Assessment of Impacts from the Hart-Miller Dredged Material Containment Facility, Maryland.

Year 23 Technical Report (September 2004 – 2005)

Prepared by:

Maryland Department of the Environment

Chesapeake Biological Laboratory · Solomons

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State of Maryland Department of Natural Resources

MDE

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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

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[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.

PROJECT 1: PROJECT MANAGEMENT AND SCIENTIFIC/TECHNICAL COORDINATION

Hart-Miller Island Exterior Monitoring Program

September 2004 - September 2005

Prepared for

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The Year 23 Hart-Miller Island (HMI) Exterior Monitoring Program would not have been successful without the help of several Technical and Regulatory Services Administration (TARSA) staff members, including: Mr. George Harman, Chairman; Mr. Matthew Rowe, Project Manager; Mr. Christopher Luckett, Benthic Ecologist; Miss Caroline Myers, Mr. Sean Sipple, Mr. Nicholas Kaltenbach, and Mr. Jeff Carter, Biologists; and, Mr. Charles Poukish, Division Chief of Ecological Assessments. The dedication and subject matter expertise of these professionals was an invaluable asset in fulfilling this year's monitoring effort.

The team work of Dr. James Hill of the Maryland Geological Survey and Mr. Andrew Heyes of the University of Maryland was essential in assessing any facility impacts to local sediments or biota surrounding the facility. The Maryland Department of the Environment would like to thank the members of the HMI Citizens' Oversight Committee (COC) for their useful comments and suggestions throughout the project year, as well as their long-term commitment to the HMI project. Maryland Environmental Service (MES) provided helpful comments on the exterior monitoring reports and improved overall report presentation and content.

Lastly, thanks are due to Mr. Robin Grove, former Director of TARSA, and Dr. Rich Eskin, TARSA Director, 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 secured Maryland's place as a stronghold for ship-borne commerce. 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. The State of Maryland must provide placement sites for material dredged from these federal maintenance channels. In 1983, 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, northeast of Baltimore Harbor. Construction of HMI began by building a facility connecting the remnants of Hart and Miller Islands and encompassing an open-water area of approximately 1,100 acres. The facility was constructed from sand excavated from the proposed interior of the facility. The eastern or Bay side of the facility was reinforced with filter cloth and rip-rap to protect the facility from wave and storm induced erosion. Completed in 1983, the facility is approximately 29,000 feet long and is divided into North and South Cells by a 4,300 foot interior cross-facility. Placement of dredged material within HMI began with facility completion and continues presently.

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 2309, at which time it will also be converted into a wildlife refuge. The remnants of Hart and Miller Islands, which lie outside of the facility, serve as a state park and receive heavy recreational use throughout the summer months.

Environmental Monitoring

Background

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 local water quality and biota. Results from the monitoring are used to detect changes from baseline environmental conditions (studies

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[2] From page 250 of the 1987 Clean Water Act published by the Water Pollution Control Federation.

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 sampling protocols recommended by the project's technical experts. 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 flexible enough to incorporate such changes as long as they do not undermine the State's ability to assess aquatic impacts.

Experimental Design

The HMI Exterior Monitoring is currently modeled after the Sediment Quality Triad developed in the mid-1980s (Long and Chapman, 1985). This approach consists of three separate components: sediment chemistry, sediment toxicity, and benthic community composition. The sediment chemistry project (Project 2) assesses contamination by evaluating metals concentrations in exterior sediments[2]. The sediment toxicity project (Project 4) looks at benthic tissue concentrations for both metals and organics in the brackish-water clam, *Rangia cuneata*. Project 3, benthic community studies, examines the structure of the macroinvertebrate assemblage surrounding HMI. Whereas sediment contamination thresholds, benthic toxicity benchmarks, and benthic macroinvertebrate indices alone require caution in their application and interpretation, combining them into a triad approach provides a greater level of confidence when assessing ecological impacts. Table 1 below illustrates this concept.

Table 1: Information Provided by Differential Triad Responses (taken from Chapman, 1990).

Situation	Contamination	Toxicity	Alteration	Possible Conclusions
1.	+	+	+	Strong evidence for pollution-induced degradation
2.	-	-	-	Strong evidence that there is no pollution induced contamination
3.	+	-	-	Contaminants are not bioavailable
4.	-	+	-	Unmeasured chemicals or conditions exist with the potential to cause degradation
5.	-	-	+	Alteration is not due to toxic chemicals
6.	+	+	-	Toxic chemicals are stressing the

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[2] Project 4 also does some sediment chemistry work for ancillary metals not monitored in Project 2.

Situation	Contamination	Toxicity	Alteration	Possible Conclusions
				system
7.	-	+	+	Unmeasured toxic chemicals are causing degradation
8.	+	-	+	Chemicals are not bioavailable or alteration is not due to toxic chemicals

Responses are shown as either positive (+) or negative (-), indicating whether or not measurable (e.g., statistically significant) differences from control/reference conditions are determined.

Situation number one in the above table demonstrates a clear impact as a result of statistically significant differences from reference conditions in all three components (contamination, toxicity and alteration of the benthic community). Situation number two is negative for all components and suggests no aquatic impacts. Situation numbers 6, 7 and 8 indicate some level of degradation and the need for continued monitoring. Situations 3, 4 and 5 have only a single line of evidence pointing to a potential problem and are likely the lowest priority for follow-up monitoring or remedial action.

The strength of the triad approach is that it uses a weight-of-evidence approach to determine overall environmental impact. Each component is an individual line of evidence that, when coupled with the others, forms a convincing argument for or against pollution induced degradation. The Triad is a particularly useful tool for identifying sediment “hot-spots” and prioritizing remedial actions.

PROJECT SUMMARIES

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

In July 1995, responsibility for Project I was transferred to the Maryland Department of the Environment (MDE) from the Maryland Department of Natural Resources (DNR). As the permitting authority, MDE reviews the overall exterior monitoring program to make sure it meets the general and special conditions of the state’s wetlands license. 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 Principal Investigators (PIs) for each project. MDE recommends changes to the monitoring that will improve the State’s ability to accurately assess the condition of waters surrounding the HMI facility. The Department also coordinates all field sampling among PIs for each project to ensure efficient, timely and representative sample collection.

Project I includes data management and providing HMI data to the public through several media, including written reports and the Internet. HMI monitoring data is now publicly available on the Environmental Protection Agency's STORET Web site (www.epa.gov/storet). Oversight of project budgets, invoicing and deliverable submittal is also a major component of Project I. This includes review of quarterly project status reports to ensure that project goals are met in a timely fashion and within budget.

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

The Coastal and Estuarine Geology Program of the Maryland Geological Survey (MGS) has been involved in monitoring the physical and chemical behavior of near-surface sediments around the Hart-Miller Island Confined Disposal Facility (HMI) from the initial planning stages of construction of the facility through to the present. As part of this year's exterior monitoring program, MGS collected bottom sediment samples from 43 sites on September 23, 2004, and from 43 sites on April 7, 2005. Survey geologists then analyzed various physical and chemical properties of the samples: (1) grain size composition (relative proportions of sand, silt, and clay) and (2) total elemental concentrations of iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), chromium (Cr), nickel (Ni), cadmium (Cd), lead (Pb), phosphorous (P), carbon (C), nitrogen (N), and sulfur (S).

For exterior bottom sediments sampled during Year 23, the pattern of the grain size distribution varies slightly from one cruise to the next. The reasons for the variations are difficult to decipher, due to the complexity of the depositional environment and the multiple sources of material to the area. However, in general, sediment distribution is consistent with the findings of previous monitoring years, dating back to 1988, two years following the initial release of effluent from HMI.

Concentrations of trace metals surrounding the facility fell into two groups, those exceeding the effects range-low (ERL) and those exceeding the effects range-median (ERM). Cadmium, Cr, Cu, Ni, Pb and Zn were found at some sites with concentrations that exceed the ERL values. At times, Ni and Zn were also found to exceed the ERM.

ERL and ERM values, established by the National Oceanic and Atmospheric Administration (Long, E.R. 1992, Long and others 1995), represent three different biological effects thresholds. Sediment contaminant concentrations below the ERL suggest a minimal effects-range where biological impacts are unlikely to occur. Values above the ERL, but below the ERM, identify a possible effects-range where effects may occasionally occur. Values above the ERM represent a probable effects-range where impacts frequently occur. ERLs and ERMs were developed using mostly Pacific Coast data that were not normalized to sediment grain size. When the data are normalized, Pb, and to a lesser extent Zn, have samples significantly enriched above baseline. However, based on work done in Baltimore Harbor, the normalized values are well below anticipated biological effects thresholds.

Pb and Zn enriched samples are associated with the three local sources HMI, Baltimore Harbor and Back River. Material from the Harbor does not influence the sediments adjacent to the facility in the proximal zone ascribed to HMI. This is supported by both the sedimentation and metals distribution patterns in the area. The higher levels blanketing the area though may reflect a residual signature from the preceding years' near record rainfall.

In the area effected by facility operations, Zn and Pb both showed enriched levels. The September sampling cruise had higher levels, and a greater areal extent as compared to the April sampling. This is consistent with historical responses of the sedimentary environment to facility operations. Generally, the low flow periods corresponding to crust management periods are conductive to oxidizing the sediments within the facility, which are reflected in enrichment in the exterior sediments. However, due to dredged material inflow occurring over the summer period, conditions were not optimal for the establishment of extensive acid formation so the loadings to the sediment were not at levels of concern.

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

The benthic macroinvertebrate community in the vicinity of the Hart-Miller Island Dredged Material Containment Facility (HMI) was studied for the twenty-third consecutive year under Project III of the HMI Exterior Monitoring Program. The communities living close to the facility (Nearfield, South Cell Restoration Baseline, and Back River/Hawk Cove stations) were compared to communities located at some distance from the facility (Reference stations). Water quality parameters, including dissolved oxygen concentrations, salinity, temperature, pH, conductivity and secchi depth were measured *in situ.*

Twenty stations (11 Nearfield, 3 Reference, 3 Back River/Hawk Cove stations, and 3 South Cell Restoration Baseline stations) were sampled on September 24, 2003 and on April 13, 2004. Infaunal samples were collected using a Ponar grab sampler, which collects 0.05 m^2 of substrate. Water quality parameters were measured using a Hydrolab Data Sonde 4a at one meter from the bottom and at one-half meter from the surface to develop vertical water quality profiles.

A total of 38 taxa of benthic macroinvertebrates were found at these twenty benthic community stations during Year 23 of monitoring. Several of the 38 taxa were clearly dominant. *Marenzelleria viridis, Rangia cuneata,* Oligochaete worms of the family Tubificidae and *Cyathura polita* were among the numerically dominant taxa on both sampling dates. Only the fifth most dominant species differed between the two sampling seasons; in September 2004 it was *Mytilopsis leucophaeata*, while in April 2005 it was chironomids of the genus *Procladius* (*Holotanypus*). Polychaete taxa richness was similar for the two seasons, although *Streblospio benedicti* was completely absent from the April 2005 sampling. Total abundance of all invertebrates (excluding Bryozoa) was higher at most stations in April 2005 than September 2004 due to high seasonal recruitment, especially of the polychaete worm *M. viridis.*

Species diversity was examined using the Shannon-Wiener diversity index. Diversity was higher in April 2005 at eleven stations, and higher in September 2004 at nine stations. The calculation of the proportion of pollution-sensitive taxa and the proportion of pollution indicative taxa could only be made for two stations (MDE-24 and MDE-27) in the September 2004 sampling. Tidal freshwater conditions prevailed at the other stations in the fall, and at all stations in April 2005. No pollution sensitive taxa have been identified for tidal freshwater in Chesapeake Bay. Calculation of the pollution indicative index for freshwater requires special mounting procedures and examination of tubificid worms for capilliform chaetae, which was not conducted in Year 23.

The Chesapeake Bay Benthic Index of Biotic Integrity (B-IBI, Weisberg et al. 1997), a multi-metric index of biotic condition that evaluates summer populations (during the July 15th to September 30th timeframe) of benthic macroinvertebrates, was calculated for all stations sampled during the September 2004 cruise. Overall, the Benthic Index of Biotic Integrity scores improved or remained the same when compared to Year 22 and were generally similar to the B-IBI scores of the previous 6 years of monitoring at Hart-Miller Island. This year, nineteen stations exceeded the benchmark criteria of 3.0, and only 1 station failed to meet the benchmark.

In contrast to Year 22, in Year 23 there were no significant differences for the ten most abundant infaunal taxa among the four station types, based on results of the nonparametric Friedman's test.

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

For year 23 monitoring at HMI, the Project 4 goals were to continue to collect clams, worms (if available), and associated sediment for analyses of trace metals, PCB's and PAH's. For the summer sampling only, Project 4 also analyzed sediments for ancillary metals [specifically mercury (Hg), monomethylmercury (MMHg), silver (Ag), and arsenic (As) - also cadmium (Cd) and lead (Pb)] not monitored by the Maryland Geological Survey. Analytical equipment at the Solomons Lab was contaminated by smoke from the recent fire and organics results are thus unavailable at this time. The organics values will be included with the final report.

Forty-three stations were sampled in the summer of Year 23 for sediment metals concentrations. Concentrations of As, Se, Cd and Pb in the sediment are similar to previous years and not substantially different than the concentrations found elsewhere in the Chesapeake Bay or in marine sediments. The significant exceptions were sites 43 (for Cd and Ag) and 44 (for Cd and Pb). To a lesser degree, sites 4 and 6 had slightly elevated Pb concentrations compared to the long-term average. Concentrations of mercury (T-Hg) and methylmercury (MeHg) in sediment are lower than the average of previous years, but within expected standard deviation.

Nine stations were sampled for metals in the clam *Rangia cuneata*. Concentrations of the metals As, Se, Ag, Cd, and Pb in the clam displayed some variations from previous years. Most metal concentrations were low and varied little among the sites. Concentrations of As and Ag remained similar to previous years whereas Se and Cd where considerably lower. Concentrations of Pb were 5 times higher than the average of the previous years. The fact that the increase was observed at all sites and some anomalous lead concentrations where also observed in some sediments suggests a regional increase in water born Pb, not likely associated with any HMI discharge. The concentrations of both T-Hg and MeHg in clams collected in year 23 are close to the average for previous years.

Difference in the proportions of water between sediments and the organisms means that an evaluation of bioaccumulation factors (BAF) must be done on a dry weight basis. The wet/dry ratios for are on the order of 10 to 15 whereas the ratio for sediments is closer to 2. The BAF's for trace metals are summarized in Figure 8. The BAF for As and Cd is between 1 and 10 indicating some moderate bioaccumulation. The BAF for Se floats around 1 across the sites indicating little to no bioaccumulation. The BAF for Pb is less than one, suggesting exclusion. The BAF's for Hg (not shown) is less than 1 but the BAF for MeHg ranges widely from 1 to 200 among the sites. The BAF for Ag is approximately 100 at all the sites. The high BAF for Ag has been observed in previous years.

CONCLUSIONS AND CRECOMMENDATIONS

Continued monitoring of the HMI facility is recommended to monitor compliance with the state’s wetland license. This monitoring will become more important as the facility reaches closure in 2009 and longer-term oxidation patterns in the dredged material produce acidic leachate. Due to tidal currents, inaccuracies in GPS navigational systems, etc., it is also recommended that HMI samples for each project be collected synoptically during a single cruise. This will ensure that the benthic community and tissue samples come from the same parent sample in which sediments are analyzed. This synoptic sampling scheme will allow for a more accurate assessment of the triad response. Finally, limited laboratory toxicity work should be undertaken to assess any lethal, sublethal or chronic effects not captured by tissue analyses alone.

PROJECT 2: SEDIMENTARY ENVIRONMENT
(September 2004 - October 2005)

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EXECUTIVE SUMMARY

The Coastal and Estuarine Geology Program of the Maryland Geological Survey (MGS) has been involved in monitoring the physical and chemical behavior of near-surface sediments around the Hart-Miller Island Confined Disposal Facility (HMI) from the initial planning stages of construction of the facility through to the present. As part of this year's exterior monitoring program, MGS collected bottom sediment samples from 43 sites on September 23, 2004, and from 43 sites on April 7, 2005. Survey geologists then analyzed various physical and chemical properties of the samples: (1) grain size composition (relative proportions of sand, silt, and clay) and (2) total elemental concentrations of iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), chromium (Cr), nickel (Ni), cadmium (Cd), lead (Pb), phosphorous (P), carbon (C), nitrogen (N), and sulfur (S).

For exterior bottom sediments sampled during Year 23, the pattern of the grain size distribution varies slightly from one cruise to the next. The reasons for the variations are difficult to decipher, due to the complexity of the depositional environment and the multiple sources of material to the area. However, in general, sediment distribution is consistent with the findings of previous monitoring years, dating back to 1988, two years following the initial release of effluent from HMI.

With regard to trace metals some features to note are:

1. Cd, Cr, Cu, Ni, Pb and Zn are found at some sites with concentrations that exceed the Effects Range Low (ERL) values; and
2. Ni and Zn exceed the ERM values at some sites.

ERL and Effects Range Medium (ERM) are proposed criteria put forward by National Oceanic and Atmospheric Administration (NOAA - Long et al. 1995) to gauge the potential for deleterious biological effects. Sediments with concentrations below the ERL are considered baseline concentrations with no expected adverse effects. Concentrations between the ERL and ERM may have adverse impacts to benthic organisms, while values greater than the ERM have probable adverse biological effects. These criteria are based on a statistical method of termed preponderance of evidence. The method does not allow for unique basin conditions and does not take into account grain size induced variability in metal concentrations in the sediment. The values are useful as a guide, but are limited in applicability due to regional difference. The grain size normalization procedure outlined in the previous section is a means to correct the deficiencies of the guidelines by taking into account the unique character of Chesapeake Bay sediments and eliminating grain size variability. When the data are normalized, Pb, and Zn have significantly enriched samples compared to the baseline; however, based on work done in Baltimore Harbor, the normalized values are below anticipated biological effects thresholds.

Pb and Zn enriched samples are associated with the three local sources HMI, Baltimore Harbor and Back River. Material from the Harbor does not influence the sediments adjacent to the facility in the proximal zone ascribed to HMI. This is supported by both the sedimentation and metals distribution patterns in the area. The higher levels blanketing the area though may reflect a residual signature from the preceding years' near record rainfall.

In the area effected by facility operations, Zn and Pb both showed enriched levels. The September sampling cruise had higher levels, and a greater areal extent as compared to the April sampling. This is consistent with historical responses of the sedimentary environment to facility operations. Generally, the low flow periods corresponding to crust management periods are conductive to oxidizing the sediments within the facility, which are reflected in enrichment in the exterior sediments. However, due to dredged material inflow occurring over the summer period, conditions were not optimal for the establishment of extensive acid formation so the loadings to the sediment were not at levels of concern.

Persistent elevated metal levels in sediments around HMI indicate a need for continued monitoring. This is emphasized in the increasing trend of metal enrichment since 2002. The metal levels in the exterior sediments continued to show a consistent response to the operations of the facility; low discharge rates increasing the metal loads to the sediment. Currently, the facility is actively accepting material, but the amount of material accepted is declining as the facility reaches its capacity. Consequently, the volume of effluent is declining; dewatering operations will increase which 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 Bay floor and are increasing the long-term sediment load in the Bay. Continued monitoring is needed in order to; detect if the levels increase to a point where action is required, document the effect that operations has on the exterior environment (for future project design), and to assess the effectiveness of any amelioration protocol implemented by MES to counteract the effects of exposing contained dredged material to the atmosphere. Close cooperation with MES is important in this endeavor.

In order to assess the potential influence of Baltimore Harbor on the HMI exterior sediments better, the additional sampling sites be maintained, at least temporarily. Further, the South Cell has been converted to an environmental restoration project; water will be circulated through the ponds during certain times of the year to produce either mudflats or a ponded area. The additional sample locations near the discharge point should be maintained to assess this new operation of the facility as part of the on-going monitoring program.

In regard to monitoring the discharge from the spillways, in light of the new sampling procedures, a re-evaluation of the sampling frequency and protocols is needed *if* comparison of the data with historical records is considered important.

INTRODUCTION

Since 1981, the Maryland Geological Survey (MGS) has monitored the sedimentary environment in the vicinity of Hart-Miller Island Dredged Material Containment Facility (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 1). Designed specifically to contain material dredged from Baltimore Harbor and its approach channels, the oblong structure was constructed of sediment dredged from the facility interior. The physical and geochemical properties of the older, "pristine" sediment used in facility construction differed from those of modern sediments accumulating around the island. Likewise, material dredged from shipping channels and deposited inside the facility also differs from recently deposited sediments in the region. Much of the material generated by channel deepening is fine-grained and enriched in trace metals and organic constituents. In addition, oxidation of the sediment placed in the facility during dewatering and crust management produces effluent enriched in metals. These differences in sediment properties and discharge from the facility have allowed the detection of changes attributable to construction and operation of the facility.

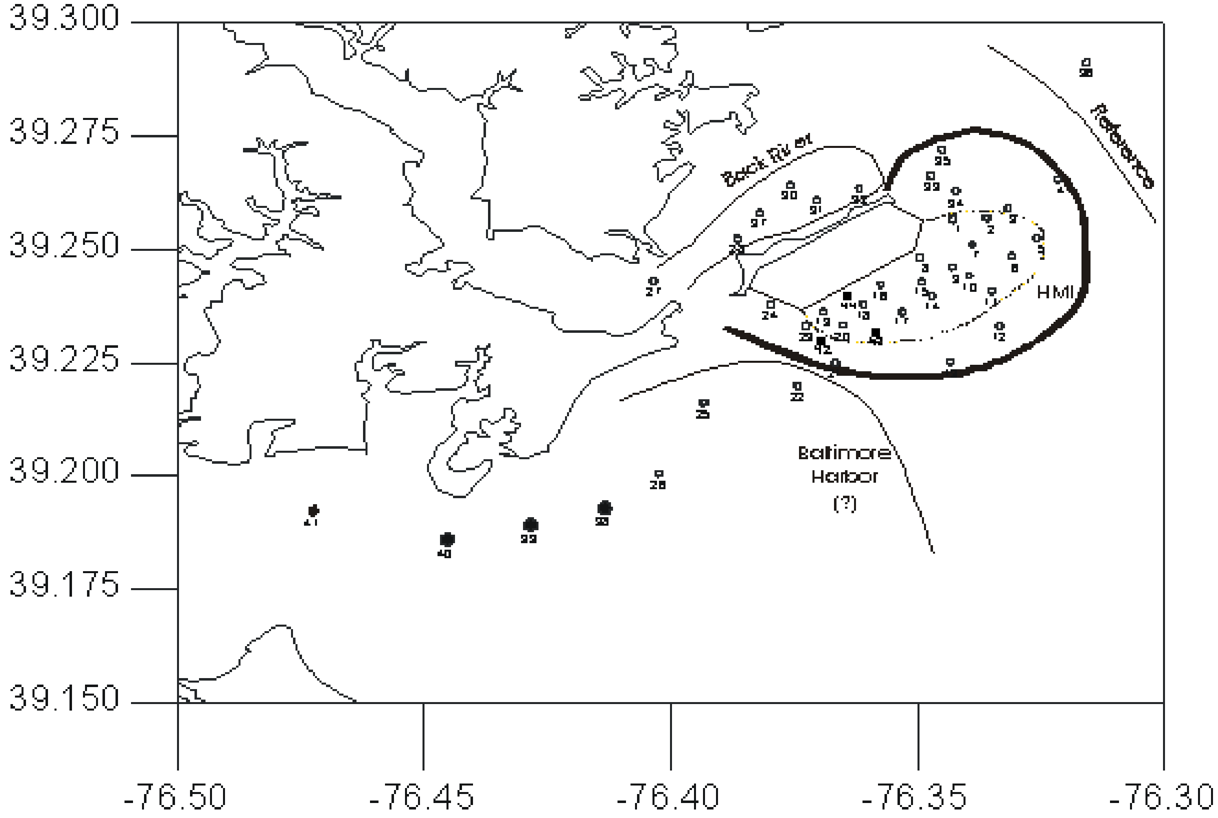


Figure 1: Sampling locations for Year 23. Contours show zones of influence found in previous studies. Solid circles show location of sites added in Year 18 to measure the influence of Baltimore Harbor and the more recent sites added to determine the influence of the conversion of the South Cell to upland wetlands.

Previous Work

Events in the history of the facility can be meaningfully 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 facility construction has been well documented in earlier reports (Kerhin et al. 1982a, l982b; 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 facility could be measured. The most notable effect of facility construction on the surrounding sedimentary environment was the deposition of a thick, light gray to pink layer of "fluid mud" immediately southeast of the facility.

For a number of years after HMI 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 facility, anomalously high Zn values were detected in samples collected near spillway #1 (Hennessee et al., 1990b). Zn levels rose, from the regional average enrichment factor of 3.2 to 5.5; enrichment factors are normalized concentrations, referenced to a standard material. Enrichment factors are the ratios of concentrations, in this case Zn to Fe, which is in term normalized to the same ratio in a standard reference material; this number is dimensionless. Effluent discharged during normal operation of the facility was thought to be the probable source of the enrichment of 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 facility, coupled with discharge records from the spillways. From the discharge records it was noted that there is a significant increase in metal loading to the exterior sediments during periods of low discharge (<10MGD); periods of higher discharge rates corresponded to lower metal levels in the exterior sediments.

The factors that influence the metals loadings to the exterior sediments are circulation patterns in the northern Bay and the rate and the nature of discharge from the facility. The results of the hydrodynamic model pertinent to a discussion of contaminant distribution around HMI follow (see the *10th 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 the facility against the eastern and southeastern perimeter of the facility.

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

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

3. The circulation gyre is modulated 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 facility. Conversely, the lower the flow, the less the compression and the greater the dispersion away from the facility.

4. Discharge from the HMI spillways 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 modulated the concentration of a hypothetical conservative species released from the facility; the higher the discharge, the higher the concentration in the plume outside the facility.

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 facility was examined, as reported in the *11th Year Interpretive Report*. As a result of this examination, a model was constructed to predict the general trend in the behavior of Zn as a function of discharge rate from the facility. The model has two components: (1) loading due to 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, the size of the affected area has fluctuated, as have metal concentrations within the area. Nonetheless, in the vicinity of the facility higher than expected levels of Zn and Pb have persisted to the present. Figure 1, in addition to showing the sampling sites for Year 23, show zones which indicate influence of sources of material to the exterior sedimentary environment based on a elevated metal levels from previous years' studies. These influences are noted in the figure as:

1. *Reference* - representing the overall blanketing of sediment from the Susquehanna River;

2. *Back River* - Gradients showing the sewage treatment plant as a source carried by the river have varied through time; the sites in this zone encompass the area that has shown the influence from this source. Further documentation of this source was done in the Year 16 report, where samples were collected upstream beyond the sewage treatment plant. These samples clearly showed a continuous gradient from the plant down Back River approaching HMI;

3. *HMI* - The area of influence from the facility is divided into two zones, (a) the proximal zone, which shows the most consistent enrichment levels through time, and (b) the distal zone, which is affected primarily during extended periods of dewatering and crust management, and;

4. *Baltimore Harbor* – Sites in the southern portion of the area have consistently shown a gradient, indicating that Baltimore Harbor is a source of metals in the area south of HMI. The consistent pattern seen in the monitoring studies is base level values near HMI, which increase towards Baltimore Harbor. This pattern supports the results of a hydrodynamic model analyses performed in conjunction with the 1997 sediment characterization of Baltimore Harbor and Back River (Baker et al., 1998). During Year 22 monitoring near record rainfall levels in the area strongly influenced the hydrodynamic flow, resulting in the incursion of Baltimore Harbor material into the HMI zone. This sampling period was the only time in the 22 years of monitoring that this occurred.

Facility Operations

Certain activities associated with the operation of HMI have a direct impact on the exterior sedimentary environment. Local Bay floor sediments are sensitive, both physically and geochemically, to the release of effluent from the facility. Events or operational decisions that affect the quality or quantity of effluent discharged from the facility account for some of the changes in exterior sediment properties observed over time. For this reason, facility operations during the periods preceding each of the Year 23 cruises are summarized below. Information was extracted from *Operations Reports* prepared by MES, covering the periods April 1, 2004 - April 30, 2005; a detailed synopsis of this period and digital discharge records were provided to MGS for this report by MES (Jennifer Harlan, personal communication)

HMI was operating at very low acceptance levels. The total amount of material accepted was 0.192 million cubic yards in contrast to the previous year of 1.9 million cubic yards. Material was accepted 7 months of the year monitoring period, with close to 70% of the year's total input placed in March 2005; near the end of the monitoring year. No inflow occurred November 2004 through February 2005. As a result of the low input volumes, the discharge rates from HMI were low. This is seen in Figure 2, which shows both the cumulative discharge (left axis) and the daily discharge rate. Six months prior to each sampling event close to 90% of the days had no discharge.

Low flow and dewatering operations are conducive to the production of acidic conditions resulting from oxidation of the sediment. From previous observations, it takes a period longer than six months to establish oxidizing conditions which would show a significant effect on the discharge. During this monitoring year conditions were not optimal for acid leaching conditions to be established. However, there was a 4-month no flow period and flow rates were generally low so slightly elevated metal levels would be expected. Higher metal loadings would be expected during the September cruise (Cruise 49) as compared to the April cruise (Cruise 50) due to the lower discharge rates.

Due to a revision in the permit required monitoring, the way pH is measured was changed during this monitoring year so the pH data cannot be used to corroborate this prediction, nor can the facility operations be compared to previous years. Prior to this monitoring year pH was measured on a continual basis during discharge events, pH records were maintained; pH values changed during discharge events, and the and high and low values reported. pH values cannot be averaged since they are logarithmic metrics of acidity, so the range of data is an important indicator of the processes occurring. The new collection method is to collect one grab sample for each discharge event; MGS feels this is inadequate to characterize the processes operating at the facility. The best method is a flow proportionate sampling of each event, with continual monitoring as the second choice.

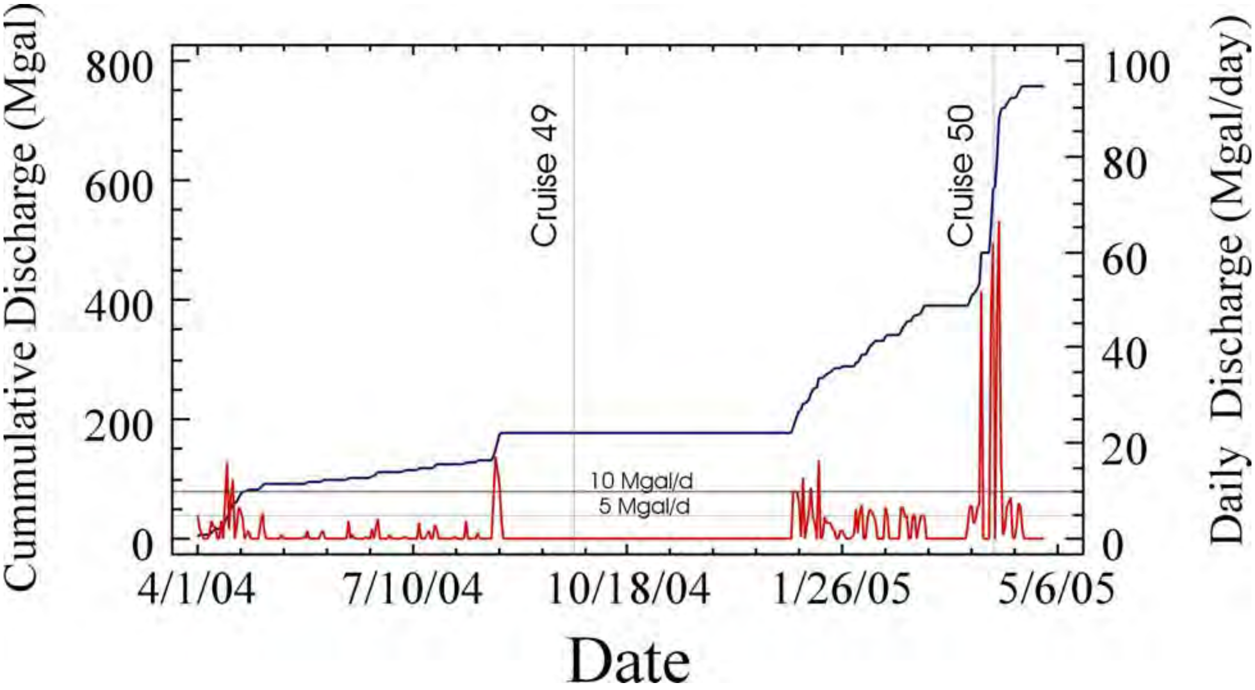


Figure 2: Cumulative and daily discharge from North Cell spillways at HMI.

OBJECTIVES

As in the past, the main objectives of the Year 23 study were (1) to measure specific physical and geochemical properties of near-surface sediments around HMI and (2) to assess detected changes in the sedimentary environment. Tracking the extent and persistence of the area of historically elevated metals concentrations was again of particular interest.

METHODS AND MATERIALS

Field Methods

The information presented in this report is based on observations and analyses of surficial sediment samples collected around HMI during two cruises aboard the *R/V Kerhin.* The first cruise took place on September 23, 2004, and the second, on April 7, 2005.

Sampling sites (Figure 1) were located in the field by means of a Leica Model MX412B differential global positioning system (GPS) with a built-in beacon receiver. According to the captain, Rick Younger, the repeatability of the navigation system, that is, the ability to return to a location at which a navigation fix has previously been obtained, is between 5-10 m (16-33 ft). Where replicates were collected, the captain repositioned the vessel between samples to counteract drifting off station during sample retrieval. At most sites, the captain recorded station coordinates and water depth. Target and actual coordinates (latitude and longitude -- North American Datum of 1983) of Year 23 sample locations are reported in the companion *Year 23 Data Report*.

Using a dip-galvanized Petersen sampler (maximum depth of penetration = 38 cm or 15 inches), crew members collected undisturbed samples, or grabs, of surficial sediments at 43 sites, MDE-1 through MDE-28 and MDE-30 through MDE-44, for both Year 23 cruises. The spring cruise of Year 22 contained the three additional sites, MDE-42 through MDE-44, in the vicinity of spillway #3. With the exception of the three sites added not being present prior to the spring cruise of Year 22, the stations were identical to those sampled during Years 21 and 22.

At 39 stations for both the fall and the spring cruises, a single grab sample was collected, described lithologically, and split. Triplicate grab samples were collected at the remaining four stations (MDE-2, MDE-7, MDE-9 and MDE-31) and, likewise, described and split. MGS analyzed one split for grain size composition, a suite of trace metals, and carbon/sulfur/nitrogen. The Chesapeake Biological Laboratory (CBL) analyzed the second split collected for a different suite of trace metals. Field descriptions of samples are included as appendices in the *Year 23 Data Report.*

Using plastic scoops rinsed with deionized water, the crew took sediment sub-samples from below the flocculent layer, usually several centimeters from the top, and away from the sides of the sampler to avoid possible contamination by the sampler itself. MGS's sub-samples were placed in 18-oz Whirl-Pak^{TM} bags and refrigerated. They were maintained at 4^{o}C until they could be processed in the laboratory. CBL's splits were handled in much the same way, except that they included the floc layer and were frozen instead of refrigerated. CBL's samples are only collected for the fall sampling of each monitoring year. Therefore, the spring sampling procedure does not include a split.

Laboratory Procedures

Textural Analyses

In the laboratory, sub-samples 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 g of the wet sample, drying the sediment at 65^{o}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.

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 3).

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; however, 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 analysis are discussed in terms of percent sand and clay:mud ratios, not Pejrup's classes themselves.

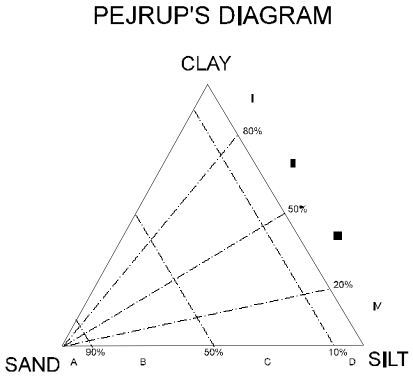


Figure 3: Pejrup's (1988) classification of sediment type.

Trace Metal Analysis

Trace elements were analyzed by *Activation Laboratories Inc*. (ActLab) as opposed to being measured in-house as in the previous monitoring years. This change was instituted due to fiscal and policy changes in which the ICAP equipment was no longer supported. MGS has been using ActLab for approximately 5 years to do analyses for other MGS projects. For all of the projects the Quality assurance and quality control has proved to meet MGS standards and requirements. In addition to the nine elements historically measured by MGS [iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), chromium (Cr), nickel (Ni), lead (Pb), cadmium (Cd), and total phosphorus (P)], forty-one (41) additional elements were analyzed. Samples were prepared and ground in-house and sent to ActLab for analyses using both a four acid “near total” digestion technique followed by analysis on an Inductively Coupled Argon Plasma Spectrometer (ICAP), and Nuetron Activation Analysis (NAA). In addition to the standards and blanks used by ActLab, NIST and CRC standard reference materials were inserted as blind samples for analyses; 1 in 8 samples.

Results of the analyses of the SRM's (NIST-SRM #2702 - Inorganics in Marine Sediment; NIST-SRM #8704 - Buffalo River Sediment; National Research Council of Canada #PACS-2 - Marine Sediment) reported by ActLab had recoveries (accuracies) within one standard deviation of replicate analyses for all of the metals analyzed (see the Year 23 Data Report for details and comparison of ActLab with MGS).

Carbon-Sulfur-Nitrogen Analysis

Sediments were analyzed for total nitrogen, carbon and sulfur (CNS) contents using a Carlo Erba NA1500 analyzer. This analyzer uses complete combustion of the sample followed by separation and analysis of the resulting gasses by gas chromatographic techniques employing a thermal conductivity detector. The NA1500 Analyzer is configured for CNS analysis using the manufacturer's recommended settings. As a primary standard, 5-chloro- 4-hydroxy- 3-methoxy-benzylisothiourea phosphate is used. Blanks (tin capsules containing only vanadium pentoxide) were run at the beginning of the analyses and after 12 to 15 unknowns (samples) and standards.

Replicates of every fifth sample are run. As a secondary standard, a NIST reference material (NIST SRM #1646 - Estuarine Sediment) is run after every 6 to 7 sediment samples. The recovery of the SRM is excellent with the agreement between the NIST certified values and MGS's results well within the one standard deviation of replicate analyses.

RESULTS AND DISCUSSION

Sediment Distribution

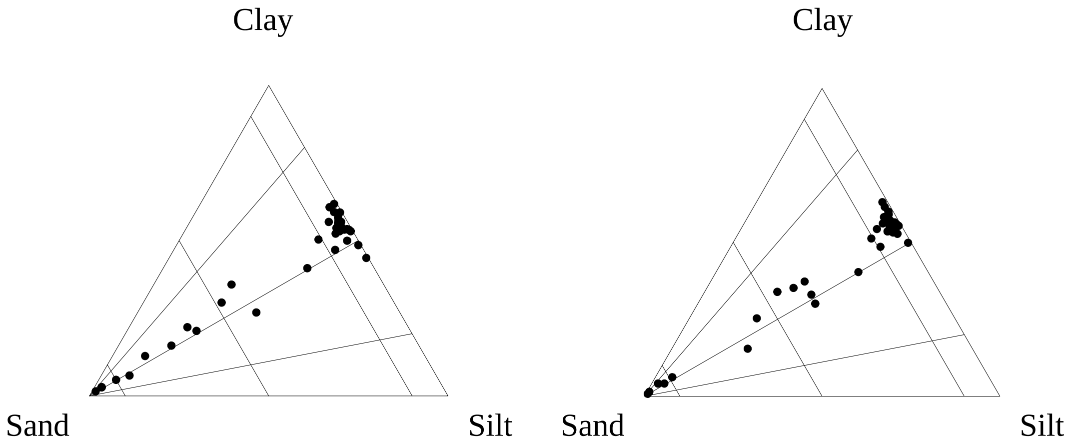
The monitoring effort around HMI is based on the identification of long-term trends in sediment distribution and on the detection of changes in those trends. The sampling scheme, revised in Year 17 and expanded in Year 18, established a new baseline against which any future changes in the sedimentary environment will be measured. Through Year 19, results of all cruises beginning with Year 17 were reported and compared. Starting with Year 20, results of the current year were discussed with respect to the preceding year. Therefore, for this report, the current Year 23 results are discussed with respect to the preceding Year 22 results.

Thirty-eight of the sampling sites visited during Year 23 yielded results that can be compared to those measured during Year 22. The grain size composition (proportions of sand, silt, and clay) of the 38 samples is depicted as a series of Pejrup's diagrams in Figure 4. Within a diagram, each solid circle represents one sediment sample. Related statistics, by cruise, are presented in Table 2.

Table 2: Summary statistics for Years 22 - 23, for 38 sediment samples common to all four cruises.

Variable	Aug 2003 Cruise 47	Apr 2004 Cruise 48	Sept 2004 Cruise 49	Apr 2005 Cruise 50
Sand (%)				
Mean	24.96	23.10	25.28	23.91
Median	3.88	3.78	4.44	5.03
Minimum	0.54	0.81	0.60	0.74
Maximum	97.54	98.59	96.45	97.78
Range	97.00	97.79	95.85	97.04
Count	38	38	38	38
Clay:Mud				
Mean	0.55	0.57	0.56	0.56
Median	0.56	0.57	0.56	0.56
Minimum	0.45	0.42	0.43	0.48
Maximum	0.62	0.70	0.70	0.66
Range	0.18	0.28	0.27	0.18
Count	38	38	38	38

The ternary diagrams show similar distributions of sediment type. The samples range widely in composition, from very sandy (>90% sand) to very muddy (<10% sand). Muddy sediments predominate; at least two-thirds of the samples contain less than 10% sand. All of the points fall fairly close to the line that extends from the sand apex and bisects the opposite side of the triangle (clay:mud = 0.50). In general, points lie above the 0.50 line, indicating that the fine (muddy) fraction of the sediments tends to be somewhat richer in clay than in silt.



(a) August 2003 (Cruise 47)

(b) April 2004 (Cruise 48)

Clay

Sand

Silt

Clay

Sand

Silt

(c) September 2004 (Cruise 49)

(d) April 2005 (Cruise 50)

Figure 4: Ternary diagrams showing the grain size composition of sediment samples collected in Years 22 and 23 from the 38 sampling sites common to all four cruises: (a) August 2003, (b) April 2004, (c) September 2004, and (d) April 2005.

Based on the summary statistics (Table 2), average grain size composition, reported as % sand and as clay:mud ratios, varied little over the four sampling periods. The mean clay:mud was slightly higher for cruise 48, with a value of 0.57, due to the 0.70 clay:mud ratio for sampling site 2 increasing the average. The mean clay:mud decreased to 0.56 for cruise 49 and remained stable at 0.56 for cruise 50. As in the past, no clear seasonal trends are evident in either sand content or the clay:mud ratios.

For the two monitoring years, the grain-size distribution of bottom sediments around HMI is depicted in contour maps showing (1) the percentage of sand in bottom sediments and (2) the clay:mud ratios. In Figures 6 and 7, three contour levels represent 10%, 50%, and 90% sand, coinciding with the parallel lines in Pejrup's diagram. Generally, sand content diminishes with distance from the containment facility. Scattered around the perimeter of the facility, the sandiest sediments (>50% sand) are confined to relatively shallow (<15 ft) waters. Broadest north and west of the facility, the shoals are the erosional remnants of a larger neck of land. The once continuous landmass has been reduced to a series of islands, including Hart and Miller, extending from the peninsula that now forms the south shore of Back River. However, not all shallow water samples are sandy. In particular, several of the shallow water samples from Hawk Cove (e.g., MDE-30 and MDE-32) contain less than 10% sand. Sand distribution maps for Years 22 and 23 are similar in appearance. Sand contents continue to be highest near the perimeter of HMI in shallow water depths. No significant changes in sand content occurred during monitoring Year 23. In general, the distribution of sand around HMI has remained largely unchanged since November 1988, two years after the first release of effluent from the facility.

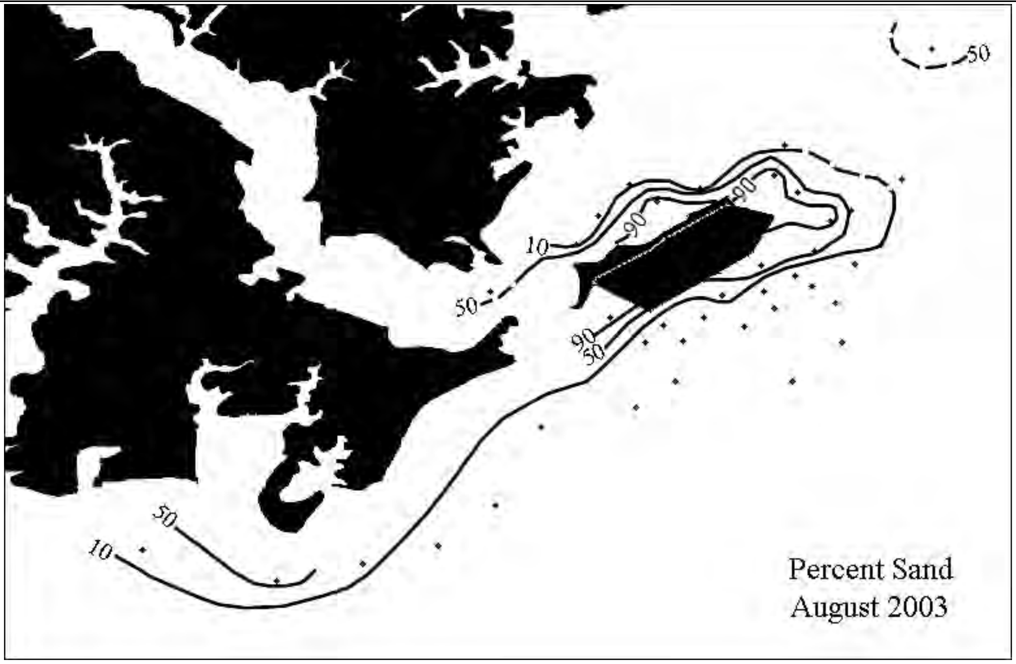
Figure 5: Average water depths, based on Year 17 Monitoring (Contour interval = 5 ft).

Compared to the distribution of sand, the distribution of clay:mud ratios has tended to be more variable over time. The fine (mud) fraction of the sediments around HMI is generally richer in clay than in silt. That is, the clay:mud ratio usually exceeds 0.50, as shown in the ternary diagrams above. However, slight variations in the most clay-rich (clay:mud ratio ≥ 0.60) and in the most silt-rich (clay:mud ratio < 0.50) of the fine fractions are evident (Figures 8 & 9). MDE-41, at the mouth of Baltimore Harbor, continued to be clay-rich for three of the four samplings. In August 2003, there were two areas that were clay-rich along with the pocket at MDE-41. The one just south of HMI consisted of MDE-18 and MDE-20 and was very similar to that of September 2002 in the same location. The second area was located at MDE-10 to the southeast of HMI, which is also a station that has been clay-rich prior to Year 22. A more noticeable increase in clay-rich area is seen in April 2004. Here, in addition to the MDE-41 site, there was one large area to the south of HMI consisting of seven previously sampled sites as well as one of the sampling sites added in April 2004 (MDE-42). Although it has not been common to see quite as large a pocket of clay-rich samples previously, the contours denote that this entire area has continually had clay:mud values above 0.55, and many of the small pockets previously recorded have been located throughout this area. With the exception of MDE-21, which had a clay:mud ratio of 0.59 in August 2003, all of the stations within the clay-rich area in April 2004 had a clay:mud ratio at or above 0.60 at least once during the previous three samplings going back to September 2002. Therefore, the larger, singular clay-rich pocket in April 2004 is not significantly different from previous results.

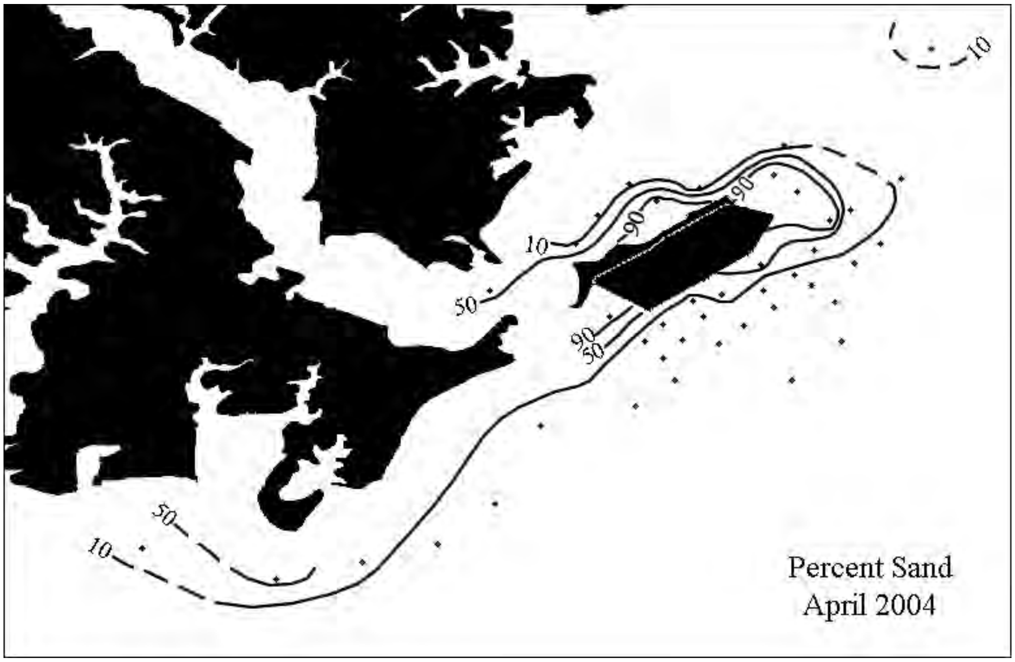
The clay-rich area South of HMI continued to be present in both September 2004 and April 2005 with no significant changes. In September 2004, four stations had clay:mud ratios at or above 0.60 south of HMI (MDE-10, MDE 17, MDE 18, MDE, 21) to create the clay-rich area for this sampling. In April 2005, MDE-10 and MDE-18 continued to be clay-rich. The clay:mud values of both MDE-17 and MDE-21 declined slightly from September 2004 to below 0.60 while MDE-44 and MDE-20 increased to above 0.60. This accounts for the slight variation in shape of the clay-rich pocket from September 2004 to April 2005. A clay-rich area was also present to the North of HMI for both September 2004 and April 2005 (Figure 9). Note that this area lies close to the perimeter of HMI where sand contents are consistently at or above 90 percent (Figures 6 & 7). This area is due to increased clay:mud ratios of sampling sites with high sand content. In sandy sediments, a very small increase in clay percentage will increase the clay:mud ratio above 0.60. The clay-rich areas for Year 23 are similar to those from Year 22 with no significant changes.

Silt-rich sediments (clay:mud ratio < 0.50) are generally found immediately adjacent to the walls of the facility, commonly in the vicinity of spillways. In August 2003, four sites were silt-rich. These were MDE-8, adjacent to the wall of the facility to the southeast, MDE-12, MDE-19 on the southwest corner of the facility, and MDE-27 in Back River. The silt-rich samples in April 2004 consisted of two sites, MDE-8 and MDE-27. The increase in clay:mud ratio at MDE-12 and MDE-19 to above 0.50 in April 2004 correlates with the increase in clay-rich samples also seen in April 2004. In September 2004, four sites consisting of MDE-8 and MDE-16 adjacent to the wall of the facility to the southeast, MDE-24 to the southwest of the facility, and MDE-27 were silt-rich. The area adjacent to the wall of the facility to the southeast continued to be silt-rich in April 2005 with MDE-8 and MDE-16. Also silt-rich in April 2005 was MDE-12 and MDE-27. MDE-12 was silt-rich for all samplings except September 2004 when there was a slight increase in the clay:mud value to 0.53 for this station. This change was insignificant and can be seen by the absence of the 0.50 contour line on the southeastern extent of the sampling area for September 2004 (Figure 9). The silt-rich areas were very consistent during both Year 22 and Year 23 monitoring with the area adjacent to the walls of the facility to the south remaining silt-rich along with MDE-27 in Back River.

Understanding the specific reasons for these variations in grain size is difficult. They involve the amount, quality, and timing of discharge from particular spillways and the interaction of the effluent with tides and currents in the receiving waters. Those, in turn, are influenced by flow from the Susquehanna River. The increase in the number of clay-rich samples along with the increase in clay:mud ratio values at MDE-12 and MDE-19 to above 0.50 found in April 2004 suggests a higher input of clay-rich sediment following the August 2003 sampling. The exact source of that higher input is unknown. One possible source includes clay-rich sediment eroded from nearby shorelines as a result of Hurricane Isabel, which occurred after the August 2003 sampling. The data for September 2004 and April 2005 remain very similar to that of April 2004 with no significant changes. Based on the similarities between the fine fraction results from Year 22 and Year 23, one may conclude that the depositional environment in the vicinity of HMI was unchanged over this period. No clear trends affecting many samples from a large area are evident. The grain size distribution of Year 23 samples is largely consistent with the findings of past monitoring years.

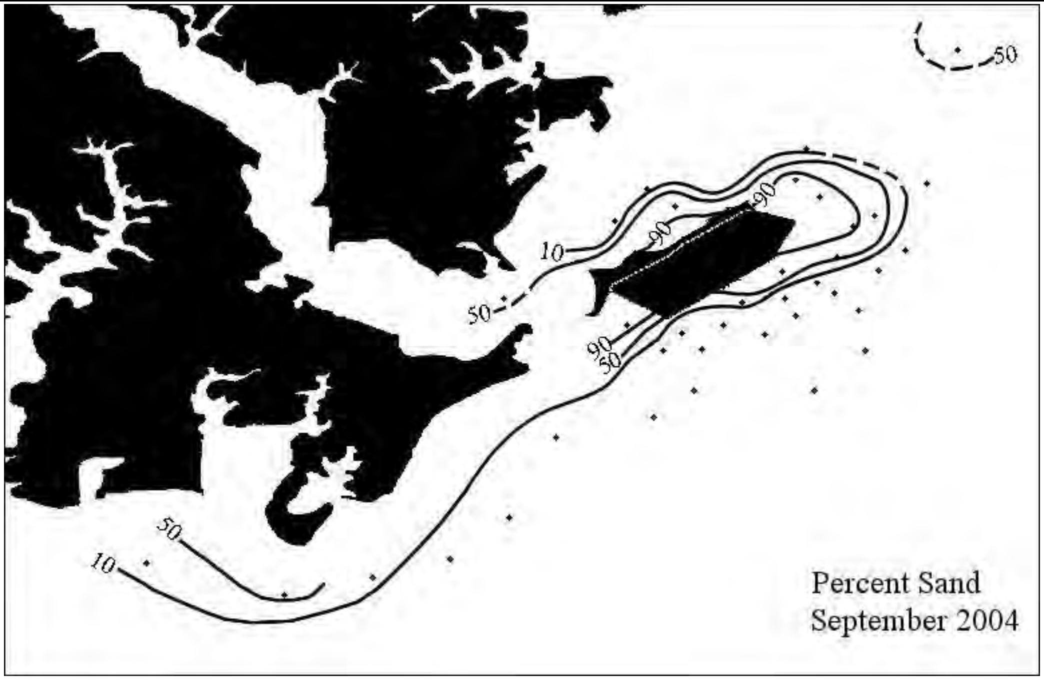


(a) Cruise 47

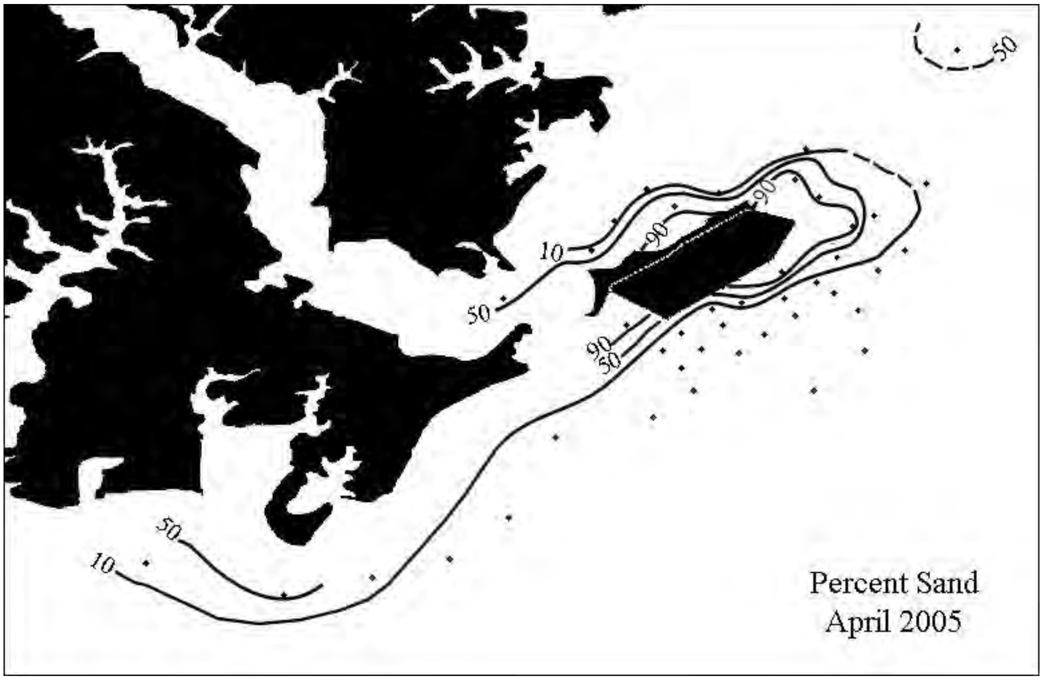


(b) Cruise 48

Figure 6: Sand distribution for Monitoring Year 22: (a) August 2003, (b) April 2004. Contour intervals are 10%, 50%, and 90% sand.

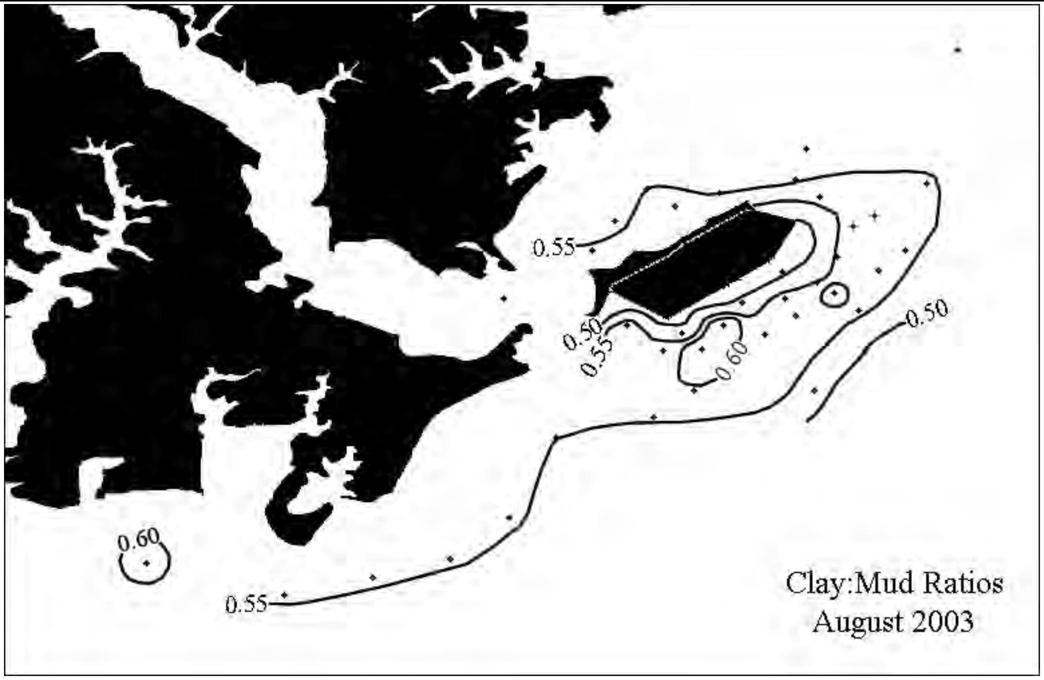


(a) Cruise 49

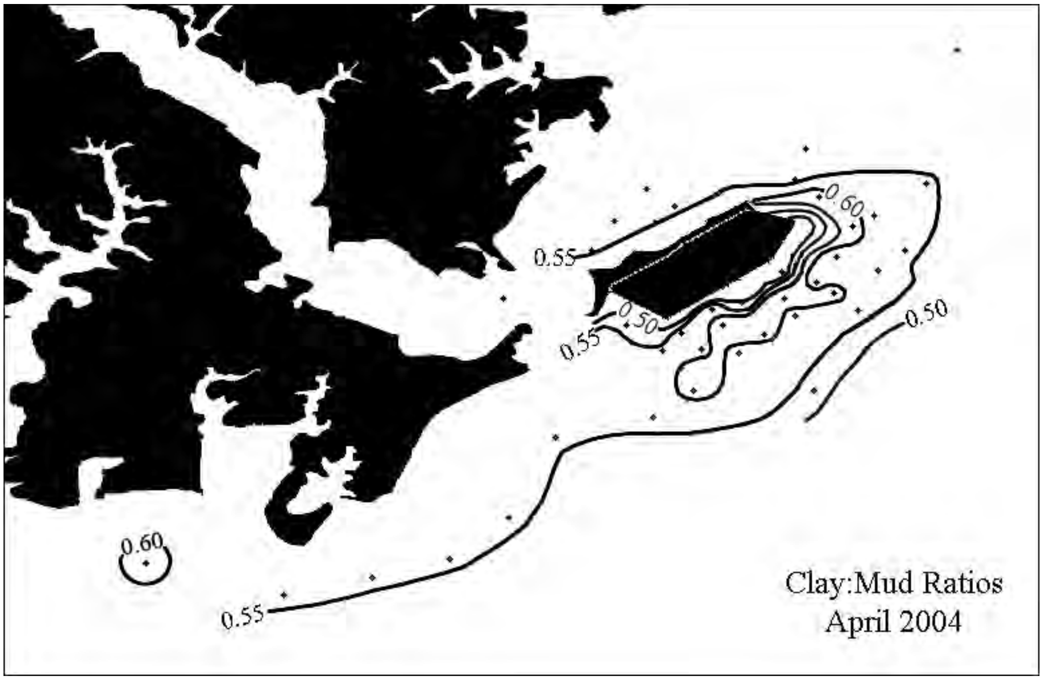


(b) Cruise 50

Figure 7: Sand distribution for Monitoring Year 23: (a) September 2004, (b) April 2005. Contour intervals are 10%, 50%, and 90% sand.

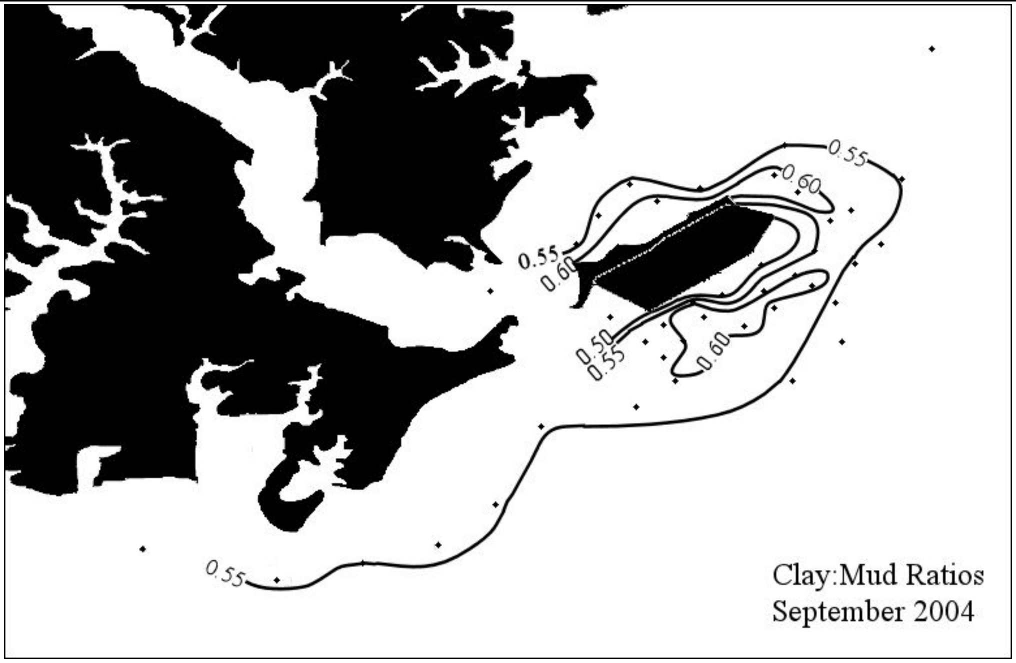


(a) Cruise 47

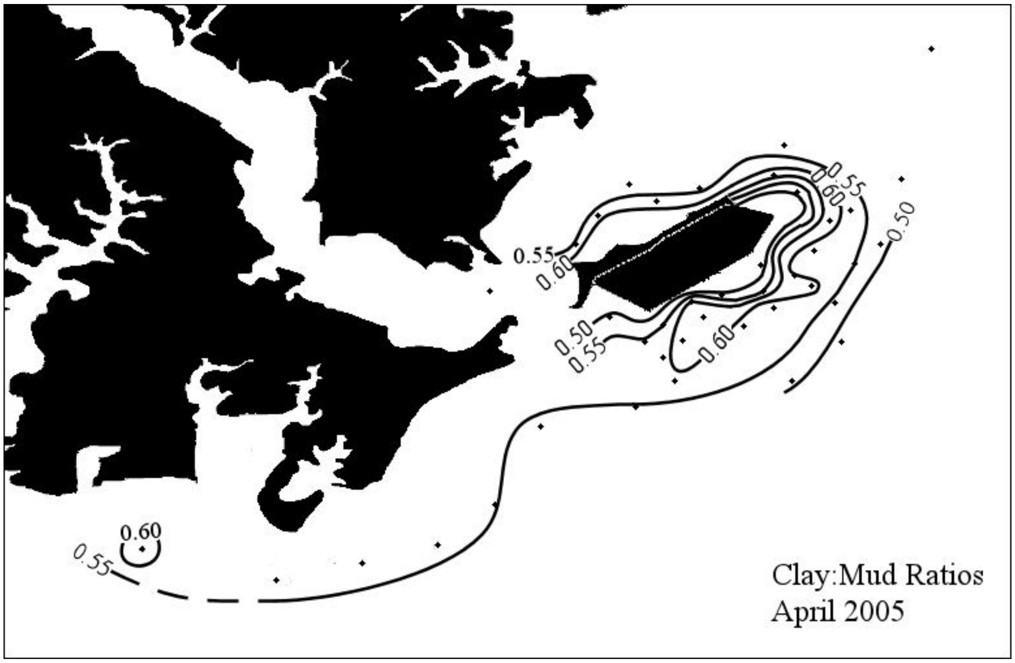


(b) Cruise 48

Figure 8: Clay:Mud ratios for Monitoring Year 22. Contour intervals are 0.50, 0.55, and 0.60.



(a) Cruise 49



(b) Cruise 50

Figure 9: Clay:Mud ratios for Monitoring Year 23. Contour intervals are 0.50, 0.55, and 0.60.

Elemental Analyses

Interpretive Technique for Trace Metals

Previous monitoring years have focused on eight trace metals as part of the ongoing effort to assess the effects of operation of the containment facility 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. 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:

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

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 3. The correlations are excellent for Cr, Fe, Ni, 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; however, the relationship is still significant. 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.

Table 3: 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.

$$X = [\ a*\text{Sand} + b*\text{Silt} + c*\text{Clay}\ ]/100$$

	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	1.373
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. A metal concentration can be predicted by substituting the least squares coefficients from Table 3 for the constants in equation 2, and using the measured grain size at the site of interest. 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 HMI.

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

Note: Zn is used in the equation because of its significance in previous studies, however any metal of interest could be used.

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 % 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 ±3σ 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 3. The sigma level for Zn is ~30% (e.g. 1σ = 30%, 2σ = 60%, etc.).

General Results

A listing of the summary statistics for the elements analyzed is given in Table 4. Some features to note are:

1. Cd, Cr, Cu, Ni, Pb and Zn are found at some sites with concentrations that exceed the Effects Range Low (ERL) values; and
2. Ni and Zn exceed the ERM values at some sites.

ERL and Effects Range Medium (ERM) are proposed criteria put forward by National Oceanic and Atmospheric Administration (NOAA - Long et al. 1995) to gauge the potential for deleterious biological effects. Sediments with concentrations below the ERL are considered baseline concentrations with no expected adverse effects. Concentrations between the ERL and ERM may have adverse impacts to benthic organisms, while values greater than the ERM have probable adverse biological effects. These criteria are based on a statistical method of termed preponderance of evidence. The method does not allow for unique basin conditions and does not take into account grain size induced variability in metal concentrations in the sediment. The values are useful as a guide, but are limited in applicability due to regional difference. The grain size normalization procedure outlined in the previous section is a means to correct the deficiencies of the guidelines by taking into account the unique character of Chesapeake Bay sediments and eliminating grain size variability. When the data are normalized, Pb, and to a lesser extent Zn have samples significantly enriched compared to the baseline; however, based on work done in Baltimore Harbor, the normalized values are below anticipated biological effects thresholds.

Table 4: Summary statistics for elements analyzed. ***[All concentrations are in ug/g unless otherwise noted]***

	Cd	**Cr**	**Cu**	**Fe(%)**	**Mn**	**Ni**	**Pb**	**Zn**
Count	72	81	81	81	81	81	81	81
Ave.	1.2	102.4	49.3	4.37	2693	83.4	60.8	321
Std.	0.4	52.0	20.0	1.74	1635	35.6	29.1	155
Min.	0.3	8.0	3.0	0.21	253	7.0	5.4	16
Max.	2.3	341.0	90.0	7.97	8600	167.4	133.4	764
ERL	1.3	81.0	34.0	*n/a*	*n/a*	20.9	46.7	150
#>ERL	31.0	61.0	61.0	*n/a*	*n/a*	75.0	57.0	66
ERM	9.5	370.0	270.0	*n/a*	*n/a*	51.6	218.0	410
#>ERM	0.0	0.0	0.0	*n/a*	*n/a*	65.0	0.0	18
	C(%)	**N(%)**	**S(%)**	**P(%)**				
Count	81	81	81	81				
Ave.	2.877	0.197	0.387	0.085				
Std.	1.226	0.076	0.244	0.035				
Min.	0.116	0.011	0.000	0.006				
Max.	6.071	0.303	1.382	0.173				

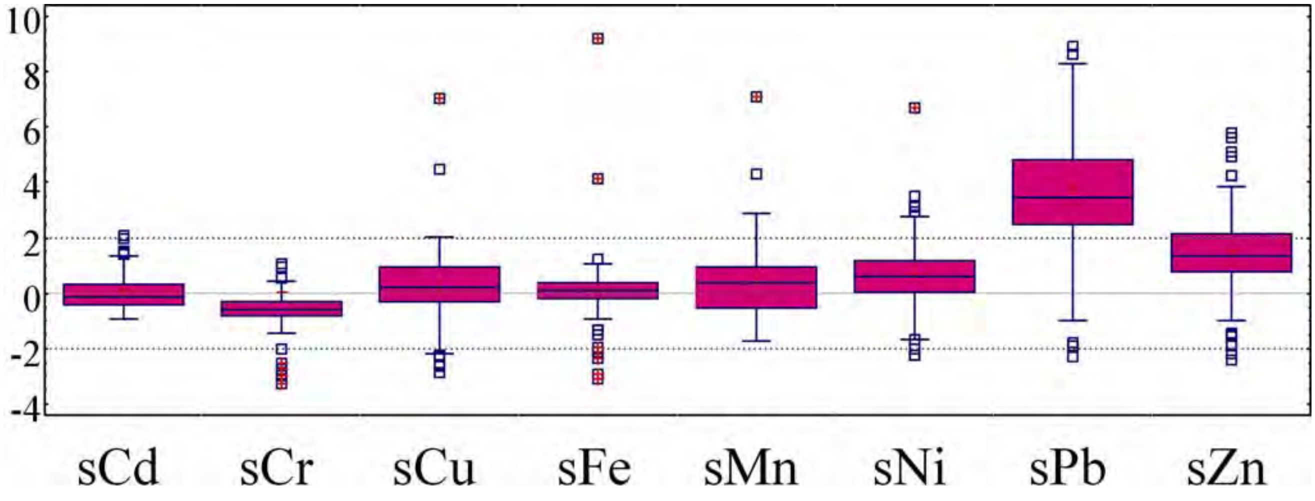


Figure 10: A box and whisker diagram showing the range of the data for both the fall and spring cruise.

The values presented in Table 4 are the measured concentrations of metals in the sediment, not normalized with respect to grain size variability, as outlined in the preceding *Interpretive Techniques* section. Figure 10 shows the variation of the data from the predicted baseline behavior for each of the elements measured. The values are in units of multiples of standard deviations from the norm; zero values indicate measurements that are identical to the predicted baseline behavior, values within plus or minus two (2) sigma are considered to be within the natural variability of the baseline values.

For both sampling cruises, all of the metals except Pb and Zn are within the range expected for normal baseline behavior in the area. Pb has greater than 3/4 of the samples significantly exceeding the baseline levels, and Zn approximately a quarter of the samples. Zn and Pb will be discussed in the following sections.

Metal Distributions

Since the eighth monitoring year, increased metal levels (specifically Zn) have been noted in bottom sediments east and south of spillway #1; similarly since the start of monitoring Pb in Year 15, elevated levels of Pb have been found in the same areas, but generally higher relative loadings. The results of previous monitoring studies have shown that the areal extent and magnitude of metals loadings 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 contribute excess metals to the sediment (see *Twelfth Year Interpretive Report*). The high metal loading to the exterior environment is the result of low input of water, which allows 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 sulfuric acid, which leaches 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, the water throughput (input from dredge disposal to release of excess water) submerges the sediment within the facility, minimizing atmospheric exposure, and dilutes and buffers 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 *10th 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 the facility against the eastern and southeastern perimeter of the facility;
    b. The circulation gyre is modulated 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 facility. Conversely, the lower the flow, the less the compression and the greater the dispersion away from the facility; and
    c. Discharge from the facility 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 modulated the concentration of a

hypothetical conservative species released from the facility; the higher the discharge, the higher the concentration in the plume outside the facility.

3. The positions of the primary discharge points from the facility - 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 spillways #1 and #4 travel in a narrow, highly concentrated band up and down the eastern side of the facility. This explains the location of the areas of periodic high metal enrichment to the east and southeast of the facility; and
    b. Releases from spillway #2 are spread more evenly to the north, east, and west. However, dispersion is not as great as from spillways #1 and #4 because of the lower shearing and straining motions.

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.

Figure11 shows the sigma levels for Pb for Year 23 monitoring periods in the study area adjacent to HMI; sigma levels for Zn are shown in Figure 12. Sigma levels are the multiple of the standard deviation of the baseline data set. Data that falls within +/-2 sigma are considered within normal baseline variability. Data within the 2 -3 sigma range are transitional; statistically one sample in 100 would normally be expected to occur, in a small data set. The occurrence of 2 or more spatially contiguous stations in this range is significant. Any sample >3 sigma is significantly elevated above background. The shading in Figures 11 & 12 is used to highlight the areas that are significantly elevated above baseline levels. As shown in Figure 1 there are three primary areas of interest that will be referred to: Back River, Baltimore Harbor, and HMI.

1. *Back River* - The Back River influence is strongly seen for Pb. Pb apparently is being discharged by Back River during both of the sampling periods with the Early Fall levels being slightly more elevated than the spring, both periods having a similar spatial extent. Zn concentrations were slightly elevated at the mouth of Back River in the Early Fall, but were within background levels for the spring sampling event. The one transitional site near the northwestern side of HMI may be in response to discharge from Spillway #2.

2. *Baltimore Harbor* - Elevated levels of Pb and Zn extend into the area south of HMI. The Zn levels are clearly isolated from the HMI zone of influence adjacent to the island. Pb on the other hand is a more complex. There is a diminishing gradient from Baltimore Harbor, then levels rise again in the HMI zone.

3. *HMI* - The area adjacent to HMI had the higher metals (Pb and Zn) loading than had been seen in several years. Pb reaching levels of 8 sigma in the fall and 7 sigma in the spring, with Zn having levels of 5 and 4 respectively. The Zn signature is clearly differentiated from The Baltimore Harbor influence, while it is not as clear a separation for Pb. In previous monitoring years the Pb gradient from Baltimore Harbor would drop to

> background levels south of HMI, providing a clear separation in source material to the area. However, the gradients and high levels adjacent to HMI indicate that HMI is the source of the high Pb levels.

The distributions of Zn and Pb are similar in that the higher levels are found in the Early Fall sampling (Cruise 49) as compared to the Spring sampling (Cruise 50). Elevated metals levels for Zn and Pb were seen in the three zones as described above. The spatial extent and the levels found in the Baltimore Harbor and Back River zones vary according to seasonal climatic changes, which influence the hydrodynamic conditions and sediment loading, and activity within those sources. Commonly the Late Summer - Early Fall levels are higher than the spring sampling for the Baltimore Harbor and Back River zones; this is the case for this monitoring year.

The HMI zone, prior to Year 22 monitoring, was independent of Baltimore Harbor and Back River inputs. Generally, the levels within the HMI zone are influenced by operations in the facility and input from the regional background (i.e. Susquehanna River). In regard to facility operations, this was a period of low activity in regard to sediment placement within HMI. Most of the monitoring period had no discharge, with one contiguous four (4) month period of no discharge. When discharge occurred it was at rates of less than 10 Mgal/day, except during that last month of the monitoring period where the rates exceeded 40 Mgal/day. Optimum conditions for the establishment of acid leaching occur at discharge rates <10 Mgal/day, in conjunction with dewatering and crust management operations (without sediment input) that have been operating for 6 months or more. These conditions have produced the highest levels of metals in the exterior sedimentary environment during previous monitoring periods. Although not optimal, these conditions were developing in Year 23; the lower flow conditions in the Early Fall would be conducive to higher exterior loadings as compared to the spring cruise. This is seen in the sigma distribution maps for Zn and Pb, Figures 11 and 12. The sigma level is the multiple of the standard deviation from the normal background distribution; samples within plus or minus 2 sigma are within historical background levels, samples greater than three sigma are significantly different from the background behavior. The shaded areas in Figures 11 and 12 are the significantly enriched areas. Aside from the influences of Baltimore and Back River, there are two areas within the HMI influenced zone that are elevated for both Zn and Pb; with Pb exhibiting higher levels for both cruises.

The first area of enrichment within the HMI influenced zone is east of the northern end of HMI, this area has consistently been influenced by discharge by old Spillway #1 (now Spillway #007), as seen in the previous monitoring years. The areal extent and enrichment for Zn in this area is comparable for both sampling periods. Similarly, Pb shows comparable areal extent and enrichment for both cruises. However there is an additional area branching to the north during the spring sampling event. This northern branch is most likely the result of additional activity from Spillway #008 (old Spillway #2), which is on the northern part of HMI.

The other area of enrichment is in the vicinity of Old Spillway 3, part of the South Cell drainage system. This area has the highest levels of Zn and Pb for the Early Fall cruise, and significantly elevated levels in the spring. For Pb, the gradient from this area merges with the elevated area associated with Spillway 007. The South Cell is undergoing final construction for its ultimate use as an upland wetland. It would be reasonable to assume that the levels reflect these operations; however, no discharges are recorded from the South Cell during this period so the source of the sediment enrichment is unclear.

Pb is enriched in the entire area from Baltimore Harbor into the HMI influenced zone. However, based on the gradients the two zones are again distinct. The blanketing effect seen in the higher levels may be, in part, a residual signature in the sediment from the previous year where near record rainfall levels occurred The high rainfall volumes facilitated the transport of material from Baltimore Harbor into the HMI influenced zone for the first time since construction of the facility.

Figure 13 shows the highest level of Zn found within the HMI influenced zone through time. The data from this monitoring year are shown as the solid points. Since the 2002 near-background minimum, there has been a steadily increasing enrichment trend.

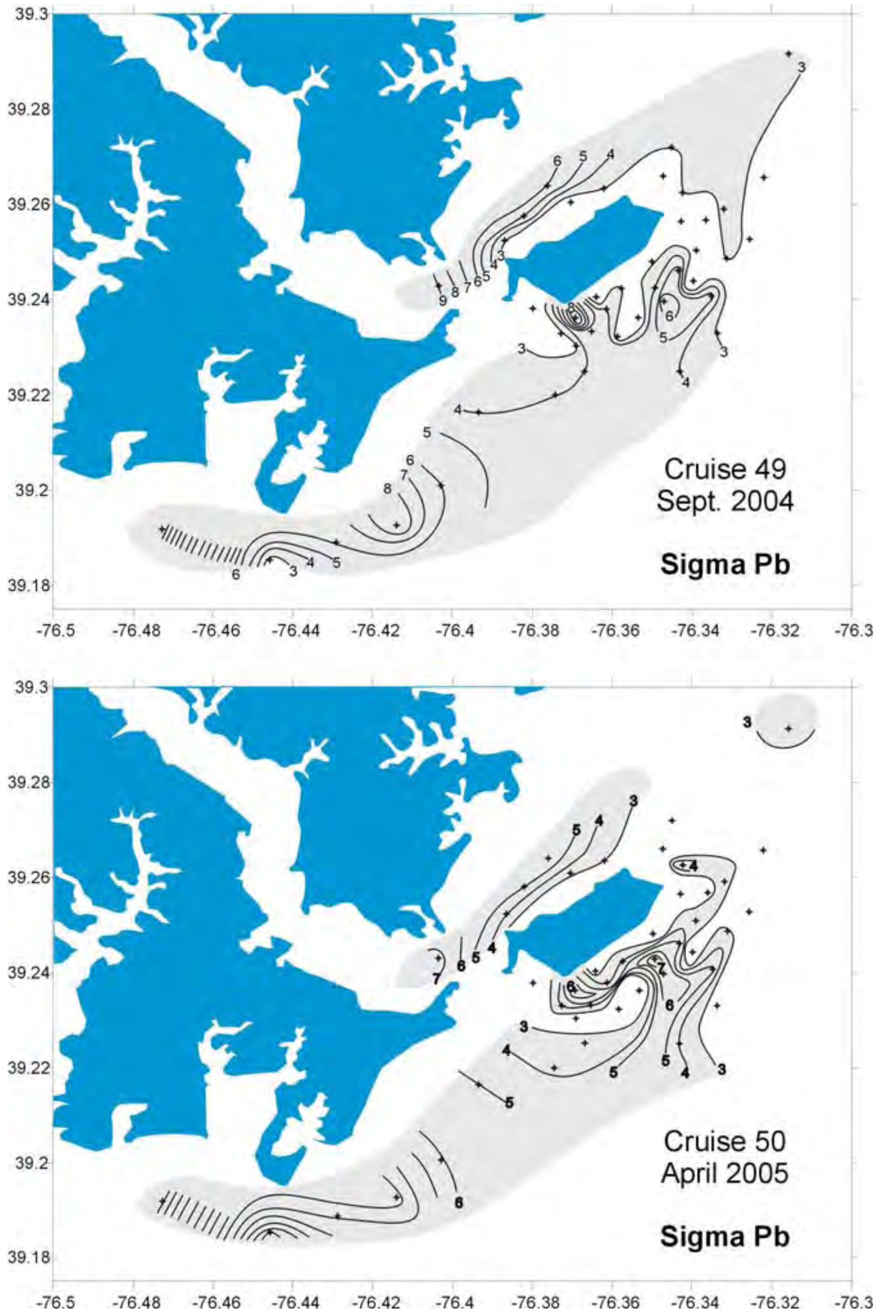


Figure 11: Distribution of Pb in the study area for the fall and spring sampling cruises. Units are in multiples of standard deviations - Sigma levels: 0 = baseline, +/- 2 = baseline, 2-3 = transitional(values less than 3 not shown), >3 = significantly enriched (shaded in figures).

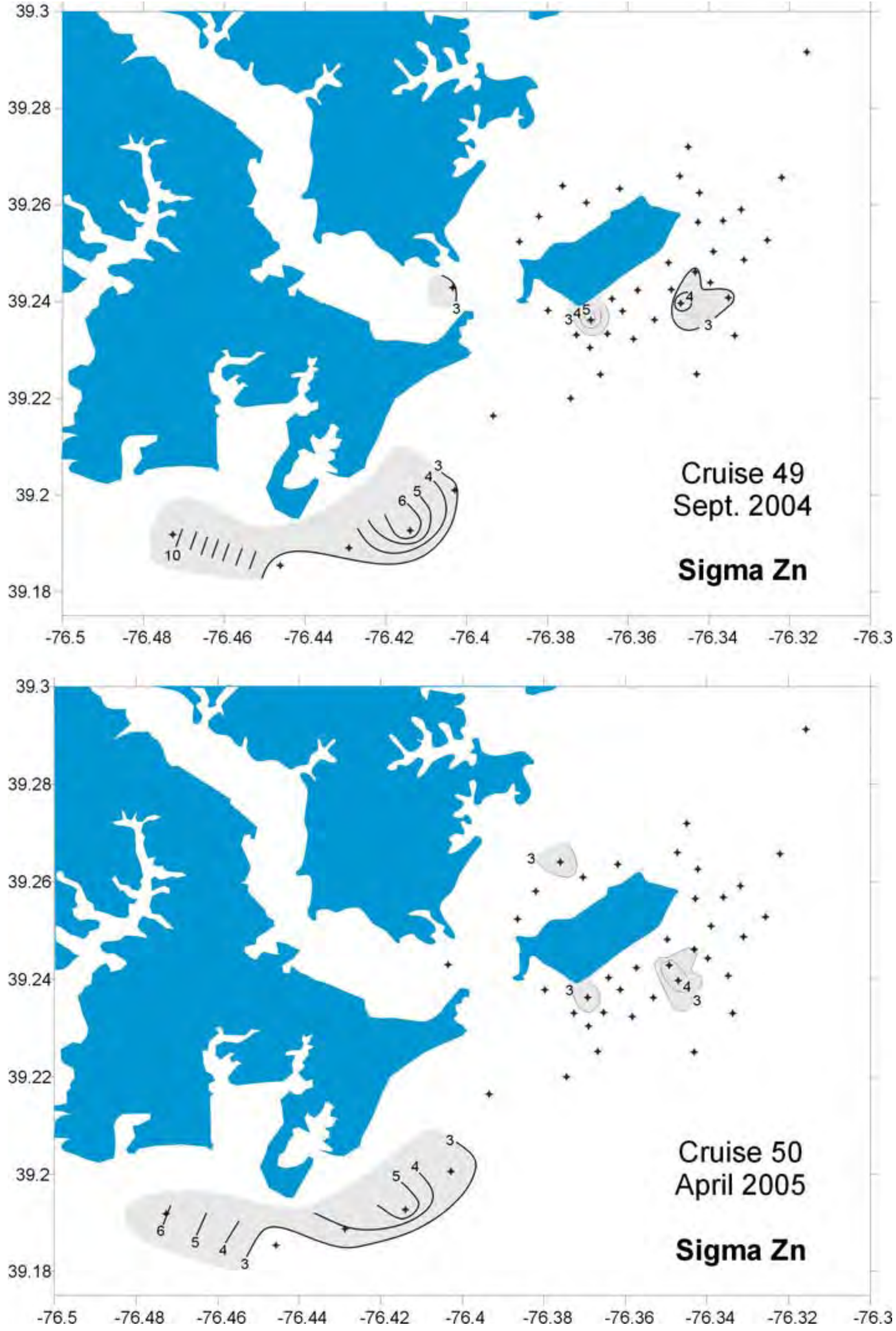


Figure 12: Distribution of Zn in the study area for the fall and spring sampling cruises. Units are in multiples of standard deviations - Sigma levels: 0 = baseline, +/- 2 = baseline, 2-3 = transitional(values less than 3 not shown), >3 = significantly enriched (shaded in figures).

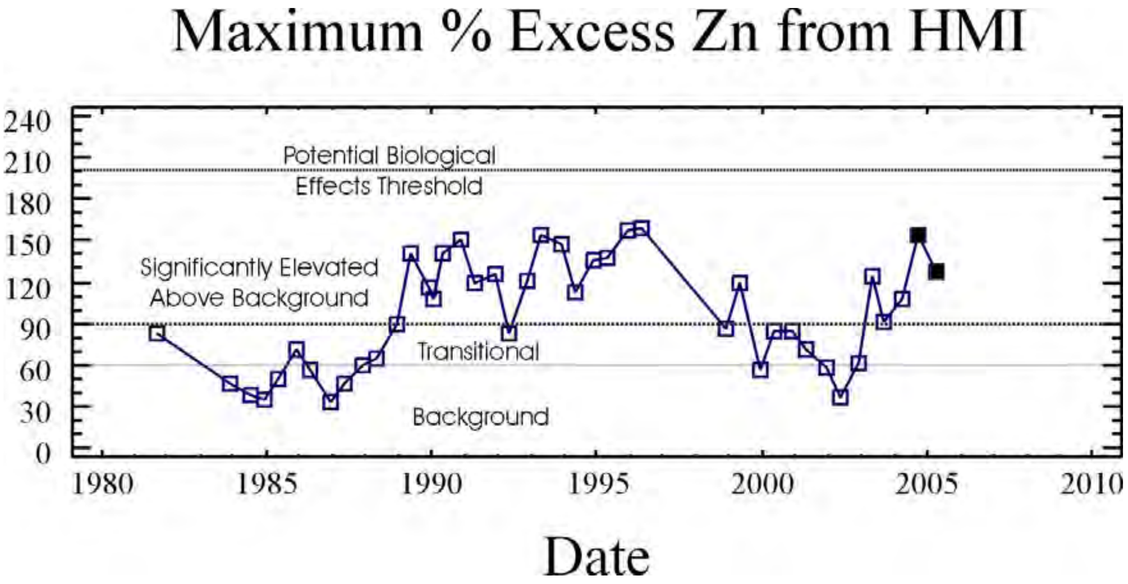


Figure 13: Record of the maximum % Excess Zn for all of the cruises MGS analyzed the sediments.

CONCLUSIONS AND RECOMMENDATIONS

The grain size distribution of the Year 23 sediment samples does not show any clear trends in sedimentation patterns from cruise to cruise. This is due to the complexity of the environmental conditions and source of material to the area. The clay:mud ratios show that the depositional environment was very similar during Year 22 and Year 23. A slight increase in clay content at several stations created a larger area of clay-rich samples in April 2004, which may be due to an increased sediment input from nearby shoreline erosion during Hurricane Isabel coupled with a slightly less turbulent environment during the Spring of 2004. This area continued to be present through monitoring Year 23 with very little change. The general sediment distribution pattern is consistent with the findings of previous monitoring years dating back to 1988 (the second year after the start of release from HMI) and no significant changes occurred during Year 23. The main reason for adding the Baltimore Harbor samples was to determine if the Harbor was a possible source of the trace metals often concentrated in sediments deposited between spillways #3 and #4. As was the case in previous monitoring years, the clay:mud distributions continued to argue against that possibility. In April 2004, there was an increase in the extent of clay-rich sediments in the vicinity of the facility coupled with no changes at the Harbor mouth, again indicating two distinct depositional environments, as has been the case in the past. Presumably, trace metals derived from Baltimore Harbor are more likely to settle with clay-rich sediments at the mouth of the Harbor; whereas, those derived from the containment facility are deposited in the vicinity of the facility. The three stations added in the vicinity of spillway #3 in April 2004 continued to be monitored for Year 23 and will provide a baseline for future samplings in order assess the operation of the South Cell as an environmental restoration project with discharge from this spillway.

With regard to trace metals some features to note are:

1. Cd, Cr, Cu, Ni, Pb and Zn are found at some sites with concentrations that exceed the Effects Range Low (ERL) values; and
2. Ni and Zn exceed the ERM values at some sites.

ERL and Effects Range Medium (ERM) are proposed criteria put forward by National Oceanic and Atmospheric Administration (NOAA - Long et al. 1995) to gauge the potential for deleterious biological effects. Sediments with concentrations below the ERL are considered baseline concentrations with no expected adverse effects. Concentrations between the ERL and ERM may have adverse impacts to benthic organisms, while values greater than the ERM have probable adverse biological effects. These criteria are based on a statistical method of termed preponderance of evidence. The method does not allow for unique basin conditions and does not take into account grain size induced variability in metal concentrations in the sediment. The values are useful as a guide, but are limited in applicability due to regional difference. The grain size normalization procedure outlined in the previous section is a means to correct the deficiencies of the guidelines by taking into account the unique character of Chesapeake Bay sediments and eliminating grain size variability. When the data are normalized, Pb, and Zn have significantly enriched samples compared to the baseline; however, based on work done in Baltimore Harbor, the normalized values are below anticipated biological effects thresholds.

Pb and Zn enriched samples are associated with the three local sources HMI, Baltimore Harbor and Back River. Material from the Harbor does not influence the sediments adjacent to the facility in the proximal zone ascribed to HMI. This is supported by both the sedimentation and metals distribution patterns in the area. The higher levels blanketing the area though may reflect a residual signature from the preceding years' near record rainfall.

In the area effected by facility operations, Zn and Pb both showed enriched levels. The September sampling cruise had higher levels, and a greater areal extent as compared to the April sampling. This is consistent with historical responses of the sedimentary environment to facility operations. Generally, the low flow periods corresponding to crust management periods are conductive to oxidizing the sediments within the facility, which are reflected in enrichment in the exterior sediments. However, due to dredged material inflow occurring over the summer period, conditions were not optimal for the establishment of extensive acid formation so the loadings to the sediment were not at levels of concern.

Persistent elevated metal levels in sediments around HMI indicate a need for continued monitoring. This is emphasized in the increasing trend of metal enrichment since 2002. The metal levels in the exterior sediments continued to show a consistent response to the operations of the facility; low discharge rates increasing the metal loads to the sediment. Currently, the facility is actively accepting material, but the amount of material accepted is declining as the facility reaches its capacity. Consequently, the volume of effluent is declining, dewatering operations will increase which 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 Bay floor and are concentrating the long-term sediment load in the Bay. Continued monitoring is needed in order to; detect if the levels increase to a point where action is required, document the effect that operations has on the exterior environment (for future project design), and to assess the effectiveness of any amelioration protocol implemented by MES to counteract the effects of exposing contained dredged material to the atmosphere. Close cooperation with MES is important in this endeavor.

In order to assess the potential influence of Baltimore Harbor on the HMI exterior sediments better, MGC is suggesting that the additional sampling sites be maintained, at least temporarily. Further, the South Cell has been converted to an environmental restoration project; water will be circulated through the ponds during certain times of the year to produce either mudflats or a ponded area. The additional sample locations near the discharge point should be maintained to assess this new operation of the facility as part of the on-going monitoring program.

In regard to monitoring the discharge from the spillways, a re-evaluation of the sampling frequency and protocols is needed if comparison of the data with historical records is considered important.

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PROJECT 3: BENTHIC COMMUNITY STUDIES
(September 2004 - September 2005)

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ABSTRACT

The benthic macroinvertebrate community in the vicinity of the Hart-Miller Island Dredged Material Containment Facility (HMI) was studied for the twenty-third consecutive year under Project III of the HMI Exterior Monitoring Program. The communities living close to the facility (Nearfield, South Cell Restoration Baseline, and Back River/Hawk Cove stations) were compared to communities located at some distance from the facility (Reference stations). Water quality parameters, including dissolved oxygen concentrations, salinity, temperature, pH, conductivity and secchi depth were measured *in situ.*

Twenty stations (11 Nearfield, 3 Reference, 3 Back River/Hawk Cove stations, and 3 South Cell Restoration Baseline stations) were sampled on September 24, 2004 and on April 13, 2005. Macroinvertebrate samples were collected using a Ponar grab sampler, which collects 0.05 m^2 of substrate. Water quality parameters were measured using a Hydrolab Surveyor II at one-half meter from the bottom and at one-half meter from the surface.

A total of 38 taxa of benthic macroinvertebrates were found at these twenty benthic community stations during Year 22 of monitoring. Several of the 38 taxa were clearly dominant. *Marenzelleria viridis, Rangia cuneata,* Oligochaete worms of the family Tubificidae and *Cyathura polita* were among the numerically dominant taxa on both sampling dates. Only the fifth most dominant species differed between the two sampling seasons; in September 2004 it was *Mytilopsis leucophaeata*, while in April 2005 it was chironomids of the genus *Procladius* (*Holotanypus*). Polychaete taxa richness was similar for the two seasons, although *Streblospio benedicti* was completely absent from the April 2005 sampling. Total abundance of all invertebrates (excluding Bryozoa) was higher at most stations in April 2005 than September 2004 due to high seasonal recruitment, especially of the polychaete worm *M. viridis.*

Species diversity was examined using the Shannon-Wiener diversity index. Diversity was higher in April 2005 at eleven stations, and higher in September 2004 at nine stations. The calculation of the proportion of pollution-sensitive taxa and the proportion of pollution indicative taxa could only be made for two stations (MDE-24 and MDE-27) in the September 2004 sampling. Tidal freshwater conditions prevailed at the other stations in the fall, and at all stations in April 2005. No pollution sensitive taxa have been identified for tidal freshwater in Chesapeake Bay. Calculation of the pollution indicative index for freshwaters requires special mounting procedures and examination of tubificid worms for capilliform chaetae, which was not conducted in Year 23.

The Chesapeake Bay Benthic Index of Biotic Integrity (B-IBI, Weisberg et al. 1997), a multi-metric index of biotic condition that evaluates summer populations (during the July 15th to September 30th timeframe) of benthic macroinvertebrates, was calculated for all stations sampled during the September 2004 cruise. Overall, the Benthic Index of Biotic Integrity scores improved or remained the same when compared to Year 22 and were generally similar to the B-IBI scores of the previous 6 years of monitoring at Hart-Miller Island. This year, nineteen stations exceeded the benchmark criteria of 3.0, and only 1 station failed to meet the benchmark. In contrast to Year 22, in Year 23 there were no significant differences for the ten most abundant infaunal taxa among the four station types, based on results of the nonparametric Friedman's test.

INTRODUCTION

Annual dredging of the shipping lanes leading to the Port of Baltimore is necessary to remove navigation hazards. An average of 4-5 million cubic yards of Bay sediments are dredged each year to maintain access to the Port. This requires the State of Maryland to develop environmentally responsible placement sites for dredged material. In 1981, the Hart-Miller Island Dredged Material Containment Facility (HMI) was constructed to accommodate the dredged material management needs for the Port of Baltimore and specifically the need to manage contaminated sediments dredged from Baltimore's Inner Harbor. HMI is a 1,140-acre artificial island surrounded by a 29,000-foot long berm constructed along the historical footprints of Hart and Miller Islands at the mouth of the Back River. A series of five spillways are located around the facility's perimeter that discharge excess water released from on-site dredged material disposal operations.

As part of the environmental permitting process for dredged material containment facilities, an exterior monitoring program was developed to assess any environmental impacts associated with HMI. Various agencies have worked together since the inception of this program to monitor for environmental impacts resulting from facility construction and dredged material management activities. Studies were completed prior to and during the early construction period to determine baseline environmental conditions in the HMI vicinity. The results of post-construction monitoring have then been compared to this baseline, as well as to interseasonal and interannual data. This report represents the twenty-third consecutive year of the benthic macroinvertebrate community monitoring since 1981. In Year 23, the Maryland Department of the Environment was responsible for all aspects of benthic community monitoring.

The goals of the Year 23 benthic community monitoring were:

- To monitor the benthic community condition in fulfillment of environmental permit requirements;

- To examine the condition of the benthic macroinvertebrate community using, among other analytical tools, the Chesapeake Bay Benthic Index of Biological Integrity (B-IBI; Llanso 2002), and to compare the results at Nearfield stations to present local reference conditions;

- To monitor other potential sources of contamination to the HMI region by sampling transects along the mouth of Back River;

- To facilitate trend analysis by providing data of high quality for comparison with past HMI monitoring studies; and,

- To establish a record of beseline benthic community conditions in a transect leading away from the South Cell spillway #3. This will help the State to assess any environmental impacts resulting from the South Cell closure and restoration.

METHODS AND MATERIALS

For the Year 23 benthic community studies, staff from the Maryland Department of the Environment's Biological Assessment Section collected all macroinvertebrate and water quality samples. Field sampling for both cruises were conducted from the Maryland Department of Natural Resources vessel, the *Kerhin*. The same twenty benthic stations were monitored during both fall and spring seasons (Table 5; Figure 14). Environmental parameters recorded at the time of sample collection are included in Tables 6 through 9.

Table 5: Target Locations (latitudes and longitudes in degrees, decimal minutes), and 7-digit codes of stations used for Year 23 benthic community monitoring and Predominant sediment type at each station for September and April.

Station #	Latitude	Longitude	Sediment Type		Maryland 7-Digit Station Designation
			Fall	Spring	
Nearfield Station					
MDE-01	39^{o} 15.3948	76^{o} 20.568	Sand	Sand	XIF5505
MDE-03	39^{o} 15.5436	76^{o} 19.9026	Sand	Silt/clay	XIG5699
MDE-07	39^{o} 15.0618	76^{o} 20.3406	Silt/clay	Shell	XIF5302
MDE-09	39^{o} 14.7618	76^{o} 20.5842	Silt/clay	Silt/clay	XIF4806
MDE-16	39^{o} 14.5368	76^{o} 21.4494	Silt/clay	Silt/clay	XIF4615
MDE-17	39^{o} 14.1690	76^{o} 21.1860	Silt/clay	Shell	XIF4285
MDE-19	39^{o} 14.1732	76^{o} 22.1508	Silt/clay	Silt/clay	XIF4221
MDE-24	39^{o} 14.2650	76^{o} 22.7862	Silt/clay	Sand	XIF4372
MDE-33	39^{o} 15.9702	76^{o} 20.8374	Sand	Sand	XIF6008
MDE-34	39^{o} 15.7650	76^{o} 20.5392	Sand	Sand	XIF5805
MDE-35	39^{o} 16.3182	76^{o} 20.7024	Silt/clay	Silt/clay	XIF6407
Reference Stations					
MDE-13	39^{o} 13.5102	76^{o} 20.6028	Silt/clay	Silt/clay	XIG3506
MDE-22	39^{o} 13.1934	76^{o} 22.4658	Silt/clay	Silt/clay	XIF3224
MDE-36	39^{o} 17.4768	76^{o} 18.9480	Silt/clay	Silt/clay	XIG7589
Back River/Hawk Cove Stations					
MDE-27	39^{o} 14.5770	76^{o} 24.2112	Silt/clay	Silt/clay	XIF4642
MDE-28	39^{o} 15.3900	76^{o} 22.7304	Silt/clay	Silt/clay	XIF5232
MDE-30	39^{o} 15.8502	76^{o} 22.5528	Silt/clay	Silt/clay	XIF5925
South Cell Restoration Baseline Monitoring Stations					
MDE-42	39^{o} 23.0390	76^{o} 36.9050	Silt/clay	Silt/clay	XIF3879
MDE-43	39^{o} 23.2310	76^{o} 35.8190	Silt/clay	Silt/clay	XIF3985
MDE-44	39^{o} 24.0380	76^{o} 36.3960	Silt/clay	Silt/clay	XIF4482

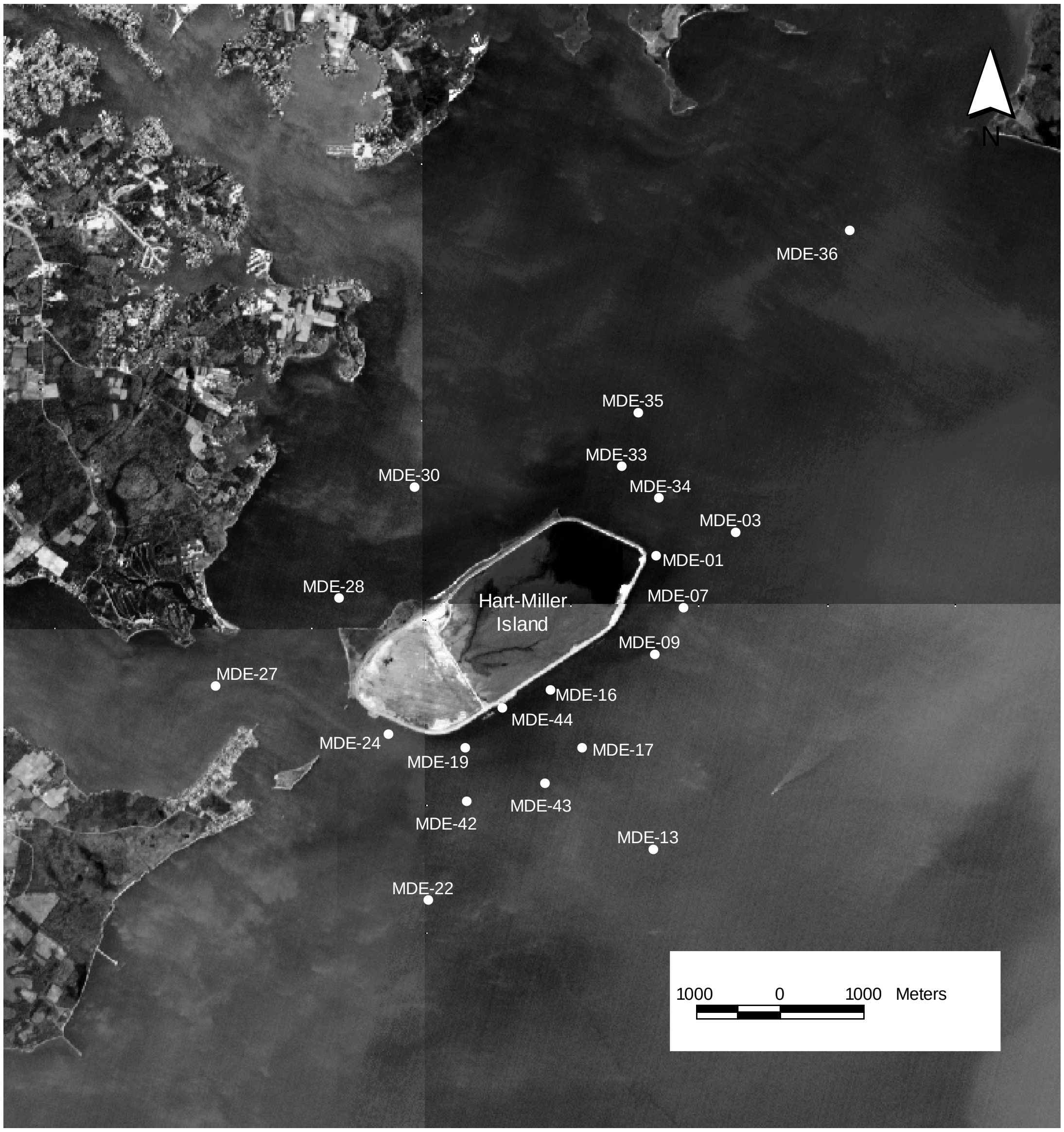

Figure 14: Year 23 Benthic Sampling Stations for the HMI Exterior Monitoring Program.

All stations sampled during Year 22 of monitoring were again sampled for Year 23. Stations were classified by location and dominant sediment type (Table 5). There were four location groups (Nearfield stations, Reference stations, Back River/Hawk Cove stations, and South Cell Restoration Baseline stations) and sediment type (silt/clay, shell, detritus, gravel, and sand). All benthic community sampling stations coincided with stations sampled by the Maryland Geological Survey (MGS) for sedimentary analysis. Stations were located using a differential global positioning system (GPS) navigation unit.

Temperature, depth, salinity, pH, conductivity, and dissolved oxygen were measured *in situ* using a Hydrolab Surveyor II water quality meter in September 2004 and April 2005. Water quality parameters were measured at approximately 0.5 m (1.6 feet) below the surface and 0.5m (1.6 feet) above the bottom. The secchi depth was measured at all stations during both seasons.

All macroinvertebrate samples were collected using a Ponar grab sampler, which collects approximately 0.05 m^2 (0.56 ft^2) of bottom substrate. Three replicate grab samples were collected at all stations. A visual estimate of the substrate composition [percent contributions of detritus, gravel, shell, sand, and silt/clay (mud)] was made at each station (Tables 6 and 8). And the dominant sediment type for each station was derived from these percentages. Each replicate was then individually rinsed through a 0.5-mm sieve on board the vessel and preserved in a solution of 10% formalin and bay water, with rose bengal dye added to stain the benthic organisms.

In the laboratory, each benthic macroinvertebrate replicate was placed into a 0.5-mm sieve and rinsed to remove field preservative and sediment. Organisms were sorted from the remaining debris, separated into vials by major taxonomic groups, and preserved in 70% ethanol. All laboratory staff were required to achieve a minimum baseline sorting efficiency of 95%and quality control checks were performed for every sample to ensure a minimum 90% recovery of all organisms in a replicate sample. For taxonomic, 10% of all samples identified were verified by an independent taxonomist.

Large organisms were identified to the lowest practical taxon using a stereo dissecting microscope. The number of specimens for each taxon collected in each replicate is presented in the Appendix (Tables 20 and 21). Members of the insect family Chironomidae were identified using methods similar to Llanso (2002). Where applicable, chironomids were slide mounted and identified to the lowest practical taxon using a binocular compound microscope. In cases where an animal was fragmented, only the head portion, if fully intact and identifiable, was counted as an individual organism. All other body fragments were discarded. Individuals of the most common clam species (*Rangia cuneata*, *Macoma balthica*, and *Macoma mitchelli*) were measured to the nearest millimeter.

Ten main measures of benthic community condition were examined, including: total infaunal abundance, relative abundance of pollution-indicative infaunal taxa, relative abundance of pollution-sensitive infaunal taxa, the Shannon-Wiener diversity index, abundance of carnivores and omnivores, Tanypodinae to Chironomidae abundance ratio, tolerance score, abundance of deep-deposit feeders, taxa richness, and total abundance of all taxa (excluding Nematoda and Bryozoa). The first eight of these measures were used to calculate the

Chesapeake Bay Benthic Index of Biotic Integrity (B-IBI) for September 2004. The B-IBI is a multi-metric index of biotic integrity used to determine if benthic populations in different areas of the Chesapeake Bay are stressed (Llanso 2002). The B-IBI has not been calibrated for periods outside the summer index period (July 15 through September 30) and, thus, was not used with the April 2005 data. In addition to the above metrics, we examined the numerically dominant taxa during each season and the length frequency distributions of the three most common clams (*R. cuneata*, *M. balthica*, and *M. mitchelli*).

Abundance measures were calculated based on the average abundance of each taxon from the three replicate samples collected at each station. Total Abundance was calculated as the average abundance of epifaunal and infaunal organisms per square meter (#/m^2), excluding Bryozoa, which are colonial. Qualitative estimates (i.e., rare, common or abundant) of the number of live bryozoan zooids are included in the *Year 23 Data Report* (MDE year 22 in review). Total Infaunal Abundance was calculated as the average abundance of infaunal organisms per square meter (#/m^2). Two different measures of total abundance were calculated because epifaunal organisms are not included in the calculation of the B-IBI (Ranasinghe et al. 1994).

Pollution-Sensitive Taxa Abundance was calculated as the percentage of total infaunal abundance represented by pollution-sensitive taxa (the worm *Marenzelleria viridis* and the isopod *Chiridotea almyra*). Pollution-indicative taxa abundance was calculated as the percentage of total infaunal abundance represented by pollution-indicative taxa (the polychaete worms *H. filiformis*, *S. benedicti*, N. *succinea*, P. *cornuta* the oligochaete worms in the family Tubificidae, the amphipod *L. plumulosus* and the chironomids *Coelotanypus* sp., *Polypedulum* sp., and *Procladius* sp.). Taxa were designated as pollution-indicative or pollution-sensitive according to Weisberg et al. (1997).

The Shannon-Wiener Diversity Index (H') was calculated for each station after data conversion to base 2 logarithms (Pielou 1966). Taxa richness (number of taxa) was calculated for each station as the total number of taxa (infaunal and epifaunal) found in all three replicates. Infaunal taxa richness was calculated as the number of infaunal taxa found in all three replicates. The abundance of the three most common taxa at reference and monitoring stations was also examined.

To evaluate the numerical similarity of the infaunal abundances among the 20 stations, a single-linkage cluster analysis was performed on an Euclidean distance matrix comprised of station infaunal abundance values for all 20 stations. This analysis was performed separately for September 2004 and April 2005 data. Friedman’s nonparametric test was used to analyze the differences of the 10 most abundant infaunal species among the Nearfield, Reference, Back River/Hawk Cove, and South Cell Restoration Baseline stations for both September 2004 and April 2005. The statistical analyses were performed using Statistica, Version 6.0.

RESULTS AND DISCUSSION

Water Quality

Variations in secchi depth, salinity, temperature, dissolved oxygen, conductivity, and pH values, indicating no water column stratification. Secchi depths were greater in September 2004 (Table 7, range=0.2 m-1.6 m, average = 0.7m ± 0.35m) than those in April 2005 (Table 9, range=0.20m-0.30m, average=0.25m ± 0.04m). Station MDE-13 had the shallowest Secchi depth (0.2 m) in September 2004. Secchi depth measurements provide a snapshot of the conditions prevalent at the time of sampling, but do not necessarily reflect the dominant water clarity conditions for the entire season.

The following discussion will be limited to bottom values for the first four parameters, because bottom water quality measurements are most relevant for benthic macroinvertebrate health. In Year 23, bottom water temperatures did not vary much between stations during both sampling seasons. The September 2004 bottom water temperatures in Year 23 (Table 7, range= 18.37 °C – 21.47 °C, average=19.98°C ± 0.79°C) were lower than those seen at HMI in the previous five monitoring years. Bottom water temperatures were seasonably lower in April 2005 (Table 9) with a range of 11.02°C –13.41 °C and an average of 12.4°C ± 0.59°C. In addition, the April 2005 bottom water temperatures were lower than those recorded in April 2004.

The bottom dissolved oxygen (DO) concentrations exceeded water quality standards during both seasons. Year 23 bottom DO concentrations were, on average, higher than in most previous years. Bottom DO concentrations were lower in September 2004 (Table 7, range=7.46 ppm-8.60 ppm, average=8.02 ppm ± 0.30 ppm) than in April 2005 (Table 9, range=9.55 ppm-12.08 ppm, average=10.65 ppm ± 0.61 ppm).

In September 2004, the lowest bottom DO concentration was 7.46 ppm, recorded at station MDE-27. This station had the highest temperature (21.47°C) in September 2004. The highest bottom DO concentration in September 2004 (8.60 ppm) was recorded at station MDE-13, which had a bottom temperature of (18.60°C). In April 2005, the lowest bottom DO concentration was 9.55 ppm, recorded at station MDE-42. The highest bottom DO concentration (12.08 ppm) was seen at Station MDE-13, and as expected, it had the lowest bottom temperature (11.02^{o}C). Solubility of oxygen (and other gases) in water decreases as temperature increases, i.e., water temperature is inversely correlated with dissolved oxygen (Smith, 1996). However, the variation in bottom oxygen concentrations observed in Year 23 cannot be completely explained by the relatively minor variation recorded in bottom water temperatures.

This region of the Bay typically ranges between the oligohaline (0.5 ppt – 5 ppt) and mesohaline (>5ppt – 18 ppt) salinity regimes (Lippson and Lippson 1997). In Year 23, salinity measurements were notably lower than those found in the previous 6 years of monitoring. In fact, most stations (18) were within the tidal fresh (0.0 ppt – <0.5) salinity regime on both of the sampling dates (September 24, 2004 and April 13, 2005). Stations MDE-24 and MDE-27 in September 2004 were the only exceptions as they fell within the oligohaline (0.5 ppt – 5 ppt) range. September 2004 salinity values were likely influenced by extensive rainfall due to Hurricane Ivan. Bottom salinity did not vary considerably between September 2004 (7, range=0.0 ppt-0.6 ppt, average=0.23 ppt ± 0.16 ppt) and April 2005 (Table 9, range=0.06 ppt-0.47 ppt, average=0.17 ppt ± 0.12 ppt).

In Year 23, in both September 2004 and in April 2005, the highest bottom salinity was seen at Back River/Hawk Cove station MDE-27 (September 2004 - 0.6 ppt) (April 2005 – 0.47 ppt). This is unusual due to the station's proximity to freshwater discharges emanating from Back River. In September 2004 the lowest salinity was seen at stations MDE-03 and MDE-13 (0.0 ppt for both stations). In April 2005 the lowest salinity occurred at stations MDE-07, MDE-17, MDE-36, and MDE-43 (0.06 ppt for all 4 stations). Except for MDE-36, these stations are not directly located near sources of freshwater and would be expected to have higher salinities due to tidal influence. It is possible, due to the extensive rainfall during Year 23, that freshwater inflow from the Gunpowder River had a further reaching effect on salinities near Hart-Miller Island than in the past.

Table 6: Year 23 Physical parameters measured *in situ* at all HMI stations on September 24, 2004

						Wind Speed (knots)				Weather		Observed Bottom Sediment (%)				
MDE Station	Time	Tide	Water Depth (m)	Wave Height (m)	Wind Direction	Min.	Max	Air Temp. (ºC)	Cloud Cover (%)	Past 24 hrs.	Today	silt/clay	sand	shell	gravel	detritus
MDE-01	10:36	Ebb	3.4	0.0	NW	0	1	20	10	0	0	0	80	20	0	0
MDE-03	10:46	Ebb	5.4	0.0	NW	0	1	20	10	0	0	30	52	15	0	3
MDE-07	10:27	Ebb	4.6	0.0	NW	0	1	20	10	0	0	74	10	15	0	1
MDE-09	10:14	Ebb	5.5	0.0	NW	0	1	20	10	0	0	75	5	15	0	5
MDE-13	9:38	Ebb	3.5	0.0	NW	0	1	20	10	0	0	80	0	18	0	2
MDE-16	10:03	Ebb	4.3	0.0	NW	0	1	20	10	0	0	70	5	20	0	5
MDE-17	9:46	Ebb	4.7	0.0	NW	0	1	20	10	0	0	40	15	40	0	5
MDE-19	9:08	Ebb	4.6	0.0	NW	0	1	20	10	0	0	92	0	7	0	1
MDE-22	8:22	Ebb	5.4	0.0	NW	0	1	19	10	0	0	93	0	5	0	2
MDE-24	8:54	Ebb	2.7	0.0	NW	0	1	20	10	0	0	70	28	1	0	1
MDE-27	12:50	Slack	3.5	0.0	NW	0	1	22	10	0	0	80	0	15	0	5
MDE-28	12:36	Slack	2.6	0.0	NW	0	1	22	10	0	0	80	0	15	0	5
MDE-30	12:16	Slack	2.4	0.0	NW	0	1	22	10	0	0	80	0	15	0	5
MDE-33	11:10	Ebb	2.0	0.0	NW	0	1	20	10	0	0	9	90	0	0	1
MDE-34	11:03	Ebb	2.1	0.0	NW	0	1	20	10	0	0	9	90	0	0	1
MDE-35	11:17	Ebb	3.6	0.0	NW	0	1	22	10	0	0	85	0	5	0	10
MDE-36	11:33	Ebb	3.2	0.0	NW	0	1	22	10	0	0	85	0	5	0	10
MDE-42	8:39	Ebb	3.9	0.0	NW	0	1	20	10	0	0	90	0	9	0	1
MDE-43	9:27	Ebb	4.8	0.0	NW	0	1	20	10	0	0	68	10	20	0	2
MDE-44	9:17	Ebb	4.3	0.0	NW	0	1	20	10	0	0	78	0	20	0	2

Table 7: Year 23 Water quality parameters measured *in situ* at all HMI stations on September 24, 2004.

MDE Station	7-Digit Code	Layer	Depth (m)	Salinity (ppt)	Temp. (C)	Dissolved Oxygen (ppm)	pH	Secchi Depth (m)	Conductivity (µmos/cm)
Nearfield Stations									
MDE-01	XIF5505	Surface	0.5	0.3	20.71	7.71	7.19	1.0	692.0
		Bottom	3.4	0.3	20.56	7.64	7.24		641.0
MDE-03	XIG5699	Surface	0.5	0.0	18.45	7.94	7.24	0.3	156.0
		Bottom	5.4	0.0	18.37	8.40	7.43		156.0
MDE-07	XIF5302	Surface	0.5	0.1	19.32	7.77	7.28	0.5	250.0
		Bottom	4.6	0.1	19.30	7.83	7.40		251.0
MDE-09	XIF4806	Surface	0.5	0.1	19.50	7.66	7.20	0.5	269.0
		Bottom	5.5	0.1	19.40	8.15	7.28		268.0
MDE-16	XIF4615	Surface	0.5	0.2	20.60	7.63	7.26	0.8	583.0
		Bottom	4.3	0.3	20.44	7.74	7.30		702.0
MDE-17	XIF4285	Surface	0.5	0.2	19.56	7.86	7.17	0.4	402.0
		Bottom	4.7	0.2	19.52	8.11	7.26		404.0
MDE-19	XIF4221	Surface	0.5	0.3	20.36	7.72	7.24	0.9	762.0
		Bottom	4.6	0.4	20.30	7.95	7.25		805.0
MDE-24	XIF4372	Surface	0.5	0.5	20.70	8.13	7.27	1.4	962.0
		Bottom	2.7	0.5	20.70	8.54	7.25		966.0
MDE-33	XIF6008	Surface	0.5	0.2	20.30	7.81	7.29	0.8	542.0
		Bottom	2.0	0.2	20.21	7.92	7.31		566.0
MDE-34	XIF5805	Surface	0.5	0.1	19.88	7.69	7.22	0.6	292.0
		Bottom	2.1	0.1	19.87	7.97	7.29		298.0
MDE-35	XIF6407	Surface	0.5	0.1	20.00	7.76	7.24	0.5	322.0
		Bottom	0.6	0.1	19.33	7.80	7.36		223.0
Reference Stations									
MDE-13	XIG3506	Surface	0.5	0.0	18.60	8.53	7.22	0.2	205.0
		Bottom	3.5	0.0	18.60	8.60	7.32		208.0
MDE-22	XIF3224	Surface	0.5	0.2	19.69	7.99	6.94	0.4	498.0
		Bottom	5.4	0.2	19.67	8.30	6.95		502.0
MDE-36	XIG7589	Surface	0.5	0.1	20.77	7.90	7.28	0.6	236.0
		Bottom	3.2	0.1	20.00	7.94	7.36		244.0
Back River/Hawk Cove Stations									
MDE-27	XIF4642	Surface	0.5	0.6	22.08	7.51	7.27	0.8	1263.0
		Bottom	3.5	0.6	21.47	7.46	7.29		1249.0
MDE-28	XIF5232	Surface	0.5	0.4	21.20	7.90	7.42	1.6	946.0
		Bottom	2.6	0.4	21.10	8.00	7.41		945.0
MDE-30	XIF5925	Surface	0.5	0.3	21.90	8.13	7.43	0.7	600.0
		Bottom	2.4	0.3	20.90	8.25	7.41		748.0
South Cell Restoration Baseline Monitoring Stations									
MDE-42	XIF3879	Surface	0.5	0.2	19.50	7.90	7.09	0.4	435.0
		Bottom	3.9	0.2	19.50	8.15	7.10		432.0
MDE-43	XIF3985	Surface	0.5	0.2	19.50	7.97	7.19	0.4	488.0
		Bottom	4.8	0.2	19.90	7.92	7.23		491.0
MDE-44	XIF4482	Surface	0.5	0.3	20.38	7.70	7.24	0.7	766.0
		Bottom	4.3	0.3	20.37	7.70	7.28		770.0

Table 8: Year 23 Physical parameters measured *in situ* at all HMI stations on April 13, 2005.

MDE Station	Time	Tide	Water Depth (m)	Wave Height (m)	Wind Direction	Wind Speed (knots)		Air Temp (ºC)	Cloud Cover (%)	Weather		Observed Bottom Sediment (%)				
						Min.	Max.			Past 24 hrs.	Today	silt/clay	sand	shell	gravel	detritus
MDE-01	10:20	Flood	4.4	0.5	NE	5	8	7	10	0	0	15	85	0	0	0
MDE-03	10:27	Flood	5.9	0.5	NE	5	8	10	10	0	0	85	0	15	0	0
MDE-07	10:10	Flood	5.0	0.3	NE	5	8	7	10	0	0	40	20	40	0	0
MDE-09	10:01	Flood	5.5	0.5	NE	5	8	7	20	0	0	80	0	15	0	5
MDE-13	9:30	Flood	4.0	0.5	NE	5	8	5	20	0	0	95	0	5	0	0
MDE-16	9:51	Flood	4.3	0.2	NE	5	8	7	20	0	0	80	0	20	0	0
MDE-17	9:45	Flood	4.8	0.5	NE	5	8	7	20	0	0	50	0	50	0	0
MDE-19	8:57	Flood	5.0	0.2	NE	5	8	5	20	0	0	90	0	10	0	0
MDE-22	8:18	Flood	3.0	0.5	NE	5	8	5	20	0	0	90	0	10	0	0
MDE-24	8:45	Flood	2.1	0.2	NE	5	8	5	20	0	0	5	90	5	0	0
MDE-27	12:13	Ebb	3.9	0.1	NE	5	8	10	10	0	0	95	0	2.5	0	2.5
MDE-28	11:58	Ebb	2.7	0.2	NE	5	8	10	10	0	0	85	0	15	0	0
MDE-30	11:47	Ebb	3.2	0.1	NE	5	8	10	10	0	0	60	0	40	0	0
MDE-33	10:56	Flood	2.3	0.2	NE	5	8	10	20	0	0	0	85	10	0	5
MDE-34	10:36	Flood	2.2	0.2	NE	5	8	10	20	0	0	10	75	10	0	5
MDE-35	11:05	Flood	3.8	0.2	NE	5	8	10	20	0	0	80	0	20	0	0
MDE-36	11:23	Slack	3.4	0.2	NE	5	8	10	20	0	0	65	0	35	0	0
MDE-42	8:34	Flood	4.7	0.5	NE	5	8	5	20	0	0	90	0	10	0	0
MDE-43	9:15	Flood	4.5	0.5	NE	5	8	5	20	0	0	85	0	15	0	0
MDE-44	9:05	Flood	4.5	0.5	NE	5	8	5	20	0	0	60	30	5	0	5

Table 9: Water quality parameters measured *in situ* at all HMI stations on April 13, 2005.

MDE Station	7-Digit Code	Layer	Depth (m)	Salinity (ppt)	Temp. (C)	Dissolved Oxygen (ppm)	pH	Secchi Depth (m)	Conductivity (μmos/cm)
Nearfield Stations									
MDE-01	XIF5505	Surface	0.5	0.20	12.71	9.91	7.74	0.20	391.4
		Bottom	3.71	0.19	12.68	10.31	7.75		382.3
MDE-03	XIG5699	Surface	0.5	0.07	11.80	10.57	7.80	0.20	155.5
		Bottom	5.21	0.07	11.77	10.77	7.91		152.5
MDE-07	XIF5302	Surface	0.5	0.06	11.97	10.39	7.82	0.20	138.4
		Bottom	4.21	0.06	11.93	10.74	7.91		139.0
MDE-09	XIF4806	Surface	0.5	0.07	11.91	10.53	7.84	0.25	160.7
		Bottom	5.38	0.07	11.82	10.89	7.94		157.4
MDE-16	XIF4615	Surface	0.5	0.17	12.70	10.10	7.78	0.25	351.7
		Bottom	4.16	0.17	12.67	10.39	7.79		347.5
MDE-17	XIF4285	Surface	0.5	0.06	12.02	10.54	7.81	0.20	146.5
		Bottom	4.46	0.06	11.97	11.20	7.88		148.1
MDE-19	XIF4221	Surface	0.5	0.21	12.75	10.08	7.80	0.25	409.0
		Bottom	4.90	0.20	12.73	11.04	7.81		401.9
MDE-24	XIF4372	Surface	0.5	0.29	12.98	10.05	7.66	0.25	574.9
		Bottom	1.95	0.33	13.04	10.15	7.60		628.8
MDE-33	XIF6008	Surface	0.5	0.21	12.73	9.89	7.80	0.30	424.9
		Bottom	2.00	0.21	12.79	10.12	7.82		426.2
MDE-34	XIF5805	Surface	0.5	0.19	12.72	9.89	7.70	0.20	378.5
		Bottom	2.45	0.19	12.70	9.95	7.69		378.8
MDE-35	XIF6407	Surface	0.5	0.10	12.36	10.23	7.83	0.30	211.0
		Bottom	3.35	0.10	12.37	10.57	7.88		217.6
Reference Stations									
MDE-13	XIG3506	Surface	0.5	0.11	11.05	10.92	7.68	0.20	227.3
		Bottom	3.91	0.10	11.02	12.08	7.73		224.4
MDE-22	XIF3224	Surface	0.5	0.08	12.17	9.47	7.62	0.30	183.6
		Bottom	3.00	0.08	12.15	10.40	7.65		179.0
MDE-36	XIG7589	Surface	0.5	0.06	11.95	10.61	7.83	0.20	134.8
		Bottom	2.08	0.06	11.94	11.12	7.88		134.5
Back River/Hawk Cove Stations									
MDE-27	XIF4642	Surface	0.5	0.43	13.45	10.18	8.05	0.30	837.3
		Bottom	3.85	0.47	13.41	10.28	7.97		899.5
MDE-28	XIF5232	Surface	0.5	0.42	13.12	10.01	7.88	0.30	812.5
		Bottom	2.41	0.42	13.05	10.40	7.81		813.1
MDE-30	XIF5925	Surface	0.5	0.30	12.27	10.10	7.75	0.30	583.7
		Bottom	3.11	0.28	13.22	10.37	7.75		553.5
South Cell Restoration Baseline Monitoring Stations									
MDE-42	XIF3879	Surface	0.5	0.10	12.34	9.52	7.78	0.25	210.0
		Bottom	4.20	0.10	12.35	9.55	7.81		207.7
MDE-43	XIF3985	Surface	0.5	0.06	11.92	10.61	7.66	0.25	138.5
		Bottom	4.30	0.06	11.93	11.84	7.72		140.1
MDE-44	XIF4482	Surface	0.5	0.17	12.71	10.07	7.86	0.25	349.4
		Bottom	4.45	0.19	12.69	10.81	7.91		379.7

Benthic Macroinvertebrate Community

Taxa Richness and Dominance

A total of 38 taxa were found over the two seasons of sampling during Year 23. This is similar to but less than the previous three years where Year 22 had a total of 45 taxa, Year 21 had a total of 43 taxa, and Year 20 had a total of 41 taxa (these lower numbers of total taxa compared to the past two years may be attributable to the fact that we dropped the Harbor transect stations in Year 23. In terms of station type, three taxa were found only at Silt/Clay stations. These three taxa were: *Macoma balthica, Amphicteis floridus,* and an undetermined species from the phylum *Cladocera.* In addition, two taxa were only found at Sand stations. These two taxa were: *Parahaustorius holmesi* and a Chironomid sp. from the *Polypedulum halterale Group*. In terms of station type, Five taxa were only found at Nearfield stations. These Five taxa were: *Balanus subalbidus, Parahaustorius holmesi, Neanthes succinea*, *Ischadium recurvum*, and a Chironomid sp. from the *Polypedulum halterale* Group. In addition, an undetermined species from the phylum *Cladocera* was only found at Back River/Hawk Cove stations.

The most common taxa were members of the phyla Arthropoda (joint-legged organisms), Annelida (segmented worms), and Mollusca (shellfish having two separate shells joined by a muscular hinge). Twenty-three species of Arthropoda were found in the course of the study. This is higher than the twenty species found in Year 22. The most common types of arthropods were the amphipods (such as *Leptocheirus plumulosus*) and the isopods (such as *C. polita*). Six species of annelid worms in the class Polychaeta were found. This is the same as the six species of polychaetes found in Year 22. Polychaete Taxa Richness was higher (6 species) in September 2004 than in April 2005 (5 species). *G. solitaria*, and *E. heteropoda* which were not found in Year 22, were also absent in Year 23. This may have been due to the lower salinities that existed in the upper bay during the Year 23 sampling period. Four species of bivalve mollusks were found. Bivalve mollusk taxa richness in Year 23 (4) was less than that of year 22 (6). However, bivalve mollusk average abundances were lower in April 2005 that in September 2004 (Tables 10 and 11). This may have been due to a winter die-off of bivalve mollusks (Poukish, personal comm.).

Table 10: Average and total abundance (individuals per square meter) of each taxon found at HMI during the September 2004 sampling; by substrate and station type. Taxa in bold are pollution sensitive while taxa highlighted in gray are pollution tolerant.

			Average Abundance by Dominant Substrate			Average Abundance by Station Type			
Taxon	**Average Abundance, All stations**	**Total Abundance, All stations**	**Silt/Clay**	**Shell**	**Sand**	**Nearfield**	**Ref.**	**Back River**	**South Cell Restoration Baseline**
Nemata	16.0	320.0	22.4	0.0	1.3	17.5	0.0	42.7	0.0
Carinoma tremophoros	3.2	64.0	2.7	12.8	2.6	4.1	6.4	0.0	0.0
Bivalvia	4.5	89.6	3.7	32.0	1.3	3.5	10.7	2.1	4.3
Macoma balthica	**7.4**	**147.2**	**10.5**	**0.0**	**0.0**	**0.0**	**25.6**	**2.1**	**21.3**
Rangia cuneata	**1731.2**	**34624.0**	**1874.7**	**204.8**	**1634.6**	**1171.2**	**1787.7**	**3584.0**	**1875.2**
Ischadium recurvum	1.0	19.2	0.5	0.0	2.6	1.7	0.0	0.0	0.0
Mytilopsis leucophaeata	77.4	1548.8	65.8	51.2	115.2	115.8	19.2	55.5	17.1
Amphicteis floridus	21.4	428.8	30.6	0.0	0.0	0.0	23.5	91.7	27.7
Heteromastus filiformis	0.6	12.8	0.0	0.0	2.6	1.2	0.0	0.0	0.0
Spionidae	0.3	6.4	0.5	0.0	0.0	0.6	0.0	0.0	0.0
Marenzellaria viridis	**388.8**	**7776.0**	**404.1**	**204.8**	**382.7**	**366.0**	**520.5**	**268.8**	**460.8**
Streblospio benedicti	73.3	1465.6	80.5	128.0	42.2	87.9	117.3	23.5	25.6
Polydora cornuta	2.9	57.6	2.3	6.4	3.8	4.1	4.3	0.0	0.0
Nereididae	1.6	32.0	0.9	6.4	2.6	2.9	0.0	0.0	0.0
Neanthes succinea	1.0	19.2	0.5	6.4	1.3	1.7	0.0	0.0	0.0
Tubificidae	239.4	4787.2	224.5	230.4	282.9	235.1	450.1	89.6	194.1
Amphipoda	4.5	89.6	4.1	0.0	6.4	5.2	6.4	4.3	0.0
Gammaridea	4.2	83.2	1.4	0.0	12.8	5.8	2.1	0.0	4.3
Ameroculodes spp complex	34.6	691.2	41.6	0.0	21.8	24.4	53.3	42.7	44.8
Leptocheirus plumulosus	19.8	396.8	28.3	0.0	0.0	5.2	36.3	42.7	34.1
Gammarus sp.	19.5	390.4	12.8	6.4	41.0	25.0	17.1	8.5	12.8
Melitadae	0.3	6.4	0.0	0.0	1.3	0.6	0.0	0.0	0.0
Melita nitida	30.4	608.0	9.1	0.0	96.0	53.5	4.3	2.1	0.0
Apocorophium lacustre	3.5	70.4	2.7	0.0	6.4	2.9	4.3	0.0	8.5
Cyathura polita	**214.4**	**4288.0**	**208.5**	**300.8**	**213.8**	**252.5**	**198.4**	**157.9**	**147.2**
Edotia triloba	57.0	1139.2	53.0	44.8	70.4	49.5	38.4	108.8	51.2
Chiridotea almyra	**27.2**	**544.0**	**2.3**	**0.0**	**102.4**	**47.7**	**2.1**	**4.3**	**0.0**
Balanus improvisus	25.9	518.4	2.3	38.4	89.6	46.5	2.1	0.0	0.0
Balanus subalbidus	4.5	89.6	0.0	12.8	15.4	8.1	0.0	0.0	0.0
Xanthidae	0.3	6.4	0.5	0.0	0.0	0.0	0.0	2.1	0.0
Rhithropanopeus harrisii	13.8	275.2	6.4	32.0	30.7	22.7	8.5	0.0	0.0

Table 10: Continued.

Taxon	Average Abundance, All stations	Total Abundance, All stations	Average Abundance by Substrate			Average Abundance by Station Type			
			Silt/ Clay	Shell	Sand	Nearfield	Ref.	Back River	South Cell Restoration Baseline
Membranipora sp	+	+	+	+	+	+	+	0.0	+
Chironomidae	0.6	12.8	0.5	0.0	1.3	0.6	2.1	0.0	0.0
Coelotanypus sp.	23.0	460.8	32.5	6.4	0.0	10.5	6.4	98.1	10.7
Cryptochironomus sp.	0.3	6.4	0.5	0.0	0.0	0.0	0.0	2.1	0.0
Procladius sp.	1.3	25.6	1.8	0.0	0.0	1.7	0.0	2.1	0.0
Procladius (Holotanypus) sp.	0.3	6.4	0.5	0.0	0.0	0.6	0.0	0.0	0.0
Polypedulum halterale Group	0.3	6.4	0.0	0.0	1.3	0.6	0.0	0.0	0.0

Table 11: Average and total abundance (individuals per square meter) of each taxon found at HMI during Year 23 Spring sampling, April 2005, by substrate and station type. Taxa in bold are pollution sensitive while taxa highlighted in gray are pollution tolerant.

			Average Abundance by Dominant Substrate			Average Abundance by Station Type			
Taxon	Average Abundance All	Total Abundance All	Silt/Clay	Shell	Sand	Near-field	Ref.	Back River	South Cell Restoration Baseline
Nemata	40.6	812.8	56.2	0.0	6.4	24.4	0.0	179.2	2.1
Carinoma tremophoros	3.8	76.8	5.0	3.2	0.0	2.3	8.5	2.1	6.4
Bivalvia	9.9	198.4	13.7	3.2	0.0	1.7	2.1	38.4	19.2
Macoma balthica	**5.8**	**115.2**	**8.2**	**0.0**	**0.0**	**0.6**	**27.7**	**2.1**	**6.4**
Rangia cuneata	**307.8**	**6156.8**	**339.7**	**102.4**	**299.2**	**226.9**	**539.7**	**565.3**	**115.2**
Ischadium recurvum	0.3	6.4	0.5	0.0	0.0	0.6	0.0	0.0	0.0
Mytilopsis leucophaeata	18.2	364.8	14.6	73.6	3.2	25.6	4.3	21.3	2.1
Heteromastus filiformis	1.3	25.6	0.5	0.0	4.8	1.7	0.0	0.0	2.1
Spionidae	21.4	428.8	14.2	16.0	49.6	26.2	19.2	4.3	23.5
Marenzellaria viridis	**2009.3**	**40185.6**	**1543.8**	**2931.2**	**3177.6**	**2122.5**	**1324.8**	**533.3**	**3754.7**
Nereididae	1.6	32.0	2.3	0.0	0.0	2.9	0.0	0.0	0.0
Neanthes succinea	1.0	19.2	0.0	9.6	0.0	1.7	0.0	0.0	0.0
Tubificidae	247.7	4953.6	288.9	272.0	91.2	207.7	339.2	134.4	416.0
Amphipoda	5.8	115.2	3.7	32.0	0.0	7.6	4.3	2.1	4.3
Ameroculodes spp complex	32.6	652.8	26.1	19.2	62.4	41.3	34.1	6.4	25.6
Leptocheirus plumulosus	39.7	793.6	54.9	0.0	6.4	9.3	14.9	202.7	12.8
Gammarus sp	17.0	339.2	14.2	54.4	8.0	16.3	23.5	19.2	10.7
Melita nitida	13.1	262.4	7.3	76.8	1.6	17.5	0.0	21.3	2.1
Corophiidae	0.3	6.4	0.5	0.0	0.0	0.0	2.1	0.0	0.0
Apocorophium lacustre	9.9	198.4	8.2	25.6	8.0	9.3	8.5	6.4	17.1
Cyathura polita	**186.6**	**3731.2**	**191.5**	**348.8**	**88.0**	**201.9**	**202.7**	**115.2**	**185.6**
Edotea triloba	10.2	204.8	12.8	0.0	6.4	2.9	4.3	46.9	6.4
Chiridotea almyra	**9.9**	**198.4**	**4.1**	**0.0**	**35.2**	**14.5**	**0.0**	**0.0**	**12.8**
Balanus improvisus	1.9	38.4	1.8	6.4	0.0	3.5	0.0	0.0	0.0
Balanus subalbidus	1.3	25.6	0.0	12.8	0.0	2.3	0.0	0.0	0.0
Rhithropanopeus harrisii	6.1	121.6	3.2	38.4	0.0	9.3	2.1	0.0	4.3
Membranipora sp	+	+	+	+	+	+	+	0.0	+
Chironomidae	6.4	128.0	6.4	3.2	8.0	7.0	0.0	14.9	2.1
Tanypodinae	0.6	12.8	0.9	0.0	0.0	0.0	4.3	0.0	0.0
Orthocladiinae	0.6	12.8	0.9	0.0	0.0	0.0	2.1	2.1	0.0
Coelotanypus sp.	29.4	588.8	42.1	0.0	0.0	8.1	17.1	136.5	12.8

Table 11: Continued.

Taxon	Average Abundance All	Total Abundance All	Average Abundance by Substrate			Average Abundance by Station Type			
			Silt/ clay	Shell	Sand	Nearfield	Ref.	Back River	South Cell Restoration Baseline
Procladius sp.	6.4	128.0	9.1	0.0	0.0	1.7	27.7	4.3	4.3
Procladius(Holotanypus) sp.	78.1	1561.6	106.1	35.2	1.6	46.5	125.9	183.5	40.5
Chironominae	3.2	64.0	2.3	0.0	8.0	4.7	2.1	2.1	0.0
Cryptochironomus sp.	7.4	147.2	6.4	3.2	12.8	7.0	4.3	14.9	4.3
Cricotopus sp.	1.0	19.2	0.5	6.4	0.0	1.2	2.1	0.0	0.0
Rheotanytarsus sp.	4.5	89.6	2.7	0.0	12.8	5.2	2.1	8.5	0.0
Polypedulum Uresipedulum flavum	3.5	70.4	0.5	6.4	12.8	5.8	0.0	2.1	0.0
Harnischia sp.	6.7	134.4	9.1	0.0	1.6	1.2	2.1	36.3	2.1
Copepoda	+	+	+	+	+	+	+	+	+
Parahaustorius holmesi	1.0	19.2	0.0	0.0	4.8	1.7	0.0	0.0	0.0
Chironomidae Pupae	0.3	6.4	0.5	0.0	0.0	0.0	0.0	2.1	0.0
Hydrozoa	15.4	307.2	5.5	115.2	0.0	25.0	0.0	0.0	10.7
Amphicteis floridus	21.8	435.2	31.1	0.0	0.0	1.2	66.1	70.4	4.3
Cyclaspis varians	0.6	12.8	0.5	3.2	0.0	0.6	2.1	0.0	0.0
Polydora cornuta	1.0	19.2	0.5	6.4	0.0	1.2	0.0	0.0	2.1
Cladocera sp.	0.3	6.4	0.5	0.0	0.0	0.0	0.0	2.1	0.0

Of the 38 taxa found in Year 23, twenty-five are considered truly infaunal, ten are considered epifaunal, and the remaining three are considered too general to classify as either infaunal or epifaunal (see Ranasinghe et al. 1994). The most common infaunal species found during Year 23 were the polychaete worm *M. viridis*, worms from the family Tubificidae, the bivalve *R. cuneata*, and the isopod *C. polita*. The most common epifaunal species was the bivalve *M. leucophaeata*. Epifaunal taxa, such as the barnacles (*B. improvisus* and *B. subalbidus*), and mud crabs (*Rhithropanopeus harrisii*), were found more often at stations where the substrate contained a large amount of shell (Tables 10 and 11).

Nearfield stations MDE-01 and MDE-09 had the highest number of taxa in September 2004 (19 taxa), followed by the Reference station MDE-13 and Back River/Hawk Cove Station MDE-27 (18 taxa) (Table 3-6). The stations with the fewest number of taxa in September 2004 of Year 23 was Back River/Hawk Cove Station MDE-30 (9 taxa), Nearfield stations MDE-33 and MDE-34, and Back River/Hawk Cove Station MDE-28 (10 taxa, Table 3-6). Overall, average taxa richness was highest at the Back River/Hawk Cove stations but did not vary greatly between stations types (average taxa richness: Back River/Hawk Cove=16 taxa, Nearfield=15 taxa, Reference=15 taxa, South Cell Restoration Baseline Monitoring=15 taxa).

Table 12: Summary of metrics for each HMI benthic station surveyed during the Year 23late summer sampling cruise, September 2004. Total Infaunal Abundance and Total Abundance, excluding Polycladida, Nematoda, and Bryozoa, are individuals per square meter.

Station	Total Infauna	Total All	All Taxa	Infaunal Taxa	Shannon-Wiener	PSTA	PITA	Tolerance Score	% Carnivore/ Omnivore	Tanypodinae: Chironomidae	B-IBI
Nearfield Stations											
MDE-01	1056	2604.8	19	10	2.66	n/a	n/a	6.00	n/a	n/a	5
MDE-03	3180.8	3468.8	13	8	2.22	n/a	n/a	6.00	n/a	n/a	5
MDE-07	1305.6	1433.6	14	9	2.38	n/a	n/a	6.00	n/a	n/a	5
MDE-09	1811.2	2444.8	19	13	2.61	n/a	n/a	6.31	n/a	n/a	5
MDE-16	1862.4	1971.2	17	11	2.44	n/a	n/a	6.07	n/a	n/a	5
MDE-17	1113.6	1312	16	10	2.52	n/a	n/a	6.01	n/a	n/a	5
MDE-19	608	684.8	13	8	2.59	n/a	n/a	6.09	n/a	n/a	4
MDE-24	2848	3155.2	12	9	1.96	15.28	13.03	6.00	10.75	0	4
MDE-33	4812.8	4838.4	10	8	0.61	n/a	n/a	6.01	n/a	n/a	4.5
MDE-34	1817.6	1843.2	10	7	1.14	n/a	n/a	6.00	n/a	n/a	5
MDE-35	4320	4352	14	10	0.88	n/a	n/a	6.01	n/a	n/a	4.5
MEANS	2248.7	2555.3	14	9	2.00	n/a	n/a	6.05	n/a	n/a	4.7
Reference Stations											
MDE-13	1638.4	1753.6	18	11	2.66	n/a	n/a	6.00	n/a	n/a	5
MDE-22	2470.4	2515.2	11	10	2.52	n/a	n/a	6.00	n/a	n/a	5
MDE-36	5664	5753.6	12	9	1.09	n/a	n/a	6.00	n/a	n/a	4.0
MEANS	3257.6	3340.8	14	10	2.09	n/a	n/a	6.00	n/a	n/a	4.7
Back River/Hawk Cove Stations											
MDE-27	6220.8	6534.4	18	14	1.48	9.77	5.35	6.01	5.48	85.71	2.3
MDE-28	6233.6	6425.6	10	7	0.46	n/a	n/a	6.00	n/a	n/a	4.5
MDE-30	812.8	819.2	9	8	2.32	n/a	n/a	6.07	n/a	n/a	4.5
MEANS	4422.4	4593.1	12	10	1.42	n/a	n/a	6.03	n/a	n/a	3.8
South Cell Restoration Baseline Monitoring Stations for South Cell											
MDE-42	4537.6	4633.6	15	11	1.30	n/a	n/a	6.00	n/a	n/a	4.5
MDE-43	3072.0	3168.0	15	11	1.67	n/a	n/a	6.00	n/a	n/a	5
MDE-44	953.6	1017.6	12	9	2.73	n/a	n/a	6.00	n/a	n/a	4.5
MEANS	2854.4	2939.7	14	10	1.90	n/a	n/a	6.00	n/a	n/a	4.7

In April 2005 the greatest taxa richness (20 taxa) occurred at three stations, Reference station MDE-36, Back River station MDE-27, and South Cell Restoration Baseline station MDE-44. Taxa richness declined slightly from the previous year (Year 22) when 23 taxa were recorded at one station and 21 taxa at another. However in Year 23, there were five stations with 19 taxa: Nearfield stations MDE-9, MDE-16, MDE-17, MDE-24, and the Back River Station MDE-28. (Table 13). The lowest taxa richness from spring sampling was recorded at three Nearfield stations: MDE-01 had 9 taxa, while MDE-19 had 10 taxa, and MDE-33 had 11 taxa. Overall, the average taxa richness was highest at the Back River/Hawk Cove stations, and lowest at Nearfield stations (average taxa richness: Nearfield=15 taxa, Reference=17 taxa, Back River/Hawk Cove=19 taxa, South Cell Restoration Baseline Monitoring Stations=17).

Table 13: Summary of metrics for each HMI benthic station surveyed during the Year 23 spring sampling cruise, April 2005. Total Infaunal Abundance and Total Abundance, excluding Polycladida, Nematoda, and Bryozoa, are individuals per square meter.

Station	Total Infauna	Total All	All Taxa	Infaunal Taxa	Shannon-Wiener	PSTA	PITA
Nearfield Stations							
MDE-01	5113.6	5126.4	9	8	0.58	n/a	n/a
MDE-03	2643.2	2662.4	15	10	2.07	n/a	n/a
MDE-07	3270.4	3545.6	18	9	1.52	n/a	n/a
MDE-09	3238.4	3449.6	19	11	1.98	n/a	n/a
MDE-16	2035.2	2112	19	12	2.00	n/a	n/a
MDE-17	4428.8	4864	19	12	1.25	n/a	n/a
MDE-19	390.4	384	10	9	2.73	n/a	n/a
MDE-24	3308.8	3404.8	19	15	1.66	n/a	n/a
MDE-33	3052.8	3052.8	11	9	1.29	n/a	n/a
MDE-34	4012.8	4038.4	14	10	1.16	n/a	n/a
MDE-35	1139.2	1164.8	15	11	2.64	n/a	n/a
MEANS	2966.7	3073.2	15	11	1.72	n/a	n/a
Reference Stations							
MDE-13	2073.6	2092.8	15	11	1.85	n/a	n/a
MDE-22	1657.6	1670.4	15	12	2.65	n/a	n/a
MDE-36	4460.8	4672	20	14	2.08	n/a	n/a
MEANS	2730.7	2811.7	17	12	2.19	n/a	n/a
Back River/Hawk Cove Stations							
MDE-27	2246.4	2809.6	20	15	2.64	n/a	n/a
MDE-28	2681.6	2956.8	19	14	2.48	n/a	n/a
MDE-30	1004.8	1088	17	12	2.58	n/a	n/a
MEANS	1977.6	2284.8	19	14	2.56	n/a	n/a
South Cell Restoration Baseline Monitoring Stations for South Cell							
MDE-42	1216.0	1216.0	15	13	2.47	n/a	n/a
MDE-43	3065.6	3161.6	15	11	1.74	n/a	n/a
MDE-44	9644.8	9734.4	20	13	0.52	n/a	n/a
MEANS	4642.1	4704.0	17	12.3	1.6	n/a	n/a

Since the first benthic survey studies of the Hart-Miller Island area in 1981, a small number of taxa have been dominant. Year 23 was no exception. During both seasons, 4 taxa were clearly dominant: the bivalve mollusk *R. cuneata*, the isopod *C. polita*, the polychaete worm *M. viridis*, and oligochaete worms of the family Tubificidae. The average abundance of each taxon (individuals per square meter) found at each station during September 2004 and April 2005 are provided in Tables 14 through 17.

Table 14: Average number of individuals collected per square meter at each station during the HMI Year 23 late summer sampling, September 2004, stations MDE-1 to MDE-22. Taxa in bold are pollution sensitive while taxa highlighted in gray are pollution tolerant.

Taxon	**Station**								
	MDE-1	**MDE-3**	**MDE-7**	**MDE-9**	**MDE-13**	**MDE-16**	**MDE-17**	**MDE-19**	**MDE-22**
Nemata	0	0	0	0	0	0	0	12.8	0
Carinoma tremophoros	0	0	0	6.4	6.4	6.4	12.8	6.4	12.8
Bivalvia	0	0	0	0	12.8	0	32	0	6.4
Macoma balthica	**0**	**0**	**0**	**0**	**6.4**	**0**	**0**	**0**	**70.4**
Rangia cuneata	**281.6**	**416**	**320**	**121.6**	**409.6**	**288**	**204.8**	**44.8**	**614.4**
Ischadium recurvum	12.8	0	6.4	0	0	0	0	0	0
Mytilopsis leucophaeata	313.6	243.2	44.8	544	6.4	32	51.2	0	0
Amphicteis floridus	0	0	0	0	0	0	0	0	0
Heteromastus filiformis	0	0	0	0	0	0	0	0	0
Spionidae	0	0	0	0	0	6.4	0	0	0
Marenzellaria viridis	**262.4**	**1184**	**441.6**	**326.4**	**198.4**	**659.2**	**204.8**	**230.4**	**358.4**
Streblospio benedicti	19.2	192	19.2	377.6	268.8	185.6	128	38.4	83.2
Polydora cornuta	6.4	12.8	0	19.2	0	0	6.4	0	0
Nereididae	12.8	0	0	12.8	0	0	6.4	0	0
Neanthes succinea	6.4	0	0	6.4	0	0	6.4	0	0
Tubificidae	115.2	928	147.2	300.8	409.6	313.6	230.4	57.6	915.2
Amphipoda	6.4	12.8	6.4	6.4	6.4	6.4	0	6.4	12.8
Gammaridea	64	0	0	0	0	0	0	0	0
Ameroculodes spp complex	19.2	12.8	12.8	38.4	76.8	25.6	0	70.4	76.8
Leptocheirus plumulosus	0	0	38.4	6.4	19.2	6.4	0	0	89.6
Gammarus sp.	51.2	19.2	38.4	12.8	19.2	6.4	6.4	0	19.2
Melitadae	6.4	0	0	0	0	0	0	0	0
Melita nitida	460.8	12.8	51.2	44.8	12.8	6.4	0	6.4	0
Apocorophium lacustre	32	0	0	0	6.4	0	0	0	0
Cyathura polita	**230.4**	**403.2**	**275.2**	**556.8**	**211.2**	**345.6**	**300.8**	**115.2**	**217.6**
Edotia triloba	6.4	12.8	0	25.6	51.2	44.8	44.8	70.4	51.2
Chiridotea almyra	**44.8**	**0**	**6.4**	**0**	**6.4**	**6.4**	**0**	**0**	**0**
Balanus improvisus	448	0	0	12.8	6.4	12.8	38.4	0	0

Table 14: Continued.

Taxon	Station								
	MDE-1	**MDE-3**	**MDE-7**	**MDE-9**	**MDE-13**	**MDE-16**	**MDE-17**	**MDE-19**	**MDE-22**
Balanus subalbidus	76.8	0	0	0	0	0	12.8	0	0
Xanthidae	0	0	0	0	0	0	0	0	0
Rhithropanopeus harrisii	128	19.2	25.6	12.8	25.6	19.2	32	6.4	0
Membranipora sp	+	+	+	+	+	+	+	+	0
Chironomidae	0	0	0	0	0	0	0	0	0
Coelotanypus sp.	0	0	0	6.4	0	0	6.4	38.4	0
Cryptochironomus sp.	0	0	0	0	0	0	0	0	0
Procladius sp.	0	0	0	12.8	0	6.4	0	0	0
Procladius (Holotanypus) sp.	0	0	0	0	0	0	0	0	0
Polypedulum halterale Group	0	0	0	0	0	0	0	0	0

Note: Presence of *Membranipora* sp. is indicated by +

Table 15: Average number of individuals collected per square meter at each station during the HMI Year 23 late summer sampling, September 2004, stations MDE-24 to MDE-36. Taxa in bold are pollution sensitive while taxa highlighted in gray are pollution tolerant.

Taxon	**Station**							
	MDE-24	**MDE-27**	**MDE-28**	**MDE-30**	**MDE-33**	**MDE-34**	**MDE-35**	**MDE-36**
Nemata	6.4	44.8	83.2	0	0	0	172.8	0
Carinoma tremophoros	12.8	0	0	0	0	0	0	0
Bivalvia	0	0	6.4	0	0	6.4	0	12.8
Macoma balthica	**0**	**6.4**	**0**	**0**	**0**	**0**	**0**	**0**
Rangia cuneata	**1664**	**4652.8**	**5760**	**339.2**	**4416**	**1395.2**	**3731.2**	**4339.2**
Ischadium recurvum	0	0	0	0	0	0	0	0
Mytilopsis leucophaeata	0	25.6	140.8	0	19.2	0	25.6	51.2
Amphicteis floridus	0	243.2	32	0	0	0	0	70.4
Heteromastus filiformis	12.8	0	0	0	0	0	0	0
Spionidae	0	0	0	0	0	0	0	0
Marenzellaria viridis	**352**	**595.2**	**128**	**83.2**	**96**	**19.2**	**249.6**	**1004.8**
Streblospio benedicti	0	44.8	19.2	6.4	0	0	6.4	0
Polydora cornuta	0	0	0	0	0	0	0	12.8
Nereididae	0	0	0	0	0	0	0	0
Neanthes succinea	0	0	0	0	0	0	0	0
Tubificidae	358.4	128	51.2	89.6	12.8	0	121.6	25.6
Amphipoda	0	6.4	6.4	0	12.8	0	0	0
Gammaridea	0	0	0	0	0	0	0	6.4
Ameroculodes spp complex	38.4	51.2	32	44.8	12.8	25.6	12.8	6.4
Leptocheirus plumulosus	0	121.6	0	6.4	0	0	6.4	0
Gammarus sp.	83.2	12.8	12.8	0	32	19.2	6.4	12.8
Melitadae	0	0	0	0	0	0	0	0
Melita nitida	0	6.4	0	0	6.4	0	0	0
Apocorophium lacustre	0	0	0	0	0	0	0	6.4
Cyathura polita	**243.2**	**300.8**	**108.8**	**64**	**128**	**64**	**115.2**	**166.4**
Edotia triloba	320	281.6	38.4	6.4	0	12.8	6.4	12.8
Chiridotea almyra	**83.2**	**12.8**	**0**	**0**	**96**	**288**	**0**	**0**
Balanus improvisus	0	0	0	0	0	0	0	0
Balanus subalbidus	0	0	0	0	0	0	0	0
Xanthidae	0	0	6.4	0	0	0	0	0
Rhithropanopeus harrisii	0	0	0	0	0	6.4	0	0
Membranipora sp	+	0	0	0	0	0	+	0

Table 15: Continued

Taxon	Station							
	MDE-24	MDE-27	MDE-28	MDE-30	MDE-33	MDE-34	MDE-35	MDE-36
Chironomidae	0	0	0	0	0	6.4	0	6.4
Coelotanypus sp.	0	32	83.2	179.2	0	0	64	19.2
Cryptochironomus sp.	0	6.4	0	0	0	0	0	0
Procladius sp.	0	6.4	0	0	0	0	0	0
Procladius (Holotanypus) sp.	0	0	0	0	0	0	6.4	0
Polypedulum halterale Group	0	0	0	0	6.4	0	0	0

Note: Presence of *Membranipora* sp. is indicated by +

Table 16: Average number of individuals collected per square meter at each station during the HMI Year 23 spring sampling, April 2005, stations MDE-1 to MDE-22. Taxa in bold are pollution sensitive while taxa highlighted in gray are pollution tolerant.

Taxon	Station								
	MDE-1	MDE-3	MDE-7	MDE-9	MDE-13	MDE-16	MDE-17	MDE-19	MDE-22
Nemata	0	0	0	0	0	0	0	0	0
Carinoma tremophoros	0	6.4	0	0	12.8	6.4	6.4	6.4	6.4
Bivalvia	0	0	6.4	12.8	0	0	0	0	6.4
Macoma balthica	**0**	**0**	**0**	**0**	**6.4**	**6.4**	**0**	**0**	**76.8**
Rangia cuneata	**153.6**	**364.8**	**102.4**	**153.6**	**115.2**	**185.6**	**102.4**	**44.8**	**307.2**
Ischadium recurvum	0	0	0	6.4	0	0	0	0	0
Mytilopsis leucophaeata	0	6.4	38.4	102.4	6.4	6.4	108.8	0	0
Heteromastus filiformis	12.8	0	0	0	0	0	0	0	0
Spionidae	12.8	19.2	19.2	6.4	0	32	12.8	0	0
Marenzellaria viridis	**4729.6**	**1395.2**	**2304**	**1836.8**	**1158.4**	**1216**	**3558.4**	**96**	**473.6**
Nereididae	0	0	0	32	0	0	0	0	0
Neanthes succinea	0	0	0	0	0	0	19.2	0	0
Tubificidae	38.4	416	294.4	505.6	512	217.6	249.6	32	384
Amphipoda	0	0	25.6	12.8	0	0	38.4	0	6.4
Ameroculodes spp complex	44.8	51.2	32	96	25.6	6.4	6.4	6.4	51.2
Leptocheirus plumulosus	0	0	0	6.4	6.4	6.4	0	38.4	32
Gammarus sp	0	19.2	25.6	12.8	25.6	0	83.2	0	0
Melita nitida	6.4	0	70.4	25.6	0	6.4	83.2	0	0
Corophiidae	0	0	0	0	0	0	0	0	0
Apocorophium lacustre	0	0	12.8	6.4	0	12.8	38.4	0	6.4
Cyathura polita	**70.4**	**294.4**	**428.8**	**499.2**	**179.2**	**249.6**	**268.8**	**51.2**	**256**
Edotea triloba	0	0	0	0	6.4	0	0	0	6.4
Chiridotea almyra	**32**	**6.4**	**0**	**6.4**	**0**	**6.4**	**0**	**0**	**0**
Balanus improvisus	0	6.4	12.8	0	0	19.2	0	0	0
Balanus subalbidus	0	0	25.6	0	0	0	0	0	0
Rhithropanopeus harrisii	0	12.8	51.2	12.8	0	0	25.6	0	0
Membranipora sp	0	+	+	+	+	+	+	0	0
Chironomidae	6.4	0	6.4	6.4	0	32	0	0	0
Tanypodinae	0	0	0	0	0	0	0	0	0
Orthocladiinae	0	0	0	0	0	0	0	0	0
Coelotanypus sp.	0	0	0	0	0	0	0	12.8	6.4
Procladius sp.	0	6.4	0	6.4	0	6.4	0	0	0
Procladius(Holotanypus) sp.	0	57.6	19.2	57.6	32	64	51.2	102.4	38.4
Chironominae	12.8	0	0	0	0	19.2	0	0	0
Cryptochironomus sp.	0	6.4	0	6.4	0	6.4	6.4	0	12.8
Cricotopus sp.	0	0	0	0	0	0	12.8	0	0
Rheotanytarsus sp.	0	0	0	0	0	6.4	0	0	0
Polypedulum Uresipedulum flavum	6.4	0	12.8	0	0	0	0	0	0

Table 16: Continued

Taxon	Station								
	MDE-1	MDE-3	MDE-7	MDE-9	MDE-13	MDE-16	MDE-17	MDE-19	MDE-22
Harnischia sp.	0	0	0	0	0	0	0	0	0
Mya arenaria	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Copepoda	0	+	+	+	+	+	+	+	+
Parahaustorius holmesi	0	0	0	0	0	0	0	0	0
Chironomidae Pupae	0	0	0	0	0	0	0	0	0
Hydrozoa	0	0	44.8	38.4	0	6.4	185.6	0	0
Amphicteis floridus	0	0	0	0	19.2	0	0	0	0
Cyclaspis varians	0	0	6.4	0	0	0	0	0	6.4
Polydora cornuta	0	0	0	0	0	0	12.8	0	0
Cladocera sp.	0	0	0	0	0	0	0	0	0

Note: Presence of *Membranipora* sp. is indicated by +

Table 17: Average number of individuals collected per square meter at each station during the HMI Year 23 spring sampling, April 2005, stations MDE-24 to MDE-44. Taxa in bold are pollution sensitive while taxa highlighted in gray are pollution tolerant.

Taxon	Station										
	MDE-24	MDE-27	MDE-28	MDE-30	MDE-33	MDE-34	MDE-35	MDE-36	MDE-42	MDE-43	MDE-44
Nemata	25.6	108.8	428.8	0	0	0	243.2	0	0	0	6.4
Carinoma tremophoros	0	6.4	0	0	0	0	0	6.4	6.4	6.4	6.4
Bivalvia	0	12.8	76.8	25.6	0	0	0	0	0	57.6	0
Macoma balthica	**0**	**6.4**	**0**	**0**	**0**	**0**	**0**	**0**	**19.2**	**0**	**0**
Rangia cuneata	**281.6**	**179.2**	**1228.8**	**288**	**300.8**	**460.8**	**345.6**	**1196.8**	**102.4**	**204.8**	**38.4**
Ischadium recurvum	0	0	0	0	0	0	0	0	0	0	0
Mytilopsis leucophaeata	6.4	0	64	0	0	6.4	6.4	6.4	0	0	6.4
Heteromastus filiformis	6.4	0	0	0	0	0	0	0	0	0	6.4
Spionidae	32	6.4	6.4	0	83.2	70.4	0	57.6	12.8	12.8	44.8
Marenzellaria viridis	**2412.8**	**851.2**	**473.6**	**275.2**	**2368**	**3200**	**230.4**	**2342.4**	**256**	**2028.8**	**8979.2**
Nereididae	0	0	0	0	0	0	0	0	0	0	0
Neanthes succinea	0	0	0	0	0	0	0	0	0	0	0
Tubificidae	172.8	179.2	102.4	121.6	102.4	51.2	204.8	121.6	563.2	428.8	256
Amphipoda	0	6.4	0	0	0	0	6.4	6.4	0	12.8	0
Ameroculodes spp complex	57.6	6.4	6.4	6.4	25.6	121.6	6.4	25.6	19.2	38.4	19.2
Leptocheirus plumulosus	19.2	563.2	44.8	0	0	6.4	25.6	6.4	19.2	12.8	6.4
Gammarus sp	19.2	12.8	44.8	0	6.4	6.4	6.4	44.8	12.8	12.8	6.4
Melita nitida	0	44.8	12.8	6.4	0	0	0	0	0	0	6.4
Corophiidae	0	0	0	0	0	0	0	6.4	0	0	0
Apocorophium lacustre	32	19.2	0	0	0	0	0	19.2	0	6.4	44.8
Cyathura polita	**134.4**	**147.2**	**121.6**	**76.8**	**115.2**	**32**	**76.8**	**172.8**	**102.4**	**224**	**230.4**
Edotea triloba	19.2	70.4	64	6.4	0	6.4	6.4	0	0	0	19.2
Chiridotea almyra	**57.6**	**0**	**0**	**0**	**12.8**	**38.4**	**0**	**0**	**0**	**0**	**38.4**
Balanus improvisus	0	0	0	0	0	0	0	0	0	0	0
Balanus subalbidus	0	0	0	0	0	0	0	0	0	0	0
Rhithropanopeus harrisii	0	0	0	0	0	0	0	6.4	0	6.4	6.4
Membranipora sp	0	0	0	0	+	0	0	0	+	0	+
Chironomidae	19.2	25.6	0	19.2	0	6.4	0	0	6.4	0	0
Tanypodinae	0	0	0	0	0	0	0	12.8	0	0	0
Orthocladiinae	0	0	6.4	0	0	0	0	6.4	0	0	0
Coelotanypus sp.	0	57.6	192	160	0	0	76.8	44.8	25.6	12.8	0
Procladius sp.	0	0	12.8	0	0	0	0	83.2	0	12.8	0
Procladius(Holotanypus) sp.	6.4	147.2	377.6	25.6	0	0	153.6	307.2	64	51.2	6.4
Chironominae	19.2	0	6.4	0	0	0	0	6.4	0	0	0
Cryptochironomus sp.	25.6	25.6	12.8	6.4	6.4	19.2	0	0	6.4	6.4	0
Cricotopus sp.	0	0	0	0	0	0	0	6.4	0	0	0
Rheotanytarsus sp.	44.8	6.4	12.8	6.4	0	6.4	0	6.4	0	0	0

Table 17: Continued

Taxon	Station										
	MDE-24	**MDE-27**	**MDE-28**	**MDE-30**	**MDE-33**	**MDE-34**	**MDE-35**	**MDE-36**	**MDE-42**	**MDE-43**	**MDE-44**
Polypedulum Uresipedulum flavum	12.8	0	0	6.4	32	0	0	0	0	0	0
Harnischia sp.	6.4	44.8	32	32	0	0	6.4	6.4	6.4	0	0
Mya arenaria	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Copepoda	0	+	+	+	+	+	+	+	+	+	0
Parahaustorius holmesi	19.2	0	0	0	0	0	0	0	0	0	0
Chironomidae Pupae	0	6.4	0	0	0	0	0	0	0	0	0
Hydrozoa	0	0	0	0	0	0	0	0	0	32	0
Amphicteis floridus	0	134.4	57.6	19.2	0	0	12.8	179.2	0	0	12.8
Cyclaspis varians	0	0	0	0	0	0	0	0	0	0	0
Polydora cornuta	0	0	0	0	0	0	0	0	0	0	6.4
Cladocera sp.	0	0	0	6.4	0	0	0	0	0	0	0

Note: Presence of *Membranipora* sp. is indicated by +

Taxa Abundance

Average total abundance was higher in the late summer (September 2004) than in the spring (April 2005). This differs from years past that usually, due to the predominance of seasonal recruitment, have greater abundances in the spring. In September 2004 total abundance in the vicinity of HMI ranged from 6.4 to 34624 organisms per square meter (individuals/m^2) and averaged 1697.42 individuals/m^2. This number does not include the Bryozoa, which are colonial epifauna and are often abundant on shell or other hard substrates. The highest September 2004 abundance was found at the Back River/Hawk Cove station MDE-27, due primarily to large numbers of the bivalve *Rangia cuneata* and the polychaete *M. viridis*. The lowest abundance in September 2004 was found at the Nearfield station MDE-19 (Table 13). There was a notable difference in the average total abundance between Reference stations and Nearfield stations in September 2004 (3340.8 individuals/m^2 and 2555.3 individuals/m^2 respectively) with the South Cell Restoration Baseline stations falling somewhere in between (2939.7 individuals/m^2). Total abundance was highest at the Back River/Hawk Cove stations (4593.1 individuals/m^2).

In April 2005, total abundance ranged from 6.4 to 40,185.6 organisms per square meter and averaged 1308.08 individuals/m^2. The station with the highest abundance was the South Cell Restoration Baseline station MDE-44, due to very high numbers of the polychaete *M. viridis*. The lowest spring abundance occurred at the Nearfield station MDE-19 (Table 13). This was due in part to the low numbers of the polychaete worm *M. viridis* and worms from the family Tubificidae, which generally occurred in high numbers at other stations (Table 13). The average total abundance was lowest at the Back River/Hawk Cove stations (2284.8 individuals/m^2) and highest at the South Cell Restoration Baseline stations (4704 individuals/m^2), with the Reference (2811.7 individuals/m^2) and Nearfield stations (3073.2 individuals/m^2) stations falling in between.

Total infaunal abundance and epifaunal abundance are subsets of total abundance. Infaunal abundance excludes certain organisms that have been omitted from the calculation of the B-IBI (see *Methods*). In Year 23, total infaunal abundance was similar to total abundance, accounting for ≥75% of all organisms at most stations during both seasons. The only exceptions were Nearfield stations MDE-01 (41%), and MDE-9 (74%) in September 2004. Epi-faunal taxa dominated abundance at Nearfield station MDE-01 in September 2004.

Diversity

Species diversity was examined using the Shannon-Wiener diversity index, which measures diversity on a numerical scale from 0 to 4. A lower score indicates an unbalanced community dominated by only one or two species whereas a higher score suggests a balanced, diverse benthic community. Pfitzenmeyer et al. (1982) suggested that diversity, as measured by the Shannon-Wiener Diversity Index (SWDI), would be higher in the summer than the spring, when recruitment decreased and predation increased thus reducing the numbers of the dominant taxa. Diversity has often been lowest at most stations in spring (April or May) due to an influx of juveniles, especially of the dominant species (Duguay et al. 1998, Duguay et al. 1995a, Duguay et al. 1995b, Duguay 1992, Duguay 1990, Pfitzenmeyer and Tenore 1987). Diversity values for Year 23 are presented in Tables 12 & 13. In this monitoring year, on average, diversity was slightly higher in September 2004 than in April 2005. These results are different from Year 22, where diversity values were moderately higher in one season versus the other.

The Shannon-Wiener diversity Index (SWDI) values in Year 23 averaged 1.91 ± 0.76 in September 2004 and 1.89 ± 0.70 in April 2005. The lowest diversity value in September 2004 occurred at Back River/Hawk Cove station MDE-28 (0.46). This was due to the predominance of the bivalve *R. cuneata*, which accounted for 92% of total infaunal abundance at this station. The highest September 2004 diversity value (2.73) occurred at South Cell Restoration Baseline Monitoring station MDE-44. The lowest diversity value in April 2005 occurred at South Cell Restoration Baseline Monitoring station MDE-44 (0.52); this was due to the large percentage of the polychaete worm *M. viridis*, which accounted for 93% of total infaunal abundance at this station. The highest April 2005 diversity value occurred at Nearfield station MDE-19 (2.73). For the most part, Nearfield stations had diversity values similar to Reference stations in September 2004. However, in April 2005, diversity did not vary much among station types, due to the predominance of *M. viridis* recruitment.

Pollution Sensitive Taxa Abundance

The calculation of the PSTA was a ratio of the relative abundance of taxa designated as “pollution sensitive” to total infaunal abundance. In Year 23, freshwater conditions (salinity less than 0.5 ppt) dominated the upper Chesapeake Bay around HMI. Tidal freshwater prevailed at all the stations in the spring sampling, and at eighteen of the twenty stations in the fall. This is somewhat unusual for waters around HMI, where oligohaline conditions normally prevail. Only at stations MDE-24 and MDE-27 in September 2004 was salinity high enough to be classified as oligohaline. As a result, PSTA scores could only be calculated for the fall samples from these two stations (MDE-24 PSTA = 15.3, MDE-27 PSTA = 9.8) because there are currently no tidal fresh pollution-sensitive taxa identified for Chesapeake Bay (Alden et al., 2002). The two "pollution-sensitive" taxa for oligohaline conditions are the polychaete worm *M. viridis* and the isopod crustacean *C. almyra.*

Poluution Indicative Taxa Abundance

PITA scores could also not be calculated for most of the stations because of the prevailing freshwater conditions. Alden et al. (2002) identifies two taxa as "pollution-indicative" for Chesapeake Bay tidal freshwaters, including one group – "tubificidae without capilliform chaetae" that occur in the waters around HMI. However, identification of tubificids without capilliform chaetae requires special mounting procedures not conducted with the Year 23 tubificid specimens. PITA scores could only be calculated for stations MDE-24 (PITA = 13.0) and MDE-27 (PITA = 5.3) in the September 2004 sampling because of the prevailing oligohaline conditions. Nine taxa found during Year 23 benthic monitoring were designated as "pollution-indicative" for Chesapeake Bay oligohaline waters according to Alden et al. (2002).. These were the Chironomids *Coelotanypus* sp., *Procladius* sp.,and *Polypedilum* sp., the polychaete worms *S. benedicti*, *H. filiformis, N. succinea*, and *P. cornuta*, the *Arthropod L. plumulosus*, and the oligochaete worms of the family Tubificidae. Relative abundance of these taxa was calculated as a proportion of total infaunal abundance.

Clam Length Frequency Distribution

In September 2004, the greatest average abundance of *R. cuneata* occurred at the Back River/Hawk Cove stations, followed by the South Cell Restoration Baseline Monitoring stations, Reference stations, and finally, the Nearfield stations. The greatest abundance of *R. cuneata* was found in the 6-10 mm size class. In April 2005, the greatest average abundance of *R. cuneata* occurred at the Back River/Hawk Cove stations, followed by Reference and Nearfield stations respectively, with lowest abundance occurring at the South Cell Restoration Baseline Monitoring stations. The greatest abundance of *R. cuneata* found during both seasons was in the 6-10 mm size class. No *M. mitchelli* were collected in Year 23. This indicates recruitment of this species was likely minimal in the spring of years of 2004 and 2005.

In September 2004 *M. balthica* had the greatest average abundance at the Reference stations, followed by the South Cell Restoration Baseline Monitoring stations, and then the Back River/Hawk Cove stations. No *M. balthica* were collected from any of the Nearfield stations in September 2004. The greatest abundance of *M. balthica* was found in the in the 21-22 mm size class. In April 2005 *M. balthica* had the greatest average abundance at the Reference stations, followed by the South Cell Restoration Baseline Monitoring and Back River/Hawk Cove stations, with lowest abundance occurring at the Nearfield stations. For all the stations in April 2005 *M. balthica* had its greatest abundance in the 20-22 mm size class.

Benthic Index of Biotic Integrity

The Chesapeake Bay Benthic Index of Biotic Integrity (B-IBI) was calculated for all stations based on September 2004 data only (see Methods and Materials). Six metrics were used to calculate the B-IBI for stations under the oligohaline classification (MDE-24 and MDE-27) (= ≥0.5-5 ppt). These metrics were total infaunal abundance, tolerance score, Tanypodinae to Chironomidae abundance ratio, abundance of carnivores and omnivores, relative abundance of pollution-sensitive taxa, and relative abundance of pollution-indicative taxa [Note: the relative abundance of pollution-sensitive taxa was included as an accepted substitution for biomass-based metrics (Weisberg et al 1997)]. The remaining stations were calculated using the B-IBI for stations under the tidal fresh classification (=0.0- <0.5 ppt). The four metrics used to calculate the B-IBI for stations under the tidal fresh classification were total infaunal abundance, tolerance score, relative abundance of pollution-indicative taxa, and abundance of deep-deposit feeders. The specific scoring criteria for the oligohaline and tidal fresh metrics are presented in tables 18 and 19. The B-IBI was developed as a benchmark to determine whether any given benthic sample taken from the Bay either approximates (B-IBI score = 5), deviates slightly (B-IBI score = 3), or deviates greatly (B-IBI score = 1) from conditions at the best Reference sites (Weisberg et al., 1997). A B-IBI score greater than or equal to 3.0 represents a benthic community that is not considered stressed by *in situ* environmental conditions. The 20 benthic stations studied during Year 23 were compared to this benchmark.

Overall, the Benthic Index of Biotic Integrity (B-IBI) scores improved or remained the same when compared to Year 22 and were generally similar to the B-IBI scores of the previous 6 years of monitoring at Hart-Miller Island. The B-IBI scores increased at 14 stations and stayed the same at 3 stations. Nineteen of the twenty stations exceeded the benchmark criteria of 3.0, only MDE-27 (B-IBI = 2.3) failed to meet this benchmark. (Table 12, Figure 19). In Year 22, 16 stations met the benchmark and 1 failed to meet it. In Year 22, the station that failed to meet the benchmark was MDE-27 (Back River/Hawk Cove). The Back River/Hawk Cove station MDE-27 also failed to meet the benchmark in Year 21.

The highest B-IBI scores were at the Reference, Nearfield, and South Cell Restoration Baseline Monitoring stations, which had an average B-IBI score of 4.7. The Back River/Hawk Cove stations had the lowest average B-IBI score of 3.8 for the forth-monitoring year in a row. The Back River has a history of poor water quality and the conditions present at these stations may have been more representative of the conditions of the Back River than the Hart-Miller Island facility. For the past 8 years, the average B-IBI scores of the Back River/Hawk Cove stations have been lower than the average Nearfield and Reference stations scores (Figure 20).

Table 18: Oligohaline Scoring Criteria for Measures Used in Calculating the Chesapeake Bay Benthic Index of Biological Integrity (B-IBI) in September 2004 (Weisberg et al. 1997).

Measure	**Score**		
	5	**3**	**1**
Total Abundance (individuals per square meter)	≥ 450 – 3350	180-450 **or** ≥ 3350-4050	< 180 **or** ≥ 4050
% Pollution-sensitive Taxa	≥ 26%	0.2-26%	<0.2%
% Pollution-indicative Taxa	≤ 27%	27-95%	> 95%
Tolerance Score	≤6	6-9.05	>9.05
% Tanypodinae to Chironomidae	≤17	17-64	>64
% Carnivores and Omnivores	≥35%	15-35%	<15%

Table 19: Tidal Fresh Scoring Criteria for Measures Used in Calculating the Chesapeake Bay Benthic Index of Biological Integrity (B-IBI) in September 2004 (Weisberg et al. 1997).

Measure	**Score**		
	5	**3**	**1**
Total Abundance (individuals per square meter)	≥ 1050-4000	800-1050 **or** ≥ 4000-5500	< 800 **or** ≥ 5500
% Pollution-indicative Taxa	≤ 39%	39-87%	> 87%
% Deep-deposit feeders	≤ 70%	70-95%	> 95%
Tolerance Score	≤6	8-9.35	>9.35

Statistical Analysis

Cluster analysis was 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 Figures 21 and 22, the stations with faunal similarity (based on a Euclidean distance matrix comprised of station infaunal abundance values for all 20 stations), are linked by vertical connections in the dendrograms. Essentially, each station was considered to be a cluster of its own, and at each step 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; Duguay et al, 1999). 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. Experience and familiarity with the area under study can usually help to explain the differences. However, when they cannot be explained other potential outside factors must be considered.

The dendrogram for September 2004 is presented in Figure 21, indicating no clear-cut pattern of faunal response to sediment type, primarily because 15 of the 20 stations had a predominately silt/clay sediment composition. The four stations with a predominately sandy sediment composition did not form a distinct grouping. Similarly, there were no distinct groupings based on station location; the Nearfield, Reference, South Cell Restoration Baseline, and Back River/Hawk Cove stations were distributed throughout the dendrogram unrelated to group formation. A grouping of stations by location could indicate that the HMI facility was impacting the surrounding environment and affecting the faunal composition. In contrast to Year 22 Fall cluster analysis results, which indicated a highly aberrant faunal composition at the Back River station MDE-27, the Year 23 cluster analysis results indicated relative uniformity of faunal composition among stations, with only moderate distinctness at station MDE-28, a silt/clay Back River station. Hence, the formation of station groups in the dendrogram, were poorly correlated to sediment type and station location. The station groups developed as followed (see Figure 21): one large group was started by the pairing of MDE-44 and MDE-17, and grew with the additions of MDE-19, MDE-7, MDE-13, MDE-16 and MDE-30; late additions of stations MDE-22, MDE-9, MDE-1, and MDE-3 completed this group. A second small group was formed by stations MDE-24, MDE-43, and MDE-34. A third group of stations was composed of MDE-35, MDE-42, MDE-27, MDE-36, and MDE-33.

The cluster analysis for April 2004 is presented in Figure 22. This dendrogram also indicated a lack of a relationship between station faunal composition and station location, but a weak relationship between faunal composition and sediment type. Group formation developed even more quickly than for the fall data. However, there was one station, MDE-44, a South Cell Restoration Baseline silt/clay station, with a relatively highly aberrant faunal composition. One distinct group was composed of stations MDE-24, MDE-33, MDE-9, MDE-43, MDE-7, MDE-13, MDE-16, and MDE-3. A second distinct group was formed by stations MDE-30, MDE-35, MDE-19, MDE-22, and MDE-42. The stations in the latter group all had a predominately silt/clay sediment composition, while three of the four stations with predominately sand sediment composition occurred in the former grouping. The cluster analyses for September and April indicated one station with a moderately aberrant fauna (MDE-28 in September) and one station with a strongly aberrant fauna (MDE-44 in April). These stations also had the two lowest Shannon-Wiener diversity scores in Year 23, which corroborated the results of the cluster analysis.

Table 20: Friedman Analysis of Variance for September 2004's 10 most abundant species among; Back River/Hawk Cove, Nearfield, South Cell Restoration Baseline Monitoring, and Reference stations. ANOVA Chi Sqr. (N = 10, df = 3) = 0.84, P < 0.84.

Station Type	Average Rank	Sum of Ranks	Mean	Std. Dev.
Nearfield	2.60	26.00	236.04	348.65
Reference	2.70	27.00	319.36	548.48
Back River	2.50	25.00	443.31	1106.14
South Cell Restoration Baseline	2.20	22.00	282.67	576.85

Table 21: Friedman Analysis of Variance for April, 2005's 10 most abundant species among; Back River/Hawk Cove, Nearfield, Reference stations, and South Cell Restoration Baseline Monitoring Stations. ANOVA Chi Sqr. (N = 10, df = 3) = 2.16, P < 0.54.

Station Type	Average rank	Sum of ranks	Mean	Std. Dev
Nearfield	2.20	22.00	288.99	650.62
Reference	2.80	28.00	266.45	410.21
Back River	2.80	28.00	212.69	186.63
South Cell Restoration Baseline	2.20	22.00	456.96	1165.85

Friedman's nonparametric test was used to determine if a significant difference could be detected among the four station types (Nearfield, Back River, South Cell Restoration Baseline and Reference) for the fall and spring sampling data. The test indicated that there were no significant differences in the 10 most abundant infaunal species between the four station types in either season of Year 23. However, the South Cell Restoration Baseline stations had the lowest average rank in the fall, and tied for lowest rank in the spring with Nearfield stations. These results appear to indicate the beginning of a possible trend begun with the Year 22 spring data when a significant Friedman's test was due to a low average rank of 1.75 for South Cell Restoration Baseline stations. Continued monitoring of South Cell Restoration Baseline stations will be important to determine if the infaunal community at this location is being adversely affected by South Cell outfall discharges from HMI and/or related activities associated with the nearby boat dock.

CONCLUSIONS AND RECOMMENDATIONS

The condition of the benthic macroinvertebrate community for Year 23, as measured by the Chesapeake Bay Benthic of Biotic Integrity (B-IBI) was similar to previous monitoring years. Overall, scores improved or remained the same when compared to Year 22, and have been increasing over the previous 7 years of monitoring at Hart-Miller Island. The B-IBI scores increased at 14 stations and did not change at 3 stations. Nineteen of the twenty stations exceeded the benchmark criteria of 3.0, while one station (MDE-27) failed to meet the benchmark. The BIBI scores indicated no differences in benthic macroinvertebrate community health between Nearfield, Reference, and South Cell Restoration Baseline sites, and a somewhat lower level of community health at Back River/Hawk Cove stations (but still above the "healthy community" threshold value of 3.0). In general the statistical analyses indicated that there were no significant differences in infauna among the Reference, Nearfield, South Cell Restoration Baseline, and Back River/Hawk Cove stations. The cluster analyses indicated some distinct clustering of stations, but the station groups formed in the dendrograms were poorly related to sediment type and station location

The Hart-Miller Island Dredged Material Containment Facility will continue to operate at least until the year 2009. To date, there have been no conclusive impacts from HMI on the benthic community in the adjacent area. However, a more rigorous and comprehensive statistical analysis of all historical HMI data for all projects, might filter out real trends from background random variation. This needs to be undertaken, before any conclusions about HMI's impact on the surrounding community can be made. It is further recommended that benthic community monitoring continue throughout the operational life-time of HMI as well as the post-operational periods in order to be certain that changes in site management do not have adverse effects on the surrounding biological community.

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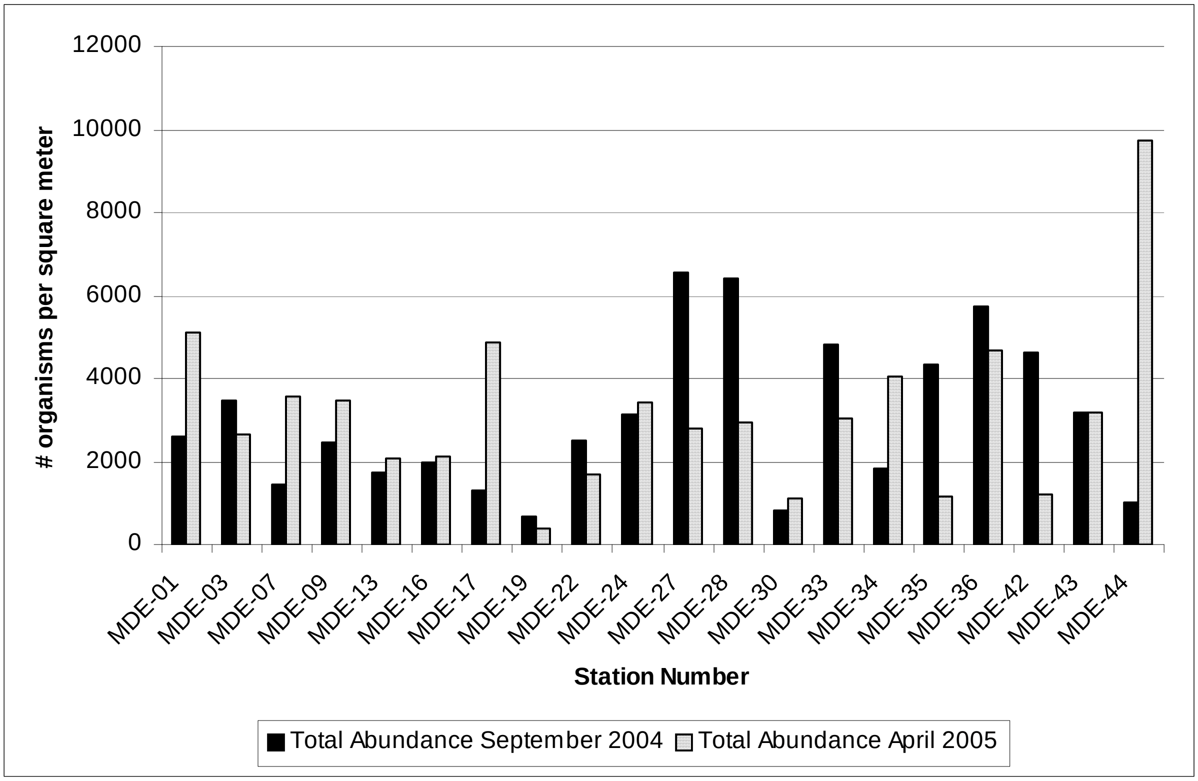

Figure 15: Total abundance of infauna and epifauna taxa collected at each HMI station in year 23, September 2004 and April 2005.

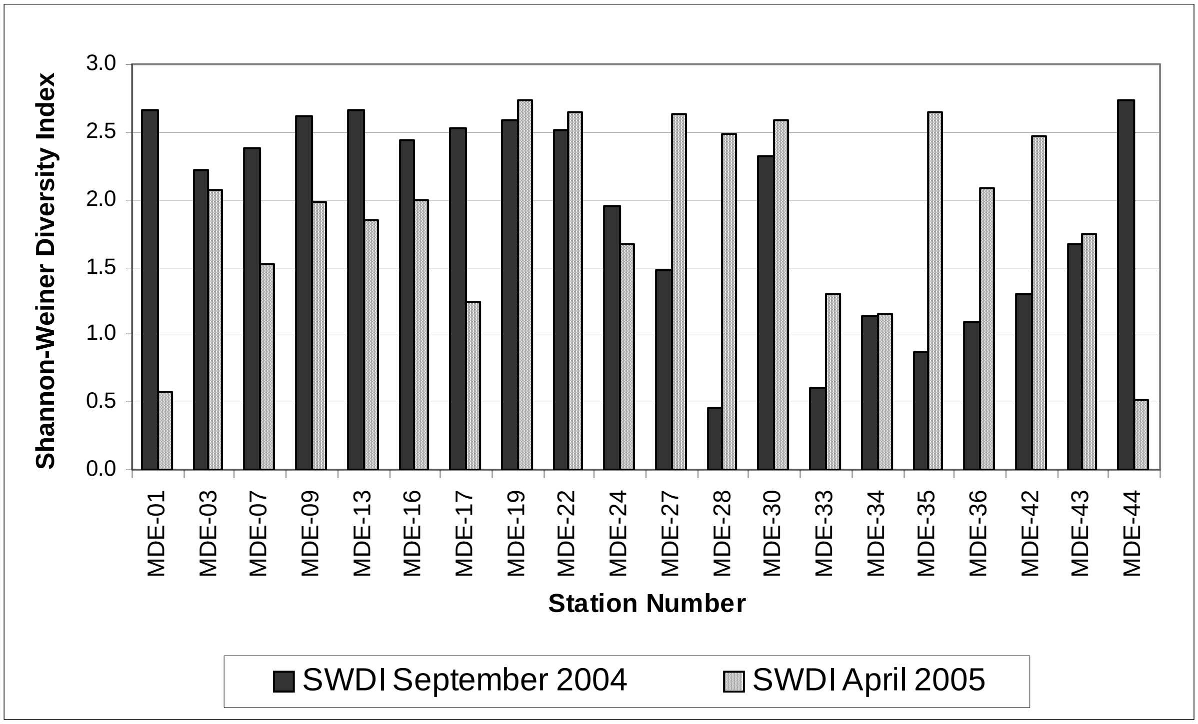

Figure 16: Shannon-Weiner Diversity Index (SWDI), HMI year 23, September 2004 and April 2005.

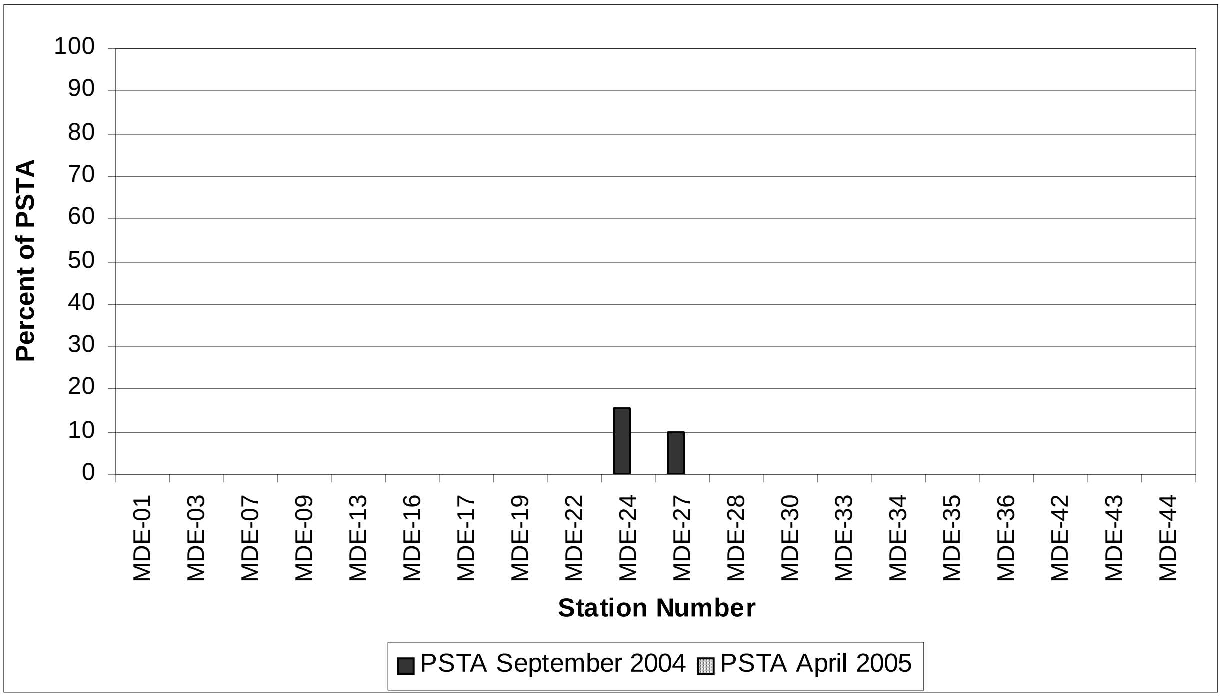

Figure 17: Percent abundance comprised of pollution sensitive taxa abundance (PSTA), HMI year 23 September 2004 and April 2005. There were few pollution sensitive taxa recorded for year 23 due to the method in which this metric is calculated. The predominance of tidal fresh conditions eliminates the need to calculate the PSTA for the purposes of the B-IBI.

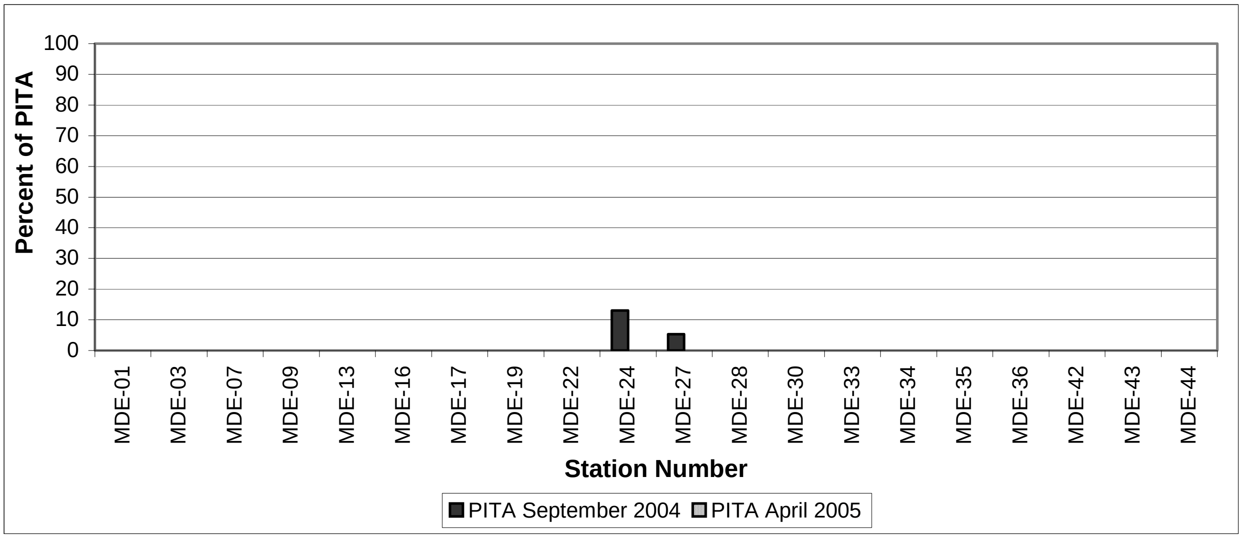

Figure 18: Percent abundance comprised of pollution indicative species (PITA), HMI year 23 September 2004 and April 2005. The PITA metric was only calculated for stations MDE-24 and MDE-27 during September 2004 s.

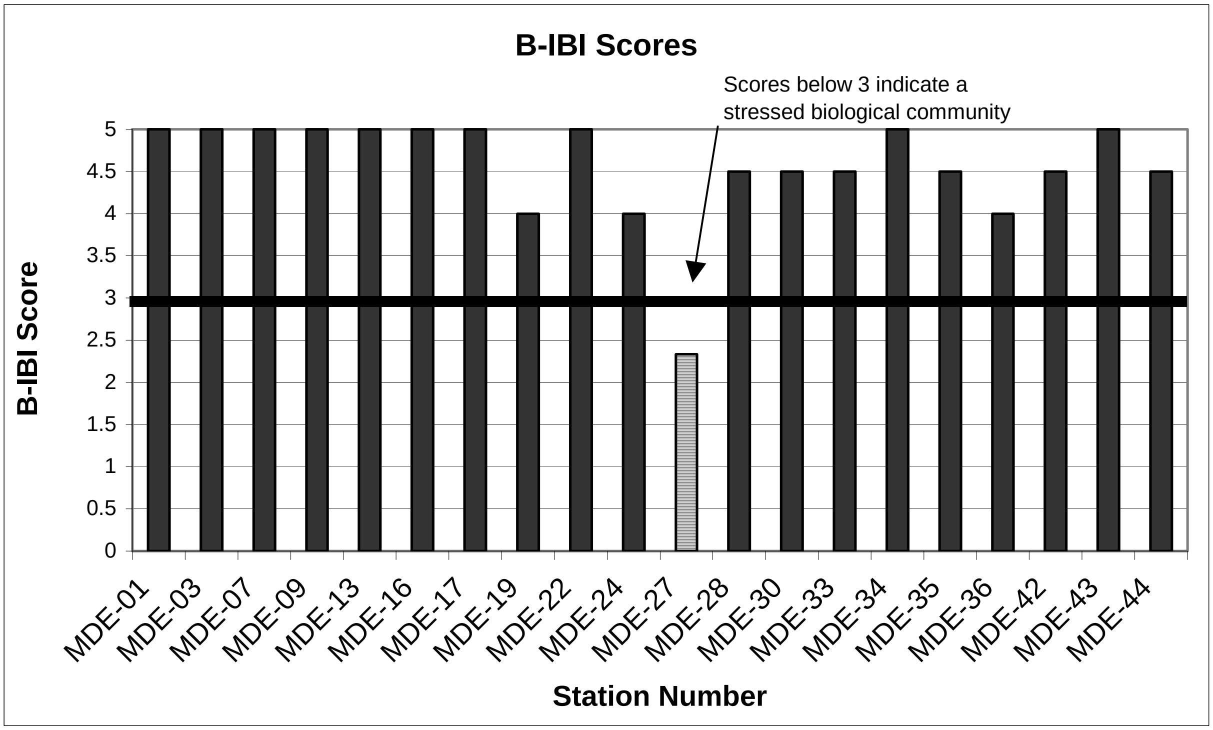

Figure 19: B-IBI Scores for all stations in September 2004.

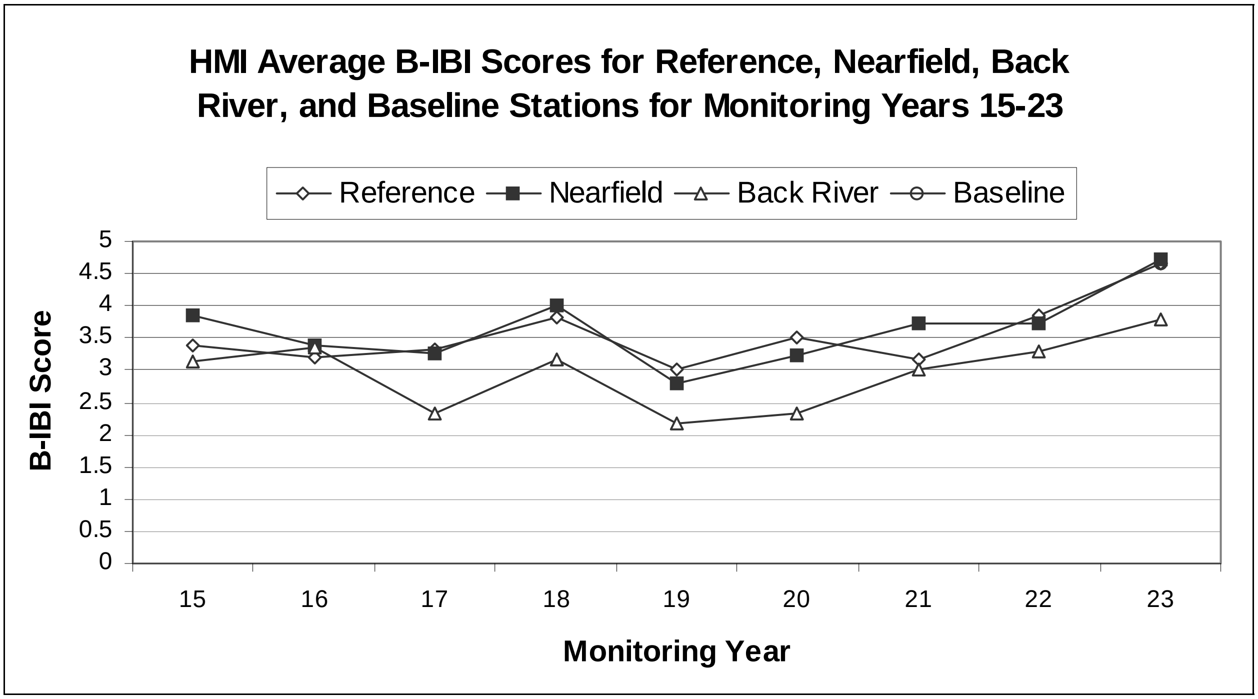

Figure 20: Average B-IBI Scores at HMI for Monitoring Years 15-23.

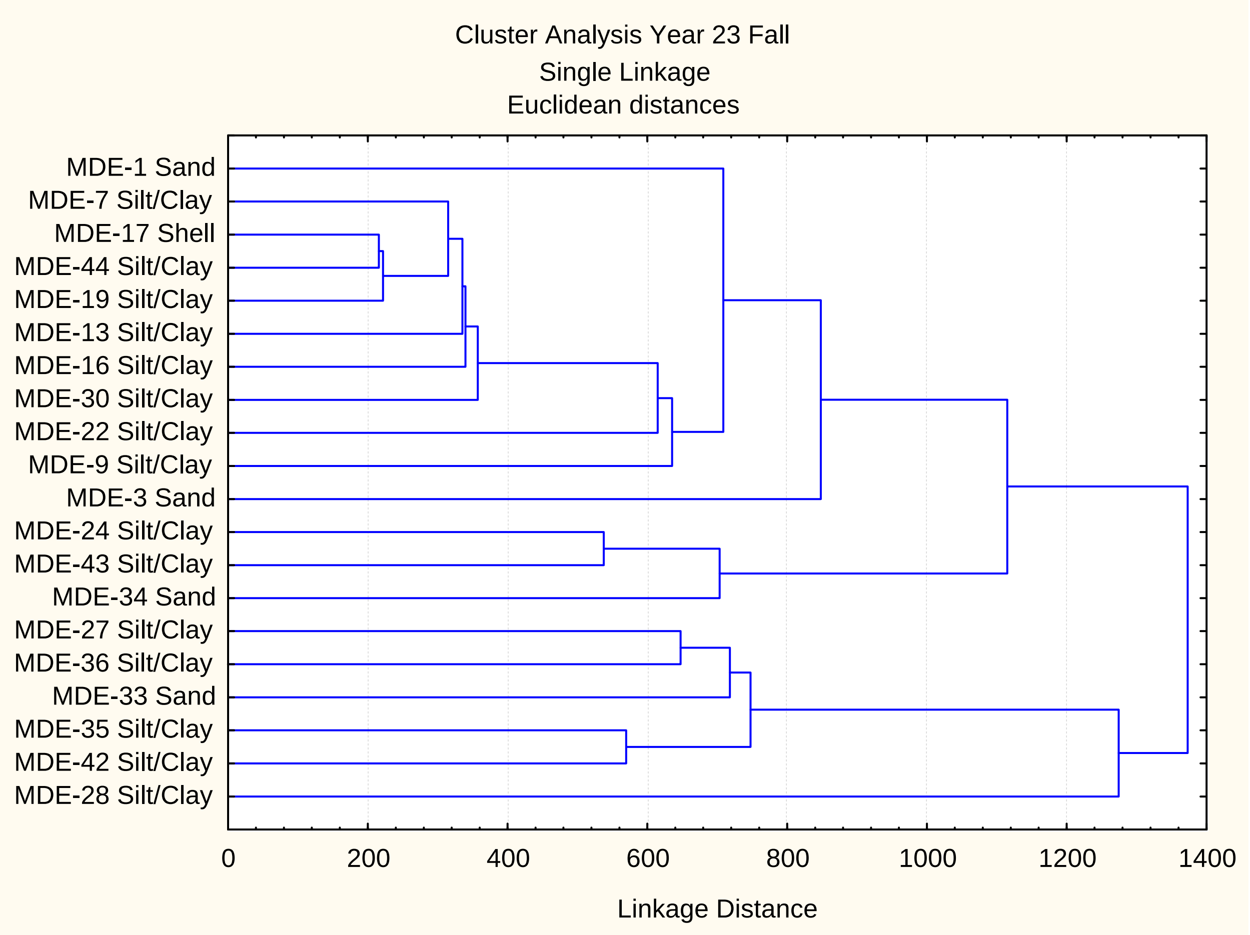

Figure 21: Cluster analysis based on Euclidean distance matrix of infaunal abundances of all HMI stations, year 23 September 2004.

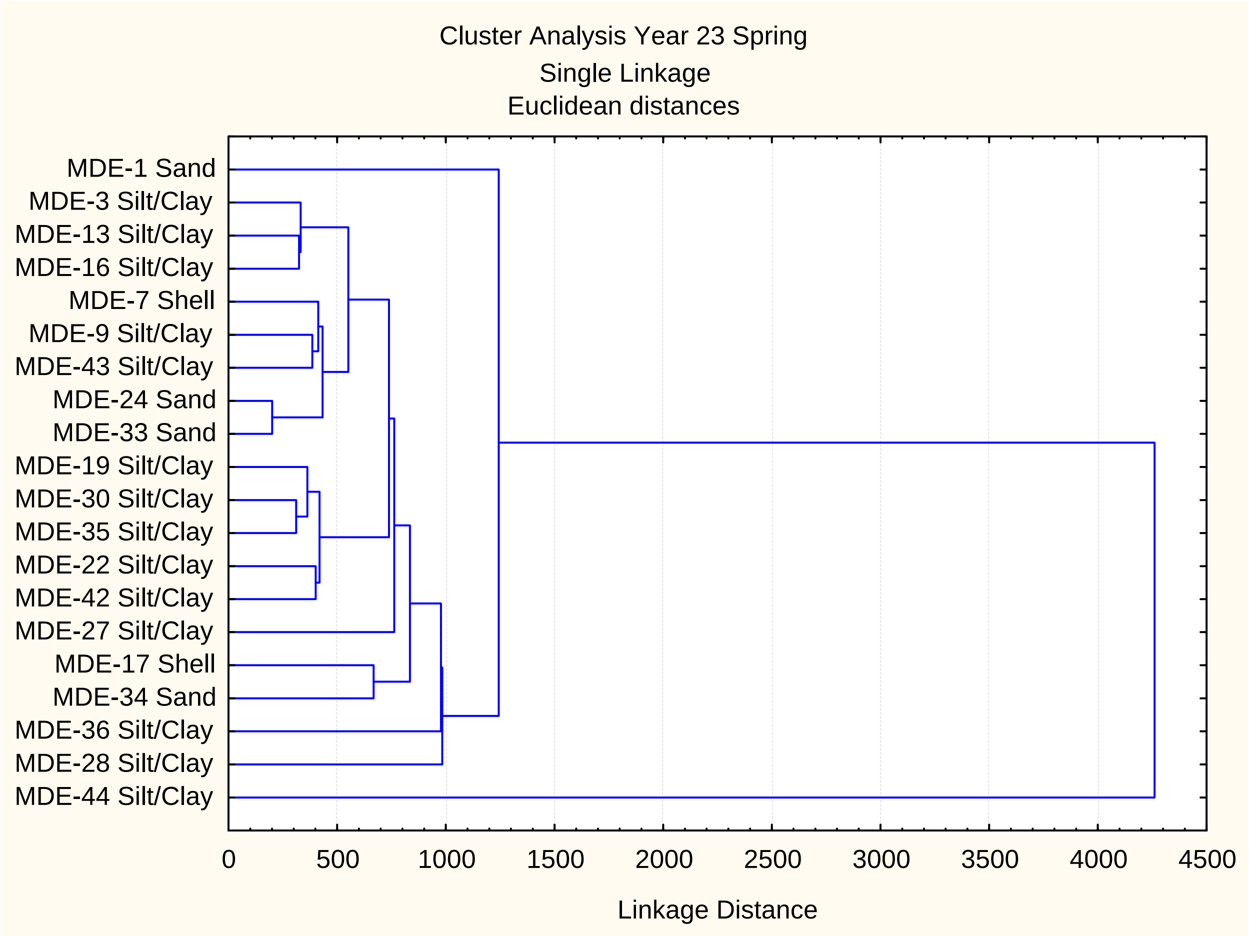

Figure 22: Cluster analysis based on Euclidean distance matrix of infaunal abundances of all HMI stations, year 23 April 2005.

APPENDIX

Table 22: Year 23 Hart-Miller Island Benthic Organism Data, September 24, 2004. Stations MDE-1 through MDE-22. Taxa in bold are pollution sensitive while taxa highlighted in gray are pollution tolerant.

TAXON	MDE-1			MDE-3			MDE-7			MDE-9			MDE-13			MDE-16			MDE-17			MDE-19			MDE-22		
	Replicate			Replicate			Replicate			Replicate			Replicate			Replicate			Replicate			Replicate			Replicate		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Nemata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0
Carinoma tremophoros	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	1	0	0	0	1	1	1	0	0	1	1	0
Bivalvia	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	5	0	0	0	0	0	0	1	0
Macoma balthica	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**7**	**3**	**1**
Rangia cuneata	**42**	**1**	**1**	**16**	**18**	**31**	**22**	**22**	**6**	**4**	**9**	**6**	**28**	**25**	**11**	**11**	**8**	**26**	**9**	**15**	**8**	**1**	**6**	**0**	**30**	**39**	**27**
Ischadium recurvum	0	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mytilopsis leucophaeata	0	23	26	18	6	14	0	4	3	31	45	9	1	0	0	0	5	0	0	5	3	0	0	0	0	0	0
Amphicteis floridus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Heteromastus filiformis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Spionidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Marenzellaria viridis	**18**	**3**	**20**	**69**	**67**	**49**	**27**	**32**	**10**	**13**	**19**	**19**	**17**	**4**	**10**	**31**	**32**	**40**	**5**	**8**	**19**	**11**	**14**	**11**	**36**	**10**	**10**
Streblospio benedicti	0	1	2	13	3	14	0	3	0	27	16	16	5	31	6	16	10	3	4	12	4	0	0	6	0	13	0
Polydora cornuta	0	0	1	1	0	1	0	0	0	0	0	3	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Nereididae	0	1	1	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Neanthes succinea	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Tubificidae	4	9	5	81	27	37	7	12	4	22	8	17	26	34	4	34	13	2	2	32	2	7	1	1	44	94	5
Amphipoda	1	0	0	0	2	0	0	1	0	1	0	0	1	0	0	0	1	0	0	0	0	0	0	1	2	0	0
Gammaridea	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ameroculodes spp complex	3	0	0	1	1	0	1	1	0	3	0	3	2	10	0	2	1	1	0	0	0	4	2	5	2	4	6
Leptocheirus plumulosus	0	0	0	0	0	0	3	3	0	0	0	1	1	2	0	0	1	0	0	0	0	0	0	0	4	8	2
Gammarus sp.	8	0	0	1	1	1	3	3	0	0	1	1	0	1	2	1	0	0	0	1	0	0	0	0	0	2	1
Melitadae	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Melita nitida	0	39	33	1	1	0	4	3	1	1	5	1	0	0	2	1	0	0	0	0	0	0	1	0	0	0	0
Apocorophium sp.	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Apocorophium lacustre	0	5	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Cyathura polita	**10**	**12**	**14**	**25**	**24**	**14**	**16**	**18**	**9**	**30**	**24**	**33**	**12**	**6**	**15**	**20**	**16**	**18**	**11**	**24**	**12**	**4**	**7**	**7**	**8**	**12**	**14**

Table 22: Continued.

TAXON	MDE-1			MDE-3			MDE-7			MDE-9			MDE-13			MDE-16			MDE-17			MDE-19			MDE-22		
	Replicate			Replicate			Replicate			Replicate			Replicate			Replicate			Replicate			Replicate			Replicate		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Edotea triloba	1	0	0	1	0	1	0	0	0	2	2	0	0	8	0	3	1	3	4	0	3	4	4	3	2	4	2
Chiridotea almyra	**7**	**0**	**0**	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Balanus improvisus	0	27	43	0	0	0	0	0	0	0	2	0	1	0	0	0	2	0	0	6	0	0	0	0	0	0	0
Balanus subalbidus	0	4	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0
Xanthidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rhithropanopeus harrisii	3	9	8	2	1	0	2	1	1	2	0	0	2	0	2	0	2	1	1	4	0	0	1	0	0	0	0
Membranipora sp	C	A	A	C	C	R	0	C	0	C	0	C	A	R	C	C	R	0	R	C	A	R	0	0	0	0	0
Chironomidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Coelotanypus sp.	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	3	1	2	0	0	0
Cryptochiromomus sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Procladius sp.	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Procladius (*Holotanypus*) sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Polypedulum halterale Group	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

A= Abundant (> 500/m2); C= Common (>100-500/m2); R= Rare (>1-100/m2)

Table 22: Continued.

TAXON	MDE-24			MDE-27			MDE-28			MDE-30			MDE-33			MDE-34			MDE-35			MDE-36		
	Replicate			Replicate			Replicate			Replicate			Replicate			Replicate			Replicate			Replicate		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Nemata	0	0	1	7	0	0	0	0	13	0	0	0	0	0	0	0	0	0	2	22	3	0	0	0
Carinoma tremophoros	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bivalvia	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	2	0
Macoma balthica	**0**	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	0
Rangia cuneata	**109**	**77**	**74**	**174**	**221**	**332**	**253**	**311**	**336**	**4**	**28**	**21**	**261**	**205**	**224**	**59**	**72**	**87**	**132**	**230**	**221**	**156**	**223**	299
Ischadium recurvum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mytilopsis leucophaeata	0	0	0	2	1	1	6	9	7	0	0	0	1	0	2	0	0	0	0	2	2	3	2	3
Amphicteis floridus	0	0	0	15	6	17	3	1	1	0	0	0	0	0	0	0	0	0	0	0	0	3	3	5
Heteromastus filiformis	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Spionidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Marenzellaria viridis	**6**	**3**	**46**	**16**	**36**	**41**	**8**	**3**	**9**	**7**	**4**	**2**	**9**	**2**	**4**	**2**	**0**	**1**	**4**	**17**	**18**	**58**	**48**	51
Streblospio benedicti	0	0	0	1	3	3	3	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0
Polydora cornuta	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
Nereididae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Neanthes succinea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tubificidae	20	23	13	5	12	3	5	1	2	0	2	12	0	2	0	0	0	0	1	17	1	3	0	1
Amphipoda	0	0	0	0	1	0	0	0	1	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0
Gammaridea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Ameroculodes spp complex	5	1	0	2	4	2	4	1	0	4	0	3	1	1	0	1	2	1	0	0	2	0	1	0
Leptocheirus plumulosus	0	0	0	9	5	5	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Gammarus sp.	5	2	6	2	0	0	2	0	0	0	0	0	1	2	2	1	1	1	1	0	0	0	2	0
Melitadae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Melita nitida	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Apocorophium sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Apocorophium lacustre	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Cyathura polita	**15**	**3**	**20**	**15**	**14**	**18**	**5**	**5**	**7**	**2**	**4**	**4**	**4**	**7**	**9**	**0**	**3**	**7**	**4**	**5**	**9**	**10**	**6**	**10**

Table 22: Continued.

TAXON	MDE-24			MDE-27			MDE-28			MDE-30			MDE-33			MDE-34			MDE-35			MDE-36		
	Replicate			Replicate			Replicate			Replicate			Replicate			Replicate			Replicate			Replicate		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Edotea triloba	34	4	12	10	17	17	2	1	3	0	0	1	0	0	0	0	1	1	1	0	0	0	0	2
Chiridotea almyra	**9**	**2**	**2**	**0**	**2**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**3**	**7**	**5**	**12**	**18**	**15**	**0**	**0**	**0**	**0**	**0**	**0**
Balanus improvisus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Balanus subalbidus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Xanthidae	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rhithropanopeus harrisii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Membranipora sp	C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	R	0	0	0	0
Chironomidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0
Coelotanypus sp.	0	0	0	4	1	0	3	10	0	11	9	8	0	0	0	0	0	0	2	4	4	0	1	2
Cryptochiromomus sp.	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Procladius sp.	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Procladius (*Holotanypus*) sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Polypedulum halterale Group	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0

A= Abundant (> 500/m2); C= Common (>100-500/m2); R= Rare (>1-100/m2)

Table 22: Continued.

TAXON	MDE-42			MDE-43			MDE-44		
	Replicate			Replicate			Replicate		
	1	2	3	1	2	3	1	2	3
Nemata	0	0	0	0	0	0	0	0	0
Carinoma tremophoros	0	0	0	1	0	0	0	0	0
Bivalvia	0	0	0	1	1	0	0	0	0
Macoma balthica	**3**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**0**
Rangia cuneata	**11**	**11**	**3**	**32**	**33**	**25**	**0**	**2**	**0**
Ischadium recurvum	0	0	0	0	0	0	0	0	0
Mytilopsis leucophaeata	0	0	0	0	0	0	0	0	0
Amphicteis floridus	0	0	0	0	0	0	0	0	0
Heteromastus filiformis	0	0	0	0	0	0	0	0	0
Spionidae	0	0	0	0	0	0	0	0	0
Marenzellaria viridis	**7**	**17**	**11**	**24**	**37**	**4**	**55**	**2**	**8**
Streblospio benedicti	2	1	4	29	3	1	11	12	0
Polydora cornuta	0	0	0	0	0	1	0	0	0
Nereididae	0	0	0	0	0	0	0	0	0
Neanthes succinea	0	0	0	0	0	0	0	0	0
Tubificidae	24	5	7	3	3	6	1	17	0
Amphipoda	0	0	0	0	1	0	0	0	1
Gammaridea	0	0	0	1	0	1	0	0	0
Ameroculodes spp complex	3	4	3	7	9	0	1	3	0
Leptocheirus plumulosus	2	5	0	0	0	1	0	0	0
Gammarus sp.	1	0	1	1	3	0	0	0	11
Melitadae	0	0	0	0	0	0	0	0	0
Melita nitida	0	0	0	1	0	0	0	0	2
Apocorophium sp.	0	0	0	0	0	0	0	0	0
Apocorophium lacustre	0	1	0	0	0	0	0	0	1
Cyathura polita	**4**	**12**	**7**	**15**	**20**	**11**	**12**	**2**	**10**
Nemata	0	0	0	0	0	0	0	0	0

Table 22: Continued.

TAXON	MDE-42			MDE-43			MDE-44		
	Replicate			Replicate			Replicate		
	1	2	3	1	2	3	1	2	3
Edotea triloba	4	3	2	5	5	2	2	4	1
Chiridotea almyra	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Balanus improvisus	0	0	0	0	0	0	0	1	0
Balanus subalbidus	0	0	0	0	0	0	0	0	0
Xanthidae	0	0	0	0	0	0	0	0	0
Rhithropanopeus harrisii	0	0	0	0	0	0	0	0	0
Membranipora sp	0	R	C	R	R	C	0	R	0
Chironomidae	0	0	0	0	0	0	0	0	0
Coelotanypus sp.	0	0	0	0	0	0	0	0	0
Cryptochiromomus sp.	0	0	0	0	0	0	0	0	0
Procladius sp.	0	0	0	0	0	0	0	0	0
Procladius (*Holotanypus*) sp.	0	0	0	0	0	0	0	0	0
Polypedulum halterale Group	0	0	0	0	0	0	0	0	0

A= Abundant (> 500/m2); C= Common (>100-500/m2); R= Rare (>1-100/m2)

Table 23: Year 23 Hart-Miller Island Benthic Organism Data, April 13, 2005. Stations MDE-1 through MDE-22. Taxa in bold are pollution sensitive while taxa highlighted in gray are pollution tolerant.

TAXON	MDE-1			MDE-3			MDE-7			MDE-9			MDE-13			MDE-16			MDE-17			MDE-19			MDE-22		
	Replicate			Replicate			Replicate			Replicate			Replicate			Replicate			Replicate			Replicate			Replicate		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Nemata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Carinoma tremophoros	0	0	0	1	0	0	0	0	0	0	0	0	1	0	1	1	0	0	0	1	0	0	0	1	0	0	1
Bivalvia	0	0	0	0	0	0	0	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Macoma balthica	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	4	4	4
Rangia cuneata	11	4	9	19	17	21	0	3	13	12	5	7	4	8	6	13	9	7	3	3	10	3	1	3	15	25	8
Ischadium recurvum	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mytilopsis leucophaeata	0	0	0	0	0	1	3	1	2	3	1	12	1	0	0	1	0	0	1	4	12	0	0	0	0	0	0
Heteromastus filiformis	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Spionidae	0	1	1	0	3	0	0	0	3	0	1	0	0	0	0	5	0	0	0	2	0	0	0	0	0	0	0
Marenzellaria viridis	327	74	338	52	98	68	116	101	143	83	64	140	86	22	73	46	95	49	117	232	207	2	4	9	31	24	19
Nereididae	0	0	0	0	0	0	0	0	0	1	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Neanthes succinea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	0	0	0	0	0	0
Tubificidae	5	0	1	10	33	22	17	20	9	7	19	53	20	30	30	20	10	4	10	15	14	0	2	3	1	25	34
Amphipoda	0	0	0	0	0	0	2	0	2	0	1	1	0	0	0	0	0	0	1	0	5	0	0	0	1	0	0
Ameroculodes spp complex	3	2	2	3	1	4	0	4	1	1	9	5	2	0	2	0	1	0	0	1	0	0	0	1	1	0	7
Leptocheirus plumulosus	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	1	0	0	0	1	3	2	1	3	1
Gammarus sp	0	0	0	2	1	0	1	1	2	0	0	2	4	0	0	0	0	0	3	4	6	0	0	0	0	0	0
Melita nitida	0	1	0	0	0	0	2	0	9	0	0	4	0	0	0	0	1	0	3	5	5	0	0	0	0	0	0
Corophiidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Apocorophium lacustre	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	1	1	0	1	1	4	0	0	0	1	0	0
Cyathura polita	3	3	5	16	18	12	22	22	23	32	23	23	9	10	9	17	15	7	11	17	14	2	1	5	14	11	15
Edotea triloba	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0
Chiridotea almyra	0	1	4	0	1	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Balanus improvisus	0	0	0	0	0	1	2	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0
Balanus subalbidus	0	0	0	0	0	0	3	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rhithropanopeus harrisii	0	0	0	0	2	0	3	0	5	1	0	1	0	0	0	0	0	0	0	1	3	0	0	0	0	0	0
Membranipora sp	0	0	0	C	R	C	0	A	C	C	C	C	R	R	R	R	0	R	C	A	A	0	0	0	0	0	0

Table 23: Continued.

TAXON	MDE-1			MDE-3			MDE-7			MDE-9			MDE-13			MDE-16			MDE-17			MDE-19			MDE-22		
	Replicate			Replicate			Replicate			Replicate			Replicate			Replicate			Replicate			Replicate			Replicate		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Chironomidae	0	0	1	0	0	0	1	0	0	0	0	1	0	0	0	0	1	4	0	0	0	0	0	0	0	0	0
Tanypodinae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Orthocladiinae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Coelotanypus sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	1	0
Procladius sp.	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Procladius (Holotanypus) sp.	0	0	0	2	3	4	1	2	0	1	4	4	3	0	2	0	4	6	3	3	2	5	6	5	4	2	0
Chironominae	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0
Cryptochironomus sp.	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	1	0	0	1	0	0	0	0	0	0	0	2
Cricotopus sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0
Rheotanytarsus sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Polypedulum Uresipedulum flavum	0	0	1	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Harnischia sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mya arenaria	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Copepoda	0	0	0	R	0	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	0	R	R	R	R
Parahaustorius holmesi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chironomidae Pupae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hydrozoa	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Amphicteis floridus	0	0	0	0	0	0	0	7	0	6	0	0	0	0	0	1	0	0	1	0	28	0	0	0	0	0	0
Cyclaspis varians	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Polydora cornuta	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Cladocera sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0

A= Abundant (> 500/m2); C= Common (>100-500/m2); R= Rare (>1-100/m2)

Table 23: Continued.

TAXON	MDE-24			MDE-27			MDE-28			MDE-30			MDE-33			MDE-34			MDE-35			MDE-36		
	Replicate			Replicate			Replicate			Replicate			Replicate			Replicate			Replicate			Replicate		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Nemata	4	0	0	3	11	3	36	3	28	0	0	0	0	0	0	0	0	0	1	29	8	0	0	0
Carinoma tremophoros	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Bivalvia	0	0	0	1	0	1	6	4	2	0	1	3	0	0	0	0	0	0	0	0	0	0	0	0
Macoma balthica	**0**	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Rangia cuneata	**24**	**12**	**8**	**5**	**15**	**8**	**59**	**58**	**75**	**6**	**17**	**22**	**15**	**8**	**24**	**27**	**19**	**26**	**27**	**22**	**5**	**51**	**31**	**105**
Ischadium recurvum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mytilopsis leucophaeata	0	1	0	0	0	0	1	6	3	0	0	0	0	0	0	1	0	0	1	0	0	1	0	0
Heteromastus filiformis	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Spionidae	0	5	0	0	0	1	0	0	1	0	0	0	0	0	13	11	0	0	0	0	0	0	0	9
Marenzellaria viridis	**166**	**140**	**71**	**57**	**56**	**20**	**50**	**0**	**24**	**5**	**25**	**13**	**58**	**92**	**220**	**114**	**87**	**299**	**10**	**19**	**7**	**109**	**136**	**121**
Nereididae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Neanthes succinea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tubificidae	22	5	0	7	20	1	12	3	1	0	13	6	1	15	0	0	0	8	10	15	7	5	7	7
Amphipoda	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0
Ameroculodes spp complex	2	0	7	0	1	0	0	1	0	0	1	0	0	1	3	5	6	8	0	1	0	1	1	2
Leptocheirus plumulosus	1	0	2	17	45	26	4	1	2	0	0	0	0	0	0	0	0	1	2	0	2	1	0	0
Gammarus sp	2	1	0	0	0	2	1	4	2	0	0	0	1	0	0	0	1	0	0	1	0	4	2	1
Melita nitida	0	0	0	0	6	1	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Corophiidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Apocorophium lacustre	4	0	1	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	1
Cyathura polita	**5**	**12**	**4**	**8**	**8**	**7**	**6**	**8**	**5**	**3**	**6**	**3**	**0**	**12**	**6**	**2**	**2**	**1**	**5**	**3**	**4**	**8**	**10**	**9**
Edotea triloba	3	0	0	5	1	5	3	2	5	0	0	1	0	0	0	0	0	1	0	0	1	0	0	0
Chiridotea almyra	**4**	**3**	**2**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**2**	**0**	**0**	**4**	**2**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Balanus improvisus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Balanus subalbidus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rhithropanopeus harrisii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Membranipora sp	0	0	0	0	0	0	0	0	0	0	0	R	0	0	0	0	0	0	0	0	0	0	0	0

Table 23: Continued.

TAXON	MDE-24			MDE-27			MDE-28			MDE-30			MDE-33			MDE-34			MDE-35			MDE-36		
	Replicate			Replicate			Replicate			Replicate			Replicate			Replicate			Replicate			Replicate		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Chironomidae	0	0	3	3	1	0	0	0	0	0	0	3	0	0	0	0	0	1	0	0	0	0	0	0
Tanypodinae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Orthocladiinae	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Coelotanypus sp.	0	0	0	6	2	1	14	6	10	8	7	10	0	0	0	0	0	0	9	2	1	4	3	0
Procladius sp.	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	5	5	3
Procladius (Holotanypus) sp.	1	0	0	9	7	7	20	21	18	0	3	1	0	0	0	0	0	0	10	10	4	16	14	18
Chironominae	0	3	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Cryptochironomus sp.	0	1	3	0	4	0	2	0	0	0	1	0	0	1	0	1	2	0	0	0	0	0	0	0
Cricotopus sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Rheotanytarsus sp.	0	1	6	0	1	0	0	0	2	1	0	0	0	0	0	1	0	0	0	0	0	0	0	1
Polypedulum Uresipedulum flavum	0	0	2	0	0	0	0	0	0	0	1	0	0	0	5	0	0	0	0	0	0	0	0	0
Harnischia sp.	1	0	0	4	2	1	2	3	0	1	4	0	0	0	0	0	0	0	0	1	0	0	0	1
Mya arenaria	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Copepoda	0	0	0	R	R	R	R	R	0	0	R	R	0	0	R	R	R	0	R	0	R	R	R	R
Parahaustorius holmesi	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chironomidae Pupae	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hydrozoa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Amphicteis floridus	0	0	0	9	4	8	5	2	2	0	3	0	0	0	0	0	0	0	1	1	0	10	15	3
Cyclaspis varians	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Polydora cornuta	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cladocera sp.	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0

A= Abundant (> 500/m2); C= Common (>100-500/m2); R= Rare (>1-100/m2)

Table 23: Continued.

TAXON	MDE-42			MDE-43			MDE-44		
	Replicate			Replicate			Replicate		
	1	2	3	1	2	3	1	2	3
Nemata	0	0	0	0	0	0	0	0	1
Carinoma tremophoros	1	0	0	0	0	1	1	0	0
Bivalvia	0	0	0	6	2	1	0	0	0
Macoma balthica	**0**	**2**	**1**	**0**	**0**	**0**	**0**	**0**	**0**
Rangia cuneata	**0**	**9**	**7**	**21**	**1**	**10**	**2**	**4**	**0**
Ischadium recurvum	0	0	0	0	0	0	0	0	0
Mytilopsis leucophaeata	0	0	0	0	0	0	0	1	0
Heteromastus filiformis	0	0	0	0	0	0	1	0	0
Spionidae	0	0	2	2	0	0	1	6	0
Marenzellaria viridis	**4**	**21**	**15**	**150**	**64**	**103**	**325**	**618**	**460**
Nereididae	0	0	0	0	0	0	0	0	0
Neanthes succinea	0	0	0	0	0	0	0	0	0
Tubificidae	0	68	20	40	17	10	7	19	14
Amphipoda	0	0	0	1	0	1	0	0	0
Ameroculodes spp complex	0	2	1	1	1	4	1	0	2
Leptocheirus plumulosus	1	1	1	0	1	1	0	1	0
Gammarus sp	2	0	0	2	0	0	0	1	0
Melita nitida	0	0	0	0	0	0	0	1	0
Corophiidae	0	0	0	0	0	0	0	0	0
Apocorophium lacustre	0	0	0	0	0	1	1	4	2
Cyathura polita	**5**	**4**	**7**	**18**	**8**	**9**	**6**	**16**	**14**
Edotea triloba	0	0	0	0	0	0	0	1	2
Chiridotea almyra	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**2**	**3**
Balanus improvisus	0	0	0	0	0	0	0	0	0
Balanus subalbidus	0	0	0	0	0	0	0	0	0
Rhithropanopeus harrisii	0	0	0	1	0	0	0	1	0
Membranipora sp	0	R	R	0	0	0	0	R	0

Table 23: Continued.

	MDE-42			**MDE-43**			**MDE-44**		
	Replicate			**Replicate**			**Replicate**		
	1	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
Chironomidae	0	0	1	0	0	0	0	0	0
Tanypodinae	0	0	0	0	0	0	0	0	0
Orthocladiinae	0	0	0	0	0	0	0	0	0
Coelotanypus sp.	2	0	2	0	1	1	0	0	0
Procladius sp.	0	0	0	1	1	0	0	0	0
Procladius (Holotanypus) sp.	2	3	5	2	4	2	0	0	1
Chironominae	0	0	0	0	0	0	0	0	0
Cryptochironomus sp.	0	0	1	0	1	0	0	0	0
Cricotopus sp.	0	0	0	0	0	0	0	0	0
Rheotanytarsus sp.	0	0	0	0	0	0	0	0	0
Polypedulum Uresipedulum flavum	0	0	0	0	0	0	0	0	0
Harnischia sp.	0	1	0	0	0	0	0	0	0
Mya arenaria	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Copepoda	0	R	R	R	R	R	0	0	0
Parahaustorius holmesi	0	0	0	0	0	0	0	0	0
Chironomidae Pupae	0	0	0	0	0	0	0	0	0
Hydrozoa	0	0	0	5	0	0	0	0	0
Amphicteis floridus	0	0	0	0	0	0	1	1	0
Cyclaspis varians	0	0	0	0	0	0	0	0	0
Polydora cornuta	0	0	0	0	0	0	1	0	0
Cladocera sp.	0	0	0	0	0	0	0	0	0

A= Abundant (> 500/m2); C= Common (>100-500/m2); R= Rare (>1-100/m2)

PROJECT 4: ANALYTICAL SERVICES
(September 2004 – September 2005)

By

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OBJECTIVES

The goals of the project in 2004-2005 were to continue to measure and evaluate the current levels of contaminants in the sediment in the vicinity of HMI and to relate these, as far as possible, to historical data. Continued comparison and correlation of this data with historical HMI data, will indicate the extent of contamination and any trend in concentrations at this location.

The objective of this study was to provide sensitive, high-quality information on the concentrations of present day trace metals in surface sediments surrounding HMI during the 23rd year of exterior monitoring, and to document any seasonal changes. Specific objectives were:

1. In the fall of 2004 and spring of 2005, collect clams and worms if available and associated sediment for analyses of trace metals, PCB’s and PAH’s.

2. To determine the concentrations of target trace elements in surface sediments around HMI collected by MGS in September 2004 as part of the annual sediment survey. Metal analysis focuses on those metals not measured by MGS, specifically mercury (Hg), monomethylmercury (MMHg), silver (Ag), and arsenic (As), as well as cadmium (Cd) and lead (Pb);

The results of the quality assurance (QA/QC) procedures and the description of the analytical and field protocols are contained in the *Year 23 Data Report*. Overall, the QA/QC results were acceptable for a study of this nature. No evidence of bias or lack of precision or accuracy was indicated by the QA/QC results. Comparisons of duplicate analyses and comparison of measured values to certified values for the analyzed Standard Reference Materials are also discussed in the *Year 23 Data Report*. Again, the QA/QC objectives were met in this regard.

METHODS AND MATERIALS

Sampling Procedures

Samples were collected using a Ponar grab sampler, from sites designated by the revised sampling plan, developed by the Maryland Department of the Environment in September 2004. Sediment for trace metal and organics analyses were collected using plastic spatulas and glass spatulas respectively, integrating the top several centimeters and avoiding the sides of the sampler to minimize the possibility of contamination. Sediments for metals were placed in plastic sampling cups and sediment for PAH and PCB analyses were placed in glass jars. Both sets were kept cooled in an ice chest or refrigerator until they could be processed in the laboratory.

Sediment was sieved for clams; the whole clams where placed in plastic bags with surface water and held on ice. The clams were frozen to allow easy shucking the next day. For organic analysis, composite samples of clams from each site were prepared by removing fresh clams whole from their shells with a stainless steel scalpel. All body fluids were retained in the sample. The scalpel was cleaned with methanol between each sample set to avoid cross contamination between stations. Tissue was placed in a clean glass jar with a Teflon-lined lid and stored in the dark below 0˚C. For metals analysis, clams were removed whole from their shells with a Teflon-coated spatula. Most of the water and body fluids were allowed to drain. The spatula was acid rinsed between each site to avoid cross contamination between sites. The clam bodies from each site 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.

Analytical Procedures

Metals

Methods used for metals analysis are similar to those described in detail in Dalal et al. (1999). Sediment and clam tissue were treated the same with regard to analysis. A sub-sample of sediment (5 g wet weight) was placed in acid-cleaned flasks for further digestion, using USEPA Methods (USEPA Methods; Keith 1991). Ten mL of 1:1 HNO_3 was added and the slurry was mixed and covered with a watch glass. The sample was heated to 95^0C and allowed to reflux for 15 minutes without boiling. The samples were cooled, 5 mL of concentrated HNO_3 was added, and then they were allowed to reflux for another 30 minutes. This step was repeated to ensure complete oxidation. The watch glasses were removed and the resulting solution was allowed to evaporate to 5 mL without boiling. When evaporation was complete and the samples cooled, 2 mL of 30% H_2O_2 was added. The flasks were then covered and returned to the hot plate for warming. The samples were heated until effervescence subsided. We continually added 30% H_2O_2 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. Lastly, 5 mL of concentrated HCl and 10 mL of deionized water were added and the samples refluxed for 15 minutes. The samples were then cooled and filtered through Whatman No. 41 filter paper by suction filtration and diluted to 50 mL with deionized water.

Sediment homogenates were then analyzed using a Hewlett Packard model 4500 Inductively Coupled Plasma Mass Spectrometer for the other metals and metalloids. These techniques are similar to USEPA Method 1632.

Samples for mercury (1-3 g wet weight) were digested in a solution of 70% sulfuric/30% nitric acid in Teflon vials, heating overnight in an oven at 60^0C (Mason and Lawrence, 1999). The digestate was then diluted to 10 mLs with distilled-deionized water. Prior to analysis, the samples were further oxidized for 30 minutes with 2 mLs 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 (CVAFS) detection after gold amalgamation in accordance with protocols outlined in USEPA Method 1631 (Mason et al. 1993).

Samples for methylmercury were distilled after adding a 50% sulfuric acid solution and a 20% potassium chloride solution (Horvat et al. 1993, Bloom 1989). The distillate was reacted with a sodium tetraethylborate solution to convert the nonvolatile MMHg to gaseous MMHg. The volatile adduct was purged from solution and recollected on a graphitic carbon column at room temperature. The MMHg was then thermally desorbed from the column and analyzed by cryogenic gas chromatography with CVAFS. Detection limits for Hg and MMHg were based on three standard deviations of the blank measurement.

For metals, a subsample of each trace metal sample (sediments) was used for dry weight determination. Weighed samples were placed in a VWR Scientific Forced Air Oven at 60^0C overnight. Upon drying, samples were then reweighed and a dry/wet ratio was calculated.

Organics

The sediment, clam and worm homogenates were extracted and purified using the method described by Kucklick et al. (1996). For this method, a subsample of clam homogenate, 5 g wet weight, is removed and ground with anhydrous sodium sulfate (~50 g). A perdueterated polyaromatic hydrocarbon (PAH) cocktail (d_8-napthalene, d_{10}-fluorene, d_{10}-fluoranthene, d_{12}-perylene) and a noncommercial polychlorinated biphenyl (PCB) solution (IUPAC #'s 14, 65, 166) are added as surrogates to each sample to track extraction efficiency. The mixture is then extracted in a Soxhlet apparatus with 250 mL of dichloromethane (DCM) for 24 hours. The extracts are then concentrated to 2 mL using a vacuum rotary evaporator and transferred into hexane. Each sample is transferred to a 4 ml Waters autosampler vial with sample and rinses amounting to approximately 4 mL. Gravimetric lipid analysis is performed on each sample with subsampled fractions determined gravimetrically (Kucklick et al. 1996). Samples are again concentrated in similar fashion as above, then solvent exchanged to hexane. To remove lipids the extracts are then eluted with 25 mL petroleum ether over 4 g deactivated Alumina [6% (w/w) water]. After concentrating, the extracts are spiked with a perdueterated 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 PAH's. 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 a HP-5972 series mass spectrometer (MS) for PAH's (Ko and Baker 1995). 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 (2.5% (w/w) water (Kucklick et al.1996). 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 ~ 1 mL.

PCB congeners are analyzed by gas chromatography using a J&W Scientific DB-5 capillary column (60m x 0.32mm, 0.25µm film thickness) coupled with an electron capture detector. Individual PCB congeners are identified and quantified using the method of Mullins et al. (1985) using the noncommercial PCB congeners IUPAC 30 and 204 as internal standards. After quantification of PCB congeners, the two Florisil fractions from each sample are recombined and pesticides are quantified by gas chromatography (30 m DB-5 column) with negative chemical ionization mass spectrometric (NCI-MS) detection. Chemical ionization with methane reagent gas is used. Pesticides are identified by their chromatographic retention times and confirmed by the relative abundance of negative fragments (confirmation ions) relative to the quantification fragment. Five-point calibration curves are used for each pesticide analyzed. Polychlorinated biphenyl congener 204 is used as the internal standard for the pesticide quantification.

RESULTS AND DISCUSSION

Metals in Sediment

Concentrations of As, Se, Cd and Pb in the sediment collected around HMI in Year 23 (2004-2005) are similar to previous years (Figures 23 and 24) and not substantially different than the concentrations found elsewhere in the Chesapeake Bay or in marine sediments. Typical As concentrations in Chesapeake Bay sediment are 20 ug g^{-1} dry weight, which are similar to the mean HMI concentration. Se concentrations are less than 3 ug g^{-1} on average and remain so in 2004. Concentrations of Cd in marine sediments range from 0.03 to 1 ug g^{-1} dry weight, which are similar to the 2004 concentrations (Figure 24). The exceptions are sites 43 and 44, where concentrations of 5.5 and 2 ug g^{-1} occurred. Concentrations of Pb in Chesapeake Bay sediment recorded by Di Giulio and Scanlon (1985) ranged from 1-134 ug g^{-1} dry weight. Concentrations around HMI in 2004 were generally less than 60 ug g^{-1} dry weight, placing them well within the historical range. Sites 4 and 6 were in the 200 ug g^{-1} range and site 44 was in the 1200 ug g^{-1} range. Sites 4 and 6 represent only a small deviation from the long term average but site 44 is substantially higher than any other site. This site does not have a long term record. Silver concentrations remained low throughout the region in 2004 when compared to past years, except for site 43 (Figure 25). Silver contamination is often associated with general urban pollution, having origins in sewage treatment plants (Purcell and Peters, 1998). Concentrations of Ag in sediment observed in 1999 and 2000 remain anomalous relative to other years.

Concentrations of mercury (T-Hg) and methylmercury (MeHg) in sediment are lower than the average of previous years but are within the error bars (Figure 25). Concentrations of T-Hg in the main stem of the Chesapeake Bay range from 0.2 to 250 ng g^{-1} dry weight and concentrations of MeHg range from 0.01 to 2.2 ng g^{-1} dry weight (Figure 27) (Heyes et al. 2006). Concentrations of both T-Hg and MeHg are highest in the upper bay, with T-Hg concentrations on the order of 130 ng g^{-1} and MeHg concentrations 1 ng g^{-1}. Concentrations of T-Hg around HMI have averaged 200 ng g^{-1} and where near or slightly above the average value in 2004. In 2004, MeHg concentrations were slightly higher than the average of 1 ng g^{-1} observed over the study (Figure 26). Many sites had MeHg concentrations of 2 ng g^{-1} but this is not unusual for sediment elsewhere in the Bay. At MDE 18 the anomalously 5 percent MeHg is driven by an unusually low T-Hg concentration.

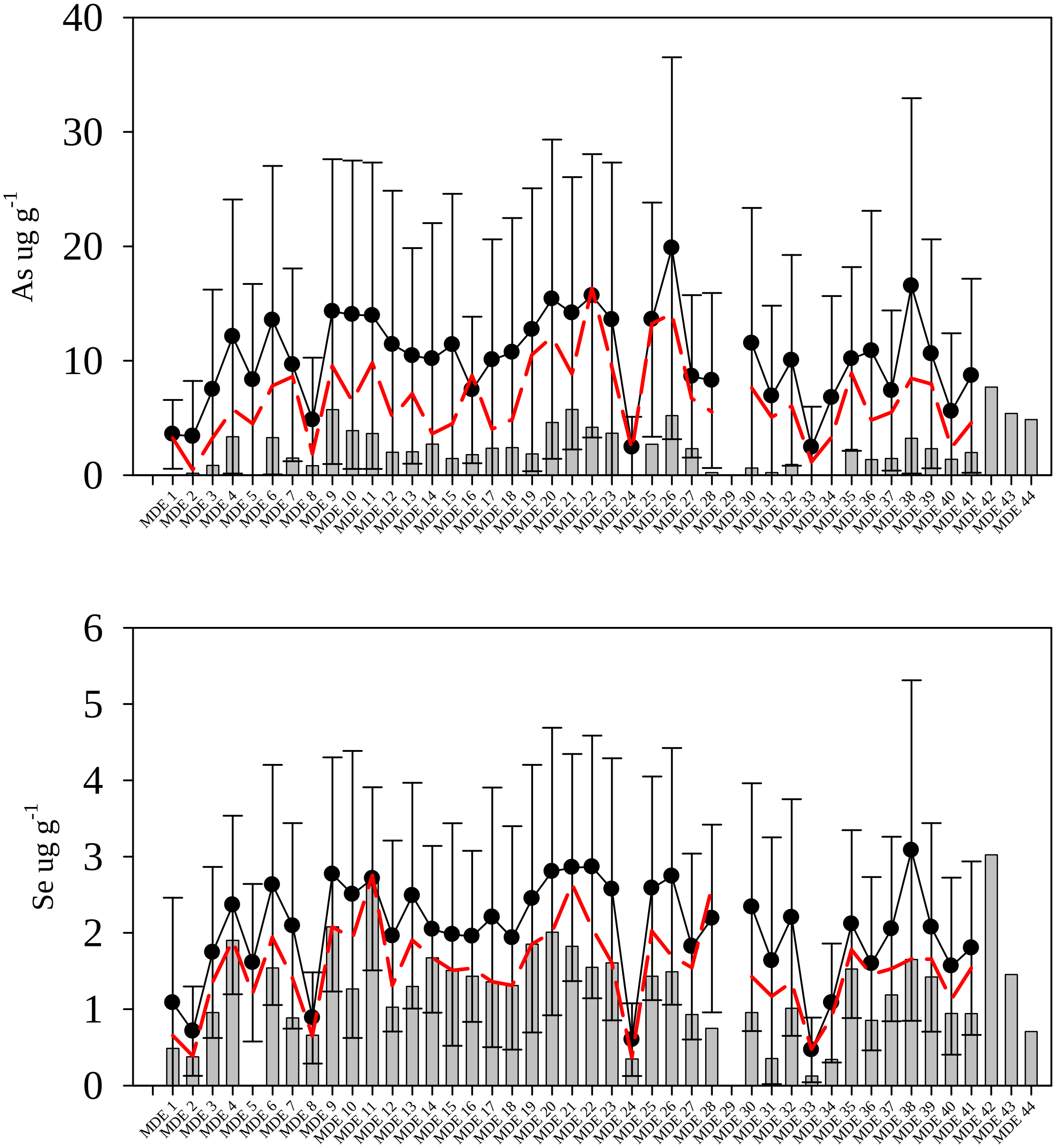
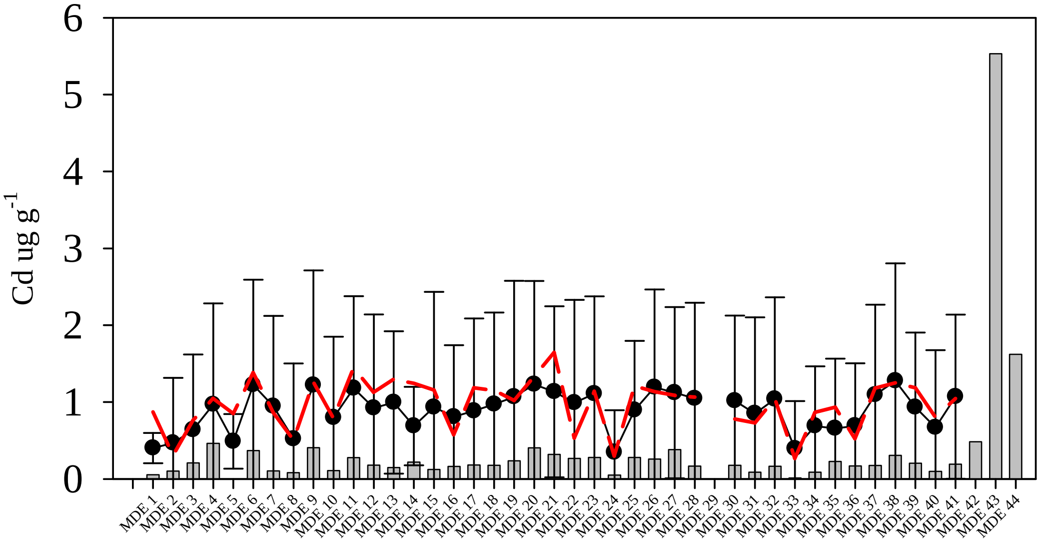


Figure 23: Arsenic (As) and selenium (Se) concentrations in sediment, expressed in dry weight, from 2004 (bars) and the 1998-2003 mean (circles) with standard deviation (error bars) and the 1998-2003 median (dashed line).



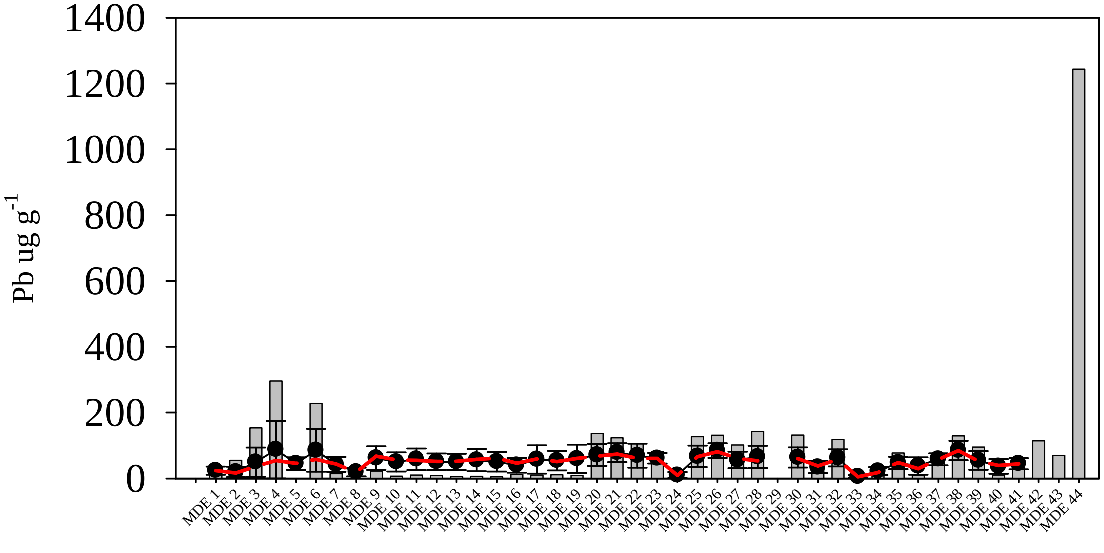


Figure 24: Cadmium (Cd) and lead (Pb) concentrations in sediment, expressed as dry weight, from 2004 (bars) and the 1998-2003 mean (circles) with standard deviation (error bars) and the 1998-2003 median (dashed line).

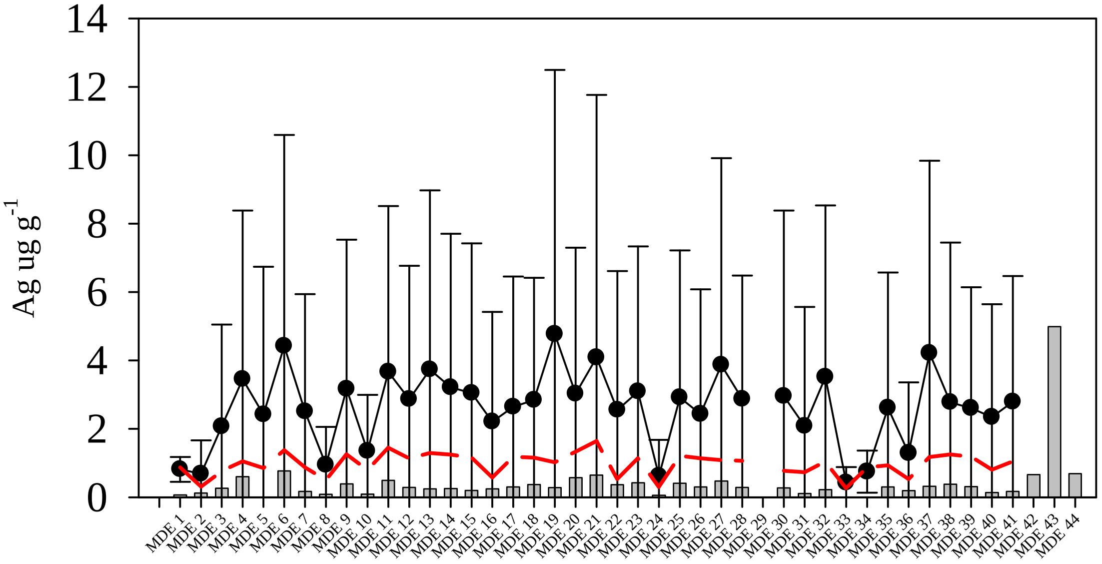


Figure 25: Silver (Ag) concentrations in sediment from 2004 (bars), expressed as dry wt, and the 1998-2003 mean (circles) with standard deviation (error bars) and the 1998-2003 median (dashed line).

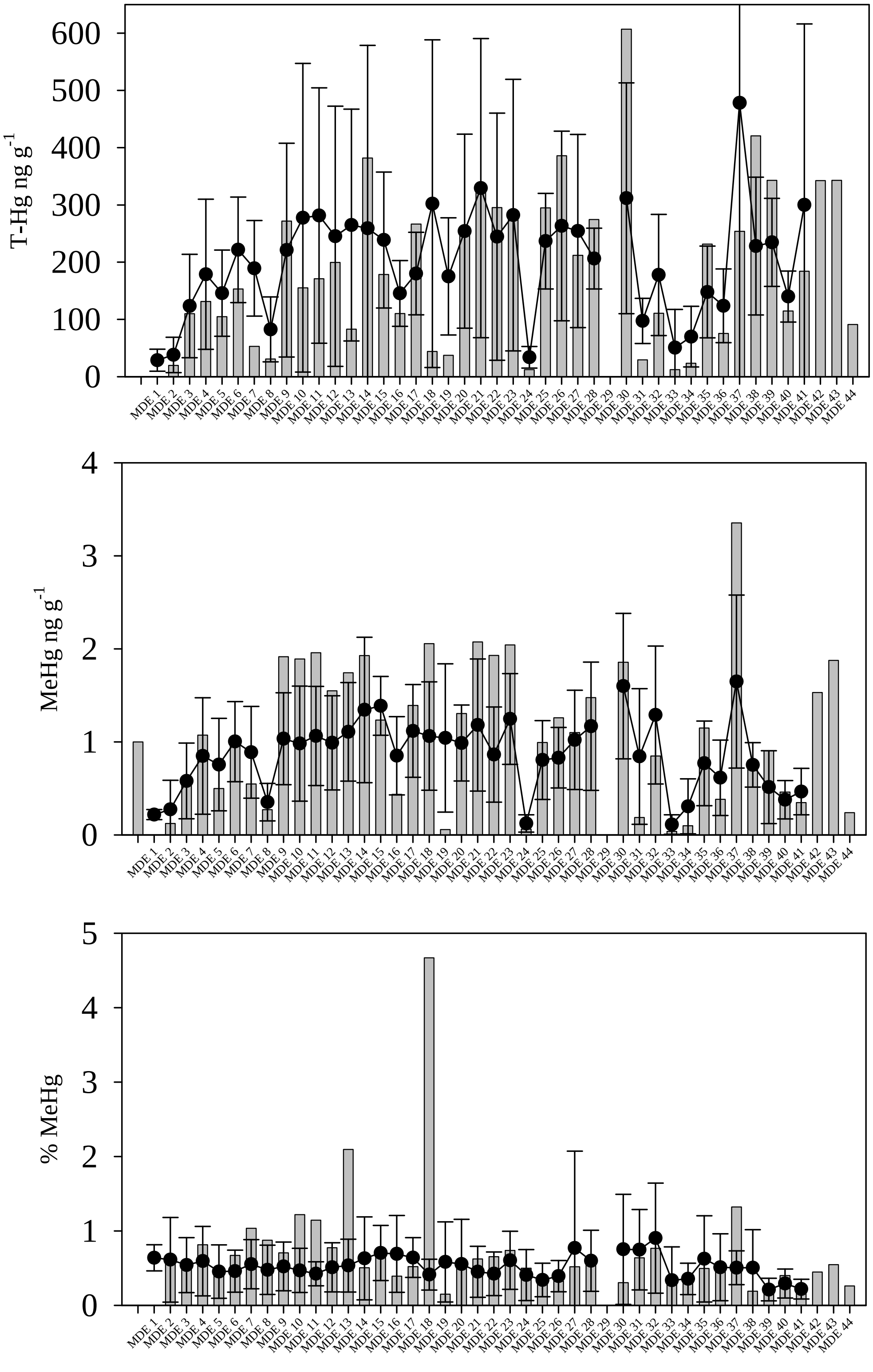


Figure 26: Mercury (Hg) and methylmercury (MeHg) concentrations, expressed as dry weight, and percent Hg as MeHg, in 2004 sediment (bars) and the 1998-2003 mean (circles) with standard deviation (error bars).

Metals in Clams

Concentrations of the metals As, Se, Ag, Cd, and Pb in the clam *Rangia* displayed some variations from previous years (Figure 27). Most metal concentrations were low and varied little among the sites. Concentrations of As and Ag remained similar to previous years whereas Se and Cd where considerably lower. Concentrations of Pb were 5 times higher than the average of the previous years. The fact that the increase was observed at all sites and anomalous Pb concentrations were also observed in some sediments, suggests a regional increase in water born Pb, not likely associated with any HMI discharge. The concentrations of both T-Hg and MeHg in clams collected in year 23 fall close to the average for previous years (Figure 28).

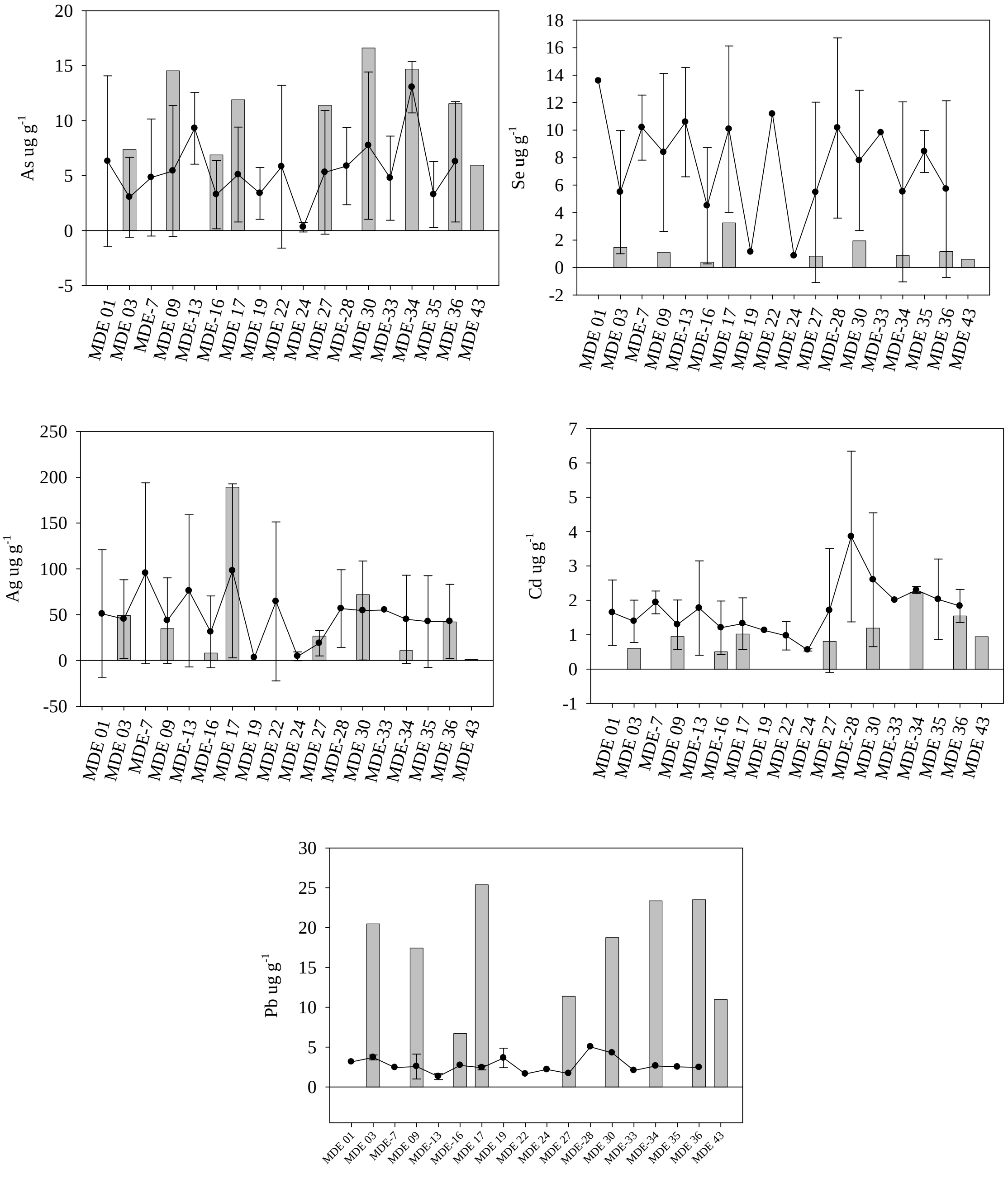


Figure 27: Concentrations of arsenic (As), selenium (Se), silver (Ag), cadmium (Cd) and lead (Pb) in the clams, expressed as dry weight, collected in 2004 (bars) and the 1998-2003 mean (circles) with standard deviation (error bars).

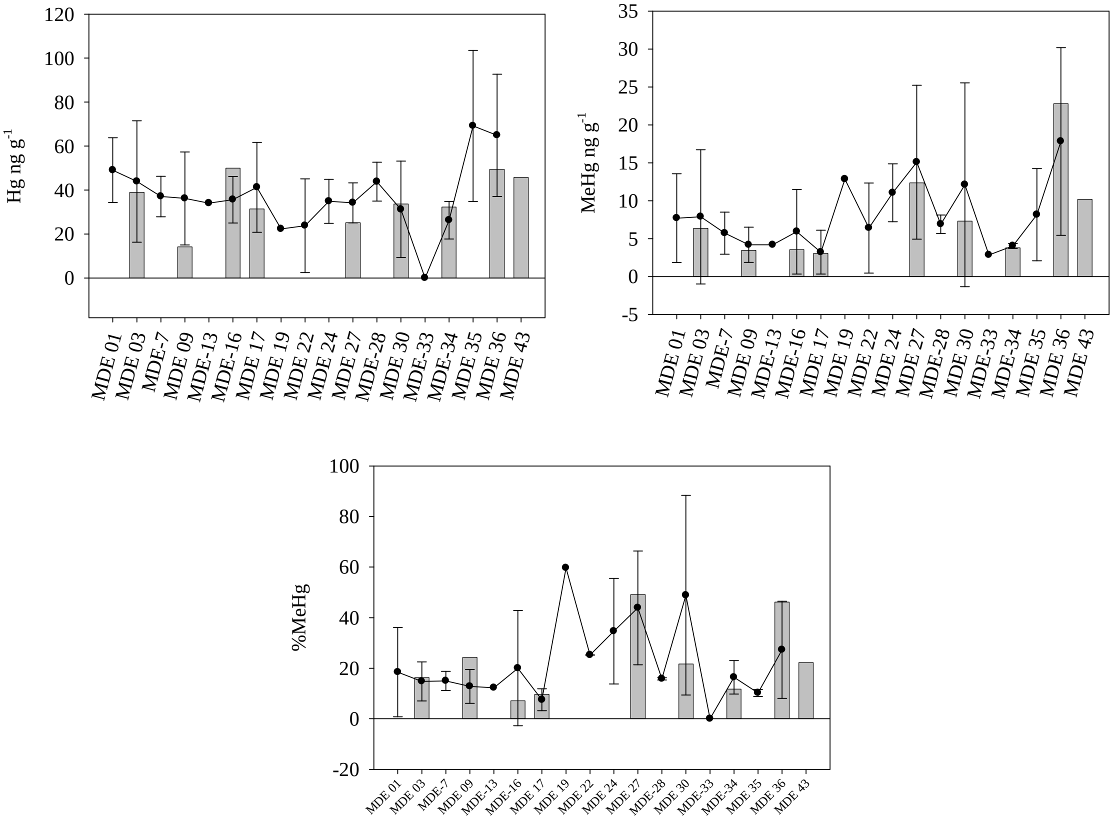


Figure 28: Mercury (Hg) and methylmercury (MeHg) concentrations, expressed on a dry weight basis, and percent Hg and MeHg in clams, collected in 2004 (bars) and the 1998-2003 mean (circles) with standard deviation (error bars).

Metal Bioaccumulation Factors

Difference in the proportions of water between sediments and the organisms means that an evaluation of bioaccumulation factors (BAF) must be done on a dry weight basis. The wet/dry ratios for are on the order of 10 to 15 whereas the ratio for sediments is closer to 2. The BAF's for trace metals are summarized in Figure 29. The BAF for As and Cd is between 1 and 10 indicating some moderate bioaccumulation. The BAF for Se floats around 1 across the sites inicating little to no bioaccumulation. The BAF for Pb is less than one, suggesting exclusion. The BAF's for Hg (not shown) is less than 1 but the BAF for MeHg ranges widely from 1 to 200 among the sites. The BAF for Ag is approximately 100 at all the sites. The high BAF for Ag has been observed in previous years.

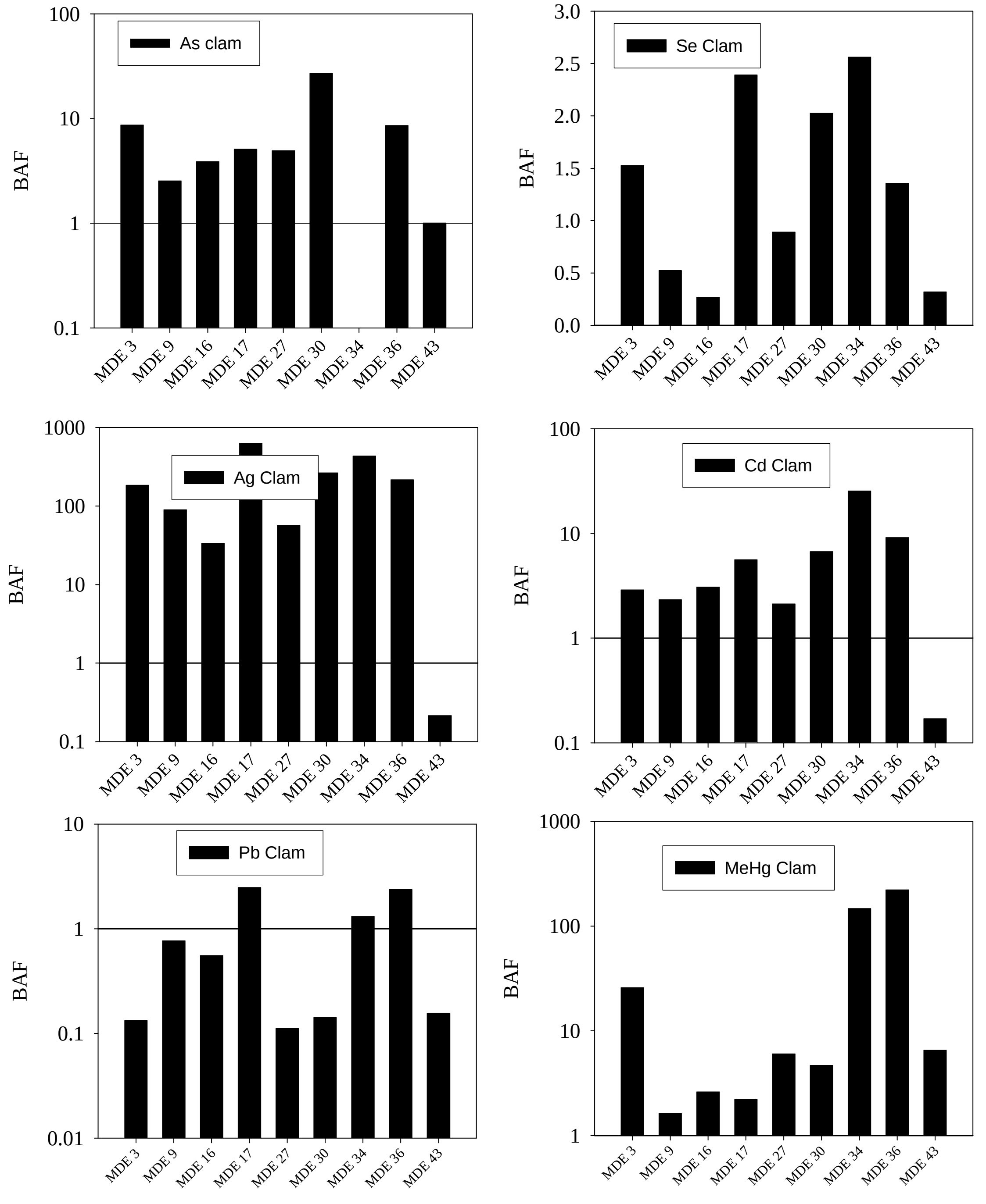


Figure 29: Bioaccumulation factors BAF's in clams from September 2004.

PCB and PAH's in Sediment

The total amounts of PCB's in the sediment around HMI are lower than what has been observed in most years but still within the standard deviation of all the years (Figure 30). The site MDE 34 remains very low largely because of low organic matter content. The new site MDE 43, near the outflow, does not have elevated levels of PCB's relative to other sites.

The total amount of PAH's in sediments are very close to the mean concentrations observed during the course of the study (Figure 31). As with PCB's organic matter content greatly effects the PAH concentrations, with sandy sites like HMI 34 having low concentrations of PAH's.

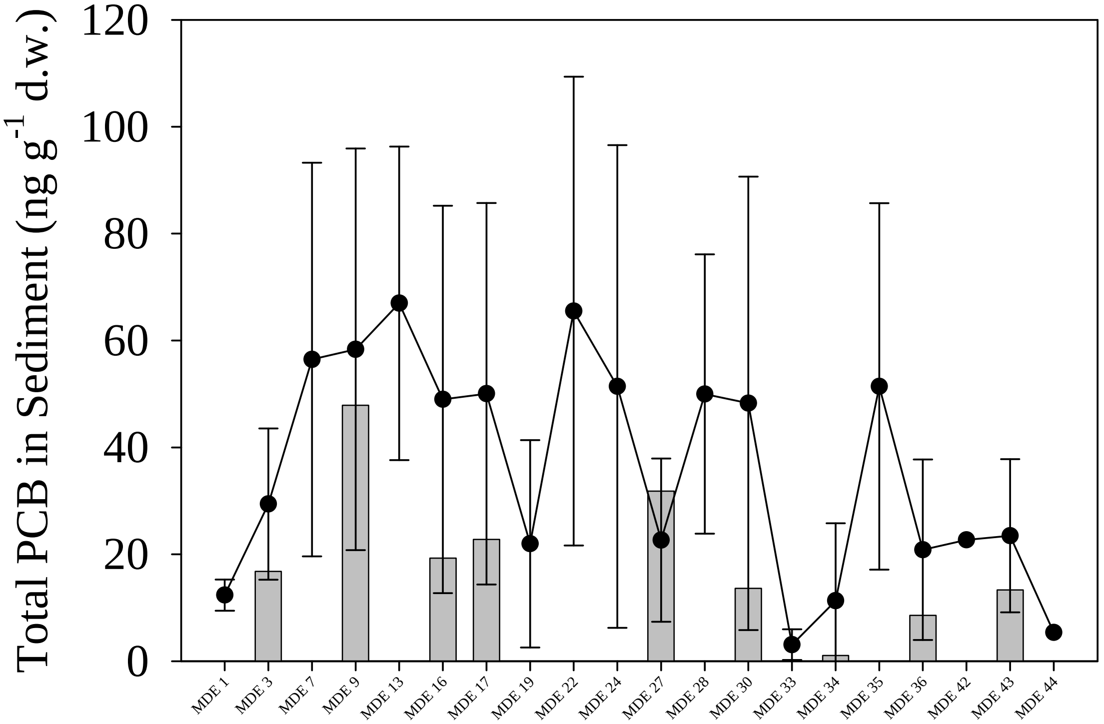


Figure 30: Total PCB concentrations in sediments collected around HMI in 2003. The bars are from 2004 where as the lines represent the mean and standard deviation of concentrations observed over the entire study period 1998-2003.

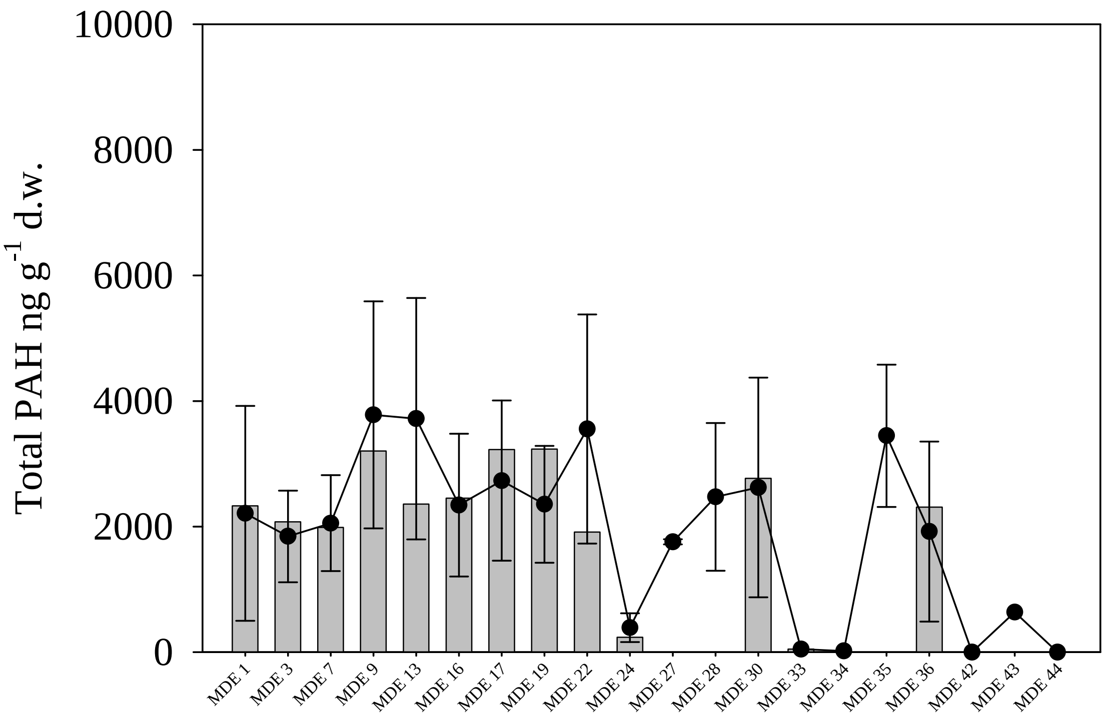


Figure 31: Concentrations of PAH concentrations in sediments around HMI. The bars are from 2004 whereas the lines represent the mean and standard deviation of concentrations observed over the entire study period.

PAH's and PCB's in Clams

The concentrations of PCB's and PAH's in clams are very close to the running mean for the study.

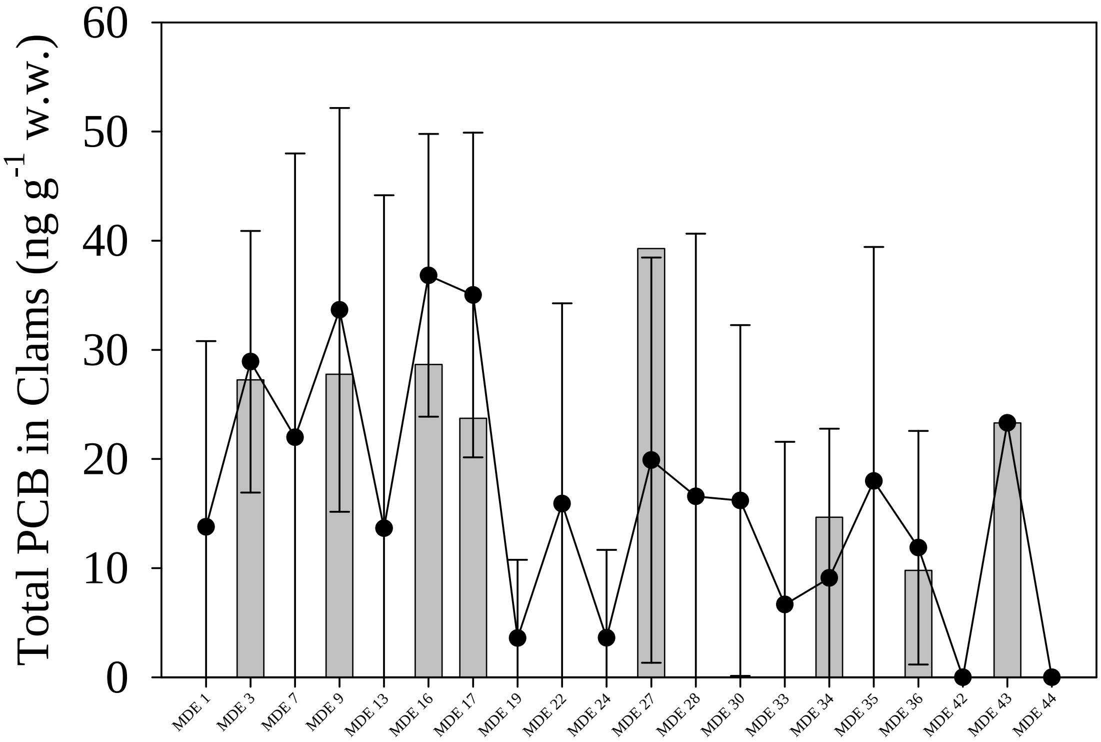


Figure 32: Total PCB concentrations (ng g^{-1} wet weight) in clams collected around the HMI. The bars are from 2004 and the lines represent the mean and standard deviation of concentrations observed over the entire study period.

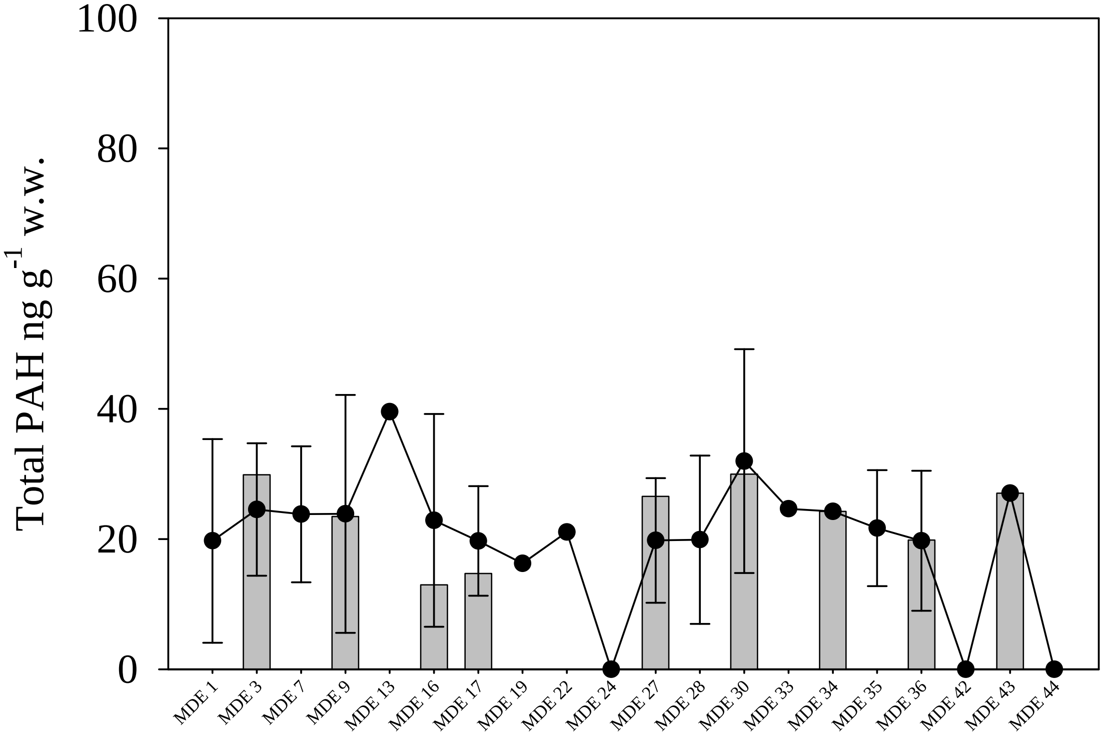
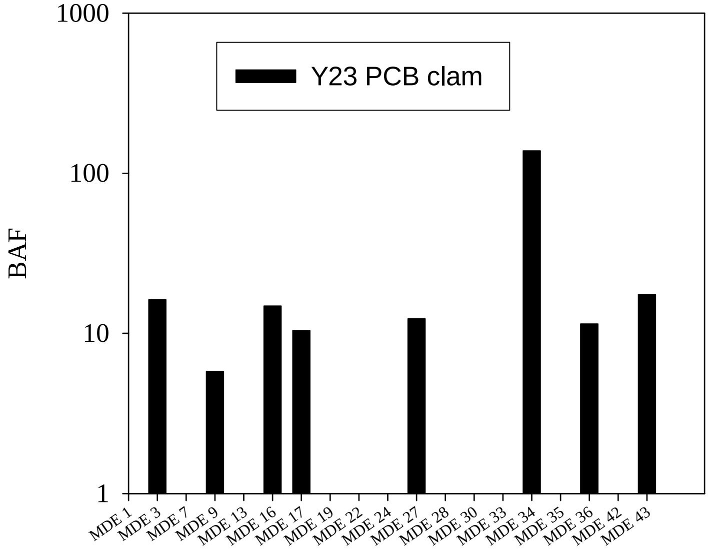


Figure 33: Total PAH concentrations (ng g^{-1} wet weight) in clams collected around the HMI. The bars are from 2004 and the lines represent the mean and standard deviation of concentrations observed over the entire study period.

Bioaccumulation of PAH's and PCB into clams

The BAF's calculated by simply dividing the sediment and clam dry weight concentrations, are 10 for PCB's but no accumulation of PAH's above the sediment concentration are observed (Figure 34).



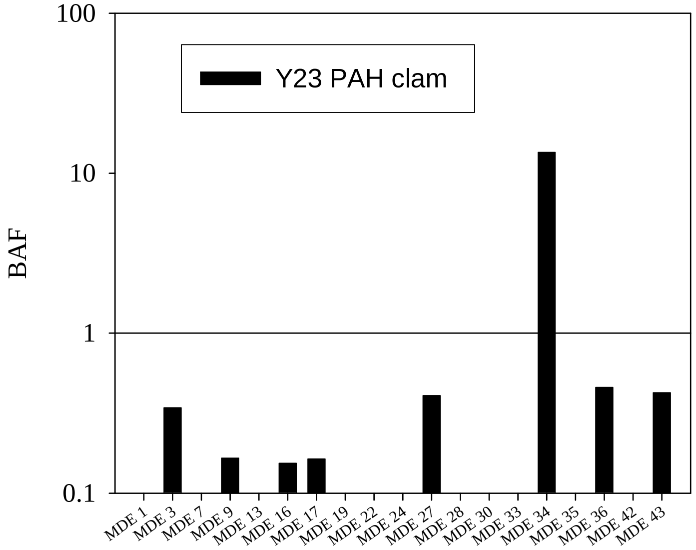


Figure 34: Bioaccumulation factors (BAF) for PCB's and PAH's in Clams

External Influences on Selected Trace Metals in Sediments and Clams

External forces such as precipitation run-off and changes in water temperature have been shown to influence trace metal concentrations and bioavailability to organisms. For example, increased precipitation increases the amount of runoff and with it the delivery of trace metals to adjacent waters. During high levels of water flow from the Susquehanna River large amounts of sediment can be released into the Bay. Higher water temperatures could stimulate microbial activity and increase MeHg production. A tertiary examination of flow and water temperature was undertaken to assess if there was any correlation between these parameters and metal concentration or uptake into clams. For this study, concentrations from all the sites were averaged, but a further breakdown of sites is likely required and will be included in future reports.

The major tributary to the Bay is the Susquehanna River which delivers the majority of the freshwater (Figure 35A). The high flow period of 2003-2005 did not appear to have influenced average metal concentrations in the sediment. One would hypothesize that localized storms would generate runoff from the Baltimore urban area and load of metals to the sediment. This does not appear to influence the sediment around HMI. In fact loading from gauged sewers (Figure 35B) has been less “flashy” than expected.

CONCLUSIONS

The trace metals Pb, Cd, As, Se, Ag. Hg and MeHg, in year 23 are similar to past years. The new sites 42,43 and 44, need watching as some anomalously high metals concentrations were recorded. However, these sites have been sampled only once. The trace metal concentrations in clams appears as expected with some bioaccumulation of Ag and MeHg.

The concentrations of PAH's and PCB also remain similar to other years. A ten fold bioaccumulation of PCB's occurs but no preferential accumulation of PAH's is occurring in clams.

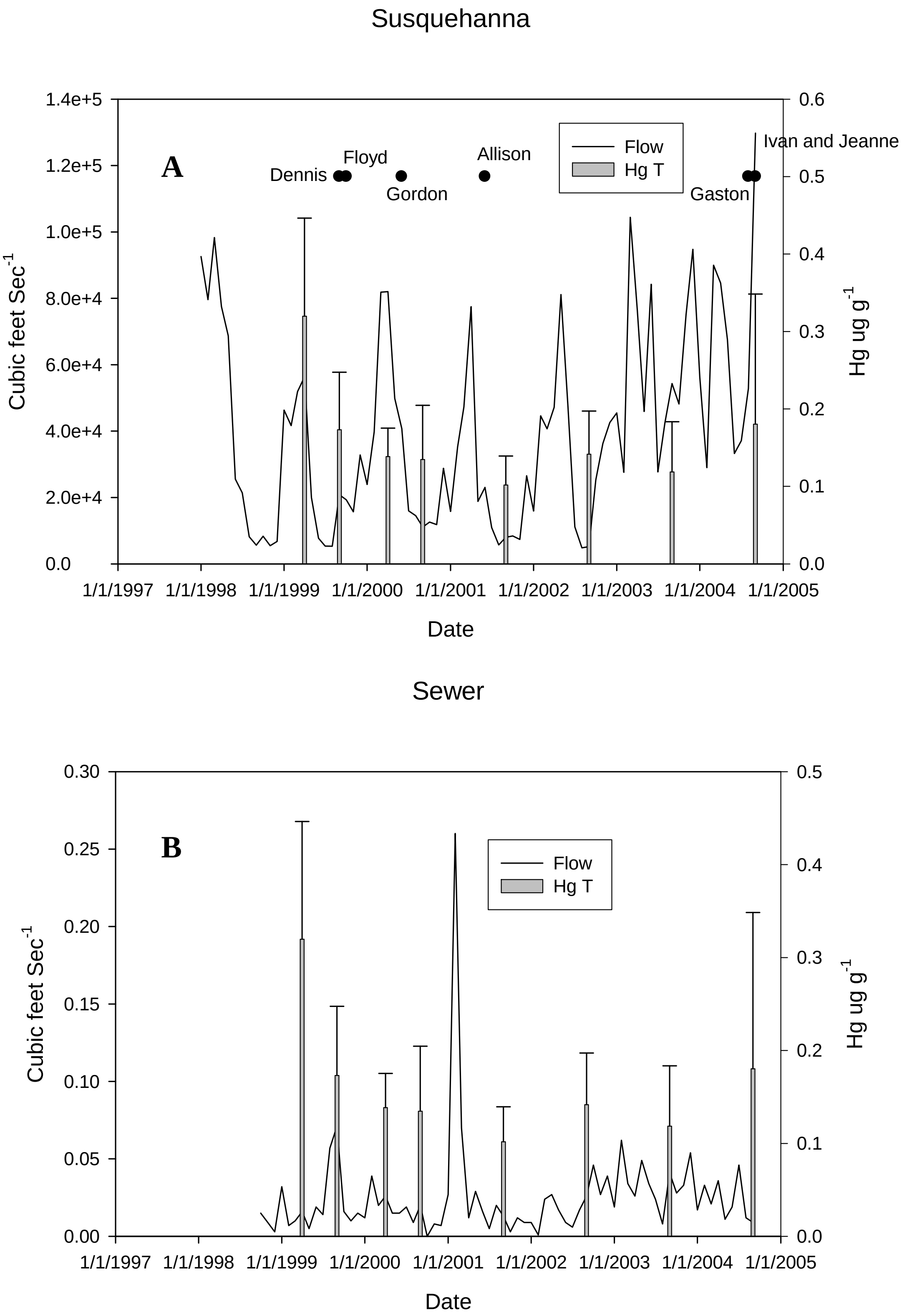


Figure 35: Average Hg concentrations in the sediment around HMI and flow from the Susquehanna River (A) and a Rognel Hts Sewer (B).

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