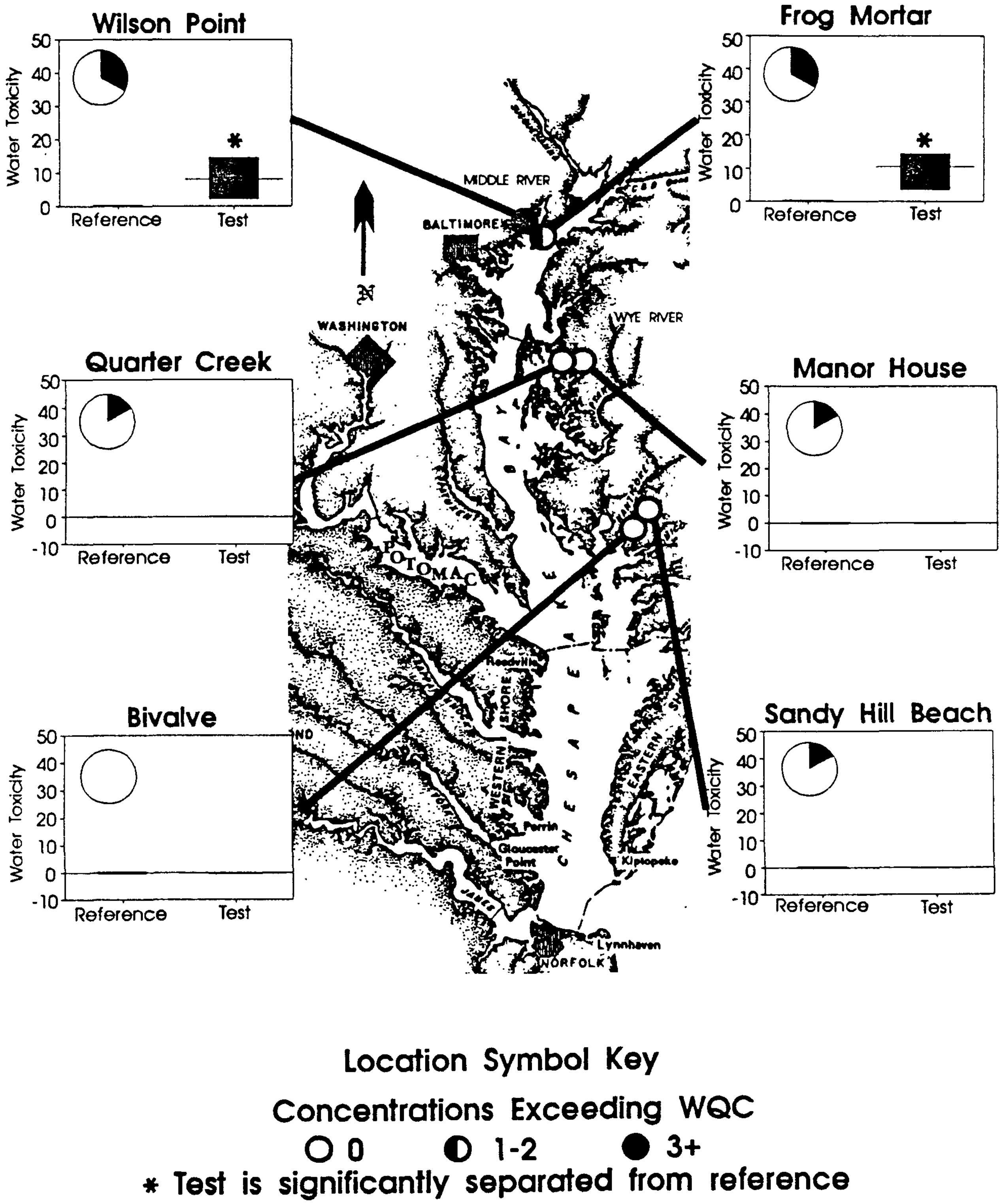


Figure 6.4a TOX-INDEX results for the 1994 water column data for the Severn, Magothy and Sassafras Rivers. (See Section 3.4 for a detailed description of presentation).

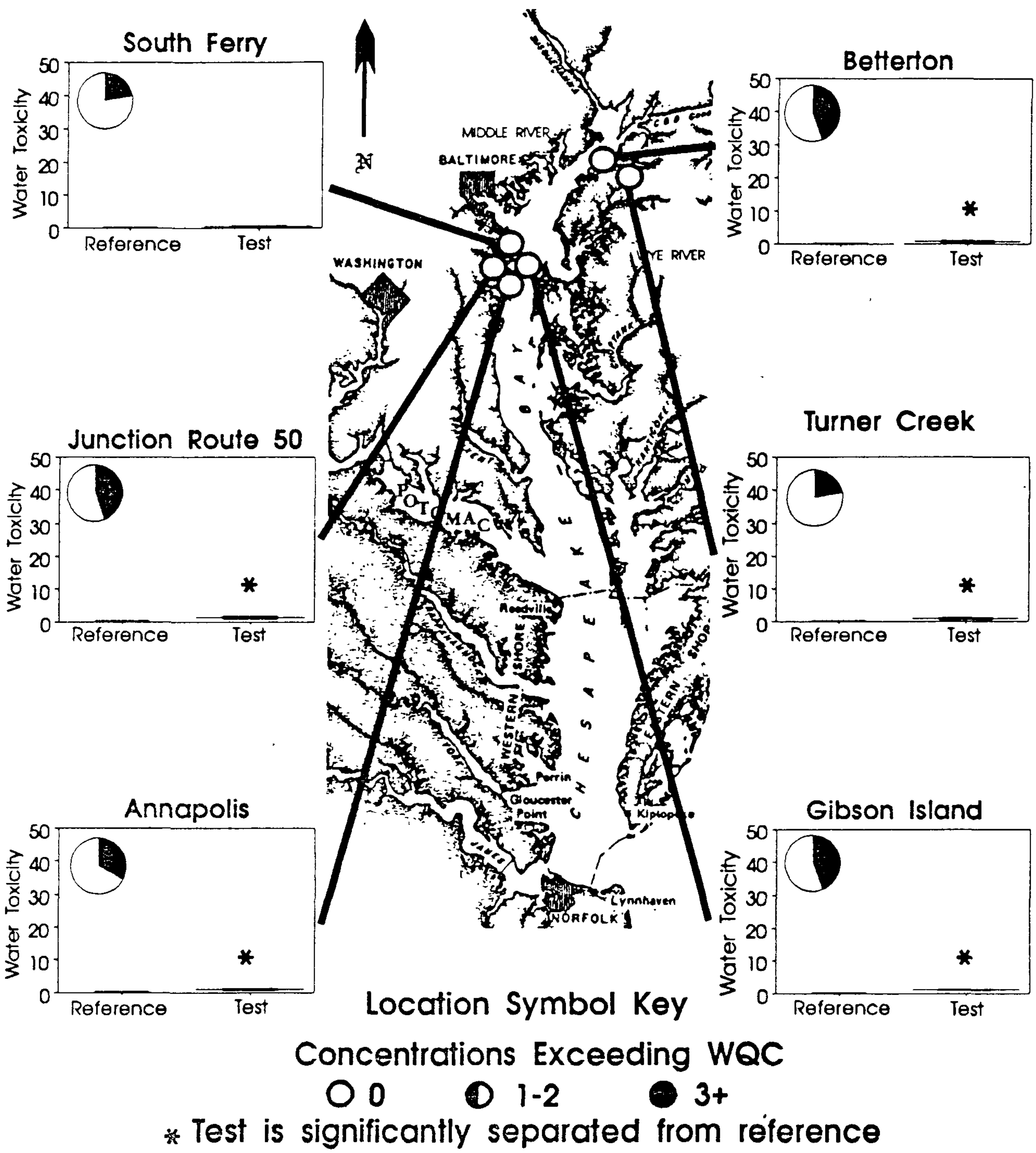


Figure 6.4b TOX-INDEX results for the 1994 water column data for Baltimore Harbor sites. (See Section 3.4 for a detailed description of presentation).

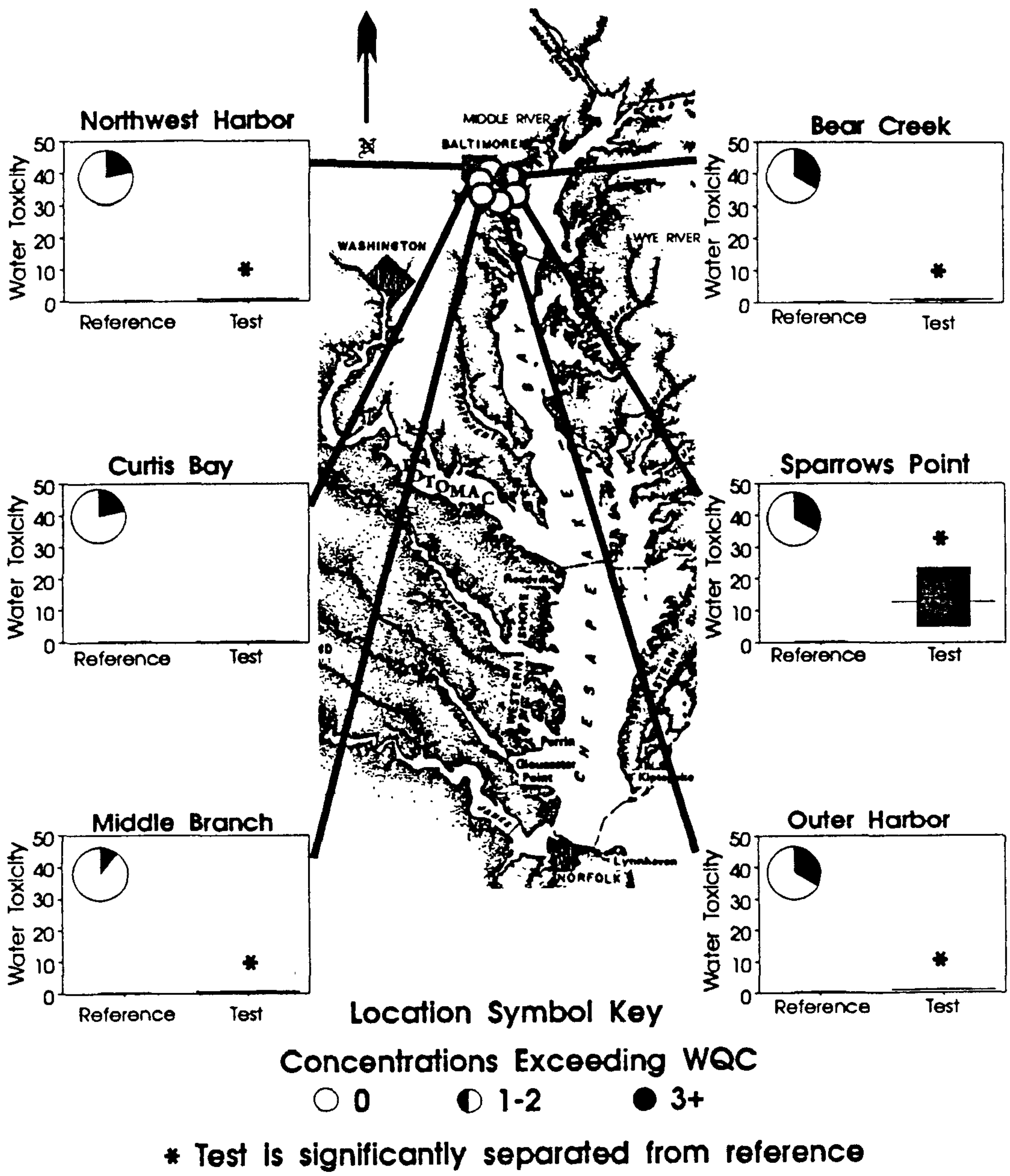


Table 6.1 Summary of comparisons of water column RTRM indices for reference and test sites presented in Figures 6.1 - 6.4. Comparisons for which confidence limits overlap are indicated by "O", those for which the confidence limits do not overlap are indicated by "X", while "--" indicates no data taken for the period

STATION	1990	1991	1992-3	1994
BALTIMORE HARBOR				
BEAR CREEK	--	--	--	X
CURTIS BAY	--	--	--	O
MIDDLE BRANCH	--	--	--	X
NORTHWEST HARBOR	--	--	--	X
OUTER HARBOR	--	--	--	X
PATAPSCO RIVER	O	O	--	--
SPARROWS POINT	--	--	--	X
ELIZABETH RIVER	X	--	--	--
MAGOTHY				
GIBSON ISLAND	--	--	--	X
SOUTH FERRY	--	--	--	O
MIDDLE RIVER				
FROG MORTAR	--	--	X	--
WILSON POINT	--	--	X	--
NANTICOKE RIVER				
BIVALVE	--	--	O	--
SANDY HILL BEACH	--	--	O	--
POTOMAC RIVER				
DAHLGREN	O	O	--	--
FREESTONE POINT	0	--	--	--
INDIAN HEAD	0	--	--	--
MORGANTOWN	0	0	--	--
POSSUM POINT	0	--	--	--
SASSAFRAS				
BETTERTON	--	--	--	X
TURNER'S CREEK	--	--	--	X
SEVERN				
ANNAPOLIS	--	--	--	X
JUNCTION ROUTE 50	--	--	--	X
WYE RIVER				
MANOR HOUSE	0	0	0	--
QUARTER CREEK	--	--	0	--

experiments are presented in Figure 6.2. Four water column tests with two endpoints for each test were used to determine the final values for two testing periods (summer and fall). The Wye River site showed the most significant effects as significant mortality was reported for two different test species during different testing periods. Although the median values from the reference and test sites were different, there was overlap of confidence limits with these two conditions. A comparison of reference and test index values for the Patapsco River, Morgantown and Dahlgren sites showed no significant differences. However, reduced growth of the sheepshead minnow was reported at both the Morgantown and Dahlgren sites during the summer experiments.

The results from the 1992-93 experiments presented in Figure 6.3 include experiments conducted during the fall (1992) and spring (1993) at each of the 6 sites (2 sites per river). The most toxic sites were reported at both Middle River stations (Wilson Point and Frog Mortar Creek). Results from the coot clam toxicity tests (2 tests per experiment conducted in the fall and spring) showed consistent toxicity at both sites. Although median values were similar for both Middle River sites, the variability at Wilson Point was greater than at Frog Mortar. Water quality criteria were exceeded at both sites. The results from TOX-INDEX analysis at the other 4 sites showed no difference between the reference and the test condition. The only other biological effect reported at any of these 4 sites was significant mortality of *E. affinis* at the Wye River-Quarter Creek site during the spring experiments.

The results of the 1994 experiments are presented in Figure 6.4a and 6.4b. The TOX-INDEX values from the Severn, Magothy and Sassafras Rivers were quite similar to those of the corresponding reference sites (Figure 6.4a). However, the confidence limits for all sites in these rivers except South Ferry (Magothy) did not overlap the limits for the reference condition. Thus, the sites displayed statistical differences but they were of questionable ecological significance. In Baltimore Harbor, Sparrows Point site displayed significant toxicity (Figure 6.4b) while Northwest Harbor, Bear Creek, Middle Branch, and Outer Harbor showed statistically significant but ecologically minimal toxicity. The Curtis Bay exhibited no toxic effects.

A summary of the four year water column data base using the TOX-INDEX analysis showed the following ranking of toxicity for the various sites:

- the Elizabeth River (1990), the Middle River (1992-93), and Sparrows Point in Baltimore Harbor (1994) were the most toxic sites tested during the first four years of the Ambient Toxicity Testing Program;

- the Wye River-Manor House test site in 1991 had a median value for the composite index greater than the control value but there was an ovelap with the confidence interval between the test and reference sites; Wye River-Manor House site tested in 1990 and Wye River (Manor House and Quarter Creek sites) tested in 1992-93 displayed no water column toxicity;

- Baltimore Harbor showed variable toxicity:

  - in 1990, the Patapsco River site showed some toxicity as evidenced by the wide confidence interval; however, the test condition on the average was not significantly different than the control;

  - in 1991, the Patapsco River site displayed no toxicity;

  - in 1994, Sparrows Point displayed significant water column toxicity, while the other 5 sites displayed little (Bear Creek, Middle Branch, Northwest Harbor, Outer Harbor) or no (Curtis Bay) overall toxic effects.

- the (1994) TOX-INDEX values for the Severn, Sassafras, and one of the Magothy River sites (Gibson Island) displayed statistically significant differences from those from the reference conditions, but the magnitude of the water column toxicity appeared to be minimal for these areas.

- the five Potomac River sites (Indian Head, Freestone Point, Possum Point, Morgantown and Dahlgren) tested in 1990 and two sites tested in 1991 (Morgantown and Dahlgren) generally showed no significant water column effects;

- the composite index for the reference and test conditions were similar at both Nanticoke River sites (1992-93), thus suggesting no significant water column effects.

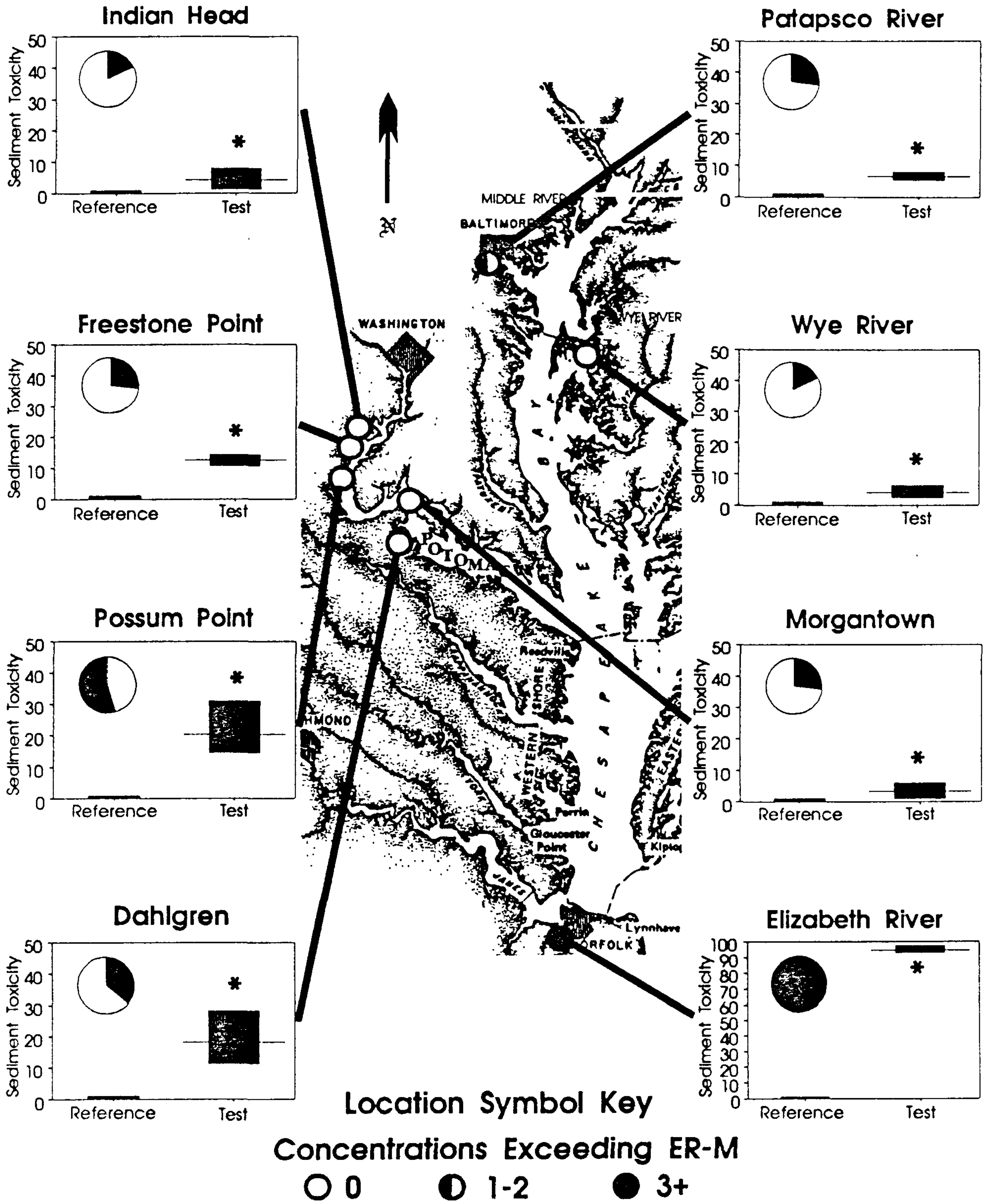
6.2 Sediment Toxicity

The results of the multivariate composite index calculations for sediment toxicity for the 1990, 1991, 1992-93, and 1994 studies are summarized in Figures 6.5, 6.6, 6.7, 6.8a and 6.8b respectively. It should be noted that the species and the number of endpoints tested varied slightly from year to year, so comparisons of index values within the figures (within the same year) are more comparable than those between figures. Nonetheless, the comparisons of concurrent reference and test experiments provide insight into the relative magnitude of the toxic responses of the various sites. Table 6.2 summarizes the comparisons presented in Figures 6.5 - 6.8.

During the 1990 study, the Elizabeth River was clearly the most toxic of the sites, since all species displayed nearly complete mortality during the first 10 days of the experiment (i.e., the median for the index for the test data was greatly separated from the median for the reference data, with little variation; Figure 6.5). The Elizabeth River provides an example of the worst case TOX-INDEX values. The confidence limits of the test data index values were well separated from those of the corresponding reference sites for a number of other sites: Patapsco River; Wye River; and the Freestone Point, Possum Point and Dahlgren sites on the Potomac River (although the latter two sites displayed a considerable degree of variation in index values). The Indian Head and Morgantown sites on the Potomac River displayed only slight separation between the median multivariate index values for the test and reference conditions. Thus, the magnitude of potential toxicity appears to be less for the Indian Head and Morgantown sites than for the others. It should be noted, however, that all sites selected for the first year of the study were those considered "suspect" due to the results of previous studies, so it is not surprising that most displayed significant deviations from the reference conditions.

The 1991 study involved an assessment of the effects of short-term temporal variability (a summer versus a fall collection) on the apparent toxicity of sediments from four sites. The separation between test and reference treatments was greatest for the Patapsco River site, with less separation being displayed for Dahlgren, Morgantown, and the Wye (Figure 6.6). The results of the Patapsco River index comparison were remarkably similar to those observed for the 1990 study. The Dahlgren site index values, which were quite variable in the 1990 study, were still separated from the reference values in the 1991 study. The small degree of separation

Figure 6.5 TOX-INDEX results for the 1990 sediment data. (See Section 3.4 for a detailed description of presentation).



* Test is significantly separated from reference

Figure 6.6 TOX-INDEX results for the 1991 sediment data. (See Section 3.4 for a detailed description of presentation).

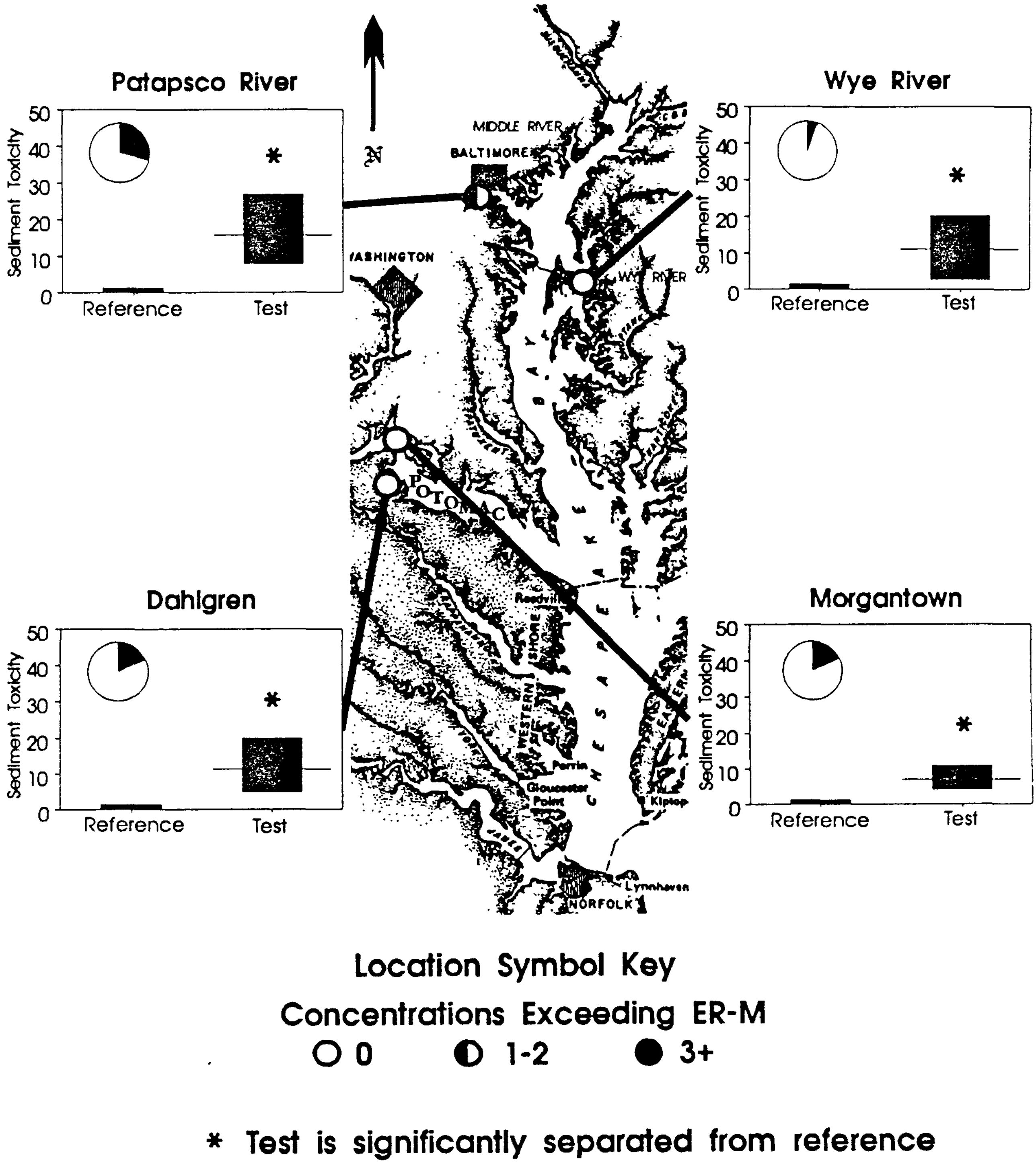


Figure 6.7 TOX-INDEX results ofr the 1992-3 sediment data. (See Section 3.4 for a detailed description of presentation).

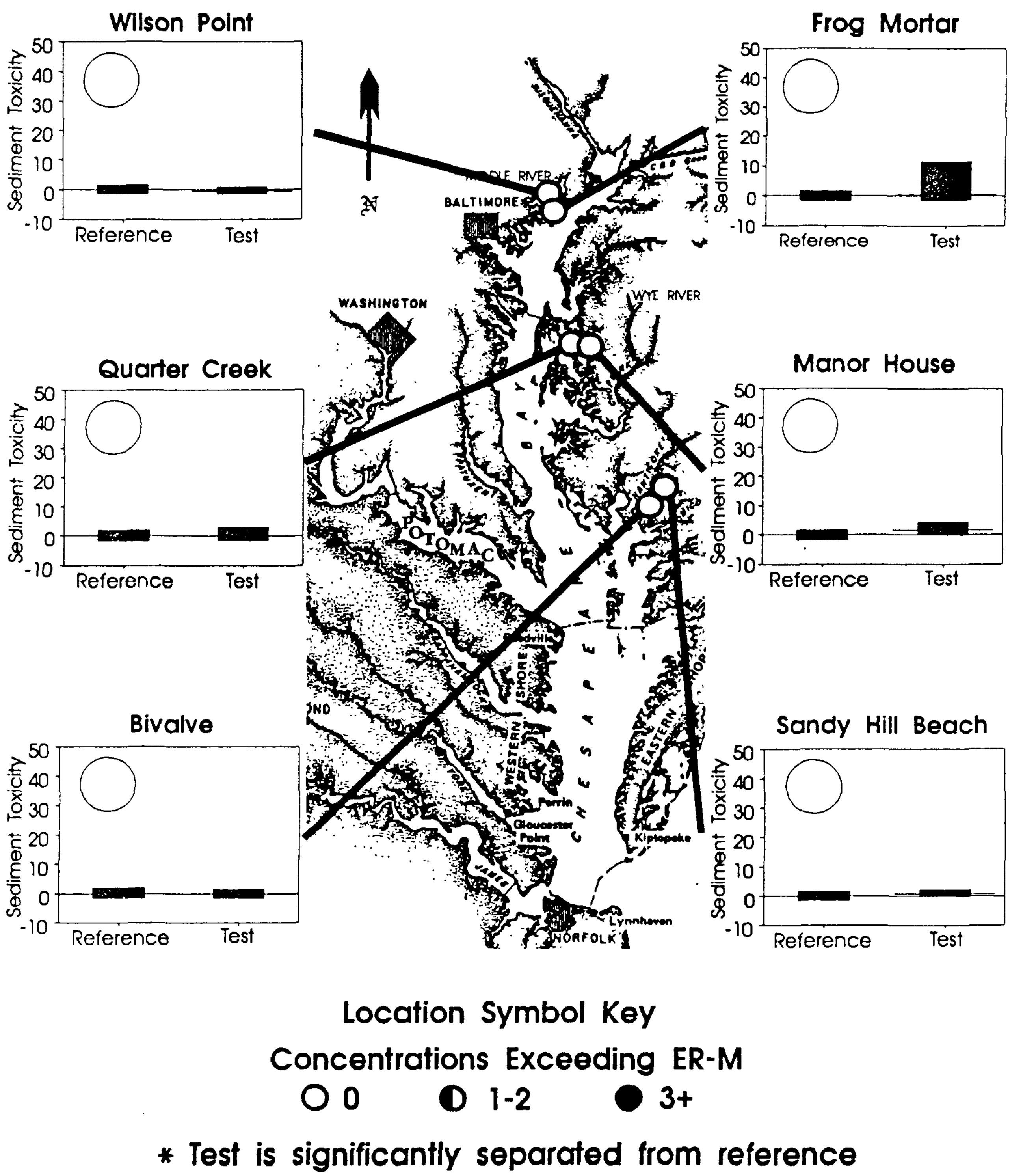


Figure 6.8a TOX-INDEX results for the 1994 sediment data for the Severn, Magothy and Sassafras Rivers. (See Section 3.4 for a detailed description of presentation).

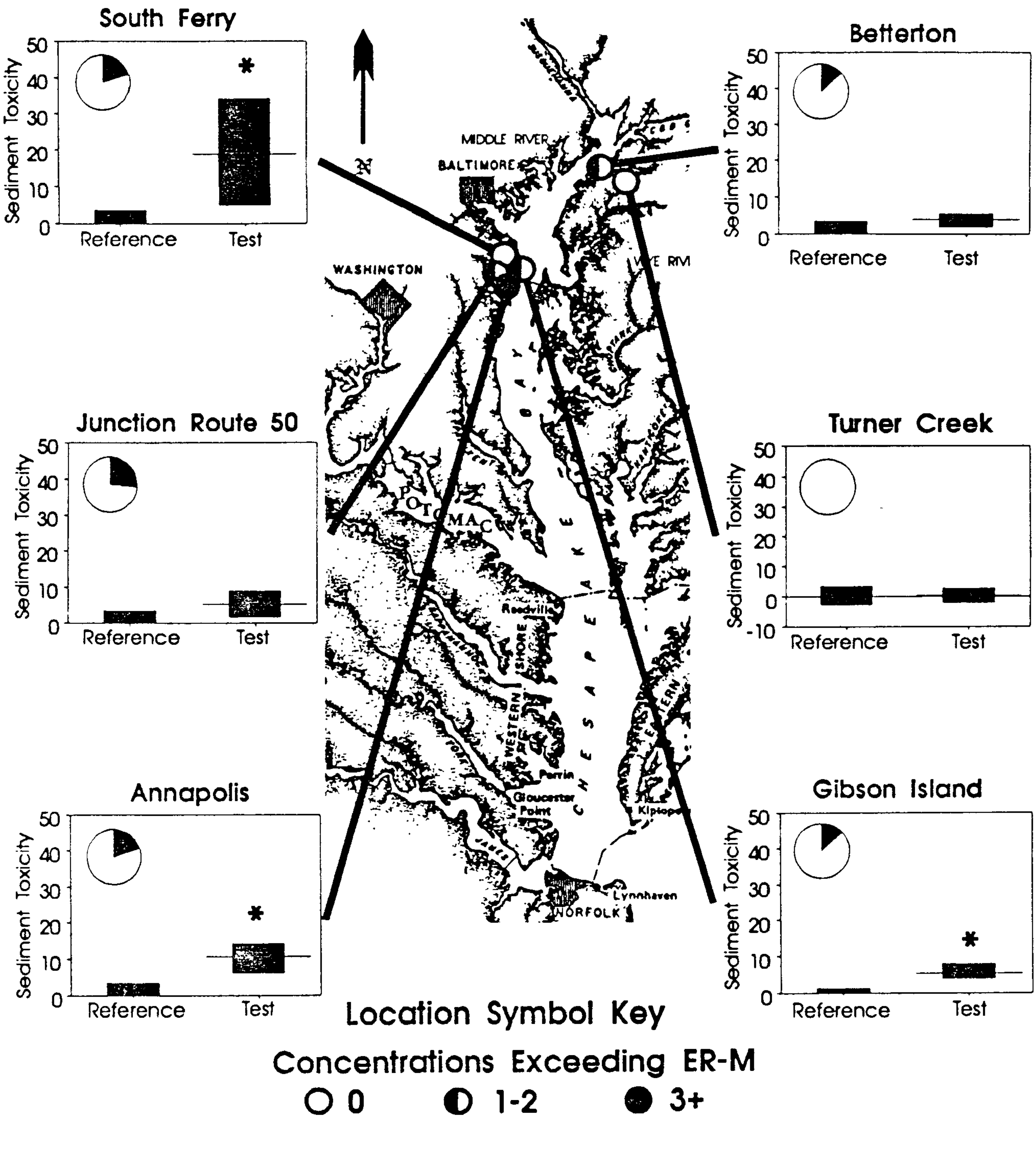


Figure 6.8b TOX-INDEX results for the 1994 sediment from the Baltimore Harbor sites. (See Section 3.4 for a detailed description of presentation).

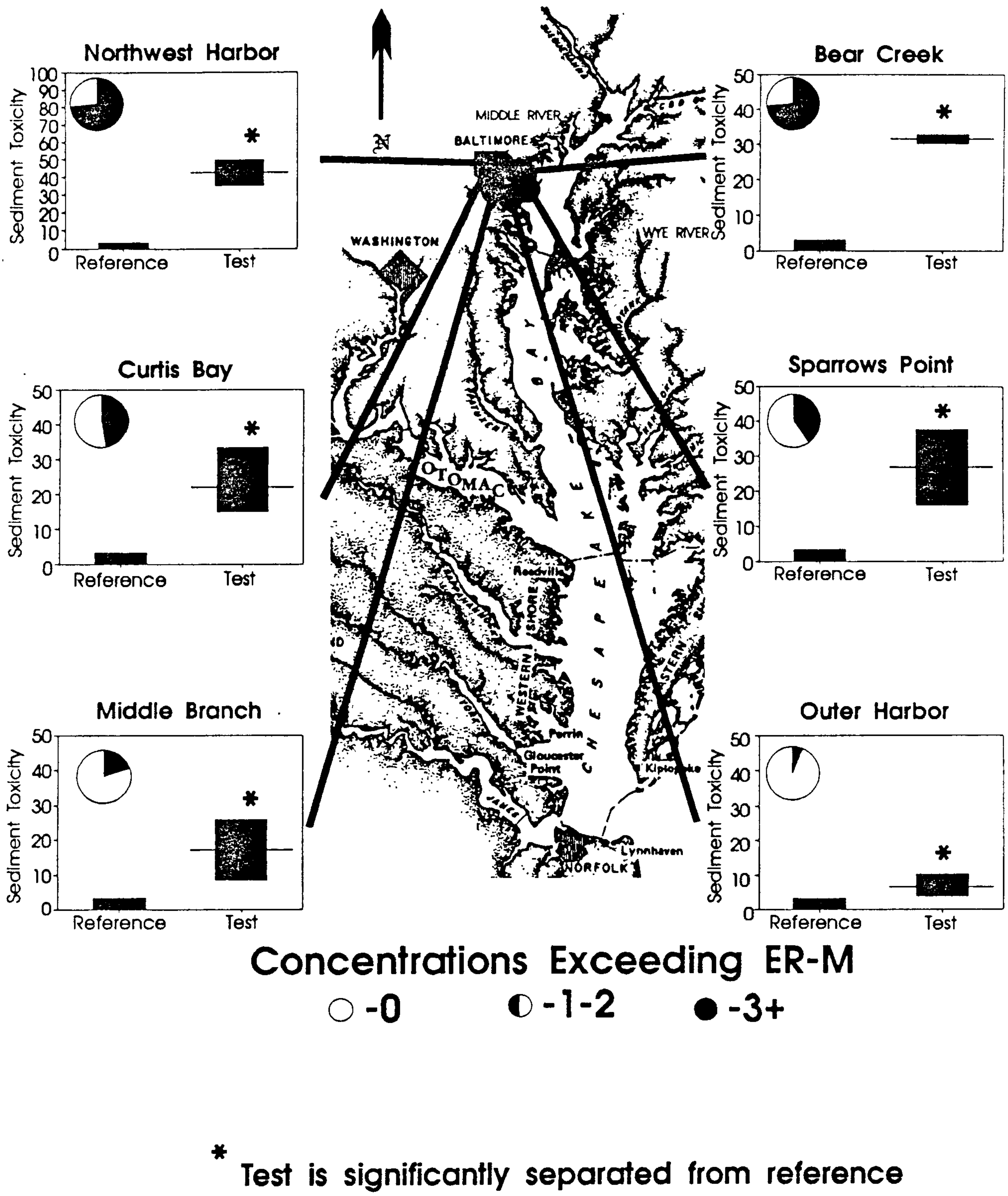


Table 6.2 Summary of comparisons of sediment RTRM indices for reference and test sites presented in Figures 6.5 - 6 8 Comparisons for which confidence limits overlap are indicated by "O", those for which the confidence limits do not overlap are indicated by "X", while "--" indicates no data taken for the period

STATION	1990	1991	1992-3	1994
BALTIMORE HARBOR				
BEAR CREEK	--	--	--	X
CURTIS BAY	--	--	--	X
MIDDLE BRANCH	--	--	--	X
NORTHWEST HARBOR	--	--	--	X
OUTER HARBOR	--	--	--	X
PATAPSCO RIVER	X	X	--	--
SPARROWS POINT	--	--	--	X
ELIZABETH RIVER	X	--	--	--
MAGOTHY				
GIBSON ISLAND	--	--	--	X
SOUTH FERRY	--	--	--	X
MIDDLE RIVER				
FROG MORTAR	--	--	O	--
WILSON POINT	--	--	O	--
NANTICOKE RIVER				
BIVALVE	--	--	O	--
SANDY HILL BEACH	--	--	O	--
POTOMAC RIVER				
DAHLGREN	X	X	--	--
FREESTONE POINT	X	--	--	--
INDIAN HEAD	X	--	--	--
MORGANTOWN	X	X	--	--
POSSUM POINT	X	--	--	--
SASSAFRAS				
BETTERTON	--	--	--	O
TURNER'S CREEK	--	--	--	O
SEVERN				
ANNAPOLIS	--	--	--	X
JUNCTION ROUTE 50	--	--	--	O
WYE RIVER				
MANOR HOUSE	X	X	O	--
QUARTER CREEK	--	--	O	--

observed between the Morgantown index limits and reference limits in 1990 was also observed for 1991. The Wye River index limits were only slightly separated from the reference limits due to the fact that only one of the two sets of experiments displayed significant differences between test and control treatments. This slight variability in responses could be due to temporal variation in toxicity, but is more likely due to small scale spatial heterogeneity (i.e., sediments were taken from the same general station, but there may have been patchiness in sediment quality in the grabs composited for the two sets of tests). Overall, the degree of variability observed in the TOX-INDEX limits for the combination of the two sampling events was quite small for all four sites. The patterns were remarkably consistent with those observed at these same sites during the previous year.

The 1992-93 study also involved two sampling periods during the Fall and Spring. The test and reference TOX-INDEX limits overlapped for all of the sites selected for testing (Figure 6.7). Thus, the sites in the Middle River (Frog Mortar and Wilson Point), the Wye River (Quarter Creek and Manor House), and the Nanticoke River (Sandy Hill Beach and Bivalve) appeared to contain sediment displaying little or no overall toxicity compared to reference conditions. It should be noted, however, that the Frog Mortar sediments were quite heterogenous in character (Hall et al., 1994). Furthermore, this site displayed somewhat elevated metals in the composite samples (as evidenced by values of copper, mercury, lead, and zinc which exceeded ER-L levels in the second set composite sample; Hall et al., 1994). Therefore, there may be patches of contaminated sediments at this site, which may have produced responses in a few of the field replicates. The purpose of taking true field replicates at two different times during the 1992-93 study was to produce confidence limits to indicate the probability of observing the same sort of response if the site were sampled again, so the observed variability provides insight into the variation in sediment quality expected for this site.

The results of the 1992-3 studies on the two Wye River sites (Quarter Creek and Manor House) displayed little difference from the reference conditions, which is in contrast to the apparent toxicity observed in 1990 and one of the sampling period of the 1991 study. The Wye River Manor House site was sampled during the first three years of testing.

The 1994 studies focused upon the Sassafras, Severn, Magothy Rivers and the Baltimore Harbor/Patapsco River (Figures 6.8a and 6.8b). The Sassafras River sites displayed little sediment toxicity (Figure 6.8a). The Magothy River sites exhibited slight to moderate toxicity, particularly the South Ferry site, which was highly variable (Figure 6.8a). The Annapolis site on the Severn River also displayed significant but moderate to low toxicity. The TOX-INDEX limits from the Severn River site at the Route 50 bridge overlapped those of the reference site. The Baltimore Harbor sites showed various degrees of toxicity from slight (Outer Harbor) to quite high (Bear Creek and Northwest Harbor), with most displaying moderate toxicity (Sparrows Point, Middle Branch and Curtis Bay; Figure 6.8b). All Baltimore Harbor sites contained sediments that exceeded ER-M values for 3 or more contaminants.

To summarize, an overview of the multivariate index results produces a qualitative ranking of sediment quality of the sites from most toxic to least toxic, as follows:

- the Elizabeth River site contained sediments that were, by far, the most toxic of those studied during the first four years of the Ambient Toxicity Program;

- the Baltimore Harbor (Patapsco River) site contained sediments which were the second most consistently toxic among the sites studied; Northwest Harbor sediments were the most toxic, followed by Bear Creek, Curtis Bay and Sparrows Point, Middle Branch and Outer Harbor;

- the Possum Point, Freestone Point, and Dahlgren sites on the Potomac River had sediments that produced the next greatest separation between test and reference responses, although the responses in the Dahlgren site experiments displayed a large degree of variability in 1990 and a diminished level of apparent toxicity in 1991, suggesting spatial heterogeneity in sediment quality;

- the Magothy River sites (Gibson Island and South Ferry) contained the next most toxic sediments; followed by the Severn River sites in the vicinity of Annapolis; the toxicity of sediments in this region generally appears to be statistically significant but of moderately low overall magnitude;

- the sediments from the Wye River Manor House collection site exhibited some apparent toxicity in 1990 and in one of the two experiments in 1991, but the Manor House and Quarter Creek sites did not show toxicity in 1992-93.

- the Indian Head and Morgantown sites on the Potomac River had sediments which produced responses which were only slightly different from the reference conditions, but these subtle toxic effects displayed a low degree of variability and were observed to be consistent during several sampling events for the latter site;

- the Frog Mortar and Wilson Point sites on the Middle River and the Sandy Hill Beach and Bivalve Harbor sites on the Nanticoke River had sediments that produced responses that were not significantly different from those from the reference site experiments, although the Frog Mortar site replicates did display a considerable degree of variability in the responses, possibly due to small scale heterogeneity in contaminant patterns for certain heavy metals.

SECTION 7

RECOMMENDATIONS

The following recommendations are suggested after four years of ambient toxicity tests in Chesapeake Bay:

- The ambient toxicity testing approach (water column and sediment tests) should be used to assess the status of important living resource habitats (e.g., spawning areas of anadromous fish). This approach could be added to an array of multi-metric assessment tools that are currently under development with the long term goal of targeting tributaries and watersheds for nonpoint source monitoring and remediation. The goals of such a targeting effort would be to determine where management-based habitat improvement programs should be focused, based on the status of biological communities and other environmental indicators.

- Community metric approaches with fish, invertebrates, or other trophic groups which assess "impact observed responses" should be conducted concurrently with ambient toxicity tests (first tier tests) which determine "impact predicted" responses. The use of both test approaches will provide a more complete strategy for assessing the impact of contaminants on specific areas in the Chesapeake Bay watershed and assessing ecological risk.

- Water column and sediment ambient toxicity tests with resident Chesapeake Bay plant species (submerged aquatic vegetation and/or phytoplankton) should be conducted (or developed if needed) in concert with the present battery of animal tests. This would provide a plant indicator that would be useful for identifying the presence of herbicides in the Chesapeake Bay.

- When selecting suspected contaminated regions for future ambient toxicity testing, background data from chemical monitoring, biological community status assessments and toxicity tests (if available) should be used to provide guidance.

SECTION 8

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APPENDIX A

Water quality conditions reported in test chambers during water column tests. Test species were *Cyprinodon variegatus* (Cv), *Eurytemora affinis* (Ea), *Palaemonetes pugio* (Pp) and *Mulinia lateralis* (ML)

Water quality conditions reported during ambient toxicity tests.

Date	Test Species	Station	T (C)	Sal (ppt)	DO (mg/L)	pH
10/11/94	Cv	CONTROL	22.2	15	7.2	7.93
		SASBT	24.1	14	7.1	7.85
		SASTC	24.0	15	6.7	8.11
		BHBCR	24.0	16	7.1	7.85
		BHCUB	24.1	14	6.9	7.94
		BHMBR	23.8	14	7.2	7.78
		BHNWB	23.9	14	6.9	7.90
		BHOTH	23.7	15	7.0	7.85
		BHSPT	23.9	14	6.6	7.80
		MAGGI	24.0	14	7.2	7.91
		MAGSF	24.2	14	6.5	7.81
		SEV50	24.0	14	6.7	7.76
		SEVAP	24.0	14	6.7	7.76
10/12/94	Ea	CONTROL	24.0	14	7.4	7.82
		SASBT	24.6	14	7.6	7.85
		SASTC	24.0	15	7.5	8.08
		BHBCR	23.7	15	7.0	7.71
		BHCUB	23.7	14	7.2	7.85
		BHMBR	23.5	14	7.1	7.70
		BHNWB	23.7	14	7.1	7.82
		BHOTH	23.5	15	7.3	7.70
		BHSPT	23.8	14	7.0	7.71
		MAGGI	24.1	14	7.4	7.82
		MAGSF	23.8	14	7.2	7.87
		SEV50	23.6	14	7.3	7.69
		SEVAP	23.5	14	7.4	7.69
10/12/94	Pp	CONTROL	24.0	14	7.4	7.82
		SASBT	24.6	14	7.6	7.85
		SASTC	24.0	15	7.5	8.08
		BHBCR	23.7	15	7.0	7.71
		BHCUB	23.7	14	7.2	7.85
		BHMBR	23.5	14	7.1	7.70
		BHNWB	23.7	14	7.1	7.82
		BHOTH	23.5	15	7.3	7.70
		BHSPT	23.8	14	7.0	7.71
		MAGGI	24.1	14	7.4	7.82
		MAGSF	23.8	14	7.2	7.87
		SEV50	23.6	14	7.3	7.69
		SEVAP	23.5	14	7.4	7.69

10/12/94	Cv	CONTROL	23.5	15	6.4	7.81
		SASBT	23.9	15	6.4	7.77
		SASTC	23.8	15	6.4	7.79
		BHBCR	23.9	16	7.0	7.91
		BHCUB	23.7	14	6.5	7.81
		BHMBR	23.5	14	6.5	7.78
		BHNWB	23.9	14	6.3	7.77
		BHOTH	23.7	15	6.7	7.83
		BHSPT	23.7	15	6.4	7.74
		MAGGI	23.9	14	6.4	7.79
		MAGSF	23.8	15	6.2	7.78
		SEV50	23.8	14	6.3	7.73
		SEVAP	24.2	14	7.8	6.55
10/13/94	Ea	CONTROL	24.5	14	7.5	8.16
		SASBT	24.8	14	7.2	8.17
		SASTC	24.6	15	7.6	8.20
		BHBCR	24.4	15	7.1	8.07
		BHCUB	24.4	14	7.1	8.06
		BHMBR	24.5	14	7.4	8.13
		BHNWB	24.2	14	7.4	8.14
		BHOTH	24.5	15	7.3	8.09
		BHSPT	24.3	15	7.4	8.11
		MAGGI	24.6	14	7.2	8.08
		MAGSF	24.4	14	7.3	8.12
		SEV50	24.4	14	7.1	8.04
		SEVAP	24.4	14	7.2	8.06
10/13/94	Pp	CONTROL	24.2	14	6.5	7.85
		SASBT	24.3	15	6.4	7.95
		SASTC	24.4	15	6.5	7.94
		BHBCR	24.3	16	6.4	7.87
		BHCUB	24.1	14	6.4	7.90
		BHMBR	24.1	14	6.4	7.87
		BHNWB	24.0	14	6.4	7.89
		BHOTH	24.1	16	6.4	7.93
		BHSPT	24.1	14	6.4	7.89
		MAGGI	24.3	14	6.5	7.89
		MAGSF	24.1	15	6.4	7.90
		SEV50	24.1	14	6.3	7.87
		SEVAP	24.1	14	6.4	7.84

10/13/94	Cv	CONTROL	24.8	15	6.3	7.87
		SASBT	25.0	15	6.4	7.92
		SASTC	24.8	16	6.4	7.91
		BHBCR	24.7	16	6.7	7.94
		BHCUB	24.7	15	6.5	7.88
		BHMBR	24.7	15	6.6	7.89
		BHNWB	25.1	14	6.5	7.88
		BHOTH	24.5	15	6.4	7.87
		BHSPT	25.0	14	6.6	7.90
		MAGGI	25.0	14	6.5	7.90
		MAGSF	24.7	15	6.3	7.88
		SEV50	24.6	14	6.4	7.84
		SEVAP	24.8	14	—	7.82
10/14/94	Ea	CONTROL	24.8	15	7.6	8.14
		SASBT	24.5	15	7.5	8.24
		SASTC	24.5	15	8.0	8.27
		BHBCR	24.3	16	7.3	8.09
		BHCUB	23.8	15	7.3	8.10
		BHMBR	24.8	14	6.9	7.99
		BHNWB	24.4	14	7.4	8.13
		BHOTH	24.0	15	7.3	8.08
		BHSPT	24.0	14	7.3	8.10
		MAGGI	24.2	14	7.3	8.10
		MAGSF	24.2	15	7.3	8.13
		SEV50	24.4	14	6.9	8.01
		SEVAP	24.2	14	7.4	8.10
10/14/94	Pp	CONTROL	24.2	15	6.5	7.85
		SASBT	24.1	15	6.5	7.94
		SASTC	24.1	16	6.2	7.90
		BHBCR	23.9	17	6.5	7.91
		BHCUB	23.5	15	6.6	7.95
		BHMBR	23.8	15	6.7	7.93
		BHNWB	24.2	14	6.5	7.95
		BHOTH	23.9	16	6.7	7.95
		BHSPT	23.9	15	6.4	7.90
		MAGGI	24.1	15	6.4	7.93
		MAGSF	24.1	15	6.4	7.95
		SEV50	23.9	15	6.6	7.88
		SEVAP	24.2	14	6.4	7.88

10/14/94	Cv	CONTROL	24.4	15	6.3	7.80
		SASBT	24.9	15	6.2	7.85
		SASTC	24.2	16	6.5	7.85
		BHBCR	23.9	17	7.9	8.14
		BHCUB	24.2	15	7.6	8.07
		BHMBR	24.2	15	7.5	8.05
		BHNWB	25.1	15	6.6	7.89
		BHOTH	24.6	16	7.0	7.96
		BHSPT	24.2	15	6.9	7.92
		MAGGI	24.9	14	6.5	7.87
		MAGSF	24.4	15	6.4	7.88
		SEV50	24.2	14	6.5	7.85
		SEVAP	24.3	14	6.8	7.78
*10/14/94	ML	CONTROL	—	—	—	7.93
		SASBT	—	—	—	7.82
		SASTC	—	—	—	7.99
		BHBCR	—	—	—	7.80
		BHCUB	—	—	—	7.76
		BHMBR	—	—	—	7.84
		BHNWB	—	—	—	7.88
		BHOTH	—	—	—	7.57
		BHSPT	—	—	—	7.90
		MAGGI	—	—	—	7.96
		MAGSF	—	—	—	7.89
		SEV50	—	—	—	7.75
		SEVAP	—	—	—	7.61
10/15/94	Ea	CONTROL	24.7	15	7.1	7.95
		SASBT	25.0	15	7.0	8.00
		SASTC	25.0	14	7.8	8.07
		BHBCR	24.8	15	6.2	7.79
		BHCUB	24.8	14	6.5	7.84
		BHMBR	24.8	14	6.3	7.81
		BHNWB	24.9	15	6.8	7.91
		BHOTH	24.6	15	6.3	7.84
		BHSPT	24.8	14	6.3	7.80
		MAGGI	24.7	15	6.8	7.92
		MAGSF	24.7	14	6.7	7.92
		SEV50	25.0	14	6.4	7.80
		SEVAP	24.9	14	6.2	7.75

* Temperature (~25C), salinity (15ppt), D.O. (>5.0 mg/L) and pH (as written) were measured in the renewal water after temperature, salinity and pH adjustment.

10/15/94	Pp	CONTROL	23.8	15	6 4	7.80
		SASBT	23.9	16	6.4	7.90
		SASTC	23.9	15	6.4	7.83
		BHBCR	23.6	15	6.3	7.85
		BHCUB	23.7	15	6.5	7.84
		BHMBR	23.6	15	6.4	7.85
		BHNWB	23.7	14	6.4	7.89
		BHOTH	23.7	15	6.5	7.85
		BHSPT	23.5	15	6.5	7.86
		MAGGI	23.9	15	6.5	7.85
		MAGSF	23.7	15	6.3	7.85
		SEV50	23.4	15	6.4	7.83
		SEVAP	23.7	15	6.4	7.81
10/15/94	Cv	CONTROL	24.5	15	6.1	7.74
		SASBT	24.8	14	6.2	7.81
		SASTC	24.6	15	6.2	7.77
		BHBCR	24.4	15	6.9	7.98
		BHCUB	24.5	15	6.7	7.87
		BHMBR	24.5	15	6.8	7.92
		BHNWB	25.1	14	6.2	7.82
		BHOTH	24.6	15	6.5	7.81
		BHSPT	24.5	15	6.3	7.81
		MAGGI	24.7	14	6.2	7.78
		MAGSF	24.5	15	6.1	7.77
		SEV50	24.4	14	6.1	7.72
		SEVAP	24.6	15	6.2	7.71
10/16/94	Ea	CONTROL	25.0	15	7.0	8.01
		SASBT	25.0	15	7.3	8.12
		SASTC	25.1	14	7.4	8.13
		BHBCR	25.1	14	7.4	7.97
		BHCUB	25.1	14	7.1	7.90
		BHMBR	24.6	14	6.7	7.95
		BHNWB	24.4	14	7.0	8.03
		BHOTH	25.0	14	6.4	7.96
		BHSPT	24.3	15	6.8	7.94
		MAGGI	25.3	14	6.8	7.96
		MAGSF	24.8	15	6.5	7.90
		SEV50	24.4	14	6.7	7.91
		SEVAP	24.8	14	6.7	7.91

10/16/94	Pp	CONTROL	23.2	15	6.6	7.86
		SASBT	23.0	15	6.8	8.01
		SASTC	23.2	15	6.6	7.88
		BHBCR	23.0	15	6.8	7.94
		BHCUB	22.9	15	6.7	7.90
		BHMBR	23.6	16	6.6	7.93
		BHNWB	23.2	15	6.8	7.97
		BHOTH	23.1	15	6.8	7.92
		BHSPT	23.0	15	6.7	7.97
		MAGGI	22.9	16	6.8	7.91
		MAGSF	23.1	15	6.6	7.92
		SEV50	22.9	15	6.5	7.90
		SEVAP	23.0	15	6.6	7.86
10/16/94	Cv	CONTROL	24.8	15	6.4	7.85
		SASBT	24.9	15	6.4	7.90
		SASTC	24.8	14	6.7	7.95
		BHBCR	24.7	15	8.5	8.39
		BHCUB	25.1	14	8.1	8.27
		BHMBR	24.6	15	7.0	8.02
		BHNWB	24.7	15	6.6	7.90
		BHOTH	24.8	14	7.0	7.96
		BHSPT	25.1	14	6.7	7.97
		MAGGI	24.8	14	6.2	7.81
		MAGSF	24.8	15	6.5	7.88
		SEV50	24.8	14	6.5	7.87
		SEVAP	24.9	15	6.5	7.87
10/17/94	Ea	CONTROL	25.0	14	7.2	7.96
		SASBT	25.4	15	7.5	8.13
		SASTC	25.8	14	7.0	7.96
		BHBCR	25.7	14	6.6	7.86
		BHCUB	24.8	14	6.8	7.89
		BHMBR	25.2	14	7.1	7.94
		BHNWB	25.4	15	6.9	7.93
		BHOTH	25.7	14	6.9	7.87
		BHSPT	25.3	14	6.7	7.87
		MAGGI	25.2	14	6.8	7.90
		MAGSF	25.5	14	6.8	7.92
		SEV50	25.4	14	6.7	7.87
		SEVAP	25.0	14	6.9	7.87

10/17/94	Pp	CONTROL	25.5	15	6.3	7.83
		SASBT	25.6	15	6.4	7.96
		SASTC	25.2	15	6.4	7.86
		BHBCR	24.9	15	6.2	7.83
		BHCUB	24.9	15	6.2	7.79
		BHMBR	25.7	15	6.4	7.88
		BHNWB	25.0	15	6.6	7.93
		BHOTH	25.0	15	6.6	7.89
		BHSPT	25.5	15	6.2	7.85
		MAGGI	25.1	16	6.3	7.85
		MAGSF	25.3	15	6.2	7.86
		SEV50	25.4	15	6.2	7.82
		SEVAP	25.0	15	6.4	7.82
10/17/94	Cv	CONTROL	25.9	15	6.1	7.70
		SASBT	26.2	15	6.2	7.85
		SASTC	25.4	15	6.2	7.79
		BHBCR	25.5	15	9.2	8.44
		BHCUB	25.1	15	7.5	8.06
		BHMBR	26.0	15	7.3	8.06
		BHNWB	26.3	15	6.9	7.94
		BHOTH	26.0	14	7.5	8.05
		BHSPT	25.1	15	5.9	7.69
		MAGGI	26.0	15	6.4	7.79
		MAGSF	26.0	15	6.4	7.86
		SEV50	25.7	15	6.1	7.77
		SEVAP	25.7	15	6.2	7.71
*10/17/94	ML	CONTROL	—	—	—	7.93
		SASBT	—	—	—	7.86
		SASTC	—	—	—	7.97
		BHBCR	—	—	—	7.41
		BHCUB	—	—	—	7.59
		BHMBR	—	—	—	7.96
		BHNWB	—	—	—	7.88
		BHOTH	—	—	—	7.88
		BHSPT	—	—	—	7.83
		MAGGI	—	—	—	7.98
		MAGSF	—	—	—	7.92
		SEV50	—	—	—	7.92
		SEVAP	—	—	—	7.61

* Temperature (~25C), salinity (15ppt), D.O. (>5.0 mg/L) and pH (as written) were measured in the renewal water after temperature, salinity and pH adjustment.

10/18/94	Ea	CONTROL	25.1	15	6.8	8.02
		SASBT	25.2	15	7.0	8.12
		SASTC	25.8	15	6.9	8.06
		BHBCR	25.4	14	6.5	7.89
		BHCUB	25.1	14	6.5	7.93
		BHMBR	24.9	14	6.6	7.98
		BHNWB	25.4	14	6.6	7.98
		BHOTH	25.7	15	6.8	7.97
		BHSPT	25.4	14	6.5	7.92
		MAGGI	25.4	14	6.6	7.97
		MAGSF	24.7	15	6.7	8.00
		SEV50	25.8	14	6.6	7.97
		SEVAP	24.7	15	6.6	7.94
10/18/94	Pp	CONTROL	25.2	16	8.3	7.89
		SASBT	25.3	16	6.4	7.94
		SASTC	25.3	15	6.3	7.88
		BHBCR	25.0	15	6.3	7.83
		BHCUB	24.9	15	6.3	7.83
		BHMBR	25.1	15	8.3	7.87
		BHNWB	25.1	15	6.5	7.94
		BHOTH	25.3	15	6.2	7.85
		BHSPT	25.2	15	6.0	7.81
		MAGGI	25.3	15	6.2	7.86
		MAGSF	25.1	15	6.3	7.86
		SEV50	25.1	16	6.3	7.86
		SEVAP	25.2	15	6.2	7.85
10/18/94	Cv	CONTROL	25.8	15	5.3	7.67
		SASBT	26.6	15	5.2	7.73
		SASTC	25.3	15	5.6	7.76
		BHBCR	25.9	14	6.8	8.01
		BHCUB	25.4	15	6.5	7.93
		BHMBR	26.2	15	5.3	7.70
		BHNWB	26.5	15	5.2	7.70
		BHOTH	26.4	15	5.6	7.70
		BHSPT	25.4	15	5.1	7.60
		MAGGI	26.3	15	5.4	7.69
		MAGSF	26.2	15	5.7	7.77
		SEV50	25.5	15	5.5	7.73
		SEVAP	25.3	15	5.5	7.66

10/19/94	Ea	CONTROL	25.8	15	6.6	8.10
		SASBT	25.1	15	7.0	8.27
		SASTC	24.6	15	6.8	8.16
		BHBCR	24.3	14	6.3	7.96
		BHCUB	25.6	15	6.5	8.02
		BHMBR	26.0	15	6.6	8.02
		BHNWB	25.6	14	6.4	8.07
		BHOTH	24.1	15	6.5	8.11
		BHSPT	25.6	14	6.6	8.03
		MAGGI	25.7	15	6.7	8.07
		MAGSF	24.9	15	6.5	8.10
		SEV50	24.8	14	6.4	8.08
		SEVAP	25.1	15	6.3	8.04
10/19/94	Pp	CONTROL	24.9	16	5.9	7.96
		SASBT	25.0	16	6.3	8.04
		SASTC	24.8	15	6.2	7.96
		BHBCR	25.4	15	6.0	7.86
		BHCUB	25.5	16	6.3	7.86
		BHMBR	24.7	15	5.9	7.95
		BHNWB	24.6	15	6.5	8.05
		BHOTH	25.6	15	6.0	7.89
		BHSPT	25.0	15	5.8	7.89
		MAGGI	25.1	15	6.0	7.97
		MAGSF	24.8	15	6.1	7.96
		SEV50	24.7	15	6.0	7.95
		SEVAP	25.1	15	6.1	7.86
10/19/94	Cv	CONTROL	25.9	16	6.5	7.95
		SASBT	26.2	16	5.5	7.79
		SASTC	27.0	15	5.8	7.79
		BHBCR	26.3	14	7.1	8.06
		BHCUB	26.9	15	6.7	7.96
		BHMBR	25.4	15	6.0	7.83
		BHNWB	26.4	15	5.4	7.69
		BHOTH	25.9	15	5.7	7.73
		BHSPT	26.6	15	6.1	7.78
		MAGGI	26.5	15	6.3	7.82
		MAGSF	25.9	15	7.6	8.14
		SEV50	26.0	15	6.6	7.91
		SEVAP	26.5	15	6.5	7.85

10/20/94	Ea	CONTROL	26.1	15	7.5	8.03
		SASBT	26.7	15	8.1	8.16
		SASTC	26.3	15	7.7	8.05
		BHBCR	26.2	14	7.0	7.82
		BHCUB	26.2	15	7.4	7.92
		BHMBR	26.5	14	7.4	8.00
		BHNWB	26.0	14	7.3	7.98
		BHOTH	26.2	15	7.5	7.97
		BHSPT	26.2	14	7.4	7.94
		MAGGI	26.3	15	7.5	7.98
		MAGSF	26.2	15	7.4	7.98
		SEV50	26.4	15	7.4	7.98
		SEVAP	26.3	15	7.4	7.96
10/20/94	Pp	CONTROL	26.2	16	6.6	8.02
		SASBT	25.8	16	7.6	8.24
		SASTC	25.4	16	7.1	8.05
		BHBCR	25.0	15	6.8	7.90
		BHCUB	25.1	16	6.9	7.95
		BHMBR	26.0	15	6.6	7.98
		BHNWB	25.4	15	8.3	8.43
		BHOTH	24.9	16	6.9	8.01
		BHSPT	25.7	15	6.8	8.03
		MAGGI	25.6	15	7.3	8.09
		MAGSF	25.6	15	7.3	8.13
		SEV50	25.8	16	6.5	7.92
		SEVAP	25.0	16	7.1	8.01

APPENDIX B

Pesticides and semi-volatile compounds data

from sediment toxicity tests (ug/g)

Organics analysis data for pesticide compounds (Note: underlined values represent concentrations exceeding "Effects Range-Medium" levels for selected polynuclear aromatic hydrocarbons, as defined by Long and Morgan, 1990).

Sample Location:Turner Creek | Collection Dates:10/7/94-10/8/94

Compound	Concentration (ug/g)	Detection Limit
Hexachlorobenzene		0.0035
Aldrin		0.0041
Alpha-BHC		0.0061
Beta-BHC		0.0058
DDD	tr.	0.0034
DDE	tr.	0.0027
DDT		0.0023
Dieldrin	tr.	0.0093
Endrin		0.0076
Heptachlor		0.0030
Heptachlor Epoxide		0.0015
Alpha-Chlordane		0.0007
Gamma-Chlordane	tr.	0.0016
Alachlor		0.0050
Metolachlor		0.0065
Trifluralin		0.0038
Chlorpyrifos		0.0016
Fenvalerate		0.0017
Lindane		0.0043
Permethrin		0.0077
2,3',5-Trichlorobiphenyl		0.0031
2,4,4'-Trichlorobiphenyl		0.0012
2,2',4,4'-Trichlorobiphenyl		0.0013
Methoxychlor		0.0026

Organics analysis data for pesticide compounds (Note: underlined values represent concentrations exceeding "Effects Range-Medium" levels for selected polynuclear aromatic hydrocarbons, as defined by Long and Morgan, 1990).

Sample Location:Betterton Collection Dates:10/7/94-10/8/94

Compound	Concentration (ug/g)	Detection Limit
Hexachlorobenzene		0.0035
Aldrin		0.0041
Alpha-BHC		0.0061
Beta-BHC		0.0058
DDD		0.0034
DDE		0.0027
DDT		0.0023
Dieldrin	tr.	0.0093
Endrin		0.0076
Heptachlor		0.0030
Heptachlor Epoxide		0.0015
Alpha-Chlordane		0.0007
Gamma-Chlordane	tr.	0.0016
Alachlor		0.0050
Metolachlor		0.0065
Trifluralin		0.0038
Chlorpyrifos		0.0016
Fenvalerate		0.0017
Lindane		0.0043
Permethrin	tr.	0.0077
2,3',5-Trichlorobiphenyl		0.0031
2,4,4'-Trichlorobiphenyl		0.0012
2,2',4,4'-Trichlorobiphenyl		0.0013
Methoxychlor		0.0026

Organics analysis data for pesticide compounds (Note: underlined values represent concentrations exceeding "Effects Range-Medium" levels for selected polynuclear aromatic hydrocarbons, as defined by Long and Morgan, 1990).

Sample Location:Bear Creek   Collection Dates:10/7/94-10/8/94

Compound	Concentration (ug/g)	Detection Limit
Hexachlorobenzene		0.0035
Aldrin		0.0041
Alpha-BHC		0.0061
Beta-BHC		0.0058
DDD		0.0034
DDE		0.0027
DDT		0.0023
Dieldrin		0.0093
Endrin	0.027	0.0076
Heptachlor		0.0030
Heptachlor Epoxide		0.0015
Alpha-Chlordane		0.0007
Gamma-Chlordane	tr.	0.0016
Alachlor	0.0258	0.0050
Metolachlor	0.0157	0.0065
Trifluralin	tr.	0.0038
Chlorpyrifos		0.0016
Fenvalerate		0.0017
Lindane	tr.	0.0043
Permethrin		0.0077
2,3',5-Trichlorobiphenyl	0.0261	0.0031
2,4,4'-Trichlorobiphenyl	0.0057	0.0012
2,2',4,4'-Trichlorobiphenyl		0.0013
Methoxychlor	0.0032	0.0026

Organics analysis data for pesticide compounds (Note: underlined values represent concentrations exceeding "Effects Range-Medium" levels for selected polynuclear aromatic hydrocarbons, as defined by Long and Morgan, 1990).

Sample Location: Curtis Bay   Collection Dates: 10/7/94-10/8/94

Compound	Concentration (ug/g)	Detection Limit
Hexachlorobenzene		0.0035
Aldrin		0.0041
Alpha-BHC		0.0061
Beta-BHC		0.0058
DDD		0.0034
DDE		0.0027
DDT		0.0023
Dieldrin		0.0093
Endrin		0.0076
Heptachlor		0.0030
Heptachlor Epoxide	tr.	0.0015
Alpha-Chlordane		0.0007
Gamma-Chlordane	tr.	0.0016
Alachlor		0.0050
Metolachlor	0.01650	0.0065
Trifluralin	tr.	0.0038
Chlorpyrifos		0.0016
Fenvalerate		0.0017
Lindane		0.0043
Permethrin		0.0077
2,3',5-Trichlorobiphenyl		0.0031
2,4,4'-Trichlorobiphenyl		0.0012
2,2',4,4'-Trichlorobiphenyl		0.0013
Methoxychlor		0.0026

Organics analysis data for pesticide compounds (Note: underlined values represent concentrations exceeding "Effects Range-Medium" levels for selected polynuclear aromatic hydrocarbons, as defined by Long and Morgan, 1990).

Sample Location:Gibson Island Collection Dates:10/7/94-10/8/94

Compound	Concentration (ug/g)	Detection Limit
Hexachlorobenzene		0.0035
Aldrin		0.0041
Alpha-BHC		0.0061
Beta-BHC		0.0058
DDD		0.0034
DDE		0.0027
DDT		0.0023
Dieldrin		0.0093
Endrin		0.0076
Heptachlor		0.0030
Heptachlor Epoxide		0.0015
Alpha-Chlordane		0.0007
Gamma-Chlordane	tr.	0.0016
Alachlor		0.0050
Metolachlor		0.0065
Trifluralin		0.0038
Chlorpyrifos		0.0016
Fenvalerate		0.0017
Lindane		0.0043
Permethrin		0.0077
2,3',5-Trichlorobiphenyl		0.0031
2,4,4'-Trichlorobiphenyl		0.0012
2,2',4,4'-Trichlorobiphenyl		0.0013
Methoxychlor		0.0026

Organics analysis data for pesticide compounds (Note: underlined values represent concentrations exceeding "Effects Range-Medium" levels for selected polynuclear aromatic hydrocarbons, as defined by Long and Morgan, 1990).

Sample Location:Junction Rt 50   Collection Dates:10/7/94-10/8/94

Compound	Concentration (ug/g)	Detection Limit
Hexachlorobenzene		0.0035
Aldrin		0.0041
Alpha-BHC		0.0061
Beta-BHC		0.0058
DDD	tr.	0.0034
DDE		0.0027
DDT		0.0023
Dieldrin	tr.	0.0093
Endrin	tr.	0.0076
Heptachlor		0.0030
Heptachlor Epoxide		0.0015
Alpha-Chlordane		0.0007
Gamma-Chlordane		0.0016
Alachlor		0.0050
Metolachlor		0.0065
Trifluralin		0.0038
Chlorpyrifos		0.0016
Fenvalerate		0.0017
Lindane		0.0043
Permethrin		0.0077
2,3',5-Trichlorobiphenyl		0.0031
2,4,4'-Trichlorobiphenyl		0.0012
2,2',4,4'-Trichlorobiphenyl		0.0013
Methoxychlor		0.0026

Organics analysis data for pesticide compounds (Note: underlined values represent concentrations exceeding "Effects Range-Medium" levels for selected polynuclear aromatic hydrocarbons, as defined by Long and Morgan, 1990).

Sample Location:Outer Harbor   Collection Dates:10/7/94-10/8/94

Compound	Concentration (ug/g)	Detection Limit
Hexachlorobenzene		0.0035
Aldrin		0.0041
Alpha-BHC		0.0061
Beta-BHC		0.0058
DDD	0.0053	0.0034
DDE		0.0027
DDT		0.0023
Dieldrin		0.0093
Endrin		0.0076
Heptachlor		0.0030
Heptachlor Epoxide	tr.	0.0015
Alpha-Chlordane		0.0007
Gamma-Chlordane		0.0016
Alachlor		0.0050
Metolachlor	0.01340	0.0065
Trifluralin	tr.	0.0038
Chlorpyrifos		0.0016
Fenvalerate		0.0017
Lindane		0.0043
Permethrin		0.0077
2,3',5-Trichlorobiphenyl		0.0031
2,4,4'-Trichlorobiphenyl		0.0012
2,2',4,4'-Trichlorobiphenyl		0.0013
Methoxychlor		0.0026

Organics analysis data for pesticide compounds (Note: underlined values represent concentrations exceeding "Effects Range-Medium" levels for selected polynuclear aromatic hydrocarbons, as defined by Long and Morgan, 1990).

Sample Location:Middle Branch Collection Dates:10/7/94-10/8/94

Compound	Concentration (ug/g)	Detection Limit
Hexachlorobenzene		0.0035
Aldrin		0.0041
Alpha-BHC		0.0061
Beta-BHC	tr.	0.0058
DDD		0.0034
DDE		0.0027
DDT		0.0023
Dieldrin		0.0093
Endrin		0.0076
Heptachlor		0.0030
Heptachlor Epoxide	tr.	0.0015
Alpha-Chlordane		0.0007
Gamma-Chlordane		0.0016
Alachlor		0.0050
Metolachlor	0.00854	0.0065
Trifluralin		0.0038
Chlorpyrifos		0.0016
Fenvalerate		0.0017
Lindane		0.0043
Permethrin		0.0077
2,3',5-Trichlorobiphenyl		0.0031
2,4,4'-Trichlorobiphenyl		0.0012
2,2',4,4'-Trichlorobiphenyl		0.0013
Methoxychlor		0.0026

Organics analysis data for pesticide compounds (Note: underlined values represent concentrations exceeding "Effects Range-Medium" levels for selected polynuclear aromatic hydrocarbons, as defined by Long and Morgan, 1990).

Sample Location:Northwest Harbor Collection Dates:10/7/94-10/8/94

Compound	Concentration (ug/g)	Detection Limit
Hexachlorobenzene	tr.	0.0035
Aldrin		0.0041
Alpha-BHC		0.0061
Beta-BHC		0.0058
DDD		0.0034
DDE		0.0027
DDT		0.0023
Dieldrin		0.0093
Endrin		0.0076
Heptachlor		0.0030
Heptachlor Epoxide	tr.	0.0015
Alpha-Chlordane		0.0007
Gamma-Chlordane		0.0016
Alachlor		0.0050
Metolachlor		0.0065
Trifluralin		0.0038
Chlorpyrifos		0.0016
Fenvalerate		0.0017
Lindane		0.0043
Permethrin		0.0077
2,3',5-Trichlorobiphenyl		0.0031
2,4,4'-Trichlorobiphenyl		0.0012
2,2',4,4'-Trichlorobiphenyl		0.0013
Methoxychlor		0.0026

Organics analysis data for pesticide compounds (Note: underlined values represent concentrations exceeding "Effects Range-Medium" levels for selected polynuclear aromatic hydrocarbons, as defined by Long and Morgan, 1990).

Sample Location: South Ferry Collection Dates: 10/7/94-10/8/94

Compound	Concentration (ug/g)	Detection Limit
Hexachlorobenzene		0.0035
Aldrin		0.0041
Alpha-BHC		0.0061
Beta-BHC		0.0058
DDD		0.0034
DDE	tr.	0.0027
DDT		0.0023
Dieldrin	tr.	0.0093
Endrin		0.0076
Heptachlor		0.0030
Heptachlor Epoxide		0.0015
Alpha-Chlordane	tr.	0.0007
Gamma-Chlordane	0.005	0.0016
Alachlor		0.0050
Metolachlor		0.0065
Trifluralin		0.0038
Chlorpyrifos		0.0016
Fenvalerate		0.0017
Lindane		0.0043
Permethrin		0.0077
2,3',5-Trichlorobiphenyl		0.0031
2,4,4'-Trichlorobiphenyl		0.0012
2,2',4,4'-Trichlorobiphenyl		0.0013
Methoxychlor		0.0026

Organics analysis data for pesticide compounds (Note: underlined values represent concentrations exceeding "Effects Range-Medium" levels for selected polynuclear aromatic hydrocarbons, as defined by Long and Morgan, 1990).

Sample Location:Sparrows Point Collection Dates:10/7/94-10/8/94

Compound	Concentration (ug/g)	Detection Limit
Hexachlorobenzene		0.0035
Aldrin		0.0041
Alpha-BHC		0.0061
Beta-BHC		0.0058
DDD		0.0034
DDE		0.0027
DDT		0.0023
Dieldrin		0.0093
Endrin		0.0076
Heptachlor		0.0030
Heptachlor Epoxide		0.0015
Alpha-Chlordane	tr.	0.0007
Gamma-Chlordane	tr.	0.0016
Alachlor		0.0050
Metolachlor	0.02770	0.0065
Trifluralin	tr.	0.0038
Chlorpyrifos		0.0016
Fenvalerate		0.0017
Lindane		0.0043
Permethrin		0.0077
2,3',5-Trichlorobiphenyl		0.0031
2,4,4'-Trichlorobiphenyl		0.0012
2,2',4,4'-Trichlorobiphenyl		0.0013
Methoxychlor		0.0026

Organics analysis data for pesticide compounds (Note: underlined values represent concentrations exceeding "Effects Range-Medium" levels for selected polynuclear aromatic hydrocarbons, as defined by Long and Morgan, 1990).

Sample Location:Annapolis Collection Dates:10/7/94-10/8/94

Compound	Concentration (ug/g)	Detection Limit
Hexachlorobenzene		0.0035
Aldrin		0.0041
Alpha-BHC		0.0061
Beta-BHC		0.0058
DDD		0.0034
DDE		0.0027
DDT		0.0023
Dieldrin	tr.	0.0093
Endrin	tr.	0.0076
Heptachlor		0.0030
Heptachlor Epoxide		0.0015
Alpha-Chlordane		0.0007
Gamma-Chlordane		0.0016
Alachlor		0.0050
Metolachlor		0.0065
Trifluralin	0.0017	0.0038
Chlorpyrifos		0.0016
Fenvalerate		0.0017
Lindane		0.0043
Permethrin		0.0077
2,3',5-Trichlorobiphenyl	tr.	0.0031
2,4,4'-Trichlorobiphenyl		0.0012
2,2',4,4'-Trichlorobiphenyl		0.0013
Methoxychlor		0.0026

Organics analysis data for semi-volatile compounds (Note: underlined values represent concentrations exceeding "Effects Range-Medium" levels for selected polynuclear aromatic hydrocarbons, as defined by Long and Morgan, 1990).

Sample Location:Curtis Bay Collection Dates:10/7/94-10/8/94

Compound	Concentration (ug/g)	Detection Limit
Naphthalene		0.0050
Acenaphthene		0.0020
Fluorene		0.0020
Phenanthrene	0.27	0.0020
Anthracene	0.04	0.0002
Fluoranthene	0.59	0.0030
Pyrene	0.719	0.0030
Benzo (a) anthracene	0.162	0.0003
Chrysene		0.0004
Benzo (a) pyrene	0.78	0.0002
Indeno (1,2,3-cd)pyrene	0.987	0.0002
Dibenzo (a,h) anthracene	<u>0.846</u>	0.0004
Benzo (g,h,i) perylene	0.661	0.0002

Organics analysis data for semi-volatile compounds (Note: underlined values represent concentrations exceeding "Effects Range-Medium" levels for selected polynuclear aromatic hydrocarbons, as defined by Long and Morgan, 1990).

Sample Location:Middle Branch Collection Dates:10/7/94-10/8/94

Compound	Concentration (ug/g)	Detection Limit
Naphthalene	0.135	0.0050
Acenaphthene		0.0020
Fluorene	0.029	0.0020
Phenanthrene	0.269	0.0020
Anthracene	0.044	0.0002
Fluoranthene	1.5	0.0030
Pyrene	1.25	0.0030
Benzo (a) anthracene	0.283	0.0002
Chrysene		0.0003
Benzo (a) pyrene	0.966	0.0002
Indeno (1,2,3-cd)pyrene	2.63	0.0001
Dibenzo (a,h) anthracene	1.9	0.0003
Benzo (g,h,i) perylene	1.82	0.0001

Organics analysis data for semi-volatile compounds (Note: underlined values represent concentrations exceeding "Effects Range-Medium" levels for selected polynuclear aromatic hydrocarbons, as defined by Long and Morgan, 1990).

Sample Location:Northwest Harbor   Collection Dates:10/7/94-10/8/94

Compound	Concentration (ug/g)	Detection Limit
Naphthalene	1.74	0.0050
Acenaphthene	0.321	0.0020
Fluorene	0.6	0.0020
Phenanthrene	5.5	0.0020
Anthracene	0.599	0.0002
Fluoranthene	<u>8.26</u>	0.0030
Pyrene	<u>10.11</u>	0.0030
Benzo (a) anthracene	1.19	0.0003
Chrysene		0.0003
Benzo (a) pyrene	5.89	0.0002
Indeno (1,2,3-cd)pyrene	4.55	0.0002
Dibenzo (a,h) anthracene	<u>5.75</u>	0.0003
Benzo (g,h,i) perylene	4.21	0.0001

Organics analysis data for semi-volatile compounds (Note: underlined values represent concentrations exceeding "Effects Range-Medium" levels for selected polynuclear aromatic hydrocarbons, as defined by Long and Morgan, 1990).

Sample Location:Outer Harbor Collection Dates:10/7/94-10/8/94

Compound	Concentration (ug/g)	Detection Limit
Naphthalene		0.0060
Acenaphthene		0.0020
Fluorene	0.05	0.0020
Phenanthrene	0.909	0.0020
Anthracene	0.058	0.0002
Fluoranthene	0.701	0.0030
Pyrene	2.2	0.0030
Benzo (a) anthracene	0.34	0.0003
Chrysene	0.501	0.0004
Benzo (a) pyrene	2.14	0.0002
Indeno (1,2,3-cd)pyrene	2.31	0.0002
Dibenzo (a,h) anthracene	1.12	0.0004
Benzo (g,h,i) perylene	1.58	0.0002

Organics analysis data for semi-volatile compounds (Note: underlined values represent concentrations exceeding "Effects Range-Medium" levels for selected polynuclear aromatic hydrocarbons, as defined by Long and Morgan, 1990).

Sample Location:Sparrows Point Collection Dates:10/7/94-10/8/94

Compound	Concentration (ug/g)	Detection Limit
Naphthalene	4.41	0.0060
Acenaphthene	0.06	0.0020
Fluorene	0.15	0.0020
Phenanthrene	4.48	0.0020
Anthracene	0.296	0.0002
Fluoranthene	2.08	0.0030
Pyrene	5.54	0.0030
Benzo (a) anthracene	1.03	0.0003
Chrysene	1.2	0.0004
Benzo (a) pyrene	5.32	0.0002
Indeno (1,2,3-cd)pyrene	6	0.0002
Dibenzo (a,h) anthracene	2.55	0.0004
Benzo (g,h,i) perylene	3.94	0.0002

Organics analysis data for semi-volatile compounds (Note: underlined values represent concentrations exceeding "Effects Range-Medium" levels for selected polynuclear aromatic hydrocarbons, as defined by Long and Morgan, 1990).

Sample Location: Betterton   Collection Dates: 10/7/94-10/8/94

Compound	Concentration (ug/g)	Detection Limit
Naphthalene	0.126	0.0050
Acenaphthene		0.0020
Fluorene	0.024	0.0020
Phenanthrene	0.215	0.0020
Anthracene	0.031	0.0002
Fluoranthene	0.395	0.0030
Pyrene	0.237	0.0030
Benzo (a) anthracene	0.063	0.0003
Chrysene	0.103	0.0003
Benzo (a) pyrene	0.121	0.0002
Indeno (1,2,3-cd)pyrene	0.339	0.0002
Dibenzo (a,h) anthracene	0.246	0.0003
Benzo (g,h,i) perylene	0.204	0.0001

Organics analysis data for semi-volatile compounds (Note: underlined values represent concentrations exceeding "Effects Range-Medium" levels for selected polynuclear aromatic hydrocarbons, as defined by Long and Morgan, 1990).

Sample Location:Turner Creek   Collection Dates:10/7/94-10/8/94

Compound	Concentration (ug/g)	Detection Limit
Naphthalene	0.254	0.0040
Acenaphthene		0.0020
Fluorene	0.046	0.0020
Phenanthrene	0.318	0.0020
Anthracene	0.047	0.0002
Fluoranthene	0.26	0.0030
Pyrene	0.384	0.0030
Benzo (a) anthracene	0.064	0.0002
Chrysene		0.0003
Benzo (a) pyrene	0.101	0.0002
Indeno (1,2,3-cd)pyrene	0.18	0.0001
Dibenzo (a,h) anthracene	0.063	0.0003
Benzo (g,h,i) perylene	0.152	0.0001

Organics analysis data for semi-volatile compounds (Note: underlined values represent concentrations exceeding "Effects Range-Medium" levels for selected polynuclear aromatic hydrocarbons, as defined by Long and Morgan, 1990).

Sample Location: South Ferry   Collection Dates: 10/7/94-10/8/94

Compound	Concentration (ug/g)	Detection Limit
Naphthalene	0.519	0.0040
Acenaphthene		0.0020
Fluorene	0.083	0.0020
Phenanthrene	0.643	0.0020
Anthracene	0.094	0.0002
Fluoranthene	1.12	0.0030
Pyrene	1.22	0.0030
Benzo (a) anthracene	0.102	0.0002
Chrysene	0.326	0.0003
Benzo (a) pyrene	0.297	0.0002
Indeno (1,2,3-cd)pyrene	0.382	0.0001
Dibenzo (a,h) anthracene	0.213	0.0003
Benzo (g,h,i) perylene	0.299	0.0001

Organics analysis data for semi-volatile compounds (Note: underlined values represent concentrations exceeding "Effects Range-Medium" levels for selected polynuclear aromatic hydrocarbons, as defined by Long and Morgan, 1990).

Sample Location:Gibson Island　　　Collection Dates:10/7/94-10/8/94

Compound	Concentration (ug/g)	Detection Limit
Naphthalene	0.124	0.0040
Acenaphthene		0.0020
Fluorene	0.031	0.0020
Phenanthrene	0.139	0.0010
Anthracene	0.033	0.0002
Fluoranthene	0.385	0.0030
Pyrene	0.283	0.0030
Benzo (a) anthracene	0.064	0.0002
Chrysene		0.0002
Benzo (a) pyrene	0.056	0.0002
Indeno (1,2,3-cd)pyrene		0.0001
Dibenzo (a,h) anthracene	0.051	0.0003
Benzo (g,h,i) perylene	0.147	0.0001

Organics analysis data for semi-volatile compounds (Note: underlined values represent concentrations exceeding "Effects Range-Medium" levels for selected polynuclear aromatic hydrocarbons, as defined by Long and Morgan, 1990).

Sample Location:Junction Rt 50   Collection Dates:10/7/94-10/8/94

Compound	Concentration (ug/g)	Detection Limit
Naphthalene	0.164	0.0040
Acenaphthene		0.0020
Fluorene	0.044	0.0020
Phenanthrene	0.2	0.0020
Anthracene	0.055	0.0002
Fluoranthene	0.6	0.0030
Pyrene	0.563	0.0030
Benzo (a) anthracene	0.152	0.0003
Chrysene		0.0003
Benzo (a) pyrene	0.231	0.0002
Indeno (1,2,3-cd)pyrene	0.408	0.0001
Dibenzo (a,h) anthracene	0.248	0.0003
Benzo (g,h,i) perylene	0.273	0.0001

Organics analysis data for semi-volatile compounds (Note: underlined values represent concentrations exceeding "Effects Range-Medium" levels for selected polynuclear aromatic hydrocarbons, as defined by Long and Morgan, 1990).

Sample Location: Annapolis Collection Dates: 10/7/94-10/8/94

Compound	Concentration (ug/g)	Detection Limit
Naphthalene	0.191	0.0040
Acenaphthene		0.0020
Fluorene	0.052	0.0020
Phenanthrene	0.304	0.0020
Anthracene	0.043	0.0002
Fluoranthene	1.22	0.0030
Pyrene	1.11	0.0030
Benzo (a) anthracene	0.27	0.0003
Chrysene		0.0003
Benzo (a) pyrene	0.401	0.0002
Indeno (1,2,3-cd)pyrene	0.604	0.0001
Dibenzo (a,h) anthracene	<u>0.385</u>	0.0003
Benzo (g,h,i) perylene	0.405	0.0001

Organics analysis data for semi-volatile compounds (Note: underlined values represent concentrations exceeding "Effects Range-Medium" levels for selected polynuclear aromatic hydrocarbons, as defined by Long and Morgan, 1990).

Sample Location: Bear Creek   Collection Dates: 10/7/94-10/8/94

Compound	Concentration (ug/g)	Detection Limit
Naphthalene	0.21	0.0050
Acenaphthene		0.0020
Fluorene		0.0020
Phenanthrene	0.98	0.0020
Anthracene	0.052	0.0002
Fluoranthene	1.82	0.0030
Pyrene	<u>6.94</u>	0.0030
Benzo (a) anthracene	0.784	0.0003
Chrysene		0.0003
Benzo (a) pyrene	<u>3.81</u>	0.0002
Indeno (1,2,3-cd)pyrene	3.24	0.0002
Dibenzo (a,h) anthracene	<u>3.55</u>	0.0003
Benzo (g,h,i) perylene	2.35	0.0001