Assessment of the Environmental Impacts of the Hart-Miller Island Confined Disposal Facility, Maryland

Year 15 Exterior Monitoring Technical Report (September 1995-August 1996)

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MDE

Prepared For
Maryland Port Administration
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LIST OF ACRONYMS AND ABBREVIATIONS

AAS - Atomic Absorption Spectrometry

Ag - Silver

As - Arsenic

AVS - Acid Volatile Sulfide

BAF - Bioaccumulation Factor

BCF - Bioconcentration Factor

B-IBI - Benthic Index of Biotic Integrity

CBL - Chesapeake Biological Laboratory

Cd - Cadmium

CDF - Confined Disposal Facility

COC - Citizens' Oversight Committee

COMAR - Code of Maryland Regulations

CWA - Clean Water Act

Cr - Chromium

Cu - Copper

CWA - Clean Water Act

DCAD - Dredging Coordination and Assessment Division

ERL - Effects Range Low

ERM - Effects Range Median

Fe - Iron

GC - Gas Chromatography

GFAAS - Graphite Furnace Atomic Absorption Spectrometry

Hg - Mercury

HMI - Hart-Miller Island Confined Disposal Facility

ICAP - Inductively Coupled Argon Plasma

LBP - Lipid Bioaccumulation Potential

MCY -Million Cubic Yards

MDE - Maryland Department of the Environment

MDNR - Maryland Department of Natural Resources

MES - Maryland Environmental Service

MGD - Million Gallons Per Day

MGS - Maryland Geological Survey

Mn - Manganese

MPA - Maryland Port Administration

MS - Mass Spectrometry

NBS - National Bureau of Standards

NEPA - National Environmental Policy Act

Ni - Nickel

NIST - National Institute of Standards and Technology

NOAA - National Oceanic and Atmospheric Administration

NRC - National Research Council of Canada

OC - Organochlorine Pesticide

PAH - Polynuclear Aromatic Hydrocarbon

Pb - Lead

PCB - Polychlorinated Biphenyl

PI(s) - Principal Investigator(s)

PPB - Parts Per Billion

PPM - Parts Per Million

PPT - Parts Per Thousand

QA - Quality Assurance

QC - Quality Control

SOP - Standard Operating Procedure

SQC - Sediment Quality Criteria

SQS - Sediment Quality Standard

SRM - Standard Reference Material

TBP - Theoretical Bioaccumulation Potential

TDL - Target Detection Limit

TEF - Toxicity Equivalency Factor

TOC - Total Organic Carbon

USACE - U.S. Army Corps of Engineers

UMCES - University of Maryland Center for Environmental Science

USCS - Unified Soil Classification System

USEPA - U.S. Environmental Protection Agency

USFDA - U.S. Food and Drug Administration

WMA - Water Management Administration

WQC - Water Quality Criteria

WQS - Water Quality Standards

Zn - Zinc

CONVERSIONS[1]

WEIGHT:

1Kg = 1000g = 2.205lbs.
1g = 1000mg = 2.205 x 10^{-3}lb
1mg = 1000μg = 2.205 x 10^{-6}lb

1 lb = 16oz = 0.454Kg

LENGTH:

1m = 100cm = 3.28ft = 39.370in
1cm = 10mm = 0.394in
1mm = 1000μm = 0.0394in

1ft = 12in = 0.348m

CONCENTRATION:

1ppm = 1mg/L = 1mg/Kg = 1μg/g = 1mL/m^3
1g/cc = 1Kg/L = 8.345 lbs/gallon
1g/m^3 = 1mg/L = 6.243 x 10^{-5}lbs/ft^3

1 lb/gal = 7.481 lbs/ft^3 = 0.120g/cc = 119.826g/L = 119.826Kg/m^3
1oz/gal = 7.489Kg/m^3

VOLUME:

1L = 1000mL
1mL = 1000μL
1cc = $10^{-6}m^3$

1yd^3 = 27ft^3 = 764.55L = 0.764m^3
1acre-ft = 1233.482m^3
1 gallon = 3785cc
1ft^3 = 0.028m^3 = 28.317L

FLOW:

1m/s = 196.850ft/min = 3.281ft/s
1m^3/s = 35.7ft^3/s

1ft^3/s = 1699.011L/min = 28.317L/s
1ft^2/hr = 2.778 x $10^{-4}ft^2$/s = 2.581 x $10^{-5}m^2$/s
1ft/s = 0.031m/s
1yd^3/min = 0.45ft^3/s
1yd^3/s = 202.03gal/s = 764.55L/s

AREA:

1m^2 = 10.764ft^2
1hectare = 10000m^2 = 2.471acres

1ft^2 = 0.093m^2
1acre = 4046.856m^2 = 0.405 hectares

[1] Modified from the June 1994 Draft "Evaluation of Dredged Material Proposed for Discharge in Waters of the U.S. – Testing Manual" published by the U.S. Environmental Protection Agency and the U. S. Army Corp of Engineers.

CHAPTER 1: PROJECT MANAGEMENT AND SCIENTIFIC/TECHNICAL COORDINATION (PROJECT I)

Hart-Miller Island Exterior Monitoring Program

July 1995 - August 1996

Prepared for

Maryland Port Administration
Maryland Department of Transportation

By

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The Maryland Department of the Environment would like to thank all the members of the HMI Exterior Monitoring Program's TRC and the HMI Citizens' Oversight Committee (COC) for their useful comments and suggestions throughout the project year. A thank you also goes out to Dr. Steve Storms and Shane Moore of the Maryland Environmental Service (MES) for providing information on dredged material inputs to HMI for Year 15.

Lastly, thanks to Dr. Robert Summers, Director, Mr. Narendra Panday and Dr. Rich Eskin, of TARSA, for their guidance, suggestions and commitment to the Hart-Miller Island Exterior Monitoring Program.

INTRODUCTION

Site Background

Baltimore's strategic location in northern Chesapeake Bay has important economic ramifications for the state of Maryland. The Port of Baltimore depends upon annual dredging by the U.S. Army Corps of Engineers (USACE) to maintain the federal approach channels to Baltimore Harbor. In turn, the State is obligated to provide placement sites for material dredged from the federal maintenance channels. In 1983, and in fulfillment of the State's responsibility to provide long-term dredged material placement sites, Hart-Miller Island Confined Disposal Facility (HMI) was constructed to accommodate sediments dredged from Baltimore Harbor and its approaches.

HMI is located in the upper Chesapeake Bay at the mouth of Back River and northeast of Baltimore Harbor. Construction of HMI began by building a dike connecting the remnants of Hart and Miller Islands and encompassing approximately 1,100 acres. The dike was constructed of sandy sediments excavated from the proposed interior of the facility. The eastern or Bay side of the dike was reinforced with filter cloth and rip-rap to protect the dike from wave and storm induced erosion. Completed in 1983, the dike is approximately 29,000 feet long and is divided into North and South Cells by a 4,300 foot interior cross-dike. Placement of dredged material within HMI began with dike completion and continues presently. The volumes and project names for dredged material placed at HMI during Year 15 are provided below:

Table 1-1: Dredged material placed at HMI during Year 15 (11/95-10/96)

PROJECT	*CUBIC YARDS OF SEDIMENT*
Curtis Bay Channel	467,000
Craighill Upper Range	323,800
Craighill Angle	733,369
Craighill Entrance	530,000
Brewerton Extension	786,220
U.S. Coast Guard	42,000
Clinton St. (Sealift Command)	56,000
Baltimore Gas & Electric	12,600
Rukert Marine Terminal	9,000
Pleasure Island	34,376
Bills Boats	17,069
MPA Maintenance	1,424,056
HMI 265 Pier	3,192
	GRAND TOTAL = 4,438,682

The last inflow of dredged material into the South Cell of HMI was completed on October 12th, 1990. The process of converting the 300-acre South Cell into a wildlife refuge is currently underway. The North Cell is projected to reach full capacity by the year 2009, at which time it will also be converted into a wildlife refuge. The remnants of Hart and Miller Islands, which lie outside of the dike, serve as a state park and receive heavy recreational use throughout the summer months.

Environmental Monitoring

Under section 404(b&c) of the Clean Water Act (1987), entitled "Permits for Dredged or Fill Material", permits for dredged material disposal can be rescinded if it is determined that: "the discharge of such materials into such area will have an unacceptable adverse effect on municipal water supplies, shellfish beds and fishery areas (including spawning and breeding areas), wildlife, or recreational areas."[2] In accordance with this federal mandate and as a special condition of the State Wetlands License 72-127(R), a long-term compliance monitoring program was implemented in 1981 to assess the effects of HMI on the surrounding environment. Results from the monitoring are used to detect changes from baseline environmental conditions (studies conducted from 1981-1983) established in the area surrounding HMI, and to guide decisions regarding possible operational changes and remedial actions.

The Hart-Miller Island Exterior Monitoring Program has evolved over the years in response to both changes in technology and/or administrative changes adopted by one or more stakeholders, including the TRC, principal investigators (PIs) and COC. Analytical methods to detect trace metal burdens in sediments and benthic macroinvertebrates, for example, have been changed throughout the monitoring program as improved technologies with lower detection limits and greater sensitivity have been developed. Fish and crab population studies were discontinued after Year 5 due to the ineffectiveness of using the information as a compliance monitoring tool. Furthermore, beach erosion studies were discontinued after Year 13 in response to beach replenishment and stabilization with breakwaters. The Exterior Monitoring Program is designed to be flexible enough to incorporate such changes without compromising the overall credibility and scientific integrity of the project.

Prior to the start of the Year 15 monitoring, a majority decision of the TRC was enacted to reduce the sampling protocol from monitoring 2-3 times per year (Spring, Summer and Fall), depending on the project, to one time per year (Summer) for all projects[3]. Additionally, the number of stations sampled for each project was reduced. As a result, Year 15 was conducted under a less comprehensive sampling protocol compared to past HMI monitoring years.

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[2] From page 250 of the 1987 Clean Water Act published by the Water Pollution Control Federation.
[3] Technical Review Committee agenda items and minutes received from Dr. Richard Eskin, past Chairman of the Hart-Miller Island Exterior Monitoring Program.

Project Summaries

Four independent projects, which have been conducted since the inception of the Exterior Monitoring Program, were continued during Year 15 of monitoring. Summaries of the objectives and results for each project are included below.

Project I: Project Management and Scientific/Technical Coordination – Maryland Department of the Environment (MDE)

Year 15 marks the third year of the Maryland Department of the Environment's (MDE) technical oversight of the Hart-Miller Island Exterior Monitoring Program. MDE is responsible for ensuring the scientific integrity of the Exterior Monitoring Program, which includes evaluating the sampling protocols and analytical methods used by the PIs for each project. MDE makes sure that each monitoring project undergoes a rigorous program of peer review, whereby professional scientists with background in estuarine research review and comment on the HMI monitoring reports prior to publication. A three-tiered review process is utilized by MDE, whereby draft HMI reports are reviewed by: (1) the Dredging Coordination and Assessment Division (DCAD), the Technical and Regulatory Services Administration (TARSA) and the Water Management Administration (WMA) of MDE; (2) the HMI Technical Review Committee (TRC), composed of professional researchers and environmental scientists from both federal and state agencies; and (3) the HMI Citizens' Oversight Committee (COC), which is comprised of concerned citizens representing the diverse interests of the public. From the comments and concerns submitted by each level in this three-tiered approach, MDE formulates a set of recommendations for each of the PIs and their respective projects. These recommendations guarantee quality control in the monitoring effort.

MDE is responsible for grammatical and technical editing, as well as standardization of the reports for each project. MDE/DCAD coordinates all field sampling among PIs for each project to ensure efficient, timely and representative sample collection. This includes evaluating sampling protocols and monitoring stations/locations to respond to findings of previous years or address new concerns and technologies.

Project I also includes data management and providing HMI data to the public through several media, including written reports and the Internet. The Dredging Coordination and Assessment Division within MDE has recently consolidated all of the raw HMI data from the Chesapeake Bay Program's VAX server onto their NT server at MDE's Baltimore Office. In the near future, this data will be made available to the public.

Lastly, MDE is accountable for tracking the budgetary status for each project. This includes confirming receipt of all deliverables, including invoices, seasonal reports, cruise reports, and draft Data and Technical reports. The Technical and Engineering Coordination Section (TECS) within DCAD coordinates receipt of all deliverables from the PIs for each project. From the quarterly reports received by the PIs, MDE prepares

comprehensive seasonal reports for the Maryland Port Administration (MPA) which document the budgetary status and progress for each project. MDE keeps detailed financial records for each project and compiles a complete economic portfolio for the MPA.

Project II: Sedimentary Environment – Maryland Geological Survey (MGS)

During Year 15, the objectives of Maryland Geological Survey's characterization of the sedimentary environment surrounding HMI were twofold. The first objective was to analyze surficial sediments for grain size distribution in order to determine how current sediment fractionation compares with both baseline and more recent sediment analyses. Only 7 of the 17 stations sampled during Year 15 had been monitored in previous years. There are some PI concerns as to the comparability of this year's data to past monitoring years as a result of this abbreviated sampling protocol. In general, however, the percent sand and clay:mud ratios for the seventeen sites were well within expected levels according to distributions seen in past monitoring years.

The second objective was to analyze current trace metal concentrations in surficial sediments surrounding HMI for comparison with concentrations found in prior monitoring years. Past technical reports for Project II (Hill 1991, 1992 and 1993), coupled with the results of an upper Bay hydrodynamic model (Wang 1993), established a link between dike operations and metal concentrations in sediments surrounding HMI. Periods of low discharge, where crust management and dewatering are the primary activities at HMI and which typically precede the Fall cruise, result in oxidation of the sediments within the facility. Oxidation of sulfide estuarine sediments results in the formation of sulfuric acid, leaching metals from the sediments and releasing them with effluent discharge from the HMI spillways. Consequently, Fall sampling cruises, starting with Year 8, have shown elevated metal concentrations relative to those found during the Spring cruise, where inflow of dredged material is the primary operation at HMI and sediments generally do not become oxidized.

During Year 15, the metal distribution for the November cruise was typical of those seen in previous cruises following periods of low discharge. Metal levels were elevated significantly above background levels (150% excess zinc from baseline concentrations). As in Year 14, these elevated levels of zinc persisted through the Spring sampling period. This may be an indication that zinc is accumulating in the sediments surrounding HMI.

Project III: Benthic Community Studies – University of Maryland Center for Environmental Science

The objectives of the Year 15 benthic monitoring studies at HMI were to: (1) monitor nearfield benthic populations for changes in distribution and species composition; (2) continue monitoring established reference stations to compare with nearfield stations; (3) continue monitoring stations which had been designated as having

elevated concentrations of zinc; and, (4) provide the clam *Rangia cuneata* for chemical analysis of trace metals and organics.

As in past monitoring years, the major factor driving the abundance and dominance of species at a particular station was the substrate type (sand, silt, clay, shell, or a combination thereof), as well as other abiotic factors such as dissolved oxygen and seasonal salinity patterns. The most abundant species during Year 15 monitoring were the worms *Scolecolepides viridis* and *Tubificoides heterochaetus*, the crustaceans *C. polita* and *L. plumulosus*, the clam *Rangia cuneata* and insect larvae of the midge family *Chironomidae*. A total of 26 different species were collected this year compared to a range of 26 to 35 total species found in prior years.

Due to changes in the sampling protocol, this year's data were not as easy to compare with previous HMI monitoring data. In general, however, it appears that the Year 15 data are similar to that of previous monitoring years and no significant changes in the benthic community can be attributed to HMI.

Project IV: Analytical Services – University of Maryland Center for Environmental Science

Objectives for the Analytical Services portion of the Year 15 Exterior Monitoring Program were to characterize trace metals and organics [Polychlorinated Biphenyls (PCBs) and Polycyclic Aromatic Hydrocarbons (PAHs)] concentrations in sediments and clams. Tissue data for the clam *Rangia cuneata* were collected at HMI and compared to data collected at Poplar Island for the clam *Mya arenaria*. Sediment trace metals and organics concentrations were compared to data from the Baltimore Harbor/Back River sediment study and to Bay-wide averages.

On the whole, comparison of tissue metal results showed no strong indication of higher metal concentrations at HMI. The only significant exception was nickel (Ni), which was clearly elevated at HMI in relation to clams from Poplar Island. To a lesser extent, silver (Ag) and cadmium (Cd) were also elevated. Overall, the differences observed between the two sites could be attributable to interspecies differences alone and do not necessarily indicate elevated metal burdens among HMI clams.

Comparisons were also made between the Year 15 data and data collected from HMI during Year 10 (1990-1991) and Year 13 (1993-1994). Metal concentrations observed during the current monitoring year are either comparable to or below levels detected in these two years. It was concluded that no elevation of metal concentrations in clams have occurred over the past six years.

Concentrations of organic contaminants detected in *Rangia* during Year 15 were compared to concentrations found in *Mya arenaria* at Poplar Island. Organics levels in *Rangia* were tenfold higher than those found in *Mya*. This is expected due to the higher concentrations of contaminants found in northern Chesapeake Bay relative to the mid-

Bay region around Poplar Island. Furthermore, the concentrations of PCBs and PAHs are low overall and below the detection limits of previous HMI studies.

For sediment analyses, values observed during Year 15 were compared to those from the "Spatial Mapping of Sedimentary Contaminants in the Baltimore Harbor/Patapsco River/Back River System" (Baker et al. 1997). Concentrations of PAHs at HMI are not enriched above regional background levels. For some of the metals, including cadmium (Cd), lead (Pb), copper (Cu), zinc (Zn) and mercury (Hg), concentrations in the sediments of Back River station #75 are at least twice that of HMI average values. Thus, Back River may be a source of contaminants to sediments in the vicinity of HMI[4]. Compared to Chesapeake Bay average values for metals in sediments, HMI concentrations are not significantly different from sites uninfluenced by HMI. Further studies of Back River, and possibly Baltimore Harbor, as a source of contamination to sediments in the vicinity of HMI are suggested.

[4] An independent report by Universe Technologies, Inc. entitled "*Comprehensive Zinc Study for Hart-Miller Island Confined Disposal Site, Maryland*" and published in September 1999, addresses the issue of Back River, among other sites, as a possible source of contamination to sediments in the vicinity of HMI.

CHAPTER 2: SEDIMENTARY ENVIRONMENT (PROJECT II)

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ABSTRACT

The Coastal and Estuarine Geology Program of the MGS has been involved in monitoring the physical and chemical behavior of near-surface sediments around Hart-Miller Island Confined Disposal Facility (HMI) for more than a decade. In a separate effort, the program's staff has also documented the erosional and depositional changes along the recreational beach between Hart and Miller Islands. Beach monitoring was discontinued in Year 14, because plans to stabilize the beach with breakwaters were underway. At the onset of the Year 15 monitoring effort, there was a change in managing agency from the Maryland Department of Natural Resources (MDNR) to MDE[5]. As a result of this, the composition of the TRC was changed. The TRC, in turn, changed the scope of the monitoring effort to sampling once a year at 17 stations, a decrease from twice a year at forty-three stations. During the uncertainty of this transition, MGS took it upon itself to maintain the existing sampling pattern and frequency in order to assure adequate spatial and temporal sample coverage of the exterior environment.

Surficial bottom sediments were sampled during three cruises (November 1995, May 1996, and August 1996) and analyzed for grain size composition and trace metal content. Samples taken during the first two cruises were collected and analyzed following the protocol of previous sampling years. The August 1996 cruise followed a new collection plan and protocol established by the TRC. The results of these analyses were compared to one another and to previous years' results for trace metals. Only the August cruise is presented for grain size composition.

The grain size distribution of exterior bottom sediments (presented as percent sand and clay:mud ratios) is consistent with earlier post-discharge periods. However, the paucity of data makes it impossible to determine the spatial distribution of the sediment. In addition, the August sampling period does not correspond to existing monitoring records, making any comments on site changes tenuous. The previous sampling periods were selected to correspond with site operations, flow from the Susquehanna River and benthic community activity. The Year 15 sampling period does not correspond to the processes that occur in April and November, the previous sampling periods.

In April 1989, abnormally high zinc (Zn) loadings were discovered in the sediments around HMI. Since the initial detection of this Zn-enrichment, both the metal concentrations and the size of the affected area have fluctuated. Nonetheless, higher than expected Zn levels persisted through Year 15 in the vicinity of HMI. In previous reports Zn levels were correlated with the discharge rate of effluent from HMI. Metal levels in ponded water increase, through a process analogous to acid mine drainage, due to leaching of metals from the sediments contained

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[5]MDE did assume management of the HMI Exterior Monitoring Program during Year 15, but inherited the backlog of reports for the prior two years (13 and 14). This is why the Project I claims involvement starting with Year 13.

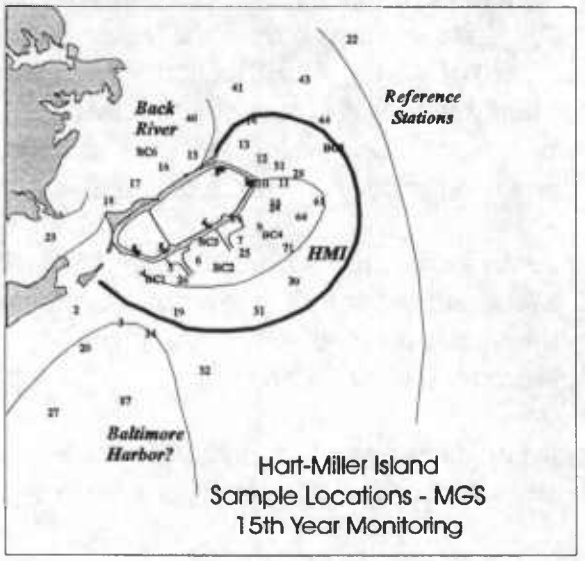
by the dike. The maximum Zn loading due to leaching occurs at releases between 0.3-10 million gallons per day (MGD). At higher discharge rates, flushing with large volumes of water effectively dilutes Zn loadings in the effluent, precluding Zn-enrichment in the sediments surrounding HMI. The metal distribution around HMI for Year 15 shows persistent enriched metals loading to the exterior sediments, which appears to be independent of these fluctuations in discharge.

The sampling plan used in August is inadequate to show the effects of HMI on the exterior sediments. The sampling established by the TRC is too sparse in the area of historical metal enrichment and does not adequately cover areas that are potential sources of material to exterior HMI sediments. In addition, biannual sampling at consistent periods is needed to show loading trends that reflect response to facility operations.

Continued monitoring is recommended, using a more spatially and temporally diverse sampling program than the one implemented according to the TRC recommendations. However, the number of sites could be reduced from the number sampled in previous monitoring years. During the dewatering phase of operations, exposure of dredged material to the air is likely to result in the mobilization of metals associated with those sediments. Higher metal levels in the effluent may increase metal loadings to exterior bottom sediments, particularly if discharge rates are low. Currently, these metal levels are below concentrations at which deleterious biological effects would be seen. However, future monitoring will be needed to detect such increases in metal loading and the accompanying biological effects. Additionally, the persistence of the enriched area during periods of higher discharge may indicate the development of a long term metal enriched zone within the exterior sediments. Monitoring will be valuable in assessing both the effectiveness of any treatment to the sediments which is implemented to counteract the effects of exposing dredged material to the atmosphere as well as the long term effects to the sedimentary environment from facility operations. The new sampling protocol will not address these concerns.

INTRODUCTION

Since 1981, the MGS has monitored the sedimentary environment in the vicinity of HMI. HMI is a man-made enclosure in northern Chesapeake Bay, named for the two natural islands that form part of its western perimeter (Figure 2-1). Designed specifically to contain material dredged from Baltimore Harbor and its approach channels, the oblong structure was constructed of sediment dredged from the area that is now the dike interior. The physical and geochemical properties of the older, "pristine" sediment used in dike construction differed from those of modern sediments accumulating around the island. Likewise, materials dredged from shipping channels and deposited inside the dike also differ from recently deposited sediments outside of HMI. Much of the material generated by channel deepening is fine-grained and enriched in trace metals and organic constituents. These differences in sediment properties have allowed the detection of changes attributable to construction and operation of HMI.



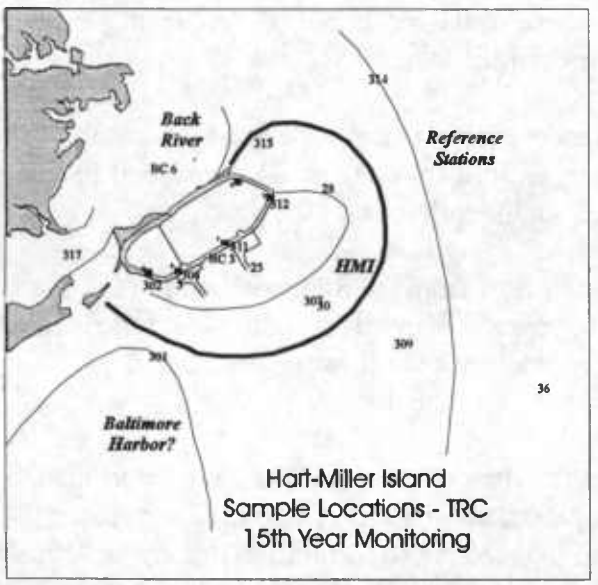


Figure 2-1: Sample locations for the November 1995 and May 1996 (MGS), and the August 1996 (TRC) Cruises. Lines show zones of influence.

Previous Work

Events in the history of HMI can be grouped into the following periods:

1. preconstruction (Summer 1981 and earlier)
2. construction (Fall 1981 - Winter 1983)
3. post-construction
   a. pre-discharge (Spring 1984 - Fall 1986)
   b. post-discharge (Fall 1986 - present).

The nature of the sedimentary environment prior to and during dike construction has been well-documented in previous reports (Kerhin et al. 1982a, 1982b; Wells and Kerhin 1983; Wells et al. 1984; Wells and Kerhin 1985). This work established a baseline against which changes due to operation of the dike could be measured. The most notable effect of dike construction on the surrounding sedimentary environment was the deposition of a thick, light gray to pink layer of

"fluid mud" immediately southeast of HMI. This layer is still evident in a few cores, although the uppermost sections of the layer have been bioturbated (reworked by bottom-dwelling organisms) and eroded.

For a number of years after the facility began operating, no major changes were observed in the surrounding sedimentary environment. Then, in April 1989, more than two years after the first release of effluent from the spillways, anomalously high Zn values were detected in samples collected near HMI spillway #1 (Hennessee et al. 1990b). Zinc levels rose from the regional average enrichment factor (a dimensionless number or ratio) of 3.2 to 5.5. Effluent discharged during normal operation of HMI was thought to be the likely source of excess Zn accumulating in the sediments. This was confirmed by use of the Upper Bay Model (Wang 1993), a numerical, hydrodynamic model, which was used to predict the dispersion of discharge from the spillways.

The factors that influence metal loadings to the exterior sediments from HMI are; (1) circulation patterns in northern Chesapeake Bay and (2) the rate and nature of discharge from the spillways. The results of the hydrodynamic model pertinent to a discussion of contaminant distribution around HMI follow (see the *10 th Year Interpretive Report* for details):

1. A circulation gyre exists east of HMI. The gyre circulates water in a clockwise pattern, compressing the discharge from HMI against the eastern and southeastern perimeter of the dike.

2. Releases from HMI Spillways #1 and #4 travel in a narrow, highly concentrated band up and down the eastern side of the dike. This explains the location of the areas of periodic high metal enrichment to the east and southeast of the facility.

   Releases from HMI Spillway #2 are spread more evenly to the north, east, and west. However, dispersion is not as great as from HMI Spillways #1 and #4 because of the lower shearing and straining motions away from the influence of the gyre.

3. The circulation gyre is regulated by fresh water flow from the Susquehanna River. The higher the flow from the Susquehanna, the stronger the circulation pattern and the greater the compression against the dike. Conversely, the lower the flow, the less the compression and the greater the dispersion away from the dike.

4. Discharge from the dike has no influence on the circulation gyre. This was determined by simulating point discharges of 0-70 million gallons/day (MGD) from three different spillways. Changes in discharge rate only influenced the concentration of a hypothetical conservative species released from the dike; the higher the discharge, the higher the concentration in the plume outside the dike.

The 3-D hydrodynamic model explains the structure of the plume of material found in the exterior sediments, but it does not explain why the level of Zn in the sediments increases at lower discharges. To account for this behavior, the chemistry of the effluent discharged from the dike was examined and reported in the *11th Year Interpretive Report*. As a result of this examination, a model was constructed that predicts the general trend in the behavior of Zn as a function of discharge rate from the dike. The model has two components: (1) loadings of material similar to the sediment in place and (2) loading of enriched material as predicted from a regression line based on discharge data supplied by the Maryland Environmental Service (MES). The behavior of this model supports the hypothesis of metal contamination during low flow conditions. Sediments discharged from the facility are the source of metals that enrich the exterior sediments. When exposed to the atmosphere, these sediments oxidize in a process analogous to acid mine drainage (i.e., sulfide minerals oxidize to produce sulfuric acid, which leaches acid-soluble metals, nutrients, and organic compounds that are released with the discharged waters).

Since the initial detection of Zn enrichment, the size of the affected area has fluctuated, as have metal concentrations within the area. Nonetheless, higher than expected Zn levels persisted through Year 15 in the vicinity of HMI.

Dike Operations

Certain activities associated with the operation of HMI have a direct impact on the exterior sedimentary environment. Local Bay floor sediments appear to be sensitive, both physically and geochemically, to the release of effluent from the spillways. Events or operational decisions that affect the quality or quantity of effluent discharged from HMI may account for some of the changes in exterior sediment properties observed over time. For this reason, dike operations during the periods preceding each of the Year 15 cruises are summarized below. Information was extracted from two *Operations Reports* prepared by MES, covering the periods April 1, 1995 - September 30, 1995, and October 1, 1995 - March 31, 1996, and digital discharge records.

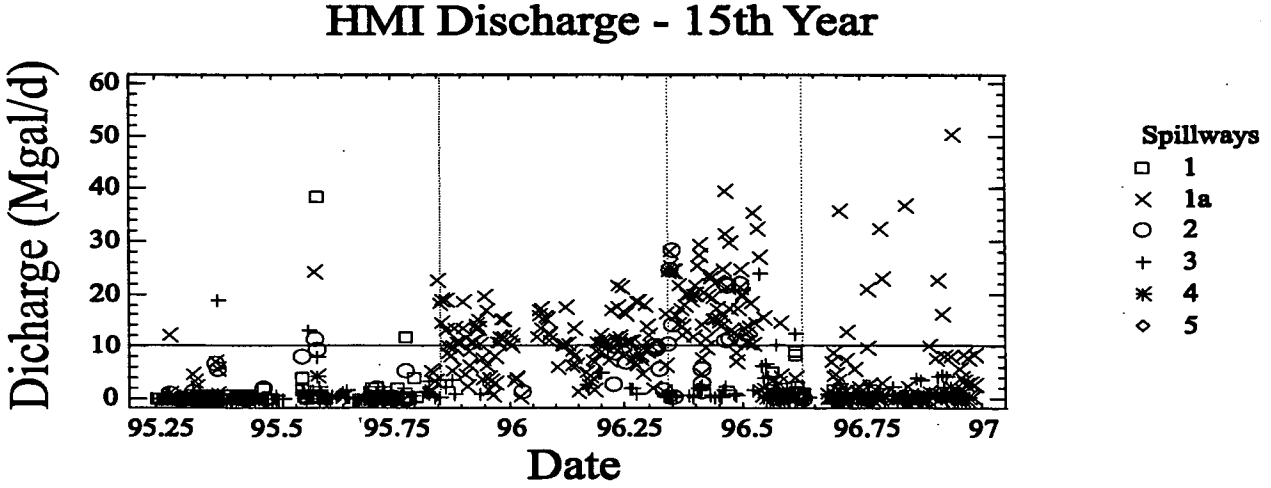


Figure 2-2: HMI Discharge from all spillways for the period covered in this report. The vertical lines indicate the dates of sampling cruises.

In the period prior to the November sampling cruise the primary emphasis of dike operations was on dewatering and crust management. Two dredging operations were completed in this period, with a total of 72,800 cubic yards of sediments placed at HMI. This is reflected in the low discharge rates from the dike as shown in Figure 2-2. As noted in previous reports and shown in Figure 2-3, low discharge rates are accompanied by more acidic conditions.

The May 1996 cruise followed a period of active placement of dredged material at HMI. There were seven active dredging operations prior to sampling, depositing a total of roughly 2.2 MCY of material. This is reflected in the higher discharge rates and the lack of mineral acidity in the discharge from the dike. Dredged material was actively placed until the start of July and precluded crust management operations.

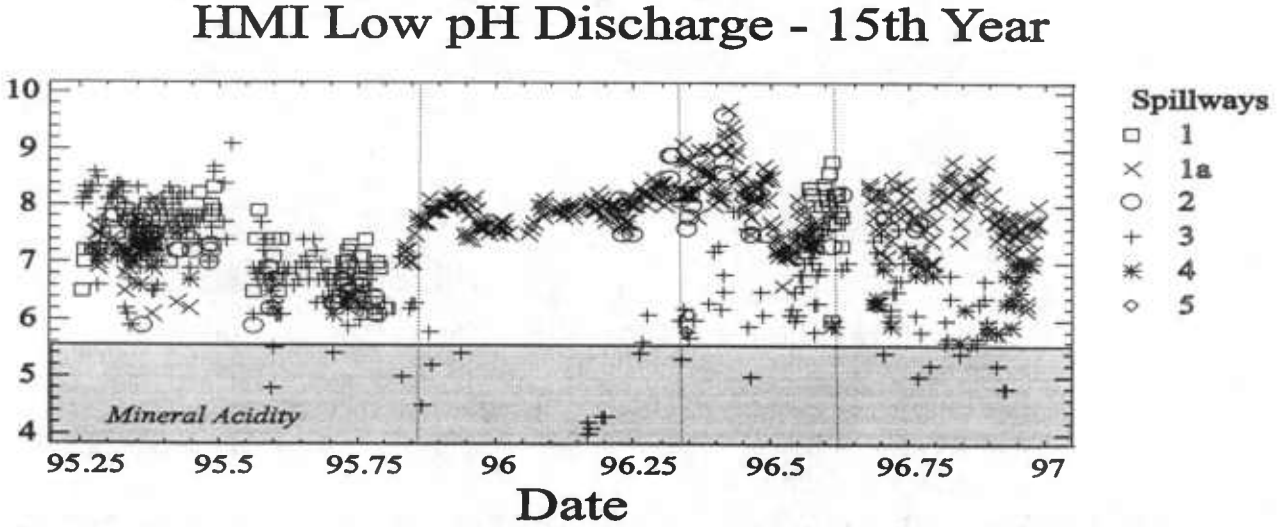


Figure 2-3: Low pH discharge from all spillways. The shaded area denotes the pH zone where there is expected to be free mineral acidity from leaching.

The effluent was in compliance with the discharge permit for the entire monitoring period. However, there were periods low pH excursions and sodium carbonate was used twice to ameliorate the ponded water prior to discharge. It was determined that due to the large amount of sodium carbonate required, it is impractical to use sodium carbonate on a regular basis and its use will be discontinued until further notice. As noted in Figure 2-3, most of the high acidity events occurred in the south cell (spillway #'s 3 and 5) where no new material is being added and crust management and dewatering are the primary operations. Lowering of the pH occurred at all discharge points when the discharge rates fell to below 10 MGD.

Susquehanna River Flow

Flow from the Susquehanna River for the period affecting the Year 15 samples is shown in Figure 2-4. This figure shows the daily discharge record from Conowingo Dam, normalized to the 10-year daily average (values equal to one indicate average flow conditions). Flow during the period prior to the November 1995 cruise was well below normal. This condition allows

dispersion of material further away from the dike. Conversely, flow during periods preceding the other two cruises were well above the average flow. These higher flow conditions compress material against the eastern perimeter of the dike (Wang 1993).

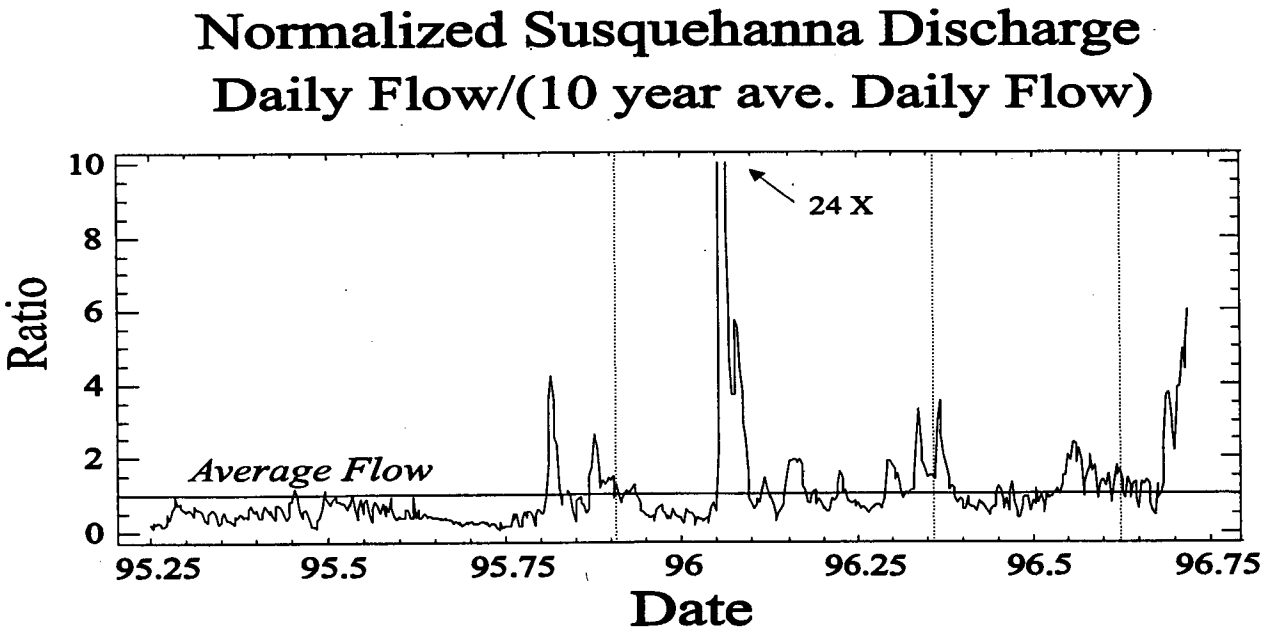


Figure 2-4: Normalized daily flow of the Susquehanna River over the Conowingo Dam. A value of one indicates the average flow condition for any day, based on a 10 year daily average.

OBJECTIVES

As in the past, the main objectives of the Year 15 study were (1) to measure specific physical and geochemical properties of near-surface sediments around HMI and (2) to assess changes detected in the sedimentary environment. Tracking the extent and persistence of the area of Zn-enrichment was again of particular interest.

METHODS AND MATERIALS

Field Methods

The information presented in this report is based on observations and analyses of sediment samples collected on three cruises during Year 15 of exterior monitoring. The first two cruises (November 1995 and May 1996) took place aboard the *R/V Discovery*; the third (August 1996) was aboard the *R/V Aquarius*. Field methods differed for the third cruise. The remainder of this section discusses the first two cruises and the third cruise separately.

1. November 1995 and May 1996 (Cruises 34 and 35)

During the first two cruises of the monitoring year, sampling sites (Figure 2-1) were located in the field by means of an MX300 survey-grade Differential Global Positioning System (DGPS) with an MS50R radio beacon receiver for differential corrections. The repeatability of the navigation system, the ability to return to a location at which a navigation fix has previously been obtained, is 3-5 m (10-16 ft) according to the manufacturer's specifications. On the basis of experimental results, the actual accuracy is 1-3 m (3-10 ft). Target, as opposed to actual, geographic coordinates (latitude and longitude, North American Datum of 1983 or NAD83) for stations sampled during these two cruises are presented in the *Year 15 Data Report*.

Surficial sediment samples were collected in November 1995 (Cruise 34) and May 1996 (Cruise 35). DuringYear 9, the number of sampling stations was increased in response to the detection of abnormally high Zn levels in sediments near HMI spillway #1 (Hennessee and Hill 1992). Sampling sites were added to determine the extent of the area of Zn-enrichment and to coincide with benthic sampling stations. The expanded sampling scheme (60-66 locations/cruise) was retained through Year 11.

During Year 12, the number of stations occupied during each cruise was reduced to 47, based, in part, on output from the 3-D hydrodynamic model of the upper Chesapeake Bay. The 22 stations that had been monitored continuously since dike completion were retained, as were the stations that corresponded to benthic sampling sites. Selection of the remaining stations was based on discharge activity during the months preceding each cruise, coupled with the results of the hydrodynamic model (Wang 1993). All of the sites chosen on the basis of the model had

been occupied previously. The same locations sampled during Year 12 were revisited during each cruise through May 1996.

Undisturbed samples of the surficial sediments surounding HMI were obtained with a dip-galvanized Petersen sampler. At least one grab sample was collected at each station and split for textural and trace metal analyses. Triplicate grab samples were collected at seven stations (11, 16, 24, 25, 28, BC3, and BC6). Upon collection, each sediment sample was described lithologically and subsampled. Field descriptions of the samples can be found in the *Year 15 Data Report.*

Sediment and trace metal subsamples were collected using plastic scoops rinsed with distilled water. These samples were taken several centimeters from the top, below the flocculent layer, and away from the sides of the sampler to avoid contamination from the sampler. The samples were placed in 18-oz Whirl-Pak™ bags. Samples designated for textural analysis were stored out of direct sunlight at ambient temperatures. Those intended for trace metal analyses were refrigerated and maintained at 4°C until they could be processed in the laboratory.

In May 1996, gravity cores were collected at three stations (25, BC3, and BC6) (Figure 2-1). A Benthos gravity corer (Model #2171) fitted with clean cellulose acetate butyrate (CAB) liners, 6.7 cm in diameter, was used. Each core was cut and capped at the sediment-water interface, then refrigerated until it could be x-rayed and processed in the lab.

2. August 1996 (Cruise 36)

In August 1996, during the third cruise of the monitoring year, the captain of the *R/V Aquarius* used LORAN-C to navigate to the sampling stations. The repeatability of LORAN-C is affected by seasonal and weather-related changes along the signal transmission path. Halka (1987) estimated that when a vessel equipped with LORAN-C reoccupies an established station in Chesapeake Bay, it should be within about 100 m (328 ft) of its original location. While on station, the captain recorded the DGPS coordinates (latitude/longitude, NAD83) at each point. In the future, these geographic coordinates will be used in revisiting stations. For samples collected in August 1996, the *Year 15 Data Report* lists target and actual LORAN-C time delays (TDs) and actual latitude and longitude (NAD83) computed by the DGPS unit.

In response to a decision made this year by the newly-constituted HMI TRC, the sampling plan was radically altered beginning with this cruise. The committee decided to: (1) limit monitoring to once a year (in August); (2) coordinate benthic and sediment sampling; and, (3) collect fewer samples. In August 1996, surficial sediment and benthic samples were collected at 17 sites. Only seven of these correspond to previously established sediment sampling locations and only four date back to the early years of monitoring. No cores were taken. Sites where marker horizons existed, which are used for both bioturbation measurements and historical (i.e. sedimentation/erosion) information, were dredged for biological samples and rendered useless for future studies of this nature.

Undisturbed samples of the surficial sediments surrounding HMI were obtained with a Wildco Ponar Grab Sampler. At least one grab sample was collected at each station and split for textural and trace metal analyses. Triplicate grab samples were collected at three stations (25, 28, BC6). Upon collection, each sediment sample was described lithologically and subsampled. Field descriptions are included in the *Year 15 Data Report*. The collection techniques (type of scoop, location of sample within grab, storage conditions) were similar to those described for the two previous cruises.

Laboratory Procedures

1. Radiographic Technique

Prior to processing, the upper 50 cm of each core were x-rayed at MGS, using a TORR-MED x-ray unit (x-ray settings: 90 kv, 5 mas, 30 sec). A negative x-ray image of the core was obtained by xeroradiographic processing. On a negative xeroradiograph, denser objects or materials, such as shells or sand, produce lighter images. Objects of lesser density permit easier penetration of x-rays and, therefore, appear as darker features. The xeroradiographs are reproduced in the appendix to the *Year 15 Data Report*.

Each core was then extruded, split with an osmotic knife, photographed, and described. Visual and radiographic observations of the cores are also presented in the *Year 15 Data Report*. On the basis of these observations, sediment samples for textural and trace metal analyses were taken at selected intervals from each core.

2. Textural Analysis

In the laboratory, subsamples from both the surficial grabs and gravity cores were analyzed for water content and grain size composition (sand-silt-clay content). Water content was calculated as the percentage of the water weight to the total weight of the wet sediment:

$$\mathbf{Wc = \frac{Ww}{Wt} \times 100} \qquad \mathbf{(1)}$$

where: Wc = water content (%)
Ww = weight of water (g)
Wt = weight of wet sediment (g)

Water weight was determined by weighing approximately 25 grams of the wet sample, drying the sediment at 65°C, and reweighing it. The difference between total wet weight (Wt) and dry weight equals water weight (Ww). Bulk density was also determined from water content measurements.

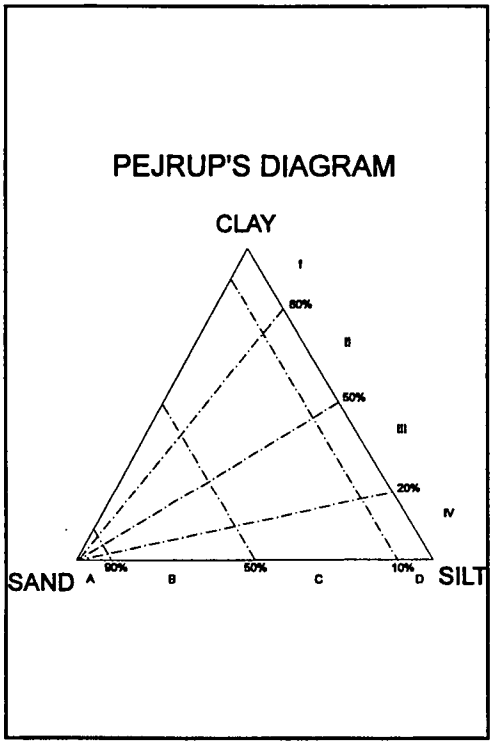


Figure 2-5: Pejrup's (1988) classification of sediment type.

The relative proportions of sand, silt, and clay were determined using the sedimentological procedures described in Kerhin et al. (1988). The sediment samples were pre-treated with hydrochloric acid and hydrogen peroxide to remove carbonate and organic matter, respectively. Then the samples were wet sieved through a 62-μm mesh to separate the sand from the mud (silt plus clay) fraction. The finer fraction was analyzed using the pipette method to determine the silt and clay components (Blatt et al. 1980). Each fraction was weighed; percent sand, silt, and clay were determined; and, the sediments were categorized according to Pejrup's (1988) classification (Figure 2-5).

Pejrup's diagram, developed specifically for estuarine sediments, is a tool for graphing a three-component system summing to 100%. Lines paralleling the side of the triangle opposite the sand apex indicate the percentage of sand. Each of the lines fanning out from the sand apex represents a constant clay:mud ratio (the proportion of clay in the mud, or fine, fraction). Class names consist of letter-Roman numeral combinations. Class D-II, for example, includes all samples with less than 10% sand and a clay:mud ratio between 0.50 and 0.80.

The primary advantage of Pejrup's classification system over other schemes is that the clay:mud ratio can be used as a simple indicator of hydrodynamic conditions during sedimentation. (Here, hydrodynamic conditions refer to the combined effect of current velocity, wave turbulence, and water depth.) The higher the clay:mud ratio, the quieter the depositional environment. Sand content cannot be similarly used as an indicator of depositional environment, even though it is well-suited to a rough textural classification of sediment.

Although the classification scheme is useful in reducing a three-component system to a single term, the arbitrarily defined boundaries separating classes sometimes create artificial differences between similar samples. Samples may be assigned to different categories, not because of marked differences in sand-silt-clay composition, but because they fall close to, but on opposite sides of, a class boundary. To avoid that problem, the results of grain size analyses are discussed in terms of percent sand and clay:mud ratios, not Pejrup's classes themselves.

3. Trace Metal Analysis

Sediment solids were analyzed for eight trace metals - iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), chromium (Cr), nickel (Ni), lead (Pb) and cadmium (Cd). Lead and Cd were added to the list of elements monitored to conform to other monitoring efforts in the Chesapeake Bay region. Samples were digested using a microwave digestion technique followed by analysis on an Inductively Coupled Argon Plasma Spectrometer (ICAP). The digestion method was modified from USEPA Method #3051 in order to achieve total recovery of the elements analyzed. The MGS laboratory followed the steps below in handling and preparing trace metal samples:

1. Samples were homogenized in the Whirl-Pak™ bags in which they were stored and refrigerated (4°C).

2. Approximately 10 g of wet sediment sample were transferred to Teflon evaporating dishes and dried overnight at 105-110°C.

3. Dried samples were hand-ground with an agate mortar and pestle, powdered in a ball mill, and stored in Whirl-Pak™ bags.

4. 0.5000 ± 0.0005 g of dried, ground sample was weighed and transferred to a Teflon digestion vessel.

5. 2.5 ml concentrated HNO_3 (trace metal grade), 7.5 ml concentrated HCl (trace metal grade), and 1 mL ultra-pure water were added to the Teflon vessel.

6. The vessel was capped with a Teflon seal, and the top was hand tightened. Between four and twelve vessels were placed in the microwave carousel. (Preparation blanks were made by using 0.5 mL of high purity water plus the acids used in Step 5.)

7. Samples were irradiated using programmed steps appropriate for the number of samples in the carousel. These steps were optimized based on pressure and percent power. The samples were brought to a temperature of 175°C in 5.5 minutes, then maintained between 175-180°C for 9.5 minutes. (The pressure during this time peaked at approximately 6 atm for most samples.)

8. Vessels were cooled to room temperature and uncapped. The contents were transferred to a 100 ml volumetric flask, and high purity water was added to bring the volume to 100 ml. The dissolved samples were transferred to polyethylene bottles and stored for analysis.

9. The sample was analyzed.

All surfaces that came into contact with the samples were acid washed (3 days 1:1 HNO_3; 3 days 1:1 HCl), rinsed six times in high purity water (less than 5 mega-ohms), and stored in high-purity water until use.

The dissolved samples were analyzed with a Jarrel-Ash AtomScan 25 sequential ICAP spectrometer using the method of bracketing standards (Van Loon 1980). The instrumental parameters used to determine the solution concentrations were the recommended, standard ICAP conditions given in the Jarrel-Ash manuals, optimized using standard reference materials (SRM) from the National Institute of Standards and Technology (NIST) and the National Research Council (NRC) of Canada. Blanks and SRM's were run every 10 samples.

Results of the analyses of three SRM's (NIST-SRM #1646 - Estuarine Sediment; NIST-SRM #2704 - Buffalo River Sediment; NRC #PACS-1 - Marine Sediment) are given in Table 2-1. The microwave/ICAP method has recoveries (accuracies) within ±5% for all of the metals analyzed, except Mn. The recoveries for Mn and Ni, although less than those for other metals, are acceptable. The poorer recoveries for Ni and Mn are due to the concentrations of these elements being near detection limits. The SRM's have unrealistically low concentrations compared to the samples around HMI.

Table 2-1: Results of MGS's analysis of three standard reference materials, showing the recovery of the certified metals of interest.

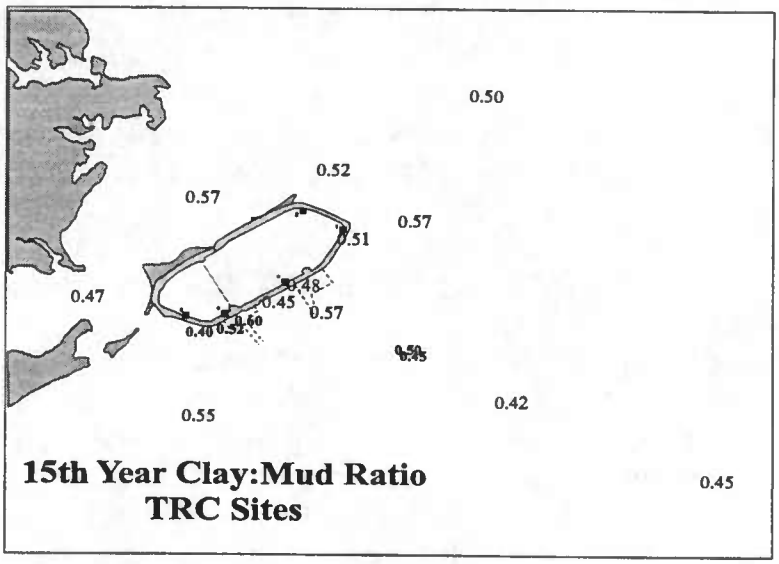
	Precent Recovery		*(n=15)*
Metal	**NIST 1646**	**Buffalo River**	**PACS**
Fe	93±4	99±2	92±3
Mn	93±6	83±4	79±5
Zn	100±1	90±1	101±2
Cu	99±5	96±4	101±2
Cr	96±4	115±5	101±4
Ni	93±9	105±9	89±8
Cd	98±9	bdl	bdl
Pb	92±3	87±4	100±5

bdl = below detection limits.

RESULTS AND DISCUSSION

Sediment Distribution - August 1996 Cruise

Due to the changes in the sampling distribution, only 7 of the 17 stations were previously occupied stations. This, coupled with the new sampling season, made it virtually impossible to perform accurate, high resolution comparisons with previous monitoring years. The new sampling protocol has effectively reset the monitoring effort. Given these limitations, the percent Sand and Clay:Mud ratios (Figure 2-6) for the seventeen sites are within levels expected from the distributions seen in the previous years.



Trace Metals

1. Interpretive Technique

Eight trace metals were analyzed to assess the effects of the operation of HMI on the surrounding sedimentary environment. The method used to interpret changes in the observed metal concentrations takes into account grain size induced variability and references the data to a regional norm. The method involves correlating trace metal levels with grain size composition on a data set that can be used as a reference for comparison. For the HMI study area, data collected between 1983 and 1988 are used as the reference

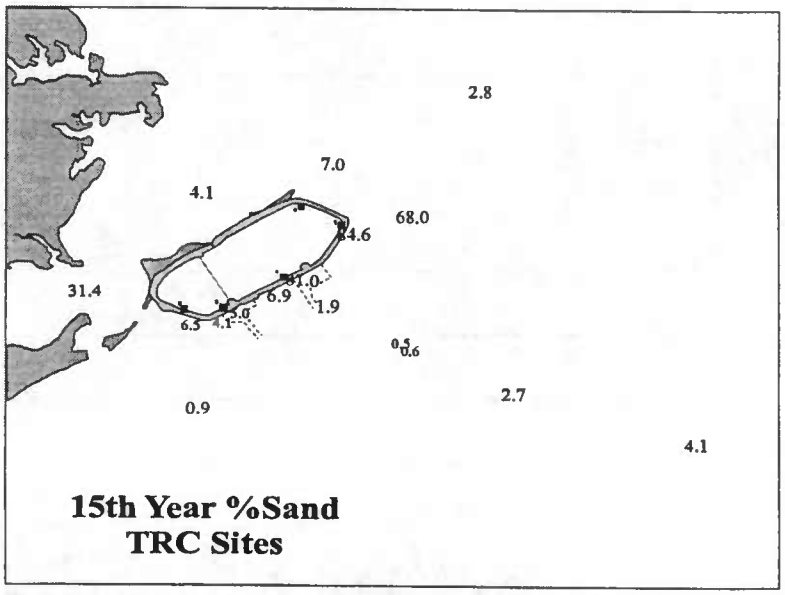


Figure 2-6: Grain size distribution for Year 15: % sand and clay:mud ratio.

for the six original trace metals. Baseline levels for Cd and Pb were determined from analyses of 30 samples collected in a reference area on the eastern side of the northern Bay. The baseline was established as part of a study examining toxic loading to Baltimore Harbor. Samples collected during this time showed no aberrant behavior in trace metal levels. Normalization of grain size induced variability of trace element concentrations was accomplished by fitting the data to the following equation:

$$X = a(Sand) + b(Silt) + c(Clay) \qquad (2)$$

where: X = the element of interest
a, b, and c = the determined coefficients
Sand, Silt, and Clay = the grain size fractions of the sample

A least squares fit of the data was obtained by using a Marquardt (1963) type algorithm. The results of this analysis are presented in Table 2-2. The correlations are excellent for Cr, Fe, Ni, Pb and Zn, indicating that the concentrations of these metals are directly related to the grain size of the sediment. The correlations for Mn and Cu are weaker, though still strong. In addition to being part of the lattice and adsorbed structure of the mineral grains, Mn occurs as oxy-hydroxide chemical precipitate coatings. These coatings cover exposed surfaces, that is, they cover individual particles as well as particle aggregates. Consequently, the correlation between Mn and the disaggregated sediment size fraction is weaker than for elements, like Fe, that occur primarily as components of the mineral structure. The behavior of Cu is more strongly influenced by sorption into the oxy-hydroxide than are the other elements. The poor relationship with regard to Cd is due to the baseline being established at or near the detection limit.

Table 2-2: Coefficients and R^2 for a best fit of trace metal data as a linear function of sediment grain size around HMI. The data are based on analyses of samples collected during eight cruises, from May 1985 to April 1988. Trace metals data are normalized to grain size using the formula X = [a*Sand + b*Silt + c*Clay]/100.

	Cr	Mn	Fe	Ni	Cu	Zn	Pb	Cd
a	25.27	668	0.553	15.3	12.3	44.4	6.81	0.32
b	71.92	218	1.17	0	18.7	0	4.10	0.14
c	160.8	4158	7.57	136	70.8	472	77	1
R^2	0.733	0.36	0.91	0.82	0.61	0.77	0.88	0.12

The strong correlation between the metals and the physical size fractions makes it possible to predict metal levels at a given site if the grain size composition is known. This can be done by substituting the least squares coefficients from Table 2-2 for the determined coefficients in equation 2. These predicted values can then be used to determine variations from the regional norm due to deposition; to exposure of older, more metal-depleted sediments; or to loadings from anthropogenic or other enriched sources.

The following equation was used to examine the variation from the norm around the containment facility:

$$\% \text{ excess Zn} = \frac{(\text{measured Zn} - \text{predicted Zn}) * 100}{\text{predicted Zn}} \qquad (3)$$

Zn is used in the following discussion as an indicator of change in sediment chemistry. As elaborated in previous reports (Kerhin et al. 1982a; Wells et al. 1984), there are several reasons for focusing on Zn:

1. Of the chemical species measured, Zn has been the least influenced by variation in analytical technique. Since 1976, at least four different laboratories have been involved in monitoring the region around HMI. The most consistent results have been obtained for Zn.

2. Zn is one of the few metals in the Bay that has been shown to be affected by anthropogenic input.

3. There is a significant down-the-Chesapeake-Bay gradient in Zn enrichment that can be used to detect the source of imported material.

4. Zn concentrations are highly correlated with other metals of environmental interest.

In Equation 3, the differences between the measured and predicted levels of Zn are normalized to predicted Zn levels. This means that, compared to the regional baseline, a value of zero (0%) excess metal is at the regional norm, positive values are enriched, and negative values are depleted. Direct comparisons of different metals in all sediment types can be made due to the method of normalization. As useful as the Percent Excess Metal values are, alone they do not give a complete picture of the loading to the sediments. Natural variability in the samples as well as analytical variations must be taken into account. As result of the normalization of the data, Gaussian statistics can be applied to the interpretation of the data. Data falling within $\pm 2\sigma$ (± 2 standard deviations) are within normal background variability for the region. Samples with a value of $\pm 3\sigma$ can be within accepted background variability, but it is marginal depending on the trends in the distribution. Any values falling outside this range indicate a significant perturbation to the environment. The standard deviation (σ) of the baseline data set, the data used to determine the coefficients in Equation 2, is the basis for determining the sigma level of the data. Each metal has a different standard deviation, as reflected in the R^2 values in Table 1-3. The sigma level for Zn is ~30% (e.g. $1\sigma = 30\%$, $2\sigma = 60\%$, etc.)

2. Results

Sampling Protocol

The biggest change in the monitoring program has been the change in both temporal frequency and spatial density of the sampling protocol. Figure 2-1 show the changes in sampling pattern and the areas of influence surrounding HMI. There are four areas of influence:

1. Back River - samples in this area were selected to determine any influence from Back River and the sewage plant located upstream. To date, no influence has been noted since the use of tertiary treatment was implemented (see *Year 14 Interpretive Report*).

2. Baltimore Harbor - This area south of HMI has frequently shown enrichment coming from the south. This is tentatively assigned as being from the harbor but further work is required to clarify the link.

3. Reference Area - stations located in this area are free from the influence of HMI. This is based on the 3-D hydrodynamic model and the results of previous monitoring years.

4. The area of influence of HMI - This is based on the results of previous monitoring years. This area is further divided into the area closest to the dike, which has consistently shown Zn enrichment.

The new pattern established by the TRC does not adequately cover the main areas of interest, virtually by-passing the historically highest area of enrichment. The sparse density of samples does not allow tracking of the variation in the areal extent of the enriched zone, nor is it adequate to track any influence from Back River or Baltimore Harbor. In addition, the sampling does not provide information as to the response of the sediment to long term loading.

Metal Loadings

Since Year 8, increased levels of Zn have been noted in bottom sediments east and south of HMI spillway #1. The results of previous monitoring studies have shown that the areal extent and magnitude of metal loading to the exterior sedimentary environment is controlled by three primary factors. These factors are:

1. Discharge rate - controls the amount of metals discharged to the external sedimentary environment. Discharge from HMI at flows less than 10 MGD contributes excess metals to the sediment (see *12 th Year Interpretive Report*). The high metal loading to the exterior environment is the result of low input of water, allowing exposure of the sediment to the atmosphere. When the sediments are exposed to atmospheric oxygen, naturally occurring sulfide minerals in the sediment oxidize to produce acidic conditions. Acids leach metals and other acid-soluble chemical species from the sediment. The process is similar to acid mine

drainage. At discharge rates greater than 10 MGD, water throughput (input from dredge disposal to release of excess water) submerges the sediment in the dike, minimizing aerial exposure, and diluting and buffering any acidic leachate. As a result, higher discharge rates produce metal loadings that are close to background levels.

2. Flow of freshwater into the Bay from the Susquehanna River - The hydrodynamics of the Bay in the area of HMI are controlled by the mixing of freshwater and brackish water south of the area. Details of the hydrodynamics of this region were determined by a modeling effort presented as an addendum to the *10 th Year Interpretive Report* (Wang 1993). The effects of Susquehanna flow to the contaminant distribution around HMI follow:

    a. A circulation gyre exists east of HMI. The gyre circulates water in a clockwise pattern, compressing the discharge from HMI against the eastern and southeastern perimeter of the dike.

    b. The circulation gyre is regulated by fresh water flow from the Susquehanna River. The higher the flow from the Susquehanna, the stronger the circulation pattern and the greater the compression against the dike. Conversely, the lower the flow, the less the compression and the greater the dispersion away from the dike.

    c. Discharge from the dike has no influence on the circulation gyre. This was determined by simulating point discharges of 0-70 MGD from three different spillways. Changes in discharge rate only influenced the concentration of a hypothetical conservative species released from the dike; the higher the discharge, the higher the concentration in the plume outside the dike.

3. The positions of the primary discharge points from the dike - The areal distribution of the metals in the sediment also depends on the primary discharge locations to the Bay. The effects of discharge location were determined as part of the hydrodynamic model of the region around HMI. The effects of discharge location are:

    a. Releases from HMI spillways #1 and #4 travel in a narrow, highly concentrated band up and down the eastern side of the dike. This explains the location of the areas of periodic high metal enrichment to the east and southeast of HMI.

    b. Releases from HMI spillway #2 are spread more evenly to the north, east, and west. However, dispersion is not as great as from HMI spillways #1 and #4 because of the lower shearing and straining motions away from the influence of the gyre.

The 3-D hydrodynamic model explains the structure of the plume of material found in the exterior sediments, and the functional relationship of contaminants to discharge rate accounts for the magnitude of the loading to the sediments.

Figure 2-7 shows the % Excess Zn levels around HMI for the three cruises for Year 15. Figures showing the distributions for Years 7 through 14 appear in the *Year 14 Technical Report*. The metal distribution for the November 1995 cruise was typical of the distribution seen in previous cruises following periods of low discharge rates. Prior to the November 1995 sampling cruise, crust management and dewatering were the primary operational activities at HMI. These activities resulted in low discharge rates, with associated lower pH and high metal concentrations in ponded water in the facility (see section on *Dike Operations*). Metal levels were elevated significantly above background levels (150% Excess Zn; 5σ). These levels are some of the highest seen to date. An unusual feature of Year 15 was that elevated levels of Zn found in the November 1995 cruise were maintained into the May 1996 cruise, although the affected area did diminish. April samples were collected following a period of active disposal of sediment into the dike, resulting in higher discharge rates. In previous years, high discharge rates lowered the load of excess Zn . This was due to HMI's acting as a flow-through system discharging material at

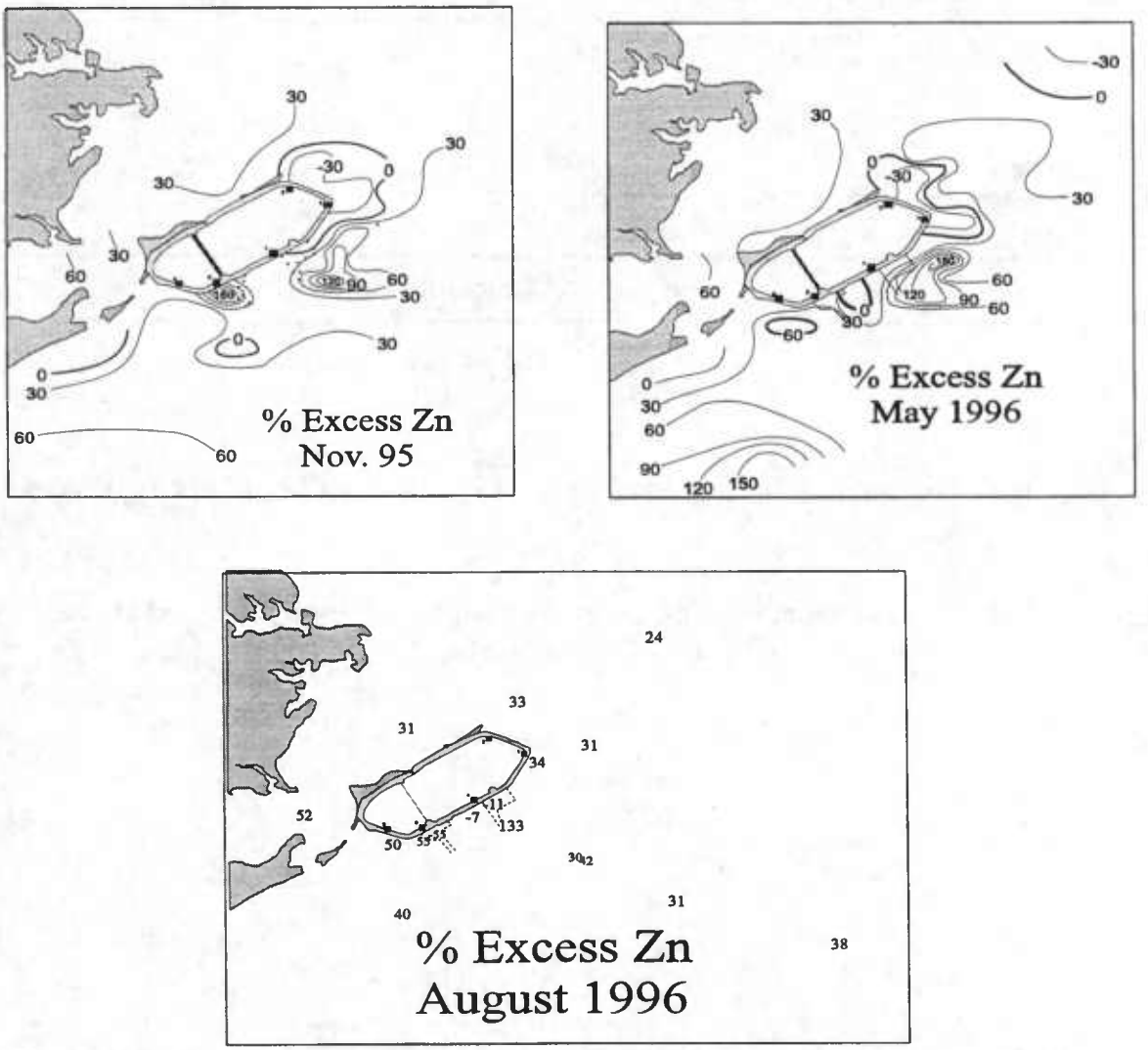


Figure 2-7: Distribution of percent excess Zn for the three sampling cruises of Year 15.

ambient levels. This would, in turn, blanket and mix with any existing higher metal levels in the exterior sediments, effectively diluting the material and lowering levels to ambient concentrations. The expected lowering of metals levels did not occur for the Year 14 April cruise. This pattern was maintained for Year 15, indicating that the sediments are building up a reservoir of enriched metals. This can be seen in Figure 2-8, which shows the highest excess Zn level found in the area influenced by HMI. The levels to date are well below the biological effects threshold, an estimate derived from work done in Baltimore Harbor (Hill et al. in prep).

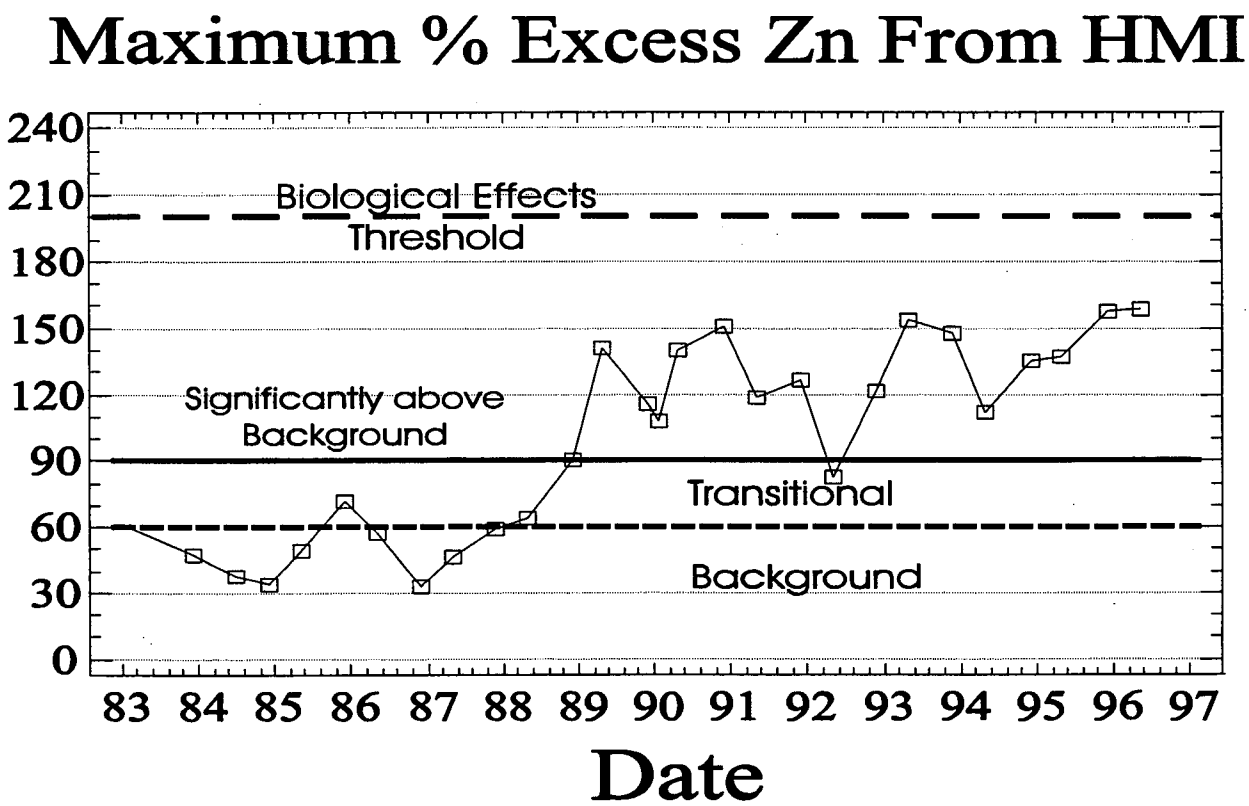


Figure 2-8: Trend of maximum percent excess Zn trough time. The biological effects threshold is based on work done in the Baltimore Harbor.

CONCLUSIONS AND RECOMMENDATIONS

In response to decisions made by the newly-constituted HMI TRC, the exterior monitoring changed radically during Year 15. Sample collection during the first two cruises (November 1995 and May 1996) was consistent with that of previous monitoring years in terms of season of the year and the numbers/locations of samples collected. The third cruise, in August 1996, reflected the decisions of the TRC. Sediment sampling occurred during a different season of the year and, consequently, a different flow regime of the Susquehanna River. Fewer samples were collected, and many of these were from sites that had never been analyzed for their physical and geochemical properties. The paucity of samples and the lack of comparable, "baseline" data from past monitoring years made it extremely difficult to analyze the data (e.g., construct distribution maps, detect trends). Changes in the data might reflect season or sample location, rather than facility operations. The new sampling protocol, in effect, restarted the monitoring process in a less than adequate format.

The new sampling protocol is inadequate for monitoring the exterior sedimentary environment surrounding HMI. At a minimum, additional sediment samples are needed to delineate the distribution of the various parameters analyzed (i.e., grain size, trace metal content). Furthermore, it is recommeded that twice a year sampling be reinstated. If cruises continue to be scheduled only in August, several more years of data will be required to establish a baseline against which future changes can be assessed.

Since the initial detection of Zn-enrichment, the size of the affected area has fluctuated primarily in response to changes in operations of the dike. However, in the past two monitoring years higher than expected Zn levels persisted through changes in operations that would normally have resulted in lower levels of Zn in sediments surrounding HMI. It appears as though the sediment reservoir near the dike is proceeding to long term elevated levels of metals.

Persistent high metal levels in sediments around HMI indicate a need for continued monitoring. Even though the dike has nearly reached its capacity and the volume of effluent is expected to decline, dewatering of the contained material may lead to higher metal levels in the effluent. Exposure of dredged material to the air is likely to result in the mobilization of metals associated with those sediments, an effect analogous to acid mine drainage. Metals released in the effluent, particularly at low discharge rates, are deposited on the surrounding Chesapeake Bay floor and are increasing the long term sediment load. Although these levels are much lower than the biological effects threshold, continued monitoring is needed to determine if the levels increase to a point where action is required. In addition, monitoring is required to assess the effectiveness of any amelioration protocol implemented by MES to counteract the effects of exposing confined dredged material to the atmosphere. Close cooperation with MES will be important in this endeavor.

CHAPTER 3: BENTHIC COMMUNITY (PROJECT III)

By

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ABSTRACT

Benthic invertebrate populations in the vicinity of HMI in the upper Chesapeake Bay were monitored for the fifteenth consecutive year in order to examine any potential effects of HMI on benthic macroinvertebrates. In August 1996 organisms living within the sediments (infaunal) and close to HMI (nearfield stations) were collected along with organisms living at some distance from HMI (reference stations). Stations were only sampled once this year based on a December 6th, 1995 meeting of the PIs/contractors with the TRC. Also at the December meeting, only seventeen stations were selected to be sampled this year. All sampling (benthic, sediments, metals and organics) was conducted at a single time at each station over a two day period (August 26 and 27, 1996). The epifaunal stations (scraping samples) were discontinued this year due to a joint decision by the TRC/ PIs.

The infaunal samples were collected with a 0.05 m^2 Ponar grab and washed on a 0.7 mm mesh screen. Seventeen stations were sampled during the two day cruise: five nearfield stations (S2, S3, S5, S6, and BC3); 8 reference stations (HM7, HM9, HM16, HM22, HM26, BC6, 30, and New); and four Zn-enriched stations (G5, G25, G84, and HM12). Four of these stations were new to the benthic studies project. Station BC6 is northwest of HMI, BC3 is south of it, and stations 30 and New were added to complete a transect leading in a southeast direction away from HMI. The infaunal stations have sediments of varying compositions and include silt-clay stations, oyster shell stations and sand substrate stations. A total of 26 species were collected from these seventeen infaunal stations. The most abundant species were the worms *Scolecolepides viridis* and *Tubificoides heterochaetus*; the crustaceans *Leptocheirus plumulosus* and *Cyathura polita*; the clam *Rangia cuneata* and insect larvae of the midge family *Chironomidae*. Species diversity (H') values were evaluated at each of the infaunal stations. The highest diversity value (3.332) was obtained for the Zn-enriched station G84. This year, the lowest diversity value (1.589) occurred at the nearfield station S5.

The length-frequency distributions of the clams *Rangia cuneata*, *Macoma balthica*, and *Macoma mitchelli* were examined at the nearfield, reference, and Zn-enriched stations. There was good correspondence in terms of numbers of clams present and the relative size groupings for the August sampling dates. *Rangia cuneata* continues to be the most abundant clam species for all three groups of stations, followed by *Macoma balthica*. *Macoma mitchelli* is the least abundant of the 3 predominant clam species.

This year, the Chesapeake Bay Benthic Index of Biotic Integrity (B-IBI) was used to score all the benthic stations. This multimetric index of biotic integrity was developed using data from five Chesapeake Bay sampling programs (Weisberg 1997). Assemblages with an average score of 3.0 or less are considered stressed because they have metric values that are less than the values at the poorest reference sites. The only site to have an average score of <3.0 was the new reference station BC6 (average score of 2.6).

The results of the Year 15 studies reveal that no adverse effects on the benthic populations have been observed which could be attributed to the maintenance and operation of HMI. We have continued to monitor the Zn-enriched stations (G5, G25, G84, and HM12) established in Year 9 as a result of MGS's findings of elevated concentrations of zinc in sediments surrounding HMI. During the seventh consecutive year of monitoring at these Zn-enriched stations, these stations do not appear to differ in any distinct manner from the nearfield and reference infaunal stations. Continued monitoring of the benthic populations in the area is strongly recommended in order to track any changes associated with the continued placement of dredged material at HMI.

INTRODUCTION

The results of the benthic population studies conducted during Year 15 of the Exterior Monitoring Program are presented in this report. HMI lies within the estuarine portion of Chesapeake Bay and experiences seasonal salinity and temperature fluctuations. This region of Chesapeake Bay encompasses vast soft-bottom shoals, which serve as important breeding and nursery grounds for many commercial and non-commercial species of invertebrates and migratory fish. Since it is an area that is environmentally unpredictable from year to year, it is important to maintain a complete record on all facets of the ecosystem. Holland (1985 and 1987) completed long-term studies of more stable mesohaline [5-18 parts per thousand (ppt) salinity (Weisberg 1997)] areas of Chesapeake Bay south of HMI and found that most macrobenthic species showed significant year-to-year fluctuations in abundance. This was primarily a result of slight salinity changes and the fact that the Spring season was a critical period for the establishment of both regional and long-term benthic distribution patterns. One would expect even greater fluctuations in benthic organisms inhabiting the region of HMI, which is located in the highly variable oligohaline [0.5-5 ppt salinity (Weisberg 1997)] portion of the Bay. Indeed, past studies (Pfitzenmeyer and Tenore 1987; Duguay, Tenore, and Pfitzenmeyer 1989; Duguay 1989, 1990, 1992, 1993, 1995, and 1997) indicate that the benthic invertebrate populations in this region are predominantly opportunistic or r-selected species with short life spans, small body size and frequently high numerical densities. These opportunistic species are characteristic of disturbed or environmentally variable regions (Beukema 1988).

The major objectives of the Year 15 benthic monitoring studies were:

1. To monitor the nearfield benthic populations for possible effects from discharged effluent or possible seepage of dredged materials from HMI by following changes in population size and species composition;

2. Continued monitoring of benthic populations at established reference stations for comparison with the nearfield stations surrounding HMI;

3. Continued monitoring of benthic populations at four stations at where MGS found elevated levels of Zn in Year 9; and

4. To provide the clam *Rangia cuneata* to research groups at the CBL for chemical analyses of trace metal and organic concentrations in order to ascertain contaminant levels and bioaccumulation in these organisms.

METHODS AND MATERIALS

A two day field cruise was conducted in August 1996 (August 26 & 27). The location of all the sampling stations (reference, nearfield, and Zn-enriched) are shown in Figure 3-1 with their CBL designations. The stations were located in the field with a Northstar 941XD DGPS navigational system. Latitude and longitude of each station and the state identification numbers can be found in the *Year 15 Data Report*. State designation numbers are also listed in Table 3-1 of this report. Three replicate grabs were taken with a 0.05 m^2 Ponar grab at seventeen benthic infaunal stations (S2, S3, S5, S6, HM7, HM9, HM16, HM22, HM26, HM12, G5, G25, G84, 30, New, BC3, and BC6). All of the individual samples were washed on a 0.7 mm sieve and fixed in 10% formalin/seawater on board the ship. Station depths were recorded from the ship's fathometer. Surface and bottom temperatures were determined with a Hydrolab Surveyor 3 Multiparameter Water Quality Logging system to the nearest 0.01°C. Salinity for the surface and bottom waters was also determined with the Hydrolab to the nearest tenth ppt.

In the laboratory, samples were again washed on a 0.5 mm sieve and then transferred to 70% ethyl alcohol. The samples were then sorted and each organism was removed, identified, and enumerated. Measurements of length-frequency were made on the three most abundant clams. After the identification and enumeration, the samples were analyzed for dry weight. All species were individually dried to a constant weight in a 60°C oven. The clams were shucked and the shells were discarded before they were dried. Total dry weight of each sample was determined on an analytical balance. The total dry weights for the three replicates for each station were averaged. Average dry weight (biomass) was one of the metrics used in the Chesapeake B-IBI. The B-IBI is a multimetric index of biotic integrity used to determine if benthic populations in different areas of the Chesapeake Bay are stressed (Weisberg 1997). The other metrics used were total abundance, Shannon-Weiner/species diversity, relative abundance of pollution sensitive taxa and relative abundance of pollution indicative taxa.

Quantitative infaunal sample data were analyzed by a series of statistical tests carried out with the Statistical Analytical Software package (SAS Institute, Cary, N.C.). Simpson's (1949) method of rank analysis was used to determine the dominance factor. The Shannon-Weiner (H') diversity index was calculated for each station after data conversion to base $_2$ logarithms (Pielou 1966). After constructing a distance matrix comprised of pairwise station abundance chi-square values, stations were grouped according to numerical similarity of the fauna by single-linkage cluster analysis. Analysis of variance and the Ryan-Einot-Gabriel-Welsch multiple comparison procedure (Ryan 1960; Einot and Gabriel 1975; Welsch 1977) were used to determine differences in faunal abundance between stations. Friedman's nonparametric rank analysis test (Elliott 1977) was used to compare mean numbers of the 11 most abundant species, between the silt/clay - nearfield, reference, and Zn-enriched stations singly. The reference, nearfield and Zn-enriched stations were then added together and retested.

RESULTS AND DISCUSSION

Since the beginning of the benthic survey studies in 1981, a small number of species have been the dominant members of the benthic invertebrates collected at the nearfield and reference sites in the vicinity of HMI. The most abundant species this year were the annelid worms *Scolecolepides viridis* and *Tubificoides heterochaetus*; the crustaceans *Leptocheirus plumulosus* and *Cyathura polita*; the clam *Rangia cuneata*; and midge larvae [*Chironomidae* family (Tables 3-2, 3-3, and 3-4)]. Variations in the range and average number of *S. viridis, L. plumulosus*, and *R. cuneata* at the reference stations since the initial sampling in August 1981 are presented in Table 3-5. The populations of these three species have remained relatively stable over the monitoring period. This year is not as easy to compare to the previous years because some of the station locations have changed, but overall the results appear to be similar to previous years. This year the *S.viridis* numbers have increased somewhat from last year. The abundance of *R. cuneata* has decreased from last year's record high, but they compare favorably to the rest of the sampling years. The *L. plumulosus* numbers have decreased when compared to recent years, but they are similar to the numbers found in the earlier years of the project.

The major variations observed in the dominant or most abundant species for a station occur primarily as a result of the different bottom types (Table 3-6). Soft bottoms are preferred by the annelid worms *S. viridis*, *Tubificoides* sp., and *S. benedicti*, as well as the crustaceans *L. plumulosus* and *C. polita*. The most common inhabitants of the predominately old oyster shell substrates are more variable, often with the barnacle *Balanus improvisus*, the worm *Nereis succinea*, or the encrusting bryozoan *Membranipora tenuis* amongst the dominant organisms. This year, the most common organisms found at the soft bottom stations were the isopod *Cyathura polita* and the worm *S. viridis*. *S. viridis* was also the most common organism found at the shell bottom stations.

Station HM26, at the mouth of the Back River, has in past years usually had the most diverse annelid worm fauna. However, this year, New (a reference station) and G84 (a Zn-enriched station) each had 6 species of worms in the August sampling period. A diverse annelid fauna was also recorded this year at stations HM9 and HM26. Both of these reference stations had 5 species of worms (Tables 3-2, 3-3 and 3-4). This year the most abundant worm species at the nearfield, reference, and Zn-enriched stations was *S. viridis*.

The worms *S. viridis* and *Tubificoides heterochaetus,* the clam *R. cuneata*, the crustaceans *C. polita* and *L. plumulosus* and the midge larvae (*Chironomidae* family) occurred frequently at all three sets of stations (nearfield, reference, and Zn-enriched). Over the course of the benthic monitoring studies, the worm *S. viridis* has frequently alternated with the crustaceans *C. polita* and *L. plumulosus* as the foremost dominant species. It appears that slight modifications in the salinity patterns during the important seasonal recruitment period in late Spring play an important role in determining the dominance of these species. The crustaceans *C. polita* and *L. plumulosus* become more abundant during low salinity years while the worm *S. viridis* prefers slightly higher salinities. This year *S. viridis* was the most abundant species,

followed by *C. polita.*

This year *C. polita* was more abundant than *L. plumulosus* (Tables 3-2, 3-3, and 3-4). Both were present at all stations in August. The isopod crustacean *Cyathura polita* appears to be very tolerant of physical and chemical disturbances and repopulates areas such as dredged material disposal sites more quickly than other crustacean species (Pfitzenmeyer 1985).

All of the dominant species, with the exception of *R. cuneata*, brood their young. This is an advantage in an area of unstable and variable environmental conditions such as the low salinity regions of the upper Chesapeake Bay. Organisms released from their parents as juveniles are known to have high survival rates and often reach high densities of individuals (Wells 1961). The total number of individual organisms collected at the various reference, nearfield, and Zn-enriched stations are comparable and ranged between 500 and 5,000 individuals/m^2. The highest recorded value was found at the nearfield station S2. This was mainly due to the high number of *S. viridis* (2,720 individuals/m^2). The lowest recorded value occurred at one of the new reference stations BC6 (499 individuals/m^2). There do not appear to be any consistent pattern in terms of the highs and lows at the reference or nearfield stations. The predominant benthic populations at the three sets of stations (nearfield, reference, and Zn-enriched) are similar and consist of detrital feeders which have an ample supply of fine substrates in this region of Chesapeake Bay, particularly around HMI (Wells et al. 1984).

Salinity and temperature (both surface and bottom) were recorded at most infaunal stations in August (Table 3-1). The surface salinity in August ranged from 2.6-5.6 ppt. Last year, the surface salinity range in August was 4.9-5.9 ppt. All the bottom salinities were the same or higher than the surface salinities for all sites. The bottom salinity range was 2.9-8.4 ppt. This year the average temperature for surface waters was 27.2°C, compared with the previous year's average of 26.4°C. The average bottom water temperature was 26.4°C.

Species diversity values must be interpreted carefully in analyzing benthic data from the upper Chesapeake Bay. Generally, high diversity values reflect a healthy, stable fauna with the numbers of all species in the population somewhat equally distributed and no obvious dominance by one or two species. However this year, in this area of Chesapeake Bay, we have observed, as in the past monitoring studies, that the normal condition is for one, two or three species to assume numerical dominance. This dominance is variable from year to year depending on environmental factors, particularly the amount of freshwater entering Chesapeake Bay from the Susquehanna River. Because of the overwhelming numerical dominance of a few species, diversity values are fairly low in this area of the Bay. Diversity values for each of the quantitative benthic samples for August are presented in Table 3-7. It was postulated in the First Interpretive Report (Pfitzenmeyer et al. 1982) that the highest diversity values would occur in the summer months, as was frequently the case for a majority of the stations during the early years of the study. The highest diversity value (3.332) was recorded at the Zn-enriched station G84, while the lowest diversity value (1.589) was recorded for the nearfield station S5. The largest number of species recorded for any station was 21 at station New (reference). The lowest number of species, 8, was recorded at reference station BC6. Both BC6 and New represent stations

which were added to the benthic sampling grid for the first time this year.

Three species of clams *Rangia cuneata*, *Macoma balthica*, and *Macoma mitchelli*, were measured to the nearest millimeter (mm) in shell length to determine if any size/growth differences were noticeable between stations (Figure 3-2). The clam numbers this year were down from last year's higher than normal numbers. The most abundant clam again this year was *R. cuneata*. Overall, the nearfield, Zn-enriched and reference stations had similar numbers of *R. cuneata* (Figure 3-2). The majority of *Rangia* were observed in the 5mm size class and the reference stations had a higher abundance of 5mm *Rangia* than the nearfield or Zn-enriched stations.

The next most abundant clam during Year 15, as was the case for the nine previous years (six through fourteen) was *M. balthica* (Figure 3-2). *M. mitchelli* was the least abundant of the three clam species recorded in the vicinity of HMI. Neither *M. balthica* nor *M. mitchelli* was very abundant at the various stations during the August sampling period.

Cluster analysis was again employed in this year's study to examine relationships among the different groups of stations based upon the numerical distribution of the numbers of species and individuals of a species. In Figure 3-3, the stations with faunal similarity (based on chi-square statistics derived from the differences between the values of the variables for the stations) are linked by vertical connections in the three dendrograms. Essentially, each station was considered to be a cluster of its own and at each step (amalgamated distances) the clusters with the shortest distance between them were combined (amalgamated) and treated as one cluster. Cluster analysis in past studies at HMI has clearly indicated a faunal response to bottom type (Pfitzenmeyer 1985). Thus, any unusual grouping of stations tends to suggest changes are occurring due to factors other than bottom type and further examinations of these stations may be warranted. Most of the time, experience and familiarity with the area under study can help to explain the differences. However, other outside factors must be considered when differences cannot be explained.

The Summer sampling period represents a season of continued recruitment for the majority of benthic species, as well as a period of heavy stress from predatory activities, higher salinity, and higher water temperature. These stresses exert a moderating effect on the benthic community, holding the various populations in check. This year, the first two pairs of stations to join the dendrogram consisted of 3 silt/clay (G5, S6, and HM22) and 1 sand (S3) station. The first pair to join the dendrogram consisted of G5, a Zn-enriched station and S3, a nearfield station. The second pair included S6, a nearfield station and HM22, a reference station. The clusters that formed during the August sampling period represented previously observed normal groupings for the reference and nearfield stations with no unusually isolated stations. These clusters were consistent with earlier studies and often grouped stations according to bottom type and general location within the study area. The Zn-enriched stations clustered along with the nearfield and reference stations and indicated no unusually isolated stations in this recently sampled group of stations. If the benthic invertebrates in this region were being affected by some adverse or outside force, it would appear in the groupings. No such indications were found

during the August sampling period.

The Ryan-Einot-Gabriel-Welsch Multiple Comparison test was used to determine if a significant difference could be detected when population means of benthic invertebrates were compared at the various sampling stations. The total number of individuals of each species was transformed (log) before the analysis was performed. Subsets of groups, the highest and lowest means of which do not differ by more than the shortest significant range for a subset of that size, are listed as homogeneous subsets. The results of this test are presented in Table 3-8.

The analysis of the August 1996 data resulted in the formation of four subsets this year. The first subset consisted of three nearfield stations (S2, S3, S5), three reference stations (New, HM9, HM26) and two Zn-enriched stations (G25, HM12). The other three subsets contained a mixture of nearfield, reference, and Zn-enriched stations.

The results of Friedman's non-parametric test for differences in the means of samples (for ranked abundances of 11 selected species) taken only at the silt/clay stations for the nearfield, reference, and Zn-enriched stations are presented in Table 3-9. Significant differences ($p<0.05$) were found among the reference stations, between the nearfield and reference stations, and between the Zn-enriched and reference stations. All of the sources involving the reference stations showed a significant difference. This also occurred in the Year 12 results in December 1992. Three new reference stations were added (BC6, 30, New) this year and there does appear to be a large range within these stations with regard to the total number of species (8-21) and total number of individuals (75-566) which most likely contributed to the observed results.

For the first time, the Chesapeake Bay B-IBI was used to score all benthic sampling stations (Weisberg 1997). The majority of the stations are oligohaline as defined by the B-IBI. However, three stations (HM16, New, and G84) are considered low mesohaline. Five metrics (abundance, biomass, abundance of pollution indicative taxa, abundance of pollution sensitive taxa, Shannon-Wiener/species diversity) were used to score the 17 benthic stations. Assemblages are considered stressed if they have an average metric value below 3.0. Only one station was in this category. The new reference station, BC6, had an average score of 2.6. Overall, the benthic stations in the area surrounding HMI do not appear to be stressed according to the parameters of the Chesapeake Bay B-IBI.

CONCLUSIONS AND RECOMMENDATIONS

For Year 15 of sampling and monitoring the benthic populations surrounding HMI, the sampling locations, sampling techniques and analyses of the data were maintained as close as possible to previous years in order to minimize variation. Maintenance of sampling locations, techniques and analyses should render differences due to effects of HMI more readily apparent. This year, by a joint decision of the TRC and PIs, four of our nearfield stations were dropped and four new stations were added [1 nearfield (BC3) and 3 reference(30, New and BC6)]. We have continued to monitor all four infaunal sampling stations which were established over the course of Year 9 in response to the findings of the sedimentary group from the Maryland Geological Survey of an observable enrichment of Zn in the sediments at this location.

The results presented in this report are similar to those presented in the reports of the last ten years (Years five through thirteen of monitoring). A total of 26 species (compared 26, 30, 35, 31, 34, 32, 35, 30, and 30 for years five through thirteen, respectively) were collected in the quantitative infaunal grab samples. Four species were numerically dominant on soft bottoms. These four dominants are the worm *S. viridis*, the crustaceans *C. polita* and *L. plumulosus*, and the clam *R. cuneata.* The oyster shell substrate stations had two numerically dominant species; the worm *S. viridis* and the crustacean *C. polita.* Salinity fluctuations on yearly and seasonal time scales appear to be important in regulating the position of dominance of the major species in this low and variable salinity region of Chesapeake Bay.

The average number of individuals per square meter (m^2) per station was highest for the nearfield (2,946) stations with decreasing values observed for the reference stations (2,174) and Zn-enriched (2,094) during the August sampling period. The highest average species diversity value this year was found at the Zn-enriched station G84 and the lowest diversity value was recorded for the nearfield station S5. The Zn-enriched clam populations appeared comparable to those observed at the reference and nearfield stations.

Similar to previous years, cluster analysis grouped stations of similar faunal composition in response to sediment type and general location within the HMI study area. There were no incidences of individual stations being isolated from common groupings during the August sampling period. The Ryan-Einot-Gabriel-Welsch multiple range test resulted in subsets of stations which contained a mix of nearfield, reference, and Zn-enriched stations. Friedman's non-parametric test indicated significant differences for the reference station, the nearfield and reference stations, and the Zn-enriched and reference stations. According to the Chesapeake B-IBI, the area surrounding HMI is not stressed.

At present, there do not appear to be any discernible differences in the populations of benthic organisms at the nearfield, reference and Zn-enriched stations resulting directly from HMI. It is strongly recommended that the infaunal populations continue to be sampled at the established locations during this period of active operation of the facility in order to ascertain any impacts. Station locations and sampling techniques should be maintained as close as possible to

eliminate sampling variations and permit rapid recognition of effects resulting from HMI.

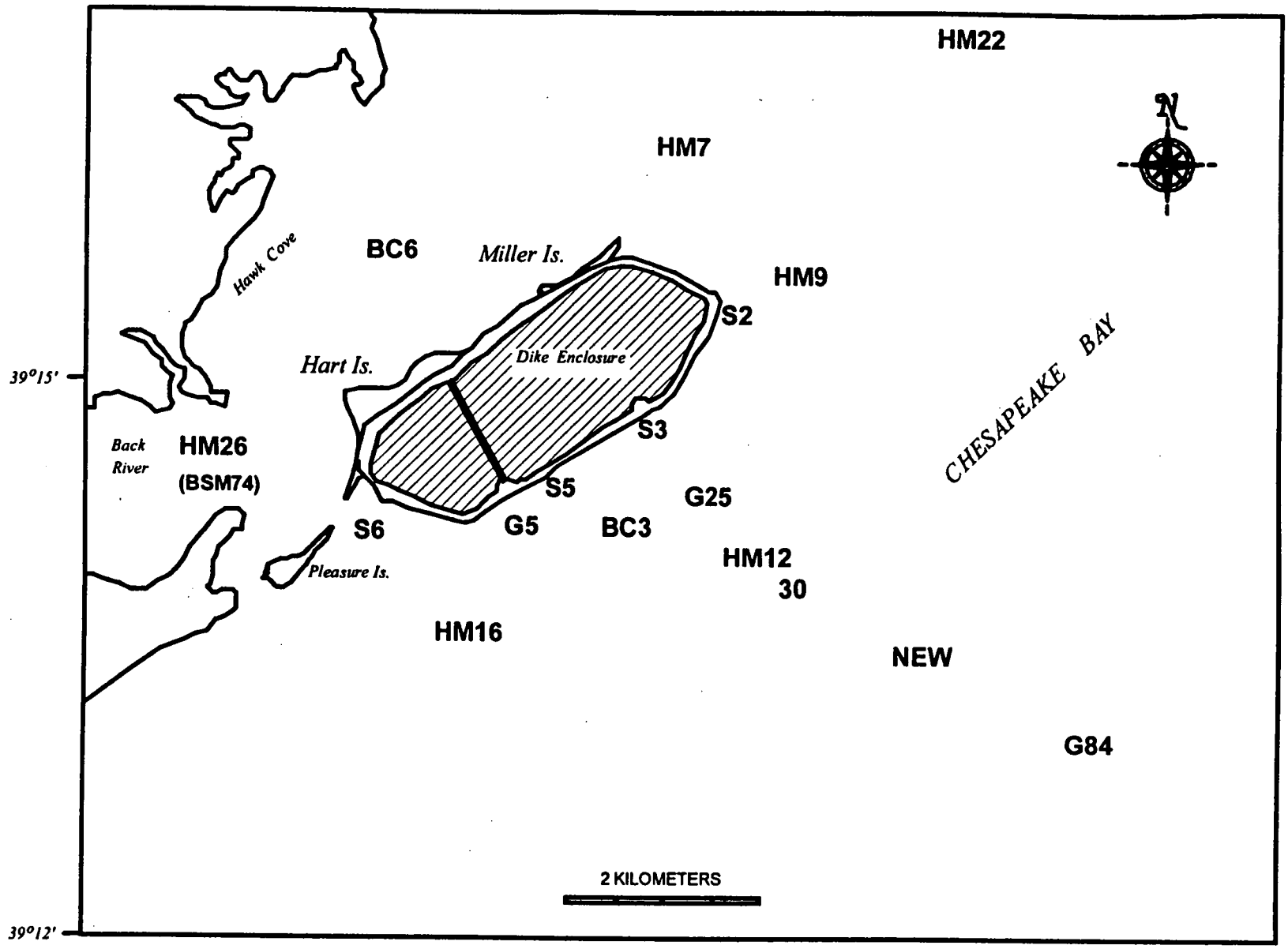

Figure 3-1: Year 15 Benthic Community sampling locations surrounding HMI

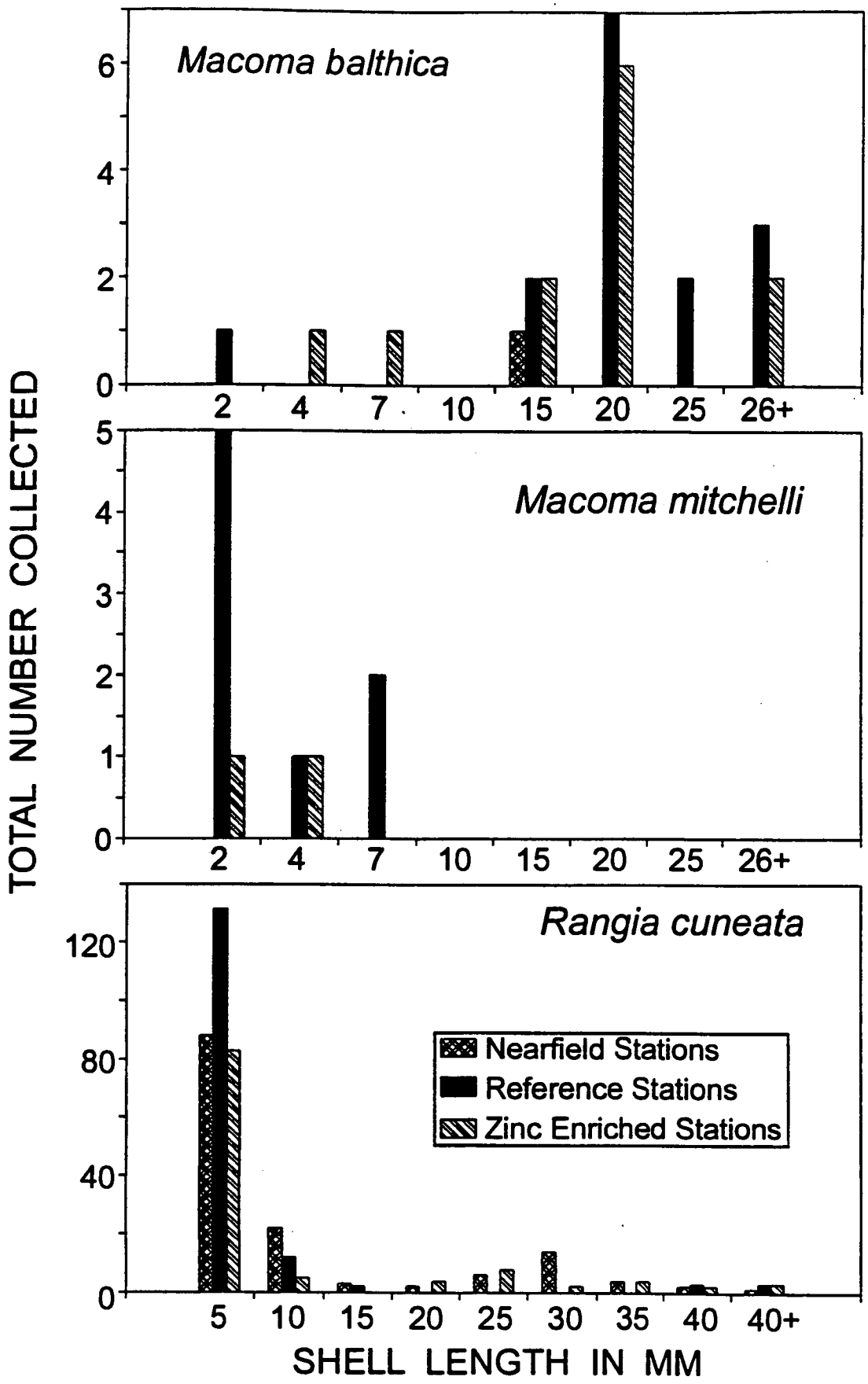

Figure 3-2: Length frequency distribution of the clams *Macoma balthica*, *Macoma mitchelli* and *Rangia cuneata* during Year 15 of Benthic Community Studies at HMI.

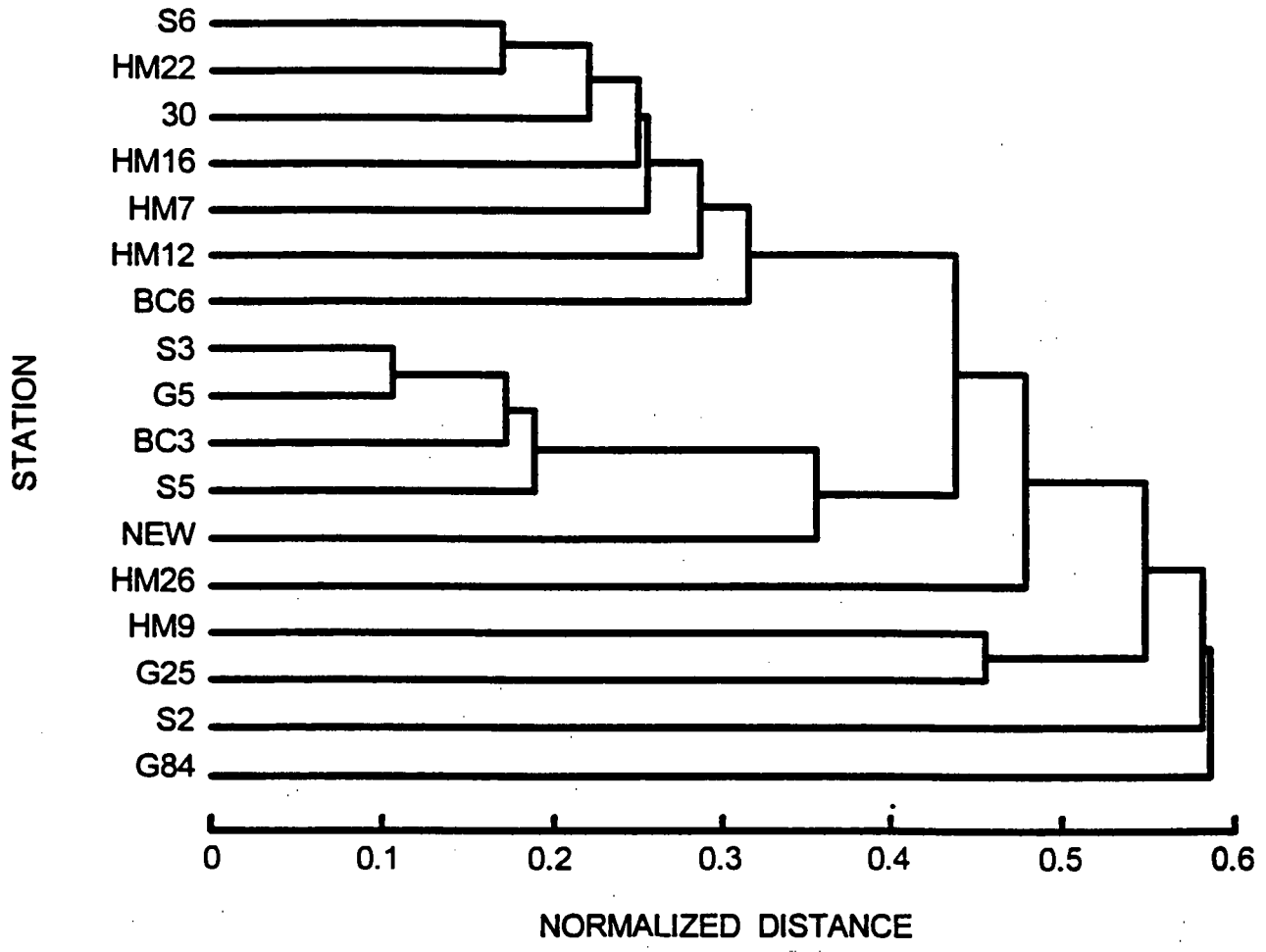

Figure 3-3: Cluster analysis for all of the HMI stations during Year 15 of Benthic Community Studies.

T ABLE 3-1: Average abundances (# per square meter) of three of the most abundant species of bentbic organisms whicb occur at tbe HM1 silt/clay reference stations over the fifteen year study period from August 1981 to August 1996.

	Aug.,Nov. 1981 Feb.,May, 1982	Aug.,Nov. 1982 Feb.,May 1983	Sep.1983 Mar.1984	Oct.1984 Apr.1985	Dec. 1985 Apr., Aug. 1986	Dec.1986 Apr.,Aug. 1987	Dec.1987 Apr.,Aug. 1988	Dec.1988 Apr.,Aug. 1989	Dec.1989 Apr.,Aug. 1990	Dec.1990 Apr.,Aug. 1991	Dec.1991 Apr.,Aug. 1992	Dec.1992 Apr.,Aug. 1993	Dec.1993 Apr.,Aug. 1994	Nov.1994 Apr.,Aug. 1995	Aug.1996
Scolecolepides viridis															
Range/m2	3-667	0-197	0-217	143-463	7-1287	13-320	0-567	20-3420	27-4147	7-253	20-753	60-693	47-2300	167-893	120-1693
Avg./m2	144	49	109	311	413	129	166	971	1037	87	215	249	932	436	594
Leptocheirus plumulosus															
Range/m2	0-4540	113-5763	0-427	843-1353	7-1293	7-3313	0-1047	0-2473	167-2820	40-3607	73-2400	13-3513	67-4820	367-3713	13-560
Avg./m2	1900	2546	180	1076	402	1250	187	486	1193	1170	990	769	1361	1443	376
Rangia cuneata															
Range/m2	0-27	0-27	3-540	0-227	0-273	0-3007	7-2267	0-580	13-10820	0-3867	13-660	73-733	0-227	20-4780	13-560
Avg./m2	3	12	216	110	124	631	447	179	1352	827	224	343	105	884	376

TABLE 3-2: A list of the 3 numerically dominant benthic organisms collected from each bottom type on each sampling date during Year 15 of Benthic Community Studies at HMI.

STATION	AUGUST 1996
NEARFIELD SILT-CLAY BOTTOM (S5,6,BC3)	Scolecolepides viridis Cyathura polita Rangia cuneata
NEARFIELD SHELL BOTTOM (S2)	Scolecolepides viridis Cyathura polita Rangia cuneata
NEARFIELD SAND BOTTOM (S3)	Scolecolepides viridis Cyathura polita Leptocheirus plumulosus
REFERENCE SILT-CLAY BOTTOM (HM7,16,22,30,NEW,BC6)	Scolecolepides viridis Leptocheirus plumulosus Cyathura polita
REFERENCE SHELL BOTTOM (HM9)	Scolecolepides viridis Cyathura polita Tubificoides sp.
BACK RIVER REFERENCE SAND/SILT-CLAY BOTTOM (HM26)	Leptocheirus plumulosus Chironomid sp. Cyathura polita
HISTORICALLY ZINC ENRICHED SILT-CLAY BOTTOM (G5,25,84,HM12)	Scolecolepides viridis Cyathura polita Rangia cuneata

TABLE 3-3: Number of benthic organisms (# per meter squared) found at the reference stations during Year 15 (August 1996) of Benthic Community Studies at HMI.

PHYLUM	SPECIES NAME	#	HM7	HM9	HM16	HM22	HM26	BC6	30	NEW96	TOTALS
RHYNCHOCOELA (ribbon worms)	Micrura leidyi	2	27	73	33	27	100	7	80	73	420
ANNELIDA (worms)	Heteromastus filiformis	3		33	7	7	7			7	61
	Nereis succinea	5		7			7		7	13	34
	Eteone heteropoda	8					40				40
	Polydora ligni	9		33						7	40
	Scolecolepides viridis	10	860	1340	287	133	180	120	473	1693	5086
	Streblospio benedicti	11								7	7
	Limnodrilus hoffmeisteri	13									0
	Tubificoides heterochaetus	14		480	153		133	113	33	87	999
	Capitella capitata	15									0
MOLLUSCA (mollusks)	Ischadium recurvus	16									0
	Congeria leucophaeta	17	13				7		7		27
	Littoridinops sp.	18	13		7	7			7	33	67
	Macoma balthica	19	7		33				13	47	100
	Macoma mitchelli	20			13				7	33	53
	Rangia cuneata	21	80	193	220	60	187	13	133	120	1006
	Mya arenaria	22									0
	Hydrobia sp.	23									0
	Doridella obscura	25									0
ARTHROPODA (crustaceans)	Balanus improvisus	27									0
	Balanus subalbidus	28									0
	Leucon americanus	29									0
	Cyathura polita	30	233	753	493	180	227	93	300	733	3012
	Cassidinidea lunifrons	31									0
	Edotea triloba	33					60			140	200
	Gammarus palustris	35									0
	Leptocheirus plumulosus	36	513	20	487	147	1107	13	560	533	3380
	Corophium lacustre	37		7			7				14
	Gammarus daiberi	38									0
	Gammerus tigrinus	39	7			7	187		27	13	241
	Melita nitida	40	100		73	27	93		20	27	340
	Chirodotea almyra	41					87				87
	Monoculodes edwardsi	42	73	173	33		120		73	87	559
	Chironomid sp.	43	353	27	27	80	307	133	47	40	1014
	Rithropanopeus harrisi	44	7	147					7	40	201
COELENTERA (hydroids)	Garveia franciscana	47								20	20
PLATYHELMIA (flatworms)	Stylochus ellipticus	48									0
BRYOZOA (bryozoans)	Membrania tenuis	49		347				7	7	20	381
	Victorella pavida	50									0
	TOTAL NUMBERS		2286	3633	1866	675	2856	499	1801	3773	17389

TABLE 3-4: Number of benthic organisms (# per meter squared) found at the nearfield stations during Year 15 (August 1996) of Benthic Community Studies at HMI.

PHYLUM	SPECIES NAME	#	S2	S3	S5	S6	BC3	TOTALS
RHYNCHOCOELA (ribbon worms)	Micrura leidyi	2	7	27	33	53	13	133
ANNELIDA (worms)	Heteromastus filiformis	3	33	7				40
	Nereis succinea	5						0
	Eteone heteropoda	8						0
	Polydora ligni	9	33					33
	Scolecolepides viridis	10	2720	1907	1607	560	1560	8354
	Streblospio benedicti	11						0
	Limnodrilus hoffmeisteri	13						0
	Tubificoides heterochaetus	14	253	93	80	53	13	492
	Capitella capitata	15						0
MOLLUSCA (mollusks)	Ischadium recurvus	16						0
	Congeria leucophaeta	17	7					7
	Littoridinops sp.	18			7			7
	Macoma balthica	19					7	7
	Macoma mitchelli	20						0
	Rangia cuneata	21	327	247	120	180	73	947
	Mya arenaria	22						0
	Hydrobia sp.	23						0
	Doridella obscura	25						0
ARTHROPODA (crustaceans)	Balanus improvisus	27						0
	Balanus subalbidus	28						0
	Leucon americanus	29						0
	Cyathura polita	30	820	553	553	347	367	2640
	Cassidinidea lunifrons	31						0
	Edotea triloba	33	33	40				73
	Gammarus palustris	35						0
	Leptocheirus plumulosus	36	7	293	13	200	113	626
	Corophium lacustre	37	120					120
	Gammarus daiberi	38						0
	Gammarus tigrinus	39	47	7	7	7		68
	Melita nitida	40	33	27		7	7	74
	Chirodotea almyra	41	27	7				34
	Monoculodes edwardsi	42	127	33	13	13	27	213
	Chironomid sp.	43		67	53	200	73	393
	Rithropanopeus harrisi	44	193				7	200
	Gammarus mucronatus	45						0
COELENTERA (hydroids)	Garvela franciscana	47						0
PLATYHELMIA (flatworms)	Stylochus ellipticus	48						0
BRYOZOA (bryozoans)	Membranipora tenuis	49	147			7	113	267
	Victorella pavida	50						0
	TOTAL NUMBERS		4934	3308	2486	1627	2373	14728

TABLE 3-5: Number of benthic organisms (# per meter squared) found at the Zn-enriched stations during Year 15 (August 1996) of Benthic Community Studies at HMI.

PHYLUM	SPECIES NAME	#	G5	G25	G84	HM12	TOTALS
RHYNCHOCOELA (ribbon worms)	Micrura leidyi	2	13	67	107	53	240
ANNELIDA (worms)	Heteromastus filiformis	3			93	13	106
	Nereis succinea	5			27		27
	Eteone heteropoda	8					0
	Polydora ligni	9		7	7		14
	Scolecolepides viridis	10	1273	973	267	673	3186
	Streblospio benedicti	11			40		40
	Limnodrilus hoffmeisteri	13					0
	Tubificoides heterochaetus	14	33	40	200	80	353
	Capitella capitata	15					0
MOLLUSCA (mollusks)	Ischadium recurvus	16					0
	Congeria leucophaeta	17					0
	Littoridinops sp.	18				20	20
	Macoma balthica	19	13	7	60		80
	Macoma mitchelli	20			13		13
	Rangia cuneata	21	100	220	27	393	740
	Mya arenaria	22					0
	Hydrobia sp.	23					0
	Doridella obscura	25					0
ARTHROPODA (crustaceans)	Balanus improvisus	27		7			7
	Balanus subalbidus	28					0
	Leucon americanus	29					0
	Cyathura polita	30	393	467	393	600	1853
	Cassidinidea lunifrons	31					0
	Edotea triloba	33	7	13	53	13	86
	Gammarus palustris	35					0
	Leptocheirus plumulosus	36	133	27	33	380	573
	Corophium lacustre	37					0
	Gammarus daiberi	38					0
	Gammerus tigrinus	39			20	13	33
	Melita nitida	40		7		13	20
	Chirodotea almyra	41					0
	Monoculodes edwardsi	42	20	73	107	80	280
	Chironomid sp.	43	20	93		40	153
	Rithropanopeus harrisi	44		73	40	13	126
COELENTERA (hydroids)	Garvela franciscana	47					0
PLATYHELMIA (flatworms)	Stylochus ellipticus	48					0
BRYOZOA (bryozoans)	Membranipora tenuis	49		387	13	27	427
	Victorella pavida	50					0
	TOTAL NUMBERS		2005	2461	1500	2411	8377

TABLE 3-6: Salinity (in parts per thousand), temperature (in degrees centigrade) and depth (feet) for the benthic sampling stations during Year 15 of Benthic Community Studies at HMI (August 1996).

CBL STA. ID	STATE STA. #	DEPTH	TEMPERATURE	SALINITY
S2	XIF5406	0	**NR	NR
S2	XIF5406	11	NR	NR
S3	XIF4811	0	28.00	4.0
S3	XIF4811	14	NR	NR
S5	XIF4420	0	26.83	3.0
S5	XIF4420	19	26.13	4.2
S6	XIF4327	0	26.53	3.4
S6	XIF4327	10	26.20	4.5
HM7	XIF6388	0	27.57	3.1
HM7	XIF6388	10	26.80	3.2
HM9	XIF5297	0	28.00	3.0
HM9	XIF5297	15	NR	NR
HM12	XIF5805	0	26.62	4.2
HM12	XIF5805	16	26.55	4.5
HM16	XIF3325	0	26.45	3.4
HM16	XIF3325	16	26.17	5.4
HM22	XIG7689	0	27.20	3.6
HM22	XIG7689	11	26.80	3.7
HM26	XIF5145	0	27.94	3.3
HM26	XIF5145	15	26.96	3.4
G5	XIF4221	0	26.56	3.1
G5	XIF4221	16	26.13	4.3
G25	XIF4405	0	27.42	3.2
G25	XIF4405	16	26.31	3.8
G84	XIG2964	0	26.33	5.6
G84	XIG2964	17	25.94	8.4
30	XIF4000	0	26.68	4.2
30	XIF4000	16	26.16	4.7
NEW		0	26.55	5.4
NEW		19	26.19	5.8
BC3	XIF4615	0	27.20	3.1
BC3	XIF4615	13	26.14	3.5
BC6	XIF5925	0	28.88	2.6
BC6	XIF5925	8	26.78	2.9

**NR= NOT RECORDED

TABLE 3-7: Number of species and the total number of individuals collected in three grab samples (0.05m2 each) at the infaunal stations for August 1996. Bottom substrate, species diversity (H') and dominance factor (S.I.) are also shown. Data for Year 15 of Benthic Community Studies at HMI.

STATION	SUBSTRATE	NO. SPECIES	NO. INDIVIDUALS	SPECIES DIVERSITY (H')	DOMINAN FACTOR S.I.
NEARFIELD					
S2	Shell	17	740	2.321	0.343
S3	Sand	13	496	2.048	0.376
S5	Silt-Clay	10	373	1.589	0.471
S6	Silt-Clay	11	244	2.578	0.209
BC3	Silt-Clay	12	356	1.771	0.463
REFERENCE					
HM 7	Silt-Clay	13	343	2.528	0.231
HM 9	Shell	14	545	2.697	0.213
HM16	Silt-Clay	13	280	2.779	0.185
HM22	Silt-Clay	10	101	2.693	0.184
30	Silt-Clay	17	270	2.765	0.204
NEW	Silt-Clay	21	566	2.647	0.264
BC6	Silt-Clay	8	75	2.385	0.217
BACK RIVER REFERENCE					
HM26	Sand/Silt-Clay	17	428	3.100	0.189
ZINC ENRICHED					
G5	Silt-Clay	10	301	1.707	0.449
G25	Silt-Clay	15	369	2.638	0.230
G84	Silt-Clay	17	225	3.332	0.138
HM12	Silt-Clay	15	362	2.741	0.194

TABLE 3-8: The Ryan-Einot-Gabriel-Welsch Multiple F test of significance among mean number of individuals per station for stations sampled in August 1996. Subsets show groupings of stations different at (P<0.05). Stations in a separate vertical row and column are significantly different from others. Year 15 of Benthic Community Studies at HMI.

AUGUST 1996

SUBSET	STATION NUMBERS															
1	S2	NEW	HM9	S3	HM26	S5	G25	HM12								
2		NEW	HM9	S3	HM26	S5	G25	HM12	BC3	HM7	G5	HM16	30	S6	G84	
3			HM9	S3	HM26	S5	G25	HM12	BC3	HM7	G5	HM16	30	S6	G84	HM22
4				S3	HM26	S5	G25	HM12	BC3	HM7	G5	HM16	30	S6	G84	HM22	BC6

ANALYSIS OF VARIANCE

SOURCE	D.F.	SUM OF SQUARES	MEAN SQUARES	F RATIO	F PROB.
BETWEEN GROUPS	16	147528	9220	4.29	0.0002
WITHIN GROUPS	34	73155	2152		
TOTAL	50	220683			

TABLE 3-9: Results of Friedman's non-parametric test for differences in the abundances of 11 selected species between stations with silt/clay substrates for Year 15 of Benthic Community Studies at HMI. (Silt/clay stations are: Nearfild Stas.- S5, S6,BC3; Reference Stas.- HM7, HM16, HM22,30,NEW,BC6; Zinc-Enriched Stas.- G5,G25,G84,HM12.)

	SOURCE	D.F.	CHI-SQUARE	CHI-SQUARE (0.05)
AUG 1996				
	NEARFIELD	2	0.59	5.99
	REFERENCE	5	18.08 *	11.07
	ZINC ENRICHED	3	7.69	7.82
	NEARFIELD & REFERENCE	8	22.02 *	15.51
	ZINC ENRICHED & REFERENCE	9	28.57 *	16.92

*SIGNIFICANT DIFFERENCE AT THE 0.05 LEVEL.

Table 3-10: Benthic Index of Biotic Integrity (B-IBI) metric scores for Year 15 of Benthic Community Studies at HMI.

STATIONS		ABUNDANCE (#m2)	BIOMASS (g/m2)	ABUNDANCE OF POLLUTION INDICATIVE TAXA (%)	ABUNDANCE OF POLLUTION SENSITIVE TAXA (%)	SHANNON-WEINER (SPECIES DIVERSITY)	AVERAGE SCORE
REFERENCE:	HM7	5	1	5	5	5	4.2
	HM9	3	1	5	5	5	3.8
	HM16	5	1	3	3	5	3.4
	HM22	1	1	5	5	5	3.4
	HM26	5	1	5	3	5	3.8
	BC6	1	1	3	5	3	2.6*
	30	5	1	5	5	5	4.2
	NEW	3	1	5	3	5	3.4
NEARFIELD:	S2	3	3	5	5	3	3.8
	S3	3	3	5	5	3	3.8
	S5	5	1	5	5	1	3.4
	S6	5	1	5	5	5	4.2
	BC3	5	1	5	5	1	3.4
ZINC-ENRICHED:	G5	5	3	5	5	1	3.8
	G25	5	1	5	5	5	4.2
	G84	3	1	3	3	5	3.0
	HM12	5	3	5	5	5	4.6

* Assemblages with an average score of <3.0 are considered stressed, as they have metric values that are less than values at the poorest reference sites.

CHAPTER 4: ANALYTICAL SERVICES (PROJECT IV)

By

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OBJECTIVES

The objectives of the Year 15 study were to characterize trace metal and organic contaminant concentrations in both clams (*Rangia cuneata*) and sediments surrounding HMI (Figure 4-1). Samples have been collected at HMI since 1981 as part of an Exterior Monitoring Program. The current Year 15 sampling effort for Project IV was initiated in concert with this long-term study. Comparison and correlation of these Year 15 data with data from other nearby locations, as well as with historical HMI data, will indicate the extent of contamination and any trend in concentrations at this location.

The results of the quality assurance/quality control (QA/QC) procedures and the description of the analytical and field protocols are contained in the *Year 15 Data Report*. Overall, the QA/QC results were acceptable for a study of this nature. No evidence of bias or lack of preciscion or accuracy was indicated by the QA/QC results. Comparisons of duplicate analyses and of measured values to certified values for the analyzed SRMs are also discussed in the *Year 15 Data Report*. The QA/QC objectives for SRMs, duplicates, spikes and blanks were met in this regard.

METHODS AND MATERIALS

Sampling Procedures

Attempts were made to collect *Rangia* samples from the 17 sites visited around HMI using a Ponar grab sampler. Up to six grabs of the sampler were taken at each site to provide enough clams for contaminant analyses. Some sites had no living clams or too few large ones to analyze. Overall, clams were found at 14 of the 17 sites (excluding HM26, S5 and New) and were saved for organic contaminant and trace metal analyses. Clam samples were placed in zip-lock bags and stored on ice until they were returned to the laboratory.

Many clams were taken that were less than 3.5 cm, but most clams selected for analysis were >3.0 cm. One site (S3) had enough clams that a separate comparison of small and large clams was made for organic contaminant analysis (*Year 15 Data Report*). For metals, no distinction with regard to size was made, but the total pooled sample was split to provide a field duplicate. An insufficient sample was available for organic analysis at site BC3, but the clams were analyzed for metals.

Back at the laboratory, the clam samples were cataloged and divided into subsamples for trace metal and organic contaminant analyses. For organic analysis, composite samples of clams from each site were prepared by removing whole fresh clams from their shells with a stainless steel scalpel. Most of the water and body fluids were then allowed to drain. A clean scalpel tip was used for the clams at each site to avoid cross contamination. Tissue was placed in a clean glass jar with a Teflon-lined lid and stored in the freezer. For metals analysis, clams were removed whole from their shells with a Teflon-coated spatula. Most of the water and body fluids were then allowed to drain. The spatula was acid rinsed between samples to avoid cross contamination. The clam bodies

were homogenized in a plastic blender with a stainless steel blade. Unused samples were returned to their respective bags and stored in the freezer until further analysis.

Sediment samples were taken at all sites, even when no clams could be found. Sediment samples for metal analysis, however, were not saved initially from all sites and could not be later subsampled because of contamination concerns. Consequently, only 10 sediment samples were analyzed for metals. The sediment sample from site S5 was lost during transit back to the laboratory.. Surficial sediment was collected from each Ponar grab, and a single composite sample from each site was stored in a pre-cleaned glass jar (organic contaminants), or plastic bag (metals), and transported on ice back to the laboratory.

Analytical Procedures for Metals

Methods used for both trace metals and organic contaminant analyses are similar to those described in detail in Dalal et al. (1999). For metals, a subsample of each trace metal sample (sediments and clams) was used for dry weight determination. Weighed samples were placed in a VWR Scientific Forced Air Oven at 60^{0}C overnight and were then reweighed to calculate a dry/wet ratio. Another subsample of clam tissue (5 g wet weight) was placed in acid-cleaned flasks for further digestion using USEPA Methods (USEPA Method 1620; Keith 1991) described below.

1. Ten mL of 1:1 HNO_3 was added and the slurry was mixed and covered with a watch glass;

2. The sample was heated to 95^{0}C and allowed to reflux for 15 minutes without boiling;

3. The samples were cooled, 5 mL of concentrated HNO_3 was added, and the samples were allowed to reflux for another 30 minutes. This step was repeated to ensure complete oxidation;

4. The watch glasses were removed and the resulting solution was allowed to evaporate to 5 mL without boiling;

5. When evaporation was completed and the samples cooled, 2 mL of 30% H_2O_2 was added;

6. The flasks were then covered and returned to the hot plate for warming. The samples were heated until effervescence subsided;

7. A solution of 30% H_2O_2 was continually added in 1 mL aliquots with warming until the effervescence was minimal. No more than a total of 10 mL of H_2O_2 was added to each sample;

8. Lastly, 5 mL of concentrated HCl and 10 mL of deionized water were added and the samples refluxed for 15 minutes; and

9. The samples were then cooled and filtered through Whatman No. 41 filter paper by suction filtration and diluted to 100 mL with deionized water. Sediments were digested in a similar fashion.

The clam and sediment homogenates were then analyzed using a Perkin-Elmer Zeeman 5000 HGA-400 Graphite Furnace Atomic Absorption Spectrophotometer (GF-AAS) for Cu, Cd, Pb, Cr, Ni and silver (Ag) concentrations (USEPA Methods, 7000 Series). Standards were prepared according to the Perkin-Elmer Analytical Methods manual. Spectral interferences associated with Pb were minimized using a $Mg(NO_3)_2$ and PO_4 matrix. Martix modifiers were not needed for Cu and Cd analysis. For enhanced sensitivity, pyrolytically coated graphite tubes with platforms were used. For arsenic (As), samples were analyzed by hydride generation techniques using a PSA analyzer. These techniques are similar to USEPA Method 1632.

Samples tested for mercury [Hg(1-3 g wet weight)] were digested in a solution of 70% sulfuric /30% nitric acid in Teflon vials and heated overnight in an oven at 60°C (Mason et al. 1995). The digestate was then diluted to 10 mL with distilled-deionized water. Prior to analysis, the samples were further oxidized for 30 minutes with 2 mL of bromine monochloride solution. The excess oxidant was neutralized with 10% hydroxylamine solution and the concentration of mercury in an aliquot of the solution was determined by tin chloride reduction cold vapor atomic fluorescence detection in accordance with protocols outlined in USEPA Method 1631 (Mason et al. 1993).

Analytical Procedures for Organic Contaminants

Whole clams were removed from shells using a stainless steel scalpel and stored in pre-cleaned glass jars with Teflon lined lids. The clams were separated by site and collection date. The clam bodies were homogenized in a stainless steel tissue blender and returned to their respective sample jars. As described below, clam homogenates were extracted and purified using the methods of Kucklick et al. (1996):

1. A subsample of clam homogenate, 2 g wet weight, is removed and ground with anhydrous sodium sulfate (~50 g). A perdeuterated PAH cocktail (d_8-napthalene, d_{10}-fluorene, d_{10}-fluoranthene, d_{12}-perylene) and a noncommercial PCB solution (IUPAC #'s 14, 65, 166) are added as surrogates to each sample to track extraction efficiency;

2. The mixture is then extracted in a Soxhlet apparatus with 250 mL of dichloromethane (DCM) for 24 hours;

3. The extracts are then concentrated to 10 mL using a vacuum rotary evaporator;

4. Each sample is transferred to graduated centrifuge tubes and concentrated to 6 mL under a gentle stream of nitrogen;

5. Gravimetric lipid analysis is performed on each sample (Kucklick et al. 1996);

6. Lipids are then removed through gel permeation chromatography, eluting DCM through Phenogel 50 x 7.8 mm guard, 250 x 22.5 mm Phenogel 10 ul 100 A, and 250 x 21.5 mm Phenogel 10 ul 100 A columns, in series, respectively. Samples are again concentrated in similar fashion as above, then solvent exchanged to hexane;

7. The extracts are then eluted with 35 mL petroleum ether over deactivated Alumina [6% (w/w) water];

8. After concentrating, the extracts are spiked with a perdeuterated PAH mixture (d_{10}-acenapthene, d_{10}-phenanthrene, d_{12}-benz[*a*]anthracene, d_{12}-benzo[*a*]pyrene, d_{12}-benzo[*g,h,I*]perylene) for quantification of PAHs;

9. The samples are then analyzed using a Hewlett Packard 5890 gas chromatograph (GC) with a HP-5MS (cross linked 5% phenyl methyl siloxane) capillary column (30m x 0.25mm x 0.25um film thickness) and an HP-5972 series mass spectrometer (MS) for PAHs (Ko and Baker, 1995);

10. Each sample is separated after GC/MS analysis into two fractions with 35 mL of petroleum ether and 50 mL of DCM/PET (1:1), respectively, over 8 g of deactivated Florisil (2% (w/w) water, Kucklick *et al.*1996); and

11. The first fraction (F-1) contains PCBs and 1-100%, by weight of the less polar organochlorine pesticides [heptachlor (100%), 4,4-DDT (40%), 4,4-DDE (100%), t-nonachlor (24%), heptachlor (1%), 4,4-DDT(44%)]. The second fraction, (F-2), contains 56-100% of the more polar organochlorine pesticides [a-HCH (100%), g-HCH (100%), c-chlordane (100%), t-chlordane (100%), t-nonachlor (76%), heptachlor (99%), heptachlor epoxide (100%), dieldrin (100%), 4,4-DDD (100%), 4,4-DDT (56%)]. Both fractions are solvent exchanged to hexane and concentrated to approximately 1 mL.

PCBs and remaining organochlorine pesticides (OCs) are analyzed by GC using a J&W Scientific DB-5 capillary column (60m x 0.32mm x 0.25um film thickness) coupled with an electron capture detector (ECD). PCBs are quantified on an individual congener basis following Mullins et al. (1985), using noncommercial PCB congeners (IUPAC#'s 30 and 204 added to each extract after purification) as internal standards. OCs are also quantified using PCB congeners 30 and 204 in both Florisil fractions.

RESULTS AND DISCUSSION

The concentrations of metals in the sediment at sites on the northern side of HMI (sites BC6, HM7, and HM22; Figure 4-1) are consistently higher, although not statistically significant, than the average concentrations for the data (*Year 15 Data Report*; Table 4-1). Additionally, some of the more "open water" sites, such as G84, also have elevated metal concentrations, suggesting that the cause of the higher values is not clearly HMI. Site HM9 had the lowest sediment metal concentrations overall.

Metals in Clams

For the clams, there are similar trends with higher values for the sites north of the island. No sites are clearly elevated relative to all other sites. A comparison of the clam data with those recently measured at Poplar Island (Figure 4-2), which is a more open water, less impacted site, shows that there is no strong indication of higher metal concentrations at HMI for biota. Although the clams sampled at Poplar Island were a different species (*Mya arenaria*) than those collected at HMI, the comparison provides one contrast of this data set to other recently gathered data. Overall, there is little difference between the two sites in trace metal concentrations. The exception is nickel (Ni), which is clearly elevated at HMI. The reason for the higher Ni concentrations relative to Poplar Island is not known but, as discussed below, the sediment comparisons do not indicate that sediment nickel concentrations are elevated compared to other sites. The concentrations of silver (Ag), and to a small extent cadmium (Cd), are also somewhat higher at HMI, but it is unlikely that this difference is significant given the variability in concentrations between individual sites - as detailed in the *Year 15 Data Report.*

Additionally, comparison of the clam data to Chesapeake Bay-wide average data (Table 4-2) shows no significant differences. Direct comparison is difficult because of interspecies differences. Overall, the differences in metal concentrations are typical of interspecies differences in uptake and metabolism of metals and are not considered to be indicative of any strong differences between these two sites. A comparison can also be made between the current and historic clam tissue data at HMI (Table 4-2). Data from the Year 10 report (samples collected in the winter of 1990/91) and the Year 13 report (samples collected in 1993/1994) are compared to our current measurements for 1996 as an example of long-term trends. The current average concentration of copper is within the range of previous values while the values for Zn and Ni are less than those reported previously, although the values for Zn are not substantially different (i.e. less than a factor of 2). In the previous data there were some very high values for Ni in clams and the reason for this is not known. Values for Ni are fairly consistent across sites for the 1996 data - the relative standard deviation is about 25%. Chromium values were much higher previously, as are the limited previous As data. The dramatic decrease in concentration of Cr and As is unlikely due to changes in inputs, given that the other metals have not changed in concentration to the same extent. There is potential that high blanks and sample contamination in the older data could account for these differences.

A more detailed examination of all the long-term records is needed if this question is to be adequately addressed. Such an analysis is beyond the scope of this report and has not been proposed. For Cu, Zn and Ni, the comparison with historic data indicate that there might be a decrease in the concentration of metals in the clams at some sites. This may be an artifact, however, because of the differences in sampling methods, locations and analytical methods, such as blanks, digestion procedures, detection limits,. Overall, we can conclude that there has been no elevation in the concentration of metals in clams collected around HMI in the last six years.

Metals in Sediments

For the sediments, the values obtained at HMI are compared to those found during our recent mapping survey of the Baltimore Harbor/Back River area (Figure 4-3). The stations chosen for comparison are: station #74, which is comparable to station HM 26; station #75, near the mouth of Back River and further away from the island; station #80, further up Back River and further from HMI. Additionally, the average values for Chesapeake Bay, as reported by the Chesapeake Bay Program (1994) are also plotted. For some of the metals (Pb, Cr, Cu, Zn and Hg), the concentrations in the sediment at site #75 are at least twice that of the HMI average values. Additionally, the concentration for all metals is significantly higher at site #80, and additional sites sampled in Back River. These concentration trends suggest that the Back River could be an important source of metals to HMI. A recommendation that further sampling in 1997 be designed to clarify the role of the Back River as a source has been accepted and this issue will therefore be addressed by the results of the Year 16 study.

For Hg, the concentrations at sites in close proximity to HMI (e.g. HM7, HM9, S2, S3) are slightly higher than the value at site #80. Thus, it is not as clear that the Back River is supplying Hg, and possibly Cd, to HMI. The concentration difference for Hg is also a factor of two higher than the Bay average values (Figure 4-3). This is the case for most of the other metals (Cd, Pb and Cu) where average data is available (no average data are available for Ni or Zn) as the concentrations at HMI are around twice those of the Bay average. Only Cr has a lower average value for HMI. Finally, the data for HMI are typically lower than the values we have found in Baltimore Harbor.

Based on the comparison of sediments, it can be concluded that the concentrations of metals in sediments around HMI are somewhat elevated compared to Chesapeake Bay average concentrations, but are not significantly different from other sites that are clearly not impacted by activities at HMI. A comparison with the limited sediment data from the Special Report 1 (October 1982) give values of 100-400 ppm for Zn, 10-50 for Cu, 6-45 for Cr and 20-75 for Ni. These values are not different from the 1996 data, when samples in the historic data potentially compromised by contamination are not considered. Back River could be an important source of contamination to this region but more analysis of existing data, and likely more sampling, is needed to confirm this. Further investigations should be focused on addressing certain aspects indicated by the current dataset. These include the influence of Back River, and a further investigation of the concentrations of Hg, Zn and Ni, all of which are possibly elevated in either

biota or sediment when compared to other sites. Additionally, we are continuing to examine the data to investigate the relationships between sediment and biota concentrations. There does not seem to be a strong relationship between sediment concentration and biota concentration (Figure 4-4). The slope of the line is an indication of the sediment/clam bioconcentration factor. However, the relationships found are not significant, illustrating the lack of dependence of clam concentration on total sediment concentration. For Cd, clam concentrations are higher than that of the sediment while for Hg the clam values are somewhat lower. The clam concentrations for Pb are nearly 2 orders of magnitude lower than that of the sediment. It is well known that there is not a simple relationship between sediment concentration for metals and benthic biota concentration (Luoma, 1989) and it is recommended that further investigations should be aimed at understanding the factors influencing accumulation in the region of HMI. Such studies are currently being completed through projects of Mason and Baker funded by other sources besides MDE (e.g., USEPA and NOAA/Sea Grant).

Organic Contaminants

Concentrations of organic contaminants in *Rangia* tissue and in surficial sediments are detailed in Tables 4-4 and 4-5 of the *Year 15 Data Report*; and summarized here as Table 4-3. Concentrations of total PAHs (sum of 42 individual analytes) in *Rangia* tissue ranged from 12 to 89 ng/g-wet weight, and averaged 46.2±23.5 ng/g-wet weight (excluding the sample from HM-22 and the small-sized *Rangia* sample from S-3, neither of which contained detectable levels of PAHs). Total PCB concentrations (sum of 82 chromatographic peaks containing PCB congeners) averaged 36.8±13.6 ng/g-wet weight and ranged from 20 to 64 ng/g-wet weight. These concentrations of PAHs and PCBs are extremely low and are below the detection limits of previous investigations. For example, detection limits listed in the Year 13 report are around > 300 ng/g for individual PAHs while the current values are significantly less than 100 ng/g. PCB detection levels are similarly lower than in previous studies. Thus, there are no historical data for meaningful comparison. The FDA advisory level for PCBs based on human consumption is 2000 ng/g-wet weight, or 50 times greater than the PCB concentrations observed around Hart-Miller Island. Organochlorine pesticide (OC) levels in these *Rangia* samples are also quite low, with virtually all OC analytes present at levels less than 1 ng/g-wet weight. While no quantitative guidelines exist for the protection of ecosystem health, these very low levels of organic contaminants in *Rangia* tissue are unlikely to directly impact either the organisms themselves or their predators

.

To put the data into perspective, average concentrations of PCB congeners in HMI *Rangia* are compared with concentrations measured in the softshell clam *Mya* collected from the Poplar Island Restoration Project site (Figure 4-5). PCB concentrations are approximately tenfold higher in HMI *Rangia*, consistent with the relatively higher contaminant concentrations in the northern Chesapeake Bay relative to the mid-bay region around the Poplar Island site. Again, we emphasize that organic contaminant levels at both sites are very low and consistent with unimpacted areas. Other organic contaminant levels published in the *National Status and Trends Program: Mussel Watch and Benthic Surveillance Project* (NOAA 1996) report

concentrations in *Crassostrea virginica* (American Oyster) within similar ranges (Figure 4-6). The comparison cannot be completely quantitative since the numbers reflect different organisms. Although both *C. virginica* and *Rangia* are suspension feeders, variability between species habits and life cycles affect their abilities to absorb and retain contaminants. Three PAH analytes (biphenyl, fluorene, and benzo[a]pyrene), and eleven PCB congeners (44, 52, 66, 101, 105, 128, 153, 170, 180, 187) were compared for five NS&T sites and the average of HMI. NOAA reported all of the PCB congeners as a single peak, whereas, some of the congeners coelute in our analysis and reflect higher concentrations. For coelution of congeners see the *Year 15 Data Report*. These comparisons provide evidence that HMI does not contribute substantially to organic contamination of the surrounding benthic population.

Concentrations of total PAHs in surficial sediments range from 806 ng/g-dry weight at BC-3 to 4530 ng/g-dry weight at Site HMI-New, and averaged 2570±1030 ng/g-dry weight. PAHs are not enriched above regional background levels at any of the stations immediately adjacent to the HMI. The average total PAH concentration is approximately 2.5 times the geometric mean concentration of total PAHs in northern mainstem Chesapeake Bay sediments above the Potomac River mouth (total PAH geometric means of 1090 ng/g, Nakanishi 1996). However, it is also orders of magnitude lower than PAH concentrations measured in surficial sediments in the impacted Baltimore Harbor and Back River systems, where total PAH concentrations ranged from 116 to 47,260 ng/g-dry weight and averaged 11,460 ng/g-dry weight (Baker et al. 1997). In fact, spatial analysis suggests a large gradient in PAHs (and other analytes) along a downstream transect in the Back River, leading to HMI (Figure 4-7).

PAH concentrations in surficial sediments around HMI are all below the 'Effect Range - Medium'(ER-M) concentrations published by Long et al. (1995). ER-M is a statistically-derived sediment guideline above which adverse biological impacts were observed in 50% of the studies. At a few sites (*i.e.*, HMI-New, HM-30, and HM-9), concentrations of lower molecular weight PAHs exceeded the 'Effects Range-Low' (biological effects in 10% of studied areas with PAH concentrations equal to ER-L) by one to three fold. The location of HMI-New suggests that it is impacted by PAHs transported from Baltimore Harbor.

To investigate whether any relationship exists between the levels of organic contaminants in surficial sediment and *Rangia* at HMI, we plotted concentrations of individual PAHs in sediments (normalized to carbon) against their corresponding concentrations in *Rangia* (normalized to lipid) in Figure 4-9. Virtually all of the points fall below the 1:1 line, indicating that the organisms contain lower concentrations of PAHs than predicted by equilibrium partitioning (Di Toro et al. 1991). The large error bars reflect the fact that total concentrations in sediments have been measured and this is not a strong indication of actual bioavailability which depends on the source and nature of the phase containing the organic contaminant. Thus, possible mechanisms for these relatively depleted PAH concentrations in biota include reduced bioavailability of sedimentary PAHs, rapid growth of the biota resulting in dilution of PAHs by freshly formed tissue, and the lack of equilibrium of these relatively young animals with their surroundings. In any case, concentrations of organic contaminants in biota around HMI are low

and less than predicted in the equilibrium partitioning model. Calculated PAH biota-sediment accumulation factors average less than one across HMI, and are less than 0.2 for higher molecular weight analytes such as benzo[*a*]pyrene (Figure 4-9).

Overall, for both the metal and the organic data there is little significant difference between sites for sediment concentrations and biota concentrations. While the differences given might appear substantial - for example, the near order of magnitude difference in PAH concentrations between sites (*Year 15 Data Report*) - the differences are likely due to changes in the sediment characteristics. The analyses by Jim Hill (see, for example, HMI Year 13 Report), wherein metal concentrations are linked to sediment characteristics, is likely to have bearing on the organic contaminant distribution as well. The amount of organic matter in the sediment controls to some degree the organic concentration and the organic content is a function of grain size and sediment type. However, the differences in behavior between organic contaminants and metals is such that it is possible to find metals in locations where organic contaminants are low and *vice versa*. Clearly, the differences in concentrations between sites reflect both the differences in the factors controlling sediment concentration (e.g. organic content) and the differences in sources. It has been suggested that HMI is likely not the only potential source of metals and organic contaminants to this region. To gather data sufficient to account for the inter-station differences is beyond the scope of this and the previous studies. Clearly while differences of an order of magnitude likely reflect important source signatures, differences of less than a factor of 5 do not. Thus, while differences between stations might appear significant, we conclude that the overall data set does not show clear evidence of elevated concentrations of metals and organic contaminants in the sediments around HMI when compared to regional concentration in this part of Chesapeake Bay. This conclusion appears to contradict the conclusions of Project II that there are areas of zinc enrichment around HMI. The reason for these different interpretations is due to some degree to differences in sampling locations. A 160% enrichment is equivalent to the measured value being about 2.5 times greater than the predicted value - based on the formula presented in Project II. That such a site can be considered enriched must be based on a long-term dataset, not one year of measurement. Thus, the conclusions reached by the two groups are a function of the differences in perspective and are not contradictory.

CONCLUSIONS AND RECOMMENDATIONS

1. Concentrations of trace metals and organic contaminants in surficial sediments around HMI are generally low, and are consistent with typical sediments in the northern Chesapeake Bay.

2. Concentrations of trace metals and organic contaminants in surficial sediments around HMI are much less than those in nearby Back River and Baltimore Harbor. Large gradients down the Back River suggest the possibility of the river transporting contaminants to HMI. Whether transport from the Baltimore Harbor region also contributes to the contaminant levels observed around HMI is unclear, although the relatively elevated levels of PAHs at the HMI-New site are suggestive.

3. Concentrations of trace metal and organic contaminants in surficial sediment and in biota sampled around HMI are low relative to published sediment and biota guidelines.

4. The comparison of current and historical data, although limited, suggests that there has been no significant increase in metal concentrations in biota over the time span of operations.

While the measurements contained in the Year 15 Report are not indicative of significant input and might be construed to suggest that continued sampling is not necessary, this is not recommended. The following are the recommendations for future work:

1. Study in detail the likelihood of the Back River as a source of contaminants to HMI.

2. Continue to collect sediment and biota samples as measurements of loadings in organisms and to provide insight not apparent from sediment analysis alone.

3. Re-investigate seasonal patterns by sampling at other times of the year besides mid-summer, such as at the startup and/or abatement of discharge.

4. It is recommended that, because of the physiology and feeding strategy of *Rangia* (suspension feeder), it is not the most suitable monitoring species. A deposit feeding benthic invertebrate, such as a polychaete worm or an amphipod, is recommended as the monitoring organism.

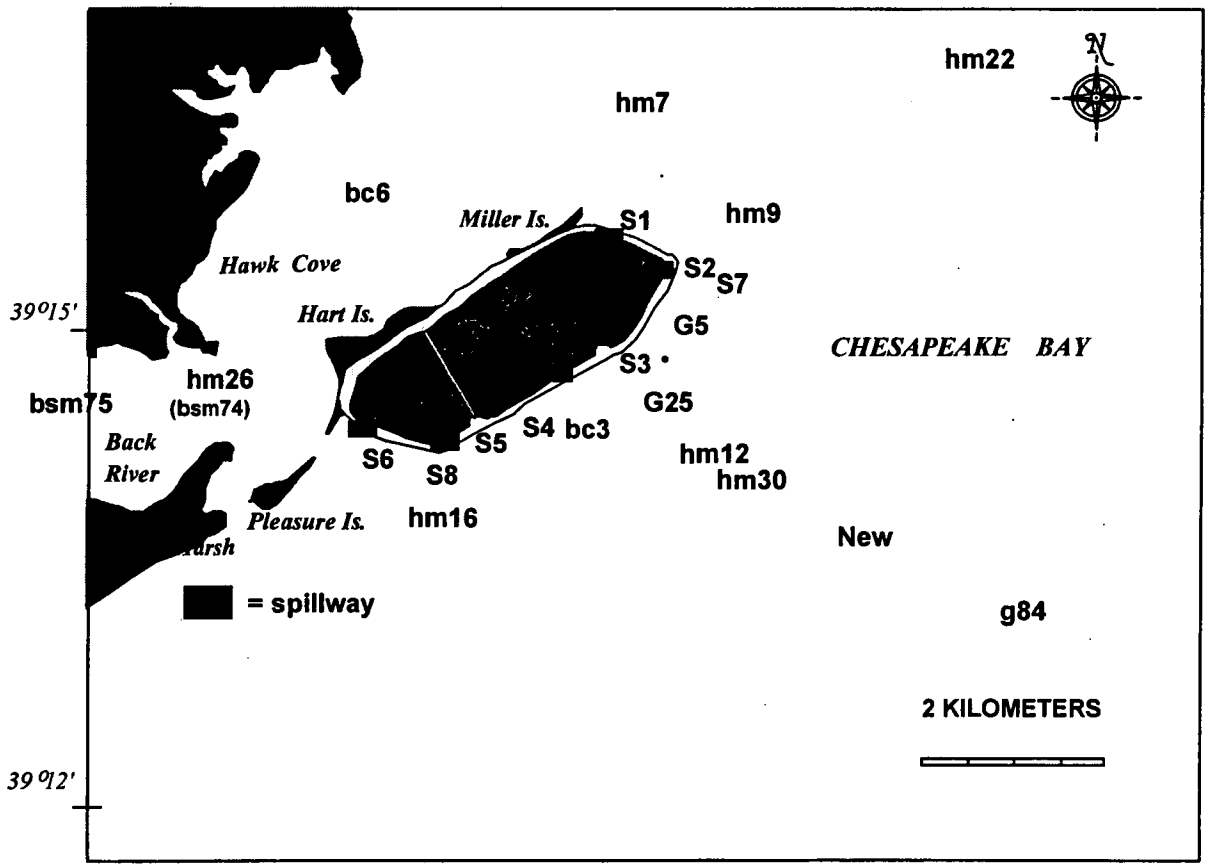


Figure 4-1: Tissue sampling stations at HMI for Year 15.

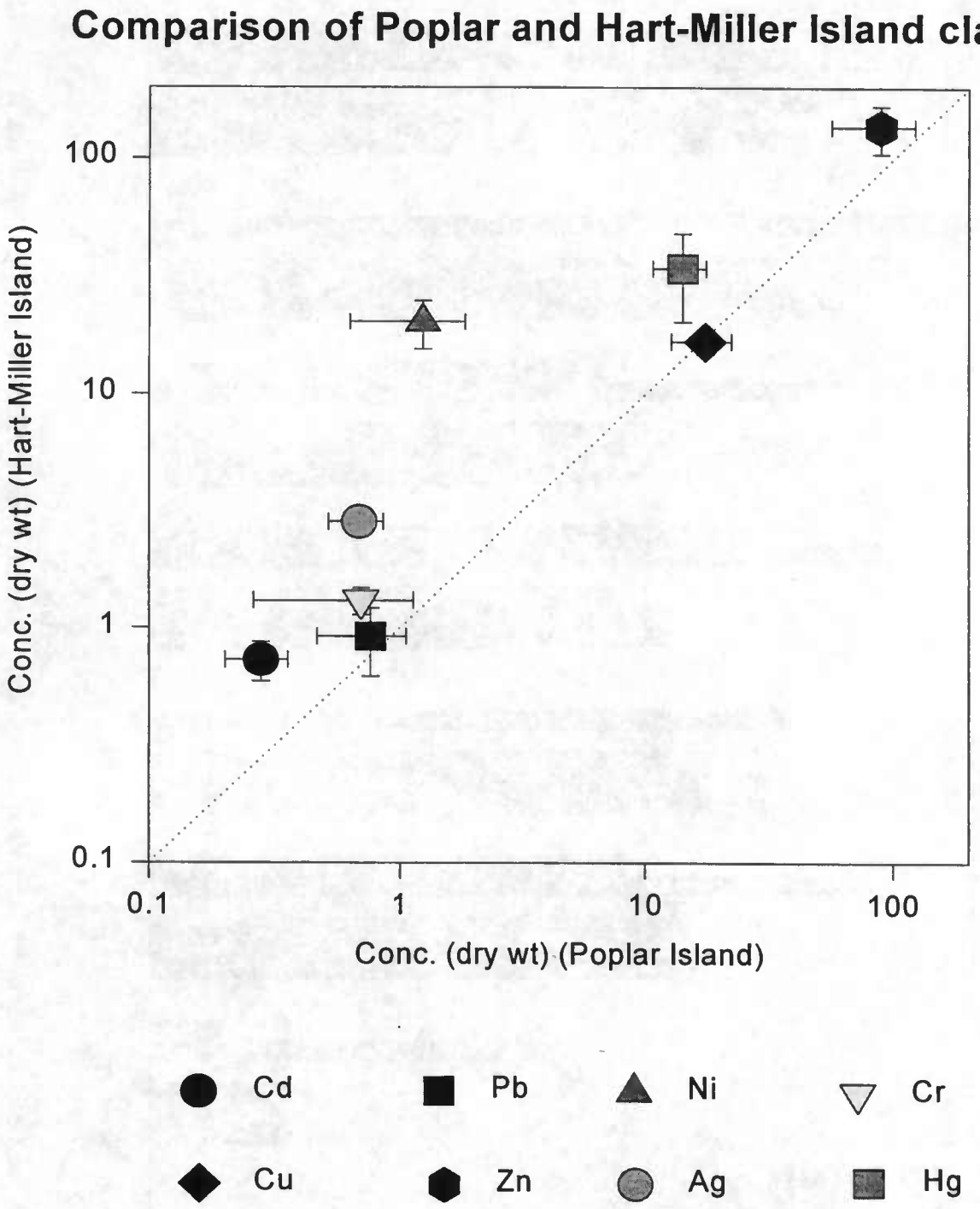


Figure 4-2: PCB concentrations in clams from HMI compared to Poplar Island.

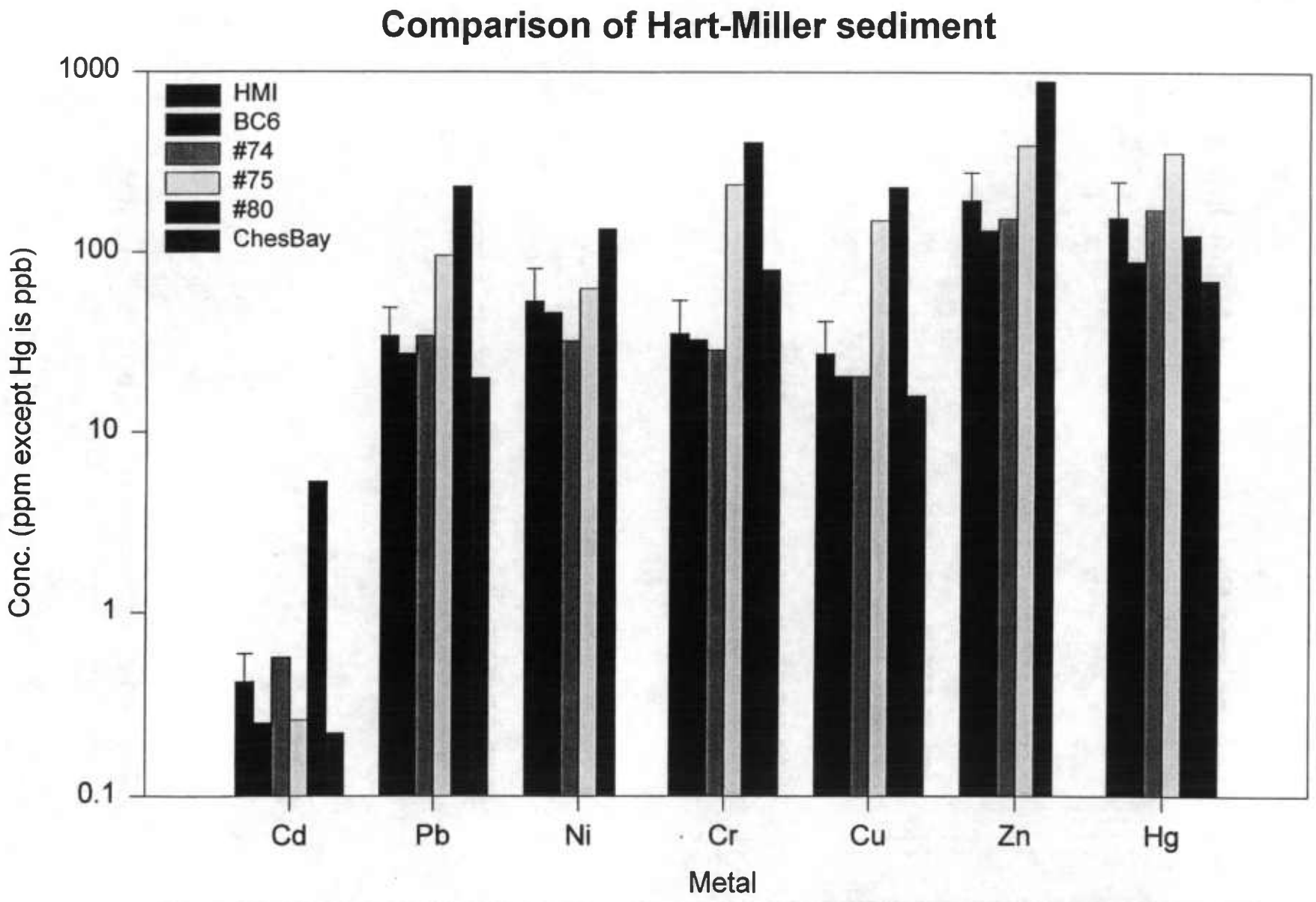


Figure 4-3: Comparison of sediment contaminant concentrations at HMI with those from Back River and Bay-wide averages.

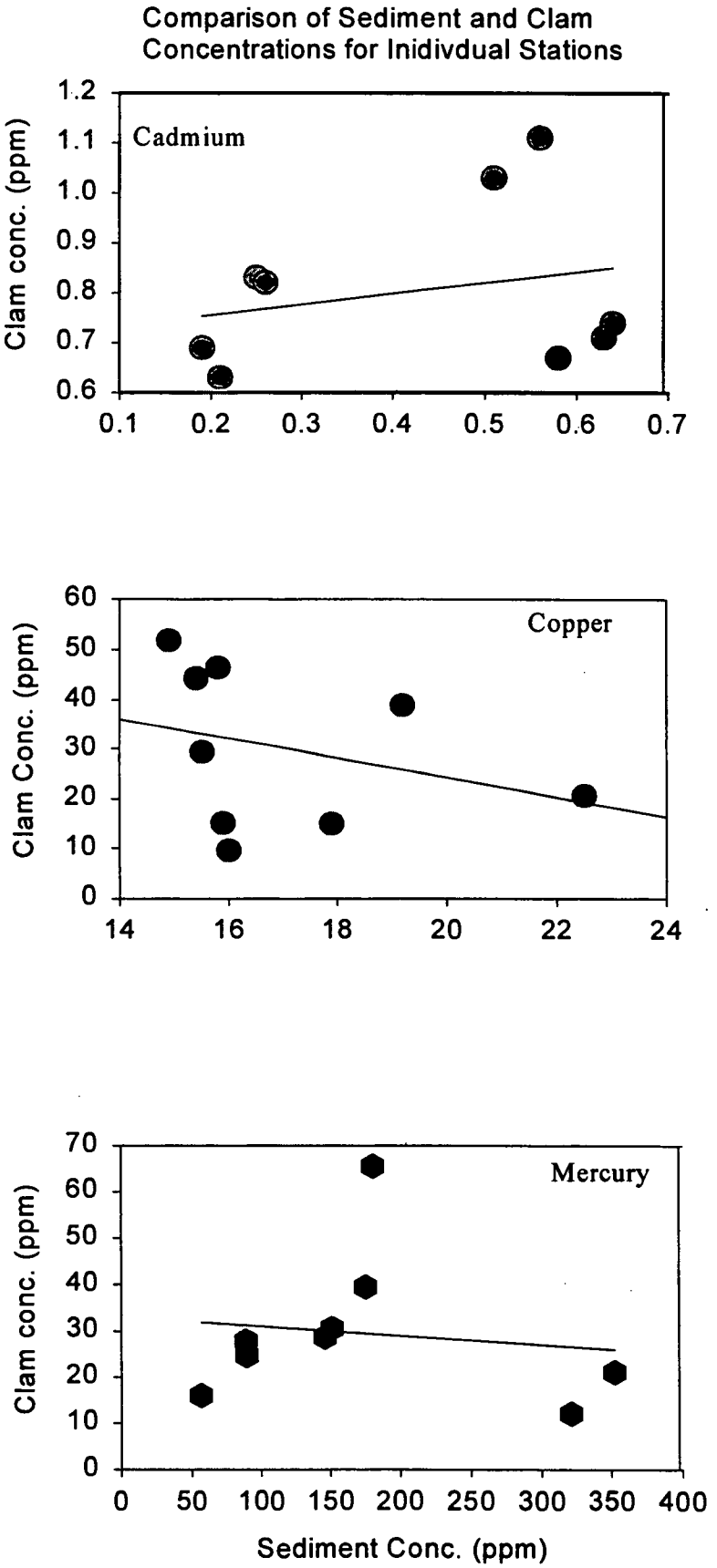


Figure 4-4: Biota versus sediment concentrations at HMI.

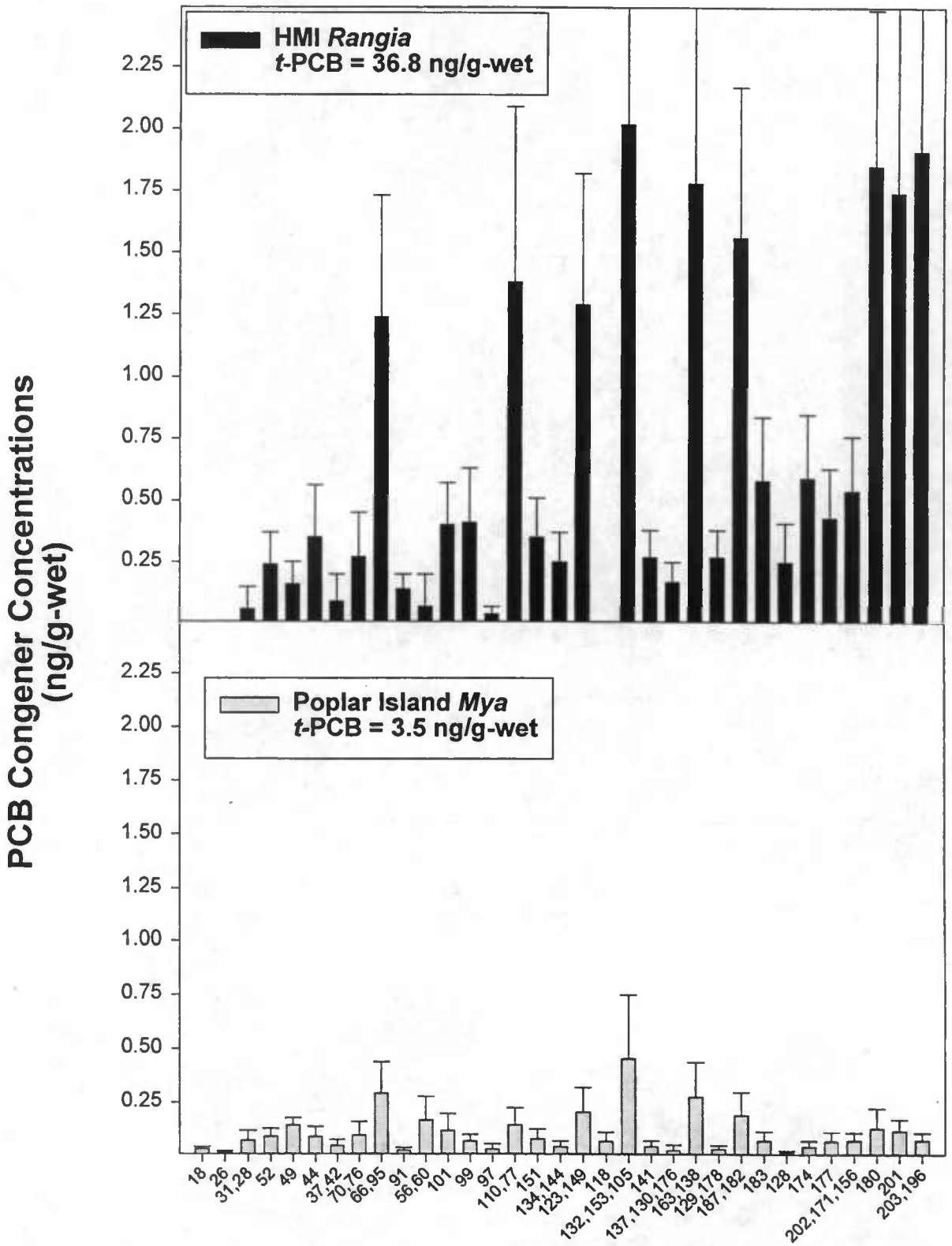
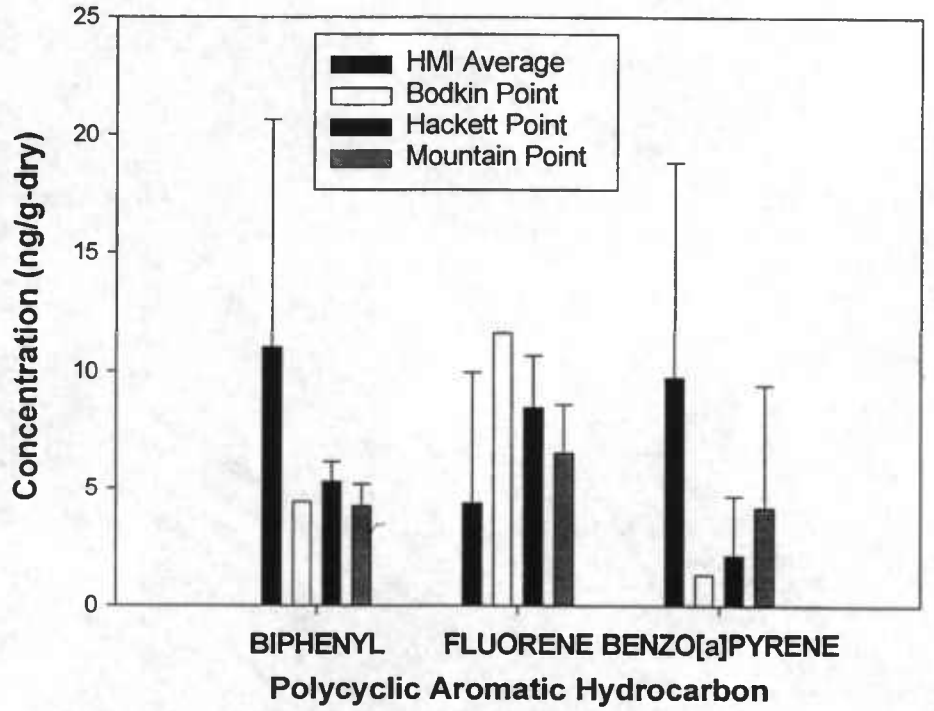


Figure 4-5: Organic contaminant concentrations in HMI *Rangia* compared to *Mya* from Poplar Island.



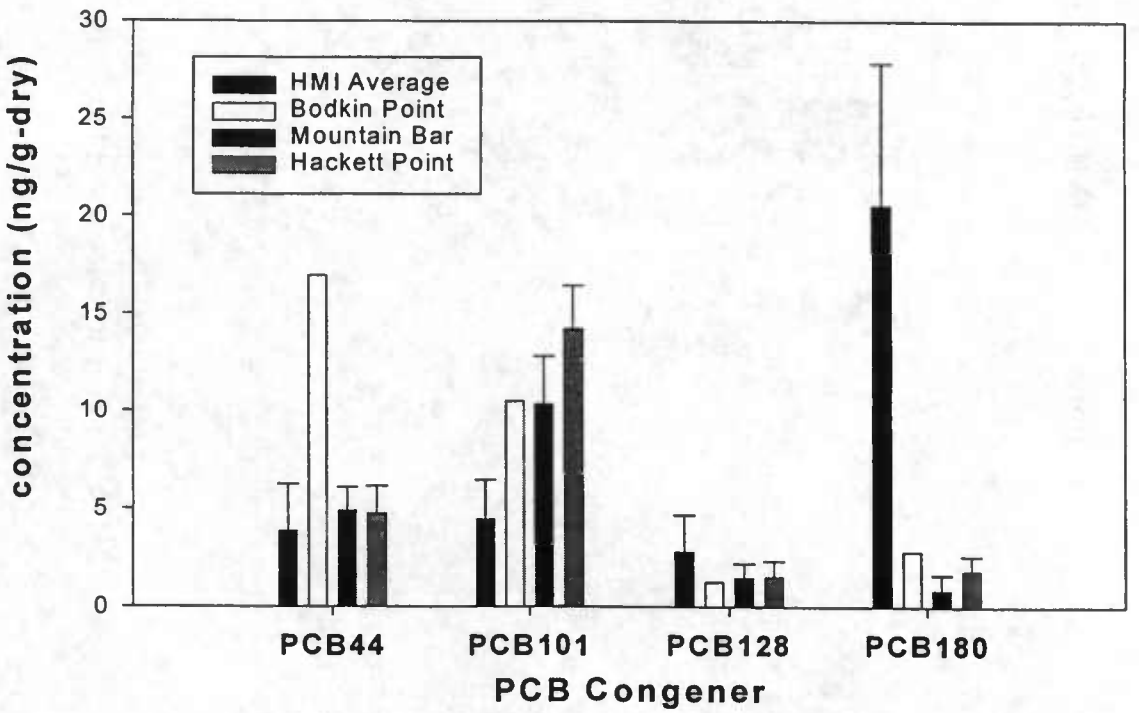


Figure 4-6: PAH and PCB concentrations in HMI *Rangia* compared to *Crassostrea viriginca* from the NOAA status and trends program.

Comparison of HMI [PAH] and Patterns to Back River Sediments

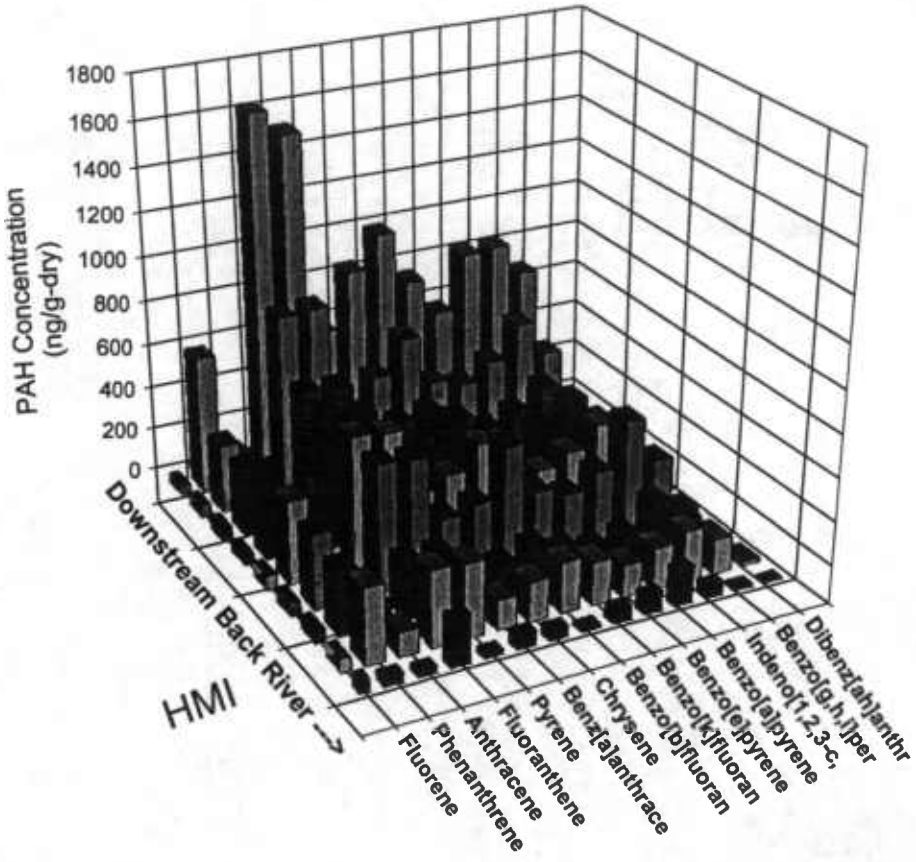


Figure 4-7: Comparison of PAH concentrations on a transect leading down Back River with values found at HMI.

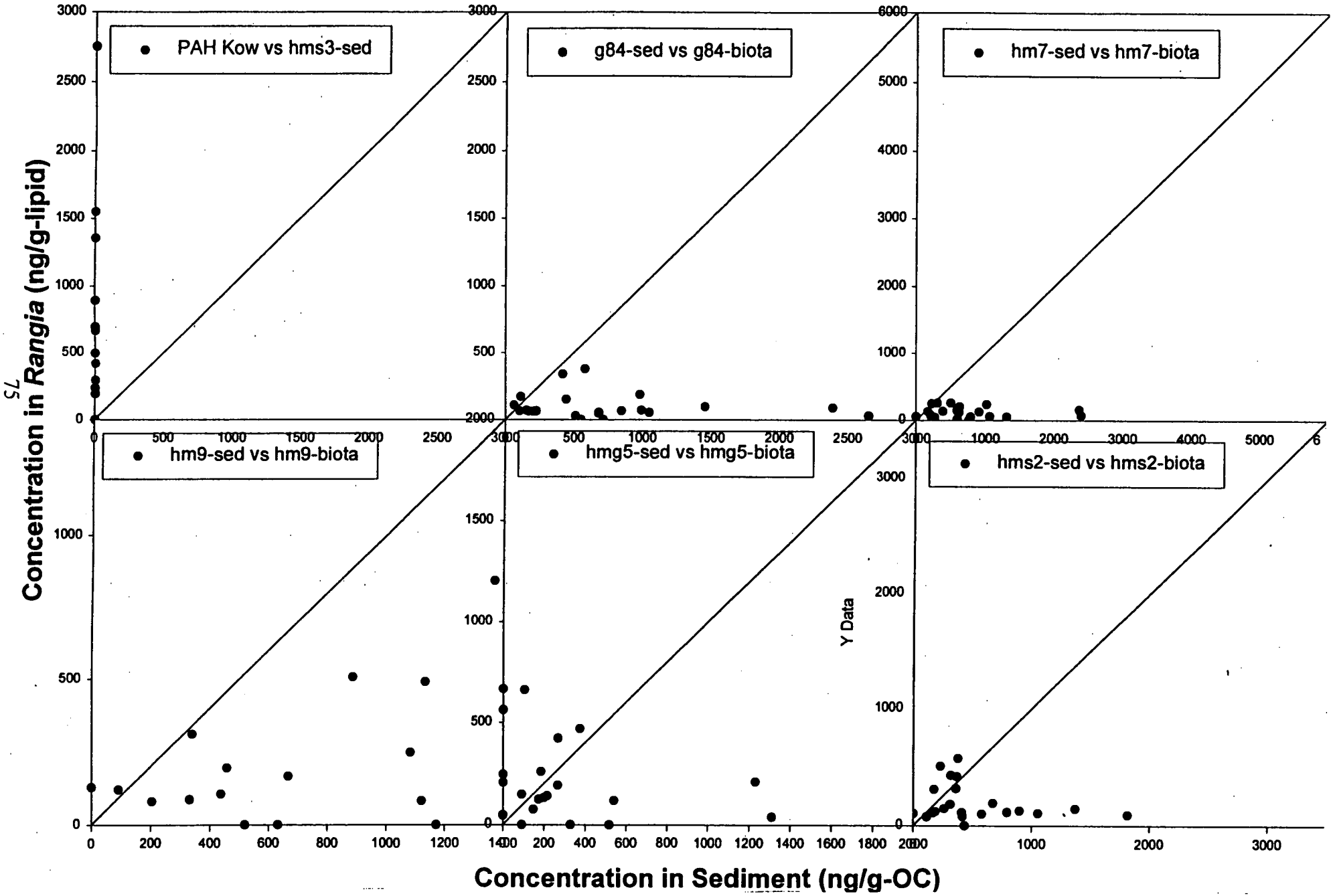


Figure 4-8: Comparison of contaminant levels in sediments with those in clams at the same sites.

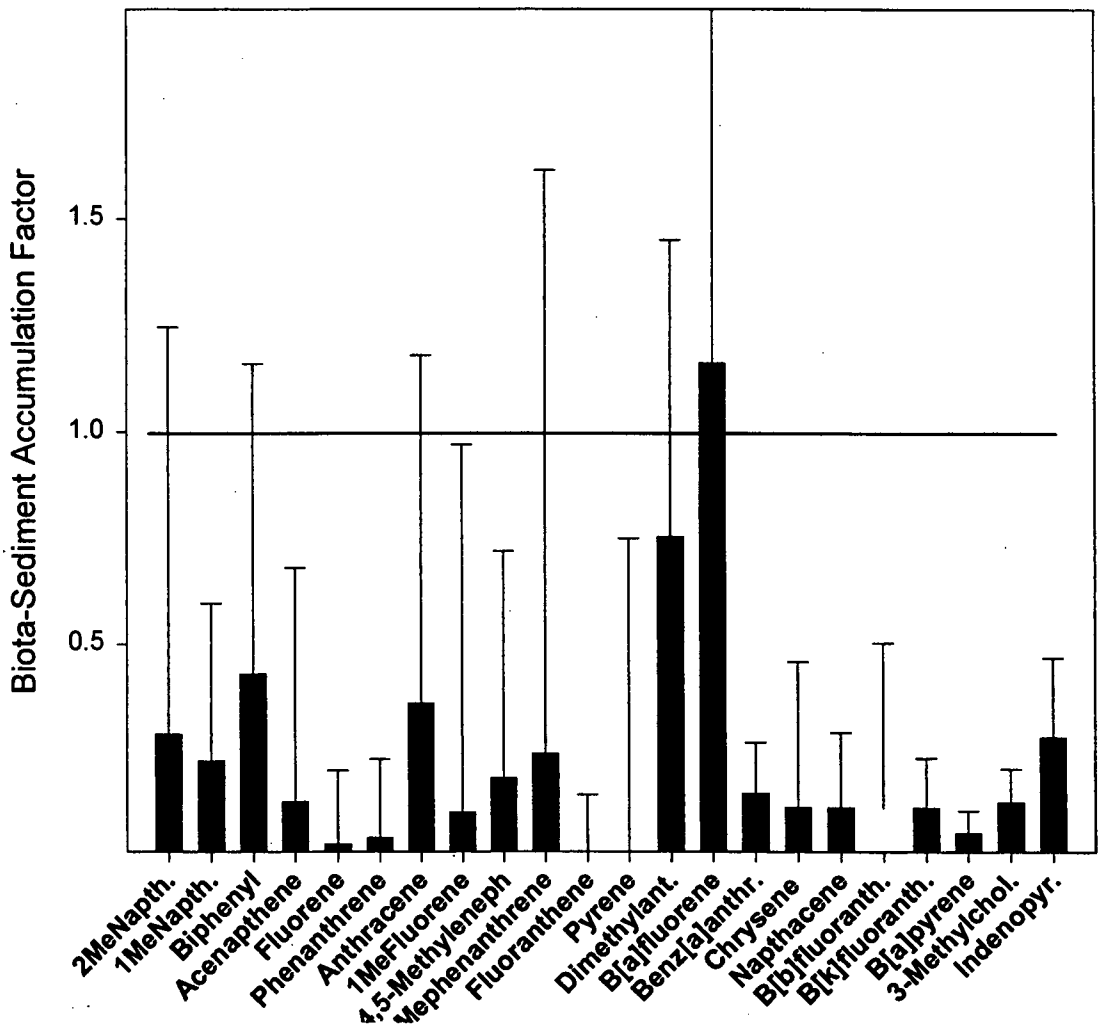


Figure 4-9: PAH bioconcentration factors for HMI *Rangia*. Sediments are normalized to organic carbon and clams are normalized to lipid.

Table 4-1: Hart-Miller Island Sediment- Total Metal Concentrations - Summer 1996

All concentrations reported in ug/g dry weight, except Hg is in ng/g.

Sample #	Site	Cd conc	Pb conc	Ni conc	Cr conc	Cu conc	Zn conc	Ag conc	As conc	Hg conc
1	Site 30	0.635	46.71	80.2	53.32	46.39	288.03	0.751	25.90	151.20
2	New	0.356	36.35	74.28	40.27	16.32	219.82	0.505	17.52	141.29
3	BC 6	0.249	27.45	46.55	32.87	20.63	133.01	0.359	5.63	89.13
4	BC 6 field dup.	0.548	58.54	88.05	68.5	35.26	298.88	0.795	14.51	65.96
5	HM 7	0.559	47.35	67.68	60.71	38.99	257.42	0.624	20.28	180.82
6	HM 22	0.512	46.4	97.67	55.22	44.26	261.66	0.648	21.95	175.65
7	HM 9	0.19	13.77	23.65	15.35	9.6	107.17	0.221	4.63	89.69
8	HM 9 lab dup.	0.18	15.04	23.75	17.7	14.14	90.92	0.221	4.99	91.66
9	HM 26	0.566	34.69	32.38	29.02	20.52	154.76	0.639	7.07	173.80
10	G 84	0.578	43.91	58.25	24.59	51.82	266.98	0.854	21.04	352.29
11	G 84 lab dup.	0.634	45.44	63.51	36.45	29.5	263.21	0.876	19.00	321.18
12	S 2	0.255	18.59	24.63	16.09	15.09	112.63	0.248	5.37	57.05
13	S 3	0.205	16.3	19.15	13.99	14.89	86.47	0.21	5.16	146.15
14	Blank	0.001	0.028	0.07	0.14	0.98	3.4	0.005	0.00	
15	SRM 1646a	0.104	7.19	17.3	36.46	11.08	37.6	0.048	7.08	25.30
	NIST value	**.148±.007**	**11.7±1.2**	**23**	**40.9±1.9**	**10.01±.34**	**48.9±1.6**	**None**	**6.23±0.21**	**40***

* not certified

Table 4-2: Concentrations of metals in clams collected in 1990/91, 1993/94 and in 1996 and comparison with baywide average oyster tissue data. Comparison is made on a dry weight basis.

Metal (μg/g dry wt.)	1996	1993/94 *	1990/91 *	Oyster Baywide av. (1990)**
Cd	0.5-1.1	1.5-3.4		0.2-1.6
Pb	0.38-1.6			
Ni	15.1-30.1	28-63	24-120	
Cr	1.0-1.7	2.4-62	<8	
Cu	14.3-22.5	15-22	14-31	
Zn	103-195	162-322	176-264	300-700
Ag	0.32-6.3			
As	0.50-2.1	7.8-63		0.6-1.4
Hg	0.012-0.066			

Notes: * Data were converted from a wet weight basis to a dry weight basis by assuming a wet/dry ratio of 8. Data for 1993/94 from the year 13 Report. 1990/91 data are from the 10th Year Report. All data are for *Rangia*.
** Data from the Chesapeake Bay Toxics Reduction Re-evaluation Report. Data are for oysters only.

Table 4-3: Summary Table of the Concentration of Organic Contaminants in Sediment and Biota. Shown are the Concentrations of Total PAHs and Total PCBs for Each Station. Biota concentrations are in ng/g wet weight; sediment concentrations are in ng/g dry weight.

Site	Total PAHs Sediment	Total PCBs Sediment	Total PAHs Biota	Total PCBs Biota
BC6	2539; 2677	48.1; 56.7	82.3	36.0
G25	2091	67.5	23.4	-
G84	2704	51.1	38.3	29.9
HM7	3127	88.8	46.4	21.9
HM9	3780	142.9	50.9	53.6
HM12	3920	61.5	59.2	38.5
HM16	3067	49.0	13.9	63.5
HM22	2413	38.2	0	51.8
HM30	1694	70.5	38.5	49.2
G5	2035	15.0	88.9	19.8
S2	1008	31.2	63.4	21.6
S3	1269	19.4	37.2	30.8
S6	2161	46.1	11.6	22.5
New	4529	75.9	-	-
BC3	805	13.9	-	-
HM26	1694	71.0	-	-

GLOSSARY

Accuracy: The ability to obtain a true value; determined by the degree of agreement between an observed value and an accepted reference value.

Acid volatile sulfide (AVS): The sulfides removed from sediment by cold acid extraction, consisting mainly of H2S and FeS. AVS is a possible predictive tool for divalent metal sediment toxicity.

Acute: Having a sudden onset, lasting a short time.

Acute toxicity: Short-term toxicity to organism(s) that have been affected by the properties of a substance, such as contaminated sediment. The acute toxicity of a sediment is generally determined by quantifying the mortality of appropriately sensitive organisms that are put into contact with the sediment, under either field or laboratory conditions, for a specified period.

Adjacent: Bordering, contiguous or neighboring. Wetlands separated from other waters of the United States by man-made dikes or barriers, natural river berms, beach dunes and the like are "adjacent wetlands".

Amphipod: A large group usually - an order of crustaceans - comprising the beach fleas and related forms - being mainly of small size with laterally compressed body, four anterior pairs of thoracic limbs directed forward - and three posterior pairs directed backward - and upward - the thoracic limbs bearing gills-aquatic in fresh or salt water.

Application factor (AF): A numerical, unitless value, calculated as the threshold chronically toxic concentration of a test substance divided by its acutely toxic concentration. The AF is usually reported as a range and is multiplied by the median lethal concentration as determined in a short-term (acute) toxicity test to estimate an expected no- effect concentration under chronic exposure.

Benchmark organism: Test organism designated by USACE and EPA as appropriately sensitive and useful for determining biological data applicable to the real world. Test protocols with such organisms are published, reproducible and standardized.

Bioaccumulation: The accumulation of contaminants in the tissue of organisms through any route, including respiration, ingestion, or direct contact with contaminated water, sediment, pore water or dredged material. [The regulations require that bioaccumulation be considered as part of the environmental evaluation of dredged material proposed for disposal. This consideration involves predicting whether there will be a cause-and-effect relationship between an organism's presence in the area influenced by the dredged material and an environmentally important elevation of its tissue content or body burden of contaminants above that in similar animals not influenced by the disposal of the dredged material].

Bioaccumulation factor: The degree to which an organism accumulates a chemical compared to the source. It is a dimensionless number or factor derived by dividing the concentration in the organism by that in the source.

Bioassay: A bioassay is a test using a biological system. It involves exposing an organism to a test material and determining a response. There are two major types of bioassays differentiated by response: toxicity tests which measure an effect (e.g., acute toxicity, sublethal/chronic toxicity) and bioaccumulation tests which measure a phenomenon (e.g., the uptake of contaminants into tissues).

Bioavailable: Can affect organisms.

Bioconcentration: Uptake of a substance from water.

Biomagnification: Bioaccumulation up the food chain, e.g., the route of accumulation is solely through food. Organisms at higher trophic levels will have higher body burdens than those at lower trophic levels.

Biota sediment accumulation factor: Relative concentration of a substance in the tissues of an organism compared to the concentration of the same substance in the sediment.

Bryozoan: A small phylum of aquatic animals that reproduce by budding - that usually form branching, flat or mosslike colonies -permanently attached on stones or seaweed and enclosed by an external cuticle soft and gelatinous or rigid and chitinous or calcareous - that consist of complex zooids (polyps) each having alimentary canal with separate mouth and anus.

Bulk sediment chemistry: Results of chemical analyses of whole sediments (in terms of wet or dry weight), without normalization (e.g., to organic carbon, grain-size, acid volatile sulfide).

Chronic: Involving a stimulus that is lingering or which continues for a long time.

Chronic toxicity: See sublethal/chronic toxicity.

Comparability: The confidence with which one data set can be compared to others and the expression of results consistent with other organizations reporting similar data. Comparability of procedures also implies using methodologies that produce results comparable in terms of precision and bias.

Completeness: A measure of the amount of valid data obtained versus the amount of data originally intended to be collected.

Confined disposal: A disposal method that isolates the dredged material from the environment. Confined disposal is placement of dredged material within diked confined disposal facilities via pipeline or other means.

Confined disposal facility (CDF): A diked area, either in-water or upland, used to contain dredged material. The terms confined disposal facility (CDF), dredged material containment area, diked disposal facility, and confined disposal area are used interchangeably.

Constituents: Chemical substances, solids, liquids, organic matter, and organisms associated with or contained in or on dredged material.

Contaminant: A chemical or biological substance in a form that can be incorporated into, onto or be ingested by and that harms aquatic organisms, consumers of aquatic organisms, or users of the aquatic environment, and includes but is not limited to the substances on the 307(a)(1) list of toxic pollutants promulgated on January 31, 1978 (43 FR 4109). [Note: A contaminant that causes actual harm is technically referred to as a pollutant, but the regulatory definition of a "pollutant" in the Guidelines is different, reflecting the intent of the CWA.]

Contaminant of concern: A contaminant present in a given sediment thought to have the potential for unacceptable adverse environmental impact due to a proposed discharge.

Control sediment: A sediment essentially free of contaminants and which is used routinely to assess the acceptability of a test. Control sediment may be the sediment from which the test organisms are collected or a laboratory sediment, provided the organisms meet control standards. Test procedures are conducted with the control sediment in the same way as the reference sediment and dredged material. The purpose of the control sediment is to confirm the biological acceptability of the test conditions and to help verify the health of the organisms during the test. Excessive mortality in the control sediment indicates a problem with the test conditions or organisms, and can invalidate the results of the corresponding dredged material test.

Data quality indicators: Quantitative statistics and qualitative descriptors which are used to interpret the degree of acceptability or utility of data to the user; include bias (systematic error), precision, accuracy, comparability, completeness, representativeness, detectability and statistical confidence.

Data quality objectives (DQOs): Qualitative and quantitative statements of the overall uncertainty that a decision maker is willing to accept in results or decisions derived from environmental data. DQOs provide the framework for planning environmental data operations consistent with the data user's needs.

Dendrogram: A branching diagrammatic representation of the interrelations of a group of items sharing some common factors (as of natural groups connected by ancestral forms).

Discharge of dredged material: Any addition of dredged material into waters of the United States. [Dredged material discharges include: open water discharges; discharges resulting from unconfined disposal operations (such as beach nourishment or other beneficial uses); discharges from confined disposal facilities which enter waters of the United States (such as effluent, surface runoff, or leachate); and, overflow from dredge hoppers, scows, or other transport vessels]. Material resuspended during normal dredging operations is considered "de minimus" and is not regulated under Section 404 as a dredged material discharge. See 33 CFR 323.2 for a detailed definition. The potential impact of resuspension due to dredging can be addressed under NEPA.

Disposal site: That portion of the "waters of the United States" where specific disposal activities are permitted and consist of a bottom surface area and any overlying volume of water. In the case of wetlands on which surface water is not present, the disposal site consists of the wetland surface area. [Note: upland locations, although not mentioned in this definition in the Regulations, can also be disposal sites].

District: A USACE administrative area.

Dredged material: Material that is excavated or dredged from waters of the United States.

EC50: The median effective concentration. The concentration of a substance that causes a specified effect (generally sublethal rather than acutely lethal) in 50% of the organisms tested in a laboratory toxicity test of specified duration.

Elutriate: Material prepared from the sediment dilution water and used for chemical analyses and toxicity testing. Different types of elutriates are prepared for two different procedures as noted in this manual.

Evaluation: The process of judging data in order to reach a decision.

Factual determination: A determination in writing of the potential short-term or long-term effects of a proposed discharge of dredged or fill material on the physical, chemical and biological components of the aquatic environment in light of Subparts C-F of the Guidelines.

Federal Standard: The dredged material disposal alternative(s) identified by the U.S. Army Corps of Engineers that represent the least costly, environmentally acceptable alternative(s) consistent with sound engineering practices and which meet the environmental standards established by the 404(b)(1) evaluation process. [See Engler et al. (1988) and 33 CFR 335-338].

Fill material: Any material used for the primary purpose of replacing an aquatic area with dry land or changing the bottom elevation of a water body for any purpose. The term does not include any pollutant discharged into the water primarily to dispose of waste, as that activity is regulated under Section 402 of the Clean Water Act. [Note: dredged material can be used as fill material].

Grain-size effects: Mortality or other effects in laboratory toxicity tests due to sediment granulometry, not chemical toxicity. [It is clearly best to use test organisms which are not likely to react to grain-size but, if this is not reasonably possible, then testing must account for any grain-size effects.]

Guidelines: Substantive environmental criteria by which proposed discharges of dredged material are evaluated. CWA Section 404(b)(1) final rule (40 CFR 230) promulgated December 24, 1980.

Hydroid: An order of Hydrozoan coelenterates - comprising forms that alternate a well developed asexual polyp generation with a generation of free medusa or of an abortive medusoid reproductive structure on the polyps - resembling a polyp.

LC50: The median lethal concentration. The concentration of a substance that kills 50% of the organisms tested in a laboratory toxicity test of specified duration.

Leachate: Water or any other liquid that may contain dissolved (leached) soluble materials, such as organic salts and mineral salts, derived from a solid material.

Lethal: Causing death.

Loading density: The ratio of organism biomass or numbers to the volume of test solution in an exposure chamber.

Management actions: Those actions considered necessary to rapidly render harmless the material proposed for discharge (e.g., non-toxic, non-bioaccumulative) and which may include containment in or out of the waters of the U.S. (see 40 CFR Subpart H). Management actions are employed to reduce adverse impacts of proposed discharges of dredged material.

Management unit: A manageable, dredgeable unit of sediment which can be differentiated by sampling and which can be separately dredged and disposed within a larger dredging area. Management units are not differentiated solely on physical or other measures or tests but are also based on site- and project-specific considerations.

Method detection limit (MDL): The minimum concentration of a substance which can be identified, measured, and reported with 99% confidence that the analyte concentration is greater than zero.

Mixing zone: A limited volume of water serving as a zone of initial dilution in the immediate vicinity of a discharge point where receiving water quality may not meet quality standards or other requirements otherwise applicable to the receiving water. [The mixing zone may be defined by the volume and/or the surface area of the disposal site or specific mixing zone definitions in State water quality standards].

Open water disposal: Placement of dredged material in rivers, lakes or estuaries via pipeline or surface release from hopper dredges or barges.

Pathway: In the case of bioavailable contaminants, the route of exposure (e.g., water, food).

Pollution: The man-made or man-induced alteration of the chemical, physical, biological or radiological integrity of an aquatic ecosystem. [See definition of contaminant].

Practicable: Available and capable of being done after taking into consideration cost, existing technology, and logistics in light of overall project purposes.

Practical quantitation limit (PQL): The lowest concentration that can be reliably quantified with specified limits of precision and accuracy during routine laboratory operating conditions.

Precision: The ability to replicate a value; the degree to which observations or measurements of the same property, usually obtained under similar conditions, conform to themselves. Usually expressed as standard deviation, variance or range.

QA: Quality assurance, the total integrated program for assuring the reliability of data. A system for integrating the quality planning, quality control, quality assessment, and quality improvement efforts to meet user requirements and defined standards of quality with a stated level of confidence.

QC: Quality control, the overall system of technical activities for obtaining prescribed standards of performance in the monitoring and measurement process to meet user requirements.

Reason to believe: Subpart G of the 404(b) (1) guidelines requires the use of available information to make a preliminary determination concerning the need for testing of the material proposed for dredging. This principle is commonly known as "reason to believe", and is contained in Tier I of the tiered testing framework. The decision to not perform additional testing based on prior information must be documented, in order to provide a "reasonable assurance that the proposed discharge material is not a carrier of contaminants" (230.60(b)).

Reference sediment: Point of comparison for evaluating test sediment. Testing requirements in the Section 404(b)(1) Guidelines regarding the point of comparison for evaluating proposed discharges of dredged material are being updated to provide for comparison to a "reference sediment" as opposed to sediment from the disposal site. Because subsequent discharges at a disposal site could adversely impact the point of comparison, adoption of a reference sediment that is unimpacted by previous discharges of dredged material will result in a more scientifically sound evaluation of potential individual and cumulative contaminant-related impacts. This change to the Guidelines was proposed in the Federal Register in January 1995, public comments have been received, and a final rule Notice is being prepared. It is expected that the final rule will be published prior to July 1, 1998, and as a result the reference sediment approach will be implemented in the ITM.

Reference site: The location from which reference sediment is obtained.

Region: An EPA administrative area.

region: A geographical area.

Regulations: Procedures and concepts published in the Code of Federal Regulations for evaluating the discharge of dredged material into waters of the United States.

Representativeness: The degree to which sample data depict an existing environmental condition; a measure of the total variability associated with sampling and measuring that includes the two major error components: systematic error (bias) and random error. Sampling representativeness is accomplished through proper selection of sampling locations and sampling techniques, collection of sufficient number of samples, and use of appropriate subsampling and handling techniques.

Sediment: Material, such as sand, silt, or clay, suspended in or settled on the bottom of a water body.

Should: Is used to state that the specified condition is recommended and ought to be met unless there are clear and definite reasons not to do so.

Standard operating procedure (SOP): A written document which details an operation, analysis, or action whose mechanisms are thoroughly prescribed and which is commonly accepted as the method for performing certain routine or repetitive tasks.

Standardized: In the case of methodology, a published procedure which has been peer reviewed (e.g., journal, technical report), and generally accepted by the relevant technical community of experts.

Sublethal: Not directly causing death; producing less obvious effects on behavior, biochemical and/or physiological function, histology of organisms.

Sublethal/chronic toxicity: Biological tests which use such factors as abnormal development, growth and reproduction, rather than solely lethality, as end-points. These tests involve all or at least an important, sensitive portion of an organism's life-history. A sublethal endpoint may result either from short-term or long-term (chronic) exposures.

Target detection limit: A performance goal set by consensus between the lowest, technically feasible, detection limit for routine analytical methods and available regulatory criteria or guidelines for evaluating dredged material. The target detection limit is, therefore, equal to or greater than the lowest amount of a chemical that can be reliably detected based on the variability of the blank response of routine analytical methods. However, the reliability of a chemical measurement generally increases as the concentration increases. Analytical costs may also be lower at higher detection limits. For these reasons, a target detection limit is typically set at not less than 10 times lower than available dredged material guidelines.

Tests/testing: Specific procedures which generate biological, chemical, and/or physical data to be used in evaluations. The data are usually quantitative but may be qualitative (e.g., taste, odor, organism behavior). Testing for discharges of dredged material in waters of the United States is specified at 40 CFR 230.60 and 230.61 and is implemented through the procedures in this manual.

Tiered approach: A structured, hierarchical procedure for determining data needs relative to decision-making, which involves a series of tiers or levels of intensity of investigation. Typically, tiered testing involves decreased uncertainty and increased available information with increasing tiers. This approach is intended to ensure the maintenance and protection of environmental quality, as well as the optimal use of resources. Specifically, least effort is required in situations where clear determinations can be made of whether (or not unacceptable adverse impacts are likely to occur based on available information. Most effort is required where clear determinations cannot be made with available information.

Toxicity: see Acute toxicity; Sublethal/chronic toxicity, Toxicity test.

Toxicity test: A bioassay which measures an effect (e.g., acute toxicity, sublethal/chronic toxicity). Not a bioaccumulation test (see definition of bioassay).

Water Quality Certification: A state certification, pursuant to Section 401 of the Clean Water Act, that the proposed discharge of dredged material will comply with the applicable provisions of Sections 301, 303, 306 and 307 of the Clean Water Act and relevant State laws. Typically this certification is provided by the affected State. In instances where the State lacks jurisdiction (e.g., Tribal Lands), such certification is provided by EPA or the Tribe (with an approved certification program).

Water Quality Standard (Code of Maryland Regulations - COMAR): A law or regulation that consists of the beneficial designated use or uses of a water body, the numeric and narrative water quality criteria that are necessary to protect the use or uses of that particular water body, and an anti- degradation statement.

Waters of the U.S.: In general, all waters landward of the baseline of the territorial sea and the territorial sea. Specifically, all waters defined in Section 230.3 (s) of the Guidelines. [See Appendix A].

Whole sediment: The sediment and interstitial waters of the proposed dredged material or reference sediment that have had minimal manipulation. For purposes of this manual, press-sieving to remove organisms from test sediments, homogenization of test sediments, compositing of sediment samples, and additions of small amounts of water to facilitate homogenizing or compositing sediments may be necessary to conducting bioassay tests. These procedures are considered unlikely to substantially alter chemical or toxicological properties of the respective whole sediments except in the case of AVS (acid volatile sulfide) measurements (EPA, 1991a) which are not presently required. Alternatively, wet sieving, elutriation, or freezing and thawing of sediments may alter chemical and/or toxicological properties, and sediment so processed should not be considered as whole sediment for bioassay purposes.

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