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

## Year 16 Exterior Monitoring Technical Report

*August 1997-April 1999*

Prepared by:

**Ecological Assessment Division**
**Maryland Department of the Environment**

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[1] Projects II and IV combined into one project for Year 16

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## CONVERSIONS[2]

### WEIGHT:

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

1 lb = 16oz = 0.454Kg

### LENGTH:

1m = 100cm = 3.281ft = 39.370in
1cm = 10mm = 0.394in
1mm = 1000µm = 0.039in

1ft = 12in = 0.305m

### 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$^3$ = 764.560L = 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 = 35.320ft$^3$/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 = 0.450ft$^3$/s
1yd$^3$/s = 202gal/s = 764.560L/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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[2] 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.

# LIST OF ACRONYMS

AAS - Atomic Absorption Spectrometry

AVS - Acid Volatile Sulfide

BAF - Bioaccumulation Factor

BCF - Bioconcentration Factor

CBL - Chesapeake Biological Laboratory

CDF - Confined Disposal Facility

COC - Citizens' Oversight Committee

COMAR - Code of Maryland Regulations

CWA - Clean Water Act

DCAD - Dredging Coordination and Assessment Division

EF - Enrichment Factor

ERL - Effects Range Low

ERM - Effects Range Median

GC - Gas Chromatography

GFAAS - Graphite Furnace Atomic Absorption Spectrometry

GPS - Differential Global Positioning System

HMI - Hart -Miller Island Confined Disposal Facility

ICAP- Inductively Coupled Argon Plasma

LBP - Lipid Bioaccumulation Potential

MDE - Maryland Department of the Environment

MGS - Maryland Geological Survey

MLW - Mean Low Water
MS - Mass Spectrometry

NIST - National Institute of Standards and Technology

NOAA - National Oceanic and Atmospheric Administration

NRC - National Research Council of Canada

PAH - Polynuclear Aromatic Hydrocarbons

PCB - Polychlorinated Biphenyl

ppb - Parts per billion

ppm - Parts per million

ppt - Parts per thousand

QA - Quality Assurance

QC - Quality Control

SOP - Standard Operating Procedure

SRM - Standard Reference Material

TARSA - Technical and Regulatory Services Administration

TDL - Target Detection Limit

TOC - Total Organic Carbon

TRC - Technical Review Committee

UMCES - University of Maryland Center for Environmental Science

USACE - U.S. Army Corps of Engineers

EPA - United States Environmental Protection Agency

WQC - Water Quality Certification

WQS - Water Quality Standards

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

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## ACKNOWLEDGMENTS

The Hart-Miller Island Exterior Monitoring Program for Year 16 would not have been successful without the help of several Technical and Regulatory Services Administration (TARSA) staff members, including: Mr. Visty P. Dalal, Chairman; Mr. Matthew Rowe, Technical Coordinator; and, Mr. Nathaniel Brown, Budget Manager. The Chairman was responsible for making sure that the project work was done efficiently, in a coordinated manner, and met all the technical goals set by the Technical Review Committee for Year 16. The Technical Coordinator wrote the Project I sections of the HMI reports, standardized the data and technical reports among projects, conducted technical review of documents, performed data management, and facilitated the peer review process. The Budget Manager was responsible for ensuring that all project related budgetary deliverables and services had been received and accounted for through a budgetary tracking system.

The Maryland Department of the Environment would like to thank all the members of the HMI Exterior Monitoring Program's Technical Review Committee and the HMI Citizens' Oversight Committee for their useful comments and suggestions throughout the project year. Special thanks are in order to the Maryland Port Administration, under the auspices of the Maryland Department of Transportation, for their continued commitment to and financial support of the Exterior Monitoring Program. The efforts and cooperation of the Principal Investigators for each project in the Year 16 monitoring effort are greatly appreciated. A thank you also goes out to Dr. Steve Storms and Shane Moore of the Maryland Environmental Service (MES) for providing information on the dredged material inputs to HMI for Year 16.

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

# INTRODUCTION

With a 64,000 square mile watershed and 2,300 square miles of tidal surface waters, Chesapeake Bay is the nation's largest estuary. Chesapeake Bay is a valuable natural resource and ranks third, behind only the Atlantic and Pacific oceans, among the United States' most productive fisheries. Over half of the nation's catch of blue crabs (*Callinectes sapidus*) and 70-90% of the Atlantic Coast stock of striped bass (*Morone saxatilis*) come from the Chesapeake.

As a highway for shipping, the Bay is also an important center of commerce for the Mid-Atlantic states. Two major ports are found on the Bay: the Hampton Roads Complex near the mouth of the Bay in Virginia and the Port of Baltimore located in the Upper Bay of Maryland. The Hampton Roads complex ranks third in the nation and Baltimore ninth in foreign water-borne commerce. Baltimore is the nation's leading exporter of cars and trucks.

The Port of Baltimore's geographic location, approximately 120 miles north of the mouth of the Bay and 70 miles south of the Chesapeake and Delaware Canal, requires a network of commercial shipping channels. Tributaries contribute vast quantities of sediment to the mainstem Bay, creating a complex of shoals and shallows which shift with tidal currents, freshwater inflow and storm events. These dynamic sediment transport processes operating in the Bay watershed require annual maintenance dredging of the approach channels to the port of Baltimore.

## *Site Background*

Finding placement sites for the material dredged from the approach channels to Baltimore Harbor is an ongoing concern. Moreover, sediments dredged from Baltimore's Inner Harbor are contaminated and require placement in specially designed disposal facilities. In 1981, construction of the Hart-Miller Island Confined Disposal Facility (HMI) was initiated to provide storage capacity for the Port of Baltimore's dredging projects. A 29,000-foot long dike encircling a 1,100-acre area was constructed along the historical footprints of Hart and Miller Islands at the mouth of Back River. The eastern or Bay side of the dike was reinforced with filter cloth and rip-rap to protect the dike from wave and storm-induced erosion. A 4,300-foot long cross-dike was also constructed across the interior of the facility, dividing HMI into a 300-acre South Cell and an 800-acre North Cell. A series of five spillways are located on the perimeter dike, with spillways 1, 2 and 4 located in the North Cell and spillways 3 and 5 located in the South Cell. The spillways are designed to release supernatant water from dredged material deposited at HMI.

The dikes in the North Cell were raised from +18 feet above mean low water (MLW) to +28 feet in 1988 in order to provide sufficient capacity for the 50-foot channel deepening project. The site was filled to capacity in June 1996. Raising the dikes around the North Cell by an additional 16 feet (to +44 feet MLW) increased the placement capacity by 30 million cubic yards, giving the site an additional 12 years of operational life, beginning 10/01/96. Volumes and project names for dredged materials placed at HMI during monitoring Year 16 are provided in Table 1-1.

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

**Table 1-1: Dredged material placed at HMI during Year 16 (7/97-6/98)**[3]

| PROJECT | CUBIC YARDS OF MATERIAL |
|---|---:|
| FT. McHENRY CHANNEL | 327,500 |
| CRAIGHILL ENTRANCE | 653,054 |
| CRAIGHILL ANGLE | 1,215,669 |
| GREENHILL COVE | 24,353 |
| BREWERTON EXTENSION | 425,000 |
| BLUE CIRCLE CEMENT | 44,500 |
| PIER 11 USNS COMFORT | 12,692 |
| CLINTON STREET/GEMINI REALTY | 24,799 |
| MUDDY GUT | 27,374 |
| BG&E BRANDON SHORES | 5,836 |

**GRAND TOTAL =2,760,777**

### *Environmental Monitoring*

Revenues to the State's economy from Chesapeake Bay's seafood industry rival those from the Port of Baltimore. It was recognized prior to construction that any adverse impacts to the Bay's fishery resources or water quality from HMI could override facility operations. 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 revoked 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."[4] In accordance with this federal mandate and as a special condition of State Wetlands License 72-127(R), a long-term compliance monitoring program was implemented in 1981 to assess the effects of HMI on the surrounding environment. Results from the monitoring are used to detect changes from baseline environmental conditions in the area surrounding HMI, and, if necessary, to guide decisions regarding operational changes and remedial actions.

The Hart-Miller Island Exterior Monitoring Program has evolved over the past sixteen years, involving different agencies, monitoring components, sampling times and methods. The baseline studies conducted around HMI from 1981-1983 included studies of the water column, currents, submerged aquatic vegetation, fisheries, benthic macroinvertebrates, sediment grain

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[3] Placement volumes provided by the Maryland Environmental Service

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

size, sediment geochemistry, and toxicological analyses. Some of these projects were discontinued over the years. The following four projects, which have been consistently monitored from the beginning of the program to the present day, are: (1) Project Management and Scientific/Technical Coordination, (2) Sedimentary Environment, (3) Benthic Community Studies, and (4) Analytical Services.

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

During the baseline monitoring years (1981-1983), the Chesapeake Research Consortium was responsible for project management, followed by the Maryland Department of Natural Resources (DNR) from 1984 to 1995. In 1995, part way through the Year 15 monitoring effort, project management was transferred from the Maryland DNR to the Maryland Department of the Environment (MDE). The Ecological Assessment Division (EAD) within the Technical and Regulatory Services Administration (TARSA) of MDE presently coordinates the Hart-Miller Island Exterior Monitoring Program.

Project management entails comprehensive oversight of the HMI Exterior Monitoring Program to ensure coordination between the different projects and principal investigators (PIs). Before a monitoring year begins, EAD reviews draft monitoring proposals for the upcoming year and consults with the PIs concerning sampling stations and analyses. Following approval of the proposals by the Maryland Port Administration (MPA), EAD develops formats and timeframes for receipt of deliverables (seasonal reports, draft technical and data reports, invoices and attendance at quarterly meetings from the PIs), as well as Memoranda of Understanding between the different monitoring agencies. Budgets and invoices for each of the PIs are tracked by MDE.

Upon receipt of the draft data and technical reports, EAD initiates a three-tiered peer review process to address the technical and editorial issues. The first level of review is conducted internally by MDE staff knowledgeable in the fields of dredging and environmental risk assessment, including toxicologists, engineers, benthic and aquatic ecologists. The next level of review is performed by the HMI Technical Review Committee (TRC) consisting of researchers/staff from the University of Maryland, and State and Federal agencies, who have backgrounds in estuarine ecology and processes. The final tier in the review process is the HMI Citizens' Oversight Committee (COC), a group of stakeholders from the public, watermen's associations and environmental groups, who bring the cares and concerns of Maryland's citizens to bear on the monitoring effort. EAD compiles and organizes the comments received and submits them to the PIs for response and incorporation into the draft reports. This process promotes quality assurance in the final HMI reports.

Lastly, EAD conducts database management, production and standardization of the data and technical reports, and holds quarterly and special meetings among the PIs and the TRC. Project I is a constantly evolving, dynamic project which strives to constantly improve the scientific merit of the exterior monitoring program and the presentation of the data and technical reports.

## Project II/IV: Analysis of Contaminants in Benthic Organisms and Sediments – University of Maryland Center for Environmental Science/Chesapeake Biological Laboratory (UMCES/CBL)

In Year 16, analyses of sediments and tissues were conducted by the Chesapeake Biological Laboratory (CBL) of the University of Maryland Center for Environmental Science (UMCES). CBL has been involved in the analysis of benthic tissues since Year 14. Field sampling was only conducted once this year during August 1997.

### *Sediments*

Sediments were analyzed in Year 16 for the following ten metals: cadmium (Cd), lead (Pb), nickel (Ni), chromium (Cr), copper (Cu), zinc (Zn), silver (Ag), arsenic (As), mercury (Hg), and methyl mercury (MMHg). The sedimentary analysis for Year 16 used a different methodology from previous years. In previous years, the Maryland Geological Survey (MGS) performed sedimentary characterization and trace metal analysis. MGS normalized trace metal concentrations to sediment grain size. However, in Year 16, CBL normalized metal concentration data to sediment carbon content. Acid volatile sulfide (AVS), percent nitrogen, percent phosphorus and total organic matter (TOM) were also used in Year 16 to examine correlations between these parameters and metal concentrations.

An upstream transect of stations in Back River was established this year to investigate the contribution of metals from Back River to the HMI vicinity. Two of the Back River sites were chosen to overlap with the sites in the Baltimore Harbor Sediment Study (Baker et al. 1996). Much higher concentrations of Pb, Cu, Cr, and Zn were seen upstream in Back River; but concentrations declined dramatically between station BSM75 and the rest of the Back River stations. Arsenic, however, was higher around HMI than at the Back River stations.

Given the differences in methodology, the values for Year 16 and Year 15 are comparable to each other, within a factor of two. Although metal concentrations in sediments are generally higher in Back River, it cannot be concluded that Back River is the dominant source of metals to the area around HMI. Metal concentrations around HMI are typical of the Northern Bay area and are also much lower than concentrations in the Inner Harbor/Patapsco River estuary.

### *Clams*

Tissue homogenates of the clam *Rangia cuneata* were analyzed this year for the presence of the same trace metals examined in sediments. In general, it was concluded that the clams found at HMI do not have high metal concentrations compared to Bay-wide values. The data did reveal, however, that three of the stations (BC6, M4, and M2) showed high metal levels among small clams. The authors suggest that these elevated metal levels in small clams may be due to a pulse of contamination that was not captured in the sediments. The small clams may better reflect short-term changes in the environment, whereas the larger clams integrate longer-term signatures of metal concentrations in their tissues.

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

For the sixteenth consecutive year, CBL was responsible for describing the benthic community surrounding HMI. Sampling was only conducted once this year, during August 1997. In addition to the same 17 stations sampled last year, another nearfield station (S1) and the Back River transect stations (BSM75, M1-M5) were sampled in Year 16. As in years past, a small number of species were the dominant members of the benthic community.

The most abundant species in Year 16 were the annelid worms *Scolecolepides viridis*, *Streblospio benedicti*, and *Tubificoides heterochaetus*; the crustaceans *Leptocheirus plumulosus* and *Cyathura polita*; and the clam *Rangia cuneata*. A total of 29 species were collected in the quantitative infaunal samples (compared to 26, 30, 35, 31, 34, 32, 35, 30, 30, 31, and 26 for the 5th through 15th years, respectively). The major differences in the dominant or most abundant species among stations were primarily a result of differences in sediment-type (e.g., silt/clay, shell or sand). Cluster analysis showed no unusual groupings of stations due to factors other than sediment-type.

The benthic index of biotic integrity (B-IBI) was used for the second consecutive year. Based on this index, none of the eighteen regular benthic stations sampled showed any indication of stress to the benthic macroinvertebrate community living at those stations. Only one of the Back River transect stations, BSM75, was shown to be stressed based on the B-IBI. Overall, no adverse impacts on the benthic community from the operation and maintenance of HMI were observed.

## CONCLUSIONS AND RECOMMENDATIONS

Since dredged material inputs, weather conditions and consequent site management vary on annual basis, continued monitoring of the exterior environment surrounding HMI is recommended. It is also recommended that future studies be undertaken to determine any gradients in contamination leading from Baltimore Harbor to the Hart-Miller Island vicinity. Additionally, it is recommended that a comprehensive, statistically rigorous review of all HMI data be undertaken at some point in the future to discern historical trends.

# CHAPTER 2: ANALYSIS OF CONTAMINANTS IN BENTHIC ORGANISMS AND SEDIMENTS COLLECTED NEAR HART-MILLER ISLAND (PROJECT II/IV)

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## OBJECTIVES

The objective of this study is to characterize contaminant levels in both a resident benthic organism (the clam *Rangia cuneata)* and sediments surrounding the Hart-Miller Island Confined Disposal Facility (HMI) and to compare these findings to historical data. Sampling for the HMI Exterior Monitoring Program has been conducted since 1981, and the current effort was initiated in concert with Year 16 of monitoring. Comparison of Year 16 HMI data with that of other nearby locations, as well as with historic HMI data, will assist in determining both the spatial extent of contamination and trends in contamination. Samples of clams and sediments were collected for trace metal analysis [cadmium (Cd), lead (Pb), nickel (Ni), chromium (Cr), copper (Cu), zinc (Zn), silver (Ag), arsenic (As), mercury (Hg), and methylmercury (MMHg)] and for ancillary parameters (Acid Volatile Sulfide, Total Organic Material, %Carbon, %Nitrogen and %Phosphorus).

The results of the quality assurance and quality control (QA/QC) procedures and the description of the analytical and field protocols are contained in the *Year 16 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 results. Comparisons of duplicate analyses and of measured values to certified values for the analyzed Standard Reference Materials (SRMs) are discussed in the *Year 16 Data Report*. Again, all QA/QC objectives were met in this regard.

## METHODS AND MATERIALS

### *Sampling Procedures*

Samples of clams and sediments were collected for analysis of trace metals and ancillary parameters. In addition to collecting samples from the historical HMI sites, samples were also collected on a transect down the Back River and across the northern side of HMI (Figure 2/4-1). Using a modified dredge, Clam (*Rangia cuneata*) samples were taken from all sites around HMI where they could be found. Up to six pulls of the dredge were taken at each site to provide enough clams for contaminant analysis. A total of 14 sites had clams. Clams were placed in zip-lock bags and stored on ice until they were returned to the laboratory. Nine sites had enough clams so that a separate comparison of small and large clams could be made.

Back at the laboratory, the clam samples were cataloged and divided into subsamples for trace metals and ancillary parameters. 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 samples at each site to avoid cross contamination. The clam bodies were homogenized in a plastic blender with a stainless steel blade. Unused samples were returned to their respective bags and stored in the freezer until further analysis.

Sediment samples were taken at all sites using a Ponar grab sampler. Surficial sediments were collected from each Ponar grab. A single composite sample for each site was stored in a pre-acid-cleaned plastic jar and transported on ice back to the laboratory.

### *Analytical Procedures for Metals and Ancillary Parameters*

Methods used for metals are similar to those described in detail in Dalal et al. (1999) and in Baker et al. (1997). For metals, a subsample of each trace metal sample (sediments and clams) was used for dry weight determination. Weighed samples were placed in a VWR Scientific Forced Air Oven at $60^0$C and left overnight. The next day, samples were reweighed and a dry/wet ratio was calculated. After determining the water content of the sediment, the samples were heated to $550^0$ C overnight. The samples were then reweighed and the percent organic matter (TOM in Table 2/4-2) in the sediment was determined by the percent loss on ignition (LOI).

Another subsample of clam tissue (5 g wet weight) was placed in acid-cleaned flasks for further digestion, using U.S. EPA 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 $95^0$C 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% $H_2O_2$ were 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 100 mL with deionized water. Sediments were digested in a similar fashion.

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

Samples for Hg were digested in a solution of 70% sulfuric/30% nitric acid in Teflon vials and heated overnight in a $60^0$C oven (Mason et al. 1995). The digestate was then diluted to

10 mL with distilled-deionized water. Prior to analysis, the samples were oxidized for 30 minutes with 2 mL of bromine monochloride solution. The excess oxidant was neutralized with 10% hydroxylamine solution and the concentration of mercury in an aliquot of the solution was determined by tin chloride reduction cold vapor atomic fluorescence (CVAFS) detection in accordance with protocols outlined in U.S. EPA Method 1631 (Mason and Fitzgerald 1993).

Samples for MMHg 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 methylethylmercury 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. Detection limits on a dry weight basis were 2.6 ng/g Hg and 0.04 ng/g MMHg for sediment samples, and 0.66 ng/g Hg and 0.2 ng/g MMHg for clams.

Acid-volatile sulfide (AVS) analysis was performed using a modified version of the U.S. EPA method (Cornwell and Morse 1987). Wet sediments (2.0g ± 0.2) were digested in a system flushed with nitrogen using degassed cold 6N HCl. The evolved $H_2S$ was collected in a deaerated solution of zinc acetate and sodium acetate buffer. The precipitated sulfide was then measured using a sulfide probe with a Pb titration. Detection limits for AVS were 0.01 µmol/g (dry weight). Total carbon, nitrogen and phosphorous of sediments were determined by the Chesapeake Biological Laboratory (CBL) Analytical Services using standard techniques.

## RESULTS AND DISCUSSION

### *Sediments*

The concentrations of metals in the sediments are compared to: values obtained by the CBL for HMI in 1996, to those found during the Baltimore Harbor Mapping Study (Baker et al. 1997), and to the averages for Chesapeake Bay in general (DNR 1990, Table 2/4-1). For some of the metals, the relationship between the data collected in 1996 and 1997, for comparable stations, is shown in Figure 2/4-2. Considering the fact that some samples collected in 1997 were from the contaminated Back River region, the ranges in values obtained for HMI are comparable over the two years. Values for Pb, Cu, Ni and As are comparable between years, but higher in 1996 for Zn and higher in 1997 for Cd, Cr, Ag and Hg. Differences noted in all cases are within a factor of two and are not considered to be significant given longer term variability. These results are similar to findings in the *"Comprehensive Zinc Study for Hart-Miller Island Contained Disposal Site"* (UTI 1999). For some of the metals, sites appear to fall into two groups of samples: one set which is comparable across years and one that is not - see, for example, Cd, Hg and Zn. The data for Zn and Cr particularly stand out. Why the Zn values are low in 1997, and Cr higher, is not known. The values for Cr are all less than the ER-L value of 94 ppm and much lower than the ER-M value of 370 ppm. For Zn, the values are also much lower than those that are potentially toxic (ER-M value of 410 ppm). By comparison, a significant number of the sites in Baltimore Harbor exceeded the ER-M values (70% for Zn, 24% for Cr) compared to no exceedances around HMI. Both metals are sensitive to changes in sediment redox and could reflect differences in the depth of sediment collection or a difference in surface redox status.

A matrix correlating data for metals against acid volatile sulfide (AVS), total organic matter (TOM), %Carbon and %Nitrogen shows that for the 1997 data, Zn and Cu concentrations correlate well with all parameters. Nickel correlates with most parameters (TOM, %C, %N), but not with AVS. Lead, Cd, Hg and MMHg all show a strong correlation with AVS, which is expected because they form strong sulfide bonds and bond, to some extent, with carbon (Table 2/4-2). Chromium does not strongly correlate with any of the variables. Thus, changes in sediment chemistry, as monitored by AVS and organic constituents, cannot help explain Cr variability. Cr is mobile in its oxidized form (Cr(VI)) and would therefore be lost from sediments if they were truly oxic but would be precipitated under anoxic conditions as Cr(III) is insoluble. Thus, the redox state of the sediments may influence the amount of Cr present in the surface layer. Information from sediment profiles would be required to determine if Cr mobility is the reason for the observed differences in the surface sediment concentrations between years. Given the low concentrations, however, this is not likely an important issue. Overall, the differences in the results of the inter-annual comparison are likely explained in terms of the differences in the %C, AVS and other parameters across years.

Even given these variations, metal concentrations around HMI are not elevated compared to the Bay in general and are significantly lower than those found in Baltimore Harbor (Table

2/4-1). Most metals have values that fit the lower end of the Chesapeake Bay range and all are significantly lower than Baltimore Harbor. Thus, it is difficult to conclude that metals are specifically coming from HMI sources rather than more generic Bay-wide inputs.

To investigate possible metal sources, samples were collected in 1997 on a transect from the north end of HMI to the lower reaches of the Back River (see Figure 2/4- 1 - sites BSM 75 to HM7). Two sites that overlap with the Baltimore Sediment Mapping Study were also sampled to give continuity between the data sets (Compare site locations on figs. 2/4-1a and 1b). The results of this sampling are shown in Figure 2/4-3. Samples have been normalized to sediment carbon content to remove potential influences from differences in sediment characteristics. To look at potential sources, the results are plotted in terms of distance from BSM 80 (i.e., distance downriver). The results for Pb, Cu, Cr and Zn show much higher concentrations within the Back River, with a dramatic drop-off in concentrations between BSM 75 and the rest of the HMI stations. This decrease is most dramatic for Zn (factor of 5 change) and least for Pb and Cu (factor of 2). Clearly, there are two distinct "populations" of sites and there is not a strong gradient across sites, which would be expected if the Back River was the only source of these metals to the HMI vicinity. There is a decrease in Zn concentration from Site 80 to 75, while Pb, Cu and Cr values are relatively constant. Of the other metals, Cd and MMHg show an overall small but steady decrease, while As increases and Hg shows no trend. That As concentrations are higher around HMI is interesting, but there are few data with which to compare and determine whether these concentrations are elevated or not. Overall, this analysis reinforces the notion that the concentrations of metals around HMI are generally low compared to the harbor, and are typical of northern Chesapeake Bay. Also, while the concentrations of these metals are higher in the Back River, there is no strong evidence to support it as the dominant source, although it is likely a contributing factor.

When compared to toxicity benchmarks [ER-M and ER-L values (Long et al. 1995)], it is found that Ni concentrations are the highest (all sites except M3 exceed the ER-L; 9 sites exceed the ER-M) followed by Hg (19 sites exceed ER-L; BSM 75 exceeds ER-M) and Pb (9 sites exceed the ER-L). For Cd, 4 sites exceeded the ER-L while for Zn, only BSM 75 exceeded the ER-L value. The sites with the most metals that exceeded guidelines were: BSM 75, M1, M2, M4, M5 and HM 26, all of which were sites on the lower Back River-HMI transect. By contrast, in the Baltimore harbor study (Baker et al. 1997) exceedences of the ER-L were 90% or greater for Cu, Cr, Ni, Pb and Zn; 76% for Hg; and, 44% for Cd. This again illustrates the highly degraded and polluted environment of the Harbor. These results suggest that while Zn concentrations may have been elevated and a concern in the past, the 1997 data do not suggest that this is still the case. Sites with high Zn concentrations, however, may not have been sampled during this study (UTI 1999).

### *Clams*

Metal concentrations in the clam *Rangia cuneata* are given in the *Year 16 Data Report*. The averages and standard deviations given in Table 2/4-3 are compared to the values from 1996 and to other values in the literature. Overall, values for some of the metals appear higher in 1997 compared to 1996. However, this is likely a function of clam size, as the average and standard deviation includes both small and large clams. The effect of size on concentration is discussed below. Given this, the metal concentrations in the clams do not appear substantially elevated compared to the 1993/4 data from the *13th Year HMI Report*, nor to those of the Bay itself. As with the sediment data, clams at HMI do not have high metal concentrations relative to other Bay sites. However, it should be noted that because clams were not found at all sites, and are not likely to be at the sites with the highest sediment metal loads, the information on clams should not be over-interpreted as indicating no impact. Alternatively, a lack of clams does not necessarily indicate a more contaminated site, as clams were not generally found at sites south of HMI during this sampling and these sites have overall lower sediment burdens than sites closer to HMI or to the Back River.

Clams were divided into large and small clams where possible and analyzed independently. The results are shown in Figure 2/4- 4. Most of the samples with enough clams for analysis were from the north end of HMI and thus the results are somewhat skewed in this regard. Contrary to the initial expectation, clam metal concentrations were often higher in small clams compared to large clams. This trend is strong for Cd, Pb, Cr, and to a lesser extent, As, Ag, Zn and Hg. No strong trends were seen for Ni and Cu. Further examination of the data shows that there are three stations where higher metal concentrations in small clams are particularly the case: BC6, M4 and M2. These sites are all very close together, suggesting that the smaller clams may have been impacted by a transient high pulse of metals to the sediment, or some other factor which is not reflected in the longer-lived large clams. Such a transient insult would not be reflected in the sediment data as the sampling methods sample more than one year of sediment accumulation (i.e. the sediment sample is a more integrated long-term measure and the clam data are more transient indicators). It should also be noted that because *Rangia* is a filter-feeding organism, it does not directly reflect sediment contamination. Rather, as there is some linkage in shallow, disturbed systems between the sediment and water column, there is an indirect coupling between sediment metal concentrations and clam metal concentrations. Thus, the trends between small and large clams are likely indicative of short-term fluctuations in surface sediment (floc) or suspended sediment particulate loads.

Bioaccumulation factors [(BAFs) a ratio of contaminant concentrations in organisms to concentrations in sediment] were estimated from the average data and compared between years (1996 vs 1997; Figure 2/4-5). Overall, values are similar across years, except perhaps for Pb. However, Pb is very poorly assimilated (log BAF 0.1 or less) and this could account for the lack of correlation. Also, as stated above, these BAFs are limited in the context that the clams are suspension feeders. Inorganic Hg and MMHg show some trend with organic matter of sediments, as we found in Baltimore Harbor (Mason and Lawrence in press). Some of the other metals (Ag and Cu) also show a trend with organic content but this is not strongly shown for Pb or Cd. Overall, MMHg is the most highly bioaccumulated metal (log BAFs all >1) and Pb is the least. These results are comparable to those found by others in other estuarine environments (Morse et al. 1993; NOAA 1996).

## CONCLUSIONS AND RECOMMENDATIONS

1. Concentrations of trace metals in surficial sediments around the Hart-Miller Island facility are generally low, and are consistent with typical sediments in northern Chesapeake Bay;

2. Concentrations of trace metals in surficial sediments around the Hart-Miller Island Facility are much less than those in nearby Back River and in the Baltimore Harbor. Large gradients down the Back River indicate that for some metals (Zn especially) the river is transporting contaminants to the Hart-Miller Island area. Whether transport from the Baltimore Harbor region also contributes to the contaminant levels observed around the Hart-Miller Island facility is unclear; and

3. Concentrations of trace metals in surficial sediments and clams sampled around the Hart-Miller Island facility are low relative to published sediment and biota guidelines.

While the measurements contained in the Year 16 Report are not indicative of significant input and might be construed to suggest that continued sampling is not necessary, this is not recommended. The following are recommendations for future work:

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

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

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

4. A study of the linkage between Hart-Miller Island and Baltimore Harbor, in terms of the harbor being a source to the Hart-Miller Island region, should be undertaken.

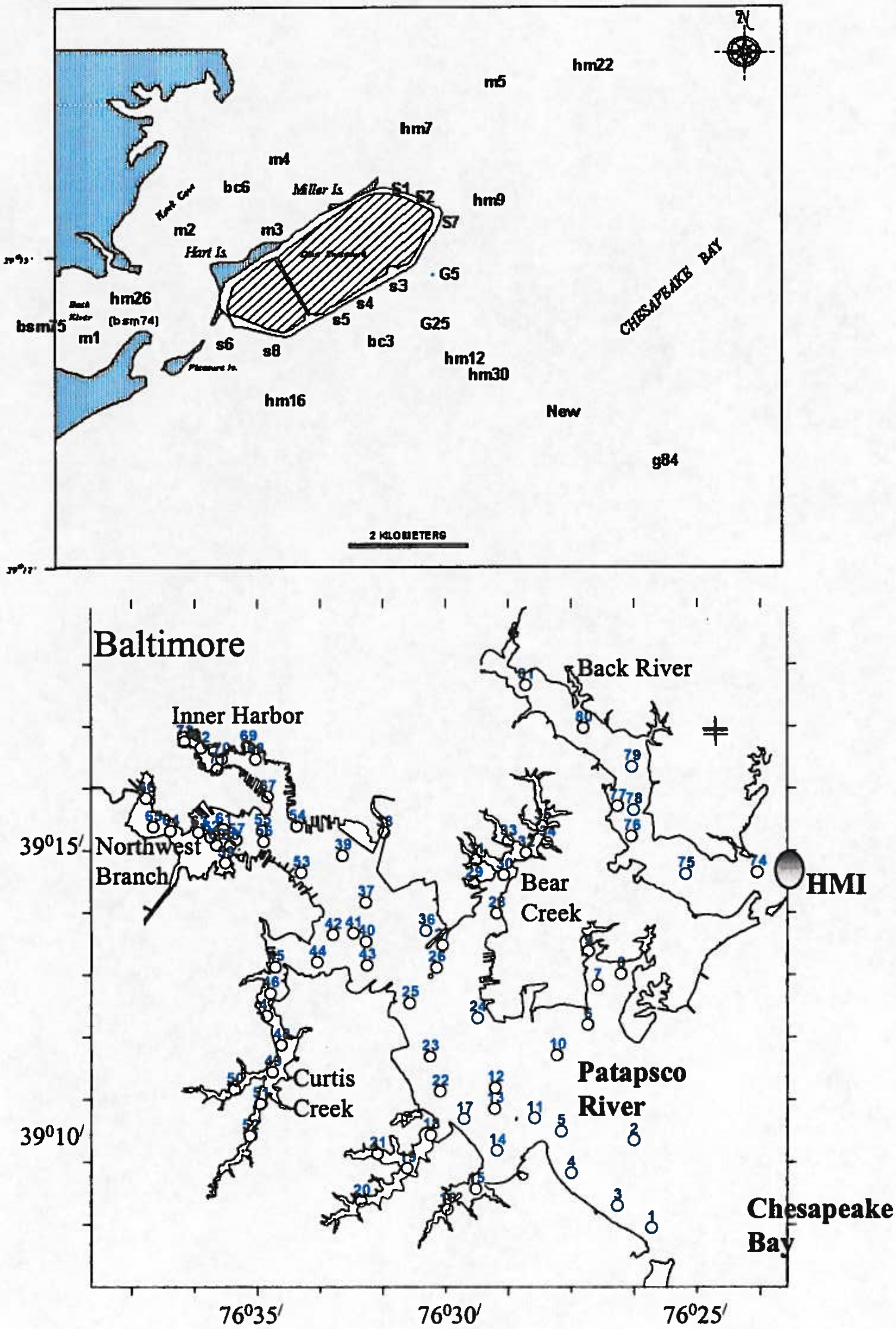


**Figure 2/4-1: (a) Site map of Hart-Miller Island showing the sampling locations; (b) Accompanying map showing the stations from the Baltimore Mapping Study.**

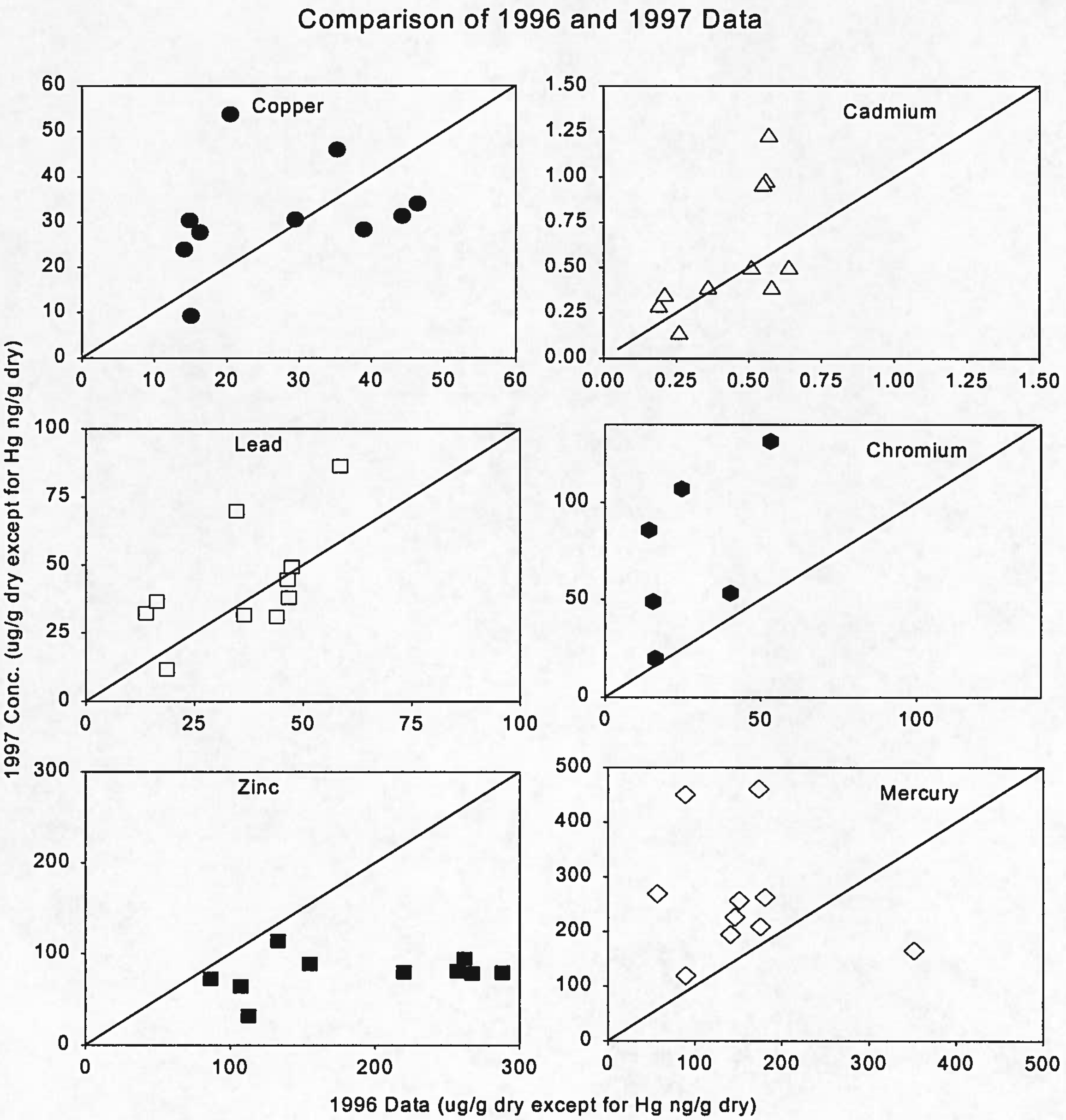
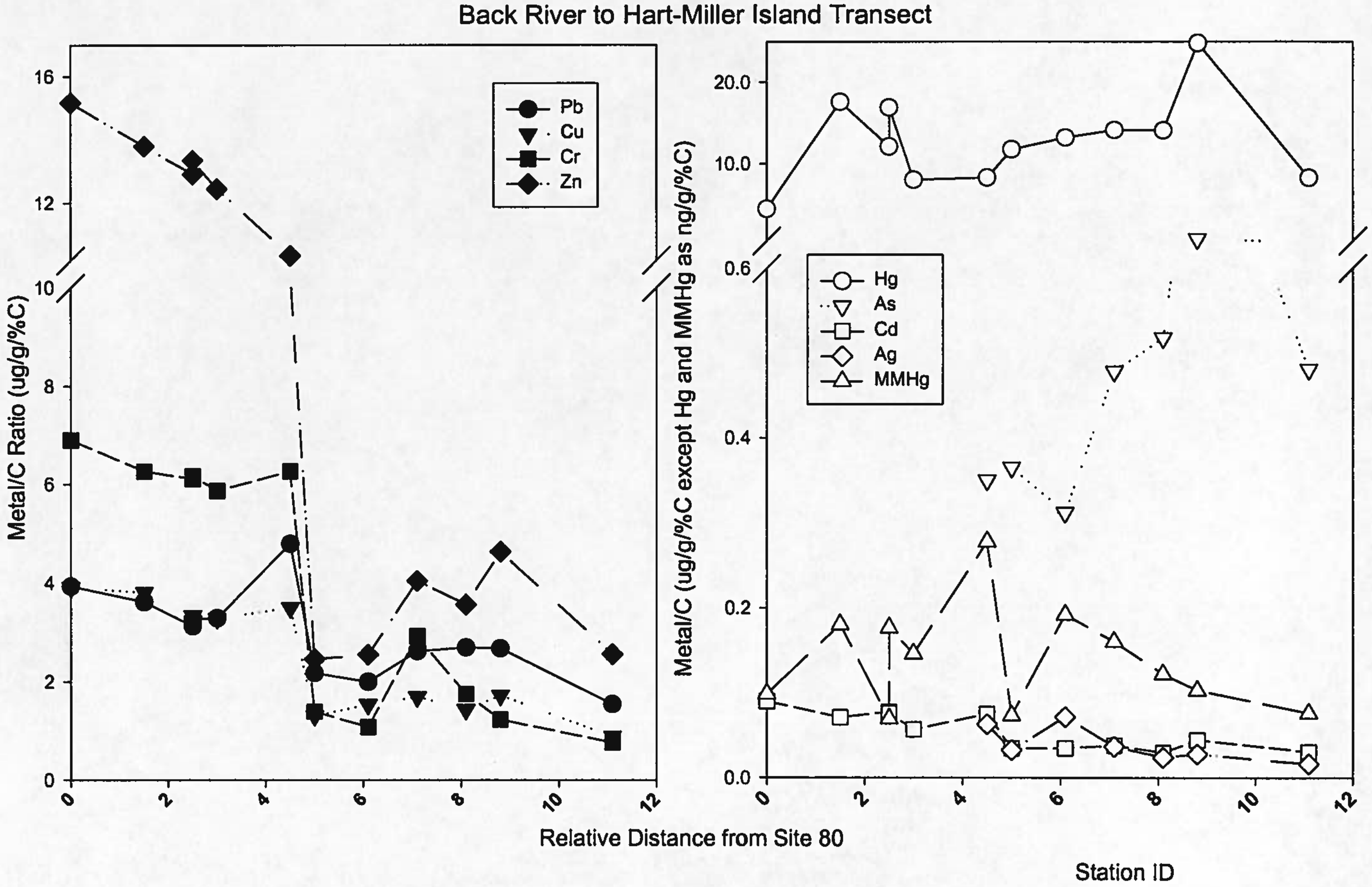


**Figure 2/4-2: A comparative plot of the sediment data for 1996 and 1997 for samples analyzed by Chesapeake Biological Laboratory.**


Back River to Hart-Miller Island Transect

Data for BSM 76-80 from Baltimore Harbor Study;
Other stations from HMI 16th Year

**Figure 2/4-3: Concentrations of metals in sediments on a transect from the Back River to Hart-Miller Island. See Figure 1 for site details.**

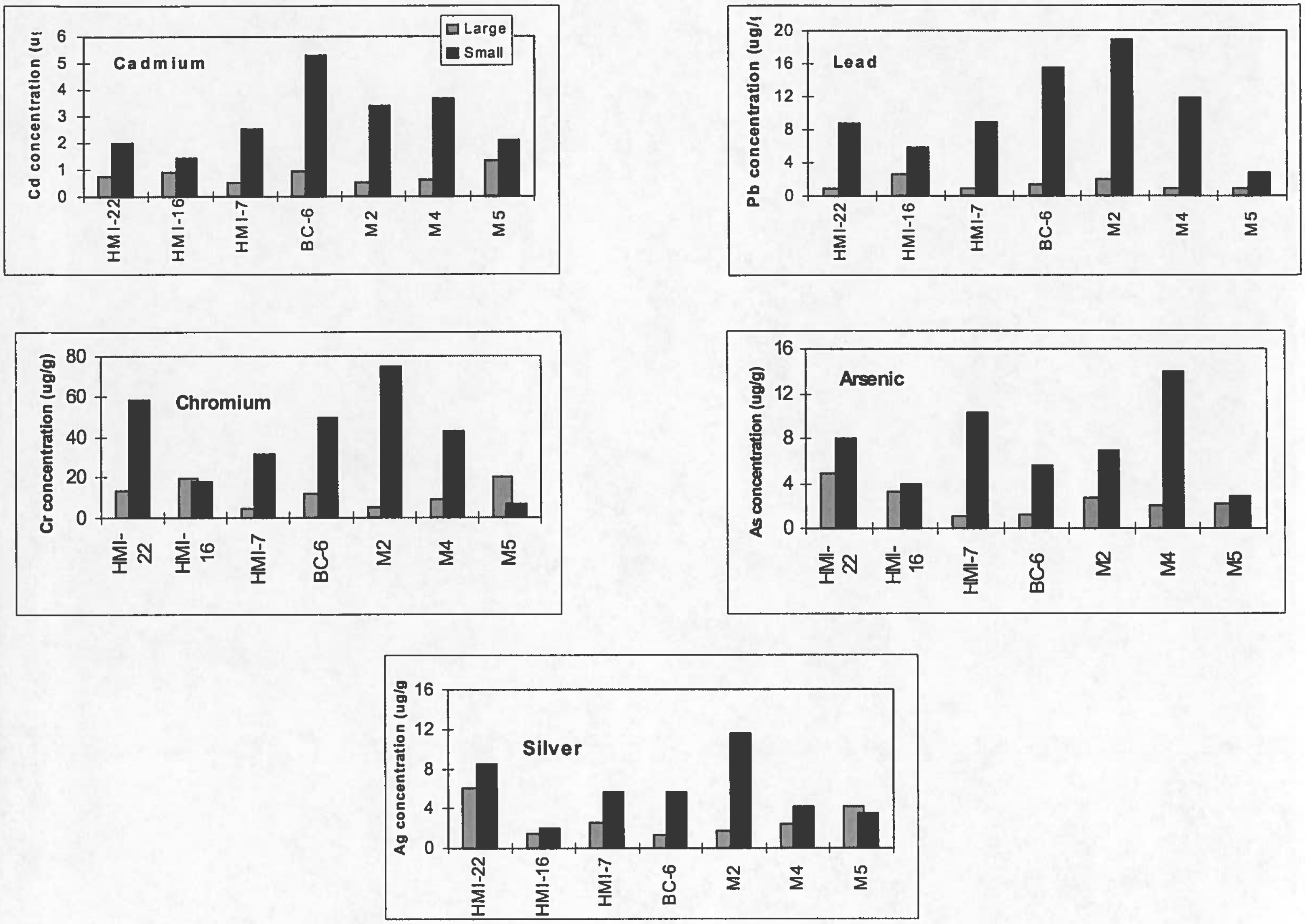


**Figure 2/4-4: Comparison of metal concentrations in small (first bar) and large (second bar) clams from the 1997 study.**

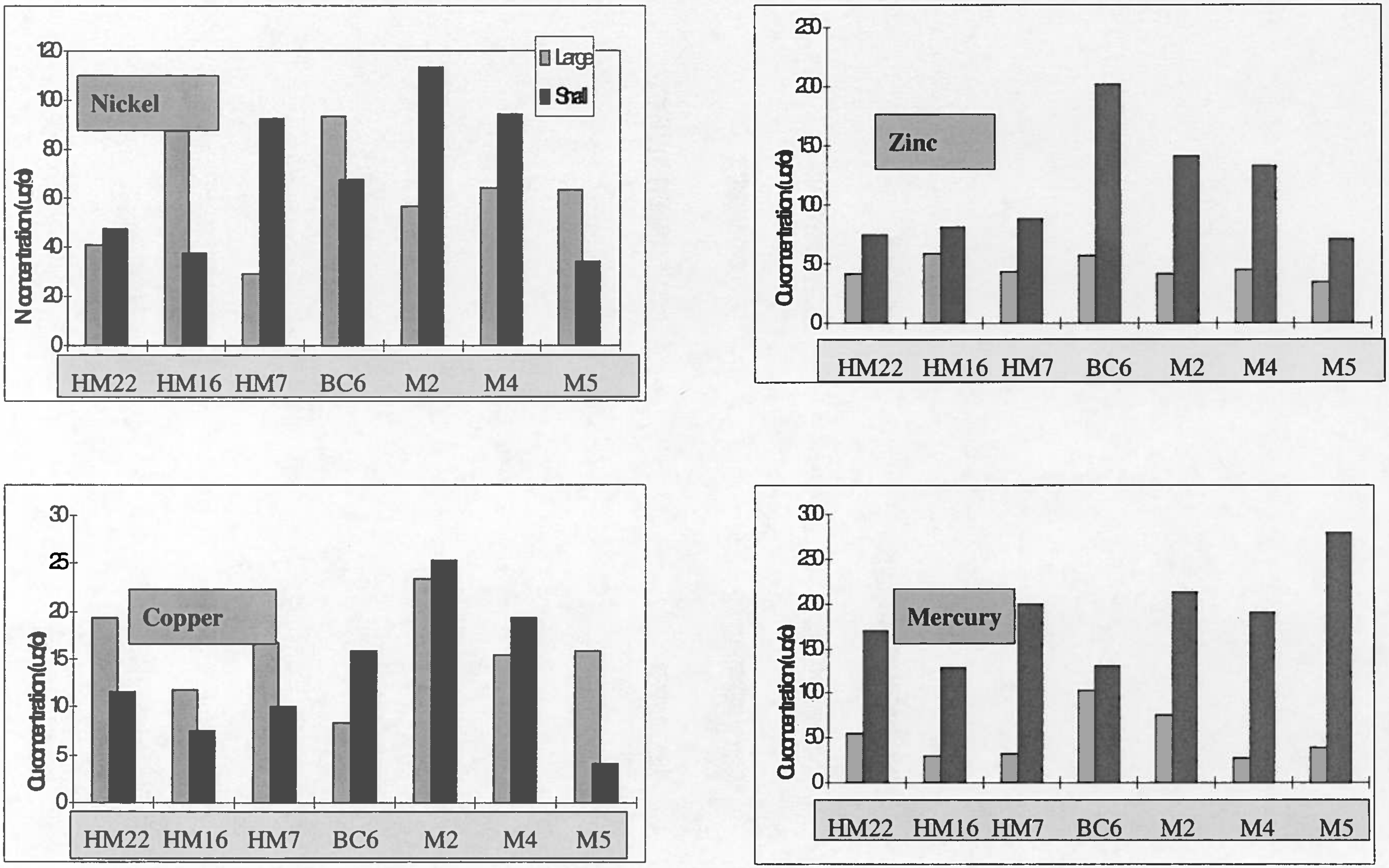


**Figure 2/4-4: (cont.)**

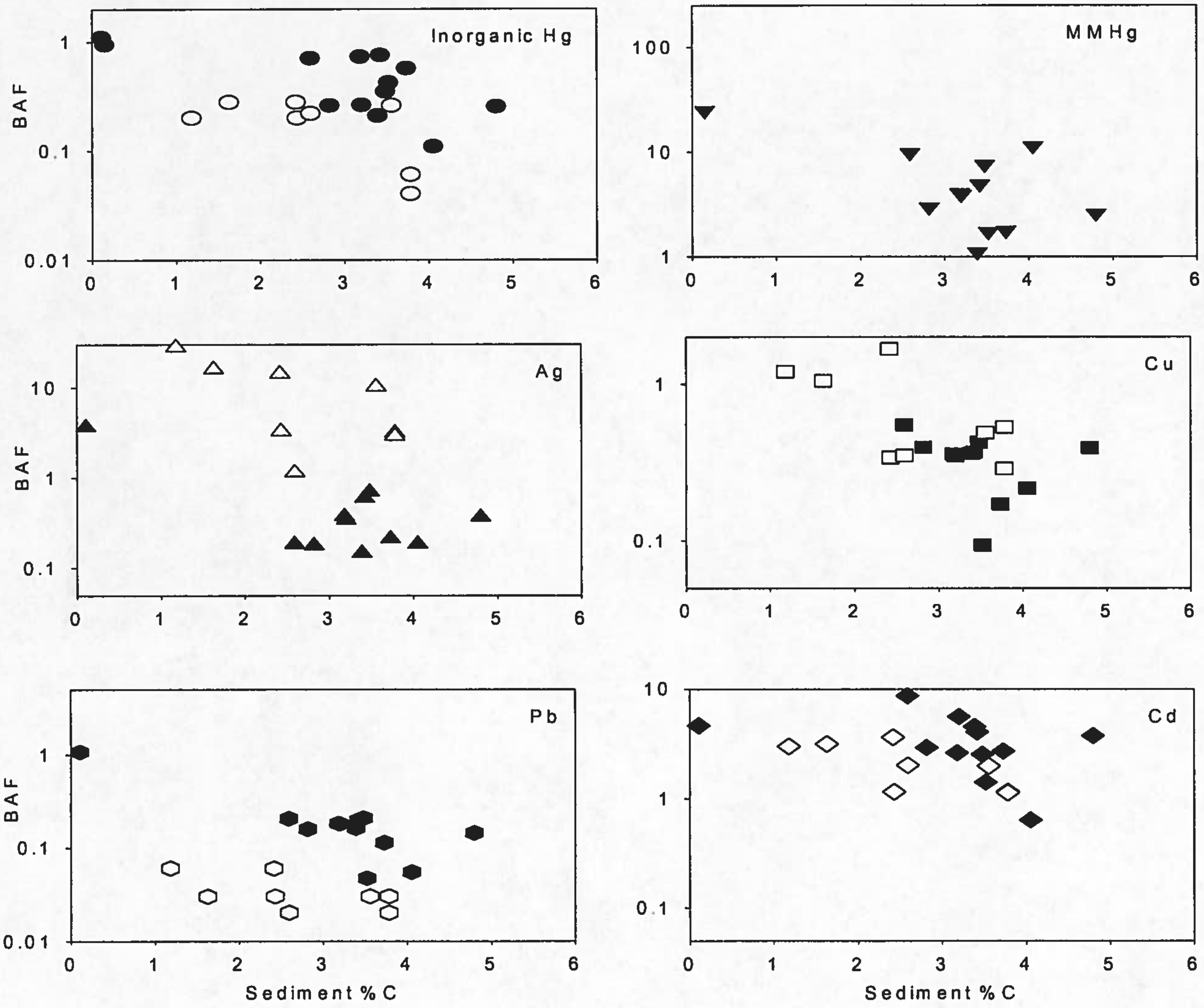


**Figure 2/4-5: Bioaccumulation factors for clams (open circles indicate 1996 data, closed 1997 data).**

**Table 2/4-1: Concentrations of metals in HMI sediments collected in 1996 and 1997 compared with baywide average values and values for Baltimore Harbor. Comparison is made on a dry weight basis.**

| Metal (µg/g dry wt.) | 1996 | 1997* | BH Study** | MDE 91** |
|---|---|---|---|---|
| Cd | 0.18-0.63 | 0.13-1.5 | 0.01-17.6 | 0.7-4 |
| Pb | 13.8-58.5 | 11.7-86.3 | 1-1014 | 78-194 |
| Ni | 19.2-97.7 | 3.6-80.6 | 3-157 | 42-113 |
| Cr | 14.0-60.7 | 6.8-172.7 | 6-1830 | 162-520 |
| Cu | 9.6-51.8 | 2.0-59.0 | 5-532 | 65-191 |
| Zn | 86.5-298.9 | 7-140.7 | 40-2580 | 353-681 |
| Ag | 0.2-0.9 | 0.04-2.5 | - | - |
| As | 4.6-25.9 | 0.5-25.4 | - | - |
| Hg | 0.057-0.35 | 0.083-0.70 | 0.004-3.13 | 0.3-0.6 |

Notes:
* 1997 data excludes site BSM 75
** Data from Baltimore Harbor Mapping and the Chesapeake Bay Toxics Reduction Re-evaluation Report.

**Table 2/4-2: Correlation matrix for metals and ancillary parameters in sediments.**

| Sediment | | | | | |
|---|---|---|---|---|---|
| | AVS | TOM | %C | %N | %P |
| Cd | 0.799 | 0.400 | 0.359 | 0.677 | 0.638 |
| Pb | 0.855 | 0.528 | 0.498 | 0.820 | 0.775 |
| Ni | 0.427 | 0.750 | 0.713 | 0.824 | 0.789 |
| Cr | 0.408 | 0.411 | 0.538 | 0.557 | 0.559 |
| Cu | 0.858 | 0.520 | 0.556 | 0.830 | 0.799 |
| Zn | 0.701 | 0.726 | 0.680 | 0.917 | 0.891 |
| Ag | 0.294 | 0.287 | 0.305 | 0.454 | 0.483 |
| As | -0.015 | 0.292 | 0.216 | 0.331 | 0.383 |
| Hg | 0.761 | 0.371 | 0.316 | 0.644 | 0.589 |
| MMHg | 0.915 | 0.524 | 0.526 | 0.815 | 0.750 |

**Table 2/4-3: Concentrations of metals in clams collected in 1997 with 1993/1994 and 1996 and comparison with baywide average oyster tissue data. Comparison is made on a dry weight basis.**

| Metal (µg/g dry wt.) | 1997 Average ± Std Dev | Range 1997 | Range 1996 | Range 1993/94* | Oyster Baywide av. (1990)** |
|---|---|---|---|---|---|
| Cd | 1.65 ± 1.20 | 0.5-5.2 | 0.5-1.1 | 1.5-3.4 | 0.2-1.6 |
| Pb | 5.73 ± 4.90 | 0.9-19 | 0.38-1.6 | | |
| Ni | 65.96 ± 25.48 | 23.7-113.2 | 15.1-30.1 | 28-63 | |
| Cr | 30.23 ± 23.19 | 4.3-90.1 | 1.0-1.7 | 2.4-62 | |
| Cu | 13.85 ± 5.12 | 8.4-25.2 | 14.3-22.5 | 15-22 | |
| Zn | 81.59 ± 39.81 | 33.7-141.1 | 103-195 | 162-322 | 300-700 |
| Ag | 3.71 ± 2.47 | 0.26-13.93 | 0.32-6.3 | | |
| As | 4.64 ± 3.38 | 0.3-13.9 | 0.50-2.1 | 7.8-63 | 0.6-1.4 |
| Hg | 0.11 ± 0.068 | 0.04-0.28 | 0.012-0.066 | | |

Notes:

* Data were converted from a wet weight basis to a dry weight basis by assuming a wet/dry ratio of 8. Data for 1993/94 from the 13th year Report. 1990/91 data are from the 10th Year Report. All data are for *Rangia*.

** Data from the Chesapeake Bay Toxics Reduction Re-evaluation Report. Data are for oysters only.

# CHAPTER 3: BENTHIC COMMUNITY STUDIES (PROJECT III)

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# ABSTRACT

Benthic invertebrate populations surrounding the Hart-Miller Island Confined Disposal Facility (HMI) in the Upper Chesapeake Bay were monitored for the sixteenth consecutive year in order to examine any potential effects from the operation of HMI. In August 1997, bottom-dwelling organisms living within (infaunal) sediments at stations both close to HMI (nearfield stations) and at some distance from the facility (reference stations) were collected. The seventeen stations sampled last year, plus the additional nearfield station S1, were sampled again this year. Also sampled were a series of Back River Stations (M1-M5, BSM75) which were being examined by Dr. Rob Mason (University of Maryland Principal Investigator for Project II/IV) to determine what contribution the Back River might have on metal concentrations in the HMI vicinity. All stations were sampled only once this year. Sampling for all projects (benthic, sediments, and metals) was conducted at a single time at each station over a two day period (August 18 and 19, 1997).

The infaunal samples were collected with a 0.05 $m^2$ Ponar grab and washed on a 0.7 mm mesh screen in the field. Twenty-four stations were sampled during the two day cruise: six nearfield stations S1, S2, S3, S5, S6, and BC3; eight reference stations HM7, HM9, HM16, HM22, HM26, BC6, 30, and NEW; four zinc stations G5, G25, G84, and HM12; and six Back River Transect stations M1, M2, M3, M4, M5, and BSM75. The infaunal stations have sediments of varying compositions and include silt-clay stations, oyster-shell stations and sand stations. A total of 29 species were collected from the eighteen standard infaunal stations. The most abundant species were the worms *Scolecolepides viridis*, *Streblospio benedicti* and *Tubificoides heterochaetus*; the crustaceans *Leptocheirus plumulosus* and *Cyathura polita*; and the clam *Rangia cuneata.* Species diversity (H') values were evaluated at each of the eighteen standard infaunal stations. The highest diversity value (2.901) was obtained for the reference station HM16. The lowest diversity value (0.447) occurred at reference station HM7.

The length-frequency distributions of the clams *Rangia cuneata*, *Macoma balthica* and *Macoma mitchelli* were examined at the nearfield, reference, and zinc stations. There was fairly good correspondence in terms of numbers of clams present and the relative size groupings for the August sampling dates; the only exception to this was for the 10mm *Rangia.* In the 10mm size class there were 143 *Rangia* at the zinc stations, 1,422 at the nearfield stations and 5,455 at the reference stations. *Rangia cuneata* continues to be the most abundant clam species for all three groups of stations, followed by *Macoma mitchelli*, and then *Macoma balthica.*

For the second year in a row, the Chesapeake Bay Benthic Index of Biotic Integrity (B-IBI, Weisberg et al. 1997) was used to score all the benthic stations. This multimetric index of biotic integrity was developed using data from five Chesapeake Bay sampling programs. Assemblages with an average score of less than 3.0 are considered stressed because they have metric values that are less than the values at the poorest reference sites. None of the sites had an average score of less than 3.0 for the standard eighteen stations. Only one station, in the Back River Transect, had an average score of less than 3.0. That was station BSM75 with an average score of 1.5; this station was the farthest upriver of the Back River transect stations. It had the lowest salinity of all 24 stations sampled.

The results of the Year 16 studies reveal no adverse impacts on the benthic community that could be attributed to maintenance and operation of HMI. We have continued to monitor the zinc stations (G5, G25, G84, HM12) established in Year 9 of sampling as a result of Maryland Geological Survey's findings of elevated zinc concentrations in HMI exterior sediments. During this eighth consecutive year of monitoring at the zinc stations, they do not appear to differ in any distinct manner from the nearfield or reference infaunal stations. Continued monitoring of the benthic populations in the area is strongly recommended in order to assess any changes associated with dredged material placement and operation of HMI.

# INTRODUCTION

The results of the benthic population studies conducted during Year 16 of the HMI Exterior Monitoring Program are presented in this report. HMI lies within the estuarine portion of Chesapeake Bay and experiences seasonal salinity and temperature fluctuations. This region of Chesapeake Bay encompasses vast soft-bottom shoals, which are important to protect since they function as critical breeding and nursery grounds for many commercial and non-commercial species of invertebrates and migratory fish. Because it is an area that is environmentally unpredictable from year to year, it is important to maintain as complete a record as possible on all facets of the ecosystem. Holland (1985, 1987) completed long-term studies of more stable mesohaline [5-18 parts per thousand salinity (Weisberg et al. 1997)] areas further south of HMI and found that most macrobenthic species showed significant year-to-year fluctuations in abundance. These fluctuations were primarily a result of slight salinity changes and the fact that the spring season was a period critical to juvenile recruitment and to the establishment of both regional and long-term distribution patterns. One would expect even greater fluctuations in the benthic organisms inhabiting the region of HMI which is located in the highly variable oligohaline [0.5-5 parts per thousand salinity (Weisberg et al. 1997)] portion of Chesapeake Bay. Indeed past studies (Pfitzenmeyer and Tenore 1987; Duguay, Tenore, and Pfitzenmeyer 1989; Duguay 1989, 1990, 1992, 1993, 1995, 1997, 1998) indicate that the benthic invertebrate populations in this region are predominantly opportunistic or r-selected species with short life spans, small body size and often high numerical densities. These opportunistic species are characteristic of disturbed or environmentally variable regions (Beukema 1988).

The major objectives of the Year 16 benthic monitoring studies were:

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

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

3. Continued monitoring of benthic populations at four stations where elevated levels of zinc were found in Year 9;

4. To provide *Rangia cuneata* to research groups at the Chesapeake Biological Laboratory (CBL) for chemical analyses of trace metal concentrations in order to ascertain various contaminant levels in benthic organisms and to determine whether there is any bioaccumulation; and

5. To monitor benthic populations at six stations along a transect from Back River. These stations were being examined by Dr. Rob Mason of CBL for their possible contribution to metal levels in the HMI vicinity.

## METHODS AND MATERIALS

A two day cruise was conducted on August 18th and 19th , 1997. The location of all the standard infaunal sampling stations (reference, nearfield, and zinc) are shown in Figure 3-1 with their CBL designations. The stations were located in the field by means of a Northstar 941XD Differential Global Positioning System (DGPS). Latitude and longitude of each station and the state identification numbers can be found in the *Year 16 Data Report* (state designation numbers are also listed in Table 3-7). Three replicate grabs were taken with a 0.05 $m^2$ Ponar grab at eighteen benthic infaunal stations (S1, S2, S3, S5, S6, HM7, HM9, HM16, HM22, HM26, HM12, G5, G25, G84, 30, NEW, BC3, and BC6). Also sampled (Figure 3-1) were the Back River Transect stations (BSM75, M1, M2, M3, M4, and M5) examined by Rob Mason for metal contribution to the HMI area. All the individual samples were washed on a 0.7 mm sieve and fixed in 10% formalin/seawater on board the ship. In the laboratory, the samples were again washed on a 0.5 mm sieve and then transferred to 70% ethyl alcohol. The samples were sorted and each organism was removed, identified, and enumerated. Station depths were recorded from the ship's fathometer. Surface and bottom temperatures were determined with a Hydrolab Surveyor 3 Multiparameter Water Quality Logging system to the nearest 0.01°C. Salinity of the surface and bottom waters was also determined with the Surveyor 3 to a tenth of a part per thousand (ppt or ‰).

After identification and enumeration, the samples were analyzed for dry weight. All species for each sample were dried to a constant weight in a 60° C oven. The clams were shucked and the shells were discarded before drying. Total dry weight of each sample was determined on an analytical balance. The total dry weights of the three replicates for each station were averaged. Average dry weight (biomass) was one of the metrics used in the Chesapeake Bay Benthic Index of Biotic Integrity (B-IBI), which we used to score our standard eighteen benthic stations and the Back River Transect stations. The Chesapeake Bay B-IBI is a multimetric index of biotic integrity used to determine if benthic populations in Chesapeake Bay are stressed (Weisberg et al. 1997). The other metrics used were total abundance, Shannon-Wiener diversity index, abundance of pollution-sensitive taxa and abundance of pollution-indicative taxa. A separate B-IBI table was used to score the Back River Transect stations.

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

# RESULTS AND DISCUSSION

Since the beginning of the benthic survey studies in 1981, a small number of species have been the dominant members of the benthic invertebrates collected in the vicinity of HMI. The most abundant species this year were the annelid worms *Scolecolepides viridis*, *Streblospio benedicti* and *Tubificoides heterochaetus*; the crustaceans *Leptocheirus plumulosus* and *Cyathura polita*; and the clam *Rangia cuneata* (Tables 3-3, 3-4, and 3-5). Variations in the range and average number of *S. viridis, L. plumulosus*, and *R. cuneata* at the reference stations since the initial sampling in August 1981 are presented in Table 3-1. The populations of these three species have remained relatively stable over the monitoring period. Overall the results of this year appear to be similar to previous years, except for the record numbers of *Rangia* in the 10mm size class (Figure 3-2). The number of *S.viridis* and *L. plumulosus* have decreased somewhat from last year, but they are similar to the numbers found in the earlier years of the project. The species found at the Back River Transect stations are shown in Table 3-6.

The major variations observed in dominant or most abundant species for a station occur primarily as a result of the different bottom types (Table 3-2). Soft bottoms are preferred by the annelid worms *S. viridis*, *Tubificoides sp.*, and *S. benedicti*, as well as the crustaceans *L. plumulosus* and *C. polita*. The most common inhabitants of the predominately old oyster shell substrates are more variable. The barnacle *Balanus improvisus*, the worm *Nereis succinea*, or the encrusting bryozoan *Membranipora tenuis* are often the dominant organisms. This year, the most common organisms found at the soft bottom stations were the clam *Rangia* and the worm *S. viridis*. *S. viridis* was also the most common organism found at the shell bottom stations.

Station HM26, at the mouth of the Back River, has in past years usually had the most diverse annelid worm fauna. However, this year, reference station HM9 was the most diverse station, having 8 species of worms in the August sampling period. A diverse annelid fauna was also recorded this year at the reference stations HM26 and 30 and the nearfield station, S6. All had 7 species of worms (Tables 3-3, 3-4, 3-5, and 3-6). This year, as in previous years, the most abundant worm species at the nearfield, reference, and zinc stations was *S. viridis*. It was also the most abundant worm at three of the six Back River stations.

The clam *R. cuneata,* the worm *S. viridis*, and the crustaceans *C. polita* and *L. plumulosus* occurred frequently at all three sets of our standard stations (nearfield, reference, and zinc) and also at the Back River stations. Over the course of the benthic monitoring studies, the worm *S. viridis* has frequently alternated with the crustaceans *C. polita* and *L. plumulosus* as the foremost dominant species. It appears that slight modifications in the salinity patterns during the important seasonal recruitment period in late spring play an important role in determining the dominance of these species. The crustaceans *C. polita* and *L. plumulosus* become more abundant during low salinity years while the worm *S. viridis* prefers slightly higher salinities. This year, *Rangia cuneata* was the most abundant species, followed by *S. viridis.*

This year, *C. polita* was more abundant than *L. plumulosus* at all three sets of standard stations (Tables 3-3, 3-4, 3-5). However, for the Back River stations *Leptocheirus* was somewhat more abundant than *C. polita*. *C. polita* was present at all stations and *L. plumulosus* was only missing from four stations (HM7, S1, S2 and M3) in August. The isopod crustacean *Cyathura* appears to be very tolerant of physical and chemical disturbances and repopulates areas such as dredged material disposal piles more quickly than other crustacean species (Pfitzenmeyer 1985).

All of the dominant species, with the exception of *R. cuneata*, brood their young. This is an advantage in an area of unstable and variable environmental conditions such as the low salinity regions of the Upper Chesapeake Bay. Organisms released from their parents as juveniles are known to have higher survival rates and often reach high densities of individuals (Wells 1961). The total number of individual organisms collected at the various reference, nearfield, zinc and Back River stations are comparable and ranged between 1,100 and 17,000 individuals/m$^2$. The highest recorded value was found at the reference station, HM7 (17,009 individuals/m$^2$); this was mainly due to the extremely high numbers of *Rangia* (16,047 individuals/m$^2$). The lowest recorded value occurred at one of the nearfield stations, S1 (1,126 individuals/m$^2$); this is a sand substrate station and frequently has had the lowest abundance levels due to its bottom type. The predominant benthic populations at the three sets of stations (nearfield, reference, and zinc) are similar and consist of detrital feeders which have an ample supply of fine substrates in this region of Chesapeake Bay, particularly around HMI (Wells et al. 1984).

Salinity and temperature (both surface and bottom) were recorded at all infaunal stations (Table 3-7). In August, the surface salinity ranged from 4.2 - 8.6 ‰. The surface salinity range was similar to the previous year's values. Last year the salinity range in August was 2.6 - 5.6 ‰. All the bottom salinities were the same or higher than the surface salinities for all sites; the bottom salinity range was 6.3 - 9.5 ‰. This year the average temperature for surface waters was 26.8°C, compared with the previous year's average of 27.2°C. The average bottom water temperature was 26.8°C.

Species diversity values must be interpreted carefully in analyzing benthic data from the Upper Chesapeake Bay. Generally, high diversity values reflect a healthy, stable fauna with the numbers of all species in the population somewhat equally distributed and no obvious dominance by one or two species. However, we observed in this and past monitoring studies, that the normal condition is for one, two or three species to assume numerical dominance in this area of the Chesapeake. This dominance is variable from year to year depending on environmental factors, in particular the amount of freshwater entering the Bay from the Susquehanna River. Because of the overwhelming numerical dominance of a few species, diversity values are fairly low in this productive area of the Bay when compared to values obtained elsewhere. Diversity values for each of the eighteen standard quantitative benthic samples for August are presented in Table 3-8. Highest diversity values occurring in the summer months were postulated in the First Interpretive Report (Pfitzenmeyer et al. 1982) and were frequently the case for a majority of the stations during the early years of the study. The highest diversity value (2.901) was recorded at reference station HM16 while the lowest diversity value (0.447) was recorded at HM7, another reference station.

The largest number of species recorded for any of the stations was 19 at stations HM9 (reference) and BC3 (nearfield). The lowest number of species, 4, was recorded at nearfield station S1. Back River station BSM75 had the second lowest number of species, 7, with reference station BC6 being third with 9 species.

Three species of clams (*Rangia cuneata*, *Macoma balthica*, and *Macoma mitchelli*) were measured to the nearest millimeter in shell length to determine if any size/growth differences were noticeable between the reference, nearfield, and zinc stations (Figure 3-2). The clam numbers for *Macoma balthica* and *Macoma mitchelli* were similar to last year's numbers, but the *Rangia cuneata* numbers were higher than they have ever been. Overall, the nearfield, zinc and reference stations had similar numbers of *R. cuneata* except for the 10mm size range (Figure 3-2). This year, in the 10mm *Rangia* size class, there were 143 individuals at the zinc stations, 1,422 individuals at the nearfield stations and 5,455 at the reference stations. *Macoma balthica* was the least abundant of the three clams species recorded in the vicinity of HMI.

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

The August or summer sampling period represents a season of continued recruitment for the majority of benthic species, as well as a period of heavy stress from predatory activities, higher salinity, and higher water temperatures. These stresses exert a moderating effect on the benthic community which holds the various populations in check. This year, the first four stations to join the dendrogram consisted of 3 silt/clay stations and 1 sand station. The first pair to join the dendrogram was HM22 (a reference station) and S1 (a nearfield station). The second pair included 30 (a reference station) and HM12 (a zinc station). The clusters that formed during the August sampling period represented previously observed normal groupings for the reference and nearfield stations with no unusually isolated stations. These clusters were consistent with earlier studies and often grouped stations according to bottom type and general location within the study area. The zinc stations clustered along with the nearfield and reference stations and indicated no unusually isolated stations. If the benthic invertebrates in this region were being affected by some adverse or outside force it would appear in the groupings. No such indications were found during the August sampling period reported in this study.

The Ryan-Einot-Gabriel-Welsch Multiple Comparison test was used to determine if a significant difference could be detected when population means of benthic invertebrates were compared at the various sampling stations. The total number of individuals of each species was transformed (log) before the analysis was performed. Subsets of groups, the highest and lowest means of which do not differ by more than the shortest significant range for a subset of that size, are listed as homogeneous subsets. The results of this test are presented in Table 3-9.

The analysis of the August 1997 data resulted in the occurrence of four subsets this year. The first subset consisted of three reference stations (HM7, HM9, HM26). The second subset consisted of two reference stations (HM9, HM26) and a nearfield station (BC3). The third subset had four nearfield stations (BC3, S3, S5, and S6) and one reference station (HM22). The fourth subset contained a mixture of nearfield, reference, and zinc stations.

The results of running Friedman's non-parametric test for differences in the means of samples (for ranked abundances of 11 selected species) taken only at the silt/clay stations for the nearfield, reference, and zinc stations are presented in Table 3-10. No significant differences ($p<0.05$) were found at any of the sources this year.

For the second time, we used the Chesapeake Bay Benthic Index of Biotic Integrity (B-IBI, Weisberg et al. 1997) to score all the benthic sampling stations. This year, all of the stations were low mesohaline as defined by the B-IBI. We used 5 metrics (total abundance, total biomass, abundance of pollution indicative taxa, abundance of pollution sensitive taxa, Shannon-Wiener diversity index) to evaluate the 18 standard benthic stations. Assemblages are considered stressed if they have an average metric value below 3.0. None of the 18 benthic stations were considered stressed. Overall, the benthic stations in the area surrounding HMI do not appear to be stressed according to the parameters of the Chesapeake Bay B-IBI.

Dr. Rob Mason’s Back River Transect stations were scored separately in Table 3-12. Only one station in this transect was considered stressed. This was station BSM75, which had a score of 1.5. Of all the transect stations, BSM75 is the farthest station upriver in the Back River transect.

## CONCLUSIONS AND RECOMMENDATIONS

During Year 16 of monitoring the benthic populations around HMI, the sampling locations, sampling techniques and analyses of the data were maintained as close as possible to that of previous years in order to limit variation. Maintenance of sampling locations, techniques and analyses should render differences due to effects of HMI more readily apparent. The same 17 benthic stations that were sampled last year were again sampled this year; nearfield station S1 was also sampled. We also sampled a Back River Transect in conjunction with Dr. Rob Mason (BSM75, M1, M2, M3, M4, and M5). The Back River transect was examined as a potential source of metals to the HMI region. We have continued to monitor all four infaunal sampling stations (HM12, G5, G25, and G84) which were established over the course of Year 9 in response to the findings of the sedimentary group of an observable enrichment of zinc in the sediments at these stations.

The results presented in this report are similar to those presented in the reports of the last eleven years. A total of 29 species (compared with 26, 30, 35, 31, 34, 32, 35, 30, 30, 31, and 26 for Years 5 through 15, respectively) were collected in the quantitative infaunal grab samples. Two species were numerically dominant on soft bottoms; these were the clam *R. cuneata* and the worm *S. viridis*. The oyster shell substrate stations had one numerically dominant species, the worm *S. viridis*. Salinity fluctuations on yearly and seasonal time scales appear to be important in regulating the position of dominance of the major species in this low and variable salinity region of the Bay. The average number of individuals per square meter (#/m$^2$) per station was highest for the reference stations (7,129) with decreasing values observed for the Back River stations (6,974), nearfield stations (4,106) and the zinc stations (2,581) during the August sampling period. The highest average species diversity value this year was found at reference station HM16; the lowest diversity value was also recorded at a reference station (HM7).

As has been the case in previous years, cluster analysis grouped stations of similar faunal composition in response to sediment type and general location within the HMI study area. There were no incidences of individual stations being isolated from common groupings during the August sampling period. The Ryan-Einot-Gabriel-Welsch multiple range test resulted in subsets of stations which contained a mix of nearfield, reference, and zinc stations. Friedman's non-parametric test indicated no significant differences among any of the station types (reference stations, nearfield stations, zinc stations or any combination thereof). According to the Chesapeake Bay B-IBI, the area surrounding the HMI is not considered stressed and only one station (BSM75) in the Back River transect was considered stressed with a average B-IBI score of 1.5. At present, there do not appear to be any discernable differences in the populations of benthic organisms at the nearfield, reference and zinc stations resulting directly from HMI.

The Hart-Miller Island Confined Disposal Facility will continue to operate well beyond the year 2000. It is strongly recommended that the infaunal populations continue to be sampled at the established locations during the period of active operation of HMI in order to ascertain any possible effects. Historical station locations and sampling techniques should be maintained to eliminate sampling variation and permit rapid recognition of effects resulting from the operation and existence of the facility.

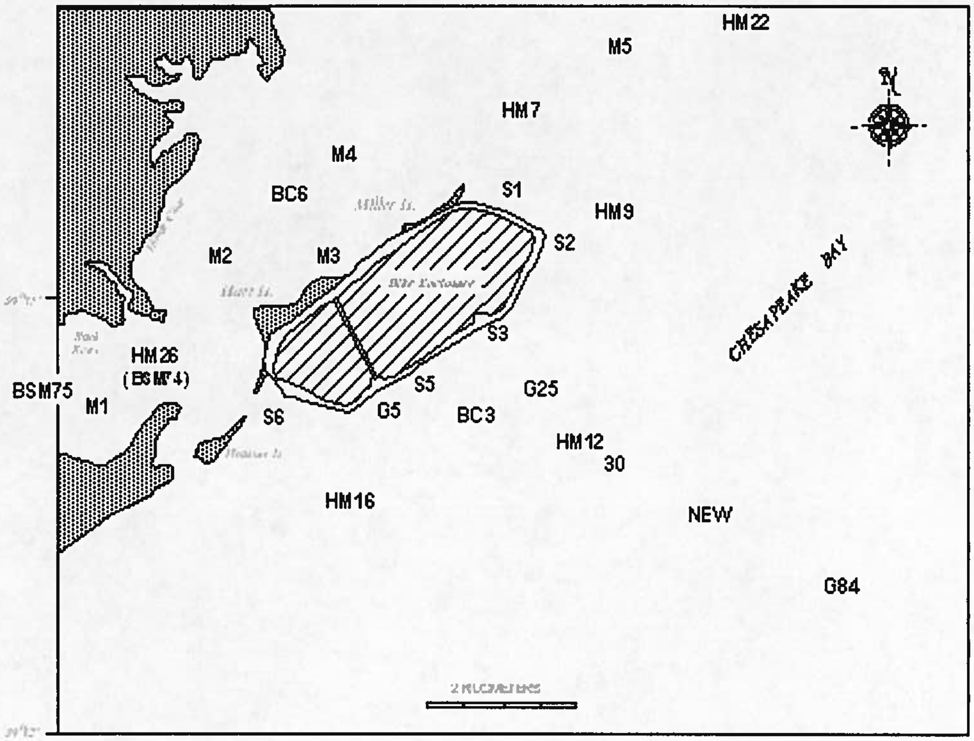

Figure 3-1: **Chesapeake Biological Lab sampling locations during Year 16 of benthic community monitoring for the Hart-Miller Island Exterior Monitoring Program.**

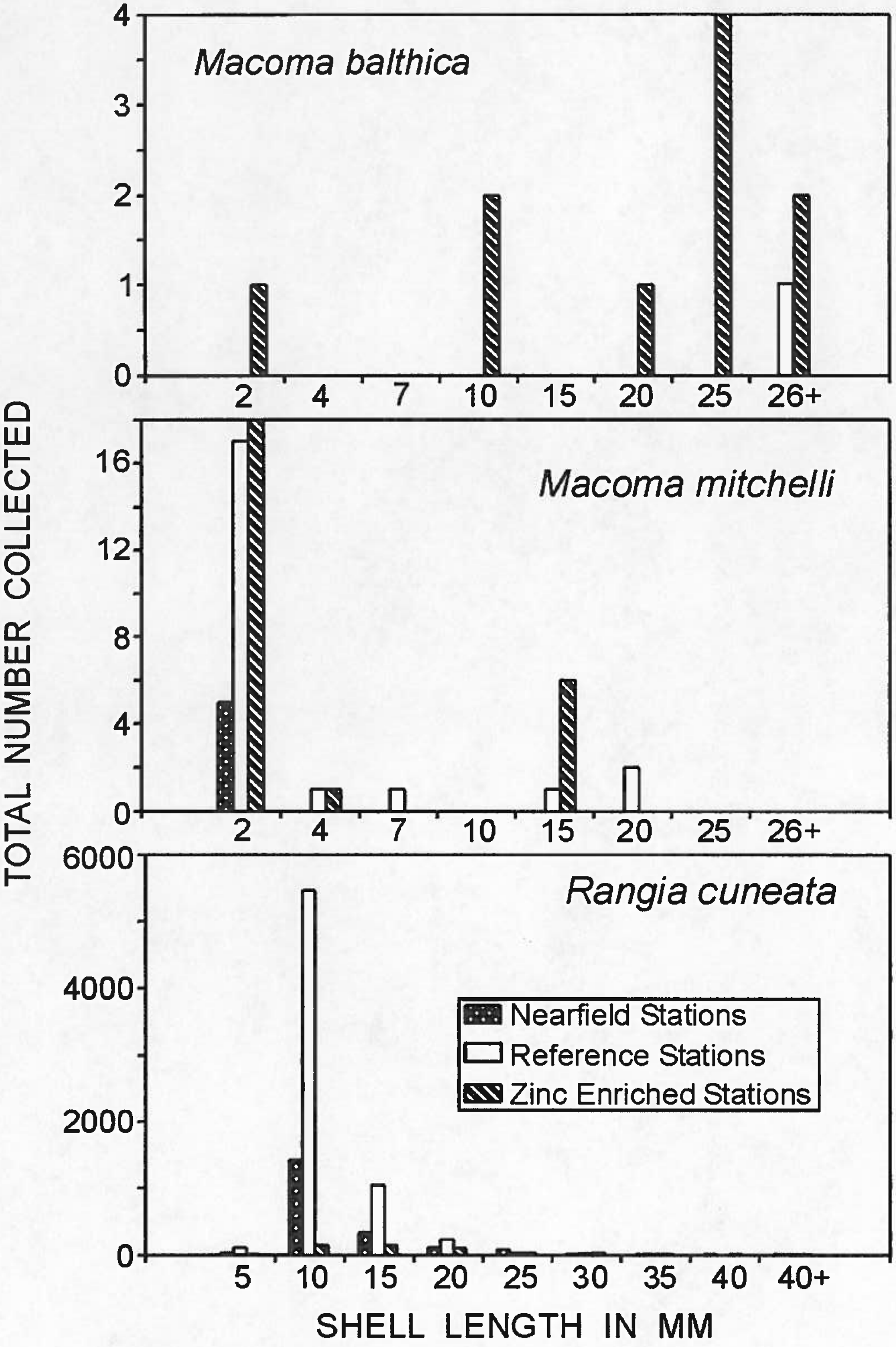

**Figure 3-2:** **Length frequency distribution of the clams *Macoma balthica, Macoma mitchelli,* and *Rangia cuneata* during Year 16 of benthic community studies at HMI.**

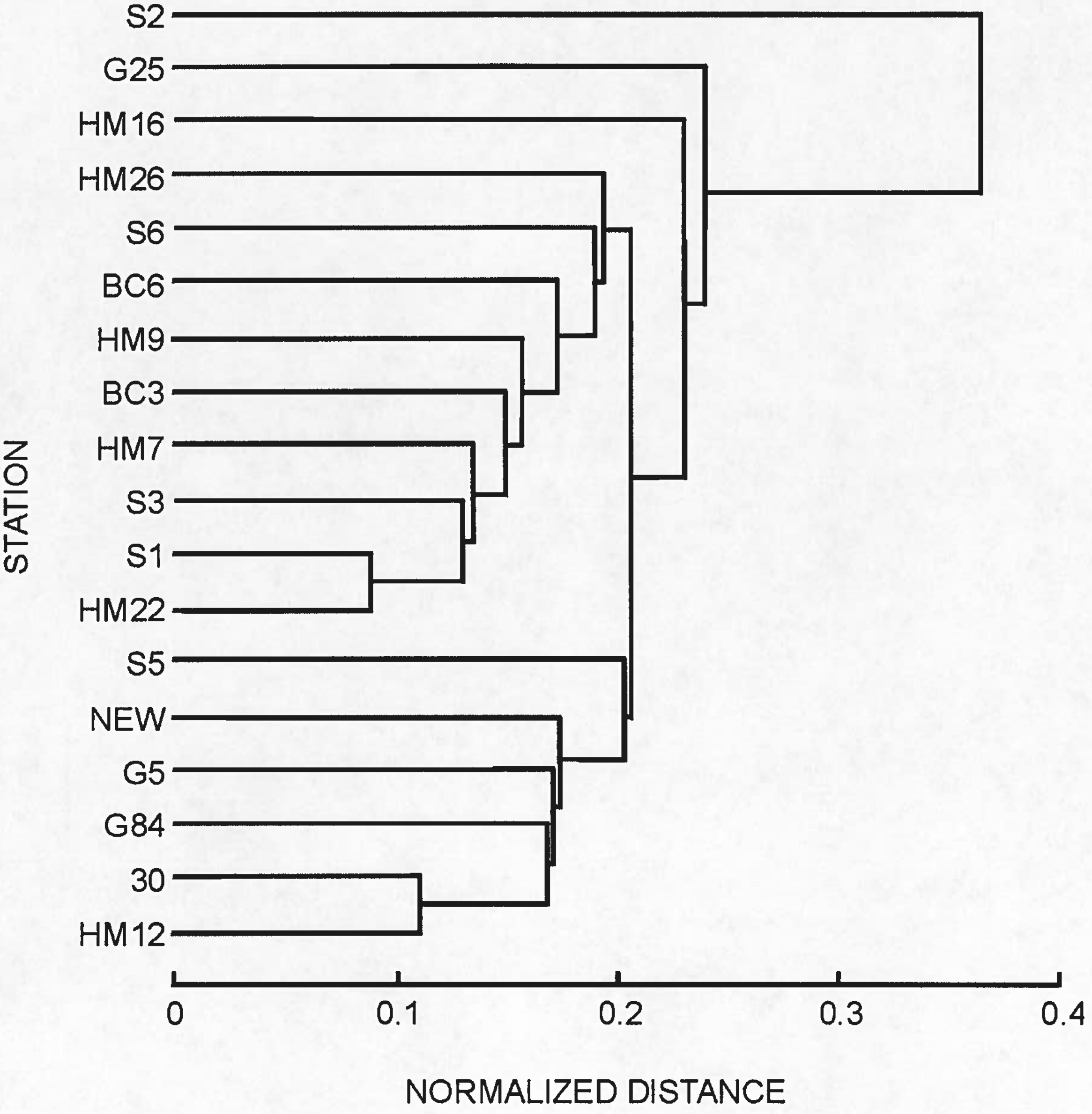

**Figure 3-3: Cluster analysis for all HMI stations during Year 16 of benthic community studies.**

**Table 3-1: Relative abundances (# per square meter) of three of the most abundant species of benthic organisms which have occurred at the HMI silt/clay Reference stations over the sixteen year study period from August 1981 to August 1997**

| | Aug.,Nov. 1981 Feb.,May, 1982 | Aug.,Nov. 1982 Feb.,May 1983 | Sep.1983 Mar.1984 | Oct.1984 Apr.1985 | Dec. 1985 Apr., Aug. 1986 | Dec.1986 Apr.,Aug. 1987 | Dec.1987 Apr.,Aug. 1988 | Dec.1988 Apr.,Aug. 1989 |
|---|---|---|---|---|---|---|---|---|
| ***Scolecolepides viridis*** | | | | | | | | |
| Range/m2 | 3-667 | 0-197 | 0-217 | 143-463 | 7-1287 | 13-320 | 0-567 | 20-3420 |
| Avg./m2 | 144 | 49 | 109 | 311 | 413 | 129 | 166 | 971 |
| ***Leptocheirus plumulosus*** | | | | | | | | |
| Range/m2 | 0-4540 | 113-5763 | 0-427 | 843-1353 | 7-1293 | 7-3313 | 0-1047 | 0-2473 |
| Avg./m2 | 1900 | 2546 | 180 | 1076 | 402 | 1250 | 187 | 486 |
| ***Rangia cuneata*** | | | | | | | | |
| Range/m2 | 0-27 | 0-27 | 3-540 | 0-227 | 0-273 | 0-3007 | 7-2267 | 0-580 |
| Avg./m2 | 3 | 12 | 216 | 110 | 124 | 631 | 447 | 179 |

| | Dec.1989 Apr.,Aug. 1990 | Dec.1990 Apr.,Aug. 1991 | Dec.1991 Apr.,Aug. 1992 | Dec.1992 Apr.,Aug. 1993 | Dec.1993 Apr.,Aug. 1994 | Nov.1994 Apr.,Aug. 1995 | Aug.1996 | Aug.1997 |
|---|---|---|---|---|---|---|---|---|
| ***Scolecolepides viridis*** | | | | | | | | |
| Range/m2 | 27-4147 | 7-253 | 20-753 | 60-693 | 47-2300 | 167-893 | 120-1693 | 127-753 |
| Avg./m2 | 1037 | 87 | 215 | 249 | 932 | 436 | 594 | 453 |
| ***Leptocheirus plumulosus*** | | | | | | | | |
| Range/m2 | 167-2820 | 40-3607 | 73-2400 | 13-3513 | 67-4820 | 367-3713 | 13-560 | 0-547 |
| Avg./m2 | 1193 | 1170 | 990 | 769 | 1361 | 1443 | 376 | 178 |
| ***Rangia cuneata*** | | | | | | | | |
| Range/m2 | 13-10820 | 0-3867 | 13-660 | 73-733 | 0-227 | 20-4780 | 13-220 | 240-16047 |
| Avg./m2 | 1352 | 827 | 224 | 343 | 105 | 884 | 104 | 4062 |

**TABLE 3-2: A list of the 3 numerically dominant benthic organisms collected from each bottom type on each sampling date during Year 16 of benthic studies at HMI.**

| STATION | AUGUST 1997 |
|---|---|
| **NEARFIELD<br>SILT-CLAY BOTTOM<br>(S5,6,BC3)** | *Rangia cuneata*<br>*Scolecolepides viridis*<br>*Cyathura polita* |
| **NEARFIELD<br>SHELL BOTTOM<br>(S2)** | *Scolecolepides viridis*<br>*Rithropanopeus harrisi*<br>*Nereis succinea* |
| **NEARFIELD<br>SAND BOTTOM<br>(S1,S3)** | *Rangia cuneata*<br>*Scolecolepides viridis*<br>*Cyathura polita* |
| **REFERENCE<br>SILT-CLAY BOTTOM<br>(HM7,16,22,30,NEW,BC6)** | *Rangia cuneata*<br>*Scolecolepides viridis*<br>*Leptocheirus plumulosus* |
| **REFERENCE<br>SHELL BOTTOM<br>(HM9)** | *Rangia cuneata*<br>*Scolecolepides viridis*<br>*Cyathura polita* |
| **BACK RIVER<br>REFERENCE<br>SAND/SILT-CLAY BOTTOM<br>(HM26)** | *Rangia cuneata*<br>*Streblospio benedicti*<br>*Cyathura polita* |
| **HISTORICALLY<br>ZINC ENRICHED<br>SILT-CLAY BOTTOM<br>(G5,25,84,HM12)** | *Scolecolepides viridis*<br>*Rangia cuneata*<br>*Cyathura polita* |

**TABLE 3-3: Number of benthic organisms per meter squared (#/m2) found at the Reference stations during Year 16 (August 1997) of benthic studies at HMI.**

| PHYLUM | SPECIES NAME | # | HM7 | HM9 | HM16 | HM22 | HM26 | BC6 | 30 | NEW | TOTALS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **RHYNCHOCOELA (ribbon worms)** | *Micrura leidyi* | 2 | 7 | 73 |  | 33 | 40 | 13 | 120 | 60 | 346 |
| **ANNELIDA (worms)** | *Heteromastus filiformis* | 3 |  | 7 |  |  |  |  |  | 13 | 20 |
|  | *Nereis succinea* | 5 | 20 | 13 | 47 |  | 13 |  | 13 | 40 | 146 |
|  | *Eteone heteropoda* | 8 |  | 7 | 27 |  | 7 |  | 13 | 13 | 67 |
|  | *Polydora ligni* | 9 | 53 | 33 |  | 107 | 147 |  |  |  | 340 |
|  | *Scolecolepides viridis* | 10 | 467 | 1073 | 307 | 387 | 160 | 127 | 680 | 753 | 3954 |
|  | *Streblospio benedicti* | 11 | 7 | 40 | 73 | 7 | 513 |  | 20 | 27 | 687 |
|  | *Hobsonia florida* | 12 | 100 | 53 |  | 20 | 107 |  | 7 |  | 287 |
|  | *Limnodrilus hoffmeisteri* | 13 |  |  |  |  |  |  |  |  | 0 |
|  | *Tubificoides heterochaetus* | 14 |  | 100 | 313 |  | 40 | 7 | 140 | 7 | 607 |
|  | *Capitella capitata* | 15 |  |  |  |  |  |  | 7 |  | 7 |
| **MOLLUSCA (mollusks)** | *Ischadium recurvus* | 16 |  |  |  |  |  |  |  |  | 0 |
|  | *Congeria leucophaeta* | 17 | 20 | 27 |  |  |  |  |  |  | 47 |
|  | *Littoridinops sp.* | 18 | 7 | 7 |  |  |  |  |  | 33 | 47 |
|  | *Macoma balthica* | 19 |  |  |  |  |  |  |  | 7 | 7 |
|  | *Macoma mitchelli* | 20 | 7 | 13 | 53 |  | 7 |  | 53 | 20 | 153 |
|  | *Rangia cuneata* | 21 | 16047 | 11053 | 240 | 5167 | 10413 | 873 | 747 | 1300 | 45840 |
|  | *Mya arenaria* | 22 |  |  |  |  |  |  |  |  | 0 |
|  | *Hydrobia sp.* | 23 |  |  |  |  | 40 |  |  |  | 40 |
|  | *Doridella obscura* | 25 |  |  |  |  |  |  |  |  | 0 |
| **ARTHROPODA (crustaceans)** | *Balanus improvisus* | 27 |  | 7 |  |  |  |  |  |  | 7 |
|  | *Balanus subalbidus* | 28 |  |  |  |  |  |  |  |  | 0 |
|  | *Leucon americanus* | 29 |  |  |  |  |  |  |  |  | 0 |
|  | *Cyathura polita* | 30 | 200 | 493 | 133 | 107 | 260 | 93 | 140 | 193 | 1619 |
|  | *Cassidinidea lunifrons* | 31 |  |  |  |  |  |  |  |  | 0 |
|  | *Edotea triloba* | 33 | 40 | 20 |  | 7 | 133 |  | 7 | 13 | 220 |
|  | *Gammarus palustris* | 35 |  |  |  |  |  |  |  |  | 0 |
|  | *Leptocheirus plumulosus* | 36 |  | 13 | 547 | 20 | 127 | 327 | 133 | 40 | 1207 |
|  | *Corophium lacustre* | 37 |  |  |  |  | 20 |  | 7 |  | 27 |
|  | *Gammarus daiberi* | 38 |  |  |  |  |  |  |  |  | 0 |
|  | *Gammerus tigrinus* | 39 |  |  |  |  |  |  |  |  | 0 |
|  | *Melita nitida* | 40 |  |  | 107 |  | 13 | 7 | 20 |  | 147 |
|  | *Chirodotea almyra* | 41 | 27 |  |  |  | 13 |  |  |  | 40 |
|  | *Monoculodes edwardsi* | 42 |  |  |  | 7 |  |  |  | 7 | 14 |
|  | *Chironomid sp.* | 43 |  |  | 27 | 147 | 127 | 127 |  |  | 428 |
|  | *Rithropanopeus harrisi* | 44 | 7 | 47 |  |  |  |  |  |  | 54 |
| **COELENTERA (hydroids)** | *Garveia franciscana* | 47 |  |  |  |  |  |  |  |  | 0 |
| **PLATYHELMIA (flatworms)** | *Stylochus ellipticus* | 48 |  |  |  |  |  |  |  |  | 0 |
| **BRYOZOA (bryozoans)** | *Membrania tenuis* | 49 |  | 347 |  |  |  | 13 | 7 | 307 | 674 |
|  | *Victorella pavida* | 50 |  |  |  |  |  |  |  |  | 0 |
|  | **TOTAL NUMBERS** |  | 17009 | 13426 | 1874 | 6009 | 12180 | 1587 | 2114 | 2833 | 57032 |

## TABLE 3-4: Number of benthic organisms per meter squared (#/m2) found at the Nearfield stations during Year 16 (August 1997) of benthic studies at HMI

| PHYLUM | SPECIES NAME | # | S1 | S2 | S3 | S5 | S6 | BC3 | TOTALS |
|---|---|---|---|---|---|---|---|---|---|
| **RHYNCHOCOELA (ribbon worms)** | *Micrura leidyi* | 2 | | 7 | 33 | 40 | 7 | 33 | 120 |
| **ANNELIDA (worms)** | *Heteromastus filiformis* | 3 | | | | | | | 0 |
| | *Nereis succinea* | 5 | | 160 | | 13 | 7 | 93 | 273 |
| | *Eteone heteropoda* | 8 | | | | | 20 | | 20 |
| | *Polydora ligni* | 9 | | 7 | | | 20 | 67 | 94 |
| | *Scolecolepides viridis* | 10 | 80 | 267 | 1200 | 1940 | 360 | 1193 | 5040 |
| | *Streblospio benedicti* | 11 | | 40 | 53 | 173 | 373 | 200 | 839 |
| | *Hobsonia florida* | 12 | | | 20 | | 13 | 7 | 40 |
| | *Limnodrilus hoffmeisteri* | 13 | | | | | | | 0 |
| | *Tubificoides heterochaetus* | 14 | | 27 | 20 | 40 | 87 | 260 | 434 |
| | *Capitella capitata* | 15 | | | | | | | 0 |
| **MOLLUSCA (mollusks)** | *Ischadium recurvus* | 16 | | | | | | | 0 |
| | *Congeria leucophaeta* | 17 | | 13 | | 27 | | 7 | 47 |
| | *Littoridinops sp.* | 18 | | | 13 | | 33 | 27 | 73 |
| | *Macoma balthica* | 19 | | | | | | | 0 |
| | *Macoma mitchelli* | 20 | | | | 13 | 20 | | 33 |
| | *Rangia cuneata* | 21 | 973 | 7 | 2853 | 1020 | 2240 | 6233 | 13326 |
| | *Mya arenaria* | 22 | | | | | | | 0 |
| | *Hydrobia sp.* | 23 | | | | | | | 0 |
| | *Doridella obscura* | 25 | | | | | | | 0 |
| **ARTHROPODA (crustaceans)** | *Balanus improvisus* | 27 | | 133 | | | | 13 | 146 |
| | *Balanus subalbidus* | 28 | | 7 | | | | | 7 |
| | *Leucon americanus* | 29 | | | | | | | 0 |
| | *Cyathura polita* | 30 | 40 | 53 | 260 | 287 | 333 | 567 | 1540 |
| | *Cassidinidea lunifrons* | 31 | | 7 | | | | | 7 |
| | *Edotea triloba* | 33 | | | 87 | 7 | 40 | 47 | 181 |
| | *Gammarus palustris* | 35 | | | | | | | 0 |
| | *Leptocheirus plumulosus* | 36 | | | 87 | 347 | 313 | 7 | 754 |
| | *Corophium lacustre* | 37 | | 7 | | | | 7 | 14 |
| | *Gammarus daiberi* | 38 | | | | | | | 0 |
| | *Gammarus tigrinus* | 39 | | | | | | | 0 |
| | *Melita nitida* | 40 | | 27 | | 53 | 20 | | 100 |
| | *Chirodotea almyra* | 41 | 33 | | 20 | | | 7 | 60 |
| | *Monoculodes edwardsi* | 42 | | | | | 20 | | 20 |
| | *Chironomid sp.* | 43 | | | 13 | 73 | 20 | 7 | 113 |
| | *Rithropanopeus harrisi* | 44 | | 167 | | | | 67 | 234 |
| | *Gammarus mucronatus* | 45 | | | | | | | 0 |
| **COELENTERA (hydroids)** | *Garvela franciscana* | 47 | | | | | | | 0 |
| **PLATYHELMIA (flatworms)** | *Stylochus ellipticus* | 48 | | | | | | | 0 |
| **BRYOZOA (bryozoans)** | *Membranipora tenuis* | 49 | | 733 | | 80 | | 307 | 1120 |
| | *Victorella pavida* | 50 | | | | | | | 0 |
| | **TOTAL NUMBERS** | | 1126 | 1662 | 4659 | 4113 | 3926 | 9149 | 24635 |

**TABLE 3-5: Number of benthic organisms per meter squared (#/$m^2$) found at the Zinc stations during Year 16 (August 1997) of benthic studies at HMI.**

| PHYLUM | SPECIES NAME | # | G5 | G25 | G84 | HM12 | TOTALS |
|---|---|---|---|---|---|---|---|
| **RHYNCHOCOELA (ribbon worms)** | *Micrura leidyi* | 2 | 20 | 87 | 113 | 80 | 300 |
| **ANNELIDA (worms)** | *Heteromastus filiformis* | 3 | | | 60 | | 60 |
| | *Nereis succinea* | 5 | 13 | 80 | 7 | 53 | 153 |
| | *Eteone heteropoda* | 8 | 7 | 13 | | 27 | 47 |
| | *Polydora ligni* | 9 | | 53 | | 7 | 60 |
| | *Scolecolepides viridis* | 10 | 780 | 800 | 620 | 1213 | 3413 |
| | *Streblospio benedicti* | 11 | 133 | 47 | 33 | 40 | 253 |
| | *Hobsonia florida* | 12 | 7 | | | | 7 |
| | *Limnodrilus hoffmeisteri* | 13 | | | | | 0 |
| | *Tubificoides heterochaetus* | 14 | 73 | 27 | 33 | 33 | 166 |
| | *Capitella capitata* | 15 | | | | | 0 |
| **MOLLUSCA (mollusks)** | *Ischadium recurvus* | 16 | | | | | 0 |
| | *Congeria leucophaeta* | 17 | | 7 | | | 7 |
| | *Littoridinops sp.* | 18 | | | | | 0 |
| | *Macoma balthica* | 19 | | | 67 | | 67 |
| | *Macoma mitchelli* | 20 | 20 | 13 | 53 | 13 | 99 |
| | *Rangia cuneata* | 21 | 746 | 507 | 493 | 1253 | 2999 |
| | *Mya arenaria* | 22 | | | | | 0 |
| | *Hydrobia sp.* | 23 | | | | | 0 |
| | *Doridella obscura* | 25 | | | | | 0 |
| **ARTHROPODA (crustaceans)** | *Balanus improvisus* | 27 | | 40 | | | 40 |
| | *Balanus subalbidus* | 28 | | | | | 0 |
| | *Leucon americanus* | 29 | | | | | 0 |
| | *Cyathura polita* | 30 | 360 | 200 | 373 | 213 | 1146 |
| | *Cassidinidea lunifrons* | 31 | | | | | 0 |
| | *Edotea triloba* | 33 | 13 | 7 | 7 | 13 | 40 |
| | *Gammarus palustris* | 35 | | | | | 0 |
| | *Leptocheirus plumulosus* | 36 | 507 | 13 | 33 | 73 | 626 |
| | *Corophium lacustre* | 37 | | | | 7 | 7 |
| | *Gammarus daiberi* | 38 | | | | | 0 |
| | *Gammerus tigrinus* | 39 | | | | | 0 |
| | *Melita nitida* | 40 | 67 | | | 13 | 80 |
| | *Chirodotea almyra* | 41 | | | | | 0 |
| | *Monoculodes edwardsi* | 42 | 20 | | 13 | 7 | 40 |
| | *Chironomid sp.* | 43 | 33 | 7 | 7 | | 47 |
| | *Rithropanopeus harrisi* | 44 | | 60 | 7 | | 67 |
| **COELENTERA (hydroids)** | *Garvela franciscana* | 47 | | | | | 0 |
| **PLATYHELMIA (flatworms)** | *Stylochus ellipticus* | 48 | | | | | 0 |
| **BRYOZOA (bryozoans)** | *Membranipora tenuis* | 49 | 7 | 573 | 13 | 7 | 600 |
| | *Victorella pavida* | 50 | | | | | 0 |
| | **TOTAL NUMBERS** | | 2806 | 2534 | 1932 | 3052 | 10324 |

TABLE 3-6: Number of benthic organisms per meter squared (#/m$^2$) found at the Back River Transect stations during Year 16 (August 1997) of benthic studies at HMI.

| PHYLUM | SPECIES NAME | # | M1 | M2 | M3 | M4 | M5 | BSM75 | TOTALS |
|---|---|---|---|---|---|---|---|---|---|
| **RHYNCHOCOELA (ribbon worms)** | *Micrura leidyi* | 2 | 40 | | | 7 | 27 | 53 | 127 |
| **ANNELIDA (worms)** | *Heteromastus filiformis* | 3 | 13 | | | | 7 | | 20 |
| | *Nereis succinea* | 5 | | 7 | 20 | | 7 | | 34 |
| | *Eteone heteropoda* | 8 | | | | | | | 0 |
| | *Polydora ligni* | 9 | | 33 | | 33 | 13 | | 79 |
| | *Scolecolepides viridis* | 10 | 300 | 180 | 260 | 153 | 467 | | 1360 |
| | *Streblospio benedicti* | 11 | 467 | 80 | | 7 | 20 | 47 | 621 |
| | *Hobsonia florida* | 12 | | 20 | 100 | 87 | | | 207 |
| | *Limnodrilus hoffmeisteri* | 13 | | | | | | | 0 |
| | *Tubificoides heterochaetus* | 14 | 487 | 13 | 113 | | 13 | 100 | 726 |
| | *Capitella capitata* | 15 | | | | | | | 0 |
| **MOLLUSCA (mollusks)** | *Ischadium recurvus* | 16 | | | | | | | 0 |
| | *Congeria leucophaeta* | 17 | | | | | 7 | | 7 |
| | *Littoridinops sp.* | 18 | | 20 | | | | | 20 |
| | *Macoma balthica* | 19 | | | | | | | 0 |
| | *Macoma mitchelli* | 20 | | | | | 20 | | 20 |
| | *Rangia cuneata* | 21 | 167 | 1833 | 7780 | 1640 | 1040 | | 12460 |
| | *Mya arenaria* | 22 | | | | | | | 0 |
| | *Hydrobia sp.* | 23 | | | | | | | 0 |
| | *Doridella obscura* | 25 | | | | | | | 0 |
| **ARTHROPODA (crustaceans)** | *Balanus improvisus* | 27 | | | | | | | 0 |
| | *Balanus subalbidus* | 28 | | | | | | | 0 |
| | *Leucon americanus* | 29 | | | | | | | 0 |
| | *Cyathura polita* | 30 | 267 | 100 | 353 | 127 | 107 | 13 | 967 |
| | *Cassidinidea lunifrons* | 31 | | | | | | | 0 |
| | *Edotea triloba* | 33 | 33 | 7 | 7 | | | | 47 |
| | *Gammarus palustris* | 35 | | | | | | | 0 |
| | *Leptocheirus plumulosus* | 36 | 407 | 1207 | | 133 | 253 | 120 | 2120 |
| | *Corophium lacustre* | 37 | | 13 | | | | | 13 |
| | *Gammarus daiberi* | 38 | | | | | | | 0 |
| | *Gammarus tigrinus* | 39 | | | | | | | 0 |
| | *Melita nitida* | 40 | 40 | 20 | | 7 | 53 | | 120 |
| | *Chirodotea almyra* | 41 | 13 | | 20 | | | 7 | 40 |
| | *Monoculodes edwardsi* | 42 | | | | 27 | 7 | | 34 |
| | *Chironomid sp.* | 43 | 333 | 373 | | 93 | 60 | 873 | 1732 |
| | *Rithropanopeus harrisi* | 44 | | 7 | 160 | 7 | | | 174 |
| | *Gammarus mucronatus* | 45 | | | | | | | 0 |
| **COELENTERA (hydroids)** | *Garvela franciscana* | 47 | | | | | | | 0 |
| **PLATYHELMIA (flatworms)** | *Stylochus ellipticus* | 48 | | | | | | | 0 |
| **BRYOZOA (bryozoans)** | *Membranipora tenuis* | 49 | | | | | | | 0 |
| | *Victorella pavida* | 50 | | | | | | | 0 |
| | TOTAL NUMBERS | | 2567 | 3913 | 8813 | 2321 | 2101 | 1213 | 20928 |

**TABLE 3-7: Salinity (in parts/thousand-0/00), temperature (degrees centigrade-°C), and dept for the benthic sampling stations on the 2 collection dates during Year 16 of Benthic studies at HMI (August 1997).**

| CBL STATION ID | STATE STATION # | DEPTH (ft.) | TEMPERATURE (oC) | SALINITY (o/oo) |
|---|---|---|---|---|
| S1 | XIF5710 | 0 | 27.27 | 6.4 |
| S1 | XIF5710 | 5 | 27.24 | 6.4 |
| S2 | XIF5406 | 0 | 27.21 | 6.3 |
| S2 | XIF5406 | 10 | 27.08 | 6.4 |
| S3 | XIF4811 | 0 | 27.06 | 6.6 |
| S3 | XIF4811 | 12 | 27.16 | 7.2 |
| S5 | XIF4420 | 0 | 27.11 | 4.2 |
| S5 | XIF4420 | 17 | 27.26 | 7.8 |
| S6 | XIF4327 | 0 | 27.19 | 7.0 |
| S6 | XIF4327 | 10 | 27.32 | 8.4 |
| HM7 | XIF6388 | 0 | 26.14 | 6.8 |
| HM7 | XIF6388 | 10 | 26.14 | 6.8 |
| HM9 | XIF5297 | 0 | 27.29 | 6.9 |
| HM9 | XIF5297 | 14 | 26.94 | 7.7 |
| HM12 | XIF5805 | 0 | 26.81 | 7.8 |
| HM12 | XIF5805 | 14 | 26.97 | 7.8 |
| HM16 | XIF3325 | 0 | 27.07 | 5.4 |
| HM16 | XIF3325 | 16 | 27.05 | 9.5 |
| HM22 | XIG7689 | 0 | 25.96 | 7.8 |
| HM22 | XIG7689 | 12 | 25.99 | 7.8 |
| HM26 | XIF5145 | 0 | 25.96 | 6.9 |
| HM26 | XIF5145 | 14 | 25.76 | 7.5 |
| G5 | XIF4221 | 0 | 27.20 | 7.0 |
| G5 | XIF4221 | 15 | 27.22 | 8.3 |
| G25 | XIF4405 | 0 | 26.97 | 7.2 |
| G25 | XIF4405 | 15 | 27.01 | 7.2 |
| G84 | XIG2964 | 0 | 26.67 | 7.8 |
| G84 | XIG2964 | 17 | 26.65 | 8.6 |
| 30 | XIF4000 | 0 | 26.93 | 8.0 |
| 30 | XIF4000 | 15 | 26.93 | 8.0 |
| NEW |  | 0 | 26.74 | 8.6 |
| NEW |  | 16 | 26.86 | 8.6 |
| BC3 | XIF4615 | 0 | 26.83 | 6.5 |
| BC3 | XIF4615 | 12 | 27.06 | 6.8 |
| BC6 | XIF5925 | 0 | 26.10 | 6.3 |
| BC6 | XIF5925 | 9 | 26.10 | 6.3 |
| 75 |  | 0 | 26.37 | 5.4 |
| 75 |  | 6 | 26.30 | 5.5 |
| M1 |  | 0 | 26.02 | 6.8 |
| M1 |  | 7 | 25.86 | 7.1 |
| M2 |  | 0 | 26.18 | 6.5 |
| M2 |  | 8 | 26.15 | 6.6 |
| M3 |  | 0 | 25.78 | 6.4 |
| M3 |  | 5 | 25.78 | 6.4 |
| M4 |  | 0 | 25.92 | 6.5 |
| M4 |  | 10 | 25.90 | 6.5 |
| M5 |  | 0 | 26.01 | 7.2 |
| M5 |  | 13 | 26.05 | 7.2 |

**TABLE 3-8: Number of species and the total number of individuals collected in three grab samples (0.05m$^2$ each) at the infaunal stations for August 1997. Bottom substrate, species diversity (H') and dominance factor (S.I.) are also shown. Data for Year 16 of benthic studies at HMI.**

| STATION | SUBSTRATE | NO. SPECIES | NO. INDIVIDUALS | SPECIES DIVERSITY (H') | DOMINANC FACTOR Simpson's Index (S.I.) |
|---|---|---|---|---|---|
| **NEARFIELD** | | | | | |
| S1 | Sand | 4 | 169 | 0.775 | 0.754 |
| S2 | Shell | 16 | 249 | 2.623 | 0.249 |
| S3 | Sand | 12 | 699 | 1.658 | 0.445 |
| S5 | Silt-Clay | 14 | 617 | 2.312 | 0.299 |
| S6 | Silt-Clay | 17 | 589 | 2.233 | 0.357 |
| BC3 | Silt-Clay | 19 | 1372 | 1.763 | 0.488 |
| **REFERENCE** | | | | | |
| HM 7 | Silt-Clay | 14 | 2551 | 0.447 | 0.891 |
| HM 9 | Shell | 19 | 2014 | 1.117 | 0.686 |
| HM16 | Silt-Clay | 11 | 281 | 2.901 | 0.168 |
| HM22 | Silt-Clay | 11 | 901 | 0.908 | 0.745 |
| 30 | Silt-Clay | 16 | 317 | 2.547 | 0.245 |
| NEW | Silt-Clay | 16 | 425 | 2.287 | 0.299 |
| BC6 | Silt-Clay | 9 | 238 | 1.948 | 0.362 |
| **BACK RIVER REFERENCE** | | | | | |
| HM26 | Sand/Silt-Clay | 18 | 1827 | 1.072 | 0.734 |
| **ZINC-ENRICHED** | | | | | |
| G5 | Silt-Clay | 16 | 431 | 2.759 | 0.193 |
| G25 | Silt-Clay | 17 | 380 | 2.790 | 0.201 |
| G84 | Silt-Clay | 16 | 290 | 2.708 | 0.213 |
| HM12 | Silt-Clay | 16 | 458 | 2.086 | 0.333 |

**TABLE 3-9: The Ryan-Einot-Gabriel-Welsch Multiple F test of significance among mean number of individuals per station for stations sampled in August 1997. Subsets show groupings of stations different at (P<0.05). Stations in a separate vertical row and column are significantly different from others. Year 16 of benthic studies**

AUGUST 1997

| SUBSET | STATION NUMBERS | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | HM7 | HM9 | HM26 | | | | | | | | | | | | | | |
| 2 | | HM9 | HM26 | BC3 | | | | | | | | | | | | | |
| 3 | | | | BC3 | HM22 | S3 | S5 | S6 | | | | | | | | | |
| 4 | | | | | HM22 | S3 | S5 | S6 | HM12 | G5 | NEW | G25 | 30 | HM16 | S2 | BC6 | S1 |

ANALYSIS OF VARIANCE

| SOURCE | D.F. | SUM OF SQUARES | MEAN SQUARES | F RATIO | F PROB. |
|---|---|---|---|---|---|
| BETWEEN GROUPS | 17 | 2783719 | 163748 | 18.22 | 0.0001 |
| WITHIN GROUPS | 36 | 323600 | 8989 | | |
| TOTAL | 53 | 3107319 | | | |

**TABLE 3-10: Results of Friedman's non-parametric test for differences in the abundances of (11) selected species between stations with silt/clay substrates for Year 16 of benthic studies at HMI. (Silt/clay stations are: NEARFIELD STAS.- S5, S6,BC3; REFERENCE STAS.- HM7, HM16, HM22, 30, NEW, BC6; ZINC ENRICHED STAS.- G5, G25, G84, HM12.)**

| | SOURCE | D.F. | CHI-SQUARE | CHI-SQUARE (0.05) |
|---|---|---|---|---|
| **AUG 1997** | | | | |
| | NEARFIELD | 2 | 2.36 | 5.99 |
| | REFERENCE | 5 | 3.81 | 11.07 |
| | ZINC-ENRICHED | 3 | 1.28 | 7.82 |
| | NEARFIELD & REFERENCE | 8 | 14.17 | 15.51 |
| | ZINC-ENRICHED & REFERENCE | 9 | 11.71 | 16.92 |

## Table 3-11: Benthic Index of Biotic Integrity (B-IBI) metric scores for Year 16.

| STATIONS | | ABUNDANCE (#/m2) | BIOMASS (g/m2) | ABUNDANCE OF POLLUTION INDICATIVE TAXA (%) | BIOMASS OF POLLUTION SENSITIVE TAXA (%) | SHANNON-WEINER (DIVERSITY INDEX) | AVERAGE SCORE |
|---|---|---|---|---|---|---|---|
| **REFERENCE:** | **HM7** | 1 | 3 | 5 | 5 | 1 | 3.0 |
| | **HM9** | 1 | 3 | 5 | 5 | 1 | 3.0 |
| | **HM16** | 5 | 1 | 1 | 5 | 5 | 3.4 |
| | **HM22** | 1 | 3 | 5 | 5 | 1 | 3.0 |
| | **HM26** | 1 | 3 | 5 | 5 | 1 | 3.0 |
| | **BC6** | 5 | 1 | 5 | 5 | 3 | 3.8 |
| | **30** | 5 | 1 | 5 | 5 | 5 | 4.2 |
| | **NEW** | 3 | 1 | 5 | 5 | 3 | 3.4 |
| **NEARFIELD:** | **S1** | 3 | 1 | 5 | 5 | 1 | 3.0 |
| | **S2** | 5 | 1 | 5 | 1 | 5 | 3.4 |
| | **S3** | 3 | 3 | 5 | 5 | 1 | 3.4 |
| | **S5** | 3 | 1 | 5 | 5 | 3 | 3.4 |
| | **S6** | 3 | 3 | 3 | 5 | 3 | 3.4 |
| | **BC3** | 1 | 3 | 5 | 5 | 3 | 3.4 |
| **ZINC-ENRICHED** | **G5** | 3 | 1 | 5 | 5 | 5 | 3.8 |
| | **G25** | 3 | 3 | 5 | 5 | 5 | 4.2 |
| | **G84** | 5 | 3 | 5 | 5 | 5 | 4.6 |
| | **HM12** | 3 | 1 | 5 | 5 | 3 | 3.4 |

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

## Table 3-12: Benthic Index of Biotic Integrity (B-IBI) metric scores for Year 16 at the Back River Transect stations.

| STATIONS | ABUNDANCE (#/m2) | BIOMASS (g/m2) | ABUNDANCE OF POLLUTION INDICATIVE TAXA (%) | BIOMASS OF POLLUTION SENSITIVE TAXA (%) | AVERAGE SCORE |
|---|---|---|---|---|---|
| **BSM75** | 3 | 1 | 1 | 1 | *1.5 |
| **M1** | 3 | 1 | 3 | 5 | 3 |
| **M2** | 3 | 1 | 5 | 5 | 3.5 |
| **M3** | 1 | 3 | 5 | 5 | 3.5 |
| **M4** | 5 | 1 | 5 | 5 | 4 |
| **M5** | 5 | 3 | 5 | 5 | 4.5 |

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

# GLOSSARY

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

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

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

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

**Adduct:** Additive product of the reaction between two compounds. In this report, the adduct is methylethylmercury, the product of the reaction between tetraethylborate and methylmercury.

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

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

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

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

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

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

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

**Bioavailable**: Can affect organisms.

**Bioconcentration**: Uptake of a substance from water.

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

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

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

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

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

**Chronic toxicity**: See sublethal/chronic toxicity.

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

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

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

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

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

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

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

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

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

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

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

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

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

**District**: A USACE administrative area.

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

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

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

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

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

**Federal Standard**: The dredged material disposal alternative(s) identified by the U.S. Army Corps of Engineers that represent the least costly, environmentally acceptable alternative(s) consistent with sound engineering practices and which meet the

environmental standards established by the 404(b)(1) evaluation process. [See Engler et al. (1988) and 33 CFR 335-338].
**Fill material**: Any material used for the primary purpose of replacing an aquatic area with dry land or changing the bottom elevation of a water body for any purpose. The term does not include any pollutant discharged into the water primarily to dispose of waste, as that activity is regulated under Section 402 of the Clean Water Act. [Note: dredged material can be used as fill material].

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

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

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

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

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

**Lethal**: Causing death.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

**Region**: An EPA administrative area.

**region**: A geographical area.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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