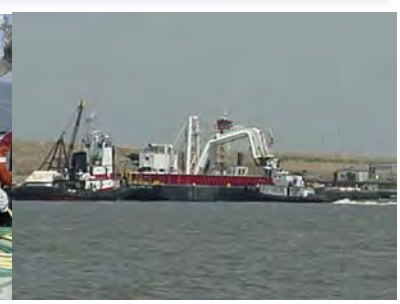
Assessment of Impacts from the Hart-Miller Dredged Material Containment Facility, Maryland.

Year 24 Technical Report (September 2005 – 2006)



Prepared by:

Maryland Department of the Environment

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SUMMARY REPORT FOR THE HART-MILLER ISLAND DREDGED MATERIAL CONTAINMENT FACILITY YEAR 24

(September 2005 – September 2006)

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INTRODUCTION

At the request of the Citizens' Oversight Committee for the Hart-Miller Island Exterior Monitoring Program, a revised report format was adopted this year for presenting monitoring program results and findings. A more detailed project summary report (below) is now provided, with the individual project reports attached as appendices (Appendices 1 – 3). The following project summary and appendices discuss the results from Year 24 (September 2005 – 2006) of monitoring at HMI.

HART-MILLER ISLAND STUDY DESIGN

The Hart-Miller Island Dredged Material Containment Facility (HMI) Exterior Monitoring Program is modeled after the Sediment Quality Triad developed in the mid-1980s (Long and Chapman, 1985). This approach consists of three separate components: sediment chemistry, sediment toxicity, and benthic community composition. The sediment chemistry project (Project II) assesses contamination by evaluating metal concentrations in exterior sediments. Project III, benthic community studies, monitors animal communities living in sediments surrounding HMI sediments. As a surrogate for toxicity, Project IV looks at benthic tissue concentrations of both metals and organics in the brackish-water clam *Rangia cuneata.* Project IV also does some sediment chemistry work for ancillary metals not monitored in Project II. Whereas sediment contamination thresholds, benthic toxicity benchmarks, and benthic macroinvertebrate indices alone may not conclusively identify pollution impacts, combining them into a triad approach provides a body of evidence for pollution determinations. Table 1 below illustrates the triad concept and Figure 1 displays site monitoring locations.

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

Scenario	Sediment Contamination (Project II)	Toxicity (Project IV)	Benthic Community Impact (Project III)	Possible Conclusions
1.	+	+	+	Strong evidence for pollution
2.	-	-	-	Strong evidence that there is no pollution
3.	+	-	-	Sediment pollutants are elevated but not affecting biota.
4.	-	+	-	Pollutant levels increasing through food chain.
5.	-	-	+	Benthic community impacts not a result of pollution.
6.	+	+	-	Pollutants are stressing the system

Scenario	Sediment Contamination (Project II)	Toxicity (Project IV)	Benthic Community Impact (Project III)	Possible Conclusions
7.	-	+	+	Pollutant levels increasing through food chain and altering the benthic community.
8.	+	-	+	Pollutants are available at chronic, non-lethal levels.

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

Figure 1: Year 24 Hart-Miller Island Monitoring Locations.

Scenario 1 (Table 1) demonstrates a clear impact as a result of statistically significant differences from reference conditions in all three projects (sediment contamination, toxicity and benthic community impacts). Scenario two is negative for all components and suggests no pollution impacts. Scenarios 6, 7 and 8 indicate some level of degradation and the need for additional monitoring. Scenarios 3, 4 and 5 have only a single monitoring pointing to a potential problem and are likely the lowest priority for follow-up monitoring or remedial action.

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

HMI PROJECT SUMMARIES

Project II: Sedimentary Environment

The Coastal and Estuarine Geology Program of the Maryland Geological Survey (MGS) has been involved in monitoring the physical and chemical behavior of near-surface sediments around HMI since the early project planning stages. As part of this year’s exterior monitoring program, MGS collected bottom sediment samples from 43 stations on both September 8, 2005, and on April 10, 2006. Survey geologists then analyzed the following parameters: (1) grain size composition (relative proportions of sand, silt, and clay) and (2) total elemental concentrations of iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), chromium (Cr), nickel (Ni), cadmium (Cd), lead (Pb), phosphorous (P), carbon (C), nitrogen (N), and sulfur (S).

For exterior bottom sediments sampled during Year 24, the pattern of grain size distribution varied minimally from September 2005 to April 2006. The reasons for variation are difficult to determine because of the Bay’s complex hydrology and the many sources of sediment to the area. However, sediment distribution is generally consistent with the findings of previous monitoring years.

Metals concentrations surrounding the facility during Year 24 fell into two groups (Figure 2); low pollution and moderate pollution likelihood. Cadmium, chromium, copper, nickel, lead and zinc were at concentrations indicating a low likelihood of pollution. However, nickel and zinc in some samples were seen at moderate pollution levels (Figure 2). Pollution likelihood is determined using National Oceanic and Atmospheric Administration (NOAA) thresholds which identify concentrations likely to cause biological degradation.

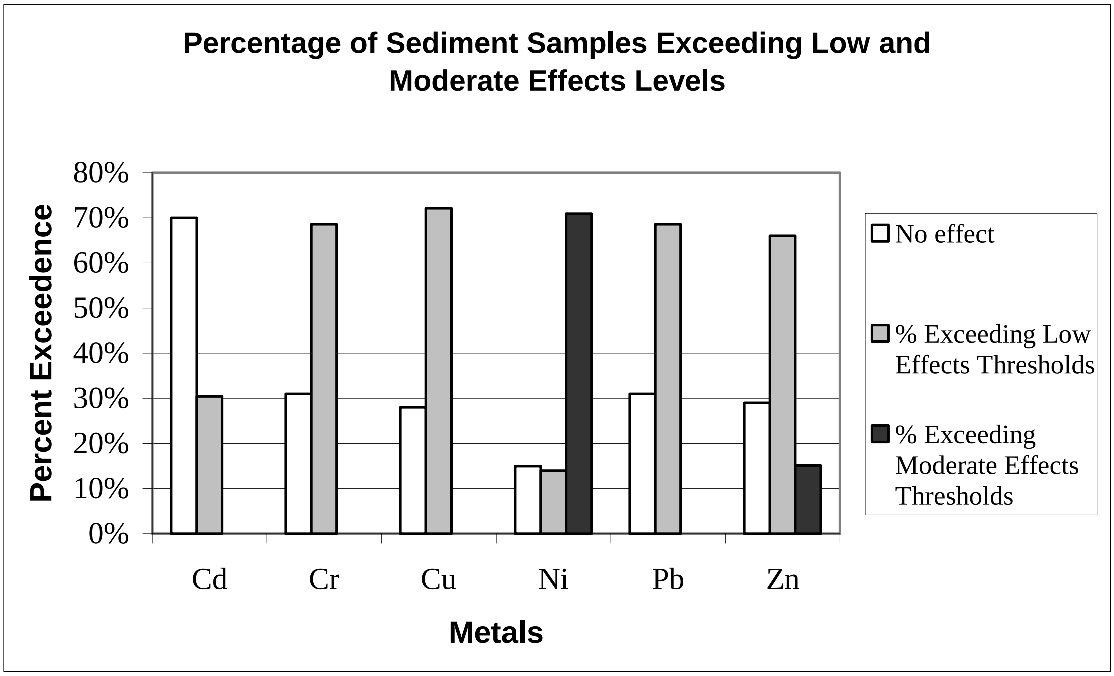

Figure 2: Percent likelihood of metals pollution at HMI stations. Determined using NOAA biological effects concentrations guidelines.

Comparing the Year 24 sediment metal concentrations to baseline concentrations around HMI reveals that only lead is significantly elevated above historical levels (Figure 3). In Year 24 less than one quarter of the zinc samples exceeded the baseline level (Figures 3 and 4). Historically, lead and zinc enriched samples are associated with the three local sources: HMI, Baltimore Harbor and Back River. In Year 24, zinc was only associated with Baltimore Harbor and Back River. Earlier studies have shown that Baltimore Harbor does not influence the sediments near HMI, and that Back River has only a localized impact. In Year 24 the area adjacent to HMI had lower metals (lead and zinc) levels than the previous monitoring year. Lead concentrations in Year 23 reached levels of 8 standard deviations (SDs) from the baseline sigma in the fall and 7 SDs in the spring, while the levels only reached 5 SDs for both cruises in Year 24. Seasonal SDs for zinc reached 5 and 4 during Year 23 fall and spring samplings, respectively, and fell to background levels in Year 24. Standard deviations above two indicate elevated sediment metal concentrations.

For lead, the April 2006 cruise revealed that the gradient from Baltimore Harbor dropped to background levels south of HMI, providing a clear separation in source material to the area. However, the September 2005 cruise showed a more complex pattern similar to the previous monitoring year where the gradient from Baltimore Harbor overlaps with the high levels adjacent to HMI. The high levels and overlap of the gradient is likely a result of lead migrating south from HMI rather than north from Baltimore Harbor.

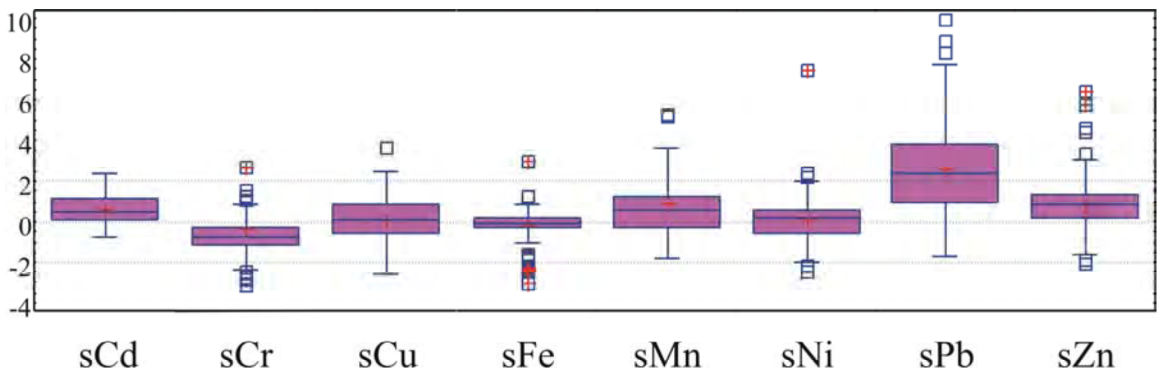

Figure 3: Year 24 concentration of metals at HMI relative to baseline values. Metal concentrations greater than 2 standard deviations (dashed lines) are considered elevated above baseline.

Overall, only lead showed enriched levels in the area affected by facility operations. The September sampling cruise had higher levels, and a greater spatial extent than the April sampling. This is consistent with historical responses of the sedimentary environment to facility operations and climatic factors. Generally, the low flow periods corresponding to crust management are conductive to oxidizing the sediments within the facility, which are reflected in enrichment in the exterior sediments. However the conditions were not optimal this year for extensive acid formation so sediment metals concentrations were not at levels of concern. Comparing historical zinc concentrations (Figure 4) demonstrates that conditions this year were not optimal for excessive metal concentrations in HMI sediments.

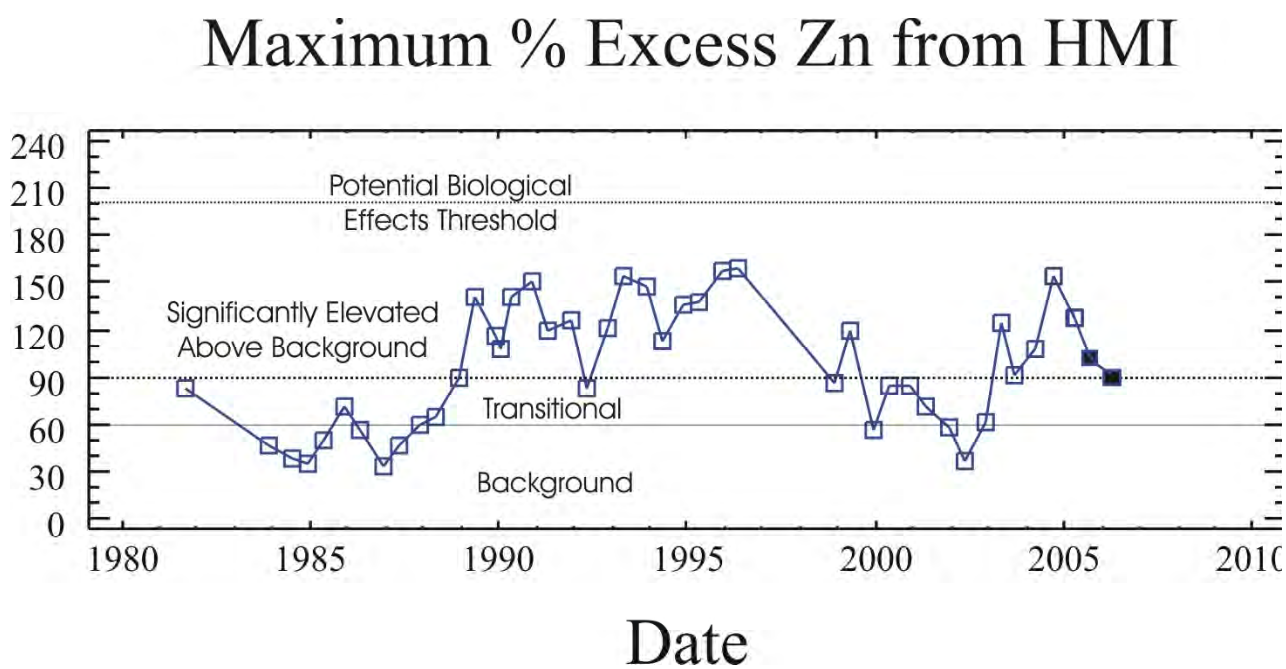

Figure 4: Historical zinc trends in sediments surrounding HMI.

Project III: Benthic Community Studies

Twenty stations (11 Nearfield, 3 Reference, 3 Back River/Hawk Cove, and 3 South Cell Restoration Baseline) were sampled on September 9, 2005 and on April 7, 2006 to monitor aquatic invertebrate communities surrounding HMI. Organisms living in sediments close to the facility (Nearfield, South Cell Restoration Baseline, and Back River/Hawk Cove stations) were compared to those located away from the influence of the facility (Reference stations). Water quality parameters, including dissolved oxygen concentrations, salinity, temperature, pH, conductivity and secchi depth were measured *in situ.*

The Chesapeake Bay Benthic Index of Biotic Integrity (B-IBI, Weisberg et al. 1997), a multi-metric index of biotic condition that evaluates summer populations (during the July 15th to September 30th timeframe) of benthic macroinvertebrates, was calculated for all stations sampled during the September 2005 cruise. Overall, the B-IBI scores decreased when compared to Year 23, but were generally similar to the B-IBI scores for previous monitoring years at HMI (Figure 5). This year, 18 stations exceeded the benchmark criteria of 3.0, and two stations (MDE -19 and MDE -24) failed to meet the benchmark (Figure 6).

In addition, Friedman's nonparametric test and cluster analysis was used in this year's study to look at significant differences in infaunal abundance and groupings of similar monitoring stations, respectively. Friedman's test indicated that there were no significant differences in the 10 most abundant infaunal species between station types (Reference, Nearfield, Back River/Hawk Cove, and South Cell) in either season of Year 24. However, the South Cell Restoration Baseline stations had the lowest average rank in the fall, and were equal to Reference stations for lowest rank in the spring. These results indicate the beginning of a possible trend, which began with the Year 22 spring data where a significant Friedman's test was due to a low average rank of 1.75 for South Cell Restoration Baseline stations. These results suggest that South Cell faunal communities differ from faunal communities from other station types. In-depth analysis of the BIBI for South Cell stations suggest that South Cell station differences are likely due to habitat factors unique to these stations, such as increased wave activity, turbulence, sediment instability/movement, or increased turbidity, and are not due to the restoration of the South Cell as no water has been discharged from this area since restoration was completed.

Cluster analyses for both Fall and Spring samples indicated benthic community impacts at station MDE-27. This station has historically shown an altered benthic community and is most directly affected by water quality conditions in the Back River/Hawk Cove. Cluster analysis also revealed evidence of other factors affecting HMI-influenced stations in September 2005, but not in April 2006. However, these habitat effects, including possible anthropogenic pollutants, vary seasonally (from fall to spring) and are not as strongly associated with station faunal compositions as bottom type.

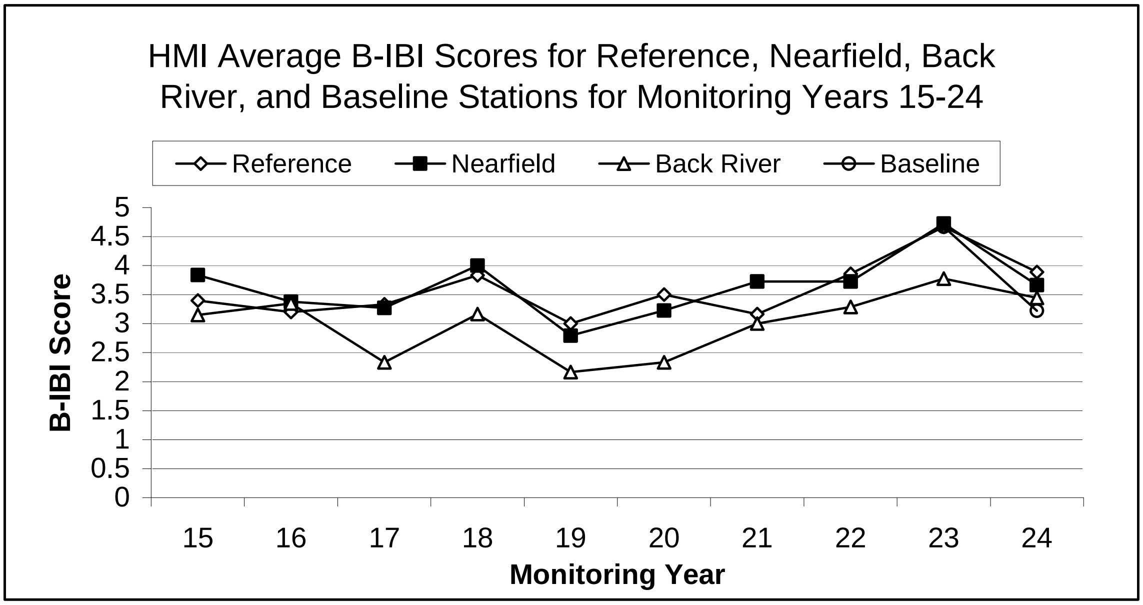

Figure 5: B-IBI Scores from HMI (Years 15 through 24).

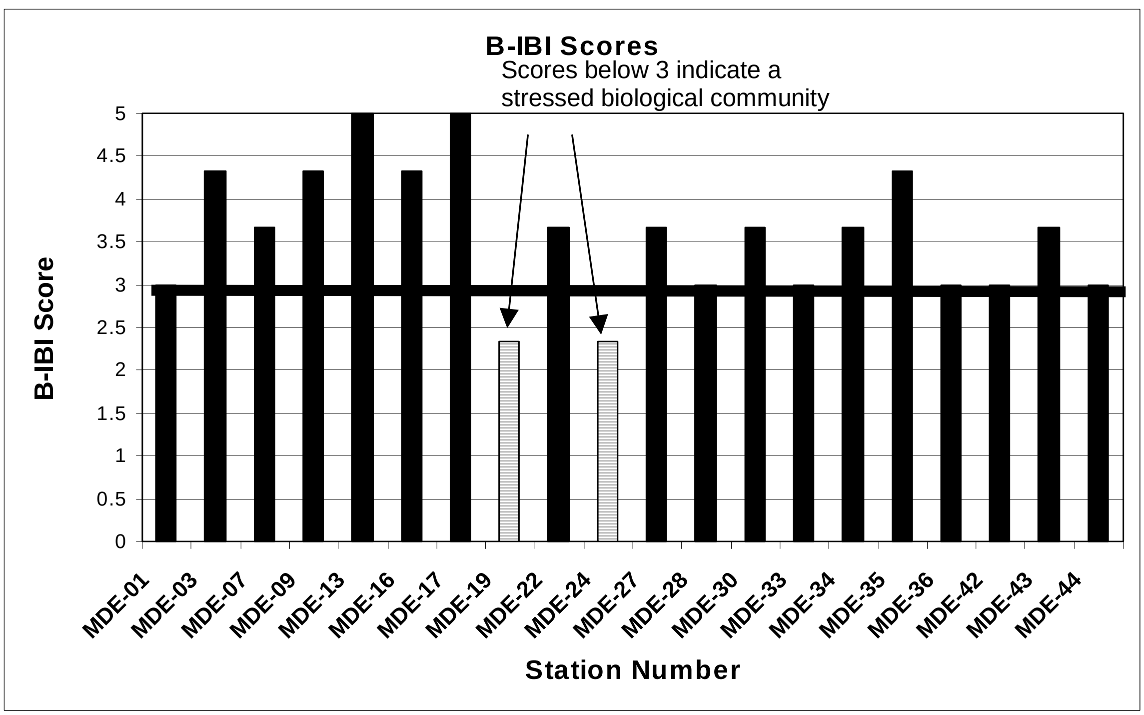

Figure 6: B-IBI Scores for Year 24.

Project IV: Analytical Services

For year 24 monitoring at HMI, the Project IV goals were to continue to collect clams and associated sediment for trace metal analyses. For the summer sampling only, Project IV analyzed sediments for additional metals not monitored by MGS [mercury (Hg), monomethylmercury (MMHg), silver (Ag), and arsenic (As) - also cadmium (Cd) lead (Pb) and selenium (Se)].

<u>Metals in Sediments</u>

Forty-three stations were sampled in the summer of Year 24 for sediment metal concentrations. Concentrations of arsenic, selenium, cadmium and lead in the sediment collected around HMI in Year 24 (2005-2006) are similar to previous years (Figures 7 and 8) and not substantially different than the concentrations found elsewhere in the Chesapeake Bay or in marine sediments. Station 38 typically has the highest lead concentrations ~100 ug g^{-1} and this was true again in 2005. The high lead concentrations observed at Station 43 in 2004 were not present. Concentrations of silver remained low throughout the region in 2005 (Figure 9).

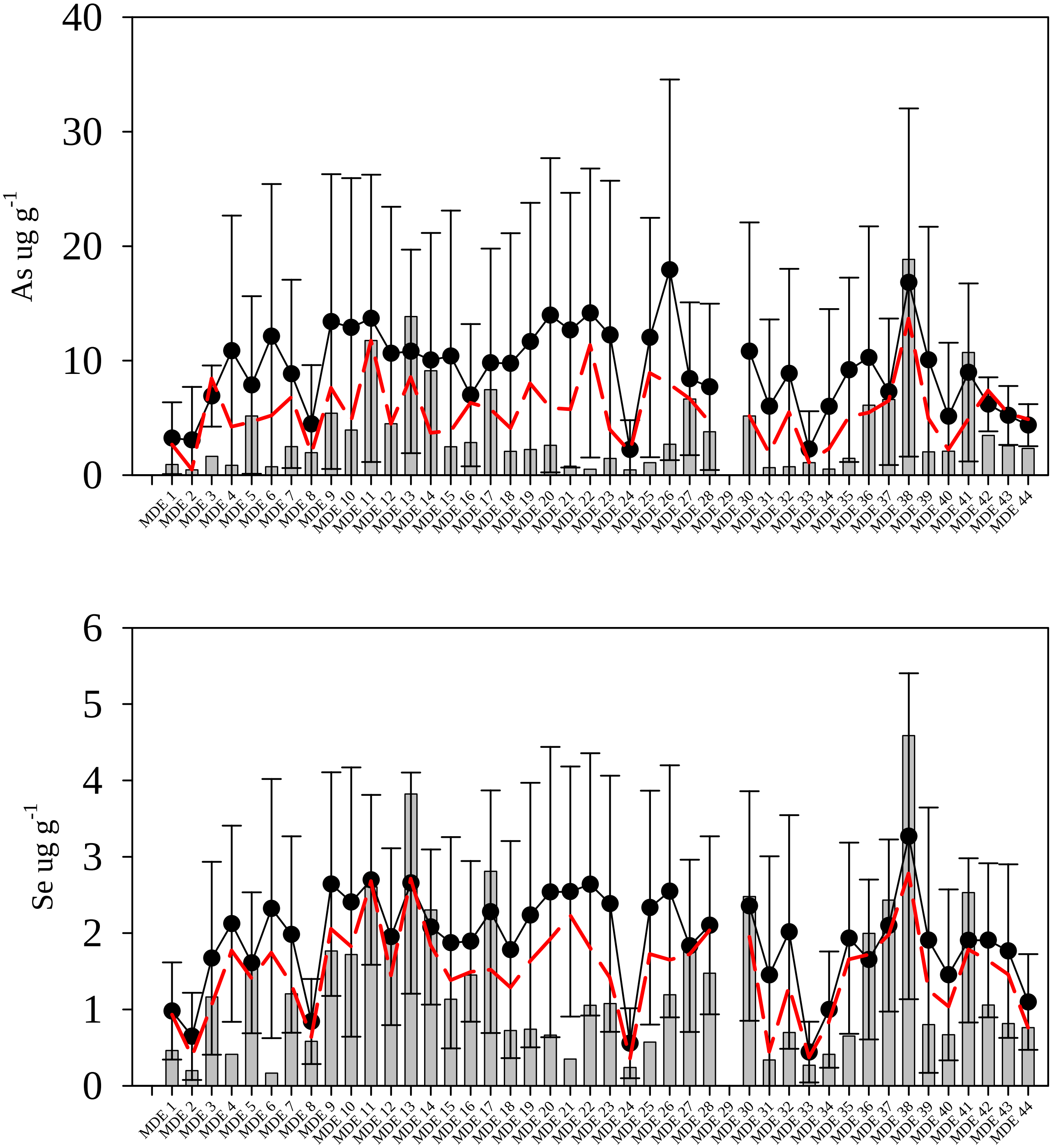

Figure 7: Arsenic (As) and selenium (Se) in sediment, expressed in dry weight concentration, from 2005 (bars) and the 1998-2004 mean (circles) with standard deviation (error bars) and the 1998-2004 median (dashed line).

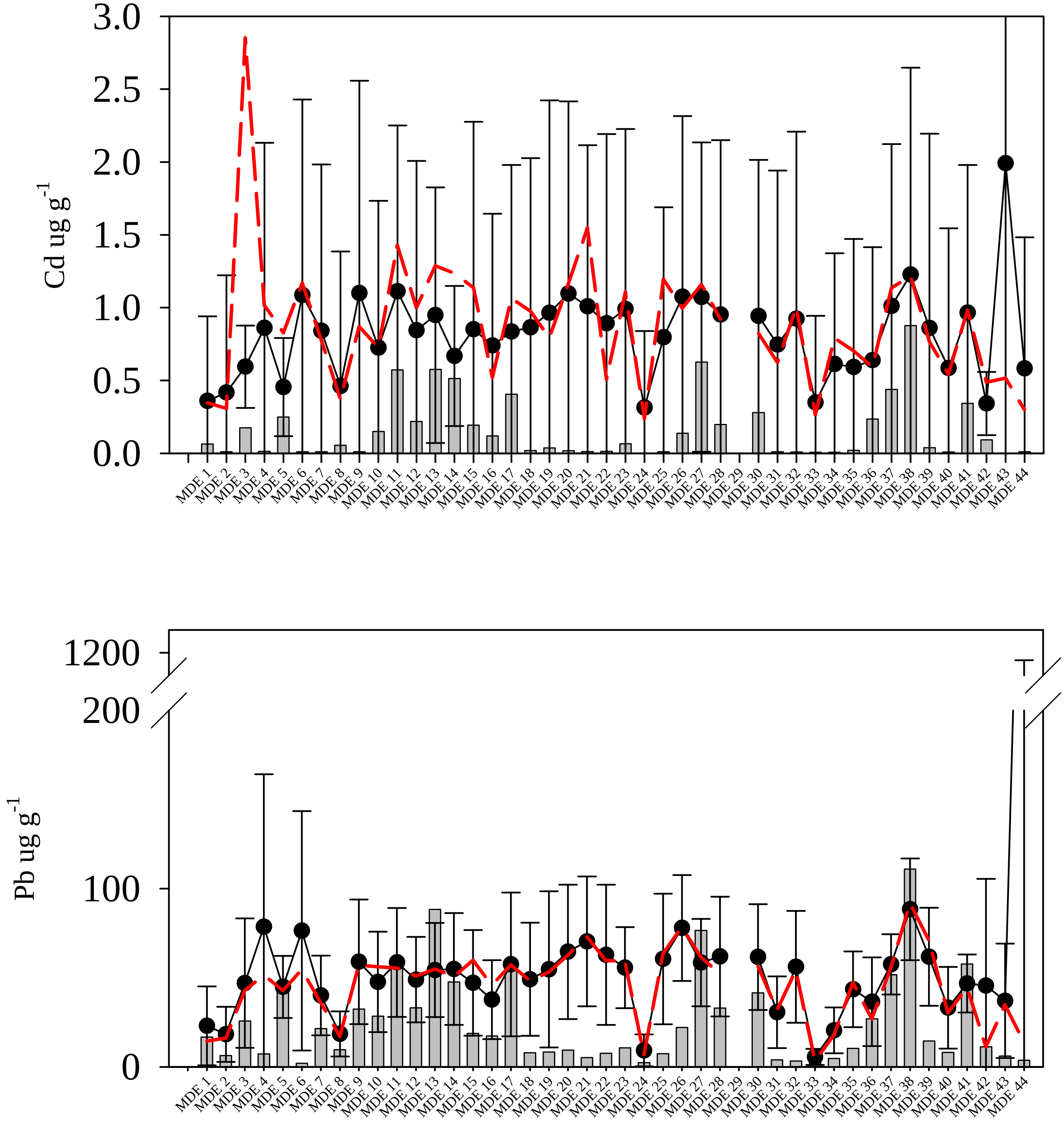

Figure 8: Cadmium (Cd) and lead (Pb) in sediment, expressed as dry weight concentration, from 2005 (bars) and the 1998-2004 mean (circles) with standard deviation (error bars) and the 1998-2004 median (dashed line).

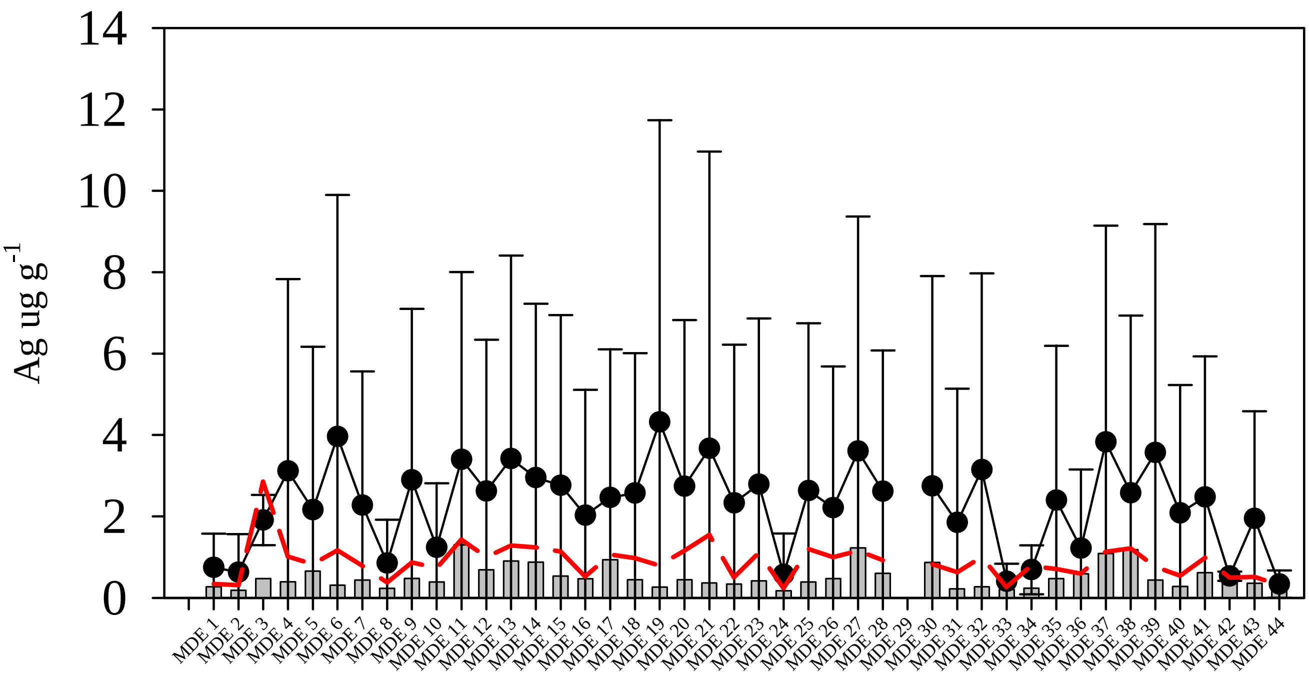

Figure 9: Silver (Ag) concentrations in sediment from 2005 (bars), expressed as dry weight concentration, and the 1998-2004 mean (circles) with standard deviation (error bars) and the 1998-2004 median (dashed line).

Concentrations of total mercury (T-Hg) and methylmercury (MeHg) in sediment are typical of previous years with station mean and median concentrations for the study period very close to the 2005 concentrations (Figure 10). Concentrations of total mercury in the main stem of the Chesapeake Bay range from 0.2 to 250 ng g^{-1} dry weight and concentrations of MeHg range from 0.01 to 2.2 ng g^{-1} dry weight (Heyes et al. 2006). Concentrations of both total mercury and methylmercury are highest in the upper bay, with total mercury concentrations on the order of 130 ng g^{-1} and methylmercury concentrations 1 ng g^{-1}. Concentrations of total mercury around HMI have averaged 200 ng g^{-1} in 2005. In 2005, about half the sediment methylmercury concentrations were slightly higher than average and about half slightly lower than the average of previous years. In year 24, Station 30 had the highest methylmercury concentration and is the highest on average. However, Station 30 has a similar percent methylmercury concentration to many other stations. Station 24 had anomalously high methylmercury (8%), which was driven by an unusually low total mercury concentration. High percent methylmercury has occurred at other stations in previous years and is typically result of lower than normal total mercury concentrations.

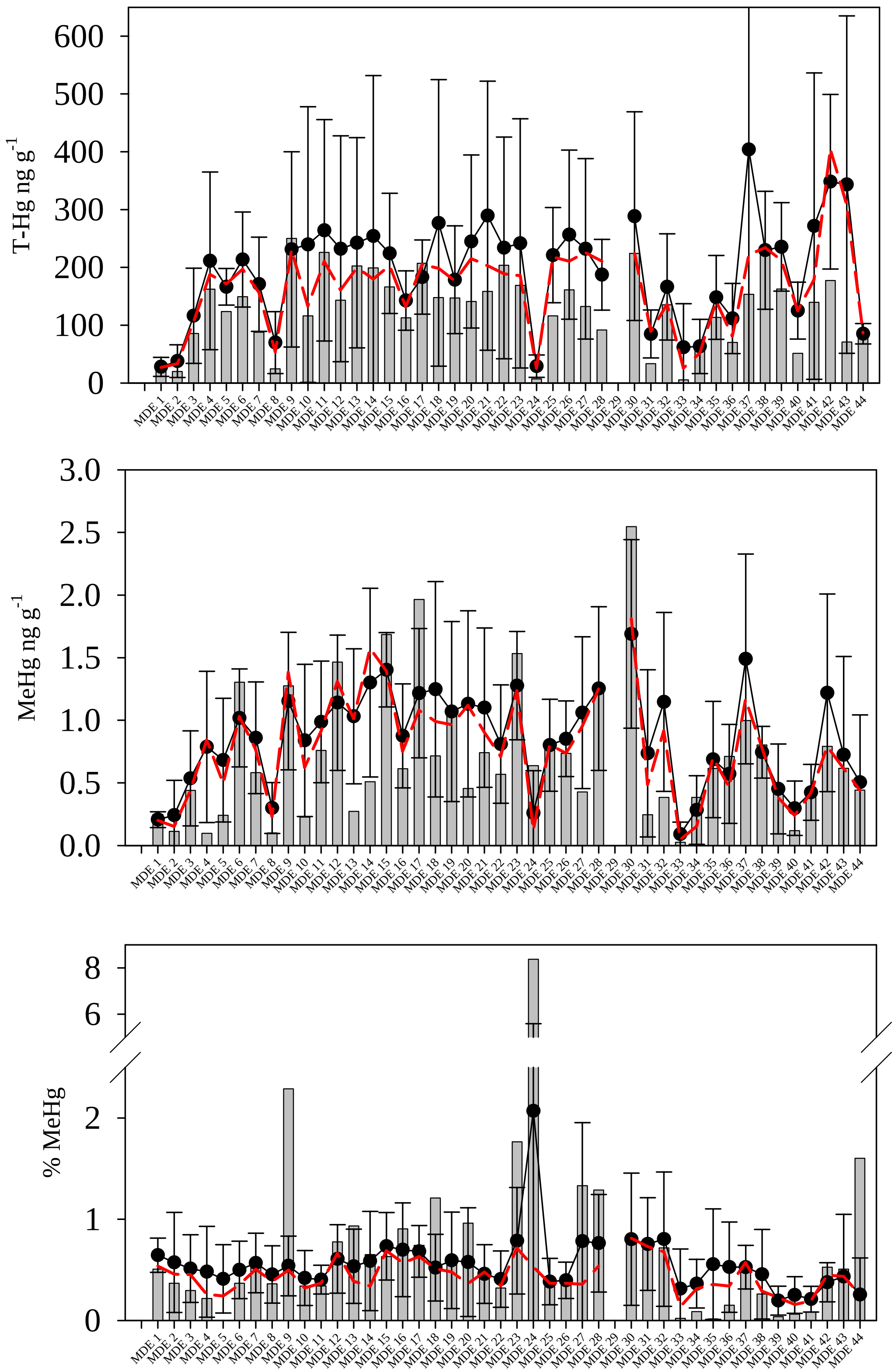

Figure 10: Mercury (Hg) and methylmercury (MeHg) expressed as dry weight concentrations, and percent Hg as MeHg, in 2005 sediment (bars) and the 1998-2004 mean (circles), median (dashed line), with standard deviation (error bars).

To gather data on sediment in areas where water from the South Cell Restoration Project would be released, three Stations (42, 43 and 44) were added to the sampling plan. Year 24 was the third year that sediment has been collected thereby providing a large enough database to begin the evaluation of these areas. For the most part, these stations appear similar to the stations on the southern end of the island. The exception was in 2004, where very high concentrations of cadmium, lead and silver were found at Station 43, 44 and 43 respectively. Concentrations of selenium and cadmium were also on the high end of the concentrations observed in 2003.

Metals in Clams

Concentrations of the metals arsenic, selenium, silver, cadmium, and lead in the clam *Rangia* displayed some variations from previous years. Most metal concentrations were low and varied little among the stations. Concentrations of arsenic, selenium, silver, and lead remained similar to previous years whereas cadmium was considerably lower. The concentrations of both total mercury and methylmercury in clams collected in year 24 fall close to the average of previous years with a couple of exceptions (Stations 3, 7 and 13 had mercury concentrations about twice the average of previous years).

SUMMARY OF PROJECT RECOMMENDATIONS

Although a zinc signature in sediments surrounding HMI has been detected over the long-term record, construction and operation the Hart-Miller Island Dredged Material Containment facility has produced no long-term biological impacts to surrounding aquatic communities. This situation is akin to scenario 3 in Table 1, where there is evidence of sediment contamination but no adverse affects to aquatic life. It may be that the contaminants are chemically bound to the fine-grained silts and clays in the sediment or are in a specific chemical form that is not bioavailable. However, The HMI Principal Investigators (PIs) for each project agree that the current monitoring framework should be maintained throughout HMI's operational life to maintain consistency with previous work, track trends in contamination, ensure no impacts to the surrounding aquatic community, and allow assessment of multiple areas of influence (HMI, Back River/Hawk Cove, Baltimore Harbor, and the South Cell). Conversations with the Maryland Port Administration, PIs, and regulatory agencies have also begun to discuss optimum post-HMI closure monitoring design and to allow plenty of time for peer and stakeholder review. All parties agree that post-closure monitoring will be as, if not more, important than current monitoring because of a tendency for extended dewatering and drying of dredged material to produce metal rich effluent if not properly treated or incorporated into a closure plan containing ponds, mudflats and wetlands, which have been shown to reduce the risk of low pH, high metal effluent.

In addition, a comprehensive analysis of all historical HMI data is recommended to better integrate the three legs of the sediment triad – sediment chemistry, sediment toxicity and benthic community. This synoptic analysis of the data will build upon the annual monitoring program and provide a more conclusive assessment of facility impacts.

APPENDIX 1: SEDIMENTARY ENVIRONMENT (PROJECT II)

(September 2005 - October 2006)

Technical Report

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EXECUTIVE SUMMARY

The Coastal and Estuarine Geology Program of the Maryland Geological Survey (MGS) has been involved in monitoring the physical and chemical behavior of near-surface sediments around the Hart-Miller Island Dredged Material Containment Facility (HMI) from the initial planning stages of construction of the facility through to the present. As part of this year's exterior monitoring program, MGS collected bottom sediment samples from 43 stations on September 8, 2005, and from 43 stations on April 10, 2006. Survey geologists then analyzed various physical and chemical properties of the samples: (1) grain size composition (relative proportions of sand, silt, and clay) and (2) total elemental concentrations of iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), chromium (Cr), nickel (Ni), cadmium (Cd), lead (Pb), phosphorous (P), carbon (C), nitrogen (N), and sulfur (S).

For exterior bottom sediments sampled during Year 24, the pattern of the grain size distribution varies slightly from one cruise to the next. The reasons for the variations are difficult to decipher, due to the complexity of the depositional environment and the multiple sources of material to the area. However, in general, sediment distribution is consistent with the findings of previous monitoring years, dating back to 1988, two years following the initial release of effluent from HMI.

With regard to trace metals some features to note are:

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

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

MES has indicated that high concentrations of Pb have not been recorded in the effluent still Pb enriched samples are associated with the three local sources, HMI, Baltimore Harbor and Back River. Although in the past high levels of Zn were recorded, currently Zn enriched samples are associated with Baltimore Harbor and Back River; there is no significant influence from HMI. Material from the Harbor did not influence the sediments adjacent to the facility in the proximal zone ascribed to HMI during this monitoring year. This is supported by both the sedimentation and metals distribution patterns in the area. The higher levels in the area may reflect a residual signature from the preceding years' climatic conditions.

In the area effected by facility operations, only Pb showed enriched levels. The September sampling cruise had higher levels, and a greater areal extent as compared to the April sampling. This is consistent with historical responses of the sedimentary environment to facility operations. Generally, the low flow periods corresponding to crust management periods are conductive to oxidizing the sediments within the facility, which are reflected in enrichment in the exterior sediments. However the conditions in Year 24 were not optimal for site crust management operations so the loadings to the sediment were not at levels of concern.

Although the effluent is tested and must meet State Discharge Permit limits before released, elevated metal levels in sediments around HMI persist which would indicate a need for continued monitoring. The metal levels in the exterior sediments continued to show a consistent response to the operations of the facility; low discharge rates increasing the metal loads to the sediment. Currently, the facility is actively accepting material, but the amount of material accepted will decline as the facility reaches its capacity. Consequently, the volume of effluent will decline and crust management operations will increase, which may lead to higher metal levels in the effluent. Exposure of dredged material to the air is likely to result in the mobilization of metals associated with those sediments. Metals released in the effluent, particularly at low discharge rates, are deposited on the surrounding Bay floor and are increasing the long-term sediment load in the Bay. Continued monitoring is needed in order to; detect if the levels increase to a point where action is required, document the effect that operations have on the exterior environment (for future project design), and to assess the effectiveness of any amelioration protocol implemented by MES to counteract the effects of exposing contained dredged material to the atmosphere. Close cooperation with MES is important in this endeavor.

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

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

INTRODUCTION

Since 1981, the Maryland Geological Survey (MGS) has monitored the sedimentary environment in the vicinity of Hart-Miller Island Dredged Material Containment Facility (HMI). HMI is a man-made enclosure in northern Chesapeake Bay, named for the two natural islands that form part of its western perimeter (Figure 11). Designed specifically to contain material

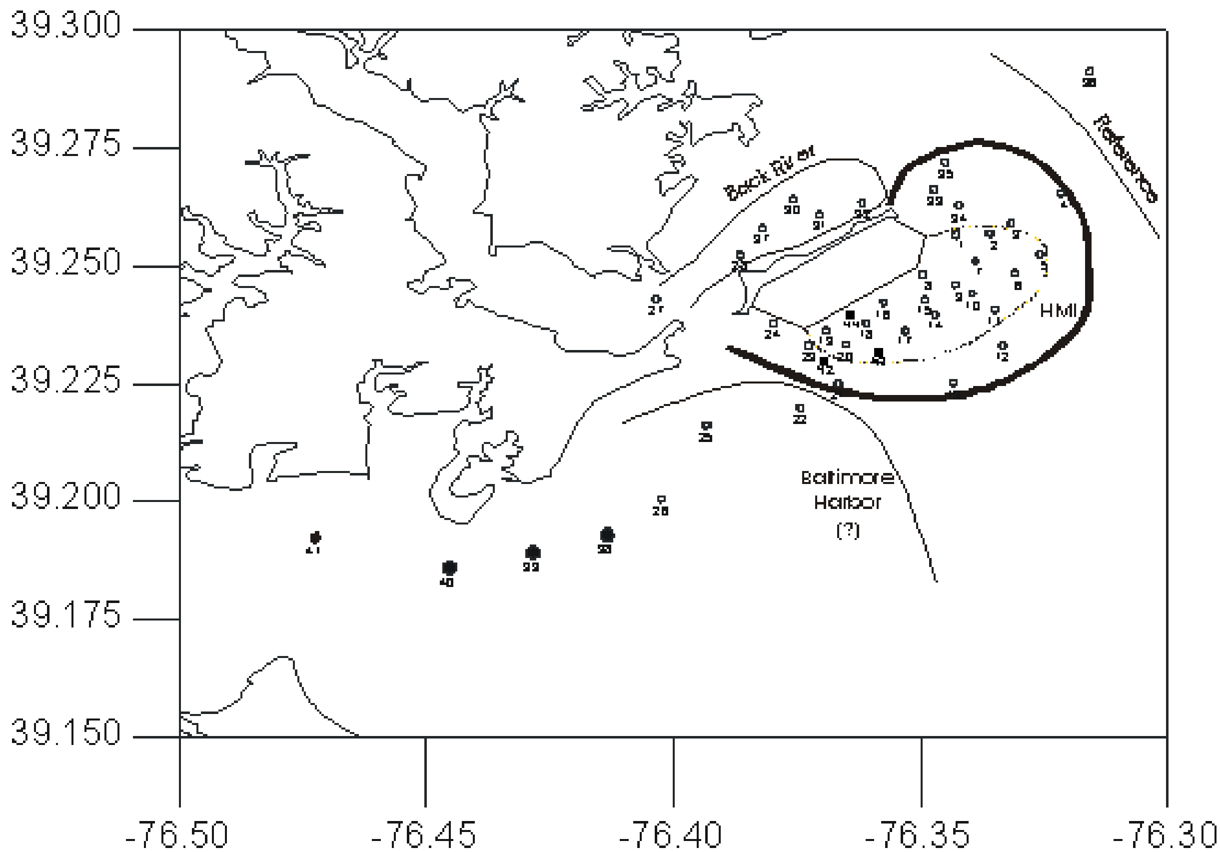


Figure 11: Sampling locations for Year 24. Contours show zones of influence found in previous studies. Solid circles show location of sites added in Year 18 to measure the influence of Baltimore Harbor and the more recent sites added to determine the influence of the conversion of the South Cell to upland wetlands.

dredged from Baltimore Harbor and its approach channels, the oblong structure was constructed of sediment dredged from the facility interior. The physical and geochemical properties of the older, "pristine" sediment used in facility construction differed from those of modern sediments accumulating around the island. Likewise, material dredged from shipping channels and deposited inside the facility also differs from recently deposited sediments in the region. Much of the material generated by channel deepening is fine-grained and enriched in trace metals and organic constituents. In addition, oxidation of the sediment placed in the facility may produce effluent enriched in metals during dewatering and crust management. These differences in sediment properties and discharge from the facility have allowed the detection of changes attributable to construction and operation of the facility.

Previous Work

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

1. Preconstruction (Summer 1981 and earlier)
2. Construction (Fall 1981 - Winter 1983)
3. Post-construction
    a. Pre-discharge (Spring 1984 - Fall 1986)
    b. Post-discharge (Fall 1986 - present).

The nature of the sedimentary environment prior to and during facility construction has been well documented in earlier reports (Kerhin et al. 1982a, l982b; Wells and Kerhin 1983; Wells et al. 1984; Wells and Kerhin 1985). This work established a baseline against which changes due to operation of the facility could be measured. The most notable effect of facility construction on the surrounding sedimentary environment was the deposition of a thick, light gray to pink layer of "fluid mud" immediately southeast of the facility.

For a number of years after HMI began operating, no major changes were observed in the surrounding sedimentary environment. Then, in April 1989, more than two years after the first release of effluent from the facility, anomalously high Zn values were detected in samples collected near Spillway 007 (Hennessee et al., 1990b). Zn levels rose from the regional average enrichment factor of 3.2 to 5.5. Enrichment factors are the ratios of concentrations, in this case Zn to Fe, which is in term normalized to the same ratio in a standard reference material; this number is dimensionless. Effluent discharged during normal operation of the facility was thought to be the probable source of the enrichment of Zn accumulating in the sediments. This was confirmed by use of the Upper Bay Model (Wang 1993), a numerical, hydrodynamic model, which was used to predict the dispersion of discharge from the facility, coupled with discharge records from the spillways. From the discharge records it was noted that there is a significant increase in metal loading to the exterior sediments during periods of low discharge (<10 million gallons per day); periods of higher discharge rates corresponded to lower metal levels in the exterior sediments.

The factors that influence the metals loadings to the exterior sediments are circulation patterns in the northern Bay and the rate and the nature of discharge from the facility. The results of the hydrodynamic model pertinent to a discussion of contaminant distribution around HMI follow (see the *Year 10 Technical Report* for details):

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

2. Releases from Spillways 007 and 009 travel in a narrow, highly concentrated band up and down the eastern side of the facility. This explains the location of areas of periodically high metal concentrations east and southeast of the facility.

3. Releases from Spillway 008 are spread more evenly to the north, east, and west. However, dispersion is not as great as from Spillways 007 and 009 because of the lower shearing and straining motions away from the influence of the gyre.

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

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

The 3-D hydrodynamic model explains the structure of the plume of material found in the exterior sediments, but it does not explain why the level of Zn in the sediments increases at lower discharges. To account for this behavior, the chemistry of the effluent discharged from the facility was examined, as reported in the *Year11Interpretive Report*. As a result of this examination, a model was constructed to predict the general trend in the behavior of Zn as a function of discharge rate from the facility. The model has two components: (1) loading due to material similar to the sediment in place and (2) loading of enriched material as predicted from a regression line based on discharge data supplied by MES. The behavior of this model supports the hypothesis of metal contamination during low flow conditions. Sediments discharged from the facility are the source of metals that enrich the exterior sediments. When exposed to the atmosphere, these sediments oxidize in a process analogous to acid mine drainage (i.e., sulfide minerals oxidize to produce sulfuric acid, which leaches acid-soluble metals, nutrients, and organic compounds that are released with the discharged waters). Since the initial detection of Zn, the size of the affected area has fluctuated, as have metal concentrations within the area. Nonetheless, in the vicinity of the facility higher than expected levels of Zn and Pb have persisted to the present. Figure 10, in addition to showing the sampling sites for Year 24, shows zones, which indicate influence of sources of material to the exterior sedimentary environment, based on elevated metal levels from previous years' studies. These influences are noted in the figure as:

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

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

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

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

Facility ***Operations***

Certain activities associated with the operation of HMI have a direct impact on the exterior sedimentary environment. Local Bay floor sediments are sensitive, both physically and geochemically, to the release of effluent from the facility. Events or operational decisions that affect the quality or quantity of effluent discharged from the facility account for some of the changes in exterior sediment properties observed over time. For this reason, facility operations during the periods preceding each of the Year 24 cruises are summarized below. Information was extracted from *Operations Reports* prepared by MES, covering the periods April 1, 2005 - April 30, 2006; a detailed synopsis of this period and digital discharge records were provided to MGS for this report by MES (pers. com.Harlan)

HMI was operating at moderately low acceptance levels. The total amount of material accepted was 1.5 million cubic yards. Material was accepted throughout the monitoring year period, with 90% of the year's total input during the three-month period Nov. - Dec. 2005. As a result of the low input volumes, the discharge rates from HMI were low, with the highest discharges occurring starting in Jan. 2006. This is seen in Figure 12, which shows both the cumulative discharge (right axis) and the daily discharge rate.

Low flow and dewatering operations are conducive to the production of acidic conditions resulting from oxidation of the sediment when it is exposed to air. From previous observations, it takes a period longer than six months to establish oxidizing conditions which would show a significant effect on the discharge. During this monitoring year, conditions were not optimal for acid leaching conditions to be established. Prior to each sampling cruise > 72% of the days had no discharge. Discharge <10 MGD occurred 24% of the days prior to Cruise 51and 6% for Cruise 52, and discharges rates >10 MGD occurred 18% of the time for Cruise 52 and less than 4% of the time for Cruise 51. Consequently, higher metal loadings would be expected during the September cruise (Cruise 51) as compared to the April cruise (Cruise 52) due to the larger number of days with discharge <10 MGD.

Due to a change in the permit required monitoring, the way pH is measured was changed during Year 23 monitoring period so the pH data cannot be used to corroborate this prediction, nor can the facility operations be compared to previous years. Prior to Year 23 pH was measured on a continual basis, tracking when pH values changed during discharge events and recording the high and low value. pH values cannot be averaged since they are logarithmic metrics of acidity, so the range of data is an important indicator of the processes occurring. The new collection method is to collect one daily grab sample for each discharge event; MGS feels this is inadequate to characterize the processes operating at the facility. For this study, the best method would be a flow proportionate sampling of each event, with continual monitoring as the second choice. Generally, the lowest pH values measured this year were during flow periods of <10 MGD as expected. The lowest values measured (pH ~ 6) did not show levels where free mineral acidity would be found. In regard to permit compliance, the monthly average for Zn was exceeded in June 2005 and the monthly average for ammonia was exceeded in August 2005; these non-compliances were reported 6/18/2005 and 8/5/2005, respectively. Both of these non-compliances occurred prior to Cruise 51 in September 2005 during periods when the discharge was <10 MGD.

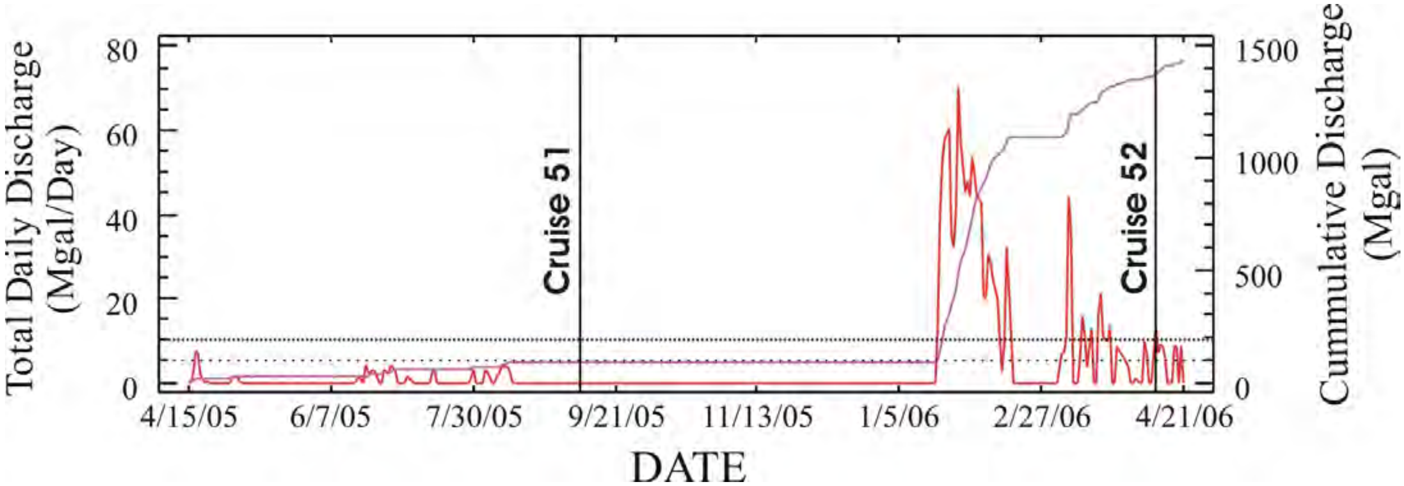


Figure 12: Daily and cumulative discharge from the HMI spillways prior to and during the Year 24 monitoring. The heavy and light dotted lines represent the 10 and 5 million gallons per day discharge levels.

OBJECTIVES

As in the past, the main objectives of the Year 24 study were (1) to measure specific physical and geochemical properties of near-surface sediments around HMI and (2) to assess detected changes in the sedimentary environment. Tracking the extent and persistence of the area of historically elevated metals concentrations was again of particular interest.

METHODS AND MATERIALS

Field Methods

The information presented in this report is based on observations and analyses of surficial sediment samples collected around HMI during two cruises aboard the *R/V Kerhin.* The first cruise took place on September 8, 2005, and the second, on April 10, 2006.

Sampling sites (Figure 11) were located in the field by means of a Leica Model MX412B differential global positioning system (GPS) with a built-in beacon receiver. According to the captain, Rick Younger, the repeatability of the navigation system, that is, the ability to return to a location at which a navigation fix has previously been obtained, is between 5-10 m (16-33 ft). Where replicates were collected, the captain repositioned the vessel between samples to counteract drifting off station during sample retrieval. At most sites, the captain recorded station coordinates and water depth. Target and actual coordinates (latitude and longitude -- North American Datum of 1983) of Year 24 sample locations are reported in the companion *Year 24 Data Report*.

Using a dip-galvanized Petersen sampler (maximum depth of penetration = 38 cm or 15 inches), crewmembers collected undisturbed samples, or grabs, of surficial sediments at 43 sites, MDE-1 through MDE-28 and MDE-30 through MDE-44, for both Year 24 cruises. The stations were identical to those sampled during Year 23.

At 39 stations for both the fall and the spring cruises, a single grab sample was collected, described lithologically, and split. Triplicate grab samples were collected at the remaining four stations (MDE-2, MDE-7, MDE-9 and MDE-31) and, likewise, described and split. MGS analyzed one split for grain size composition, a suite of trace metals, and carbon/sulfur/nitrogen. The Chesapeake Biological Laboratory (CBL) analyzed the second split collected for a different suite of trace metals. Field descriptions of samples are included as appendices in the *Year 24 Data Report*.

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

Laboratory Procedures

<u>Textural Analyses</u>

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

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

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

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

The relative proportions of sand, silt, and clay were determined using the sedimentological procedures described in Kerhin et al. (1988). The sediment samples were pre-treated with hydrochloric acid and hydrogen peroxide to remove carbonate and organic matter, respectively. Then the samples were wet sieved through a 62-µm mesh to separate the sand from the mud (silt plus clay) fraction. The finer fraction was analyzed using the pipette method to determine the silt and clay components (Blatt et al. 1980). Each fraction was weighed; percent sand, silt, and clay were determined; and the sediments were categorized according to Pejrup's (1988) classification (Figure 13).

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

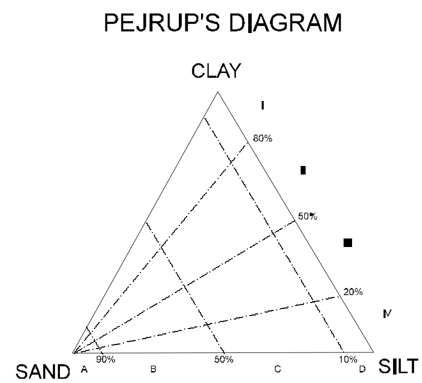


Figure 13: Pejrup's (1988) classification of sediment type

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

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

<u>Trace Metal Analysis</u>

Trace elements were analyzed by *Activation Laboratories Inc*. (ActLab). The quality assurance and quality control of ActLab has proved to meet MGS standards and requirements. In addition to the nine elements historically measured by MGS [Fe, Mn, Zn, Cu, Cr, Ni, Pb, Cd, and P], forty-one (41) additional elements were analyzed. Samples were prepared and ground in-house and sent to ActLab for analyses using both a four acid “near total” digestion technique followed by analysis on an Inductively Coupled Argon Plasma Spectrometer (ICAP), and Neutron Activation Analysis (NAA). In addition to the standards and blanks used by ActLab, National Institute of Standards and Technology (NIST) and Chesapeake Research Consortium (CRC) standard reference materials were inserted as blind samples for analyses; 1 in 8 samples.

Results of the analyses of the Standard Reference Material (SRM), (NIST-SRM #2702 - Inorganics in Marine Sediment; NIST-SRM #8704 - Buffalo River Sediment; National Research Council of Canada #PACS-2 - Marine Sediment) reported by ActLab had recoveries (accuracies) within one standard deviation of replicate analyses for all of the metals analyzed.

Carbon-Sulfur-Nitrogen Analysis

Sediments were analyzed for total nitrogen, carbon and sulfur (CNS) contents using a Carlo Erba NA1500 analyzer. This analyzer uses complete combustion of the sample followed by separation and analysis of the resulting gasses by gas chromatographic techniques employing a thermal conductivity detector. The NA1500 Analyzer is configured for CNS analysis using the manufacturer's recommended settings. As a primary standard, 5-chloro- 4-hydroxy- 3-methoxy-benzylisothiourea phosphate is used. Blanks (tin capsules containing only vanadium pentoxide) were run at the beginning of the analyses and after 12 to 15 unknowns (samples) and standards. Replicates of every fifth sample are run. As a secondary standard, a NIST reference material (NIST SRM #1646 - Estuarine Sediment) is run after every 6 to 7 sediment samples. The recovery of the SRM is excellent with the agreement between the NIST certified values and MGS's results well within the one standard deviation of replicate analyses.

RESULTS AND DISCUSSION

Sediment Distribution

The monitoring effort around HMI is based on the identification of long-term trends in sediment distribution and on the detection of changes in those trends. The sampling scheme, revised in Year 17 and expanded in Year 18, established a new baseline against which any future changes in the sedimentary environment will be measured. Through Year 19, results of all cruises beginning with Year 17 were reported and compared. Starting with Year 20, results of the current year were discussed with respect to the preceding year. Therefore, for this report, the current Year 24 results are discussed with respect to the preceding Year 23 results.

Forty-one of the sampling sites visited during Year 24 yielded results that can be compared to those measured during Year 23. The grain size composition (proportions of sand, silt, and clay) of the 41 samples is depicted as a series of Pejrup's diagrams in Figure 14. Within a diagram, each solid circle represents one sediment sample. Related statistics, by cruise, are presented in Table 2.

Table 2: Summary statistics for Years 23 - 24, for 41 sediment samples common to all four cruises.

Variable	Sept 2004 Cruise 49	Apr 2005 Cruise 50	Sept 2005 Cruise 51	Apr 2006 Cruise 52
Sand (%)				
Mean	23.59	22.34	22.39	23.17
Median	3.75	4.73	3.64	3.57
Minimum	0.60	0.74	0.47	0.00
Maximum	96.45	97.78	97.46	96.67
Range	95.85	97.04	96.99	96.67
Count	41	41	41	41
Clay:Mud				
Mean	0.56	0.56	0.56	0.57
Median	0.57	0.57	0.57	0.58
Minimum	0.43	0.48	0.37	0.46
Maximum	0.70	0.66	0.68	0.65
Range	0.27	0.18	0.30	0.19
Count	41	41	41	41

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

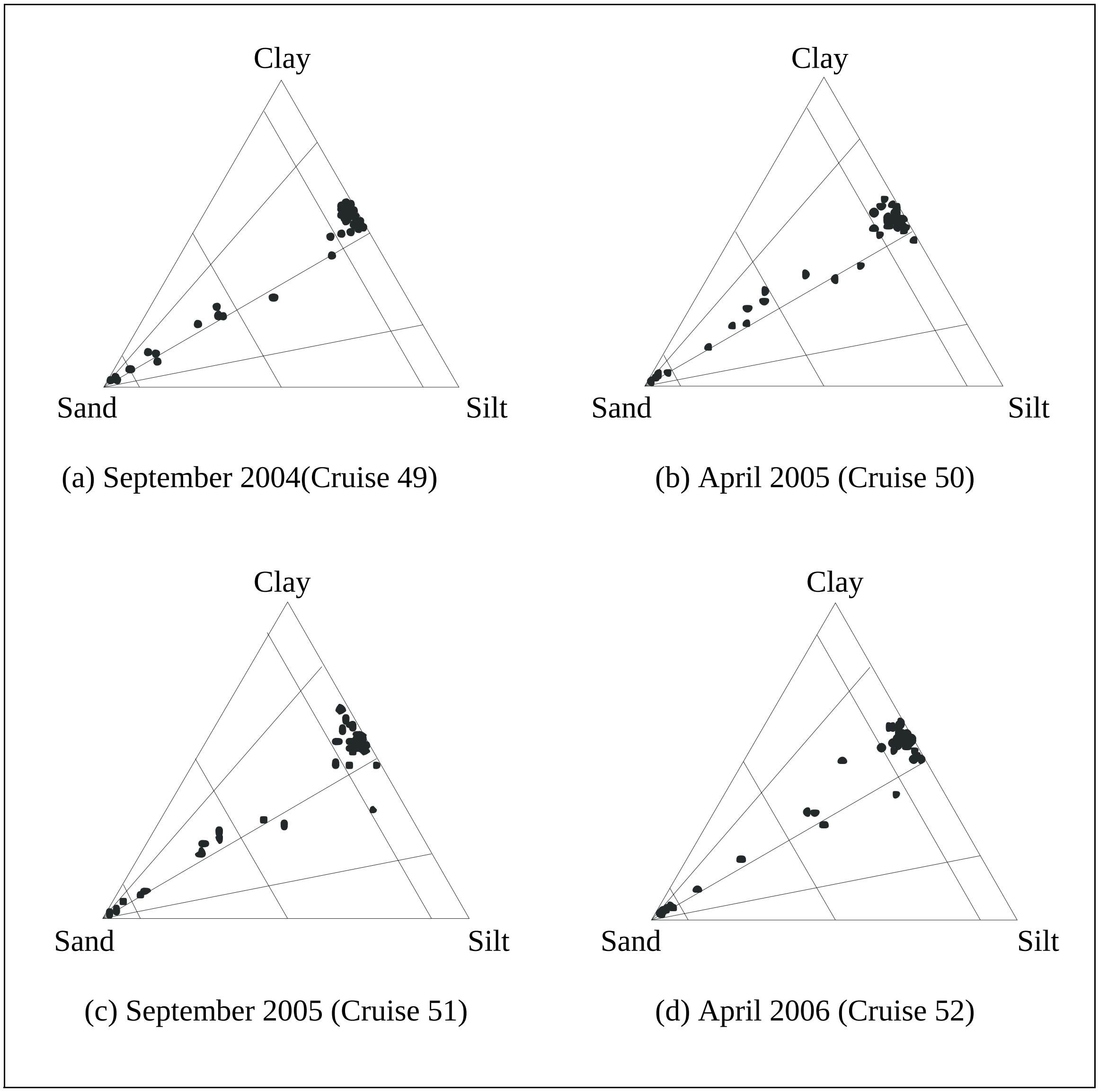


Figure 14: **Ternary diagrams showing the grain size composition of sediment samples collected in Years 23 and 24 from the 41 sampling sites common to all four cruises: (a) September 2004, (b) April 2005, (c) September 2005, and (d) April 2006.**

Based on the summary statistics (Table 2), average grain size composition, reported as % sand and as clay:mud ratios, varied little over the four sampling periods. The mean percentage of sand varied by only 1.25% for the four samplings. The mean clay:mud ratio remained at 0.56 for Cruise 49 through 51 and increased only slightly to 0.57 for sampling Cruise 52. As in the past, no clear seasonal trends are evident in either sand content or the clay:mud ratios.

For the two monitoring years, the grain-size distribution of bottom sediments around HMI is depicted in contour maps showing (1) the percentage of sand in bottom sediments and (2) the clay:mud ratios. In Figure 16 and Figure 17, three contour levels represent 10%, 50%, and 90% sand, coinciding with the parallel lines in Pejrup's diagram.

Figure 15: Average water depths, based on Year 17 Monitoring.

Generally, sand content diminishes with distance from the containment facility. Scattered around the perimeter of the facility, the sandiest sediments (>50% sand) are confined to relatively shallow (<15 ft) waters (Fig. 15). Broadest north and west of the facility, the shoals are the erosional remnants of a larger neck of land. The once continuous landmass has been reduced to a series of islands, including Hart and Miller, extending from the peninsula that now forms the south shore of Back River. However, not all shallow water samples are sandy. In particular, several of the shallow water samples from Hawk Cove (e.g.,MDE-30 and MDE-32) contain less than 10% sand. Sand distribution maps for Years 23 and 24 are similar in appearance. Sand contents continue to be highest near the perimeter of HMI in shallow water depths. No significant changes in sand content occurred during monitoring Year 24. In general, the distribution of sand around HMI has remained largely unchanged since November 1988, two years after the first release of effluent from the facility.

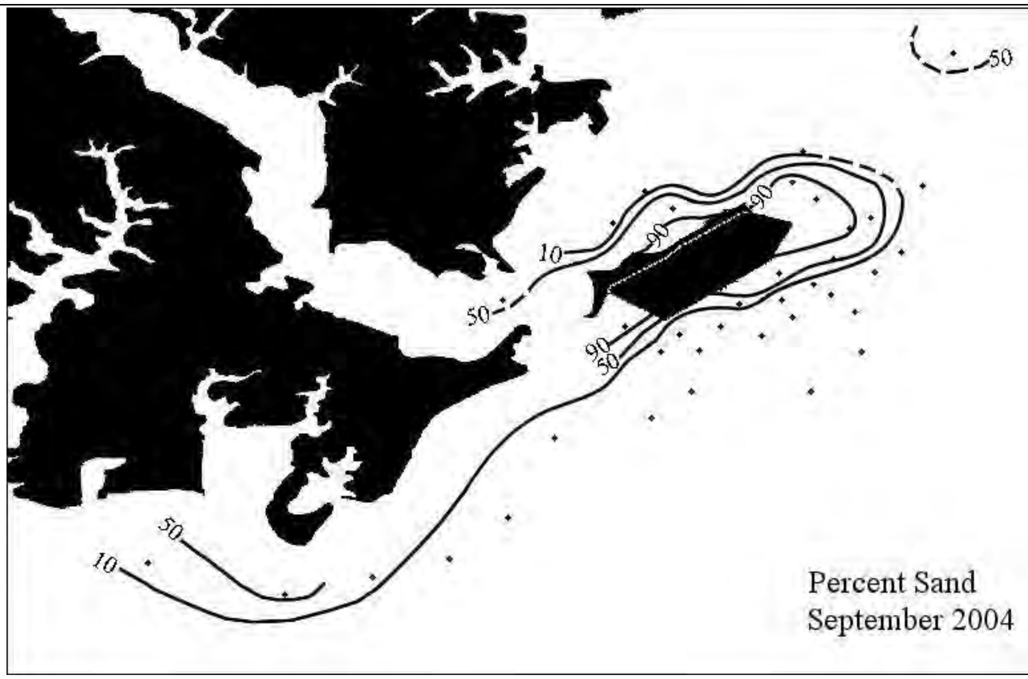
Compared to the distribution of sand, the distribution of clay:mud ratios has tended to be more variable over time. The fine (mud) fraction of the sediments around HMI is generally richer in clay than in silt. That is, the clay:mud ratio usually exceeds 0.50, as shown in the ternary diagrams in Figure 14. However, slight variations in the most clay-rich (clay:mud ratio ≥ 0.60) and in the most silt-rich (clay:mud ratio < 0.50) of the fine fractions are evident (Figures 18 and 19). MDE-41, at the mouth of Baltimore Harbor, continued to be clay-rich for three of the four samplings. A clay-rich area South of HMI was present in both September 2004 and April 2005. In September 2004, four stations had clay:mud ratios at or above 0.60 south of HMI (MDE-10, MDE 17, MDE 18, MDE, 21) to create the clay-rich area for this sampling. In April 2005, MDE-10 and MDE-18 continued to be clay-rich. The clay:mud values of both MDE-17 and MDE-21 declined slightly from September 2004 to below 0.60 while MDE-44 and MDE-20 increased to above 0.60. This accounts for the slight variation in shape of the clay-rich pocket from September 2004 to April 2005. In September 2005, MDE-10 and MDE-18 continued to be clay-rich to the south of HMI along with MDE-17, 19, and 44. The clay-rich area extends up the east side of HMI in September 2005 due to the increased clay:mud ratio at MDE-1, 2 and 3 (Fig. 19). MDE-1 and MDE-2 are both sandy sites, which make the clay:mud ratio changes here negligible as will be explained below. Seven sampling sites were clay-rich south of HMI in April

2006. In addition to MDE-10 and MDE-18, which continued to be clay-rich, MDE-15, MDE-19 thru MDE-21, and MDE-23 were clay-rich in April 2006. Although more sample sites were clay-rich in April 2006 than in the previous samplings, the contour map shows that the size of the area containing clay-rich sediments to the south of HMI did not increase significantly (Fig. 18).

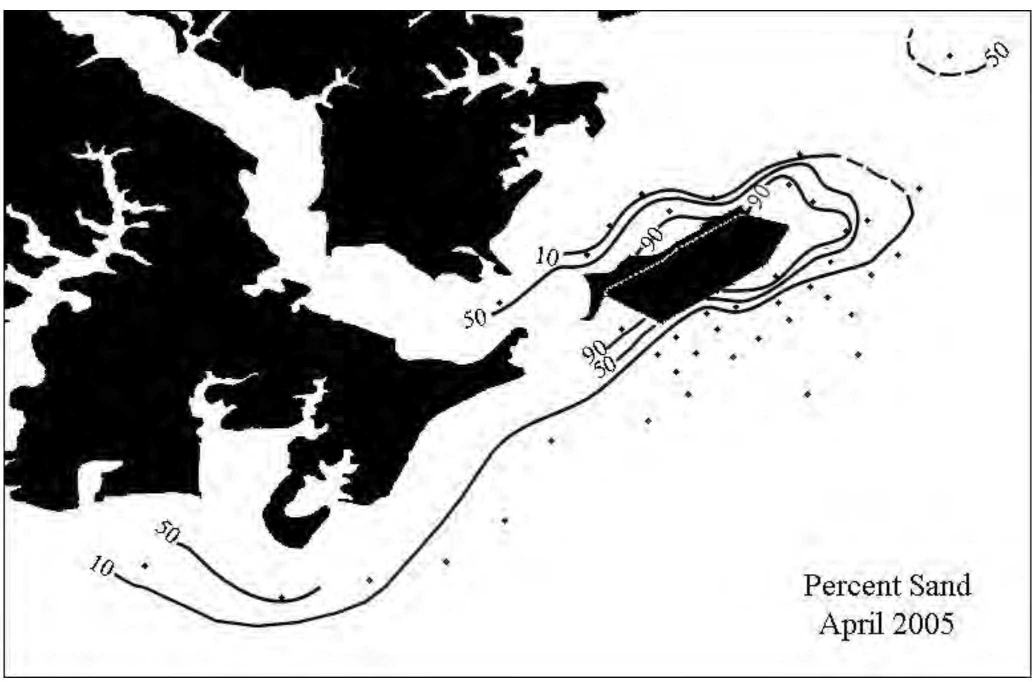
A clay-rich area was also present to the North of HMI for all four sampling cruises (Figures 17 and 18). Note that this area lies close to the perimeter of HMI where sand contents are consistently at or above 90 percent (Figures 15 and 16). This area is due to increased clay:mud ratios of sampling sites with high sand content. In sandy sediments, a very small increase in clay percentage will increase the clay:mud ratio above 0.60. The clay-rich areas for Year 24 are similar to those from Year 23 with no significant changes.

Silt-rich sediments (clay:mud ratio < 0.50) are generally found immediately adjacent to the walls of the facility, commonly in the vicinity of spillways. In September 2004, four sites consisting of MDE-8 and MDE-16, which are adjacent to the wall of the facility to the southeast, MDE-24 to the southwest of the facility, and MDE-27 in Back River were silt-rich. MDE-8 and MDE-16 continued to be silt-rich in April 2005 along with MDE-12 and MDE-27. In September 2005, MDE-12 and MDE-16 continued to be silt-rich to the southeast of the facility. Also silt-rich in September 2005 were MDE-24 to the southwest and MDE-27 in Back River. MDE-8 and MDE-16 were silt-rich to the southeast of the facility in April 2006 with MDE-27 in Back River remaining silt-rich. Both MDE-16 to the southeast of the facility and MDE-27 in Back River were consistently silt-rich for all four sampling cruises in Year 23 and 24. MDE-8 was silt-rich for three of the four samplings, while MDE 12 and MDE-24 were silt-rich for two of the four samplings. The silt-rich areas were very consistent during both Year 23 and Year 24 monitoring with the area adjacent to the walls of the facility to the south remaining silt-rich along with MDE-27 in Back River.

Understanding the specific reasons for these variations in grain size is difficult. They involve the amount, quality, and timing of discharge from particular spillways and the interaction of the effluent with tides and currents in the receiving waters. Those, in turn, are influenced by flow from the Susquehanna River. Based on the similarities between the fine fraction results from Year 23 and Year 24, one may conclude that the depositional environment in the vicinity of HMI was unchanged over this period. No clear trends affecting many samples from a large area are evident. The grain size distribution of Year 24 samples is largely consistent with the findings of past monitoring years.



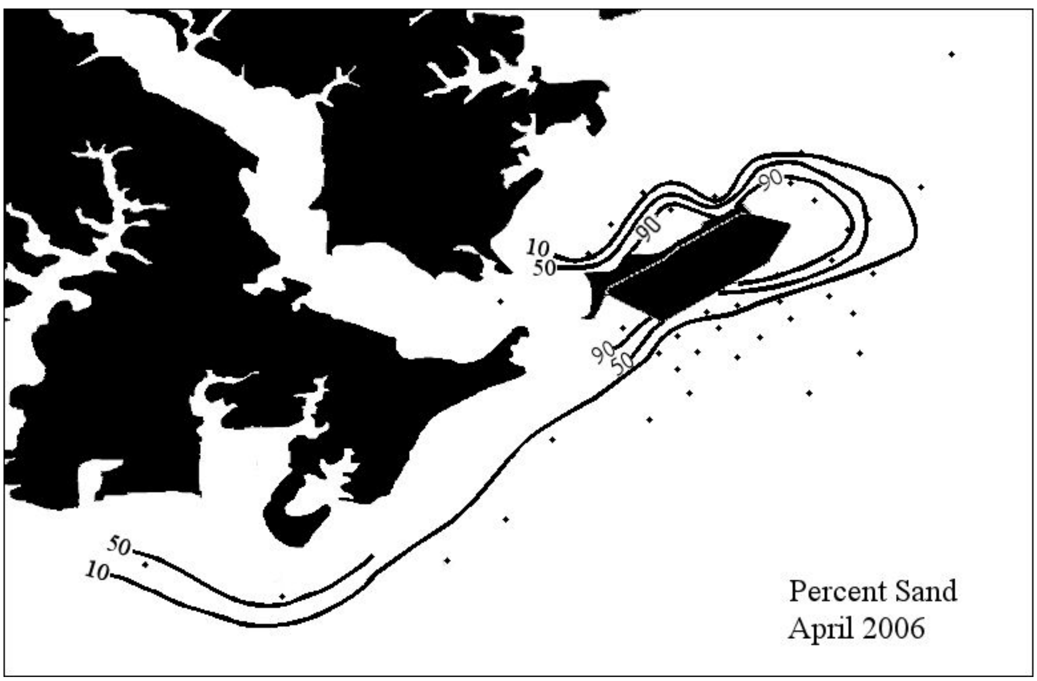
(a) Cruise 49



(b) Cruise 50

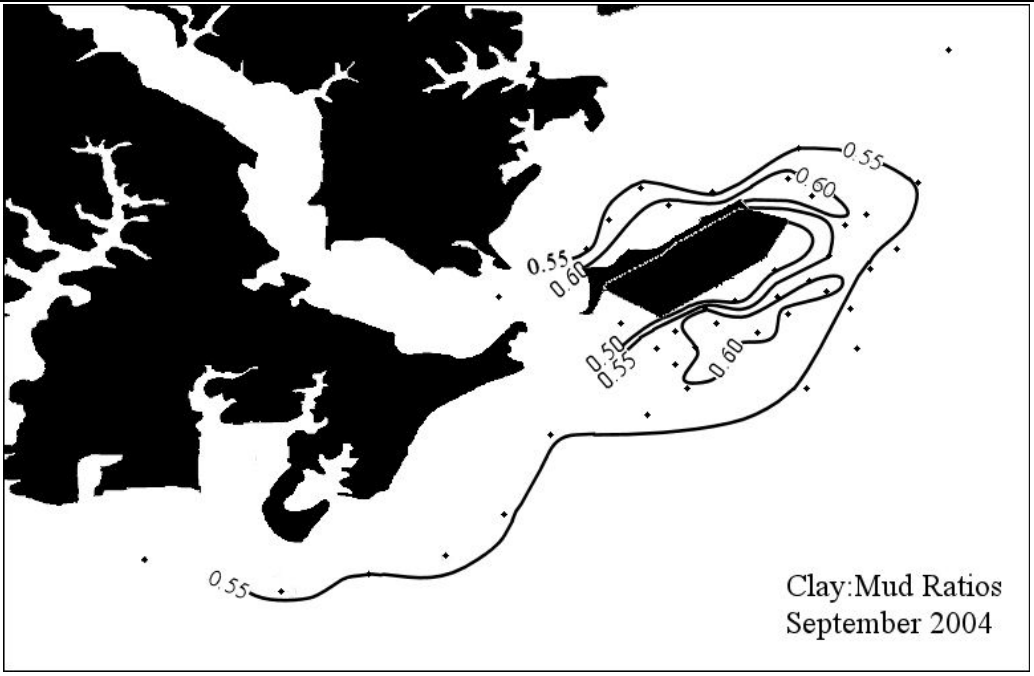
Figure 16: Sand distribution for Monitoring Year 24: (a) September 2004, (b) April 2005. Contour intervals are 10%, 50%, and 90% sand.

(a) Cruise 51

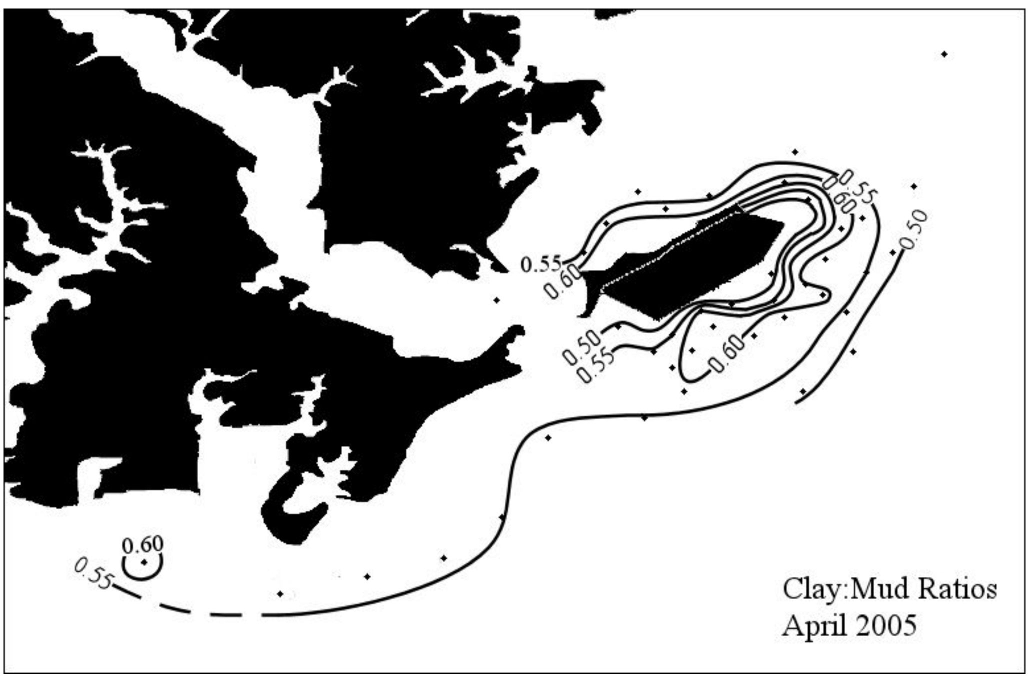


(b) Cruise 52

Figure 17: Sand distribution for Monitoring Year 24: (a) September 2005, (b) April 2006. Contour intervals are 10%, 50%, and 90% sand.

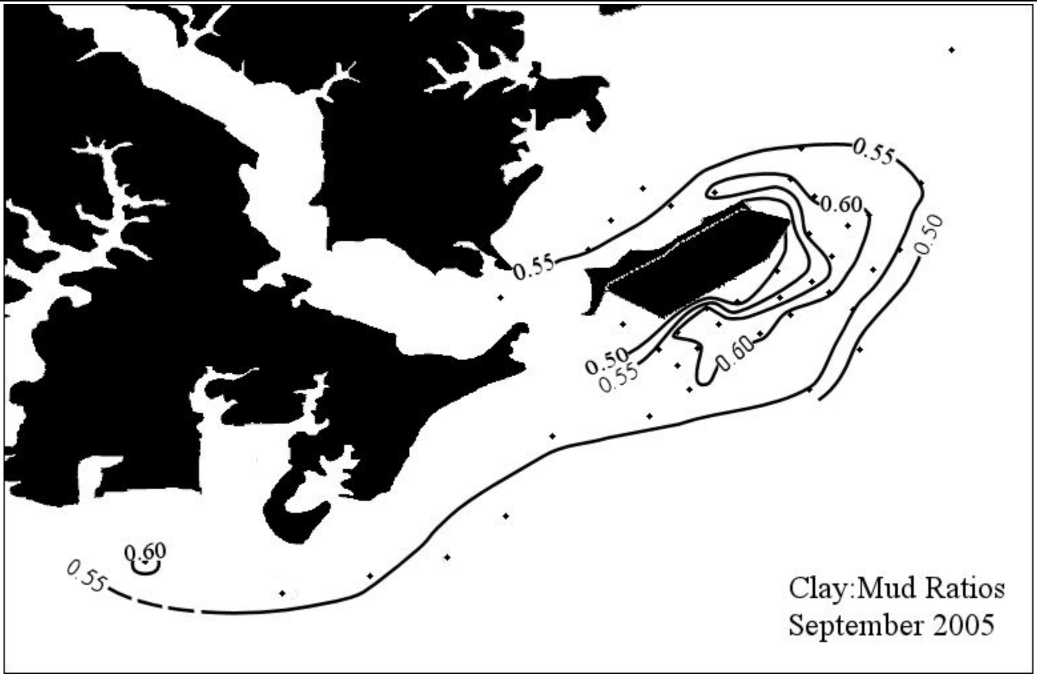


(a) Cruise 49

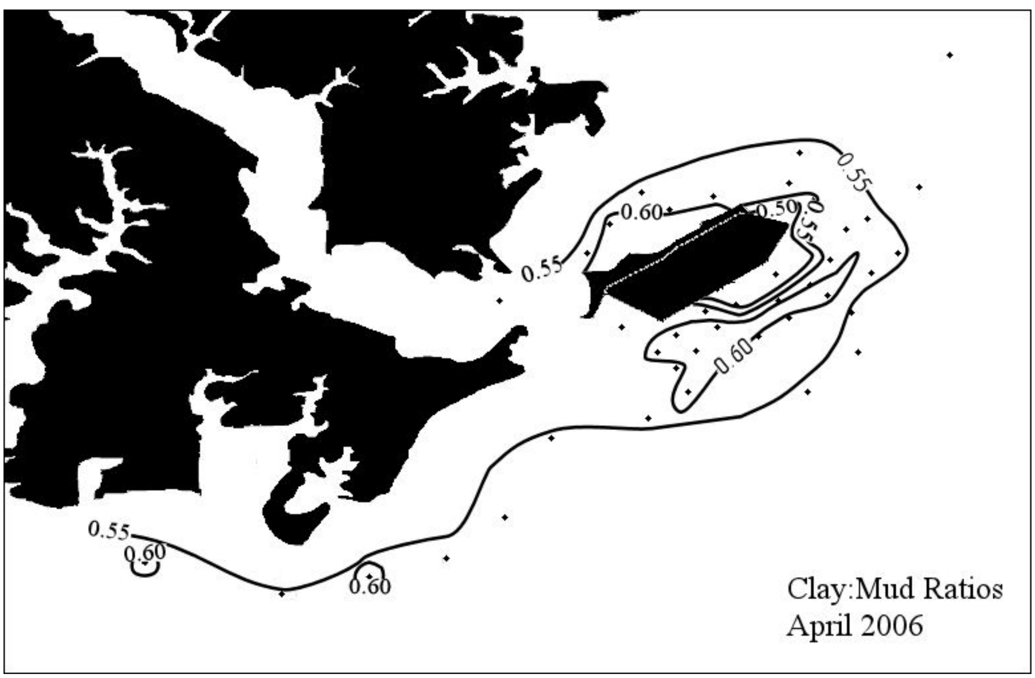


(b) Cruise 50

Figure 18: Clay:Mud ratios for Monitoring Year 24. Contour intervals are 0.50, 0.55, and 0.60.



(a) Cruise 51



(b) Cruise 52

Figure 19: Clay:Mud ratios for Monitoring Year 24. Contour intervals are 0.50, 0.55, and 0.60.

Interpretive Technique for Trace Metals

Previous monitoring years have focused on eight trace metals as part of the ongoing effort to assess the effects of operation of the containment facility on the surrounding sedimentary environment. The method used to interpret changes in the observed metal concentrations takes into account grain size induced variability and references the data to a regional norm. The method involves correlating trace metal levels with grain size composition on a data set that can be used as a reference for comparison. For the HMI study area, data collected between 1983 and 1988 are used as the reference. Samples collected during this time showed no aberrant behavior in trace metal levels. Normalization of grain size induced variability of trace element concentrations was accomplished by fitting the data to the following equation:

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

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

A least squares fit of the data was obtained by using a Marquardt (1963) type algorithm. The results of this analysis are presented in Table 3. The correlations are excellent for Cr, Fe, Ni, and Zn, indicating that the concentrations of these metals are directly related to the grain size of the sediment. The correlations for Mn and Cu are weaker, though still strong. In addition to being part of the lattice and adsorbed structure of the mineral grains, Mn occurs as oxy-hydroxide chemical precipitate coatings. These coatings cover exposed surfaces, that is, they cover individual particles as well as particle aggregates. Consequently, the correlation between Mn and the disaggregated sediment size fraction is weaker than for elements, like Fe, that occur primarily as components of the mineral structure. The behavior of Cu is more strongly influenced by sorption into the oxy-hydroxide than are the other elements. The poor relationship with regard to Cd is due to the baseline being established at or near the detection limit; however, the relationship is still significant. Baseline levels for Cd and Pb were determined from analyses of 30 samples collected in a reference area on the eastern side of the Northern Bay. The baseline was established as part of a study examining toxic loading to Baltimore Harbor.

Table 3: Coefficients and R^2 for a best fit of trace metal data as a linear function of sediment grain size around HMI. The data are based on analyses of samples collected during eight cruises, from May 1985 to April 1988.

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

	Cr	**Mn**	**Fe**	**Ni**	**Cu**	**Zn**	**Pb**	**Cd**
a	25.27	668	0.553	15.3	12.3	44.4	6.81	0.32
b	71.92	218	1.17	0	18.7	0	4.10	0.14
c	160.8	4158	7.57	136	70.8	472	77	1.373
R^2	0.733	0.36	0.91	0.82	0.61	0.77	0.88	0.12

The strong correlation between the metals and the physical size fractions makes it possible to predict metal levels at a given site if the grain size composition is known. A metal concentration can be predicted by substituting the least squares coefficients from Table 3 for the constants in equation 2, and using the measured grain size at the site of interest. These predicted values can then be used to determine variations from the regional norm due to deposition; to exposure of older, more metal-depleted sediments; or to loadings from anthropogenic or other enriched sources.

The following equation was used to examine the variation from the norm around HMI.

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

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

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

<u>General Results</u>

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

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

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

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

Parameter	P (%)	Cd	Cr	Cu	Fe (%)	Mn	Ni	Pb	Zn
Detection Limit	0.001	0.3	2	1	0.01	1	1	3	1
Ave.	0.068	1.1	89	43	3.75	2776	68	58	287
std	0.029	0.4	46	20	1.60	1685	33	30	155
RSD	42	37	51	47	43	61	48	52	54
n	86	69	86	86	86	86	86	86	86
Min.	0.003	<0.3	8	4	0.23	201	5	6	19
Max	0.128	2.1	341	92	5.84	8080	128	135	772
ERL	n/a	1.3	81	34	n/a	n/a	20.9	46.7	150
#>ERL	***n/a***	***21***	***59***	***62***	***n/a***	***n/a***	***73***	***59***	***70***
ERM	n/a	9.5	370	270	n/a	n/a	51.6	218	410
#>ERM	***n/a***	***0***	***0***	***0***	***n/a***	***n/a***	***61***	***0***	***13***

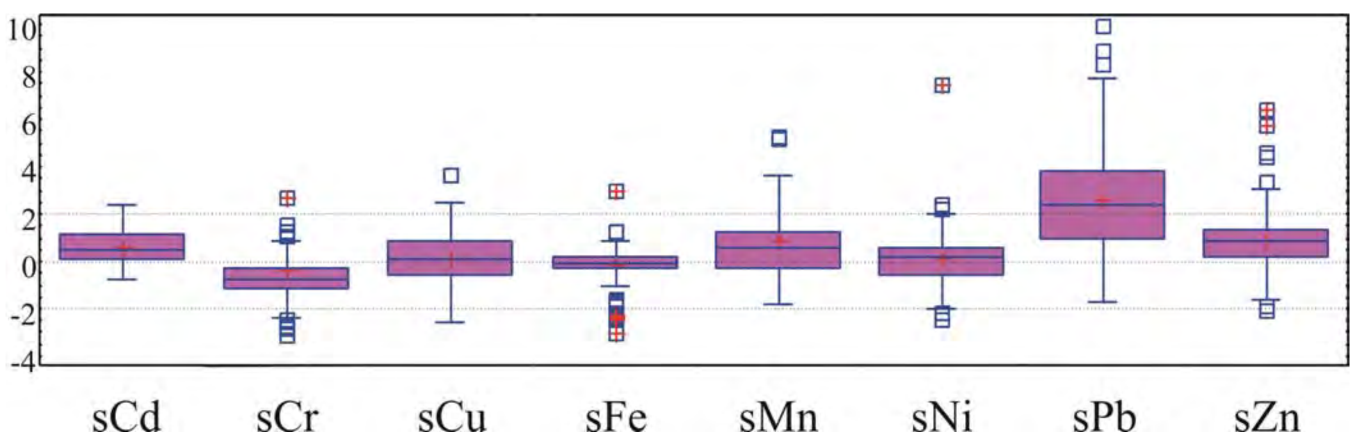


Figure 20: A box and whisker diagram showing the range of the data for both the fall and spring cruise.

The values presented in Table 4 are the measured concentrations of metals in the sediment, not normalized with respect to grain size variability, as outlined in the preceding *Interpretive Techniques* section. Figure 20 shows the variation of the data from the predicted baseline behavior for each of the elements measured. The values are in units of multiples of standard deviations from the norm; zero values indicate measurements that are identical to the predicted baseline behavior, values within plus or minus two (2) sigma are considered to be within the natural variability of the baseline values. For both sampling cruises, all of the metals except Pb and Zn are within the range expected for normal baseline behavior in the area. Pb has approximately 1/2 of the samples significantly exceeding the baseline levels, and Zn less than a quarter of the samples. Zn and Pb will be discussed in the following sections.

Metal Distributions

Since the eighth monitoring year, increased metal levels (specifically Zn) have been noted in bottom sediments east and south of Spillway 007; similarly since the start of monitoring Pb in Year 15, elevated levels of Pb have been found in the same areas, but with generally higher relative loadings. The results of previous monitoring studies have shown that the areal extent and magnitude of metals loadings to the exterior sedimentary environment is controlled by three primary factors. These factors are:

1. Discharge rate controls the amount of metals discharged to the external sedimentary environment. Discharge from HMI at flows less than 10 MGD contribute excess metals to the sediment (see *Twelfth Year Interpretive Report*). The high metal loading to the exterior environment is the result of a low pond level, which allows exposure of the sediment to the atmosphere. When the sediments are exposed to atmospheric oxygen, naturally occurring sulfide minerals in the sediment oxidize to produce sulfuric acid, which leaches metals and other acid-soluble chemical species from the sediment. The process is similar to acid mine drainage. At discharge rates greater than 10 MGD, the water throughput (input from dredged material inflow) submerges the sediment within the facility, minimizing atmospheric exposure, and dilutes and buffers any acidic leachate. As a result, higher discharge rates produce metal loadings that are close to background levels.

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

   a. A circulation gyre exists east of HMI. The gyre circulates water in a clockwise pattern, compressing the discharge from the facility against the eastern and southeastern perimeter of the facility;
   b. The circulation gyre is modulated by fresh water flow from the Susquehanna River. The higher the flow from the Susquehanna, the stronger the circulation pattern and the greater the compression against the facility. Conversely, the lower the flow, the less the compression and the greater the dispersion away from the facility; and
   c. Discharge from the facility has no influence on the circulation gyre. This was determined by simulating point discharges of 0-70 MGD from three different spillways. Changes in discharge rate only modulated the concentration of a hypothetical conservative species released from the facility; the higher the discharge, the higher the concentration in the plume outside the facility.

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

a. Releases from Spillways 007 and 009 travel in a narrow, highly concentrated band up and down the eastern side of the facility. This explains the location of the areas of periodic high metal enrichment to the east and southeast of the facility; and

b. Releases from Spillway 008 are spread more evenly to the north, east, and west. However, dispersion is not as great as from Spillways 007 and 009 because of the lower shearing and straining motions.

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

Figure 21 shows the sigma levels for Pb for Year 24 monitoring periods in the study area adjacent to HMI; sigma levels for Zn are shown in Figure 22. Sigma levels are the multiple of the standard deviation of the baseline data set. Data that falls within +/-2 sigma are considered within normal baseline variability. Data within the 2 -3 sigma range are transitional; statistically one sample in 100 would normally be expected to occur, in a small data set. The occurrence of 2 or more spatially contiguous stations in this range is significant. Any sample >3 sigma is significantly elevated above background. The shading in Figures 21 & 22 is used to highlight the areas that are significantly elevated above baseline levels. As shown in Figure 11 there are three primary areas of interest that will be referred to: Back River, Baltimore Harbor, and HMI.

Back River - The Back River influence is strongly seen for Pb. Pb apparently is being discharged by Back River during both of the sampling periods, both periods having a similar levels and spatial extent. Zn concentrations were within background levels for both sampling cruises.

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

HMI - The area adjacent to HMI had lower metals (Pb and Zn) loading than had been seen in the previous monitoring year. Pb in Year 23 reached levels of 8 sigma in the fall and 7 sigma in the spring, while the levels only reached 5 sigma for both cruises in Year 24. Zn had levels reaching 5 and 4 respectively in Year 23, that were at background levels this monitoring year. In the April cruise the Pb gradient from Baltimore Harbor dropped to background levels south of HMI, providing a clear separation in source material to the area. However, the September cruise showed a more complex pattern similar to the previous monitoring year where the gradient from Baltimore Harbor overlaps with the high levels adjacent to HMI. The high levels adjacent to HMI may indicate that HMI is the source of the high Pb levels.

Based on the operations of the HMI facility, it would not be expected that the facility would be significantly contributing to the exterior sediments during this monitoring year (see facility *Operations* section). This is clearly the case, both Pb and Zn show reduced levels; with Zn returning to background levels for the most part. In the area adjacent to HMI, there is one site in each cruise that has an elevated Zn level one sigma greater than the background variability. However since it is just one site it is not considered significant.

The distributions of Pb have higher levels in the Early Fall sampling (Cruise 51) as compared to the Spring sampling (Cruise 52). Elevated metals levels for Zn and Pb were seen in the three zones as described above. The spatial extent and the levels found in the Baltimore Harbor and Back River zones vary according to seasonal climatic changes, which influence the hydrodynamic conditions and sediment loading, and activity within those sources. Commonly the Late Summer - Early Fall levels are higher than the Spring sampling for the Baltimore Harbor and Back River zones; this is the case for this monitoring year, though not as distinct for Zn in the Back River area.

The HMI zone, prior to Year 22 monitoring, was clearly independent of Baltimore Harbor and Back River inputs. In the monitoring Years 22 and 23 an enriched area extended into the HMI region. In Year 22 near record rainfall caused the Baltimore Harbor influence to extend into the HMI region for the first time since the construction of the facility. This effect intensified during Year 23, due to continuing climatic factors. The influence of the Harbor diminished in the Year 24 monitoring , with the separation complete in the April 2006 sampling period. During Year 24 rainfall was below normal thus minimizing flow from Baltimore Harbor. This is seen in Figure 23, which shows the highest level of Zn found within the HMI influenced zone through time. The data from this monitoring year are shown as the solid points and shows a decrease from the high levels in Year 23.

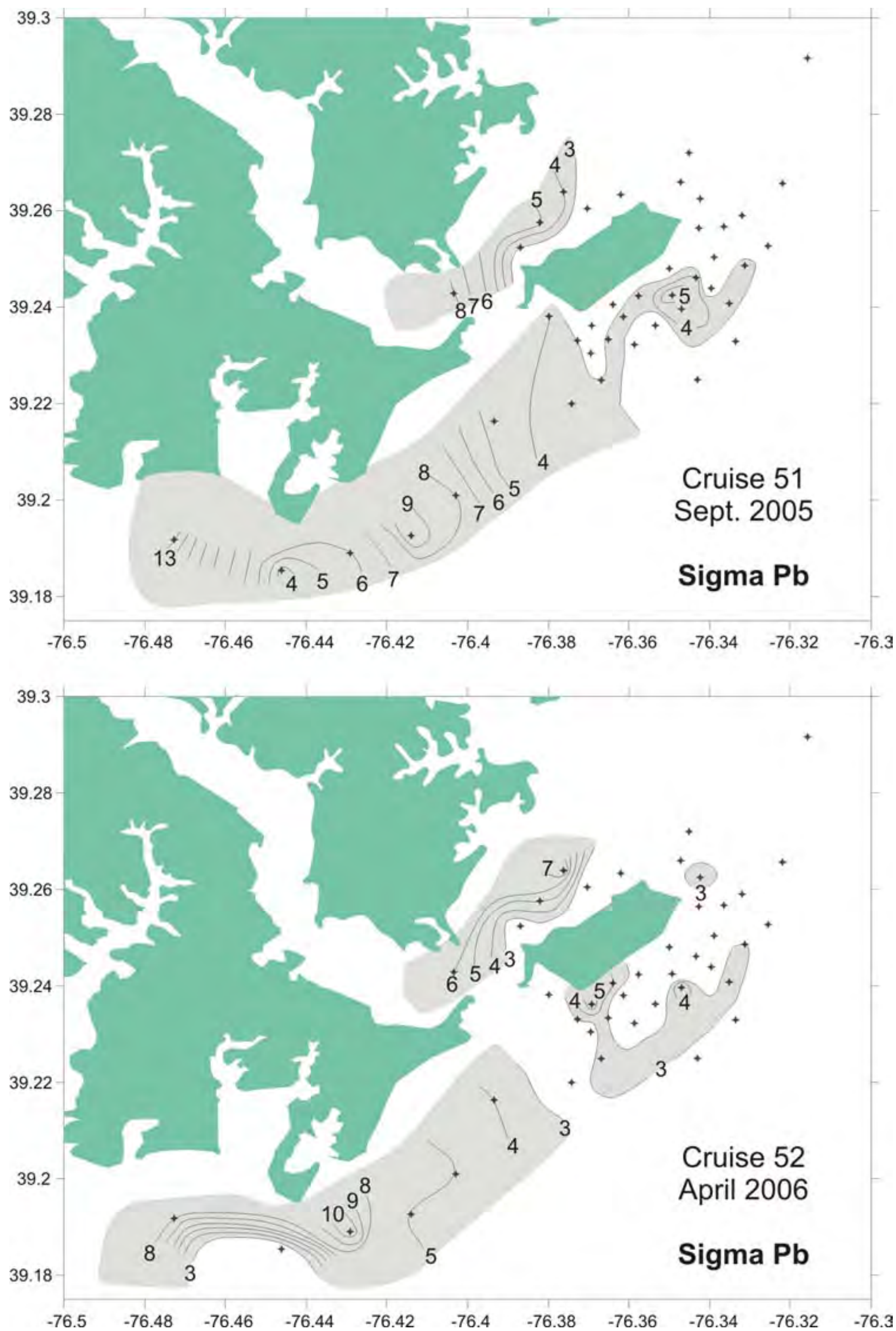


Figure 21: Distribution of lead (Pb) in the study area for the Fall and Spring sampling cruises. Units are in multiples of standard deviations - Sigma levels: 0 = baseline, +/- 2 = baseline, 2-3 = transitional(values less than 3 not shown), >3 = significantly enriched (shaded in figures).

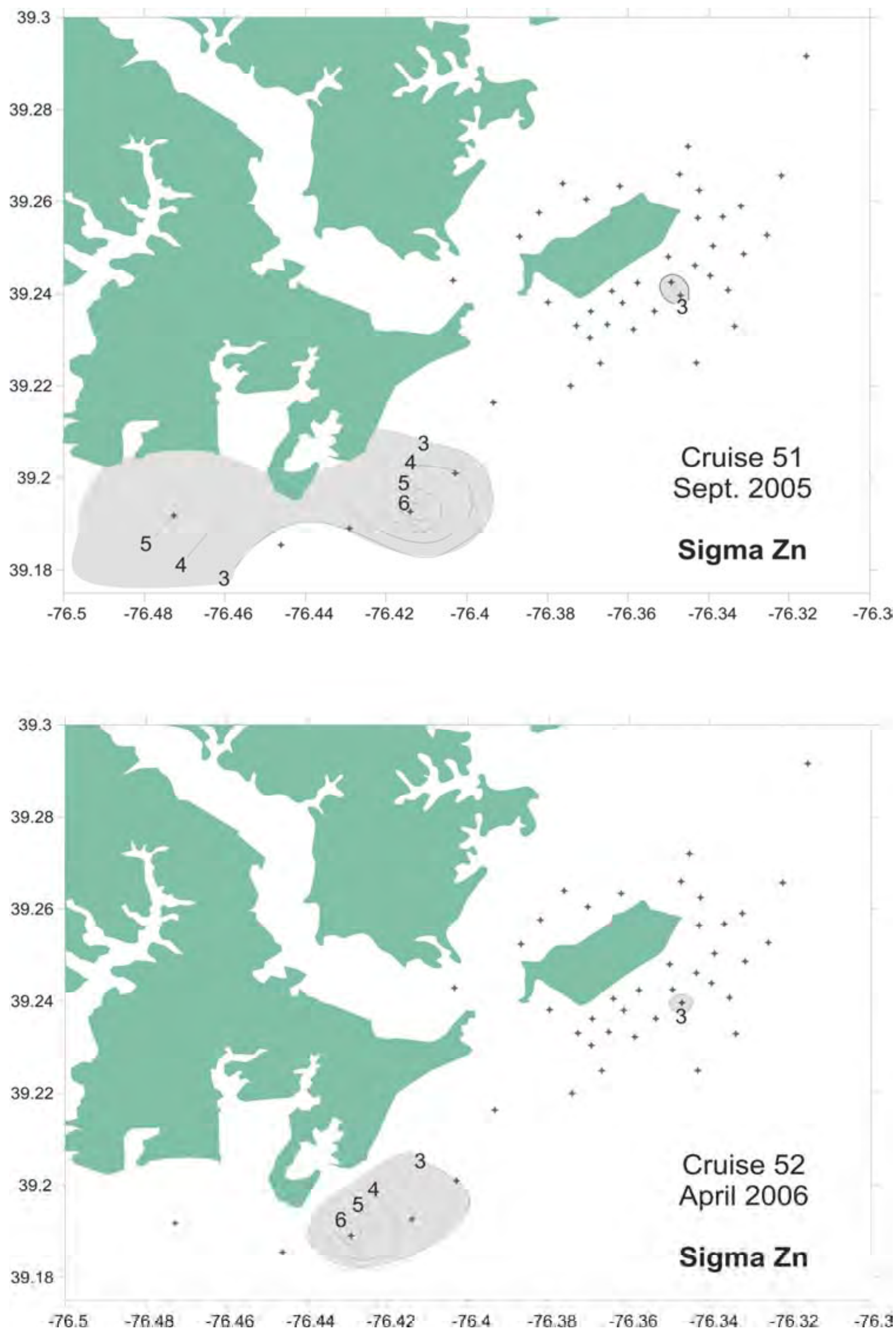


Figure 22: Distribution of zinc (Zn) in the study area for the Fall and Spring sampling cruises. Units are in multiples of standard deviations - Sigma levels: 0 = baseline, +/- 2 = baseline, 2-3 = transitional(values less than 3 not shown), >3 = significantly enriched (shaded in figures).

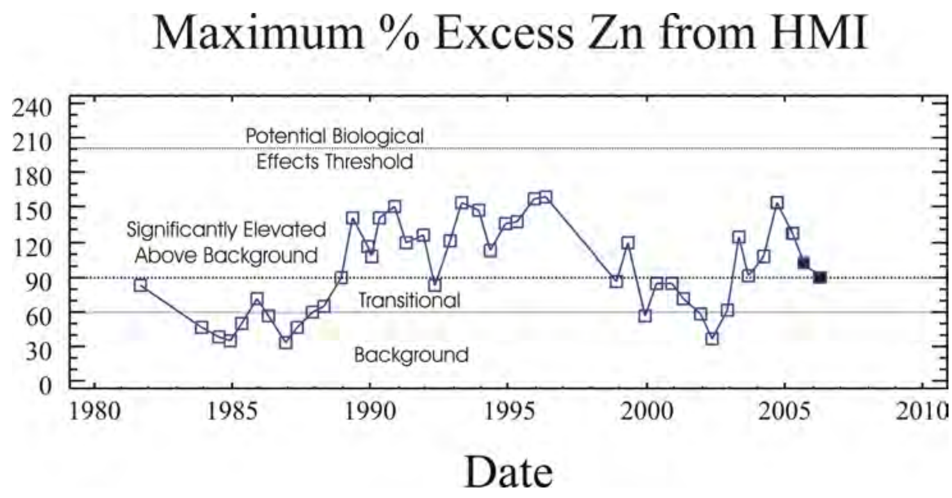


Figure 23: Record of the maximum % Excess zinc (Zn) for all of the cruises MGS analyzed the sediments. The filled points are the data from this study.

RECOMMENDATIONS

The grain size distribution of the Year 24 sediment samples does not show any clear trends in sedimentation patterns from cruise to cruise. This is due to the complexity of the environmental conditions and source of material to the area. The clay:mud ratios show that the depositional environment was very similar during Year 23 and Year 24. A slight increase in clay content at several stations to the east of the facility created a larger area of clay-rich samples in September 2005. These stations were predominately sandy, which allows for a very small increase in clay content to significantly increase the clay:mud ratio. The clay:mud ratio was back to below 0.60 in April 2006 at these stations and the dominate clay-rich area continued to be the area to the south of HMI. The general sediment distribution pattern is consistent with the findings of previous monitoring years dating back to 1988 (the second year after the start of release from HMI) and no significant changes occurred during Year 24. The main reason for adding the Baltimore Harbor samples was to determine if the Harbor was a possible source of the trace metals often concentrated in sediments deposited between Spillways 003 and 009. As was the case in previous monitoring years, the clay:mud distributions continued to argue against that possibility. Presumably, trace metals derived from Baltimore Harbor are more likely to settle with clay-rich sediments at the mouth of the Harbor; whereas, those derived from the containment facility are deposited in the vicinity of the facility. The three stations added in the vicinity of Spillway 008 in April 2004 continued to be monitored for Year 24 in order to assess the operation of the South Cell as an Environmental Restoration Project with discharge from the spillway. However, no discharge occurred from this spillway during Year 24. There were no significant changes at these three stations during Year 24 sampling.

With regard to trace metals some features to note are:

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

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

Pb enriched samples are associated with the three local sources, HMI, Baltimore Harbor and Back River. Zn enriched samples are associated with Baltimore Harbor and Back River; there is no significant influence from HMI. Material from the Harbor did not influence the sediments adjacent to the facility in the proximal zone ascribed to HMI during this monitoring year. This is supported by both the sedimentation and metals distribution patterns in the area. The higher levels associated with Baltimore Harbor influence reflects a residual signature from the preceding years' climatic conditions.

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

Persistent elevated metal levels in sediments around HMI indicate a need for continued monitoring. The metal levels in the exterior sediments continued to show a consistent response to the operations of the facility; low discharge rates increasing the metal loads to the sediment. Currently, the facility is actively accepting material, but the amount of material accepted is declining as the facility reaches its capacity. Consequently, the volume of effluent is declining, dewatering operations will increase which may lead to higher metal levels in the effluent. Exposure of dredged material to the air is likely to result in the mobilization of metals associated with those sediments, an effect analogous to acid mine drainage. Metals released in the effluent, particularly at low discharge rates, are deposited on the surrounding Bay floor and are increasing the long-term sediment load in the Bay. Continued monitoring is needed in order to; detect if the levels increase to a point where action is required, document the effect that operations has on the exterior environment (for future project design), and to assess the effectiveness of any amelioration protocol implemented by MES to counteract the effects of exposing contained dredged material to the atmosphere. Close cooperation with MES is important in this endeavor.

In order to assess the potential influence of Baltimore Harbor on the HMI exterior sediments better, the additional sampling sites be maintained, at least temporarily. Further, the South Cell will soon be converted to upland wetlands, with a constant flow of water being circulated through the ponds to produce conditions similar to tidal wetlands. The additional sample locations near the discharge point should be maintained to assess this new operation of the facility a part of the on-going monitoring program.

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

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APPENDIX 2: BENTHIC COMMUNITY STUDIES FOR YEAR 24 OF THE HART-MILLER EXTERIOR MONITORING PROGRAM (PROJECT III)

(September 2005 – September 2006)

TECHNICAL REPORT

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EXECUTIVE SUMMARY

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

Twenty stations (11 Nearfield, 3 Reference, 3 Back River/Hawk Cove stations, and 3 South Cell Restoration Baseline stations) were sampled on September 9, 2005 and on April 7, 2006. Macroinvertebrate samples were collected using a Ponar grab sampler, which collects 0.05 m^2 of substrate. Water quality parameters were measured using a Hydrolab Surveyor II at one-half meter from the bottom and at one-half meter from the surface.

A total of 43 taxa of benthic macroinvertebrates were found at these twenty benthic community stations during Year 24 of monitoring. Several of the taxa were clearly dominant. The worms *Marenzelleria viridis* and Tubificidae, the clam *Rangia cuneata*, and the arthropods *Leptocheirus plumulosus* and *Cyathura polita* were among the numerically dominant taxa on both sampling dates. The only major change in the most abundant taxa between seasons of Year 24 was for the mussel *Mytilopsis leucophaeata* and the Tubificid worms. *M. leucophaeata* declined from the first most abundant taxa in September 2005 to the seventh most abundant taxa in April 2006, while taxa in the family Tubificidae increased from eighth to third most abundant. Polychaete taxa richness was similar for the two seasons, although *Streblospio benedicti* was rare in the April 2006 sampling. Total abundance (excluding Bryozoa) was higher at most stations in April 2006 than September 2005, primarily due to the spring recruitment of the worm *M. viridis*.

Species diversity was examined using the Shannon-Wiener diversity index. Diversity was higher in September 2005 than in April 2006 at all stations. While the proportion of pollution-sensitive taxa could only be calculated for one station in Year 24 (MDE-43 in April 2006), the proportion of pollution indicative taxa could be calculated for all stations in both September 2005 and April 2006. Lower mesohaline conditions prevailed at all stations in Year 24 except MDE-43 in April 2006, where oligohaline conditions were measured. No pollution sensitive taxa have been identified for lower mesohaline conditions in Chesapeake Bay.

The Chesapeake Bay Benthic Index of Biotic Integrity (B-IBI, Weisberg et al. 1997), a multi-metric index of biotic condition that evaluates summer populations (during the July 15th to September 30th timeframe) of benthic macroinvertebrates, was calculated for all stations sampled during the September 2005 cruise. Overall, the B-IBI scores decreased when compared to Year 23. This year, 17 stations exceeded the benchmark criteria of 3.0, and 3 stations failed to meet the benchmark.

As in Year 23, in Year 24 there were no significant differences for the ten most abundant infaunal taxa among the four station types, based on results of the nonparametric Friedman’s test. However, once again, infaunal compositions at South Cell Baseline Monitoring stations had more variance than at other station types. Cluster analysis revealed station groupings related to bottom type, and possible influences of other habitat factors such as wave turbulence, sediment transport, and eutrophic waters on station faunal compositions.

INTRODUCTION

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

As part of the environmental permitting process for this dredged material containment facility, an exterior monitoring program was developed to assess any environmental impacts associated with HMI. Various agencies have worked together since the inception of this program to monitor for environmental impacts resulting from facility construction and dredged material management activities. Studies were completed prior to and during the early construction period to determine baseline environmental conditions in the HMI vicinity. The results of post-construction monitoring have then been compared to this baseline, as well as to interseasonal and interannual data. This report represents the twenty-fourth consecutive year of the benthic macroinvertebrate community monitoring since 1981. In Year 24, the Maryland Department of the Environment was responsible for all aspects of benthic community monitoring.

The goals of the Year 24 benthic community monitoring were:

- To monitor the benthic community condition: Benthic monitoring is no longer a permit requirement but continued voluntarily by MPA;

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

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

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

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

METHODS AND MATERIALS

For the Year 24 benthic community studies, staff from the Maryland Department of the Environment's Biological Assessment Section collected all macroinvertebrate and water quality samples. Field sampling cruises for both seasons were conducted from the Maryland Department of Natural Resources vessel, the *Kerhin*. The same twenty benthic stations were monitored during both fall and spring seasons (Table 5; Figure 24). Environmental parameters recorded at the time of sample collection are included in Tables 6 through 11.

Table 5: Target Locations (latitudes and longitudes in degrees, decimal minutes), 7-digit codes of stations used for Year 24 benthic community monitoring, and predominant sediment type at each station for September and April.

Station #	Latitude	Longitude	Sediment Type		Maryland 7-Digit Station Designation
			Fall	Spring	
Nearfield Station					
MDE-01	39° 15.3948	76° 20.5680	Sand	Sand	XIF5505
MDE-03	39° 15.5436	76° 19.9026	Sand	Silt/clay	XIG5699
MDE-07	39° 15.0618	76° 20.3406	Silt/clay	Silt/clay	XIF5302
MDE-09	39° 14.7618	76° 20.5842	Silt/clay	Silt/clay	XIF4806
MDE-16	39° 14.5368	76° 21.4494	Silt/clay	Silt/clay	XIF4615
MDE-17	39° 14.1690	76° 21.1860	Silt/clay	Silt/clay	XIF4285
MDE-19	39° 14.1732	76° 22.1508	Silt/clay	Silt/clay	XIF4221
MDE-24	39° 14.2650	76° 22.7862	Sand	Sand	XIF4372
MDE-33	39° 15.9702	76° 20.8374	Sand	Sand	XIF6008
MDE-34	39° 15.7650	76° 20.5392	Sand	Sand	XIF5805
MDE-35	39° 16.3182	76° 20.7024	Silt/clay	Silt/clay	XIF6407
Reference Stations					
MDE-13	39° 13.5102	76° 20.6028	Silt/clay	Silt/clay	XIG3506
MDE-22	39° 13.1934	76° 22.4658	Silt/clay	Silt/clay	XIF3224
MDE-36	39° 17.4768	76° 18.9480	Silt/clay	Silt/clay	XIG7589
Back River/Hawk Cove Stations					
MDE-27	39° 14.5770	76° 24.2112	Silt/clay	Silt/clay	XIF4642
MDE-28	39° 15.3900	76° 22.7304	Silt/clay	Silt/clay	XIF5232
MDE-30	39° 15.8502	76° 22.5528	Shell	Shell	XIF5925
South Cell Restoration Baseline Monitoring Stations					
MDE-42	39° 23.0390	76° 36.9050	Silt/clay	Silt/clay	XIF3879
MDE-43	39° 23.2310	76° 35.8190	Silt/clay	Silt/clay	XIF3985
MDE-44	39° 24.0380	76° 36.3960	Silt/clay	Silt/clay	XIF4482

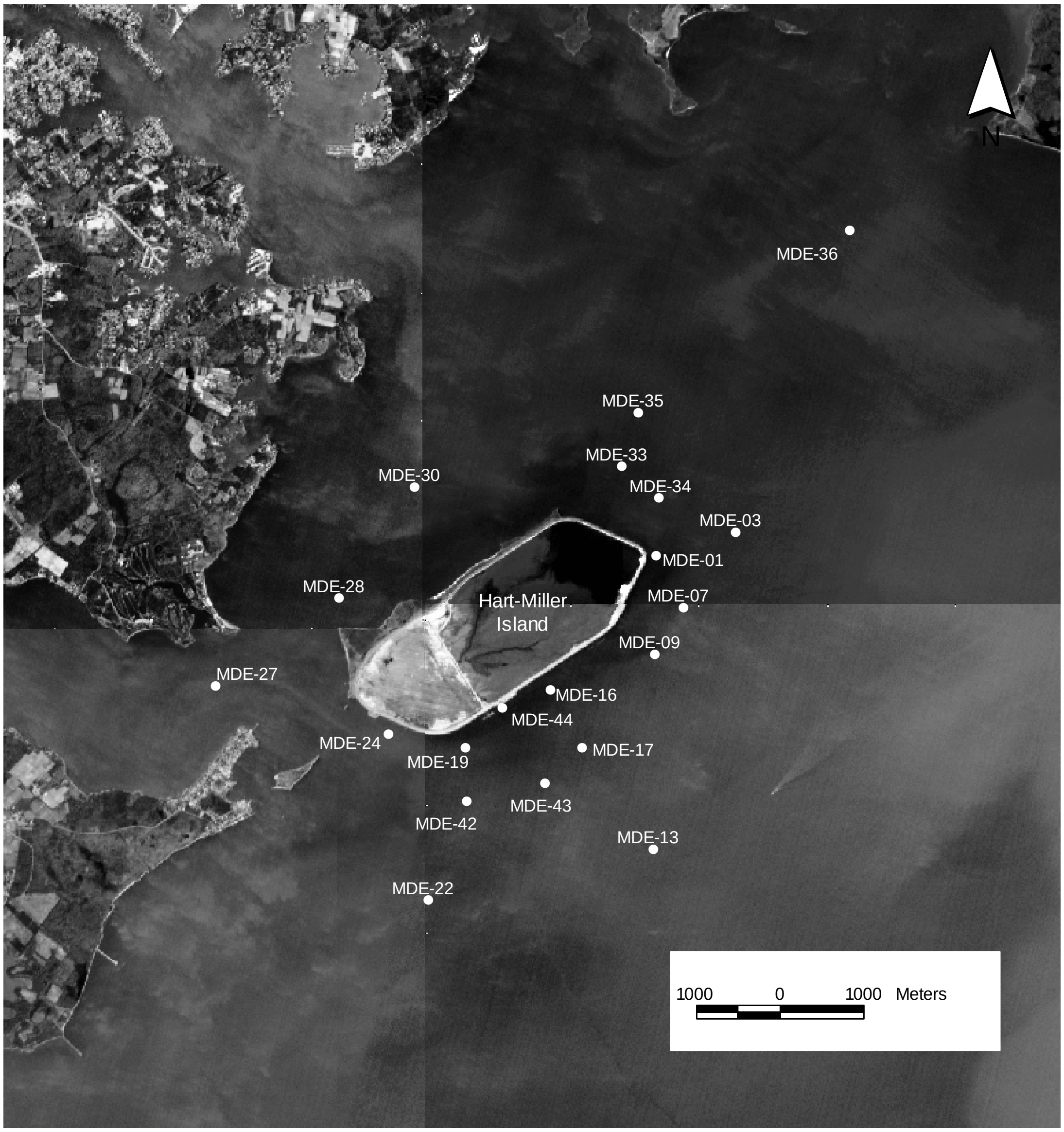

Figure 24: Year 24 Benthic Sampling Stations for the HMI Exterior Monitoring Program.

All stations sampled during Year 23 of monitoring were again sampled for Year 24. Stations were classified by location and dominant sediment type (Table 5). Stations were divided into four location groups (Nearfield stations, Reference stations, Back River/Hawk Cove stations, and South Cell Restoration Baseline stations) and five sediment types (silt/clay, shell, detritus, gravel, and sand). All benthic community sampling stations coincided with stations sampled by the Maryland Geological Survey (MGS) for sedimentary analysis. All stations were located using a differential global positioning system (GPS) navigation unit.

Temperature, depth, salinity, pH, conductivity, and dissolved oxygen were measured *in situ* using a Hydrolab Surveyor II water quality meter in September 2005 and April 2006. Water quality parameters were measured at approximately 0.5 m (1.6 feet) below the surface and 0.5 m (1.6 feet) above the bottom. The secchi depth was measured at all stations during both seasons.

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

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

Large organisms were identified to the lowest practical taxon using a stereo dissecting microscope. The number of specimens for each taxon collected in each replicate is presented in the Tables 22 and 23. Members of the insect family Chironomidae were identified using methods similar to Llanso (2002). Where applicable, chironomids were slide mounted and identified to the lowest practical taxon using a binocular compound microscope. In cases where an animal was fragmented, only the head portion was counted as an individual taxon. All other body fragments were discarded. Individuals of the most common clam species (*Rangia cuneata*, *Macoma balthica*, and *Macoma mitchelli*) were measured to the nearest millimeter.

Ten main measures of benthic community condition were examined, including: total infaunal abundance, relative abundance of pollution-indicative infaunal taxa, relative abundance of pollution-sensitive infaunal taxa, the Shannon-Wiener diversity index, taxa richness, and total abundance of all taxa (excluding Nematoda and Bryozoa). Three of these measures (total infaunal abundance, relative abundance of pollution-indicative infaunal taxa, and the Shannon-Wiener diversity index) were used to calculate the Chesapeake B-IBI for September 2005. The B-IBI is a multi-metric index of biotic integrity used to determine if benthic populations in different areas of the Chesapeake Bay are stressed (Llanso 2002). The B-IBI has not been calibrated for periods outside the summer index period (July 15 through September 30) and, thus, was not used with the April 2006 data. In addition to the above metrics, we examined the numerically dominant taxa during each season and the length frequency distributions of the three most common clams (*R. cuneata*, *M. balthica*, and *M. mitchelli*).

Abundance measures were calculated based on the average abundance of each taxon from the three replicate samples collected at each station. Total abundance was calculated as the average abundance of epifaunal and infaunal organisms per square meter (#/m^2), excluding Bryozoa, which are colonial. Qualitative estimates (i.e., rare, common, or abundant) of the number of live bryozoan zooids are included in the *Year 24 Data Report* (MDE Year 24 in review). Total Infaunal Abundance was calculated as the average abundance of infaunal organisms per square meter (#/m^2). Two different measures of total abundance were calculated because epifaunal organisms are not included in the calculation of the B-IBI (Ranasinghe et al. 1994).

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

To evaluate the numerical similarity of the infaunal abundances among the 20 stations, a single-linkage cluster analysis was performed on an Euclidean distance matrix comprised of station infaunal abundance values for all 20 stations. This analysis was performed separately for September 2005 and April 2006 data. Friedman's nonparametric test was used to analyze the differences of the 10 most abundant infaunal species among the Nearfield, Reference, Back River/Hawk Cove, and South Cell Restoration Baseline stations for both September 2005 and April 2006. The statistical analyses were performed using Statistica, Version 6.0.

RESULTS AND DISCUSSION

Water Quality

Minimal variations between surface and bottom values for salinity, temperature, dissolved oxygen, conductivity, and pH values, indicated no water column stratification. Secchi depths were greater in September 2005 (Table 7, range=0.6 m-1.6 m, average = 1.16m ± 0.26m) than those in April 2006 (Table 9, range=0.40m-0.70m, average=0.56m ± 0.13m). Station MDE-36 had the shallowest Secchi depth (0.4 m) in April 2006. Secchi depth measurements provide a snapshot of the conditions prevalent at the time of sampling, but do not necessarily reflect the dominant water clarity conditions for the entire season.

The following discussion will be limited to bottom values for the first four parameters because bottom water quality measurements are most relevant to benthic macroinvertebrate health. In Year 24, bottom water temperatures did not vary much between stations during both sampling seasons. The September 2005 bottom water temperatures in Year 24 (Table 7, range= 24.43 °C – 25.28 °C, average=24.91°C ± 0.22°C) were higher than those seen at HMI in the previous five monitoring years (this might be because the other years were pretty wet, which tends to have a cooling effect on the bay). Bottom water temperatures were seasonably lower in April 2006 (Table 9) with a range of 10.58°C –11.45 °C and an average of 11.07°C ± 0.27°C. In addition, the April 2006 bottom water temperatures were lower than those recorded in April 2005.

The bottom dissolved oxygen (DO) concentrations exceeded water quality standards, as given in the Maryland Code of Regulations (COMAR), during both seasons. Year 24 bottom DO concentrations were, on average, lower than Year 23. Bottom DO concentrations were lower in September 2005 (Table 7, range=2.60 ppm-8.22ppm, average=6.94 ppm ± 1.13 ppm) than in April 2006 (Table 9, range=6.2 ppm-11.26ppm, average=9.96 ppm ± 1.06 ppm).

In September 2005, the lowest bottom DO concentration was 2.60 ppm, recorded at station MDE-19[1]. This value appears to be an outlier when compared to the bottom DO values recorded in September for all other stations, and may have been a result of instrument error or sinking the DO probe in the mud during monitoring. No facility discharge was occurring near station MDE-19 and none of the other recorded data (pH, conductivity, etc.) provide meaningful insight. The highest bottom DO concentration in September 2005 (8.22 ppm) was recorded at station MDE-27, which had a bottom temperature of (25.05°C). In April 2006, the lowest bottom DO concentration was 6.2 ppm, recorded at station MDE-43. The highest bottom DO concentration (11.26 ppm) was seen at Station MDE-27. Solubility of oxygen (and other gases) in water decreases as temperature increases, i.e., water temperature is inversely correlated with dissolved oxygen (Smith, 1996). However, the variation in bottom oxygen concentrations observed in Year 24 cannot be completely explained by the relatively minor variation recorded in bottom water temperatures.

[1] Possible anomaly that cannot be explained by the data.

This region of the Bay typically ranges between the oligohaline (0.5 ppt – 5 ppt) and mesohaline (>5ppt – 18 ppt) salinity regimes (Lippson and Lippson 1997). Most stations (20 stations in September 2005 and 19 stations in April 2006) were within the low mesohaline (>5ppt – 12 ppt) salinity regime. Station MDE-43 in April 2006 was the only exception as it fell within the oligohaline (0.5 ppt – 5 ppt) range. Bottom salinity did not vary considerably between September 2005 (Table 7, range=7.08 ppt-9.47 ppt, average=8.32 ppt ± 0.65 ppt) and April 2006 (Table 9, range=4.80 ppt-7.50 ppt, average=6.20 ppt ± 0.63 ppt).

In Year 24, in both September 2005 and in April 2006, the highest bottom salinity was seen at Reference stations (MDE-22 September 2005 – 9.47 ppt and MDE-13 April 2006 – 7.5 ppt). In September 2005 the lowest salinity was seen at station MDE-30 (7.08 ppt). These salinity values make sense with the more southerly stations, closest to the ocean influence, having a higher salinity than the stations further north and closest to freshwater flow from the Susquehanna River.

In April 2006, the lowest salinity occurred at station MDE-43 (4.8 ppt). It is expected that higher salinity values would be found in the fall and lower values in the spring. Drier conditions in the summer would result in less mixing and greater ocean influence causing higher salinity. The lower salinity in the spring is primarily due to greater influx of fresh water from snowmelt and rain. However, this does not explain the bottom salinity value recorded at station MDE-43 (4.8 ppt). Salt water is more dense than fresh therefore, it is expected that the higher salinity would be seen at the bottom and at this particular station the surface salinity (5.9 ppt) was higher than the bottom. It is possible that there was an error in recording and 4.8 ppt bottom salinity should be treated as an outlier.

Table 6: Year 24 Physical parameters measured *in situ* at all HMI stations on September 9, 2005

MDE Station	Time	Tide	Water Depth (m)	Wave Height (m)	Wind Direction	Wind Speed (knots) Min.	Max	Air Temp. (ºC)	Cloud Cover (%)	Weather Past 24 hrs.	Today	Observed Bottom Sediment (%) silt/clay	Sand	shell	gravel	detritus
MDE-01	10:40	Flood	4.3	0	N	2	3	27	0	0	0	0	60	30	0	10
MDE-03	10:51	Flood	5.6	0	N	2	3	27	0	0	0	15	70	10	0	5
MDE-07	10:23	Flood	5.8	0	N	2	3	28	0	0	0	80	0	15	0	5
MDE-09	10:04	Flood	5.8	0	W	2	3	25	0	0	0	88	0	10	0	2
MDE-13	9:23	Flood	5.0	0	W	2	3	27	0	0	0	92	0	6	0	2
MDE-16	9:51	Flood	4.5	0	W	2	3	28	0	0	0	99	0	0	0	1
MDE-17	9:35	Flood	5.2	0	W	2	3	28	0	0	0	90	0	8	0	2
MDE-19	8:50	Slack	4.9	0	W	1	2	27	0	0	0	90	0	5	0	5
MDE-22	8:07	Slack	5.3	0	W	1	2	25	0	0	0	90	8	0	0	2
MDE-24	8:41	Slack	1.7	0	W	1	2	25	0	0	0	10	85	5	0	0
MDE-27	12:32	Slack	4.0	0	N	2	3	27	0	0	0	70	0	5	0	25
MDE-28	12:21	Ebb	2.6	0	N	2	3	29	0	0	0	90	0	5	0	5
MDE-30	12:05	Ebb	3.0	0	N	2	3	30	0	0	0	27	0	70	0	3
MDE-33	11:17	Flood	2.5	0	N	2	3	27	0	0	0	9	90	0	0	1
MDE-34	11:07	Flood	2.3	0	N	2	3	27	0	0	0	9	90	0	0	1
MDE-35	11:24	Flood	3.7	0	N	2	3	31	0	0	0	80	0	15	0	5
MDE-36	11:45	Slack	3.4	0	N	2	3	28	0	0	0	85	0	10	0	5
MDE-42	8:35	Slack	5.0	0	W	1	2	25	0	0	0	93	0	4	0	3
MDE-43	9:11	Slack	4.7	0	W	1	2	25	0	0	0	90	0	8	0	2
MDE-44	9:00	Slack	4.9	0	W	1	2	28	0	0	0	70	0	5	0	25

Note: In Table 6 and 8 the code (0) in the Weather columns indicate “Clear with no clouds”.

Table 7: Year 24 Water quality parameters measured *in situ* at all HMI stations on September 9, 2005.

MDE Station	7-Digit Code	Layer	Depth (m)	Salinity (ppt)	Temp. (C)	Dissolved Oxygen (ppm)	pH	Secchi Depth (m)	Conductivity (μmos/cm)
Nearfield Stations									
MDE-01	XIF5505	Surface	0.5	8.12	24.94	7.18	7.80	1.0	14,043
		Bottom	4.26	8.21	24.91	7.18	7.92		14,190
MDE-03	XIG5699	Surface	0.5	7.96	24.65	7.52	7.86	1.5	13,797
		Bottom	5.6	8.00	24.63	7.56	8.02		13,856
MDE-07	XIF5302	Surface	0.5	7.55	24.61	8.53	8.19	1.2	13,119
		Bottom	5.84	8.13	24.83	7.07	8.08		14,044
MDE-09	XIF4806	Surface	0.5	7.70	24.59	8.03	7.89	1.4	13,346
		Bottom	5.79	8.42	24.89	6.93	8.04		14.533
MDE-16	XIF4615	Surface	0.5	7.76	24.71	7.42	7.66	1.2	13,422
		Bottom	4.55	8.85	24.98	7.05	7.73		14,580
MDE-17	XIF4285	Surface	0.45	8.18	24.66	7.46	7.73	1.4	14,134
		Bottom	5.22	8.93	25.08	7.03	7.84		15,352
MDE-19	XIF4221	Surface	0.45	7.59	24.60	7.26	7.87	1.2	13,180
		Bottom	4.98	8.70	25.12	2.60[2]	9.29		14,841
MDE-24	XIF4372	Surface	0.5	7.81	24.72	7.25	7.50	0.9	13,543
		Bottom	1.73	8.63	25.08	6.59	7.45		14,874
MDE-33	XIF6008	Surface	0.5	7.51	24.73	7.73	7.90	1.1	13,034
		Bottom	2.45	7.67	24.82	7.56	7.91		13,400
MDE-34	XIF5805	Surface	0.5	8.41	24.98	7.20	7.89	0.8	14,084
		Bottom	2.32	8.15	24.94	7.30	8.23		14,089
MDE-35	XIF6407	Surface	0.5	7.65	24.74	7.49	7.88	1.0	13,295
		Bottom	3.66	7.79	24.72	7.56	8.08		13,514
Reference Stations									
MDE-13	XIG3506	Surface	0.44	8.61	24.65	7.00	7.61	1.4	14,835
		Bottom	5.06	8.68	24.68	6.62	7.65		14,956
	XIF3224	Surface	0.5	8.72	24.77	7.07	8.00	1.4	15,018
			5.30	9.47	25.28	6.69	8.00		16,225
MDE-36	XIG7589	Surface	0.5	7.37	24.80	7.76	8.13	1.3	12,843
		Bottom	3.41	7.46	24.63	7.92	8.24		12,974
Back River/Hawk Cove Stations									
MDE-27	XIF4642	Surface	0.5	7.62	25.28	8.74	8.68	0.6	13,261
		Bottom	4.02	8.45	25.05	8.22	8.80		14,538
MDE-28	XIF5232	Surface	0.5	7.26	25.23	9.23	8.79	0.8	12,637
		Bottom	2.57	7.42	24.43	6.28	8.36		12,915
MDE-30	XIF5925	Surface	0.5	7.06	25.10	8.49	8.39		12,329
		Bottom		7.08	24.68	7.80	8.49		
South Cell Restoration Baseline Monitoring Stations									
MDE-42	XIF3879	Surface	0.5	8.19	24.62		7.90		14,123
		Bottom		8.73	25.10	6.89	8.07		
MDE-43	XIF3985	Surface	0.43	8.05	24.56	7.46	7.72	1.6	13,935
		Bottom	4.74	9.14	25.19	6.95	7.75		15,682
MDE-44	XIF4482	Surface	0.5		24.53	7.11	7.65	1.2	13,234
		Bottom	4.95	8.54	25.07	7.05	7.95		14,724

[2] Possible anomaly that cannot be explained by the data.

Table 8: Year 24 Physical parameters measured *in situ* at all HMI stations on April 7, 2006.

MDE Station	Time	Tide	Water Depth (m)	Wave Height (m)	Wind Direction	Wind Speed (knots) Min.	Wind Speed (knots) Max.	Air Temp (ºC)	Cloud Cover (%)	Weather Past 24 hrs.	Weather Today	Observed Bottom Sediment (%) silt/clay	sand	shell	gravel	detritus
MDE-01	11:08	Flood	3.9	0.5	SE	8	10	12	100	0	5	0	96	2	0	2
MDE-03	11:17	Flood	4.3	0.5	SE	8	10	12	100	0	5	68	0	30	0	2
MDE-07	10:59	Flood	6.3	0.5	SE	8	10	12	100	0	5	60	15	10	0	15
MDE-09	10:50	Flood	5.9	0.5	SE	6	8	12	100	0	5	68	0	30	0	2
MDE-13	10:19	Flood	5.3	0.5	SE	8	10	12	100	0	5	90	0	8	0	2
MDE-16	10:39	Flood	4.8	0.5	SE	8	10	12	100	0	5	78	0	20	0	2
MDE-17	10:29	Flood	5.3	0.5	SE	8	10	12	100	0	5	78	0	20	0	2
MDE-19	9:48	Flood	5.0	0.5	SE	8	10	12	100	0	5	60	5	30	0	5
MDE-22	9:06	Flood	3.5	0.5	SE	8	10	12	100	0	5	94	0	5	0	1
MDE-24	9:34	Flood	2.6	0.5	SE	8	10	12	100	0	5	3	90	5	0	2
MDE-27	12:47	Flood	4.2	0.2	SE	8	10	12	100	0	5	80	0	5	0	15
MDE-28	12:33	Flood	2.9	0.2	SE	8	10	12	100	0	5	90	0	8	0	2
MDE-30	12:22	Flood	3.5	0.5	SE	8	10	12	100	0	5	30	0	65	0	5
MDE-33	11:37	Flood	2.8	0.5	SE	8	10	12	100	0	5	0	95	5	0	0
MDE-34	11:27	Flood	3.9	0.5	SE	8	10	12	100	0	5	0	95	5	0	0
MDE-35	11:45	Flood	4.0	0.5	SE	8	10	12	100	0	5	90	0	8	0	2
MDE-36	12:00	Flood	3.7	0.5	SE	8	10	12	100	0	5	75	3	20	0	2
MDE-42	9:24	Flood	5.0	0.5	SE	8	10	12	100	0	5	60	0	30	0	10
MDE-43	10:07	Flood	5.3	0.5	SE	8	10	12	100	0	5	87	0	10	0	3
MDE-44	9:56	Flood	5.2	0.5	SE	8	10	12	100	0	5	93	0	5	0	2

NOTE: In Table 8 the code (5) in the Weather/Today column indicates “Drizzle, light rain”.

Table 9: Water quality parameters measured *in situ* at all HMI stations on April 7, 2006.

MDE Station	7-Digit Code	Layer	Depth (m)	Salinity (ppt)	Temp. (C)	Dissolved Oxygen (ppm)	pH	Secchi Depth (m)	Conductivity (µmos/cm)
Nearfield Stations									
MDE-01	XIF5505	Surface	0.5	6.05	11.23	10.60	7.96	0.5	10,625
		Bottom	3.4	6.07	11.23	10.59	7.95		10,615
MDE-03	XIG5699	Surface	0.5	5.62	10.95	10.29	7.80	0.6	9,940
		Bottom	3.8	5.7	10.90	10.15	7.80		10,203
MDE-07	XIF5302	Surface	0.5	5.76	11.00	10.24	7.80	0.6	10,181
		Bottom	5.8	5.83	11.00	9.97	7.70		10,316
MDE-09	XIF4806	Surface	0.5	5.89	11.11	10.19	7.70	0.6	10,383
		Bottom	5.4	6.19	10.70	9.24	7.66		10,928
MDE-16	XIF4615	Surface	0.5	6.04	11.10	10.54	7.85	0.6	10,650
		Bottom	4.3	6.81	10.80	9.30	7.55		11,905
MDE-17	XIF4285	Surface	0.5	5.95	10.99	10.20	7.75	0.6	10,481
		Bottom	4.75	7.20	10.68	9.30	7.50		12,570
MDE-19	XIF4221	Surface	0.5	5.80	11.08	10.30	7.80	0.6	10,215
		Bottom	4.5	6.56	11.11	10.00	7.76		11,511
MDE-24	XIF4372	Surface	0.5	6.13	11.26	10.80	8.01	0.6	10,790
		Bottom	2.07	6.10	11.25	10.78	8.01		10,772
MDE-33	XIF6008	Surface	0.5	6.20	11.40	10.66	7.91	0.6	10,895
		Bottom	2.25	6.19	11.40	10.70	8.00		10,880
MDE-34	XIF5805	Surface	0.5	6.15	11.26	10.64	7.80	0.6	10,838
		Bottom	3.38	6.19	11.30	10.62	7.95		10,864
MDE-35	XIF6407	Surface	0.5	5.75	11.01	10.30	7.70	0.6	10,137
		Bottom	3.5	5.97	11.05	9.80	7.65		10,505
Reference Stations									
MDE-13	XIG3506	Surface	0.5	6.00	10.60	10.23	7.70	0.7	10,580
		Bottom	4.8	7.50	10.58	9.33	7.56		13,027
MDE-22	XIF3224	Surface	0.5	6.00	11.13	10.47	7.81	0.65	10,690
		Bottom	3.0	6.35	11.10	10.60	7.81		10,900
MDE-36	XIG7589	Surface	0.5	5.03	11.27	10.60	7.90	0.4	8,945
		Bottom	3.23	5.03	11.27	10.50	7.80		8,929
Back River/Hawk Cove Stations									
MDE-27	XIF4642	Surface	0.5	6.01	11.63	11.37	8.35	0.5	10,705
		Bottom	3.70	6.13	11.45	11.26	7.50		10,799
MDE-28	XIF5232	Surface	0.5	6.02	11.55	11.49	8.20	0.6	10,598
		Bottom	2.44	6.25	11.41	10.16	7.80		10,954
MDE-30	XIF5925	Surface	0.5	5.97	11.38	11.06	8.03	0.6	10,518
		Bottom	3.05	5.92	11.38	10.90	8.02		10,511
South Cell Restoration Baseline Monitoring Stations									
MDE-42	XIF3879	Surface	0.5	5.87	11.00	10.37	7.80	0.6	10,325
		Bottom	4.4	6.70	11.10	10.20	7.70		11,760
MDE-43	XIF3985	Surface	0.5	5.90	10.90	10.30	7.60	0.6	10,400
		Bottom	4.77	4.80	10.70	6.20	7.11		8,575
MDE-44	XIF4482	Surface	0.5	5.78	11.03	10.28	7.70	0.6	10,207
		Bottom	4.07	6.57	10.95	9.64	7.60		11,554

Benthic Macroinvertebrate Community

Taxa Richness and Dominance

A total of 43 taxa were found over the two seasons of sampling during Year 24. This is an increase in species richness from Year 23 (38 taxa), but similar to the number of taxa observed during the five year period from Year 18 to Year 22, where Year 22 had a total of 45 taxa, Year 21 had a total of 43 taxa, Year 20 had a total of 41 taxa, Year 19 had 42 taxa, and Year 18 had 41 taxa (mean = 42.4 taxa). In terms of station type, one taxa, *Ischadium recurvum*, was found only at Silt/Clay stations and seven taxa were only found at Nearfield stations. These seven taxa were: *Balanus subalbidus*, *Euplan gracils*, *Piscola* sp., and unidentified species of Hydrozoa, Ostracoda, and Platyhelminthes. In addition, *Rhithropanopeus harrisii* primarily occurred at Nearfield stations, but was also found at one Reference station. Many of these organisms, however, are difficult to routinely capture because they are either epifaunal and/or too small to be retained on the 500-micron sieve.

The most common taxa were members of the phyla Arthropoda (joint-legged organisms), Annelida (segmented worms), and Mollusca (shellfish having two separate shells joined by a muscular hinge). Eighteen species of Arthropoda were found in the course of the study. This is less than the previous two years when twenty-three species (Year 23) and twenty species (Year 22) were found. The most common types of arthropods were the amphipods (such as *Leptocheirus plumulosus*) and the isopods (such as *C. polita*). Eight species of annelid worms in the class Polychaeta were found. This is more than the six species of polychaetes found in Years 23 and 22.

Polychaete Taxa Richness was higher (7 species) in April 2006 than in September 2005 (6 species). *Glycinde solitaria* and *Amphicteis floridus* were not found at all in Year 24, while *H. filiformis*, *Procladius* sp., Ostracoda, Platyhelminthes, and the unknown *Boccardiella* sp. were absent from the Fall samples, and *Balanus subalbidus*, *Gobiosoma bosci*, Hydrozoa, *Euplana gracilis*, and *Eteone hetereopoda* were absent in the Spring samples. *G. solitaria* has not been observed since the Year 21 sampling season. Five species of bivalve mollusks were found. Bivalve mollusk species richness was slightly higher than Year 23 (4 species) but less than that of Year 22 (6 species). Overall, bivalve mollusk average abundance was higher in April 2006 than in September 2005 (Tables 10 and 11). These interannual and interseasonal differences in taxa richness are likely a result of natural variation in salinity and spawning/recruitment typical in this dynamic region of the Chesapeake Bay.

Table 10: Average and total abundance (individuals per square meter) of each taxon found at HMI during the September 2005 sampling; by substrate and station type. Depending on site salinity, taxa in bold are pollution sensitive while taxa highlighted in gray are pollution tolerant.

Taxon	Average Abundance, All stations	Total Abundance, All stations	Average Abundance by Dominant Substrate			Average Abundance by Station Type			
			Silt/Clay	Shell	Sand	Nearfield	Ref.	Back River	South Cell Restoration Baseline
Nemata	74.9	1497.6	105.6	6.4	2.6	75.6	4.3	217.6	0.0
Carinoma tremophoros	13.8	275.2	18.7	12.8	0.0	5.8	34.1	19.2	17.1
Bivalvia	3.8	76.8	4.6	0.0	2.6	1.2	10.7	10.7	0.0
Macoma sp.	2.2	44.8	2.7	0.0	1.3	1.7	0.0	0.0	8.5
Macoma balthica	**6.4**	**128.0**	**5.9**	**44.8**	**0.0**	**1.2**	**14.9**	**14.9**	**8.5**
Macoma mitchelli	5.1	102.4	5.9	0.0	3.8	2.9	14.9	2.1	6.4
Rangia cuneata	**166.4**	**3328.0**	**179.2**	**185.6**	**126.7**	**159.4**	**290.1**	**151.5**	**83.2**
Ischadium recurvum	1.9	38.4	2.7	0.0	0.0	2.3	2.1	0.0	2.1
Mytilopsis leucophaeata	180.5	3609.6	196.6	0.0	171.5	302.0	81.1	0.0	14.9
Amphicteis floridus	0.6	12.8	0.5	0.0	1.3	0.6	2.1	0.0	0.0
Capitellidae	0.6	12.8	0.9	0.0	0.0	1.2	0.0	0.0	0.0
Heteromastus filiformis	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Spionidae	2.6	51.2	1.4	32.0	0.0	0.6	2.1	12.8	0.0
Marenzelleria viridis	**164.5**	**3289.6**	**209.4**	**140.8**	**43.5**	**154.2**	**213.3**	**155.7**	**162.1**
Streblospio benedicti	92.5	1849.6	85.5	76.8	115.2	84.9	53.3	189.9	61.9
Polydora cornuta	27.5	550.4	18.7	279.6	7.7	14.5	8.5	115.2	6.4
Boccardiella ligerica	1.6	32.0	0.9	19.2	0.0	0.6	0.0	8.5	0.0
Nereididae	27.5	550.4	33.8	0.0	15.4	33.2	36.3	0.0	25.6
Neanthes succinea	76.8	1536.0	87.3	0.0	62.7	99.5	70.4	0.0	76.8
Eteone heteropoda	20.8	416.0	18.7	0.0	30.7	24.4	23.5	10.7	14.9
Tubificidae	82.2	1644.8	107.0	51.2	19.2	34.9	70.4	270.9	78.9
Amphipoda	16.0	320.0	21.0	6.4	3.8	12.2	17.1	34.1	10.7
Ameroculodes spp complex	1.3	25.6	0.0	0.0	5.1	2.3	0.0	0.0	0.0
Leptocheirus plumulosus	99.5	1990.4	123.9	102.4	30.7	35.5	98.1	326.4	108.8
Gammarus sp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Melitadae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Melita nitida	10.6	211.2	13.7	0.0	3.8	7.6	2.1	32.0	8.5
Corophiidae	0.3	6.4	0.5	0.0	0.0	0.0	2.1	0.0	0.0
Apocorophium lacustre	15.7	313.6	13.7	6.4	23.0	23.3	12.8	2.1	4.3
Cyathura polita	**109.4**	**2188.8**	**133.0**	**38.4**	**57.6**	**102.4**	**174.9**	**59.7**	**119.5**

Table 10: Continued.

Taxon	Average Abundance, All stations	Total Abundance, All stations	Average Abundance by Substrate			Average Abundance by Station Type			
			Silt/ Clay	Shell	Sand	Nearfield	Ref.	Back River	South Cell Restoration Baseline
Edotia triloba	11.5	230.4	10.5	0.0	16.6	16.3	4.3	12.8	0.0
Chiridotea almyra	2.9	57.6	0.9	0.0	9.0	4.7	2.1	0.0	0.0
Ciripedia	0.6	12.8	0.5	0.0	1.3	1.2	0.0	0.0	0.0
Balanus improvisus	126.7	2534.4	178.3	0.0	7.7	86.7	104.5	0.0	422.4
Balanus subalbidus	0.3	6.4	0.5	0.0	0.0	0.6	0.0	0.0	0.0
Rhithropanopeus harrisii	7.7	153.6	8.7	0.0	6.4	7.6	8.5	0.0	14.9
Membranipora sp	+	+	+	0	+	+	+	+	+
Chironomidae	0.6	12.8	0.5	6.4	0.0	0.0	2.1	2.1	0.0
Coelotanypus sp.	14.1	281.6	17.4	32.0	1.3	1.7	4.3	78.9	4.3
Procladius (*Holotanypus*) sp.	0.3	6.4	0.5	0.0	0.0	0.0	2.1	0.0	0.0
Piscicola sp.	0.3	6.4	0.0	0.0	1.3	0.6	0.0	0.0	0.0
Gobiosoma bosci	0.3	6.4	0.0	0.0	1.3	0.6	0.0	0.0	0.0
Mysidicea	1.0	19.2	1.4	0.0	0.0	0.0	2.1	2.1	2.1
Unknown Mysid Shrimp	0.3	6.4	0.5	0.0	0.0	0.6	0.0	0.0	0.0
Neanthes (*Heteroneris* Form)	0.6	12.8	0.9	0.0	0.0	1.2	0.0	0.0	0.0
Euplana gracils?	0.3	6.4	0.5	0.0	0.0	0.6	0.0	0.0	0.0
Hydrozoa	0.6	12.8	0.9	0.0	0.0	1.2	0.0	0.0	0.0
Unknown sp. H	0.3	6.4	0.0	0.0	1.3	0.6	0.0	0.0	0.0
Unknown sp. G	0.6	12.8	0.0	0.0	2.6	1.2	0.0	0.0	0.0
Unknown sp. F	2.6	51.2	3.7	0.0	0.0	0.0	0.0	17.1	0.0

Table 11: Average and total abundance (individuals per square meter) of each taxon found at HMI during Year 24 Spring sampling, April 2006, by substrate and station type. Depending on salinity, taxa in bold are pollution sensitive while taxa highlighted in gray are pollution tolerant.

Taxon	Average Abundance All	Total Abundance All	Average Abundance by Dominant Substrate			Average Abundance by Station Type			
			Silt/Clay	Shell	Sand	Near-field	Ref.	Back River	South Cell Restoration Baseline
Nemata	20.8	416.0	27.3	0.0	1.6	7.6	0.0	110.9	0.0
Carinoma tremophoros	6.1	121.6	8.20	0.0	0.0	1.7	10.7	4.3	19.2
Bivalvia	35.5	710.4	41.0	70.4	6.4	8.1	14.9	172.8	19.2
Macoma sp.	0.6	12.8	0.4	0.0	1.6	1.2	0.0	0.0	0.0
Macoma balthica	**12.8**	**256.0**	**15.8**	**0.0**	**4.8**	**5.8**	**36.3**	**0.0**	**27.7**
Macoma mitchelli	4.5	89.6	6.0	0.0	0.0	0.6	8.5	8.5	10.7
Rangia cuneata	**141.1**	**2822.4**	**165.1**	**134.4**	**52.8**	**101.8**	**388.3**	**115.2**	**64.0**
Ischadium recurvum	1.9	38.4	2.6	0.0	0.0	1.7	0.0	0.0	6.4
Mytilopsis leucophaeata	51.8	1036.8	67.8	6.4	3.2	91.9	0.0	2.1	6.4
Capitellidae	2.6	51.2	2.6	0.0	3.2	2.3	0.0	0.0	8.5
Heteromastus filiformis	10.2	204.8	11.1	0.0	9.6	7.6	23.5	6.4	10.7
Spionidae	21.4	428.8	23.0	51.2	8.0	22.1	0.0	49.1	12.8
Marenzelleria viridis	**4770.9**	**95417.6**	**4034.6**	**1267.2**	**8408.0**	**6013.1**	**3895.5**	**2946.1**	**2916.3**
Steblospio benedicti	2.9	57.6	3.8	0.0	0.0	0.0	4.3	10.7	4.3
Polydora cornuta	0.6	12.8	0.4	6.4	0.0	0.6	0.0	2.1	0.0
Boccardiella ligerica	1.9	38.4	0.0	38.4	0.0	0.0	0.0	12.8	0.0
Nereididae	20.5	409.6	26.0	19.2	0.0	26.8	4.3	6.4	27.7
Neanthes succinea	47.7	953.6	57.6	57.6	8.0	54.1	32.0	23.5	64.0
Tubificidae	142.4	2848.0	159.6	76.8	94.4	77.4	76.8	497.1	91.7
Amphipoda	25.9	518.4	32.9	0.0	6.4	11.6	38.4	44.8	46.9
Gammaridea	2.9	57.6	3.8	0.0	0.0	1.2	6.4	4.3	4.3
Ameroculodes spp complex	2.9	57.6	2.6	0.0	4.8	2.3	4.3	4.3	2.1
Leptocheirus plumulosus	211.2	4224.0	260.3	12.8	76.8	75.1	398.9	392.5	341.3
Gammaridae	1.0	19.2	1.3	0.0	0.0	0.0	0.0	6.4	0.0
Gammarus sp.	5.8	115.2	6.4	6.4	3.2	6.4	8.5	2.1	4.3
Melita nitida	3.8	76.8	5.1	0.0	0.0	1.2	2.1	14.9	4.3
Corophiidae	5.1	102.4	2.6	32.0	8.0	4.7	2.1	10.7	4.3
Apocorophium lacustre	75.8	1516.8	52.1	83.2	163.2	91.3	38.4	91.7	40.5
Cyathura polita	**79.7**	**1593.6**	**93.0**	**102.4**	**24.0**	**72.7**	**81.1**	**55.5**	**128.0**
Edotia triloba	6.7	134.4	7.3	0.0	6.4	6.4	4.3	17.1	0.0
Chiridotea almyra	0.6	12.8	0.4	0.0	1.6	0.6	0.0	2.1	0.0

Table 11: Continued.

Taxon	Average Abundance All	Total Abundance All	Average Abundance by Substrate			Average Abundance by Station Type			
			Silt/ clay	Shell	Sand	Nearfield	Ref.	Back River	South Cell Restoration Baseline
Balanus improvisus	10.6	211.2	13.2	0.0	3.2	16.3	4.3	0.0	6.4
Rhithropanopeus harrisii	0.6	12.8	0.4	0.0	1.6	1.2	0.0	0.0	0.0
Membranipora sp.	+	+	+	+	+	+	+	+	+
Coelotanypus sp.	8.3	166.4	11.1	0.0	0.0	2.3	0.0	38.4	8.5
Procladius sp.	0.3	6.4	0.4	0.0	0.0	0.0	0.0	0.0	2.1
Procladius(*Holotanypus*) sp.	0.6	12.8	0.4	0.0	1.6	1.2	0.0	0.0	0.0
Copepoda	+	+	+	+	+	+	+	+	+
Unknown sp. 10	0.3	6.4	0.4	0.0	0.0	0.0	0.0	2.1	0.0
Piscola sp.?	0.6	12.8	0.9	0.0	0.0	1.2	0.0	0.0	0.0
Ostracoda	6.7	134.4	8.1	0.0	3.2	1.7	0.0	36.3	2.1
Platyhelmintes	4.5	89.6	0.9	0.0	19.2	7.0	0.0	0.0	4.3
Unknown *Boccardiella* sp.	0.3	6.4	0.4	6.4	0.0	0.0	0.0	2.1	0.0

Of the 43 taxa found in Year 24, twenty are considered truly infaunal, ten are considered epifaunal, and the remaining thirteen are considered too general to classify as either infaunal or epifaunal (Ranasinghe et al. 1994). The most common infaunal species found during Year 24 were the polychaete worm *M. viridis*, the bivalve *R. cuneata*, the amphipod *L. plumulosus*, worms from the family Tubificidae, and the isopod *C. polita*. The most common epifaunal species were the bivalve *M. leucophaeata,* the amphipod *A. lacustre,* and the barnacle *B. improvisus*.

The highest numbers of taxa found in September 2005 (19) were found at Stations MDE-01, MDE-16 and MDE-44. Eighteen taxa were found at Reference station MDE-13, 17 taxa were found at Nearfield station MDE-07, and three stations had 16 taxa; Nearfield stations MDE-17 and MDE-35, and Back River station MDE-27, (Table 12). Ten was the fewest number of taxa found in September 2005 of Year 24 and was found at Nearfield station MDE-34, (Table 12). Overall, average taxa richness was highest at the Reference stations but did not vary greatly between stations types. Average taxa richness was: Reference = 15.0 taxa, South Cell Restoration Baseline Monitoring = 14.7 taxa, Nearfield = 14.5 taxa, and Back River/Hawk Cove = 13.3).

Table 12: Summary of metrics for each HMI benthic station surveyed during the Year 24 late summer sampling cruise, September 2005. Total Infaunal Abundance and Total Abundance, excluding Polycladida, Nematoda, and Bryozoa, are individuals per square meter.

Station	Total Infauna	Total All	All Taxa	Infaunal Taxa	Shannon-Wiener	PITA	B-IBI
Nearfield Stations							
MDE-01	569.6	736.0	19	10	3.00	43.82	3.0
MDE-03	902.4	1817.6	13	8	2.69	16.31	3.7
MDE-07	1427.2	2425.6	17	9	2.85	24.22	3.0
MDE-09	864.0	2816.0	15	9	2.60	8.89	4.3
MDE-16	1254.4	1491.2	19	10	2.61	7.14	4.3
MDE-17	1011.2	1612.8	16	9	2.94	8.86	4.3
MDE-19	416.0	441.6	13	9	2.62	27.69	2.3
MDE-24	390.4	454.4	11	9	2.85	26.23	2.3
MDE-33	518.4	556.8	11	9	2.27	62.96	2.3
MDE-34	288.0	307.2	10	8	2.54	2.22	3.7
MDE-35	889.6	908.8	16	13	2.58	7.91	4.3
MEANS	**775.6**	**1233.5**	**14.5**	**9.4**	**2.69**	**21.48**	**3.4**
Reference Stations							
MDE-13	1017.6	1651.2	18	13	3.05	8.81	4.3
MDE-22	992.0	1036.8	13	11	3.02	12.26	3.67
MDE-36	1401.6	1408.0	14	12	2.42	17.81	3.0
MEANS	**1137.1**	**1365.3**	**15**	**12.0**	**2.83**	**12.96**	**3.7**
Back River/Hawk Cove Stations							
MDE-27	2297.6	2489.6	16	13	2.69	52.92	3.7
MDE-28	1068.8	1094.4	11	9	3.05	25.75	3.0
MDE-30	998.4	1004.8	13	11	3.42	16.03	3.7
MEANS	**1454.9**	**1529.6**	**13.3**	**11**	**3.05**	**31.57**	**3.4**
South Cell Restoration Baseline Monitoring Stations for South Cell							
MDE-42	550.4	569.6	13	13	3.08	25.58	3.0
MDE-43	691.2	967.6	12	11	2.98	18.52	3.7
MDE-44	1120.0	2521.6	19	13	2.99	18.86	3.7
MEANS	**787.2**	**1262.9**	**14.7**	**12.3**	**3.02**	**20.99**	**3.4**

Note: PITA is Pollution Indicative Taxa

In April 2006, the greatest taxa richness (16 taxa) occurred at Back River/Hawk Cove station MDE-28 and South Cell Baseline Monitoring stations MDE-42. Three stations had 15 taxa; Nearfield station MDE-03, Back River/Hawk Cove station MDE-27, and Reference station MDE-22. Overall, taxa richness decreased moderately from the previous year (Year 23) when 20 taxa were recorded at one station and five stations had 19 taxa. The decrease in Year 24 taxa richness may be related to the return of more "normal" lower mesohaline salinities in this part of the Bay; in Year 23, HMI waters were dominated by somewhat atypical tidal fresh conditions, which may have stimulated diversity. The lowest taxa richness (7 taxa) from spring sampling was recorded at Nearfield stations MDE-17 and MDE-33. Overall, the average taxa richness was highest at the South Cell Restoration Baseline Monitoring Stations, and lowest at Nearfield stations (average taxa richness: Nearfield = 11.4 taxa, Reference = 13.0 taxa, Back River/Hawk Cove = 14.0 taxa, South Cell Restoration Baseline Monitoring Stations=14.7 taxa).

Table 13: Summary of metrics for each HMI benthic station surveyed during the Year 24 Spring sampling cruise, April 2006. Total Infaunal Abundance and Total Abundance, excluding Polycladida, Nematoda, and Bryozoa, are individuals per square meter.

Station	Total Infauna	Total All	All Taxa	Taxa	Shannon-Wiener	PITA
Nearfield Stations						
MDE-01	3584	3654.4	9	7	0.14	0.18
MDE-03	9574.4	9868.8	15	9	0.39	1.07
MDE-07	4742.4	4844.8	12	8	0.72	1.75
MDE-09	5696	6156.8	11	8	0.64	1.01
MDE-16	4972.8	5574.4	13	7	1.13	1.42
MDE-17	2803.2	2809.6	7	6	1.12	1.37
MDE-19	5830.4	6016	14	10	0.88	2.31
MDE-24	8339.2	8627.2	13	9	0.45	1.84
MDE-33	11008	11065.6	7	6	0.12	0.17
MDE-34	11884.8	12269	13	8	0.35	1.78
MDE-35	2899.2	2969.6	11	9	1.08	0.88
MEANS	**6484.9**	**6714.2**	**11.4**	**7.9**	**0.64**	**1.25**
Reference Stations						
MDE-13	2131.2	2169.6	13	11	1.11	1.50
MDE-22	2796.8	2848	15	12	2.24	5.49
MDE-36	10124.8	10233.6	11	9	0.72	0.57
MEANS	**5017.6**	**5083.7**	**13.0**	**10.7**	**1.4**	**2.52**
Back River/Hawk Cove Stations						
MDE-27	7001.6	7321.6	15	11	1.52	18.19
MDE-28	3923.2	4454.4	16	12	1.58	7.34
MDE-30	1772.8	1971.2	11	9	1.67	4.33
MEANS	**4232.5**	**4582.4**	**14.0**	**10.7**	**1.59**	**9.95**
South Cell Restoration Baseline Monitoring Stations for South Cell						
MDE-42	3334.4	3443.2	16	13	1.80	4.03
MDE-43	3712	3776	14	11	1.41	4.83
MDE-44	4313.6	4442	14	10	0.95	0.74
MEANS	**3786.7**	**3887.1**	**14.7**	**11.3**	**1.39**	**3.20**

Note: PITA is Pollution Indicative Taxa

Since the first benthic survey studies of the Hart-Miller Island area in 1981, a small number of taxa have been dominant. Year 24 was no exception. During both seasons, 7 taxa were consistently dominant: the bivalve mollusks *R. cuneata* and *M. leucophaeata*, the isopod *C. polita*, the polychaete worms *M. viridis* and *N. succinea*, the amphipod *Leptocheirus plumulosus*, and oligochaete worms of the family Tubificidae. The average abundance of these taxa was among the top ten most abundant during both seasons of Year 24. Three other taxa were among the top ten most abundant in one season: *S. benedicti* and *B. improvisus* in September 2005, and *A. lacustre* in April 2006. The average abundance of each taxon (individuals per square meter) found at each station during September 2005 and April 2006 are provided in Tables 14 through 17.

Table 14: Average number of individuals collected per square meter at each station during the HMI Year 24 late summer sampling, September 2005, stations MDE-1 to MDE-22. Depending on salinity, taxa in bold are pollution sensitive while taxa highlighted in gray are pollution tolerant.

Taxon	Station								
	MDE-1	MDE-3	MDE-7	MDE-9	MDE-13	MDE-16	MDE-17	MDE-19	MDE-22
Nemata	6.4	0	0	0	0	0	0	6.4	0
Carinoma tremophoros	0	0	0	6.4	32.0	19.2	12.8	6.4	57.6
Bivalvia	0	0	0	0	0	0	0	0	32.0
Macoma sp.	0	0	0	0	0	0	0	6.4	0
Macoma balthica	**0**	**0**	**0**	**6.4**	**0**	**6.4**	**0**	**0**	**44.8**
Macoma mitchelli	6.4	0	0	0	12.8	0	0	0	32.0
Rangia cuneata	**96**	**243.2**	**76.8**	**300.8**	**179.2**	**128**	**198.4**	**57.6**	**96**
Ischadium recurvum	0	0	12.8	0	6.4	6.4	6.4	0	0
Mytilopsis leucophaeata	6.4	851.2	416.0	1638.4	243.2	51.2	358.4	0	0
Amphicteis floridus	0	0	0	0	0	0	0	0	0
Capitellidae	0	0	0	0	0	12.8	0	0	0
Heteromastus filiformis	0	0	0	0	0	0	0	0	0
Spionidae	0	0	0	0	6.4	6.4	0	0	0
Marenzelleria viridis	**51.2**	**128**	**480.0**	**89.6**	**147.2**	**499.2**	**166.4**	**12.8**	**108.8**
Streblospio benedicti	172.8	76.8	147.2	38.4	12.8	44.8	44.8	51.2	12.8
Polydora cornuta	32	0	6.4	0	19.2	19.2	38.4	0	0
Boccardiella ligerica	0	0	0	0	0	0	0	0	0
Nereididae	25.6	44.8	96	83.2	102.4	83.2	25.6	0	0
Neanthes succinea	51.2	224	204.8	179.2	160	179.2	211.2	0	12.8
Eteone heteropoda	19.2	38.4	57.6	6.4	12.8	19.2	19.2	0	0
Tubificidae	57.6	25.6	140.8	32	64	12.8	25.6	57.6	102.4
Amphipoda	0	0	0	0	0	6.4	83.2	12.8	51.2
Ameroculodes spp complex	0	0	0	0	0	0	0	0	0
Leptocheirus plumulosus	12.8	0	57.6	0	19.2	0	0	160	262.4
Gammarus sp.	0	0	0	0	0	0	0	0	0

Table 14: Continued.

Taxon	Station								
	MDE-1	MDE-3	MDE-7	MDE-9	MDE-13	MDE-16	MDE-17	MDE-19	MDE-22
Melitadae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Melita nitida	19.2	0.0	38.4	0.0	0.0	6.4	6.4	6.4	6.4
Corophiidae	0.0	0.0	0.0	0.0	6.4	0.0	0.0	0.0	0.0
Apocorophium lacustre	70.4	6.4	25.6	51.2	38.4	19.2	38.4	0.0	0.0
Cyathura polita	**44.8**	**115.2**	**160.0**	**121.6**	**236.8**	**230.4**	**185.6**	**44.8**	**204.8**
Edotia triloba	32	6.4	12.8	57.6	0.0	12.8	12.8	0.0	6.4
Chiridotea almyra	0.0	0.0	0.0	0.0	6.4	0.0	0.0	6.4	0.0
Ciripedia	6.4	0.0	0.0	0.0	0.0	6.4	0.0	0.0	0.0
Balanus improvisus	0.0	38.4	454.4	192	313.6	102.4	166.4	0.0	0.0
Balanus subalbidus	0.0	0.0	6.4	0.0	0.0	0.0	0.0	0.0	0.0
Rhithropanopeus harrisii	19.2	12.8	32	6.4	25.6	6.4	6.4	0.0	0.0
Membranipora sp.	+	+	+	0	+	+	+	+	+
Chironomidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Coelotanypus sp.	0.0	6.4	0.0	0.0	0.0	0.0	0.0	6.4	0.0
Procladius (*Holotanypus*) sp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.4
Piscicola sp.	6.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gobiosoma bosci	6.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mysidicea	0.0	0.0	0.0	0.0	6.4	0.0	0.0	0.0	0.0
Unknown Mysid Shrimp	0.0	0.0	0.0	6.4	0.0	0.0	0.0	0.0	0.0
Neanthes (*Heteroneris* Form)	0.0	0.0	0.0	0.0	0.0	12.8	0.0	0.0	0.0
Euplana gracils?	0.0	0.0	0.0	0.0	0.0	0.0	6.4	0.0	0.0
Hydrozoa	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.8	0.0
Unknown sp. H	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Unknown sp. G	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Unknown sp. F	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

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

Table 15: Average number of individuals collected per square meter at each station during the HMI Year 24 late summer sampling, September 2005, stations MDE-24 to MDE-44. Depending on salinity, taxa in bold are pollution sensitive while taxa highlighted in gray are pollution tolerant.

Taxon	Station										
	MDE-24	MDE-27	MDE-28		MDE-33	MDE-34	MDE-35	MDE-36	MDE-42	MDE-43	MDE-44
Nemata	0.0	512.0	134.4	6.4	0.0	6.4	812.8	12.8	0.0	0.0	0.0
Carinoma tremophoros	0.0	25.6	19.2	12.8	0.0	0.0	19.2	12.8	6.4	12.8	32.0
Bivalvia	6.4	25.6	6.4	0.0	6.4	0.0	0.0	0.0	0.0	0.0	0.0
Macoma sp.	0.0	0.0	0.0	0.0	0.0	6.4	6.4	0.0	19.2	0.0	**6.4**
Macoma balthica	**0.0**	**0.0**	**0.0**	**44.8**	**0.0**	**0.0**	**0.0**	**0.0**	**12.8**	**6.4**	**6.4**
Macoma mitchelli	6.4	6.4	0.0	0.0	0.0	6.4	12.8	0.0	6.4	12.8	0.0
Rangia cuneata	**89.6**	**121.6**	**147.2**	**185.6**	**96.0**	**108.8**	**358.4**	**595.2**	**76.8**	**140.8**	**32.0**
Ischadium recurvum	0.0	0.0	0.0	0.0	00	0.0	0.0	0.0	0.0	0.0	6.4
Mytilopsis leucophaeata	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.4	38.4
Amphicteis floridus	6.4	0.0	0.0	0.0	0.0	0.0	0.0	6.4	0.0	0.0	0.0
Capitellidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Heteromastus filiformis	0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0
Spionidae	0.0	0.0	6.4	32.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Marenzelleria viridis	**19.2**	**172.8**	**153.6**	**140.8**	**12.8**	**6.4**	**230.4**	**384.0**	**44.8**	**134.4**	**307.2**
Streblospio benedicti	83.2	320.0	172.8	76.8	243.2	0.0	32.0	134.4	32.0	38.4	115.2
Polydora cornuta	0.0	19.2	76.8	249.6	6.4	0.0	57.6	6.4	6.4	0.0	12.8
Boccardiella ligerica	0.0	6.4	0.0	19.2	0.0	0.0	6.4	0.0	0.0	0.0	0.0
Nereididae	6.4	0.0	0.0	0.0	0.0	0.0	0.0	6.4	0.0	0.0	76.8
Neanthes succinea	19.2	0.0	0.0	0.0	19.2	0.0	6.4	38.4	12.8	6.4	211.2
Eteone heteropoda	19.2	32.0	0.0		76.8	0.0	12.8	57.6	19.2	19.2	6.4
Tubificidae		723.2		51.2		6.4	19.2	44.8		70.4	83.2
Amphipoda	12.8	25.6	70.4	6.4	0.0	6.4	12.8	0.0	12.8	19.2	0.0
Ameroculodes spp complex	0.0	0.0	0.0	0.0	0.0	25.6	0	0.0	0.0	0.0	0.0
Leptocheirus plumulosus	96	620.8	256.0	102.4	0.0		19.2	12.8	160.0	102.4	64.0
Gammarus sp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Melitadae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Melita nitida	0.0	96.0	0.0	0.0	0.0	0.0	6.4	0.0	0.0	0.0	25.6
Corophiidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 15: Continued

Taxon	Station										
	MDE-24	MDE-27	MDE-28	MDE-30	MDE-33	MDE-34	MDE-35	MDE-36	MDE-42	MDE-43	MDE-44
Apocorophium lacustre	6.4	0.0	0.0	6.4	19.2	12.8	6.4	0.0	0.0	0.0	12.8
Cyathura polita	**32**	**76.8**	**64.0**	**38.4**	**44.8**	**51.2**	**96.0**	**83.2**	**70.4**	**128.0**	**160.0**
Edotia triloba	32	19.2	19.2	0.0	12.8	0.0	0.0	6.4	0.0	0.0	0.0
Chiridotea almyra	0.0	0.0	0.0	0.0	12.8	32.0	0.0	0.0	0.0	0.0	0.0
Ciripedia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Balanus improvisus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1297.2
Balanus subalbidus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rhithropanopeus harrisii	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	44.8
Membranipora sp.	0	+	0	0	+	0	+	+	+	+	+
Chironomidae	0.0	0.0	0.0	6.4	0.0	0.0	0.0	6.4	0.0	0.0	
Coelotanypus sp.	0.0	140.8	64.0	32	0.0	0.0	6.4	12.8	6.4	0.0	6.4
Procladius (*Holotanypus*) sp.	0.0	0.0	0.0	0.0	0.	0.0		0.0	0.0	0.0	0.0
Piscicola sp.	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0	0.0
Gobiosoma bosci	0.0	0.0		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mysidicea		6.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.4
Unknown Mysid Shrimp	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Neanthes (*Heteroneris* Form)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0	0.0
Euplana gracils?	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0
Hydrozoa	0.0		0.0		0.0	0.0	0.0	0.0	0.0	0.0	0.0
Unknown sp. H		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Unknown sp. G	12.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0
Unknown sp. F	0.0	51.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

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

Table 16: Average number of individuals collected per square meter at each station during the HMI Year 24 spring sampling, April 2006, stations MDE-1 to MDE-22. Depending on salinity, taxa in bold are pollution sensitive while taxa highlighted in gray are pollution tolerant.

Taxon	Station								
	MDE-1	MDE-3	MDE-7	MDE-9	MDE-13	MDE-16	MDE-17	MDE-19	MDE-22
Nemata	6.4	0	0	0	0	0	0	6.4	0
Carinoma tremophoros	0	0	6.4	6.4	0	0	0	0	25.6
Bivalvia	6.4	6.4	6.4	0	6.4	0	0	0	32
Macoma sp.	6.4	0	0	0	0	0	0	6.4	0
Macoma balthica	**6.4**	**0**	**19.2**	**6.4**	**12.8**	**6.4**	**0**	**12.8**	**83.2**
Macoma mitchelli	0	0	0	0	6.4	0	0	0	19.2
Rangia cuneata	**19.2**	**108.8**	**70.4**	**166.4**	**76.8**	**179.2**	**121.6**	**32**	**12.8**
Ischadium recurvum	0	6.4	0	0	0	6.4	6.4	0	0
Mytilopsis leucophaeata	0	243.2	38.4	416	0	300.8	0	0	0
Capitellidae	0	0	0	0	0	0	0	12.8	0
Heteromastus filiformis	6.4	6.4	0	0	12.8	6.4	0	32	57.6
Spionidae	0	0	76.8	12.8	0	38.4	12.8	51.2	0
Marenzelleria viridis	**3532.8**	**9126.4**	**4294.4**	**5203.2**	**1785.6**	**4076.8**	**2304**	**5152**	**1113.6**
Steblospio benedicti	0	0	0	0	0	0	0	0	12.8
Polydora cornuta	0	0	0	6.4	0	0	0	0	0
Boccardiella ligerica	0	0	0	0	0	0	0	0	0
Nereididae	0	12.8	0	57.6	6.4	172.8	38.4	12.8	0
Neanthes succinea	0	102.4	25.6	57.6	19.2	243.2	134.4	0	44.8
Tubificidae	6.4	96	83.2	57.6	32	70.4	38.4	108.8	140.8
Amphipoda	0	19.2	19.2	0	0	0	0	57.6	108.8
Gammaridea	0	0	0	0	0	0	0	12.8	19.2
Ameroculodes spp complex	6.4	6.4	0	0	6.4	0	0	0	6.4
Leptocheirus plumulosus	6.4	0	89.6	0	83.2	0	51.2	179.2	1056
Gammaridae	0	0	0	0	0	0	0	0	0
Gammarus sp.	0	6.4	0	0	19.2	0	0	51.2	0
Melita nitida	0	0	6.4	0	0	6.4	0	0	6.4
Corophiidae	0	0	0	6.4	0	12.8	0	0	0
Apocorophium lacustre	57.6	6.4	12.8	32	19.2	128	0	153.6	6.4
Cyathura polita	**0**	**83.2**	**57.6**	**121.6**	**70.4**	**179.2**	**102.4**	**115.2**	**96**
Edotia triloba	0	0	38.4	0	0	0	0	6.4	6.4
Chiridotea almyra	0	0	0	0	0	0	0	0	0
Balanus improvisus	0	19.2	0	6.4	12.8	140.8	0	0	0
Rhithropanopeus harrisii	0	6.4	0	0	0	0	0	0	0
Membranipora sp.	0	+	+	+	0	+	+	+	0
Coelotanypus sp.	0	6.4	0	0	0	0	0	12.8	0
Procladius sp.	0	0	0	0	0	0	0	0	0
Procladius (*Holotanypus*) sp.	0	0	0	0	0	0	0	0	0
Copepoda	+	+	+	+	0	+	+	+	+

Table 16: Continued

Taxon	Station								
	MDE-1	MDE-3	MDE-7	MDE-9	MDE-13	MDE-16	MDE-17	MDE-19	MDE-22
Unknown sp. 10	0	0	0	0	0	0	0	0	0
Piscola sp. ?	0	6.4	0	0	0	6.4	0	0	0
Ostracoda	0	0	0	0	0	0	0	6.4	0
Platyhelmintes	0	0	0	0	0	0	0	0	0
Unknown *Boccardiella* sp.	0	0	0	0	0	0	0	0	0
Hirundinea	0	0	0	0	0	0	0	0	0

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

Table 17: Average number of individuals collected per square meter at each station during the HMI Year 24 spring sampling, April 2006, stations MDE-24 to MDE-44. Depending on salinity, taxa in bold are pollution sensitive while taxa highlighted in gray are pollution tolerant.

Taxon	Station										
	MDE-24	MDE-27	MDE-28	MDE-30	MDE-33	MDE-34	MDE-35	MDE-36	MDE-42	MDE-43	MDE-44
Nemata	0	192	140.8	0	0	0	70.4	0	0	0	0
Carinoma tremophoros	0	6.4	6.4	0	0	0	6.4	6.4	12.8	32	12.8
Bivalvia	6.4	121.6	326.4	70.4	0	12.8	51.2	6.4	57.6	0	0
Macoma sp.	0	0	0	0	0	0	0	0	0	0	0
Macoma balthica	**6.4**	**0**	**0**	**0**	**0**	**6.4**	**0**	**12.8**	**12.8**	**44.8**	**25.6**
Macoma mitchelli	0	25.6	0	0	0	0	6.4	0	32	0	0
Rangia cuneata	**19.2**	**134.4**	**76.8**	**134.4**	**57.6**	**115.2**	**230.4**	**1075.2**	**12.8**	**153.6**	**25.6**
Ischadium recurvum	0	0	0	0	0	0	0	0	0	19.2	0
Mytilopsis leucophaeata	0	0	0	6.4	0	12.8	0	0	0	0	19.2
Capitellidae	12.8	0	0	0	0	0	0	0	6.4	19.2	0
Heteromastus filiformis	32	12.8	6.4	0	0	0	0	0	19.2	0	12.8
Spionidae	0	57.6	38.4	51.2	6.4	25.6	19.2	0	25.6	0	12.8
Marenzelleria viridis	**7840**	**4755.2**	**2816**	**1267.2**	**10874**	**11385.6**	**2355.2**	**8787.2**	**2092.8**	**2912**	**3744**
Steblospio benedicti	0	25.6	6.4	0	0	0	0	0	6.4	6.4	0
Polydora cornuta	0	0	0	6.4	0		0	0	0	0	0
Boccardiella ligerica	0	0	0	38.4	0	0	0	0	0	0	0
Nereididae	0	0	0	19.2	0	0	0	6.4	0	32	51.2
Neanthes succinea	6.4	12.8	0	57.6	0	25.6	0	32	32	57.6	102.4
	140.8	1171.2	243.2	76.8	19.2	211.2	19.2		102.4	140.8	32
Amphipoda	12.8	19.2	115.2	0	12.8	0	6.4	6.4	115.2	19.2	6.4
Gammaridea	0	0	12.8	0	0	0	0	0	0	12.8	0
Ameroculodes spp complex	0	0	12.8	0	12.8	0	0	0	6.4	0	0
Leptocheirus plumulosus	243.2	684.8	480	12.8	19.2	38.4	198.4	57.6	710.4	153.6	160
Gammaridae	0	0	19.2	0	0	0	0	0	0	0	0
Gammarus sp.	0	0	0	6.4	0	12.8	0	6.4	0	0	12.8
Melita nitida	0	44.8	0	0	0	0	0	0	12.8	0	0
Corophiidae	19.2	0	0	32	6.4	6.4	0	6.4	0	0	12.8
Apocorophium lacustre	211.2	128	64	83.2	51.2	332.8	19.2	89.6	25.6	6.4	89.6
Cyathura polita	**32**	**19.2**	**44.8**	**102.4**	**0**	**64**	**44.8**	**76.8**	**134.4**	**134.4**	**115.2**
Edotia triloba	25.6	19.2	32	0	0	0	0	6.4	0	0	0
Chiridotea almyra	0	0	6.4	0	6.4	0	0	0	0	0	0
Balanus improvisus	0	0	0	0	0	12.8	0	0	0	19.2	0
Rhithropanopeus harrisii	0	0	0	0	0	6.4	0	0	0	0	0
Membranipora sp.	0	0	+	0	0	+	0	+	0	+	+
Coelotanypus sp.		76.8	38.4	0	0	0	6.4	0	19.2	6.4	0
Procladius sp.	0	0	0	0	0	0	0	0	0	6.4	0
Procladius (*Holotanypus*) sp.	6.4	0	0	0	0	0	6.4	0	0	0	0
Copepoda	0	0	+	0	0	+	0	+	0	+	+

Table 17: Continued

Taxon	Station										
	MDE-24	MDE-27	MDE-28	MDE-30	MDE-33	MDE-34	MDE-35	MDE-36		MDE-43	MDE-44
Unknown sp. 10	0	6.4	0	0	0	0	0	0	0	0	0
Piscola sp.?	0	0	0	0	0	0		0	0	0	0
Ostracoda	12.8	0	108.8	0	0	0	0	0	6.4	0	0
Platyhelmintes	38.4	0	0	0		38.4	0	0	0	0	12.8
Unknown *Boccardiella* sp.	0	0	0	6.4	0	0	0	0	0	0	0
Hirundinea	0	0	0	0	0	0	0	0	0	0	6.4

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

<u>Abundance</u>

Total infauna abundance at each sample station was lower in the late summer (September 2005) than in the spring (April 2006). This coincides with past years (excluding Year 23) and is a result of the spring recruitment of juvenile benthos into the infaunal population. In September 2005, total infauna abundance in the vicinity of HMI ranged from 288 to 2298 organisms per square meter (individuals/m^2) and averaged 933 individuals/m^2. This number does not include the Bryozoa, which are colonial epifauna and are often abundant on shell or other hard substrates. The highest total infauna abundance (2298) in September 2005 was found at the Back River/Hawk Cove station MDE-27, due primarily to large numbers of the bivalve *Rangia cuneata,* the polychaete *M. viridis,* the amphipod *L. plumulosus,* and oligocheate worms of the family Tubificidae. The lowest infauna abundance (288) in September 2005 was found at the Nearfield station MDE-34 (Table 12, Total Infauna). The average total abundance was highest at Back River/Hawk Cove stations (1,455 individuals/m^2) while the lowest total abundance (776 individuals/m^2) was found at Nearfield stations (Table 12).

In April 2006, total infauna abundance ranged from 1773 to 12307 organisms per square meter and averaged 2,739 individuals/m^2. The station with the highest infauna abundance was the Nearfield station MDE-34, due to very high numbers of the polychaete *M. viridis*. The lowest spring abundance occurred at the Nearfield station MDE-30 (Table 13). This was due in part to the low numbers of the polychaete worm *M. viridis* and worms from the family Tubificidae, which generally occurred in high numbers at other stations. The average total infauna abundance was lowest at the South Cell Restoration Baseline stations (3,787 individuals/m^2) and highest at the Nearfield stations (6,485 individuals/m^2), with the Reference (5,018 individuals/m^2) and Back River/Hawk Cove stations (4,233 individuals/m^2) stations trending in between.

Total infaunal abundance and epifaunal abundance are subsets of total abundance. Infaunal abundance excludes certain organisms that have been omitted from the calculation of the B-IBI (see *Methods*). In Year 24, total infaunal abundance was similar to total abundance, accounting for ≥75% of all organisms at most stations during both seasons. The only exceptions where infaunal abundances fell below 75% were at Nearfield stations MDE-03 (49%), MDE-07 (59%), MDE-9 (31%), MDE-17 (62%), and Reference station MDE-13 (60%) in September 2005.

Diversity

Species diversity was examined using the Shannon-Wiener diversity index, which measures diversity on a numerical scale from 0 to 4. A lower score indicates an unbalanced community dominated by only one or two species whereas a higher score suggests a balanced, diverse benthic community. Pfitzenmeyer et al. (1982) suggested that diversity, as measured by the Shannon-Wiener Diversity Index (SWDI), would be higher in the summer than the spring, when recruitment decreased and predation increased thus reducing the numbers of the dominant taxa. Diversity has often been lowest at most stations in spring (April or May) due to an increase of juveniles, especially of the dominant species (Duguay et al. 1998, Duguay et al. 1995a, Duguay et al. 1995b, Duguay 1992, Duguay 1990, Pfitzenmeyer and Tenore 1987). Diversity values for Year 24 are presented in Tables 12 & 13. In this monitoring year, on average, diversity was moderately higher in September 2005 than in April 2006. These results are different from Year 23, where diversity values were slightly higher in one season versus the other.

The Shannon-Wiener diversity Index (SWDI) values in Year 24 averaged 2.81 ± 0.22 in September 2005 and 1.00 ± 0.60 in April 2006. The lowest diversity value in September 2005 occurred at Nearfield station MDE-33 (2.27). This was due to the predominance of the amphipod *L. plumulosus*, which accounted for 40% of total infaunal abundance at this station. The highest September 2005 diversity value (3.42) occurred at Back River/Hawk Cove station MDE-30. The lowest diversity value in April 2006 occurred at Nearfield station MDE-33 (0.12); this was due to the large percentage of the polychaete worm *M. viridis* and the amphipod *L. plumulosus*, which accounted for 40% and 38%, respectively of total infaunal abundance at this station. The highest April 2006 diversity value occurred at Reference station MDE-22 (2.24). For the most part, Nearfield stations had diversity values similar to Reference stations in September 2005. However, in April 2006, diversity did not vary much among station types, due to the predominance of *M. viridis* recruitment.

Pollution Indicative Taxa Abundance

Six taxa found during the Fall sampling of Year 24 benthic monitoring were designated as “pollution-indicative” according to Alden et al. (2002). These were the Chironomids of the Genus *Coelotanypus* and *Procladius*, the polychaete worms *S. benedicti*, *E. heteropoda*, the oligochaete worms of the family Tubificidae, and worms of the family Capitellidae. Relative abundance of these taxa was calculated as a proportion of total infaunal abundance.

In Year 24, pollution indicative taxa (PITA) occurred at all station types, and the highest PITA value in the Fall occurred in Nearfield station MDE-33 and Back River station MDE-27 in the Spring. In September 2005, the relative abundance of pollution-indicative taxa (PITA) ranged from 2.2% at MDE-34 (Nearfield station) to 62.96% at MDE-33 (Nearfield station) (Tables 12 & 13, Figure 27). The average PITA for September 2005 was 21.%. In September 2005, the Nearfield stations had an average PITA of 21.5%, the Reference stations had an average of 13.0 %, and the Back River/Hawk Cove stations had an average PITA of 31.6%, and the PITA at the Baseline Monitoring stations was 21.0%. In April 2006, the PITA averaged 1.1% for Nearfield stations, 3.4% for Reference stations, 10.1% for Back River/Hawk Cove stations, and 3.5% at Baseline Monitoring stations. The Spring PITA values ranged from 0.2% at MDE-33 (Nearfield station) to 18.4% at MDE-27 (Back River/Hawk Cove station) (Tables 12 & 13, Figure 27). The average PITA was 3.3%. This low average percentage of PITA taxa may be a result of the generally heavy spring recruitment of pollution sensitive species, particularly *M. viridis*. All stations during the Fall and Spring fell under the Low Mesohaline salinity regime except MDE-43 (Oligohaline) in the Spring.

Clam Length Frequency Distribution

In September 2005, the greatest average abundance of *R. cuneata* occurred at the Reference stations, followed by the Nearfield stations, Back River/Hawk Cove stations, and the South Cell Restoration Baseline Monitoring stations. The greatest abundance of *R. cuneata* during the Fall was found in the 23-27 mm size class. In April 2006, the greatest average abundance of *R. cuneata* occurred at the Reference stations, followed by Nearfield and Back River/Hawk Cove stations respectively, with lowest abundance occurring at the South Cell Restoration Baseline Monitoring stations. The greatest abundance of *R. cuneata* found during the Spring was in the 19-23 mm size class.

In September 2005, *M. balthica* had the greatest average abundance equally at the Reference and Back River/Hawk Cove stations followed by the South Cell Restoration Baseline Monitoring stations. The Nearfield stations had the lowest average abundance of M. balthica in September 2005. The greatest abundance of *M. balthica* was found in the 21-22 mm size class. In April 2006, *M. balthica* had the greatest average abundance at the Reference stations, followed by the South Cell Restoration Baseline and Nearfield stations respectively. No *M. balthica* were found at Back River/Hawk Cove stations in April 2006. For all the stations in April 2006, *M. balthica* had its greatest abundance in the 13-14 mm size class.

The greatest average abundance of *M. mitchelli* in September 2005 was found at the Reference stations, followed the South Cell Restoration Baseline Monitoring stations, and then Nearfield and Back River/Hawk Cove stations respectively. The strongest recruitment for all station types was in the 7-8 mm size class range. In April 2006, the greatest average abundance of *M. mitchelli* was found at the South Cell Restoration Baseline Monitoring stations, followed by Back River/Hawk Cove stations, followed by the Reference, and then the Nearfield stations. The strongest recruitment for all station types was in the 7-10 mm size class range.

Benthic Index of Biotic Integrity

The Chesapeake Bay B-IBI was calculated for all stations based on September 2005 data only (see Methods and Materials). Three metrics were used to calculate the B-IBI for stations under the Low Mesohaline classification (= ≥5-12 ppt). These metrics were total infaunal abundance, the Shannon-Wiener Diversity Index (SWDI) and relative abundance of pollution-indicative taxa. The specific scoring criteria for the Low Mesohaline metrics are presented in Table 18. The B-IBI was developed as a benchmark to determine whether any given benthic sample taken from the Bay either approximates (B-IBI score = 5), deviates slightly (B-IBI score = 3), or deviates greatly (B-IBI score = 1) from conditions at the best Reference sites (Weisberg et al., 1997). A B-IBI score greater than or equal to 3.0 represents a benthic community that is not considered stressed by *in situ* environmental conditions. The 20 benthic stations studied during Year 24 were compared to this benchmark.

Overall, the B-IBI scores decreased when compared to Year 23 but were generally similar to the B-IBI scores of previous years of monitoring at Hart-Miller Island. Seventeen of the twenty stations were equal to or greater than the benchmark criteria of 3.0; only MDE-19, MDE-24 and MDE-33 (B-IBI = 2.3) failed to meet this benchmark (Table 12, Figure 28). In Year 23, 19 stations met the benchmark and 1 failed to meet it. In Year 23, the station that failed to meet the benchmark was MDE-27 (Back River/Hawk Cove). The Back River/Hawk Cove station MDE-27 also failed to meet the benchmark in Year 22.

The Reference stations had the highest average B-IBI scores at 3.67. The Back River/Hawk Cove and South Cell Restoration Baseline stations both averaged 3.44. The Nearfield stations, which had both the lowest and highest individual B-IBI scores, had the lowest average score of 3.42. For individual B-IBI scores see Table 12.

Table 18: Low Mesohaline Scoring Criteria for Measures Used in Calculating the Chesapeake Bay Benthic Index of Biological Integrity (B-IBI) in September 2005 (Weisberg et al. 1997).

Measure	Score		
	5	3	1
Shannon Diversity Index (H’)	≥ 2.5	1.7 - 2.5	< 1.7
Total Abundance (individuals per square meter)	≥ 1,500 – 2,500	500-1,500 **or** ≥ 2,500- 6,000	< 500 **or** ≥ 6,000
% Pollution-sensitive Taxa	≥ 25%	5-25%	< 5%
% Pollution-indicative Taxa	≤ 10%	10-20%	> 20%

Table 19: Oligohaline Scoring Criteria for Measures Used in Calculating the Chesapeake Bay Benthic Index of Biological Integrity (B-IBI) in September 2005 (Weisberg et al. 1997).

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

Statistical Analysis

Cluster analysis was employed in this year’s study to examine relationships among the different groups of stations based upon the numerical distribution of the numbers of species and individuals of a species. In Figures 30 and 31, the stations with faunal similarity (based on a Euclidean distance matrix comprised of station infaunal abundance values for all 20 stations), are linked by vertical connections in the dendrograms. Essentially, each station was considered to be a cluster of its own, and at each step the clusters with the shortest distance between them were combined (amalgamated) and treated as one cluster. Cluster analysis in past studies at HMI has clearly indicated a faunal response to bottom type (Pfitzenmeyer, 1985; Duguay et al, 1999). Thus, any unusual grouping of stations tends to suggest changes are occurring due to factors other than bottom type and further examinations of these stations may be warranted. Experience and familiarity with the area under study can usually help to explain the differences. However, when they cannot be explained other potential outside factors must be considered.

The dendrogram for September 2005 is presented in Figure 30, indicating a weak pattern of faunal response to sediment type. Grouping of stations was poorly articulated, i.e., there was not distinct separation of groups. Compounding the problem was the prevalence of a predominately silt/clay bottom among the stations (14 of the 20 stations). However, it was possible to identify five groups of stations based on the linkage distance, and four "outlier" stations.

Three of the identifiable groups were small and formed quickly (within 250 "linkage units"). These groups demonstrated a moderately strong response of faunal composition to bottom type, to station type, and to physical location relative to HMI. "Group 1" consisted of MDE-01 and MDE-33 and were both Nearfield stations with predominately sandy substrate. They were both located on the north end of the HMI, approximately 1000 meters apart. The second group ("Group 2") consisted of three Nearfield stations (MDE-19, MDE-24, and MDE-34) and one South Cell Baseline Monitoring station (MDE-44). MDE-19 and MDE-44 had predominately silt-clay substrate, while MDE-24 and MDE-34 were predominately sandy. MDE-19, MDE-24, and MDE-44 were all located on the southeast corner of HMI, all quite close to the island (within 100 meters). MDE-34 was at the north end of the HMI, approximately 500 meters from the facility. Stations in groups 1 and 2 generally had the lowest infaunal abundances of any other group. "Group 3" consisted of two stations with silt/clay substrate (MDE-13 and MDE-17). The former is a Reference station, and the latter is a Nearfield station. These two stations are approximately 1,400 meters apart, and are located on the southeast side of HMI. The final two distinguishable groups consisted of larger assemblages of stations. "Group 4" encompassed the stations of Group 1 and Group 2, and six other stations. In this group, four of the five stations had predominately sandy substrate (MDE-01, MDE-33, MDE-24, and MDE-34), one station that had a predominately shell substrate (MDE-30), and seven stations had predominately silt/clay substrates (MDE-19, MDE-44, MDE-22, MDE-43, MDE-42, MDE-28, and MDE-36). A mix of station types were also represented in this group: four Nearfield stations, two Reference stations, two Back River/Cove Point stations, and all three South Cell Baseline Monitoring stations. Faunal composition of Group 4 stations was also poorly related to physical location. "Group 5" consisted of four stations with predominately silt/clay substrate, and encompassed Group 3 (MDE-07, MDE-13, MDE-17, and MDE-16). This was the weakest of the identifiable Fall station groups. However, this group did show a relationship between faunal composition and bottom type, as well as between faunal composition and physical location.

The four outlier stations identified from the Fall sampling cluster analysis dendrogram were MDE-27, MDE-09, MDE-35, and MDE-03. The faunal composition from these stations was mildly (MDE-03) to moderately (MDE-27) aberrant samples, resulting in poor linkage to the faunal assemblages of the other stations. These outliers consisted of two Nearfield stations with predominately silt/clay bottom substrate (MDE-35 and MDE-09); a Nearfield station with predominately sand bottom (MDE-03); and MDE-27, a Back River/Hawk Cove station with predominately silt/clay bottom. Throughout its sampling history, MDE-27 has consistently yielded a faunal composition that deviates from the faunal composition of the majority of the other HMI stations. A common characteristic of three of the four outlier stations was a somewhat extreme PITA percentage. MDE-27 had the second highest PITA for the Fall data at 53.2 percent. MDE-09 and MDE-35 had extreme PITA percentages on the lower end (MDE-09 PITA = 9.0 percent, MDE-35 PITA = 9.4 percent). MDE-03, the weakest outlier, had a PITA percentage in the mid-range at 16.3 percent. There were also relationships between PITA percentages and the groups formed in the dendrogram. The two stations of Group 1 had very high PITA's (MDE-33 PITA = 58.6 percent, MDE-01 PITA = 43.3 percent) while the two stations Group 3 had very low PITA's (MDE-17 = 9.0 percent, MDE-13 = 9.3 percent). In addition, three of the four Group 2 stations had moderately high PITA's, while three of the four stations in Group 5 had relatively low PITA's. This analysis reveals that the groups formed in the cluster dendrogram for the Year 24 Fall sample data probably reflect other factors, like magnitude of habitat stress, which influence benthic faunal compositions. These habitat stress factors could include anthropogenic pollutants (e.g., eutrophic waters and substrate contaminants). This is likely the case for MDE-27, which was historically affected by the discharge from Back River Waste Water Treatment Plant. So there does appear to be evidence that stations more directly influenced by HMI dredge material placement activities are experiencing adverse affects to their benthic communities. However, these possible "other" habitat effects besides bottom type, including possible anthropogenic pollutants, are not as strongly associated with station faunal compositions as bottom type, and except for MDE-27, they appear intermittent on a seasonal basis, as the Year 24 Spring cluster dendrogram reveals.

The cluster analysis for April 2006 is presented in Figure 30. This dendrogram indicated a number of loosely associated groups, based on the linkage distances and linkage units required to form groups, relative to September 2005 results. In addition, there were two stations that did not fit well into any possible grouping scenario. The four most strongly associated groups were each composed of a pair of stations. In three of the four groups there was a strong relationship with bottom type: Group 2, composed of MDE-17 and MDE-35, both Nearfield stations with predominately silt clay; Group 3, composed of MDE-09 and MDE-19, also Nearfield stations with silt/clay substrate; and Group 4, composed of MDE-33 and MDE-34, two Nearfield stations with predominately sandy bottom. The faunal compositions of the fourth closely associated station pair (Group 1 – MDE-01 and MDE-44) did not correlate well with bottom type. MDE-01 is a Nearfield station that had a predominately sandy bottom, while MDE-44 is a South Cell Baseline Monitoring station, and had a predominately silt/clay bottom. Four additional groups that were distinguishable had a weaker link. Group 5 consisted of three stations with a silt/clay bottom (MDE-44, MDE-07, and MDE-16) and one station with a sand bottom (MDE-01). Group 6 was composed of six stations with a silt/clay bottom (MDE-13, MDE-17, MDE-35, MDE-28, MDE-43, and MDE-42) and the one station (MDE-30) with a sandy bottom. Group 7 was formed by the union of groups 5 and 6. Finally, Group 8 was composed of two stations with a silt/clay bottom (MDE-03 and MDE-36) and three stations with a sandy bottom (MDE-24, MDE-33, and MDE-34). This group was quite isolated in the dendrogram from the other groups, as it did not link to any other stations until 2,700 linkage units. For these four larger groups, Groups 5-8, there appeared to be a poor relationship between faunal compositions and physical location. Faunal composition relative to bottom type also weakened in these larger groups. Two stations did not link well to any of the identified groups. Back River station MDE-27 again appeared to have a somewhat unique faunal composition, similar to the September 2005 data, as did MDE-22.

The examination of PITA scores against the April 2006 dendrogram, to check for possible other potential habitat influences on faunal composition, revealed little or no relationship between the groups and this factor, except again for MDE-27, which had the highest recorded PITA score (18.4 percent) in the Spring. There was very little variation in PITA scores in the Spring, and all stations except MDE-27 had scores below 10 percent. Hence in Year 24, the cluster analyses for both Fall and Spring indicated a likely anthropogenic effect on the faunal composition at MDE-27, based on its outlier status in both seasons, and its relatively high PITA scores in both seasons. Some evidence of other habitat factors, like anthropogenic disturbance, affecting stations around HMI occurred in September 2005, but not in April 2006. Additional evidence that other factors besides bottom type were affecting station faunal compositions exists in the fact that although group membership of specific stations changed quite drastically between the two Year 24 sampling sessions, there was virtually no change in bottom type for stations between the two sampling sessions (only station MDE-03 changed in bottom type from sand in September 2005 to silt/clay in April 2006). Many of the changes from fall to spring could also be accounted for by spring recruitment/site colonization, which can result naturally patchy distributions of organisms.

Table 20: Friedman Analysis of Variance for September 2005's 10 most abundant species among; Back River/Hawk Cove, Nearfield, South Cell Restoration Baseline Monitoring, and Reference stations. ANOVA Chi Sqr. (N = 10, df = 3) = 3.79, P < 0.29.

Station Type	Average Rank	Sum of Ranks	Mean	Std. Dev.
Nearfield	2.700000	27.00000	107.1709	82.9008
Reference	2.900000	29.00000	106.8800	91.4072
Back River	2.550000	25.50000	137.3867	118.0196
South Cell Restoration Baseline	1.850000	18.50000	69.7600	79.8983

Table 21: Friedman Analysis of Variance for April, 2006's 10 most abundant species among; Back River/Hawk Cove, Nearfield, Reference stations, and South Cell Restoration Baseline Monitoring Stations. ANOVA Chi Sqr. (N = 10, df = 3) = .09, P < 0.99.

Station Type	Average rank	Sum of ranks	Mean	Std. Dev
Nearfield	2.600000	26.00000	659.0836	1881.502
Reference	2.450000	24.50000	494.7200	1204.315
Back River	2.500000	25.00000	423.4667	902.173
South Cell Restoration Baseline	2.450000	24.50000	368.0000	900.760

Friedman's nonparametric test was used to determine if a significant difference could be detected among the four station types (Nearfield, Back River, South Cell Restoration Baseline and Reference) for the fall and spring sampling data. The test indicated that there were no significant differences in the 10 most abundant infaunal species between the four station types in either season of Year 24. However, the South Cell Restoration Baseline stations had the lowest average rank in the fall, and tied for lowest rank in the spring with Reference stations. These results appear to indicate the beginning of a possible trend, which began with the Year 22 spring data when a significant Friedman's test was due to a low average rank of 1.75 for South Cell Restoration Baseline stations. These results indicate that the faunal communities of South Cell Restoration Baseline stations differ from the faunal communities of the other station types. Comparison of mean values for Shannon-Wiener diversity, PITA, total infauna, and total fauna (total all) [Tables 12 & 13] reveals that deviation of faunal communities from the South Cell Restoration Baseline stations as indicated in the Friedman's test since Year 22 is likely not due to a pollution effect. Neither mean diversity nor mean PITA indicate a trend of impairment at the South Cell Restoration Baseline stations. However, both mean total infauna and mean total all are lowest among station types for the South Cell Restoration Baseline stations in both September 2005 and April 2006. Lower faunal numbers at South Cell Restoration Baseline stations, but no evidence of impaired diversity or PITA, likely indicates the impairment is due to physical factors unique to these stations. This could include increased wave activity, turbulence, sediment instability and movement, and increased turbidity.

CONCLUSIONS AND RECOMMENDATIONS

The health of the benthic macroinvertebrate community for Year 24, as measured by the Chesapeake Bay B-IBI declined compared to previous monitoring years. Overall, scores were lower when compared to Year 23, interrupting an improving trend in B-IBI scores that had occurred over the previous 5 years of monitoring at Hart Miller Island. The B-IBI scores decreased at 17 stations, increased at one station, and did not change at 2 stations. Eighteen of the twenty stations exceeded the benchmark criteria of 3.0, while MDE-19 and MDE-24 failed to meet the benchmark. MDE-27 had a passing B-IBI in Year 24 after failing in Year 23. The BIBI scores indicated moderate differences in benthic macroinvertebrate community health between Nearfield, Reference, Back River/Hawk Cove, and South Cell Restoration Baseline sites. Friedman's nonparametric test indicated that there were no significant differences in infauna among the Reference, Nearfield, South Cell Restoration Baseline, and Back River/Hawk Cove stations. The cluster analyses indicated some distinct clustering of stations, particularly among station pairs, while larger identifiable groups of stations had weaker linkage. Comparison of PITA scores against the cluster dendrograms indicated that habitat factors other than bottom type, including anthropogenic disturbance factors, were likely influencing faunal compositions, particularly in September 2005.

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

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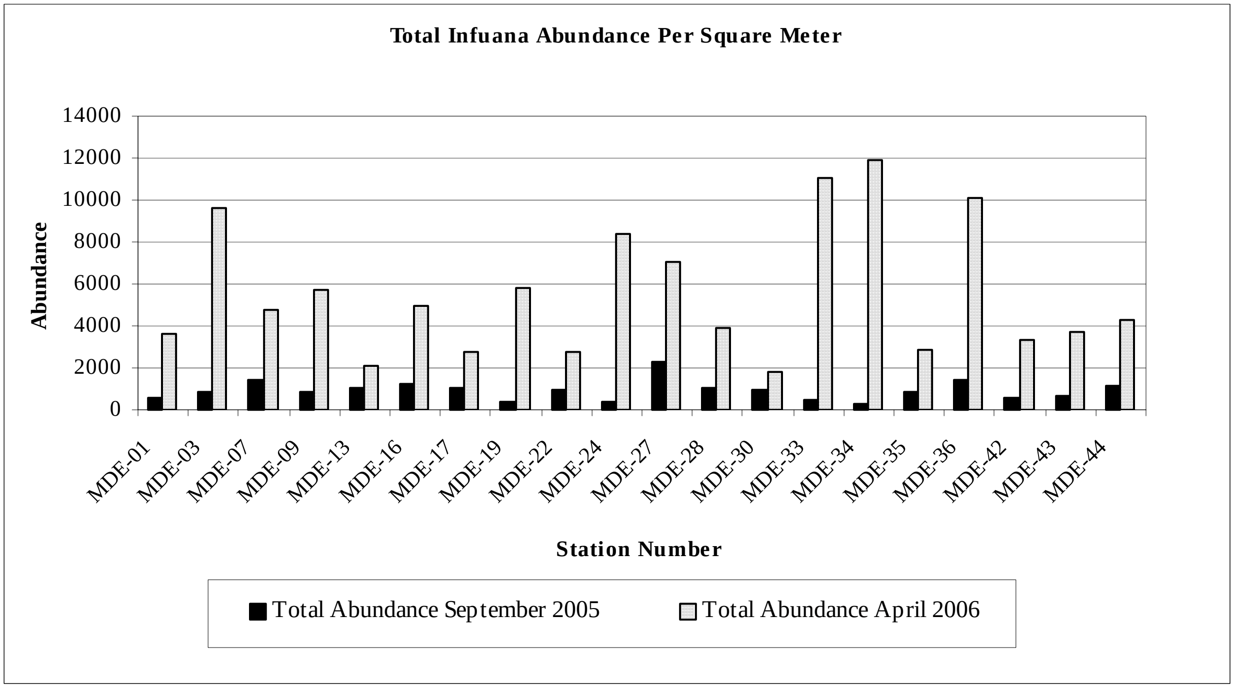

Figure 25: Total abundance of infauna taxa collected at each HMI station in Year 24, September 2005 and April 2006.

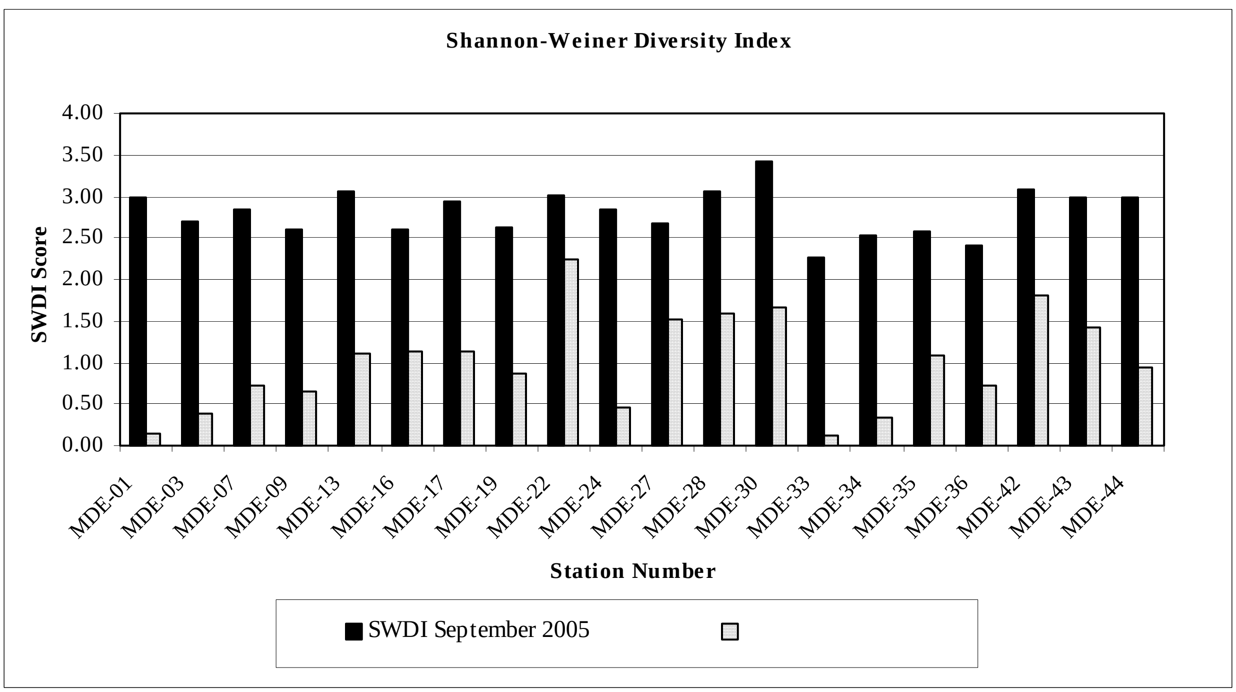

Figure 26: Shannon-Weiner Diversity Index (SWDI), HMI Year 24, September 2005 and April 2006.

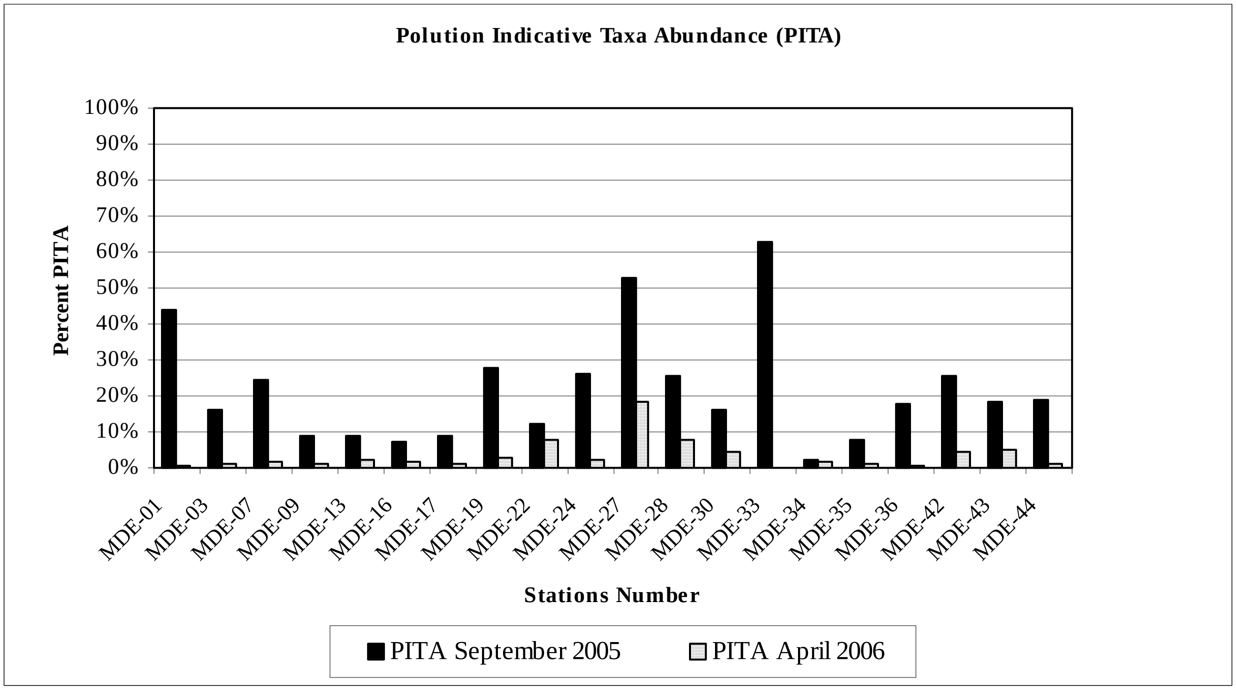

Figure 27: Percent abundance comprised of pollution indicative species (PITA), HMI year 24 September 2005 and April 2006.

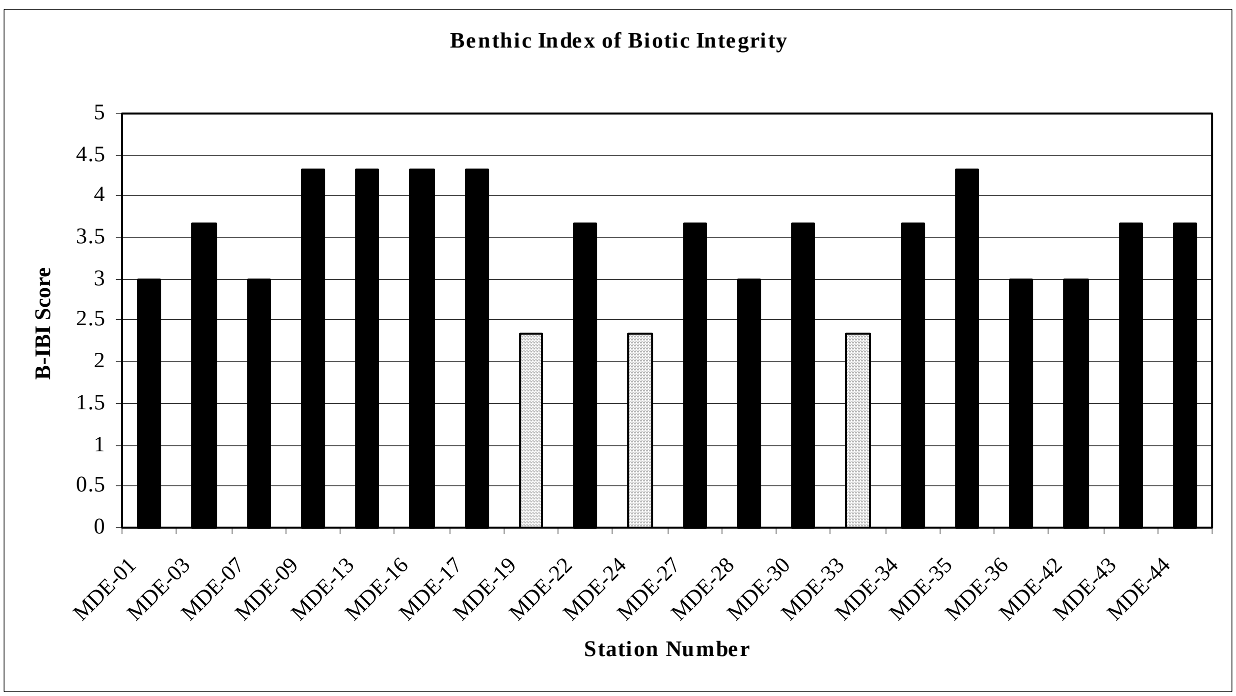

Figure 28: B-IBI Scores for all stations in September 2005.

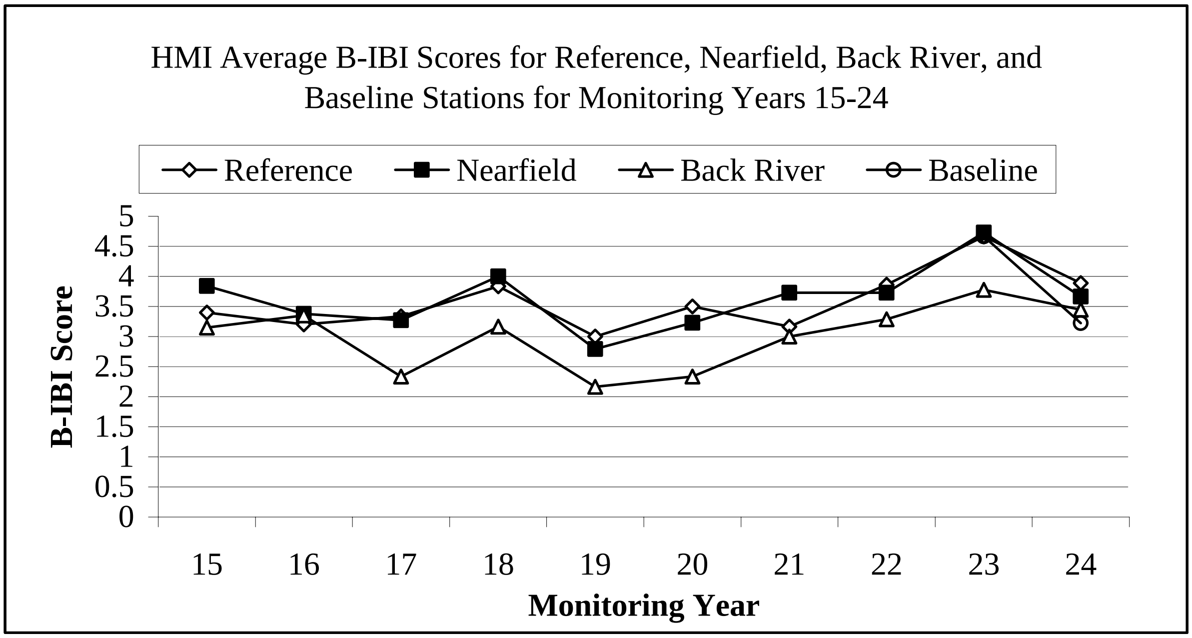

Figure 29: Average B-IBI Scores at HMI for Monitoring Years 15-24.

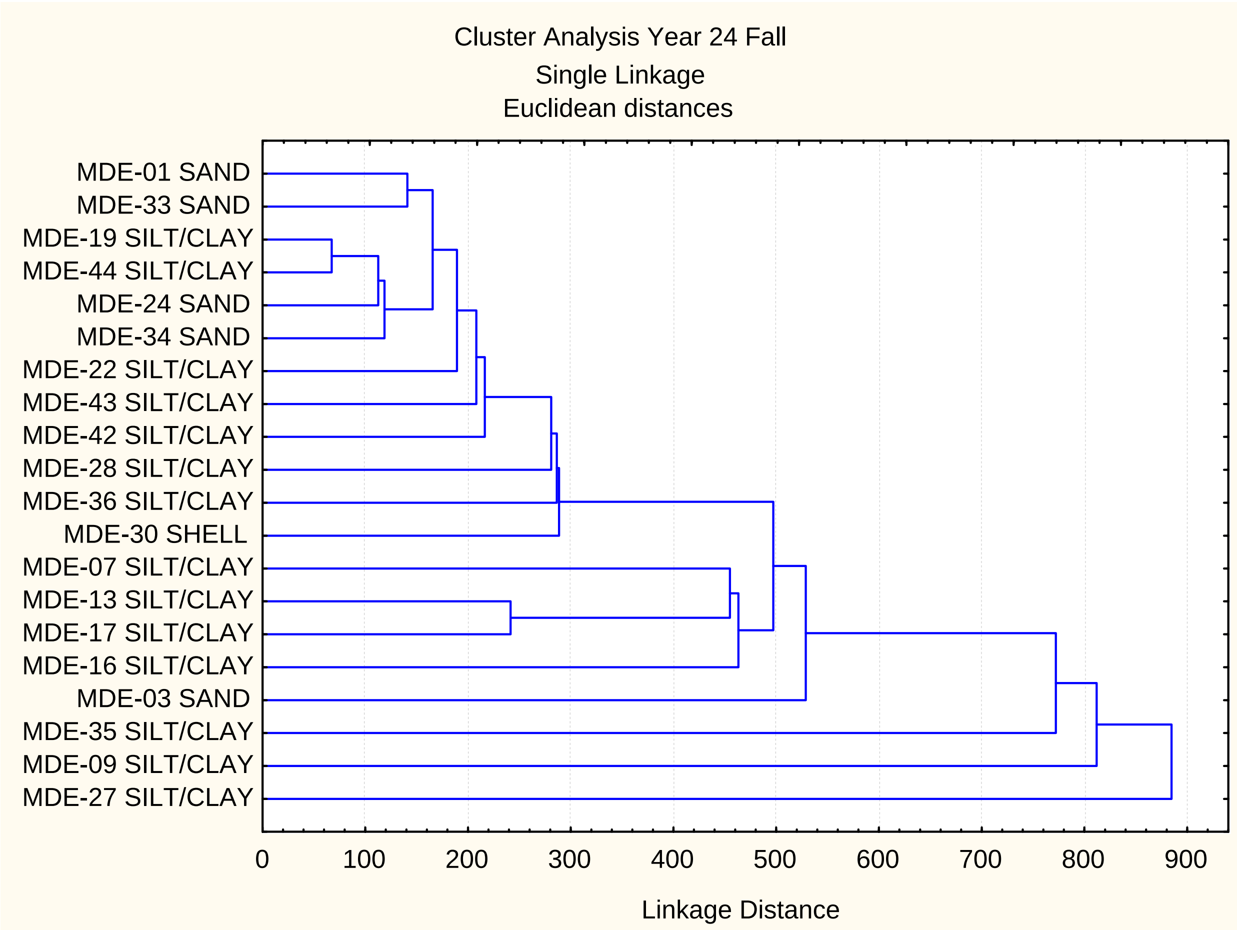

Figure 30: Cluster analysis based on Euclidean distance matrix of infaunal abundances of all HMI stations, Year 24 September 2005.

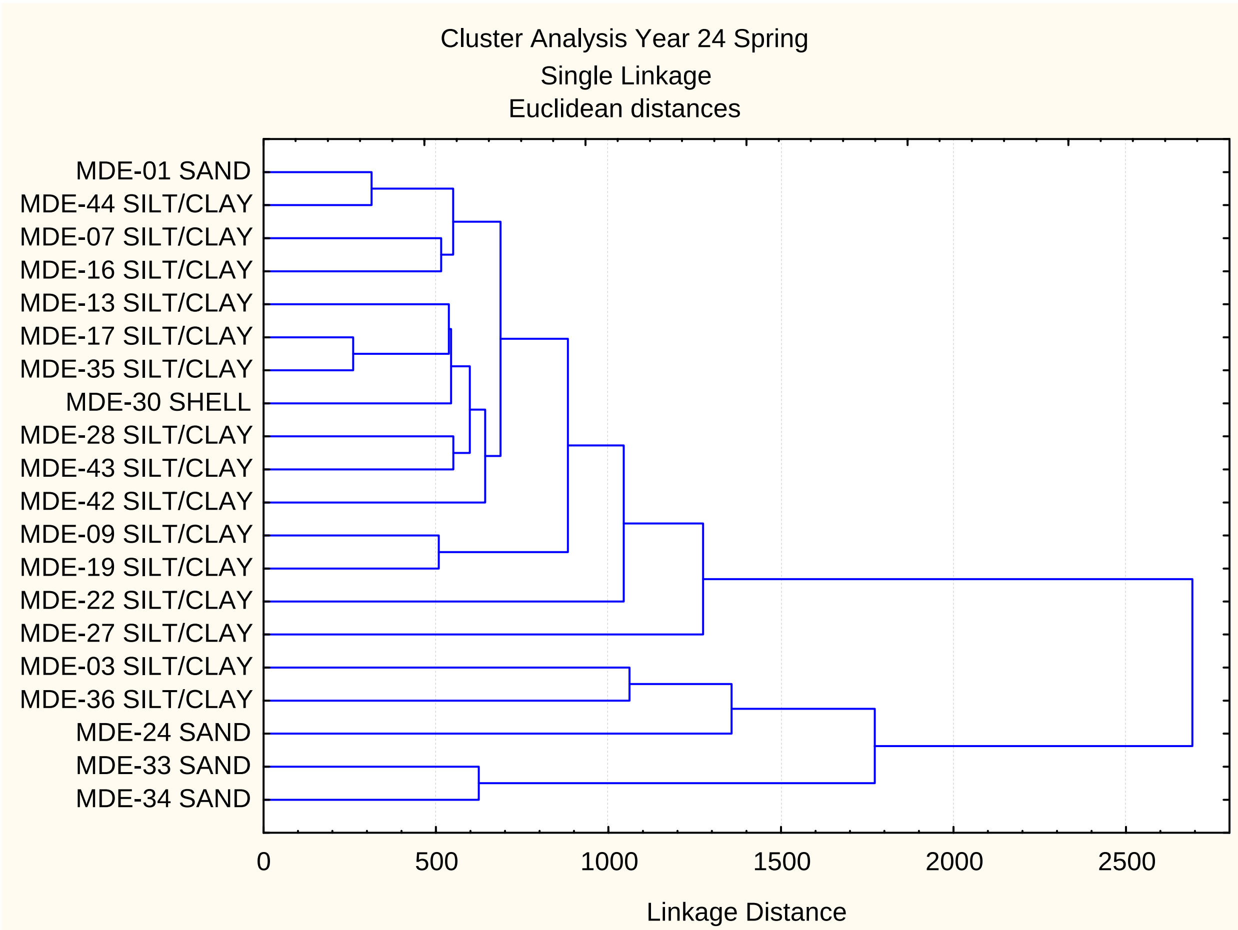

Figure 31: Cluster analysis based on Euclidean distance matrix of infaunal abundances of all HMI stations, year 24 April 2006.

Table 22: Year 24 Hart-Miller Island Benthic Organism Data, September 9, 2005. Stations MDE-1 through MDE-22. Taxa in bold are pollution sensitive while taxa highlighted in gray are pollution tolerant.

TAXON	MDE-1			MDE-3			MDE-7			MDE-9			MDE-13			MDE-16			MDE-17			MDE-19			MDE-22		
	Replicate			Replicate			Replicate			Replicate			Replicate			Replicate			Replicate			Replicate			Replicate		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Nemata	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Carinoma tremophoros	0	0	0	0	0	0	0	0	0	0	0	1	1	2	2	1	2	0	1	0	1	0	0	1	2	2	5
Bivalvia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	2	0
Macoma sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Macoma balthica	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**4**	**1**	**2**
Macoma mitchelli	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	2	3	0
Rangia cuneata	**8**	**3**	**4**	**13**	**7**	**18**	**2**	**8**	**2**	**21**	**12**	**14**	**10**	**12**	**6**	**1**	**9**	**10**	**11**	**10**	**10**	**6**	**2**	**1**	**2**	**5**	**8**
Ischadium recurvum	0	0	0	0	0	0	2	0	0	0	0	0	1	0	0	0	0	1	0	0	1	0	0	0	0	0	0
Mytilopsis leucophaeata	1	0	0	50	23	60	17	44	4	145	90	21	38	0	0	3	4	1	16	22	18	0	0	0	0	0	0
Amphicteis floridus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Capitellidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
Heteromastus filiformis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Spionidae	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Marenzelleria viridis	**4**	**1**	**3**	**8**	**4**	**8**	**5**	**10**	**60**	**5**	**8**	**1**	**14**	**2**	**7**	**36**	**37**	**5**	**3**	**4**	**19**	**0**	**1**	**1**	**1**	**7**	**9**
Streblospio benedicti	10	10	7	0	0	12	15	8	0	1	5	0	2	0	0	0	6	1	2	0	5	0	2	6	1	0	1
Polydora cornuta	0	0	5	0	0	0	1		0	0	0	0	2	1	0	0	0	3	4		2	0	0	0	0	0	0
Boccardiella ligerica	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nereididae	2	2	0	0	0	7	10	4	1	5	8	0	4	12	0	0	1	12	1	0	3	0	0	0	0	0	0
Neanthes succinea		0	8	15	3	17	17	13	2	19	8	1	11	10	4	3	3	22	14	8	11	0	0	0	1	0	1
Eteone heteropoda	2		0	2	0		4		2	0	1		2	0	0	1	2	0	0	1	2	0	0	0	0	0	0
Tubificidae	7	1	1	0	0	4	10	12	0	0	5	0	7	2	1	0	2	0		0	4	0	2	7	2	2	12
Amphipoda	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	12	2	0	0	0	7	1
Ameroculodes spp complex	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Leptocheirus plumulosus	2	0	0	0	0	0	0	0	9	0	0	0	0	0	3	0	0	0	0	0	0	8	11	6	9	15	17
Gammarus sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Melitadae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 22: Continued.

TAXON	MDE-1			MDE-3			MDE-7			MDE-9			MDE-13			MDE-16			MDE-17			MDE-19			MDE-22		
	Replicate			Replicate			Replicate			Replicate			Replicate			Replicate			Replicate			Replicate			Replicate		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Melita nitida	0	1	2	0	0	0	2	4	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	1	0	1	0
Corophiidae	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Apocorophium lacustre	2	3	6	0	0	1	1	3	0	1	7	0	4	2	0	0	3	0	6	0	0	0	0	0	0	0	0
Cyathura polita	**3**	**2**	**2**	**11**	**3**	**4**	**7**	**9**	**9**	**0**	**15**	**4**	**21**	**13**	**3**	**14**	**12**	**10**	**10**	**9**	**10**	**4**	**1**	**2**	**4**	**7**	**21**
Edotia triloba	1	3	1	0	0	1	0	0	2	8	1	0	0	0	0	1	1	0	1	0	1	0	0	0	0	1	0
Chiridotea almyra	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0
Ciripedia	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Balanus improvisus	0	0	0	0	0	6	58	12	1	13	17	0	47	2	0	3	0	13	4	15	7	0	0	0	0	0	0
Balanus subalbidus	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rhithropanopeus harrisii	0	0	3	2	0	0	3	2	0	0	1	0	3	1	0	0	0	1	0	0	1	0	0	0	0	0	0
Membranipora sp	R	0	0	R	0	R	A	C	0	0	0	0	0	A	0	R	A	A	A	C	C	0	0	R	0	R	0
Chironomidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Coelotanypus sp.	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Procladius (Holotanypus) sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Piscicola sp.	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gobiosoma bosci	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mysidicae	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unknown Mysid Shrimp	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Neanthes (*Heteroneris* Form)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0
Euplana gracils?	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Hydrozoa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
Unknown sp. H	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unknown sp. G	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unknown sp. F	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

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

Table 22: Continued.

TAXON	MDE-24			MDE-27			MDE-28			MDE-30			MDE-33			MDE-34			MDE-35			MDE-36		
	Replicate			Replicate			Replicate			Replicate			Replicate			Replicate			Replicate			Replicate		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Nemata	0	0	0	43	31	6	7	14	0	0	0	1	0	0	0	0	1	0	87	23	17	0	1	1
Carinoma tremophoros	0	0	0	1	1	2	2	0	1	0	2	0	0	0	0	0	0	0	0	3	0	0	1	1
Bivalvia	0	1	0	2	2	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Macoma sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0
Macoma balthica	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**7**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Macoma mitchelli	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0
Rangia cuneata	**5**	**7**	**2**	**10**	**6**	**3**	**11**	**6**	**6**	**0**	**11**	**18**	**9**	**3**	**3**	**3**	**14**	**0**	**24**	**19**	**13**	**28**	**30**	**35**
Ischadium recurvum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mytilopsis leucophaeata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Amphicteis floridus	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Capitellidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Heteromastus filiformis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Spionidae	0	0	0	0	0	0	1	0	0	2	1	2	0	0	0	0	0	0	0	0	0	0	0	0
Marenzelleria viridis	**1**	**1**	**1**	**14**	**3**	**10**	**3**	**11**	**10**	**3**	**9**	**10**	**0**	**0**	**2**	**0**	**0**	**1**	**13**	**13**	**10**	**35**	**17**	**8**
Streblospio benedicti	3	3	7	43	5	2	19	8	0	6	4	2	5	33	0	0	0	0	4	1	0			
Polydora cornuta	0	0	0	3		0		1	3	3	8	28	0	1	0	0	0				2	0	1	0
Boccardiella ligerica	0	0	0	1	0	0	0	0	0	1	2	0	0	0	0	0	0	0	1	0	0	0	0	0
Nereididae	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Neanthes succinea	3	0	0	0	0	0	0	0		0	0	0	0	2	1	0		0	0	0	1	3	2	1
Eteone heteropoda	1	1	1	3	1	1	0	0	0	0	0	0	2	7		0	0	0	2	0	0	1	4	4
Tubificidae	0	0	0	94	19	0	1	5	0	2	5	1		1	0	1	0	0	3	0	0	0	7	0
Amphipoda	1	0	1	2	0	2	4	5	2	0	0	1	0	0	0	0	1	0	0	2	0	0	0	0
Ameroculodes spp complex	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	1	0	0	0	0	0	0
	7	1			22	38	11	20	9	9	4	3	0	0	0	2	5	0	1	0	2	0	1	1
Gammarus sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Melitadae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 22: Continued.

TAXON	MDE-24			MDE-27			MDE-28			MDE-30			MDE-33			MDE-34			MDE-35			MDE-36		
	Replicate			Replicate			Replicate						Replicate			Replicate			Replicate			Replicate		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Melita nitida	0	0	0	4	4	7	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Corophiidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Apocorophium lacustre	1	0	0	0	0	0	0	0	0	0	1	0	3	0	0	1	0	1	1	0	0	0	0	0
Cyathura polita	**3**	**2**	**0**	**5**	**2**	**5**	**5**	**3**	**2**	**2**	**3**	**1**	**4**	**0**	**3**	**4**	**2**	**2**	**4**	**4**	**7**	**5**	**4**	**4**
Edotia triloba	3	1	1	0	3	0	1	2	0	0	0	0	0	1	1	0	0	0	0	0	0	1	0	0
Chiridotea almyra	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	4	0	0	0	0	0	0	0
Ciripedia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Balanus improvisus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Balanus subalbidus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rhithropanopeus harrisii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Membranipora sp	0	0	0	0	R	0	0	0	0	0	0	0	0	0	R	0	0	0	0	R	0	0	0	R
Chironomidae	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
Coelotanypus sp.	0	0	0	9	4	9	7	2	1	2	1	2	0	0	0	0	0	0	1	0	0	0	2	0
Procladius (Holotanypus) sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Piscicola sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gobiosoma bosci	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mysidicae	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unknown Mysid Shrimp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Neanthes (*Heteroneris* Form)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Euplana gracils?	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hydrozoa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unknown sp. H	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unknown sp. G	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unknown sp. F	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

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

Table 22: Continued.

TAXON	MDE-42			MDE-43			MDE-44		
	Replicate			Replicate			Replicate		
	1	2	3		2	3	1	2	3
Nemata	0	0	0	0	0	0	0	0	0
Carinoma tremophoros	0	1	0	0	1	1	1	0	4
Bivalvia	0	0	0	0	0	0	0	0	0
Macoma sp.	0	3	0	0	0	0	0	0	1
Macoma balthica	**1**	**0**	**1**	**0**	**1**	**0**	**1**	**0**	**0**
Macoma mitchelli	1	0	0	1	0	1	0	0	0
Rangia cuneata	**3**	**4**	**5**	**6**	**14**	**2**	**3**	**2**	**0**
Ischadium recurvum	0	0	0	0	0	0	1	0	0
Mytilopsis leucophaeata	0	0	0	1	0	0	4	2	0
Amphicteis floridus	0	0	0	0	0	0	0	0	0
Capitellidae	0	0	0	0	0	0	0	0	0
Heteromastus filiformis	0	0	0	0	0	0	0	0	0
Spionidae	0	0	0	0	0	0	0	0	0
Marenzelleria viridis	**0**	**7**	**0**	**4**	**13**	**4**	**26**	**18**	**4**
Streblospio benedicti	0	1	4	0	3	3	9	3	6
Polydora cornuta	0	0	1	0	0	0	1	1	0
Boccardiella ligerica	0	0	0	0	0	0	0	0	0
Nereididae	0	0	0	0	0	0	6	6	0
Neanthes succinea	2	0	0	0	0	1	20	13	0
Eteone heteropoda	1	1	1	0	1	2	0	0	1
Tubificidae	2	3	8	0	3	8	6	6	1
Amphipoda	1	0	1	1	0	2	0	0	0
Ameroculodes spp complex	0	0	0	0	0	0	0	0	0
Leptocheirus plumulosus	11	11	3	1	6	9	1	0	9
Gammarus sp.	0	0	0	0	0	0	0	0	0
Melitadae	0	0	0	0	0	0	0	0	0

Table 22: Continued.

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

TAXON	MDE-42			MDE-43			MDE-44		
	Replicate			Replicate					
	1	2	3	1	2	3	1	2	3
Melita nitida	0	0	0	0	0	0	4	0	0
Corophiidae	0	0	0	0	0	0	0	0	0
Apocorophium lacustre	0	0	0	0	0	0	1	1	0
Cyathura polita	**3**	**4**	**4**	**6**	**3**	**11**	**11**	**12**	**2**
Edotia triloba	0	0	0	0	0	0	0	0	0
Chiridotea almyra	0	0	0	0	0	0	0	0	0
Ciripedia	0	0	0	0	0	0	0	0	0
Balanus improvisus	0	0	0	0	0	0	113	85	0
Balanus subalbidus	0	0	0	0	0	0	0	0	0
Rhithropanopeus harrisii	0	0	0	0	0	0	6	1	0
Membranipora sp	0	R	0	C	0	R	A	R	0
Chironomidae	0	0	0	0	0	0	0	0	0
Coelotanypus sp.	1	0	0	0	0	0	0	0	
Procladius (Holotanypus) sp.	0	0	0	0	0	0	0	0	0
Piscicola sp.	0	0	0	0	0	0	0	0	0
Gobiosoma bosci	0	0	0	0	0	0	0	0	0
Mysidicae	0	0	0	0	0	0	0	1	0
Unknown Mysid Shrimp	0	0	0	0	0	0	0	0	0
Neanthes (*Heteroneris* Form)	0	0	0	0	0	0	0	0	0
Euplana gracils?	0	0	0	0	0	0	0	0	0
Hydrozoa	0	0	0	0	0	0	0	0	0
Unknown sp. H	0	0	0	0	0	0	0	0	0
Unknown sp. G	0	0	0	0	0	0	0	0	0
Unknown sp. F	0	0	0	0	0	0	0	0	0

Table 23: Year 24 Hart-Miller Island Benthic Organism Data, April 7, 2006. Stations MDE-1 through MDE-22. Taxa in bold are pollution sensitive while taxa highlighted in gray are pollution tolerant.

TAXON	MDE-1			MDE-3			MDE-7			MDE-9			MDE-13			MDE-16			MDE-17			MDE-19			MDE-22		
	Replicate			Replicate			Replicate			Replicate			Replicate			Replicate			Replicate			Replicate			Replicate		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Nemata	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Carinoma tremophoros	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	2	1	1
Bivalvia	0	0	1	0	1	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	5	0
Macoma sp.	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Macoma balthica	**0**	**1**	**0**	**0**	**0**	**0**	**3**	**0**	**0**	**0**	**0**	**1**	**1**	**1**	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**2**	**5**	**4**	**4**
Macoma mitchelli	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	1	1
Rangia cuneata	**0**	**2**	**1**	**13**	**0**	**4**	**2**	**4**	**5**	**12**	**11**	**3**	**4**	**3**	**5**	**9**	**6**	**13**	**5**	**8**	**6**	**0**	**3**	**2**	**1**	**0**	**1**
Ischadium recurvum	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0
Mytilopsis leucophaeata	0	0	0	19	13	6	0	0	6	58	7	0	0	0	0	22	0	25	0	0	0	0	0	0	0	0	0
Capitellidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
Heteromastus filiformis	0	1	0	1	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	4	1	0	1	8	0
Spionidae	0	0	0	0	0	0	12	0	0	0	2	0	0	0	0	6	0	0	0	2	0	0	0	8	0	0	0
Marenzelleria viridis	**18**	**494**	**40**	**827**	**329**	**270**	**357**	**223**	**91**	**446**	**333**	**34**	**37**	**77**	**165**	**172**	**167**	**298**	**87**	**36**	**237**	**264**	**402**	**139**	**35**	**110**	**29**
Streblospio benedicti	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0
Polydora cornuta	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Boccardiella ligerica	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nereididae	0	0	0	0	2	0	0	0	0	9	0	0	0	0	1	18	1	8	0	2	4	0	1	1	0	0	0
Neanthes succinea	0	0	0	12			2	1	1	6	3	0	1	2	0	22	4	12	8	7	6	0	0	0	3	3	1
Tubificidae	0			9	4	2	12	0	1	5	4	0	0	2	3	9	1	1	0	1	5	9	5	3	1	14	7
Amphipoda	0	0	0	2	1	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	2	3	4	12	0	5
Gammaridea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	3	0
Ameroculodes spp complex	1	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
Leptocheirus plumulosus	0	1	0	0	0	0	3	10	1	0	0	0	1	6	6			0	5	0	3	6	9	13	37	89	39
Gammaridae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gammarus sp	0	0	0	1	0	0	0	0	0	0	0	0	2	1	0	0	0	0	0	0	0	0	4	4	0	0	0
Melita nitida	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0
Corophiidae	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0

Table 23: Continued.

TAXON	MDE-1			MDE-3			MDE-7			MDE-9			MDE-13			MDE-16			MDE-17			MDE-19			MDE-22		
	Replicate			Replicate			Replicate			Replicate			Replicate			Replicate			Replicate			Replicate			Replicate		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Apocorophium lacustre	1	2	6	0	1	0	0	2	0	4	1	0	0	1	2	16	0	4	0	0	0	5	4	15	0	0	1
Cyathura polita	**0**	**0**	**0**	**7**	**2**	**4**	**6**	**0**	**3**	**11**	**6**	**2**	**4**	**4**	**3**	**9**	**9**	**10**	**6**	**3**	**7**	**6**	**6**	**6**	**10**	**3**	**2**
Edotia triloba	0	0	0	0	0	0	2	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0
Chiridotea almyra	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Balanus improvisus	0	0	0	0	0	3	0	0	0	1	0	0	2	0	0	13	0	9	0	0	0	0	0	0	0	0	0
Rhithropanopeus harrisii	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Membranipora sp	0	0	0	0	A	0	0	0	C	0	C	0	0	0	0	A	R	C	R	R	R	R	0	R	0	0	0
Coelotanypus sp.	0	0	0	1			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0
Procladius sp.	0			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Copepoda	0	R	R	0	R	0	C	0	R	R	R	0	0	0	0	R	R	0	R	0	0	R	0	R	R	R	0
Unknown sp. 10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Piscola sp.	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Ostracoda	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Platyhelmintes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unknown *Boccardiella* sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hirudinea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

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

Table 23: Continued.

TAXON	MDE-24 Replicate			MDE-27 Replicate			MDE-28 Replicate			MDE-30 Replicate			MDE-33 Replicate			MDE-34 Replicate			MDE-35 Replicate			MDE-36 Replicate		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Nemata	0	0	0	0	21	9	4	8	10	0	0	0	0	0	0	0	0	0	0	7	4	0	0	0
Carinoma tremophoros	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0
Bivalvia	0	0	1	0	17	2	0	42	9	7	1	3	0	0	0	1	1	0	5	0	3	1	0	0
Macoma sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Macoma balthica	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**2**
Macoma mitchelli	0	0	0	0	3	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Rangia cuneata	**0**	**0**	**3**	**5**	**6**	**10**	**7**	**5**	**0**	**12**	**3**	**6**	**2**	**4**	**3**	**2**	**3**	**13**	**12**	**14**	**10**	**61**	**54**	**53**
Ischadium recurvum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mytilopsis leucophaeata	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	1	0	0	0	0	0	0	0
Capitellidae	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Heteromastus filiformis	2	3	0	0	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Spionidae	0	0	0	0	9	0	0	5	1	3	0	5	0	1	0	0	4	0	3	0	0	0	0	0
Marenzelleria viridis	**265**	**769**	**191**	**99**	**357**	**287**	**249**	**124**	**67**	**80**	**58**	**60**	**710**	**337**	**652**	**659**	**784**	**336**	**163**	**70**	**135**	**462**	**389**	**522**
Streblospio benedicti	0	0	0	1	3	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Polydora cornuta	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Boccardiella ligerica	0	0	0	0	0	0	0	0	0	1	2	3	0	0	0	0	0	0	0	0	0	0	0	0
Nereididae	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	1	0	0
Neanthes succinea	0	1	0	0	1	1	0	0	0	1	8	0	0	0	0	3	0	1	0	0	0	0	2	3
Tubificidae	2	12	8	1	141	41	8	23	7	4	2	6	0	1	2	11	17	5	2	0	1	0	3	6
Amphipoda	1	1	0	0	2	1	6	4	8	0	0	0	0	0	2	0	0	0	0	1	0	0	0	1
Gammaridea	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ameroculodes spp complex	0	0	0	0	0	0	0	0	2	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0
Leptocheirus plumulosus	11	24	3	35	38	34	14	27	34	1	0	1	1	1	1	1	3	2	6	14	11	1	5	3
Gammaridae	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gammarus sp	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	2	0	0	0	0	0	1
Melita nitida	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Corophiidae	0	0	3	0	0	0	0	0	0	0	5	0	0	1	0	1	0	0	0	0	0	0	1	0

Table 23: Continued.

TAXON	MDE-24			MDE-27			MDE-28			MDE-30			MDE-33			MDE-34						MDE-36		
	Replicate			Replicate			Replicate			Replicate			Replicate			Replicate			Replicate			Replicate		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Apocorophium lacustre	22	11	0	2	8	10	6	3	1	6	4	3	3	3	2	40	2	10	1	1	1	1	4	9
Cyathura polita	**2**	**2**	**1**	**1**	**2**	**0**	**1**	**2**	**4**	**5**	**9**	**2**	**0**	**0**	**0**	**4**	**3**	**3**	**2**	**4**	**1**	**7**	**4**	**1**
Edotia triloba	2	1	1	1	1	1	1	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Chiridotea almyra	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Balanus improvisus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
Rhithropanopeus harrisii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Membranipora sp	0	0	0	0	0	0	0	R	0	0	0	0	0	0	0	C	C	0	0	0	0	0	0	R
Coelotanypus sp.	0	0	0	1	7	4	1	5	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Procladius sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Procladius (*Holotanypus*) sp.	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Copepoda	R	0	R	0	C	0	0	R	R	R	0	R	R	0	0	0	R	0	R	0	0	0	0	R
Unknown sp. 10	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Piscola sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ostracoda	2	0	0	0	0	0	17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Platyhelmintes	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0
Unknown *Boccardiella* sp.	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Hirudinea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

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

Table 23: Continued.

TAXON	MDE-42			MDE-43			MDE-44		
	Replicate			Replicate			Replicate		
	1	2	3	1	2	3	1	2	3
Nemata	0	0	0	0	0	0	0	0	0
Carinoma tremophoros	0	1	1	2	1	2	2	0	0
Bivalvia	9	0	0	0	0	0	0	0	0
Macoma sp.	0	0	0	0	0	0	0	0	0
Macoma balthica	**1**	**0**	**1**	**1**	**1**	**5**	**1**	**3**	**0**
Macoma mitchelli	3	0	2	0	0	0	0	0	0
Rangia cuneata	**0**	**1**	**1**	**8**	**6**	**10**	**1**	**0**	**3**
Ischadium recurvum	0	0	0	0	0	3	0	0	0
Mytilopsis leucophaeata	0	0	0	0	0	0	0	0	3
Capitellidae	0	1	0	0	0	3	0	0	0
Heteromastus filiformis	3	0	0	0	0	0	0	0	2
Spionidae	2	2	0	0	0	0	0	0	2
Marenzelleria viridis	**160**	**100**	**67**	**71**	**29**	**355**	**73**	**285**	**227**
Streblospio benedicti	0	1	0	0	0	1	0	0	0
Polydora cornuta	0	0	0	0	0	0	0	0	0
Boccardiella ligerica	0	0	0	0	0	0	0	0	0
Nereididae	0	0	0	0	0	5	3	0	5
Neanthes succinea	0	2	3	0	2		3	6	7
Tubificidae	9	6	1	1	2	19	2	0	3
Amphipoda	4	4	10	3	0	0	0	0	1
Gammaridea	0	0	0	0	2	0	0	0	0
Ameroculodes spp complex	1	0	0	0	0	0	0	0	0
Leptocheirus plumulosus	60	13	38	16	4	4	13	6	6
Gammaridae	0	0	0	0	0	0	0	0	0
Gammarus sp	0	0	0	0	0	0	0	2	0
Melita nitida	1	0	1	0	0	0	0	0	0
Corophiidae	0	0	0	0	0	0	0	0	2

Table 23: Continued.

	MDE-42			MDE-43			MDE-44		
	Replicate			Replicate			Replicate		
	1	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
Apocorophium lacustre	2	2	0	0	0	1	1	8	5
Cyathura polita	**6**	**8**	**7**	**7**	**7**	**7**	**6**	**7**	**5**
Edotia triloba	0	0	0	0	0	0	0	0	0
Chiridotea almyra	0	0	0	0	0	0	0	0	0
Balanus improvisus	0	0	0	0	0	3	0	0	0
Rhithropanopeus harrisii	0	0	0	0	0	0	0	0	0
Membranipora sp	0	0	0	R	0	A	C	C	C
Coelotanypus sp.	0	2	1	1	0	0	0	0	0
Procladius sp.	0	0	0	1	0	0	0	0	0
Procladius (*Holotanypus*) sp.	0	0	0	0	0	0	0	0	0
Copepoda	0	R	R	R	0	C	R	R	C
Unknown sp. 10	0	0	0	0	0	0	0	0	0
Piscola sp.	0	0	0	0	0	0	0	0	0
Ostracoda	0	0	1	0	0	0	0	0	0
Platyhelmintes	0	0	0	0	0	0	2	0	0
Unknown *Boccardiella* sp.	0	0	0	0	0	0	0	0	0
Hirudinea	0	0	0	0	0	0	0	0	1
A= Abundant (> 500/m2); C= Common (>100-500/m2); R= Rare (>1-100/m2)									

APPENDIX 3: ANALYTICAL SERVICES (PROJECT IV)

(September 2005 – October 2006)

Interpretive Report

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OBJECTIVES

The goals of the project in 2005-2006 were to continue to measure and evaluate the current levels of contaminants in the sediment in the vicinity of HMI and to relate these, as much as possible, to historical data. Continued comparison and correlation of this data with historical HMI data, will indicate the extent of contamination and any trend in concentrations at this location.

The objective of this study was to provide sensitive, high-quality information on the concentrations of present day trace metals in surface sediments surrounding HMI during the 24th year of exterior monitoring, and to document any seasonal changes. Specific objectives were:

1. In the fall of 2005 analyze clams and associated sediment for analyses of trace metals.

2. To determine the concentrations of target trace elements in surface sediments around HMI collected by MGS in September 2005 as part of the annual sediment survey. Metal analysis focuses on those metals not measured by MGS, specifically mercury (Hg), monomethylmercury (MMHg), silver (Ag), and arsenic (As), as well as selenium (Se), cadmium (Cd) and lead (Pb).

The results of the quality assurance (QA/QC) procedures and the description of the analytical and field protocols are contained in the *Year 24 Data Report*. Overall, the QA/QC results were acceptable for a study of this nature. No evidence of bias or lack of precision or accuracy was indicated by the QA/QC results. Comparisons of duplicate analyses and comparison of measured values to certified values for the analyzed Standard Reference Materials are also discussed in the *Year 24 Data Report*. Again, the QA/QC objectives were met in this regard.

METHODS AND MATERIALS

Sampling Procedures

Samples were collected using a Ponar grab sampler, from sites designated by the revised sampling plan, developed by the Maryland Department of the Environment (MDE) in September 2005. Sediment for trace metal and organics analyses were collected using plastic spatulas and glass spatulas respectively, integrating the top several centimeters and avoiding the sides of the sampler to minimize the possibility of contamination. Sediments for metals were placed in plastic sampling cups and were kept cool in an ice chest or refrigerator until they could be processed in the laboratory.

Sediment was sieved for clams; the hole clams where placed in plastic bags with surface water and held on ice. The clams were frozen to allow easy shucking the next day. For metals analysis, clams were removed whole from their shells with a Teflon-coated spatula. Most of the water and body fluids were allowed to drain. The spatula was acid rinsed between each site to avoid cross contamination between sites. The clam bodies from each site were homogenized in a plastic blender with a stainless steel blade. Unused samples were returned to their respective bags and stored in the freezer until further analysis.

Analytical Procedures for Metals

Methods used for metals are similar to those described in detail in Dalal et al. (1999). For metals, a subsample of each trace metal sample (sediments) was used for dry weight determination. Weighed samples were placed in a VWR Scientific Forced Air Oven at 60^0C overnight. Upon drying, samples were then reweighed and a dry/wet ratio was calculated.

Sediment and clam tissue were treated the same with regard to analysis. A sub-sample of sediment (5 g wet weight) was placed in acid-cleaned flasks for further digestion, using USEPA Methods (USEPA Methods; Keith 1991). Ten mL of 1:1 nitric acid (HNO_3) was added and the slurry was mixed and covered with a watch glass. The sample was heated to 95^0C and allowed to reflux for 15 minutes without boiling. The samples were cooled, 5 mL of concentrated HNO_3 was added, and then they were allowed to reflux for another 30 minutes. This step was repeated to ensure complete oxidation. The watch glasses were removed and the resulting solution was allowed to evaporate to 5 mL without boiling. When evaporation was complete and the samples cooled, 2 mL of a 30% solution of hydrogen peroxide (H_2O_2) was added. The flasks were then covered and returned to the hot plate for warming. The samples were heated until effervescence subsided. We continually added 30% H_2O_2 in 1 mL aliquots with warming until the effervescence was minimal. No more than a total of 10 mL of H_2O_2 was added to each sample. Lastly, 5 mL of concentrated hydrochloric acid (HCl) and 10 mL of deionized water were added and the samples refluxed for 15 minutes. The samples were then cooled and filtered through Whatman No. 41 filter paper by suction filtration and diluted to 50 mL with deionized water. Sediment homogenates were then analyzed using a Hewlett Packard model 4500 Inductively Coupled Plasma Mass Spectrometer for the other metals, Ag, Cd, As, Pb, Se. These techniques are similar to USEPA Method 1632.

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

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

RESULTS AND DISCUSSION

Metals in Sediment

Concentrations of As, Se, Cd and Pb in the sediment collected around HMI in Year 24 (2005-2006) are similar to previous years (Figures 32 and 33) and not substantially different than the concentrations found elsewhere in the Chesapeake Bay or in marine sediments. Concentrations of As in year 24 sediments are typically < 10 ug g^{-1} and generally lower than the average and mean concentrations from previous years. Concentrations of Se in year 24 sediments are generally less than 3 ug g^{-1}, which is consistent with concentrations from previous years. Concentrations of Cd in marine sediments range from 0.03 to 1 ug g^{-1} dry weight. The Cd concentrations observed in year 24 HMI sediments are found within this range (Figure 33). All the 2005 concentrations are below the average and median from past years. Concentrations of Pb in Chesapeake Bay sediment recorded by Di Giulio and Scanlon (1985) ranged from 1-134 ug g^{-1} dry weight. Pb concentrations in the sediment around HMI in 2005 are generally less than 60 ug g^{-1} dry weight, placing them well within this historical range. Station 38 typically has the highest Pb concentrations ≈100 ug g^{-1} and this was true in 2005 (Figure 33). The high concentrations observed at Station 43 in 2004 were not present in 2005. Concentrations of Ag remained low throughout the region in 2005 (Figure 34). Concentrations of Ag in sediment observed in 1999 and 2000 remain anomalous relative to all other years. Silver contamination is often associated with general urban pollution, having origins in sewage treatment plants (Purcell and Peters, 1998). However, we have not been able to link the anomalous concentrations from 1999 and 2000 to any source.

Concentrations of mercury (T-Hg) and methylmercury (MeHg) in sediment are typical of previous years with site mean and median concentrations for the study period being very close to the 2005 concentrations (Figure 35). Concentrations of T-Hg in the main stem of the Chesapeake Bay range from 0.2 to 250 ng g^{-1} dry weight and concentrations of MeHg range from 0.01 to 2.2 ng g^{-1} dry weight (Heyes et al. 2006). Concentrations of both T-Hg and MeHg are highest in the upper bay, with T-Hg concentrations on the order of 130 ng g^{-1} and MeHg concentrations 1 ng g^{-1}. Concentrations of T-Hg around HMI averaged 200 ng g^{-1} in 2005. In 2005, about half the sediment MeHg concentrations were slightly higher than average and about half were slightly lower than the average of previous years (Figure 35). In year 24, Station 30, which is slightly Northeast of HMI and near the mouth of Middle River had the highest

MeHg concentration and is the highest on average over the study period. Station 24 had an anomalously high 8 percent MeHg, which was driven by an unusually low T-Hg concentration. Such high percent MeHg has occurred at other sites in previous years and is the result of lower than normal T-Hg concentrations. Percent MeHg is calculated by dividing the MeHg concentration by T-Hg concentration times 100.

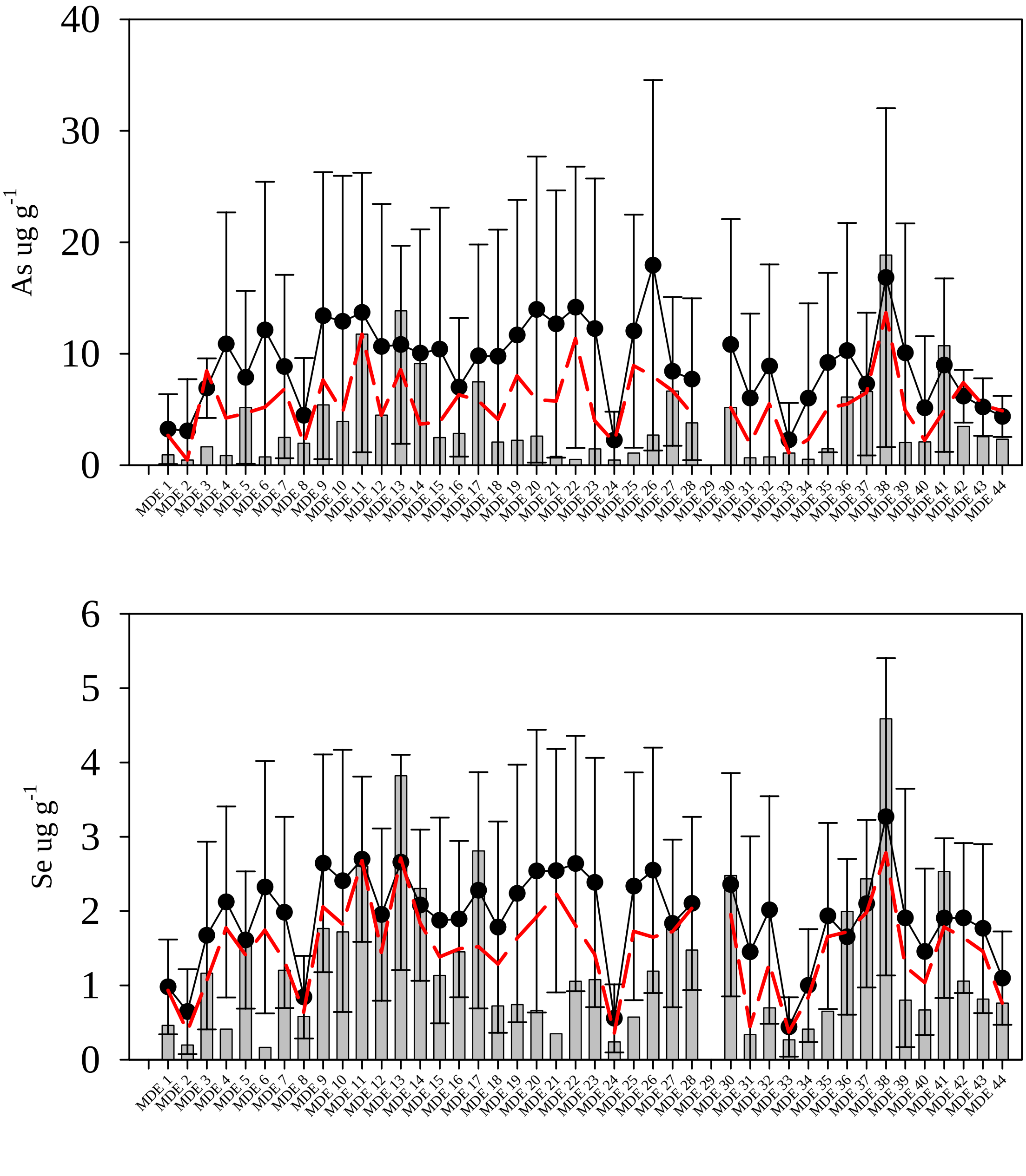

Figure 32: Arsenic (As) and selenium (Se) in sediment, expressed in dry weight concentration, from 2005 (bars) and the 1998-2004 mean (circles) with standard deviation (error bars) and the 1998-2004 median (dashed line).

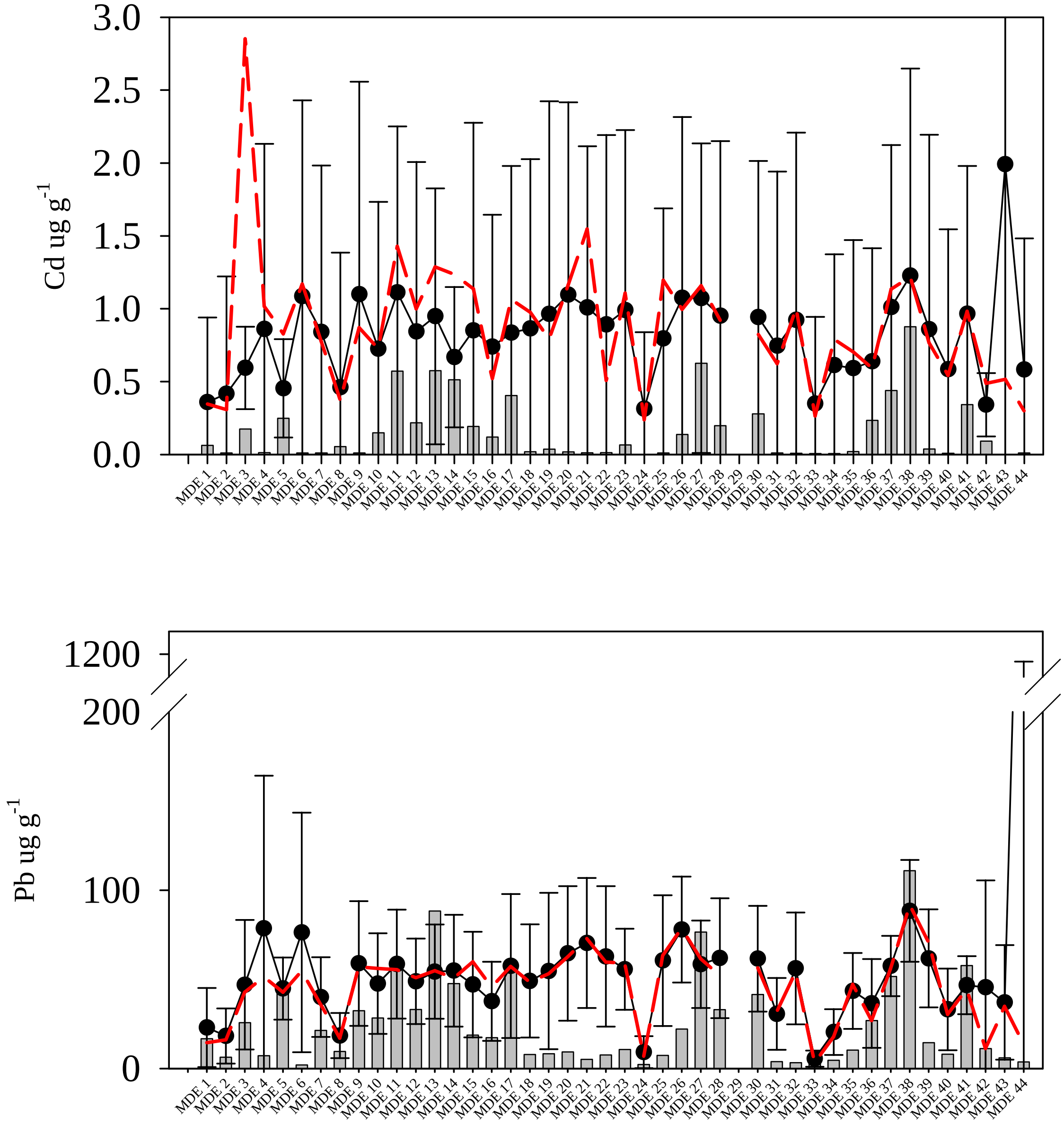

Figure 33: Cadmium (Cd) and lead (Pb) in sediment, expressed as dry weight concentration, from 2005 (bars) and the 1998-2004 mean (circles) with standard deviation (error bars) and the 1998-2004 median (dashed line).

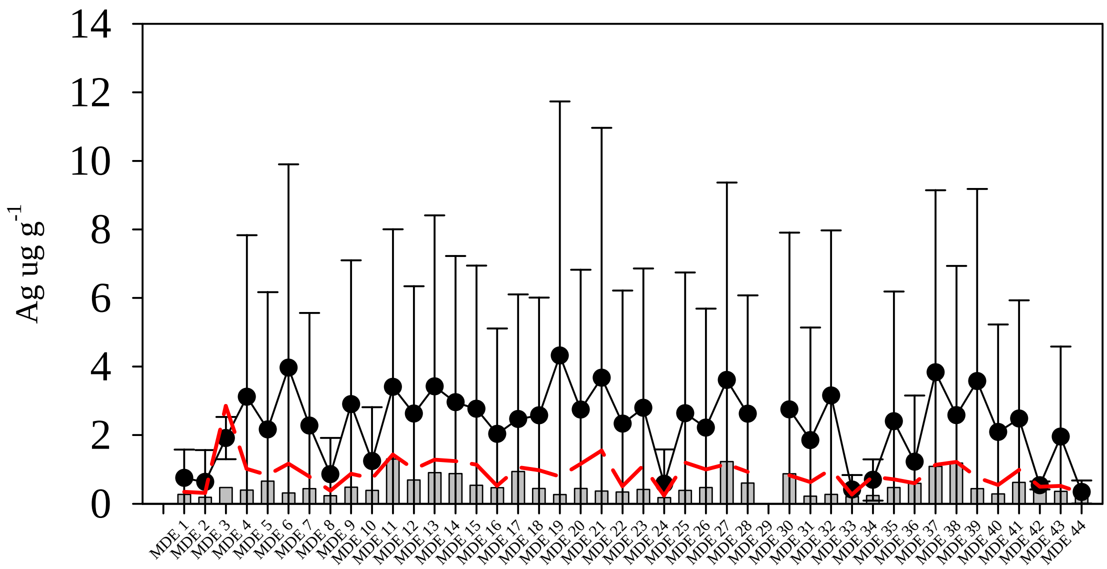

Figure 34: Silver (Ag) concentrations in sediment from 2005 (bars), expressed as dry weight concentration, and the 1998-2004 mean (circles) with standard deviation (error bars) and the 1998-2004 median (dashed line).

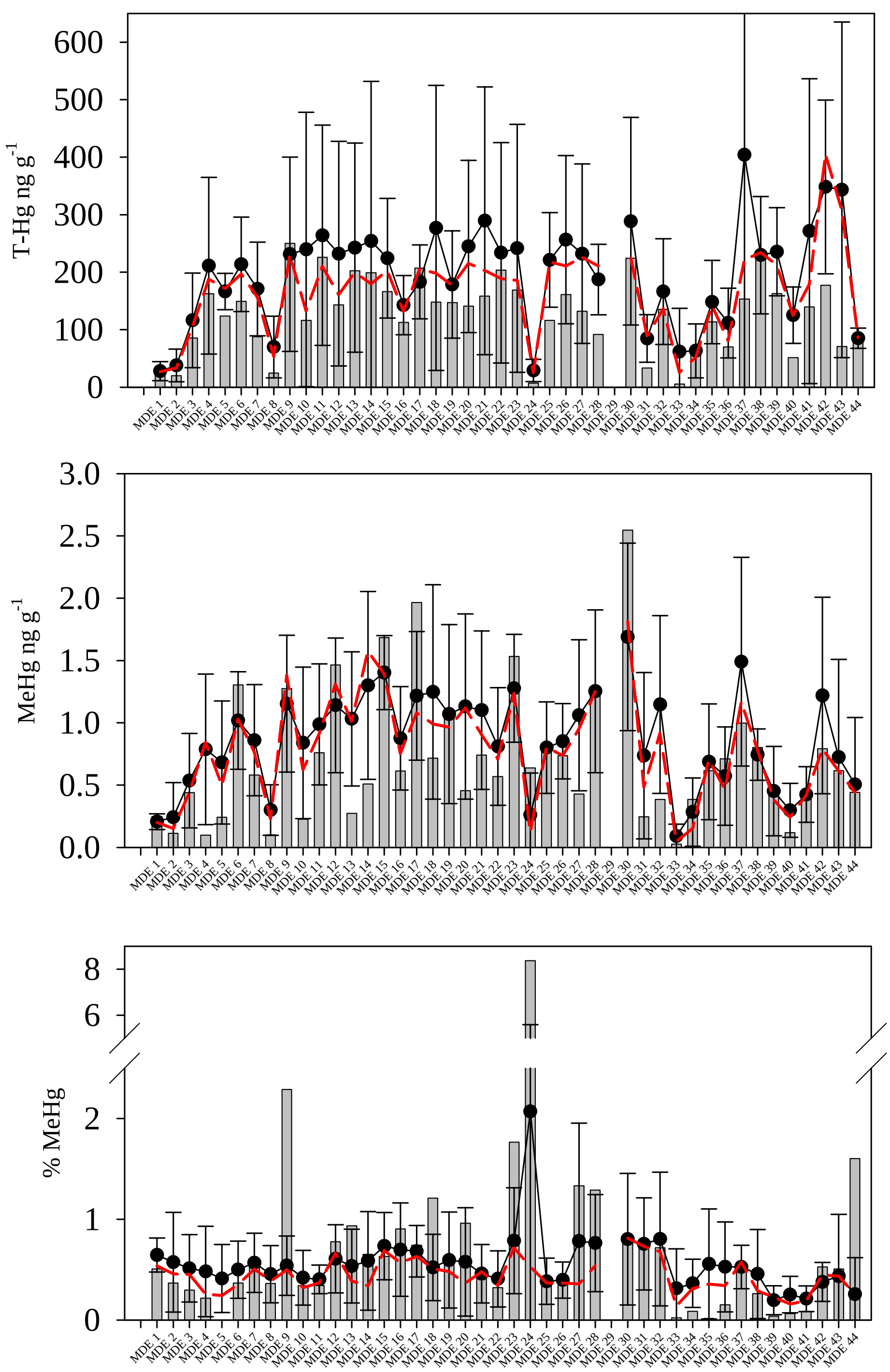

Figure 35: Mercury (Hg) and methylmercury (MeHg) expressed as dry weight concentrations, and percent Hg as MeHg, in 2005 sediment (bars) and the 1998-2004 mean (circles), median (dashed line), with standard deviation (error bars).

In general, the concentrations of metals in sediment track together, either because they have similar sources or they have similar diagenic fates. Metals often complex or associate with organic matter and Hg, Pb, and Ag all have strong relationships with loss of ignition (LOI) having r^2 of 0.60, 0.68, 0.42, respectively. Thus, relationships can also be seen between these metals such as between Hg and Pb, $r^2 = 0.46$, although it is largely driven by the organic matter relationship. Strong relationships exist between concentrations of As and Se in sediment. Both the concentration means from 1996-2003 (Figure 36) ($r^2 = 0.82$) and the 2005 sampling year (r^2 0.89) have strong correlations. Such relationships between metals indicate that if a site is contaminated by one metal it will likely be contaminated by a number of metals. Table 1 lists the sites with the highest single metal concentrations based on mean, median and the Year 24 sampling. This table excludes the Baltimore Harbor entry Stations, (38-41) and the South Cell Restoration stations (42-44). No one station around HMI dominates the table.

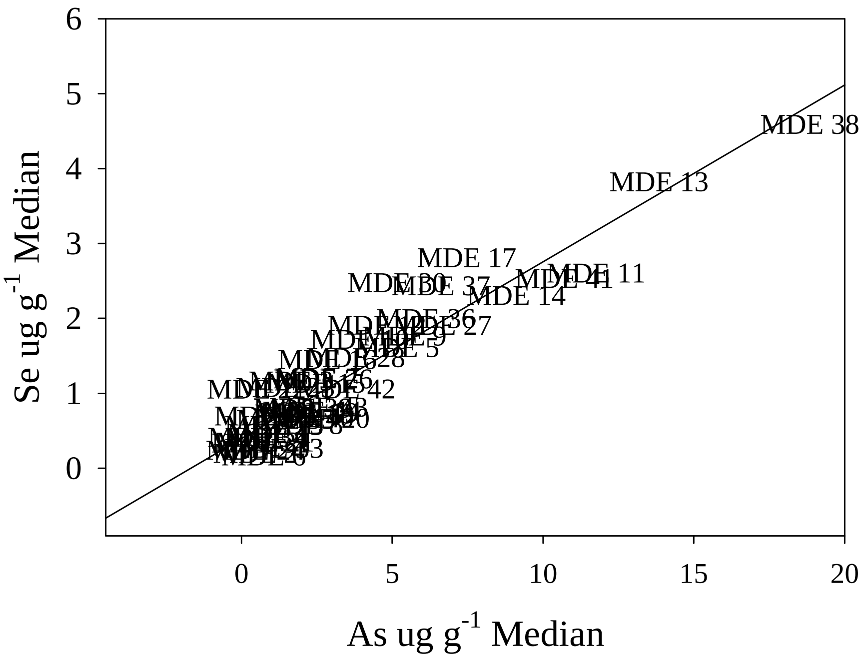

Figure 36: Plot of arsenic (As) and selenium (Se) concentrations in Year 24 sediment. Station names instead of points have been used, allowing the identification of outlier points, or points of interest even though the bulk of the station names can not be read.

Table 24: Stations with highest mean and median concentrations of metals compared to 2005.

Metal	1996-2004 Mean	1996-2004 median	2005
As	HMI 26	HMI 11	HMI 13
Se	HMI 11	HMI 13	HMI 13
Cd	HMI 11	HMI 3	HMI 27
Ag	HMI 19	HMI 3	HMI 11
Pb	HMI 4	HMI 26	HMI 13
Hg	HMI 37	HMI 9	HMI 9

South Cell Restoration Monitoring Stations 42, 43 and 44

To gather data on sediment in areas where post closure water would be released, three Stations (42, 43 and 44) were added to the sampling plan in April of 2004. Year 24 was the third year that sediment has been collected thereby providing a large enough data base to begin the evaluation of these areas. For the most part, these stations appear similar to the stations on the southern end of the island (Figures 37-39). The exception was in September of 2004, when very high concentrations of Cd, Pb and Ag were found at Stations 43, 44 and 43, respectively. Concentrations of Se and Cd were also on the high end of the concentrations observed in April of 2004 at Stations 42 and 43.

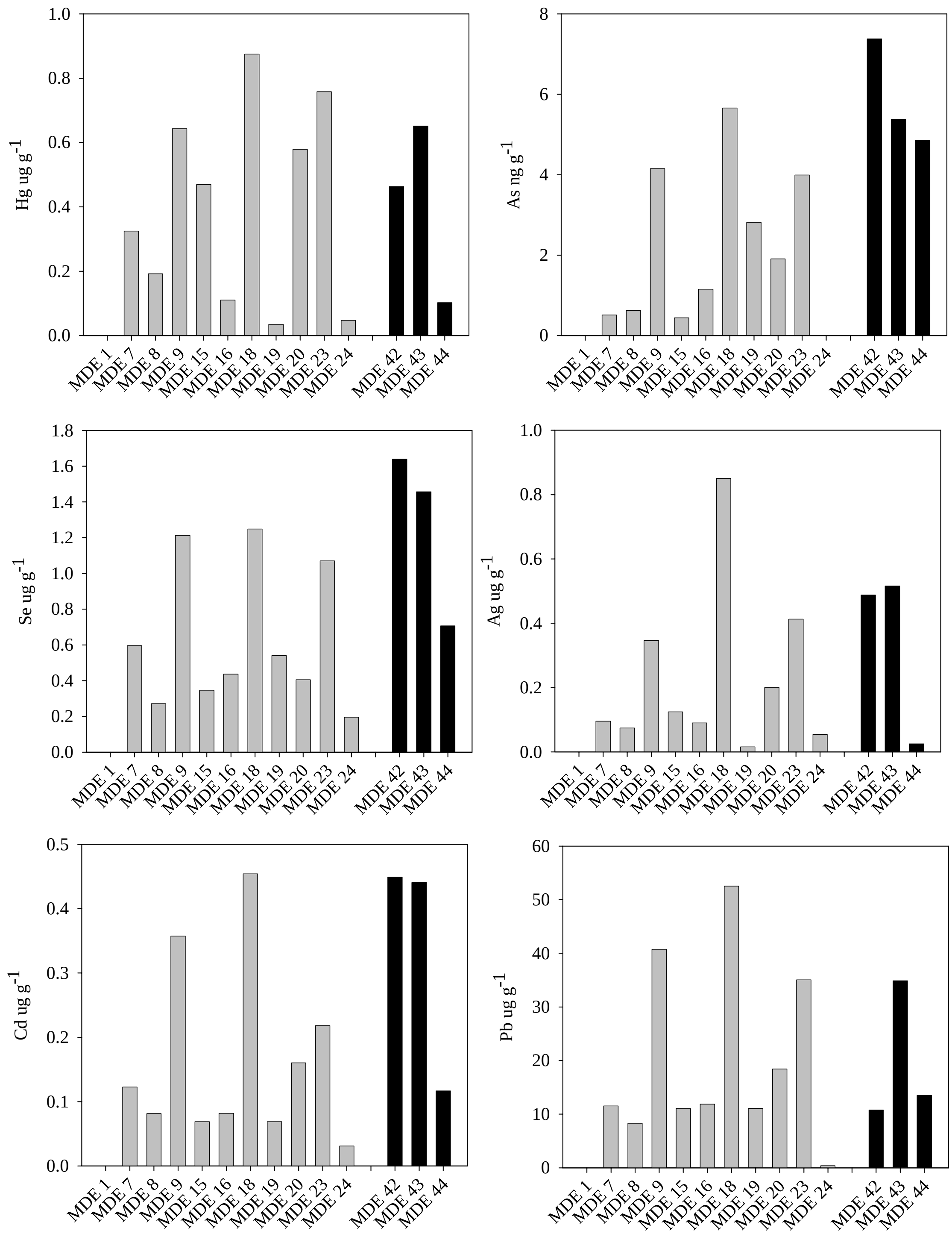

Figure 37: Trace metal concentrations in sediment in April 2004 at stations located on the southern side of the island. The new stations are indicated by the black bars.

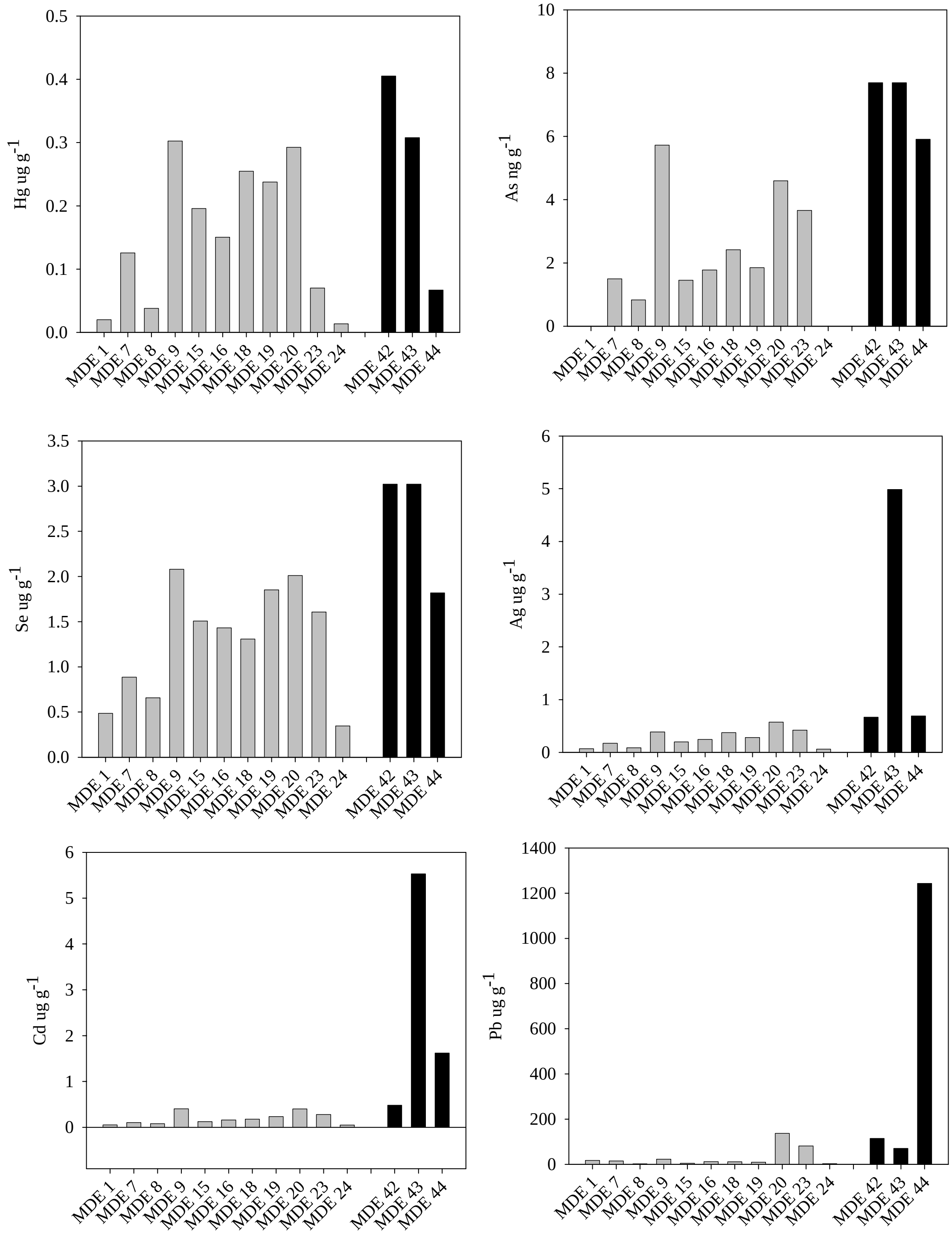

Figure 38: Trace metal concentrations in sediment in September 2004 at stations located on the southern side of the island. The new stations are indicated by the black bars.

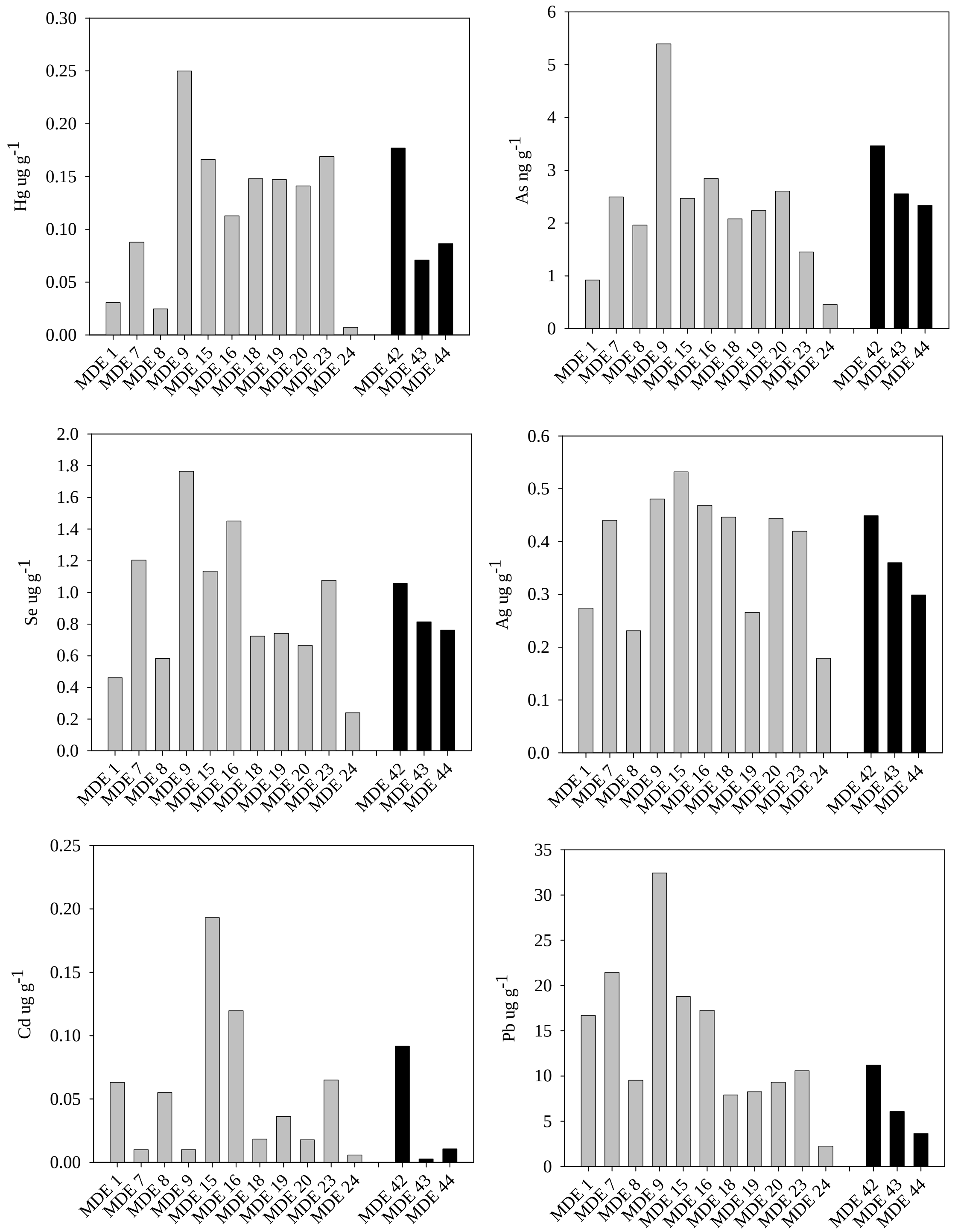

Figure 39: Trace metal concentrations in sediment in April 2005 at stations located on the southern side of the island. The new stations are indicated by the black bars.

Metals in Clams

Concentrations of the metals As, Se, Ag, Cd, and Pb in the clam *Rangia* displayed some variations from previous years (Figure 40). Most metal concentrations were low and varied little among the stations. Concentrations of As, Se, Ag and Pb remained similar to previous years whereas Cd was considerably lower. The concentrations of both T-Hg and MeHg in clams collected in year 24 fall close to the average of previous years with a couple of exceptions (Figure 41). Stations 3, 7 and 13 had Hg concentrations about twice the average of previous years.

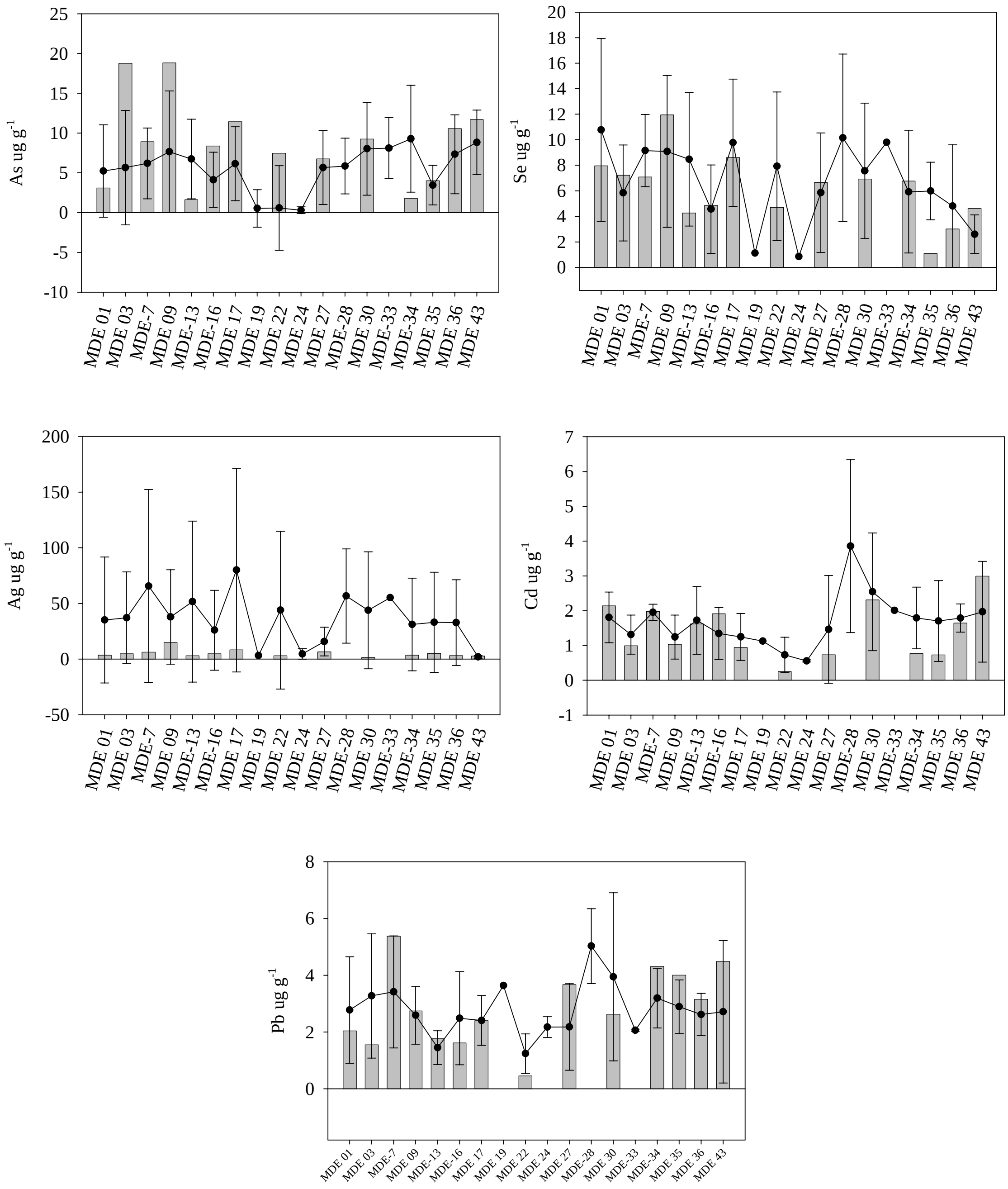

Figure 40: Concentrations of arsenic (As), selenium (Se), silver (Ag), cadmium (Cd) and lead (Pb) in the clams, expressed as dry weight, collected in 2005 (bars) and the 1998-2004 mean (circles) with standard deviation (error bars).

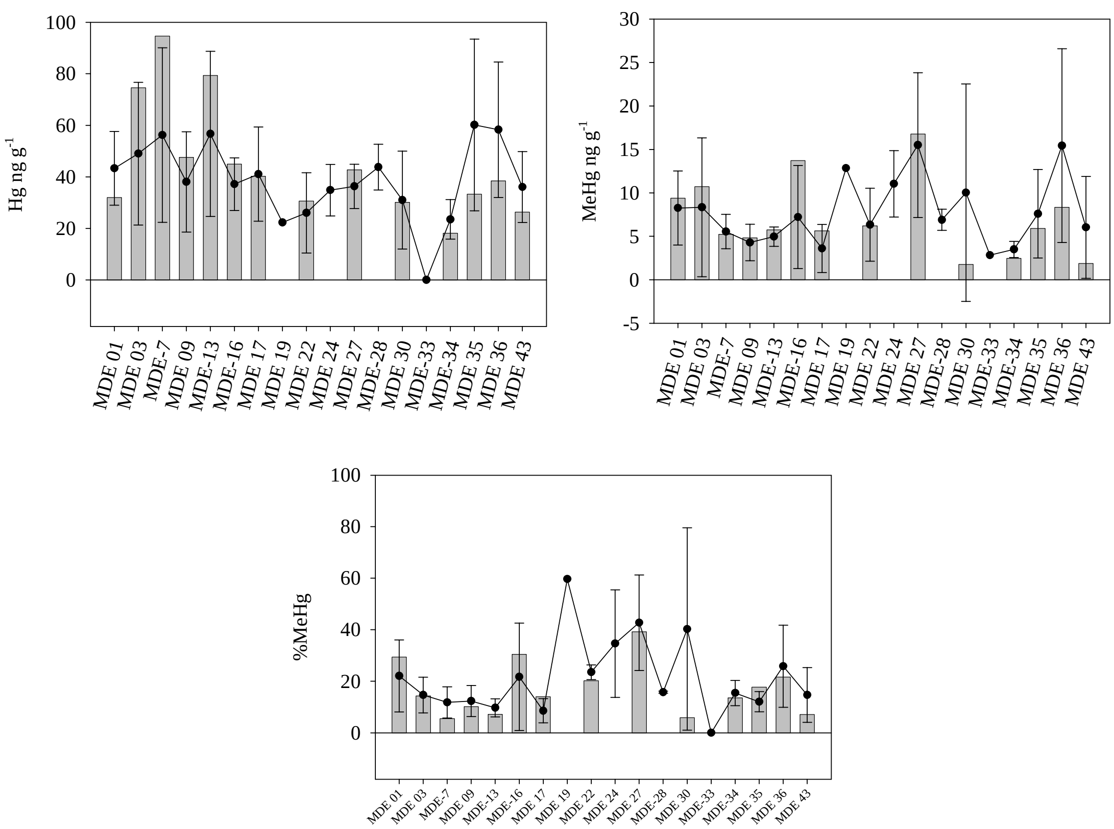

Figure 41: Mercury (Hg) and methylmercury (MeHg) concentrations, expressed on a dry weight basis, and percent of Hg that is MeHg in clams, collected in 2005 (bars) and the 1998-2004 mean (circles) with standard deviation (error bars).

Metal Bioaccumulation Factors

Difference in the proportions of water between sediments and the organisms means that an evaluation of bioaccumulation factors (BAF) must be done on a dry weight basis. The wet/dry ratios are on the order of 10 to 15 whereas the ratio for sediments is closer to 2. The BAF's for trace metals are summarized in Figure 42. The BAF's for As, Se (not shown), MeHg, and Ag are between 1 and 10 indicating some moderate bioaccumulation. The BAF for Pb and Hg are less than one, suggesting exclusion of Pb and inorganic Hg. The BAF for Cd ranges from 1 to 100 but at Station 43 the calculated BAF is much higher. This is in fact misleading as the BAF is driven by very low concentrations of Cd in the sediment, not elevated levels of Cd in the clams.

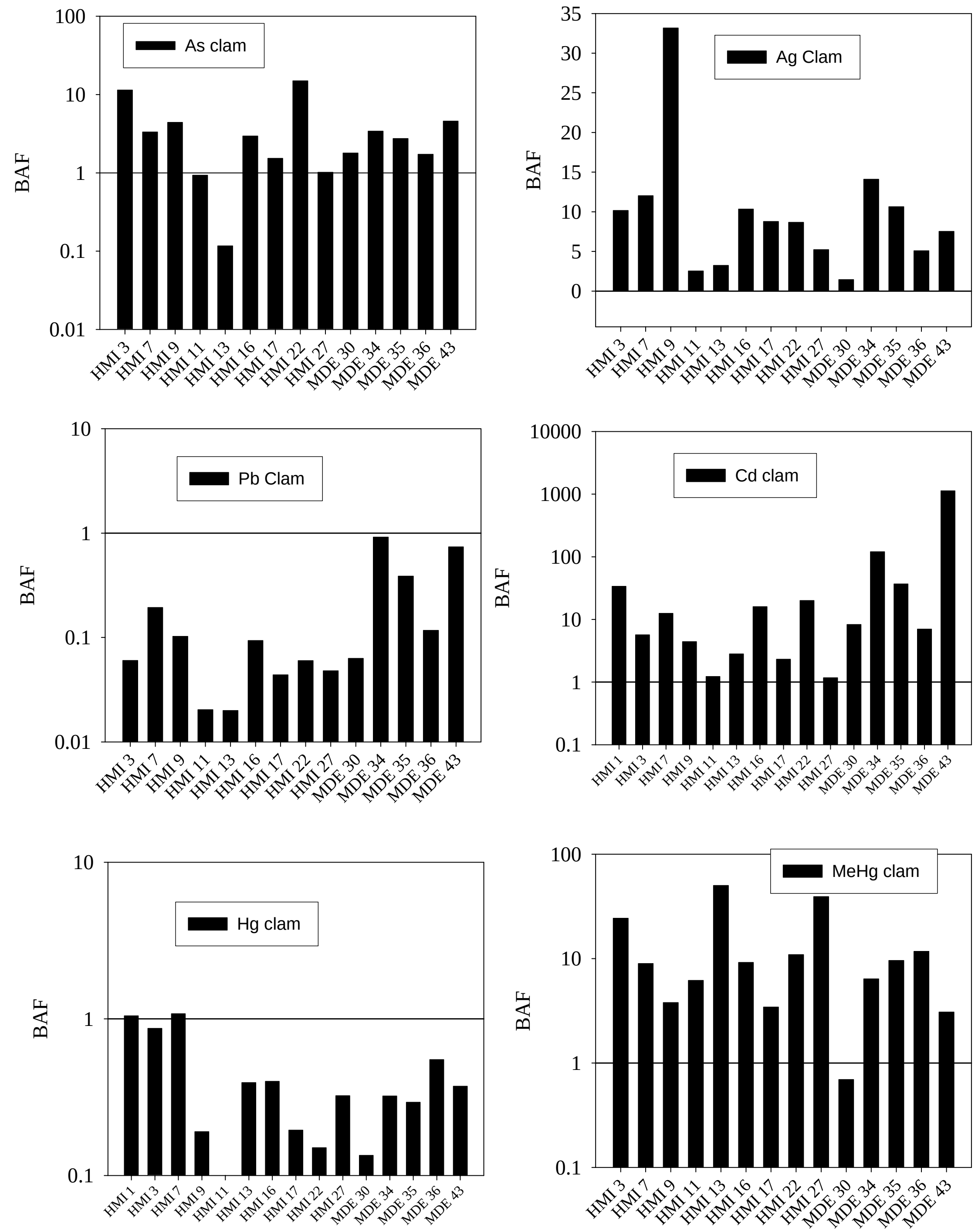

Figure 42: Bioaccumulation factors BAF's in clams from September 2005.

Year 24 Summary

Concentrations of the trace metals As, Se, Ag, Cd, Pb, Hg, and MeHg in both sediment and clams are similar to the concentrations observed in previous years. Three new stations have been sampled since 2003. The stations 42, 43 and 44 are located in the area where water will be discharged from the South Cell. In 2003 and 2005, the metal concentrations in sediment and clams were similar to other locations located on the south side of the island. The very high concentrations of Pb and Cd found in these locations in 2004 remain unexplained.

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