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

Year 25 Exterior Monitoring Technical Report
(September 2006 – August 2007)

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MDE

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DEFINTION OF TERMS

Aliquot	A portion of a larger whole, (e.g., a small portion of a sample taken for chemical analysis or other treatment).
Amphipod	Crustacean order containing laterally compressed members such as the sand hoppers.
Anion	A negatively charged ion, (e.g., Cl^- and CO_3^{2-}).
Bathymetric	Referring to contours of depth below the water's surface.
Benthic	Referring to the bottom of a body of water.
Benthos	The organisms living in or on the bottom of a body of water.
Bioaccumulation	The accumulation of contaminants in the tissue of organisms through any route, including respiration, ingestion, or direct contact with contaminated water, sediment, pore water or dredged material.
Bioaccumulation factor	The degree to which an organism accumulates a chemical compared to the source. It is a dimensionless number or factor derived by dividing the concentration in the organism by that in the source.
Bioassay	A test using a biological system. It involves exposing an organism to a test material and determining a response. There are two major types of bioassays differentiated by response: toxicity tests which measure an effect (e.g., acute toxicity, sublethal/chronic toxicity) and bioaccumulation tests which measure a phenomenon (e.g., the uptake of contaminants into tissues).
Biogenic	Resulting from the activity of living organisms. For example, bivalve shells are biogenic materials.
Biomagnification	Bioaccumulation up the food chain, e.g., the route of accumulation is solely through food. Organisms at higher trophic levels will have higher body burdens than those at lower trophic levels.
Biota	The animal and plant life of a region.
Bioturbation	Mixing of sediments by the burrowing and feeding activities of sediment-dwelling organisms. This disturbs the normal, layered patterns of sediment accumulation.

Brackish	Salty, though less saline than sea water. Characteristic of estuarine water.
Bryozoa	Phylum of colonial animals that often share one coelomic cavity. Encrusting and branching forms secrete a protective housing. (zooecium) of calcium carbonate or chitinous material. Possess lophophore feeding structure.
Bulk sediment chemistry	Results of chemical analyses of whole sediments (in terms of wet or dry weight), without normalization (e.g., to organic carbon, grain-size, acid volatile sulfide).
Cation	A positively charged ion, (e.g., Na^+ and Mg^{2+}).
Confined disposal:	A disposal method that isolates the dredged material from the environment. Confined disposal is placement of dredged material within diked confined disposal facilities via pipeline or other means.
Confined disposal facility (CDF)	A diked area, either in-water or upland, used to contain dredged material. The terms confined disposal facility (CDF), dredged material containment area, diked disposal facility, and confined disposal area are used interchangeably.
Congener	A term in chemistry that refers to one of many variants or configurations of a common chemical structure (e.g., polychlorinated biphenyls (PCBs) occur in 209 different forms with each congener having two or more chlorine atoms located at specific sites on the PCB molecule.
Contaminant	A chemical or biological substance in a form that can be incorporated into, onto or be ingested by and that harms aquatic organisms, consumers of aquatic organisms, or users of the aquatic environment, and includes but is not limited to the substances on the 307(a)(1) list of toxic pollutants promulgated on January 31, 1978 (43 FR 4109).
Contaminated material	Material dredged from Baltimore Harbor, originating to the northwest of a line from North Point to Rock Point. Material shows high concentrations of metals, PCBs, organics, etc.
Dendrogram	A branching, diagrammatic representation of the interrelations of a group of items sharing some common factors (as of natural groups connected by ancestral forms).
Desiccation	The process of drying thoroughly; exhausting or depriving of moisture.

Diversity index	A statistical measure that incorporates information on the number of species present in a habitat with the abundance of each species. A low diversity index suggests that the habitat has been stressed or disturbed.
Dominant (species)	An organism or a group of organisms that by their size and/or numbers constitute the majority of the community.
Dredge	Any of various machines equipped with scooping or suction devices used in deepening harbors and waterways and in underwater mining.
Effluent	Something that flows out or forth; an outflow or discharge of waste, as from a sewer.
Enrichment factor	A method of normalizing geochemical data to a reference material, which partially corrects for variation due to grain size.
Epifauna	Benthic animals living on the surface of the bottom.
Fine-grained material	Sediments consisting of particles less than or equal to 0.062 mm in diameter.
Flocculation	An agglomeration of particles bound by electrostatic forces.
Gas chromatography	A method of chemical analysis in which a sample is vaporized and diffused along with a carrier gas through a liquid or solid adsorbent differential adsorption. A detector records separate peaks as various compounds are released (eluted) from the column.
Gravity core	A sample of sediment from the bottom of a body of water, obtained with a cylindrical device, used to examine sediments at various depths.
Gyre	A circular motion. Used mainly in reference to the circular motion of water in each of the major ocean basins centered in subtropical high-pressure regions.
Hydrodynamics	The study of the dynamics of fluids in motion.
Hydrography	The scientific description and analysis of the physical condition, boundaries, flow, and related characteristics of oceans, rivers, lakes, and other surface waters.
Hydrozoa	A class of coelenterates that characteristically exhibit alternation of generations, with a sessile polypoid colony giving rise to a pelagic medusoid form by asexual budding.

Infauna	Benthic animals living within bottom material.
Leachate	Water or any other liquid that may contain dissolved (leached) soluble materials, such as organic salts and mineral salts, derived from a solid material.
Ligand	Lewis bases that bind by coordinate covalent bonds to transition metals to form complexes.
Littoral zone	The benthic zone between the highest and lowest normal water marks; the intertidal zone.
Mixing zone	A limited volume of water serving as a zone of initial dilution in the immediate vicinity of a discharge point where receiving water quality may not meet quality standards or other requirements otherwise applicable to the receiving water. The mixing zone may be defined by the volume and/or the surface area of the disposal site or specific mixing zone definitions in State water quality standards.
Nephelometric turbidity unit (NTU)	A unit of measurement of the amount of light scattered or reflected by particles within a liquid.
Open water disposal	Placement of dredged material in rivers, lakes or estuaries via pipeline or surface release from hopper dredges or barges.
Pore Water	The water filling the space between grains of sediment.
QA	Quality assurance, the total integrated program for assuring the reliability of data. A system for integrating the quality planning, quality control, quality assessment, and quality improvement efforts to meet user equirements and defined standards of quality with a stated level of confidence.
QC	Quality control, the overall system of technical activities for obtaining prescribed standards of performance in the monitoring and measurement process to meet user requirements.
Radiograph	An image produced on a radiosensitive surface, such as a photographic film, by radiation other than visible light, especially by x-rays passed through an object or by photographing a fluoroscopic image.

Salinity	The concentration of salt in a solution. Full strength seawater has a salinity of about 35 parts per thousand (ppt). Normally computed from conductivity or chlorinity.
Secchi depth	The depth at which a standard, black and white Secchi disk disappears from view when lowered into water.
Sediment:	Material, such as sand, silt, or clay, suspended in or settled on the bottom of a water body.
Seine	A large fishing net made to hang vertically in the water by weights at the lower edge and floats on the top.
Spectrophotometer	An instrument used in chemical analysis to measure the intensity of color in a solution.
Spillway	A channel for an overflow of water.
Substrate	A surface on or in which a plant or animal grows or is attached.
Supernatant	The clear fluid over sediment or precipitate.
Total suspended solids (TSS)	A measurement (usually in milligrams per liter or parts per million) of the amount of particulate matter suspended in a liquid.
Trace metal	A metal that occurs in minute quantities in a substance.
Trawl	A large, tapered fishing net of flattened conical shape, towed along the sea bottom. To catch fish by means of a trawl.
Turbidity	The property of the scattering or reflection of light within a fluid, as caused by suspended or stirred-up particles.
Turbidity maximum	A zone in a water body where turbidity is typically the greatest, resulting from the influx of river-borne sediments, and flocculation of clay particles due to prevailing salinity patterns.
Water Quality Certification	A state certification, pursuant to Section 404 of the Clean WaterAct, that the proposed discharge of dredged material will comply with the applicable provisions of Sections 301, 303, 306 and 307 of the Clean Water Act and relevant State laws.
Water quality standard	A law or regulation that consists of the beneficial designated use or uses of a water body, the numeric and narrative water quality criteria that are necessary to protect the use or uses of that particular water body.

SUMMARY REPORT FOR THE HART-MILLER ISLAND DREDGED MATERIAL CONTAINMENT FACILITY
YEAR 25

(September 2006 – August 2007)

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INTRODUCTION

At the request of the Hart-Miller Island (HMI) Citizens' Oversight Committee for the HMI Exterior Monitoring Program, a revised report format was adopted starting with the Year 24 report. This format is being continued this year to present monitoring program results and findings. A more detailed project summary report is provided below, with the individual project reports attached as appendices (Appendices 1 – 3A). The following project summary and appendices discuss the results from Year 25 (September 2006 – August 2007) of exterior monitoring at HMI.

HART-MILLER ISLAND STUDY DESIGN

The 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 and on sediments surrounding HMI. 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 covers some sediment chemistry for ancillary metals not monitored in Project II. In addition to conducting tissue analysis Project IV in Year 25 worked closely with the University of Maryland Wye River Research and Education Center (WREC) in conducting the whole sediment toxicity test which is the actual third component of the Sediment Quality Triad. The test used was U.S. EPA's estuarine amphipod L. *plumulosus* 10-day acute whole sediment toxicity test method with survival as the endpoint (U.S. EPA, 1994). The results of this test are discussed in Appendix 3A.

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

Scenario	**Sediment Contamination (Project II)**	**Toxicity (Project IV)**	**Benthic Community Impact (Project III)**	**Possible Conclusions**
				through food chain.
5.	-	-	+	Benthic community impacts not a result of pollution.
6.	+	+	-	Pollutants are stressing the system
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 2 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 12, 2006 (Cruise 53), and on April 6, 2007 (Cruise 54). 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).

Changes in grain size of the exterior sediments are largely dependent upon amount, quality, and timing of discharge from particular spillways, and the interaction of the discharge with the tides and currents in the receiving waters and the existing grain size distribution patterns. Basically, the depositional environment in the vicinity of HMI was unchanged between Year 24 and Year 25. However, there was an increase in the number of clay-rich sites in September 2006, and a subsequent decrease in April 2007. The reasons for variation are difficult to determine because of the Bay's complex hydrology and the many sources of sediment to the area, (sources of sediments include Back River, Middle River, run of from shoreline during storm events, Susquehanna, etc). The sediment distribution is generally consistent with the findings of previous monitoring years.

Comparing the Year 25 sediment metal concentrations to baseline concentrations around HMI reveals that only Pb is significantly enriched above regional background levels (Figure 2), and approximately one quarter of the Zn samples exceeded the background (Figures 2 and 3). Historically, Pb and Zn enriched samples are associated with the three local sources: HMI, Baltimore Harbor and Back River. In Year 25, Zn was only associated with Baltimore Harbor and to a lesser degree HMI. However, when compared to Year 24 the Zn enriched zone (i.e., exceeding 2 sigma) for Cruises 53 and 54 was contiguous to a small southeast portion of the dike indicating a possible direct influence due to operations at the facility.

For Pb, Cruises 53 and 54 both revealed that the gradient from Baltimore Harbor dropped to background levels considerably south of HMI. The area around HMI where Pb did exceed the background levels corresponds to where higher levels of Zn were found, again indicating an influence due to facility operations. One difference is that Pb had a greater spatial extent. Also, for the April 2007 cruise, Pb was seen in a significant spatial area contiguous to, and extending north and south of Spillway 007 located on the northeast end of HMI. The levels exceeded background by 2 sigma. These high levels could be as a direct result of the discharge that took place from Spillway 007 starting at the end of December 2006 continuing through the end of March 2007.

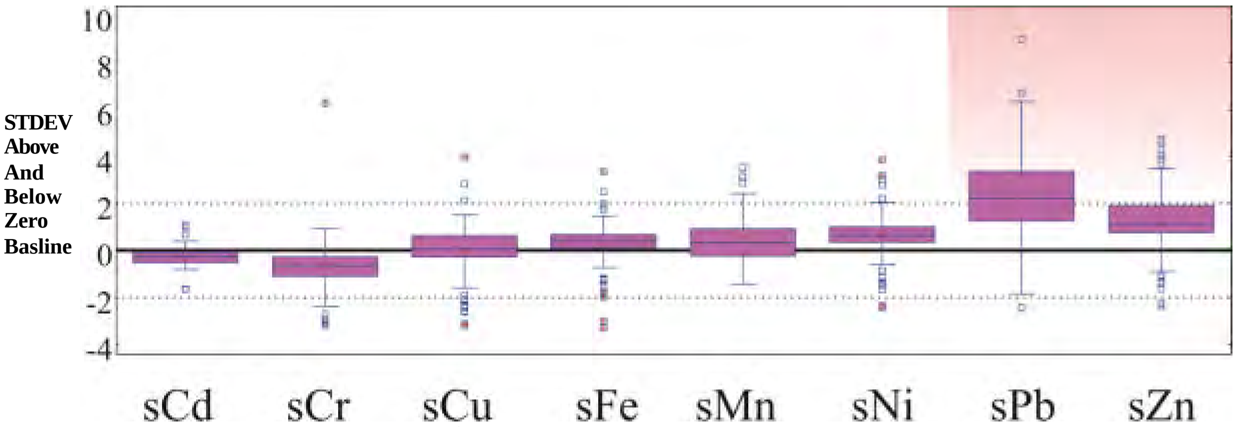

Figure 2. Year 25 concentration of metals at HMI relative to baseline values. Metal concentrations greater than 2 standard deviations (dashed lines) are considered elevated above baseline.

Overall, just over 50 percent of the Pb samples were significantly enriched and slightly less than 25 percent of the Zn enriched 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 conducive 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 Zn concentrations (Figure 3) demonstrates that conditions this year are above background levels and that there appears to be an increasing trend starting in Year 2002. This is most likely due to the fact that the facility received less dredged material during this monitoring year and dewatering and crust management operations have likely increased.

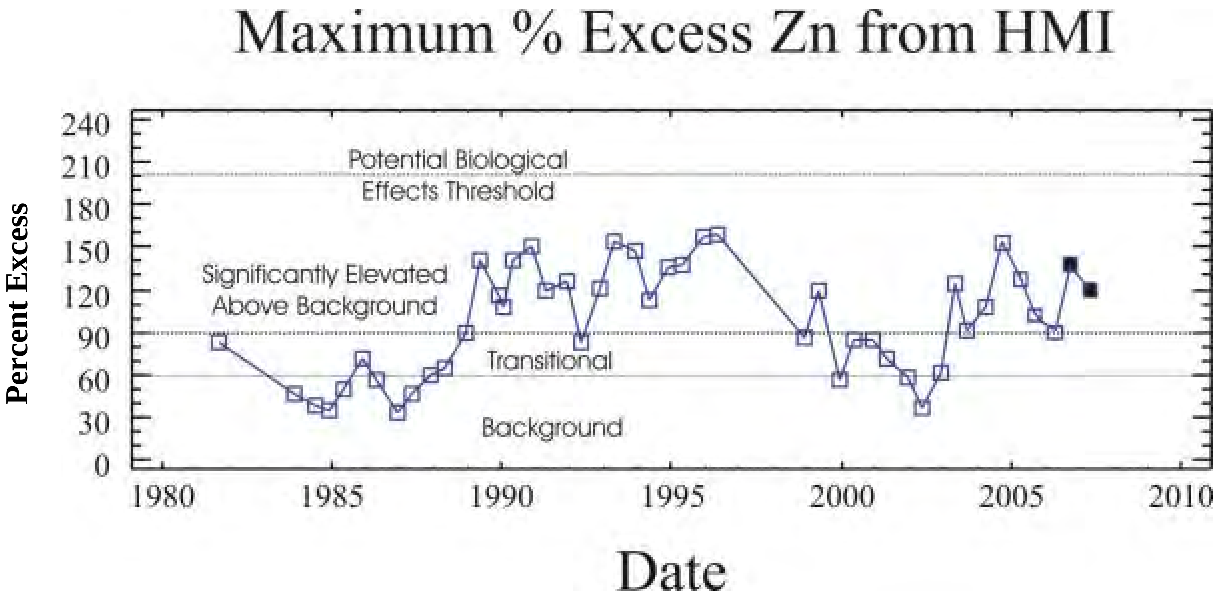

Figure 3. Historical Zn trends in sediments surrounding HMI.

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 13, 2006 and on April 13, 2007 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 (specific for July 15th to September 30th timeframe) of benthic macroinvertebrates, was calculated for all stations sampled during the September 2006 cruise. Overall, the B-IBI scores decreased when compared to Year 24, but were generally similar to the B-IBI scores for previous monitoring years at HMI (Figure 4). This year, 13 stations exceeded the benchmark criteria of 3.0, and 7 stations (MDE – 13, 17, 19, 27, 30, 35, and 44) failed to meet the benchmark as compared to Year 24 when only 3 stations failed (Figure 5). The cause for such a difference is difficult to ascertain. For example, in Year 24 in Back Neck Cove, levels for Pb were between 3 and 8 sigma and yet all 3 stations were at and above the B-IBI benchmark. Sigma level is a multiple of the standard deviation of the baseline metal behavior. Samples with sigma greater than 2 are significantly enriched. This same area in Year 25 was mostly below 3 sigma for Pb and yet 2 of the 3 stations failed the B-IBI benchmark. It would tend to indicate that neither Pb concentrations, most likely influenced by Back River, nor HMI operations were a factor. Also, for reference station MDE-13 both years were beyond any region of influence of metals and yet there was a significant difference in the B-IBI score with it failing in Year 25 (Figure 5). Here again it would indicate that the cause was something other than HMI facility operations.

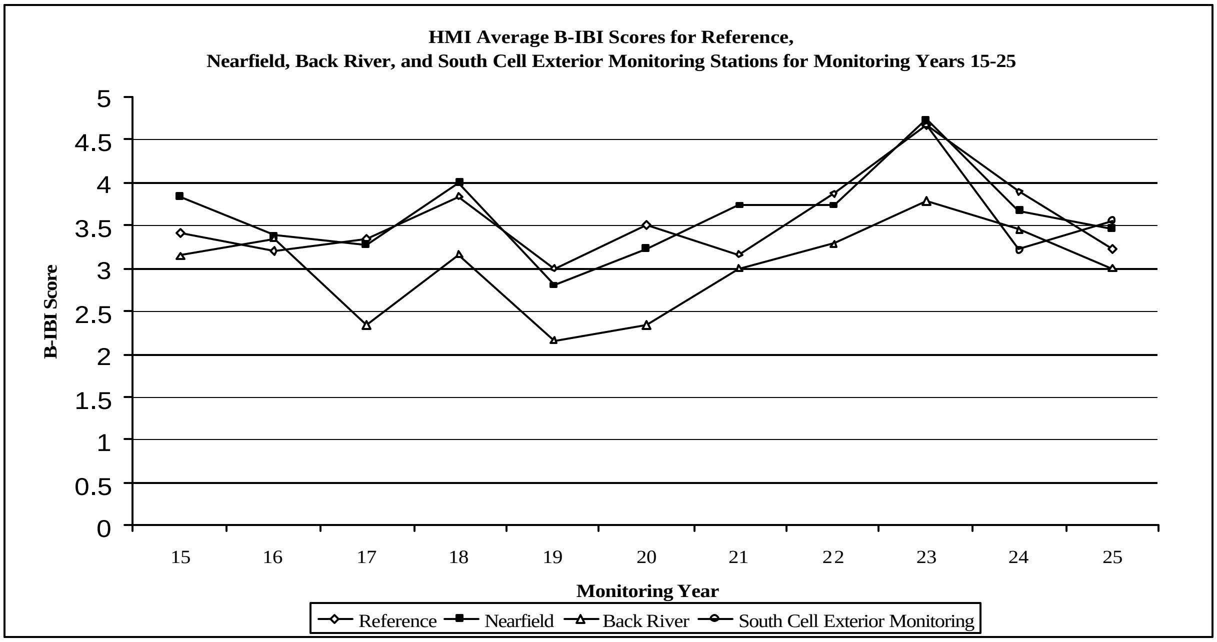

Figure 4. B-IBI Scores from HMI (Years 15 through 25).

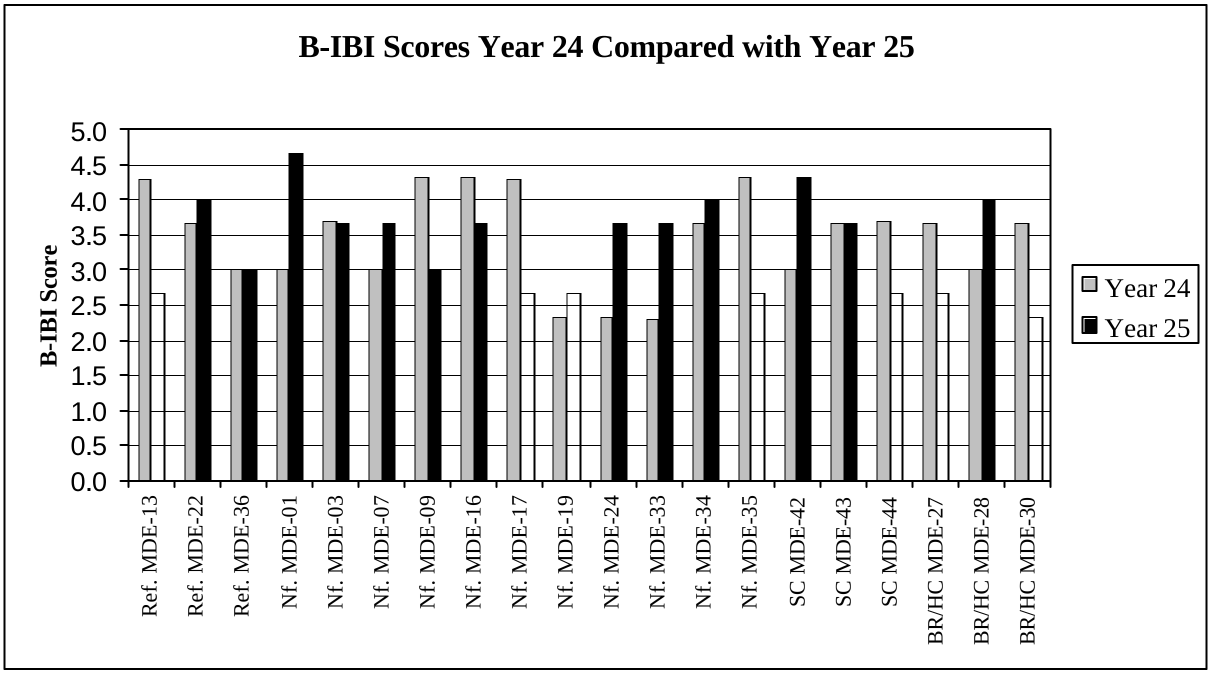

Figure 5. B-IBI Scores for Year 24 and 25.

Project IV: Analytical Services

For Year 25 monitoring at HMI, the Project IV goals were to continue to collect clams and associated sediment for trace metal analyses. Year 25 was different than Year 24 in that samples were collected in both the fall of 2006 and spring of 2007 so that metal and polychlorinated biphenyl (PCB) concentrations could be related to toxicity tests. Project IV analyzed sediments for additional metals not monitored by MGS [mercury (Hg), monomethylmercury (MMHg synonymous with MeHg), silver (Ag), arsenic (As), cadmium (Cd), lead (Pb), and selenium (Se)].

Metals in Sediments

Chesapeake Biological Laboratory (CBL) analyzed sediment samples collected in September 2006 from 43 stations by MGS for sediment metal concentrations. Concentrations of As, Se, and Cd in the sediment collected around HMI in Year 25 (2006-2007) are similar to previous years (Figures 6 and 7) and not substantially different than the concentrations found elsewhere in the Chesapeake Bay or in marine sediments. MGS in Project II showed Pb to be significantly enriched above background levels specific to the Upper Bay region, with an average of 54 ug g^{-1}; CBL found similar results with an average Pb concentration just below 60 ug g^{-1}. However, the levels for Pb are still within the range of 1 – 134 ug g^{-1} dry weigh for the Chesapeake Bay as recorded by De Giulio and Scanlon (1985) (Figure 7). Station MDE-38 typically has the highest Pb concentration on average; however, this year it was well below average (Figure 7). Concentrations of silver were low, and below the median values of previous years (Figure 8).

Concentrations of mercury (T-Hg) and methylmercury (MeHg) in sediment are typical of previous years with Year 25 sediment concentrations very similar to the site mean and median concentrations of previous years (Figure 9). Concentrations of T-Hg in the main stem of the Chesapeake Bay range from 0.2 to 250 ng g^{-1} dry weight and concentrations of MeHg range from 0.01 to 2.2 ng g^{-1} dry weight (Figure 9) (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}.

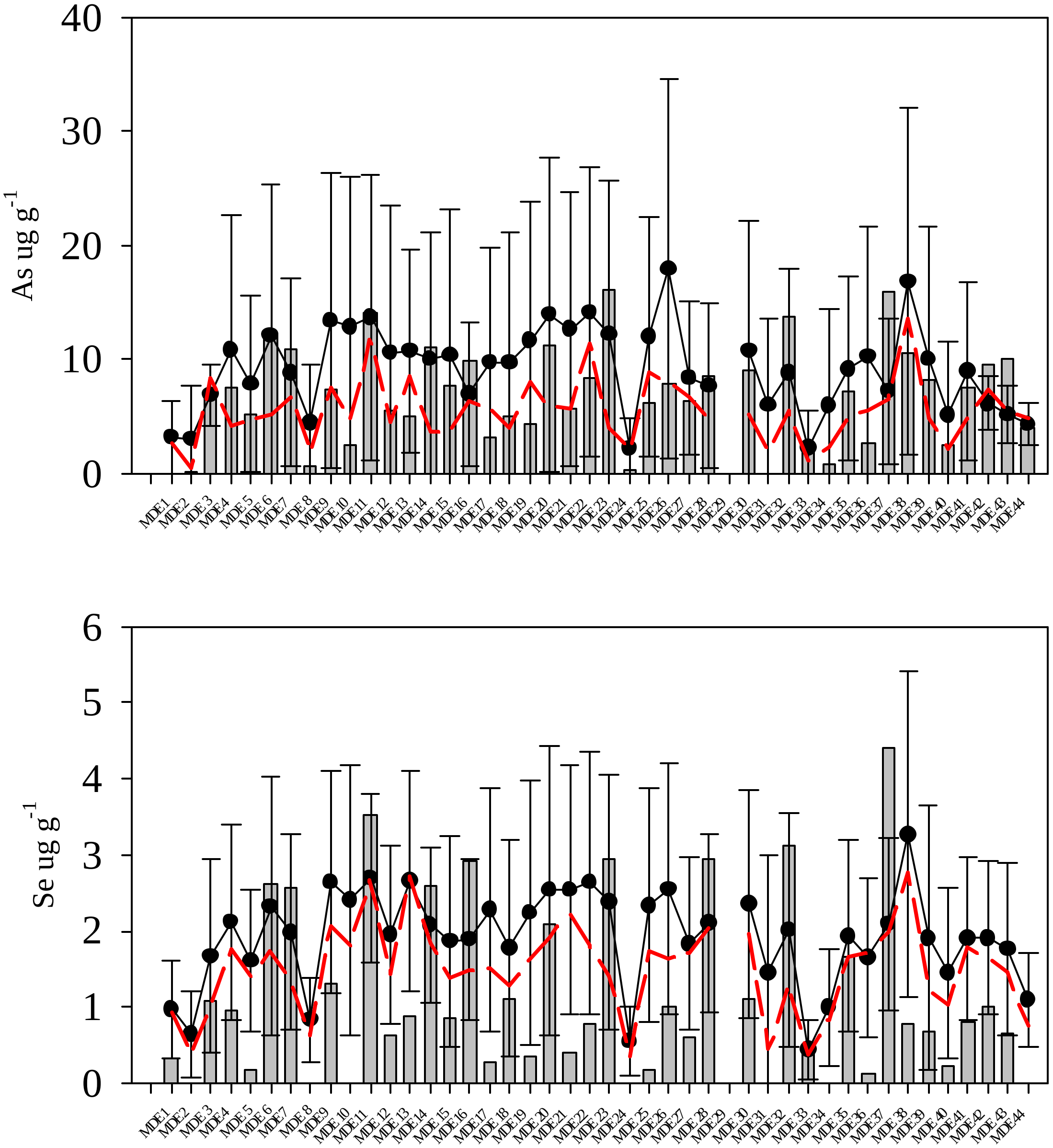

Figure 6. Arsenic (As) and selenium (Se) in sediment, expressed in dry weight concentration, from 2006 (bars) and the 1998-2005 mean (circles) with standard deviation (error bars) and the 1998-2005 median (dashed line).

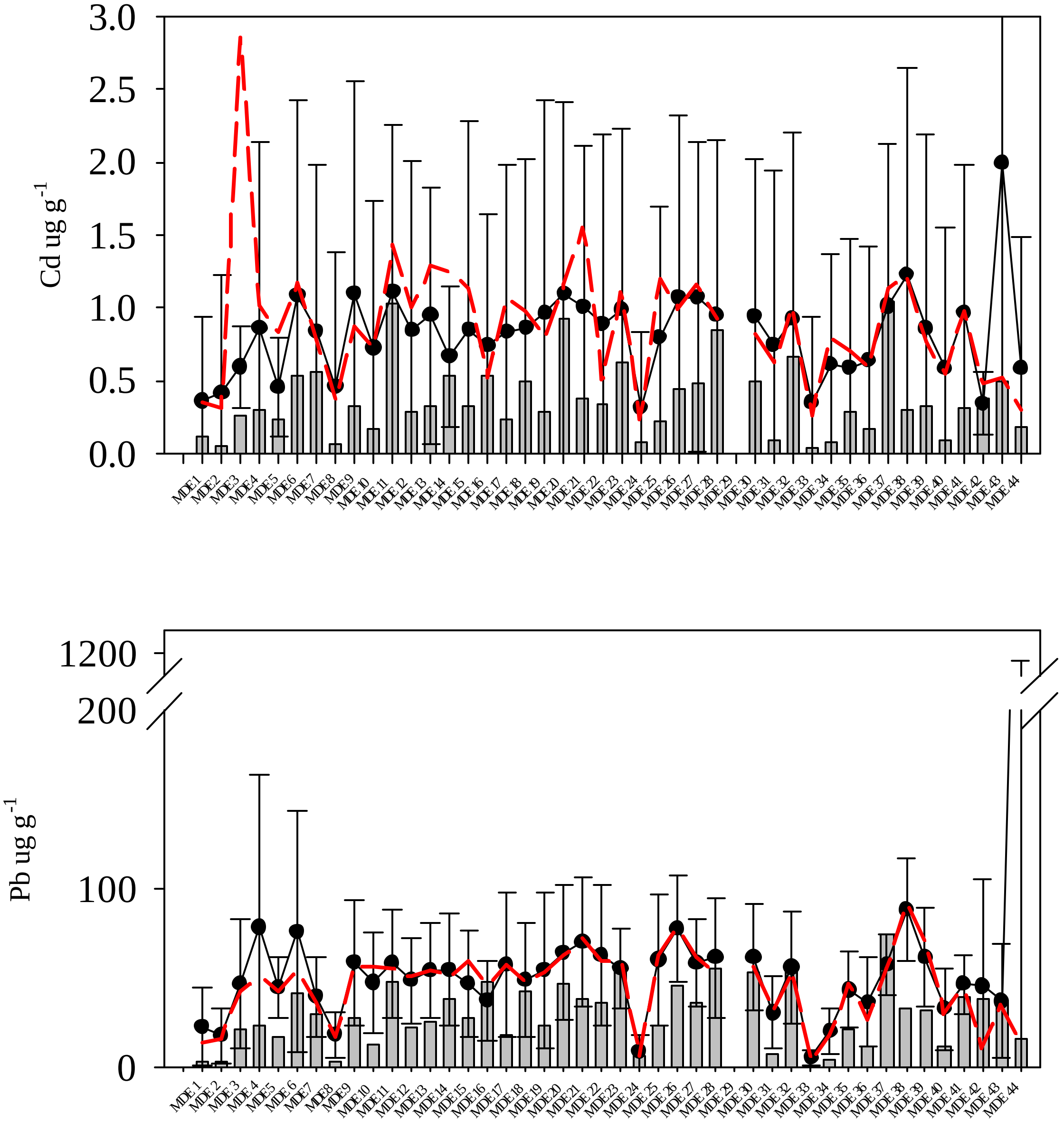

Figure 7. Cadmium (Cd) and Pb in sediment, expressed as dry weight concentration, from 2006 (bars) and the 1998-2005 mean (circles) with standard deviation (error bars) and the 1998-2005 median (dashed line).

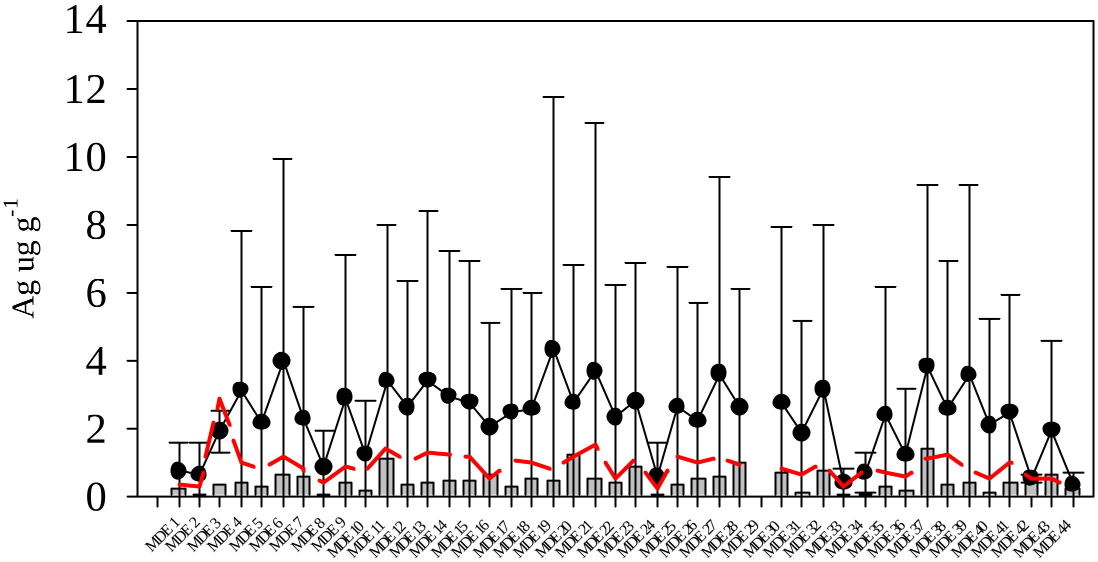

Figure 8. Silver (Ag) concentrations in sediment from 2006 (bars), expressed as dry weight concentration, and the 1998-2005 mean (circles) with standard deviation (error bars) and the 1998-2005 median (dashed line).

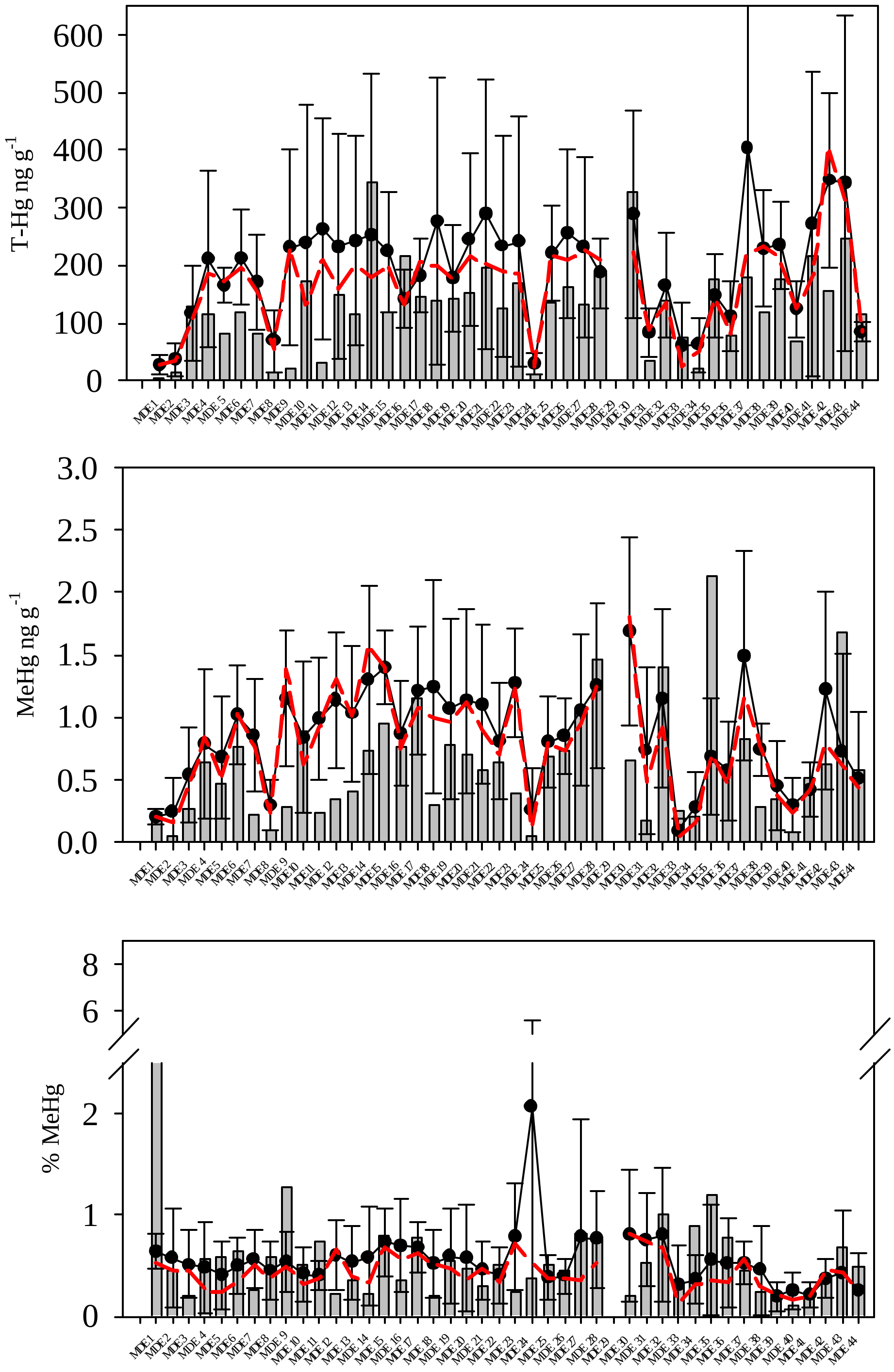

Figure 9. Mercury (Hg) and methylmercury (MeHg) expressed as dry weight concentrations, and percent Hg as MeHg, in 2006 sediment (bars) and the 1998-2005 mean (circles), median (dashed line), with standard deviation (error bars).

South Cell Exterior Monitoring Stations 42, 43 and 44

The restoration of the HMI South Cell Environmental Restoration Project (SCERP) began in 2002. In anticipation to the release of effluent from Spillway 003 located on the southeast side of HMI and other operational activities, stations MDE-42, 43 and 44 were added to the sampling plan during Year 22 (2003) (Figure 1). In 2003 concentrations of Se and Cd were slightly elevated and in 2004 very high concentrations of Cd, Pb and Ag were found at sites 43, 44 and 43, respectively. In subsequent sampling, including 2006, the sediment concentrations at these sites were found to be similar as to concentrations observed elsewhere on the southern side of the island. In cross comparison with results observed in Project II with the benthic community, in 2004 the B-IBI scores for each of these sites was above the benchmark of 3.0. Stations MDE-43 and 44 actually had rather good scores of 3.7. However, in 2006 although stations MDE-42 and 43 were above the benchmark, the B-IBI score for MDE-44 failed at 2.67. At this time no conclusions can be drawn regarding this observation.

Metals in Clam Tissue

Clams were collected in both the fall of 2006 and spring of 2007 in support of the toxicity triad. Concentrations of the metals As, Se, Ag, Cd, Pb, Hg, and MeHg in the clam *Rangia* displayed some variations from previous years. Concentrations of Hg were elevated at sites 19 and 36 being twice as high as the running mean. In the spring, As concentrations were higher than the running mean in clams from sites 9, 19 and 27. Tissue from clams collected in April 2007 contained high Pb concentrations, being 5 times higher than the running mean at all the sampled sites including the reference site MDE-36 located 2.85 miles northeast of HMI, which is well outside the HMI zone of influence. The only exception was station MDE-27 located at the entrance to the Back River. The fact that elevated concentrations were not observed in tissue from *Rangia* collected at MDE-27, where Chesapeake Bay water is least likely to mix, and that the Pb concentration in sediment collected by CBL at the same time as clams, was slightly below the running average suggests that a plume of a soluble Pb-organic complex came down the Bay. Such a compound would be readily available to clams. The widespread nature of this phenomenon indicates HMI is not the source of the compound; the source is more likely runoff delivered via the Susquehanna River. This is discussed in greater detail in Appendix 3: Analytical Services (Project IV).

Polychlorinated Biphenyls (PCB's) in Sediment and Clams

In September 2006 and April 2007 sediment samples and clam specimens were collected from stations MDE-3, 9, 13, 19, 22, 27, and 36 and tested for concentrations of PCB's. The sediments are typically high in the PCB congeners 40, 206 and 209. The sediment samples collected in year 25 were no different, were generally lower than the average, and close to the median when compared to sediment collected from the same sites in previous years. All seven sites which included the 3 references sites (MDE-13, MDE-22 and MDE-36) were similar in results. However, one abnormally high value was observed at MDE-3 for PCB congener 40.

Like the sediments the clams are typically high in the PCB congeners 206 and 209, but unlike the sediments contain the lighter mass 1 and 2 congeners. The clam samples collected in

Year 25 were no different, were generally lower than the average, and close to the median when compared to the clams collected from the same sites in previous years. As with the sediment samples, concentration of PCB's in clam tissue were similar for all 7 sites.

Polycyclic Aromatic Hydrocarbons (PAHs) in Sediment and Clams

The distribution of PAH's among the 7 sites is similar with phenanthrine and perylene often present at the highest concentrations. In analyzing the data, there is little variability in the distribution of PAH's between the seasons or years. However, the total concentrations do vary suggesting a regional overriding influence on these sites; this concept is discussed in greater detail in Appendix 3: Analytical Services (Project IV). Currently, there has not been enough data collected to adequately assess the impact of the South Cell Spillway 003. Site MDE-19 is close to the spillway and MDE-13 is in the area but likely out of the field of direct influence. These sites have similar concentrations and distributions of PAH's as the other sampling stations.

ACUTE TOXICITY STUDIES

Water Quality Test

Water quality data parameters were measured to assess potential impacts on the amphipods outside of the sampled contaminants. Both the pore water ammonia and overlying ammonia were tested and observed to be well below the level of 60 mg/L in pore water that would be considered a problem by the U.S. EPA for *L. plumulosus* (U.S. EPA/ACE, 2001). Values for pH were acceptable for all test and control sediments. No values for dissolved oxygen (DO) measured during the tests were below the acceptable level of 3.6 mg/L for *L. plumulosus* (U.S. EPA/ACE, 2001).

Sediment Toxicity Test

Performance criteria of 90% amphipod survival in control treatments was obtained for tests conducted for the fall and spring sampling events (Table 2). The Fall 2006 test had amphipod survival of 90% while the amphipod survival in the Spring 2007 test was 94% in the control treatment.

Sediments from three sites around Hart-Miller Island caused significant reductions in *L. plumulosus* survival in both the Fall 2006 and the Spring 2007 tests (Table 2). These were sites MDE-3, 9, 13. All of these sites indicated more sediment toxicity in the Fall of 2006 than in the Spring of 2007, especially MDE-3 which saw a 52.0% reduction in survival in the Fall compared to a 23.4% reduction in Spring survival.

Sediments from site MDE-19 caused a statistically significant reduction in amphipod survival in the Spring of 2007 but not in the Fall of 2006 (Table 2). This may be more of a reflection of less variability in the data in the Spring test than in the Fall test and most likely a statistical anomaly rather than a true biological difference. This is discussed in greater detail in Appendix 3: Analytical Services (Project IV).

Table 2. Summary of results from the Hart-Miller Island amphipod *Leptocheirus plumulosus* 10 day acute sediment toxicity test results for Fall 06 and Spring 07 tests. Shaded treatments are significantly < the control (% = 0.05).

	Fall 2006		Spring 2007	
Station	0 Treatment % Survival (SD)	% Reduction from Control	0 Treatment % Survival (SD)	% Reduction from Control
Control	90.0 (7.91)		94.0 (5.48)	
MDE-3	**43.0 (10.95)**	**52.2**	**72.0 (13.04)**	**23.4**
MDE-9	**61.0 (15.97)**	**32.2**	**70.0 (12.75)**	**25.5**
MDE-13	**62.0 (13.04)**	**31.1**	**68.0 (17.18)**	**27.7**
MDE-19	72.0 (10.37)	20.0	**77.0 (9.75)**	**18.1**
MDE-22	80.0 (16.20)	11.1	81.0 (8.22)	13.8
MDE-27	72.0 (15.65)	20.0	91.0 (6.52)	3.20
MDE-36	72.0 (13.04)	20.0	82.0 (9.75)	12.8

Metal as a Potential Cause for Reduced Survival in *L. plumulosus*

For some metals, the National Oceanic and Atmospheric Administration (NOAA) have established toxicological affects criteria. The three criteria used for comparison in this study are the threshold effects level (TEL), effects range low (ERL) and probable effects level (PEL), which is the highest threshold of the three. TEL is the lowest criteria of the three. Of the metals included in this study, criteria have been developed for As, Ag, Cd, Pb, and Hg.

An examination of sediment concentrations of As, Ag, Cd, Pb, and Hg from sites MDE-3, 9 and 13, which had the lowest survival, indicate nothing unusual compared to previous years or in relation to other sites. Cadmium concentrations were observed not to exceed even the TEL at the seven sites. Pb concentrations at most sites fell between the TEL and ERL. Station MDE-3, which is 1 of the 3 sites with low percent survival, was one of the exceptions; concentrations of Pb were well below the TEL in both September and April. Other than exceeding the ERL at MDE-19 in September and MDE-9 in April, arsenic was observed to only slightly exceed the TEL at 50 percent of the sites, and like Pb was below the TEL for both seasons at MDE-3. Silver was below both thresholds for all sites with the exception of MDE-27 for which the April sampling was observed right at the ERL. In the case of Hg, some sites exceeded the ERL, but the exceeding sites were not consistent between sampling dates. It is unlikely that of all the trace metals studied, any single sediment metal concentration is responsible for the observed toxicity. Metal concentrations in clams also do not vary in a manner suggesting any differences in metal bioavailability at these sites. Furthermore, concentrations of As, Cd, Hg, and MeHg in sediments around HMI appear inline with more pristine uncontaminated sediments, but Pb appears slightly elevated (Acevedo-Figueroa, 2005). While the criteria used are very conservative, erring on the side of having an impact on biota, the criteria does not address metal bioavailability directly. It may be that pore water metal concentrations are elevated or there is a cumulative effect of the metals.

Organics as a Potential Cause for Reduced Survival in *L. plumulosus*

Sediment toxicity criterion for the organic contaminants is not as well developed as it is for metals. Some PAH compounds have specific criteria but many do not. In the case of PCBs only the total PCB load is used to assess the toxicity. Many of the individual PAH concentrations are in excess of the TEL, but only phenanthrene at the site MDE-9 approached the PEL of 543 part per billion (ppb). On the whole most of the sites exceed the TEL for the total PAH concentration, including the reference site, MDE-36. All sites are well below the PEL. The same is true for the PCB concentrations, with most sites exceeding the TEL, but well under the PEL.

SUMMARY OF PROJECT RECOMMENDATIONS

Although a Zn signature in sediments surrounding HMI has been detected over the long-term record, as well as Pb, construction and operation at 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. MDE, MGS and UMCES 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. The facility will continue to be operated under a MDE issued Industrial Discharge Permit, which will have discharge limits for pH and selected metals, until MDE deems the permit unnecessary.

In anticipation of 2009 when HMI will no longer receive dredged material and restoration efforts will commence, a review of the current stations in terms of where best to conduct post closure monitoring is being conducted; decisions made during this review will be presented to the COC and stakeholders once a draft monitoring plan has been developed.

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 2006 - August 2007)

Technical Report

Prepared by
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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 DCMF) from the initial planning stages of construction of the facility to the present. As part of this year's exterior monitoring program, MGS collected bottom sediment samples from 43 sites on both September 12, 2006 and April 6, 2007. 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). In addition to the exterior sediment monitoring, an evaluation of the monitoring well data collected by MES semi-annually in 2006 was performed.

For exterior bottom sediments sampled during Year 25, the pattern of the grain size distribution varies slightly from one cruise to the next. The reasons for the variations are difficult to decipher, due to the complexity of the depositional environment and the multiple sources of material to the area. However, in general, sediment distribution is consistent with the findings of previous monitoring years, dating back to 1988, two years following the initial release of effluent from HMI.

With regard to trace metals some features to note are:

1. Cd, Cr, Cu, Ni, Pb, and Zn are found at some sites with concentrations that exceed the Effects Range Low (ERL) values; and
2. Ni and Zn exceed the 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 outlined later in this report is a means to correct the deficiencies of the NOAA 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.

In regard to potential adverse benthic effects results from this year's toxicology tests, the overlap of enrichment and concentration can be used as an indicator of potential biological impacts: based on the intensity of the effect, Zn>Ni>Pb; in regard to the number of samples, Pb>Zn>Ni. Most of the samples with potential benthic effects due to high concentrations of Ni are in the Back River and Baltimore Harbor Zones of influence. From the preliminary toxicology work done this year, enrichments of Zn and Pb are most significant in influencing benthic communities as a result of HMI operations. Pb enriched samples are associated with the three local sources HMI, Baltimore Harbor and Back River. Zn on the other hand only shows enrichment from Baltimore Harbor and HMI. Material from the Harbor did not influence the sediments in the HMI zone.

In the area effected by facility operations, Pb and Zn showed enriched levels. The April sampling cruise had higher levels, and a greater spatial extent as compared to the September sampling. 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.

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. 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 the Maryland Port Administration (MPA) and Maryland Environmental Service (MES) to counteract the effects of exposing contained dredged material to the atmosphere. Close cooperation with MPA and MES is important in this endeavor.

In order to better assess the potential influence of Baltimore Harbor on the HMI exterior sediments, sampling sites MDE-38, 39, 40, and 41 should be maintained, at least temporarily (Figure 10). Further, as of 2005 restoration of the South Cell was completed with upland wetlands, and a 200 acre pond to provide habitat for aquatic animals and migratory and resident birds. The South Cell pond water level is typically maintained at approximately 19 feet with an annual drawdown in late July through August to 17.5 feet. The additional sample locations near Spillway 003 through which the pond water is discharged should be maintained to assess this new operation of the facility as a part of the on-going monitoring program.

In regard to discharge monitoring of the spillways, a re-evaluation of the sampling frequency and protocols is needed if comparison of the data with historical records is considered important. This is particularly important as the post-closure monitoring program is designed.

The groundwater from the monitoring wells showed a pattern consistent with the 2005 Groundwater Study (Hill et al., 2005). The monitoring wells in the North Cell, where active inflow was in operation, contained groundwater similar to pore fluid in anoxic sediment; no sign of oxidation was evident. In the South Cell, the waters were anoxic, but had clearly undergone oxidation followed by reduction. Oxidation was evident from elevated sulfate and metals concentrations, and because of this process monitoring of the wells will be important during the post-closure phase of HMI operations.

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 DCMF). HMI is a man-made enclosure in northern Chesapeake Bay, named for the two natural islands that form part of its western perimeter.

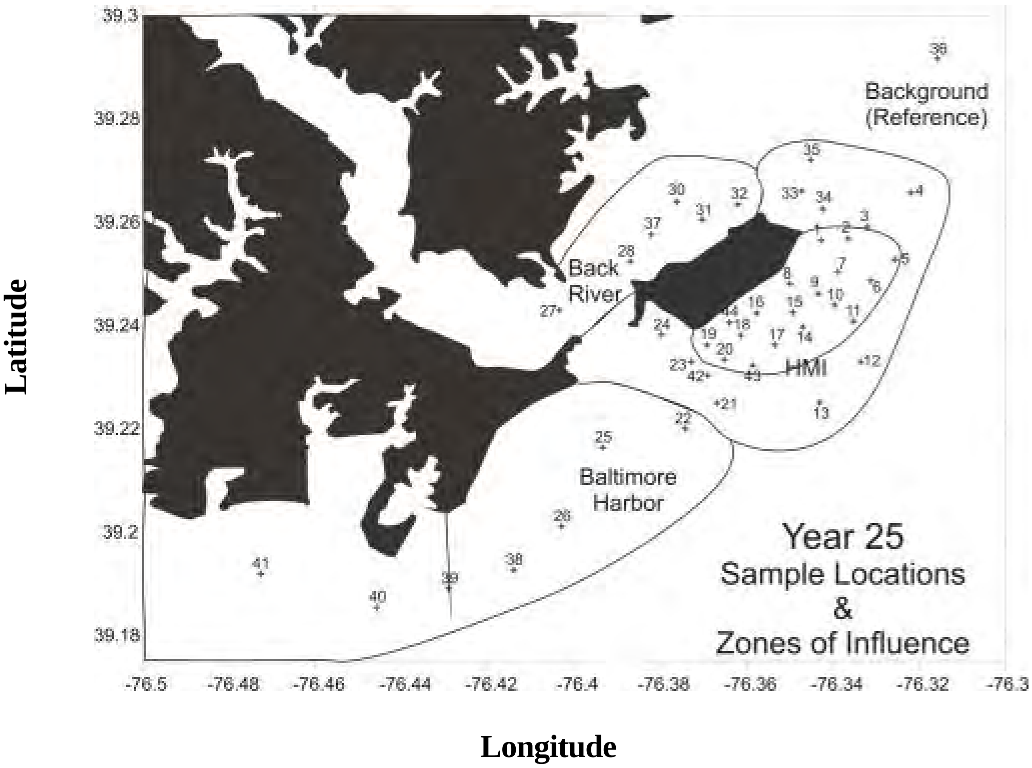


Figure 10. Sampling locations for Year 25. Contours show zones of influence found in previous studies. Stations 38 – 41 were added in Year 18 to measure the influence of Baltimore Harbor.

Designed specifically to contain material dredged from Baltimore Harbor and its approach channels, the oblong structure was constructed of sediment dredged from the facility interior. The physical and geochemical properties of the older, "pristine" sediment used in dike construction differed from those of modern sediments accumulating around the island. Likewise, material dredged from shipping channels as well as channels in Baltimore Harbor, near commercial docks, which generally have local sources of material of concern, and deposited inside the facility also differ 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 produce effluent enriched in metals. Oxidation occurs when the sediments are exposed to aerated conditions; this occurs during periods of 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 dike 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 dike 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 normalized concentrations, referenced to a standard material. Enrichment factors are the ratios of concentrations, in this case Zn to Fe, which are in turn 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 (MGD)); 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 dike.

2. Releases from Spillways 007 and 009 travel in a narrow, highly concentrated band up and down the eastern side of the dike. 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 dike. Conversely, the lower the flow, the less the compression and the greater the dispersion away from the dike.

5. Discharge from the HMI spillways 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.

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 *Year 11 Technical Report*. As a result of this examination, a model was constructed to predict the general trend in the behavior of Zn as a function of discharge rate from the facility. The model has two components: (1) loading due to material similar to the sediment in place and (2) loading of enriched material as predicted from a regression line based on discharge data supplied by the 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 25, 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 Technical 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 25 cruises are summarized below. Information was extracted from *Operations Reports* prepared by MES, covering the periods April 1, 2006 - April 30, 2007; a detailed synopsis of this period and digital discharge records were provided to MGS for this report by MES (pers. com.Harlan)

The total amount of material accepted in the North Cell was 0.7 million cubic yards, which is considered low. Material was accepted throughout the monitoring year period, with 90% of the year's total input during the six-month period prior to the April 2007 sampling cruise. The South Cell restoration was complete in 2005 and currently only discharges water to the Bay in late July through August as a normal procedure to drawdown pond water to 17.5 feet or as needed depending upon precipitation. As a result, the overall discharge rates from HMI were low, with the highest discharges starting in the last quarter of 2006. This is seen in Figure 11, which shows the daily discharge rate for each cell and the cumulative discharge for both.

Low discharge rates (<10 MGD) and dewatering operations are conducive to the production of acidic conditions resulting from oxidation of the sediment. Based on the discharge records, graphically shown in Figure 11, the South Cell discharges are optimal for releasing enriched waters into the Bay. Cruise 54 would be expected to have higher levels than Cruise 53 due to the longer discharge period prior to the sampling event. The North Cell would not be expected to be as enriched. For Cruise 53 there are several months with no discharge prior to the sampling event, so no material could be input from the North Cell. Prior to Cruise 54 there is a period of high discharge followed by a period of lower discharge, therefore this Cruise should show some effect though the potential magnitude would be lower than the South Cell discharge due to the difference in dewatering operations.

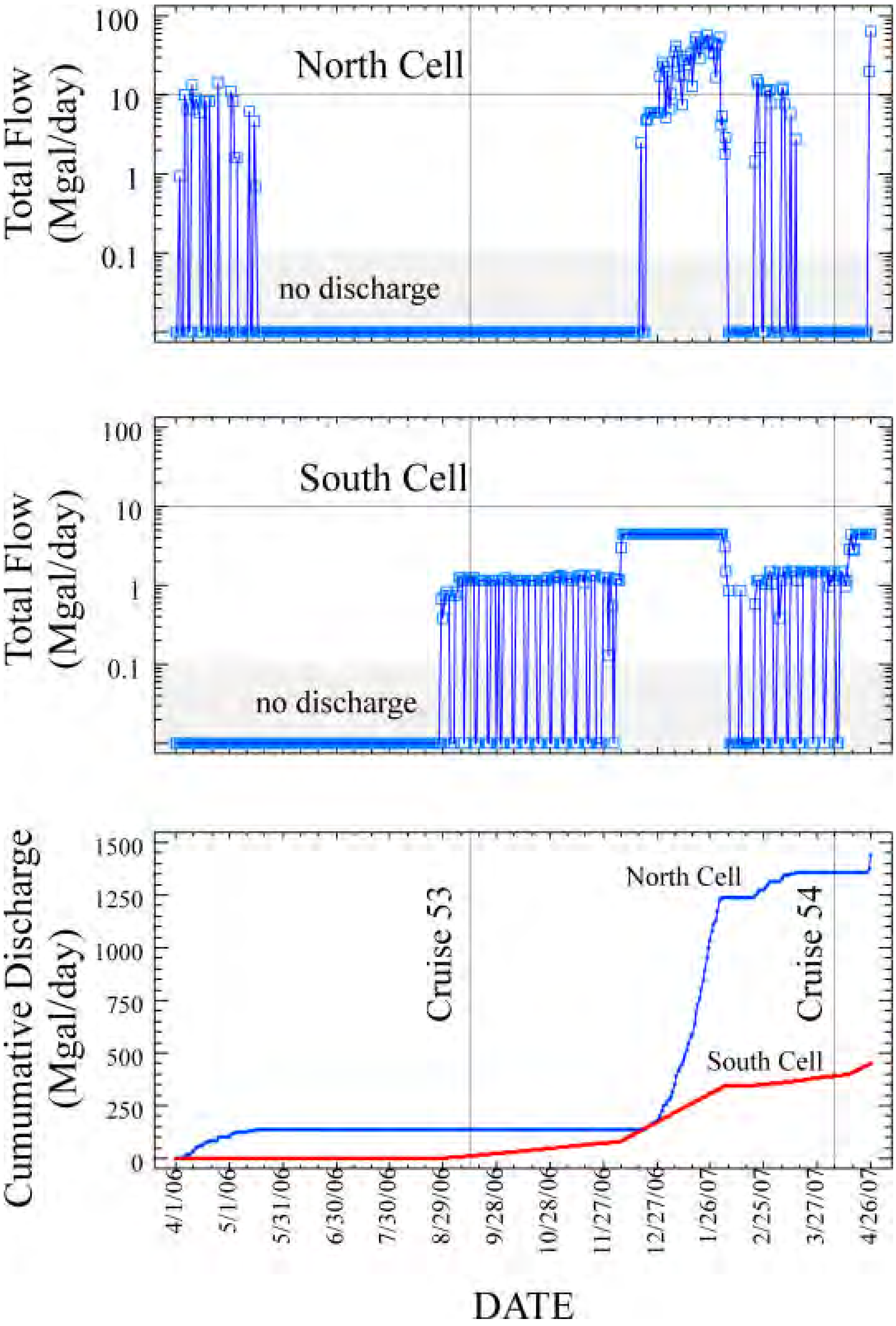


Figure 11. Daily and cumulative discharge from the North and South Cells. The sampling events are marked by the vertical lines.

Due to a change in the permit requirements, the way pH is measured was changed during the Year 23 monitoring period, therefore MGS believes that 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 during discharge events, pH records were maintained; pH values changed during discharge events; the high and low pH values for each day were recorded and reported to MDE. pH values can not be averaged since they are logarithmic metrics of acidity, so the range of data is an important indicator of the processes occurring. The new collection method is to collect one grab sample for each discharge event; MGS feels this is inadequate to characterize the processes operating at the facility. The best method would be a flow proportionate sampling of each event, with continual monitoring as the second choice.

OBJECTIVES

As in the past, the main objectives of the Year 25 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 12, 2006, and the second, on April 6, 2007.

Sampling sites (Figure 10) 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. The captain recorded station coordinates and water depth at most sites. Target and actual coordinates (latitude and longitude - North American Datum of 1983) of Year 25 sample locations are reported in the companion *Year 25 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 25 cruises. The stations were identical to those sampled during Year 24.

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 25 Data Report*.

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

Laboratory Procedures

Textural Analyses

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

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

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

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

The relative proportions of sand, silt, and clay were determined using the sedimentological procedures described in Kerhin et al. (1988). The sediment samples were pre-treated with hydrochloric acid and hydrogen peroxide to remove carbonate and organic matter, respectively. Then the samples were wet sieved through a 62-µm mesh to separate the sand from the mud (silt plus clay) fraction. The finer fraction was analyzed using the pipette method to determine the silt and clay components (Blatt et al. 1980). Each fraction was weighed; percent sand, silt, and clay were determined; and the sediments were categorized according to Pejrup's (1988) classification (Figure 12).

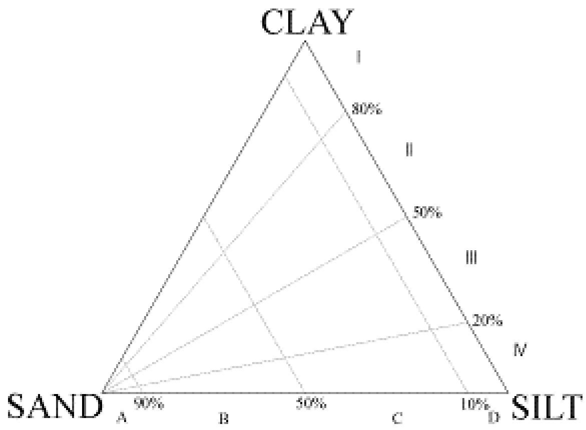


Figure 12. Pejrup's Diagram (1988) classification of sediment type

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

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

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

Trace Metal Analysis

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 total 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 Instutue for Standards (NIST) and Chesapeake Research Consortium (CRC) standard reference materials were inserted as blind samples for analyses; 1 in every 8 samples.

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

Carbon-Sulfur-Nitrogen Analysis

Sediments were analyzed for carbon, total nitrogen, 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 was 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 were also run. As a secondary standard, a NIST reference material (NIST SRM #1646 - Estuarine Sediment) was run after every 6 to 7 sediment samples. The recovery of the SRM was 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

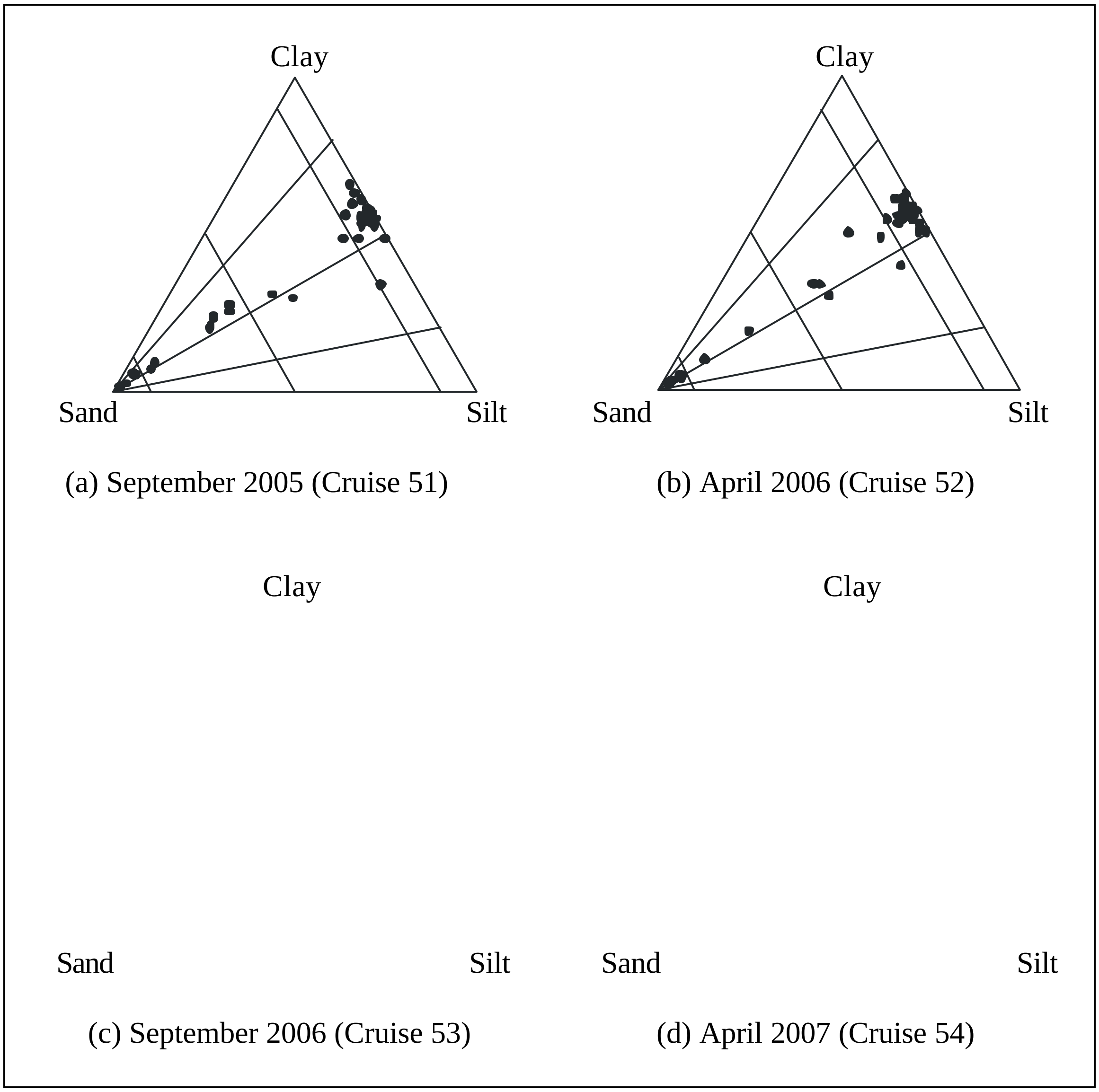
The monitoring effort around HMI is based on the identification of long-term trends in sediment distribution and on the detection of changes in those trends. The sampling scheme, revised in Year 17 and expanded in Year 18, established a new baseline against which any future changes in the sedimentary 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 25 results are discussed with respect to the preceding Year 24 results.

All 43 of the sampling sites visited during Year 25 yielded results that can be compared to those measured during Year 24. The grain size composition (proportions of sand, silt, and clay) of the 43 samples is depicted as a series of Pejrup's diagrams in Figure 13. Within a diagram, each solid circle represents one sediment sample. Related statistics, by cruise, are presented in Table 3.

Table 3. Summary statistics for Years 24 - 25, for 43 sediment samples common to all four cruises.

Variable	**Sept 2005 Cruise 51**	**Apr 2006 Cruise 52**	**Sept 2006 Cruise 53**	**Apr 2007 Cruise 54**
Sand (%)				
Mean	23.48	24.56	24.67	23.44
Median	3.64	3.82	4.44	4.38
Minimum	0.00	0.00	0.72	0.99
Maximum	97.46	96.67	96.52	98.18
Range	97.46	96.67	95.80	97.19
Count	**43**	**43**	**43**	**43**
Clay:Mud				
Mean	0.57	0.57	0.58	0.56
Median	0.57	0.58	0.58	0.57
Minimum	0.37	0.46	0.41	0.45
Maximum	0.68	0.65	0.65	0.62
Range	0.30	0.19	0.23	0.17
Count	**43**	**43**	**43**	**43**

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



(a) September 2005 (Cruise 51)

(b) April 2006 (Cruise 52)

(c) September 2006 (Cruise 53)

(d) April 2007 (Cruise 54)

Figure 13. Pejrup diagrams showing the grain size composition of sediment samples collected in Years 24 and 25 from the 43 sampling sites common to all four cruises: (a) September 2005, (b) April 2006, (c) September 2006, and (d) April 2007.

Based on the summary statistics (Table 3), 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 1.23% for the four samplings. The mean clay:mud ratio remained at 0.57 for Cruise 51 through 52 and increased only slightly to 0.58 for sampling Cruise 53. The mean clay:mud ratio then decreased slightly to 0.56 for sampling Cruise 54. 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 14 and Figure 15, three contour levels represent 10%, 50%, and 90% sand, coinciding with the parallel lines in Pejrup's diagram. Generally, sand content diminishes with distance from the containment facility. Scattered around the perimeter of the dike, the sandiest sediments (>50% sand) are confined to relatively shallow (<15 ft) waters (Figure 14).

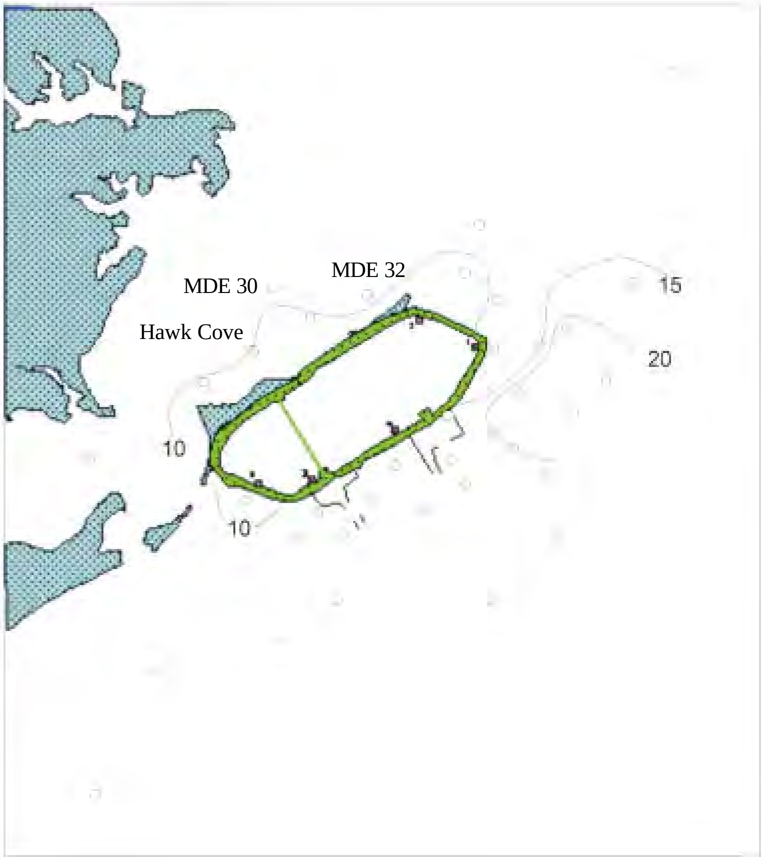
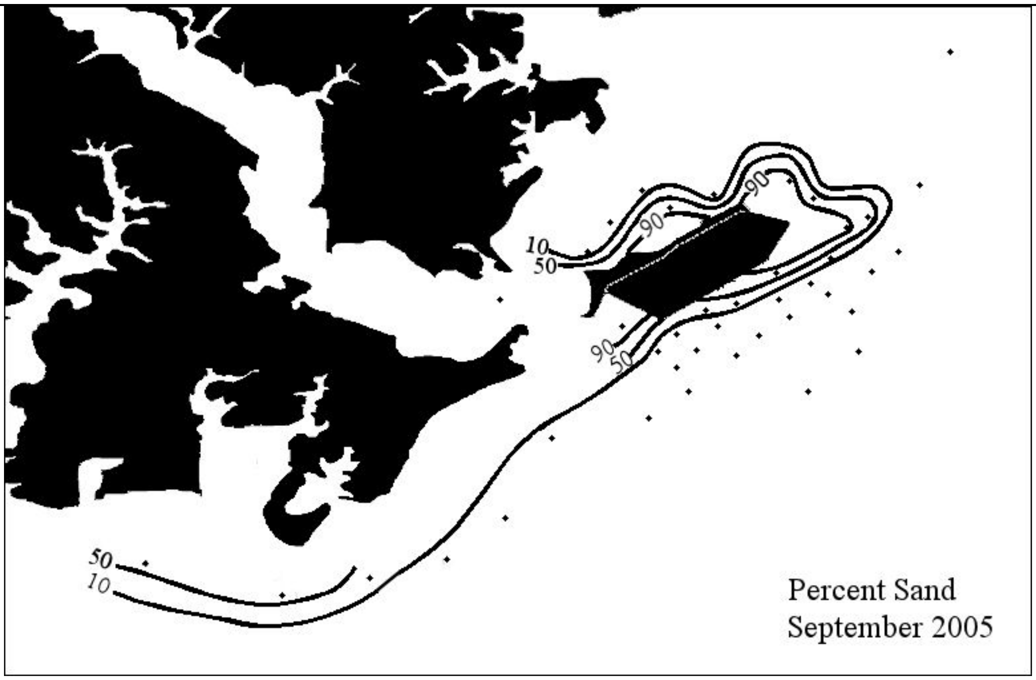


Figure 14. Average water depths, based on Year 17 Monitoring. Contour interval = 5 ft.

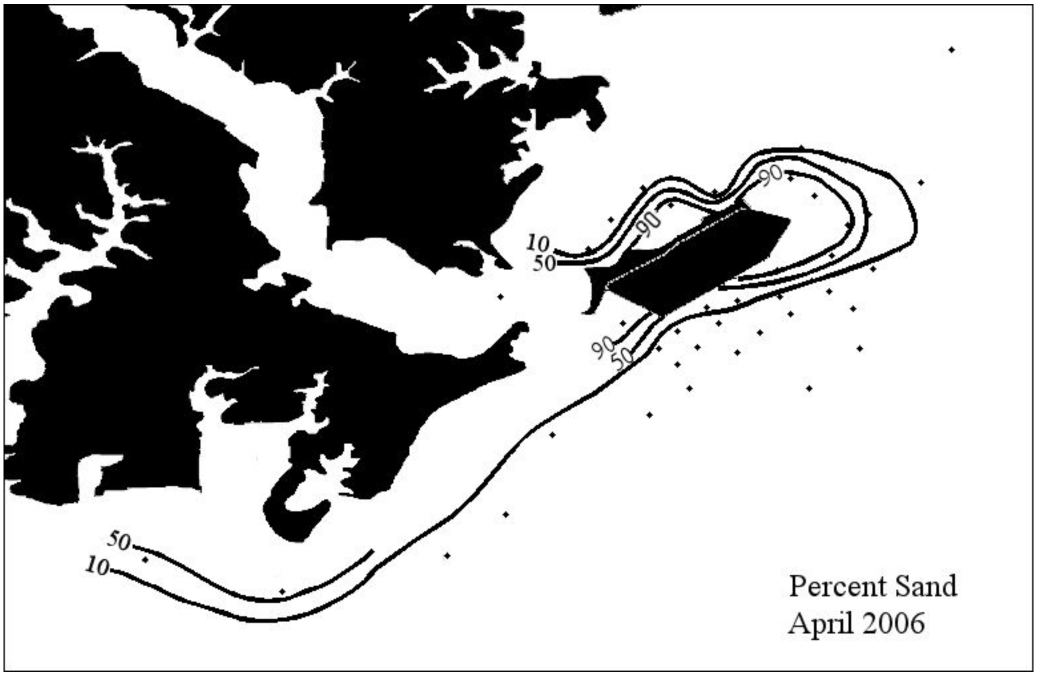
Broadest north and west of the facility, the shoals are the erosional remnants of a larger neck of land. The once continuous landmass has been reduced to a series of islands, including Hart and Miller, extending from the peninsula that now forms the south shore of Back River. However, not all shallow 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 24 and 25 are similar in appearance (Figure 15 & 16). 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 25. 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 dike.

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 13. 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 (Figure 17 & 18). MDE-41, at the mouth of Baltimore Harbor, continued to be clay-rich for all of the four samplings. A clay-rich area south of HMI was present in both September 2005 and April 2006. In September 2005, five stations had clay:mud ratios at or above 0.60 south of HMI (MDE-10, MDE -7, MDE-18, MDE-19, and MDE-44) to create the clay-rich area for this sampling. The clay-rich area extended up the east side of HMI in September 2005 due to the high clay:mud ratio seen at MDE-1, 2, 3, 32, and 33 (Figure 17). MDE-1, MDE-2, and MDE-33 are all sandy sites which make the clay:mud ratio values here negligible as will be explained below. Seven sampling sites were clay-rich south of HMI in April 2006. In addition to MDE-10, MDE-18 and MDE-19, which continued to be clay-rich, MDE-15, MDE-20, MDE-21, and MDE-23 were clay-rich in April 2006. In September 2006, nine sampling sites were clay-rich in this area. While MDE-10, 15, 18, 19, and 21 remained clay-rich, MDE-17 and MDE-42 through MDE-44 increased to above 0.60. Although more sample sites were clay-rich in September 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 (Figure 18). The following sampling in April 2007 resulted in five clay-rich sites in this area south of HMI. For this sampling, stations MDE-10, 15, 21, and 44 remained clay-rich with the addition of MDE-5. With the decrease in clay-rich sites in April 2007, the large pocket to the south of HMI was broken into three smaller pockets within the same area (Figure 18).

A clay-rich area was also present to the north of HMI for three of the sampling cruises (51-53) (Figure 17 & 18). This area was not clay-rich in April 2007. Note that this area lies close to the perimeter of HMI where sand contents are consistently at or above 90 percent (Figure 15 & 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:mud ratio at MDE-27 in Back Creek increased to 0.60 in September 2006, but decreased back to below 0.60 in April 2007. There was an overall increase in the number of clay-rich sites in September 2006 from ten stations during the previous sampling to 16 stations in this sampling event. In April 2007, the number of clay-rich sites then decreased down to eight. This is due in part to the mean monthly rainfall being higher in September 2006 then decreasing in April 2007, thereby decreasing the clay-rich sediment inputs into the Bay (Figure 18). The increase and subsequent decrease is also seen in both the Back River (MDE-27) and Baltimore Harbor (MDE-26, MDE-38) sampling sites and therefore is not in direct relation to operations of HMI. The clay-rich areas for Year 25 are similar to those from Year 24 with no significant changes.

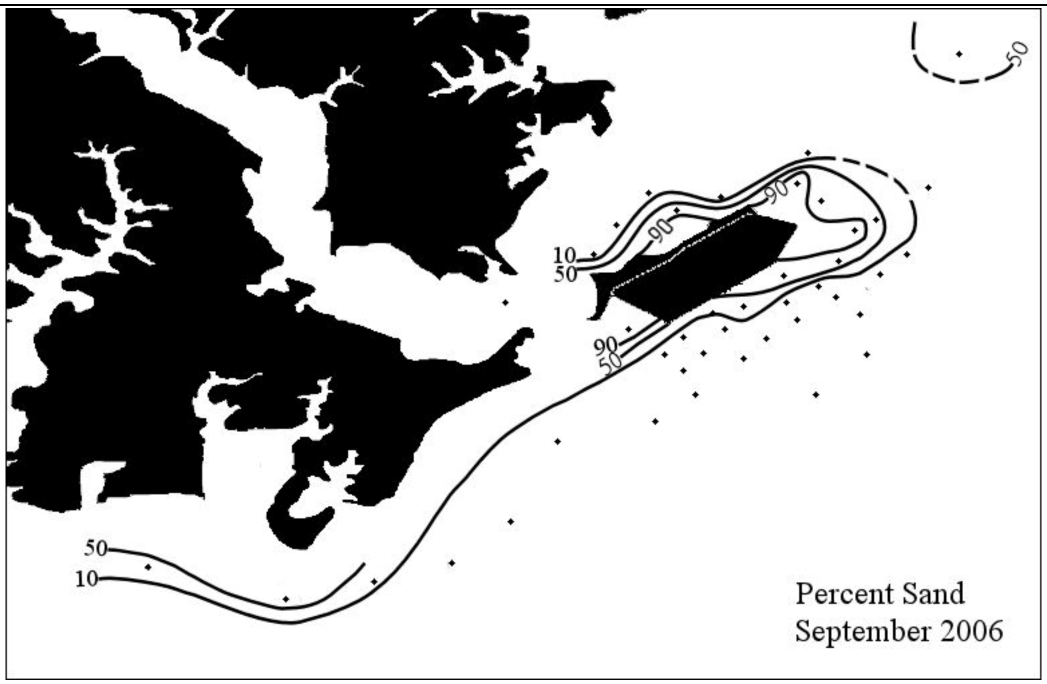


(a) Cruise 51

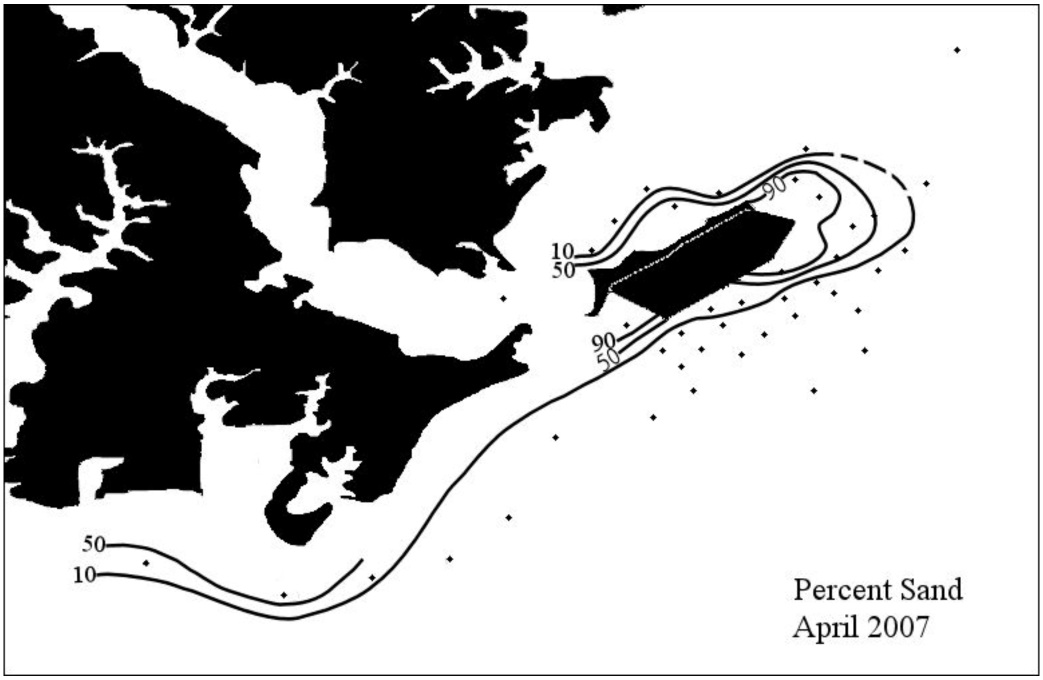


(b) Cruise 52

Figure 15. Sand distribution for Monitoring Year 24: (a) September 2005, (b) April 2006. Contour intervals are 10%, 50%, and 90% sand.

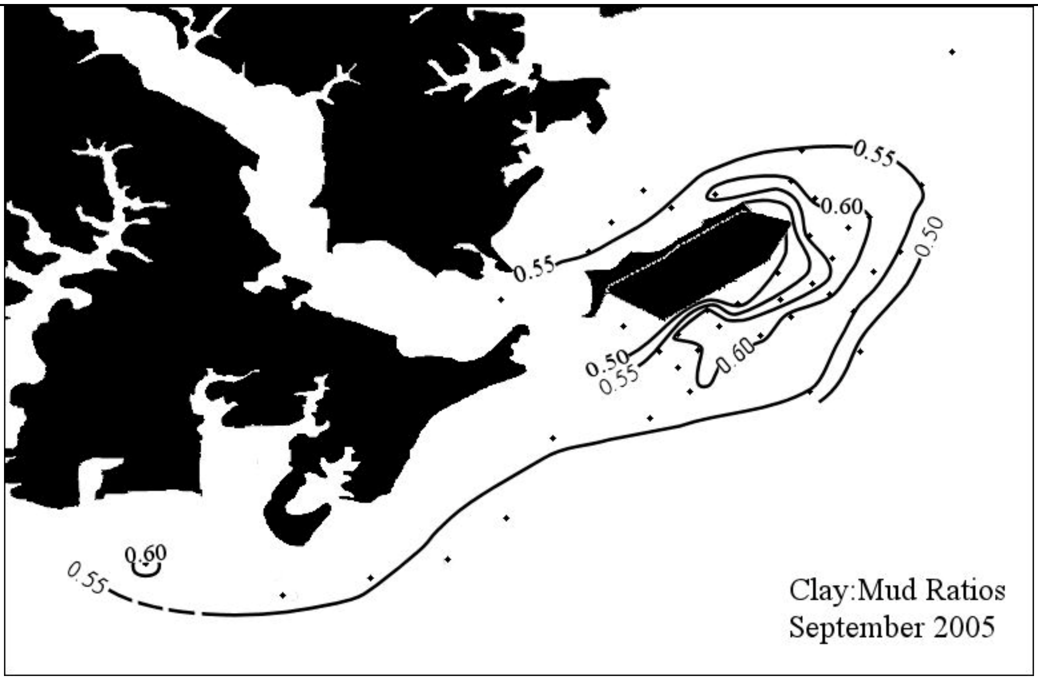


(a) Cruise 53

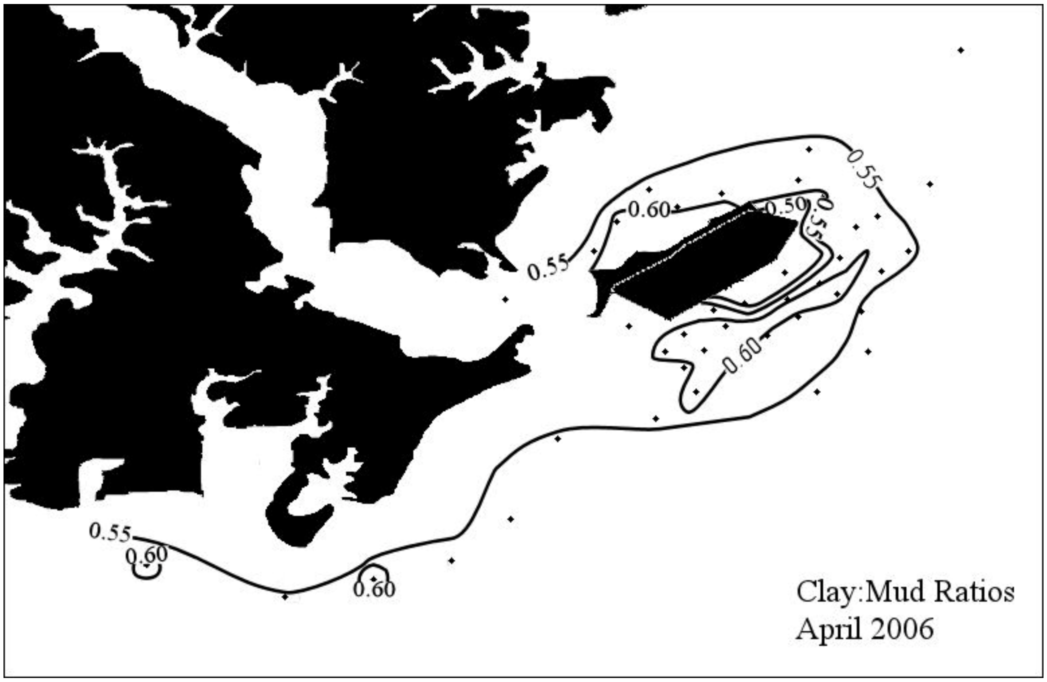


(b) Cruise 54

Figure 16. Sand distribution for Monitoring Year 25: (a) September 2006, (b) April 2007. Contour intervals are 10%, 50%, and 90% sand.

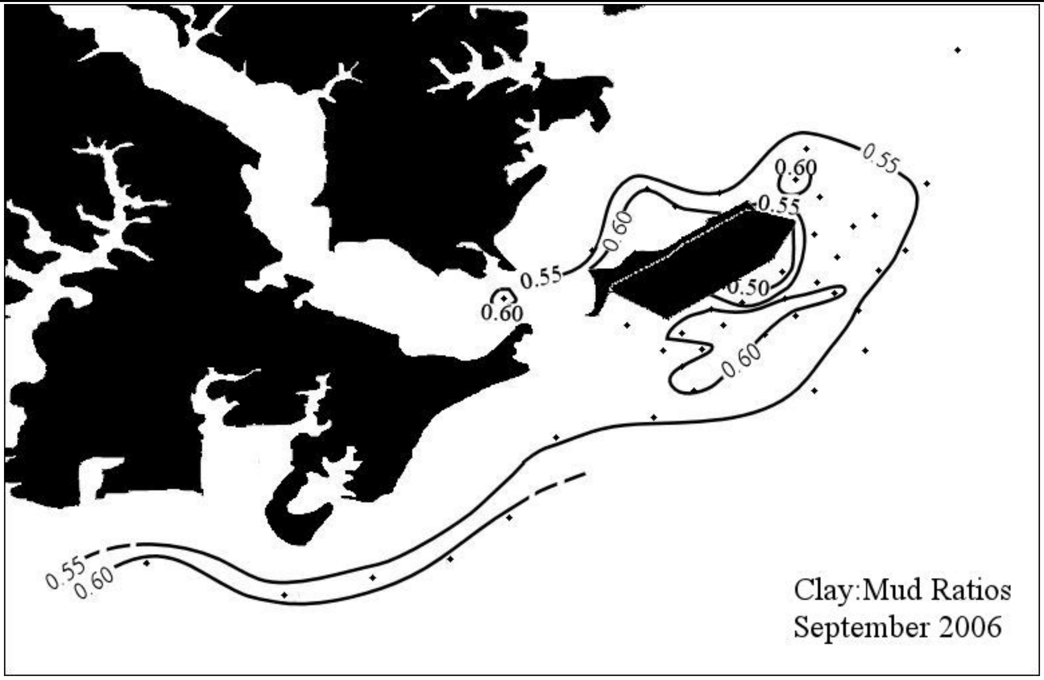


(a) Cruise 51

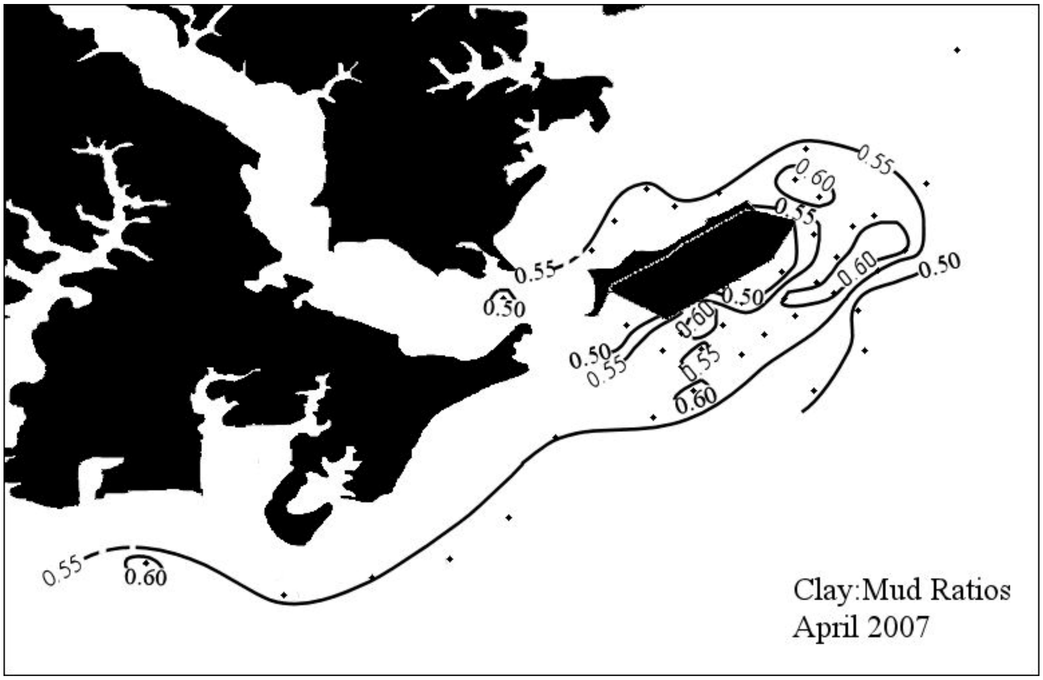


(b) Cruise 52

Figure 17. Clay:Mud ratios for Monitoring Year 24. Contour intervals are 0.50, 0.55, and 0.60.



(a) Cruise 53



(b) Cruise 54

Figure 18. Clay:Mud ratios for Monitoring Year 25. Contour intervals are 0.50, 0.55, and 0.60.

Silt-rich sediments (clay:mud ratio < 0.50) are generally found immediately adjacent to the walls of the dike, commonly in the vicinity of spillways. In September 2005, four sites consisting of MDE-16 adjacent to the wall of the dike to the southeast, MDE-24 adjacent to the south most end of the dike, MDE-12 approximately 1.3 miles southeast of the facility, and MDE-27 in Back River were silt-rich. The area adjacent to the wall of the dike to the southeast (MDE-8 and MDE-16) continued to be silt-rich in April 2006. Also silt-rich in April 2006 was MDE-27. In September 2006, MDE-8 continued to be silt-rich to the southeast of the dike. This was the only silt-rich station in September 2006. MDE-8 was again silt-rich to the southeast of the dike in April 2007 along with MDE-27 in Back River and MDE-24. Also silt-rich in April 2007 were MDE-11 and MDE-12. MDE-8 and MDE-27 were silt-rich for three of the four samplings, while MDE 12, MDE-16 and MDE-24 were silt-rich for two of the four samplings. The silt-rich areas were consistent during both Year 24 and Year 25 monitoring with regards to the area adjacent to the walls of the dike to the south remaining silt-rich.

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 24 and Year 25, one may conclude that the depositional environment in the vicinity of HMI was unchanged over this period. While there was an increase in the number of clay-rich sites in September 2006, there was a subsequent decrease in April 2007. No clear trends affecting many samples from a large area are evident. The grain size distribution of Year 25 samples is largely consistent with the findings of past monitoring years.

Elemental Analyses

Interpretive Technique for Trace Metals

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

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

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 4. 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 4. 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 4 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.

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

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 percent 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 ±2s (±2 standard deviations) are within normal background variability for the region. Samples with a value of ±3s can be within accepted background variability, but are considered marginal depending on the trends in the distribution. Any values falling outside this range indicate a significant perturbation to the environment. The standard deviation (s) 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 4. The sigma level for Zn is ~30% (e.g. 1s = 30%, 2s = 60%, etc.).

General Results

A listing of the summary statistics for the elements analyzed is given in Table 5. Some features to note are:

1. Cd, Cr, Cu, Ni, Pb and Zn are found at some sites with concentrations that exceed the ERL values; and
2. Ni and Zn exceed the 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. Sediments with concentrations below the ERL are considered baseline concentrations with no expected adverse effects. Concentrations between the ERL and ERM may have adverse impacts to benthic organisms, while values greater than the ERM have probable adverse biological effects. These criteria are based on a statistical method of termed preponderance of evidence. The method does not allow for unique basin conditions and does not take into account grain size induced variability in metal concentrations in the sediment. The values are useful as a guide, but are limited in applicability due to regional difference. The grain size normalization procedure outlined in the previous section is a means to correct the deficiencies of the guidelines by taking into account the unique character of Chesapeake Bay sediments and eliminating grain size variability. When the data are normalized, Pb and to a lesser extent Zn, have samples significantly enriched compared to the baseline (Figure 19). Based on work done by the University of Maryland during this monitoring year the most probable conditions where the metals affect the infaunal communities are:

1. When the sigma level exceeds +2 [indicating enriched metals concentrations over baseline] and;
2. When the metals level exceeds the ERL with increased probability as the level exceeds the ERM [showing absolute concentrations that have exhibited adverse effects in other systems].

Table 5. Summary statistics for elements analyzed. [All concentrations are in ug/g unless otherwise noted]

Parameter	P (%)	Cd	Cr	Cu	Fe (%)	Mn	Ni	Pb	Zn
Ave	0.070	0.71	87	42	4.15	2468	77	54	302
Std	0.028	0.21	41	19	1.69	1306	34	25	145
Min	0.003	bdl	8	2	0.19	309	5	5	15
Max	0.120	1.40	250	73	5.95	7700	159	101	637
n	84	73	86	86	86	86	86	86	86
ERL	n/a	1.3	81	34	n/a	n/a	21	47	150
#>ERL	n/a	2	62	63	n/a	n/a	76	58	70
ERM	n/a	9.5	370	270	n/a	n/a	52	218	410
#>ERM	n/a	0	0	0	n/a	n/a	68	0	14

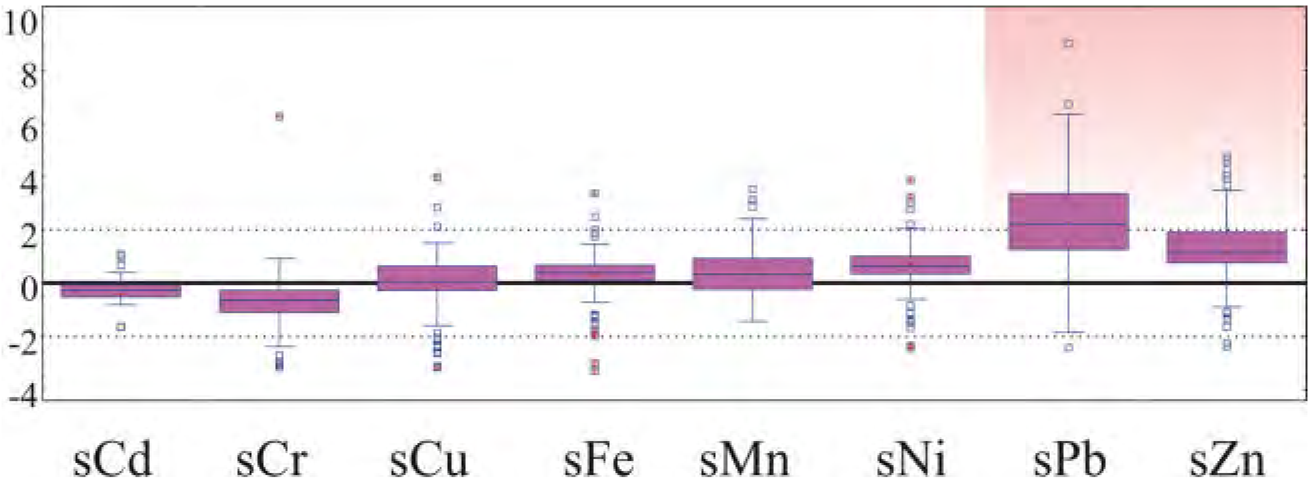


Figure 19. A box and whisker diagram showing the range of the data for both the fall and spring cruise.

The values presented in Table 5 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 19 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 more than a quarter of the samples. In regard to potential adverse benthic effects, based on the overlap of enrichment and concentration, the impact can be viewed in two different contexts: 1) based on the intensity, i.e., the extent the samples exceed background levels and reference conditions, the effect, Zn>Ni>Pb, and 2) based on the number of samples that exceed baseline levels or concentrations the effect, Pb>Zn>Ni. Most of the samples with potential benthic effects from Ni are in the Back River and Baltimore Harbor Zones of influence. The following discussion will focus on Zn and Pb, as most significant as a result of HMI operations.

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 *Year 12 Interpretive Report*). The high metal loading to the exterior environment may be 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. At discharge rates greater than 10 MGD, the water throughput (input from dredge disposal to release of excess water) submerges the sediment within the facility, minimizing atmospheric exposure, and dilutes and buffers any acidic leachate. As a result, higher discharge rates produce metal loadings that are close to background levels.

2. Flow of freshwater into the Bay from the Susquehanna River - The hydrodynamic environment of the Bay adjacent to HMI are controlled by the mixing of freshwater and brackish water south of the area. Details of the hydrodynamics of this region were determined by a modeling effort presented as an addendum to the *Year 10 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 dike;
   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 dike. Conversely, the lower the flow, the less the compression and the greater the dispersion away from the dike; 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 dike. 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 20 shows the sigma levels for Pb for Year 25 monitoring periods in the study area adjacent to HMI; sigma levels for Zn are shown in Figure 21. 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 20 & 21 is used to highlight the areas that are significantly elevated above baseline levels. As shown in Figure 10 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 higher levels in the Spring, compared to the Fall Cruise. The spatial extent is similar for both cruises. Zn concentrations were within background levels for both sampling cruises as it was for Year 24.

Baltimore Harbor - Elevated levels of Pb and Zn extend into the area south of HMI. The levels for both metals are clearly isolated from the HMI zone of influence adjacent to the island. Both metals showed lesser elevated values than in Year 24.

HMI - The area adjacent to HMI had metals (Pb and Zn) levels comparable to the previous monitoring year (Year 24), however the spatial extent this year was greater than in Year 24 with a clear separation of the zones of influence. The area around the South Cell discharge point was elevated for both metals for both cruises. The Spring sampling period showed a spatially larger area of significant deposition east of HMI.

Based on the operations of the HMI facility, it would be expected that the facility would have significant contributions of metals to the exterior sediments during this monitoring year (see *Dike Operations* section). Based on the discharge records the September sampling would be less impacted than the sediments collected in the spring. This is the case, both Pb and Zn show elevated levels for both cruises, localized in the area of the South Cell discharge levels. The influence of the North Cell discharge is evident in the spring sampling following a 3-month period of discharge. The elevated levels from the North Cell are located in the zone east of the facility, consistent with low to normal flow regimes during this period, based on rainfall records.

The spatial extent and the levels found in the Baltimore Harbor and Back River zones vary according to seasonal climatic changes, which influence the hydroynamic 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 not the case for this monitoring year, this year the spring samples show slightly higher levels, and the spatial extents are comparable. This is most probably due to climatic conditions; rainfalls were below normal prior to the Fall Cruise and average prior to the Spring Cruise.

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 dike. 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. The separation of the Baltimore Harbor zone from the HMI zone was maintained for Year 25, by the low to average rainfall in the periods prior to sampling.

In regard to the long-term trend of the data, the highest levels of Zn enrichment in the HMI zone are higher in both cruises as compared to Year 24 monitoring. The data from this monitoring year are shown in Figure 22 as the solid points, which show an increase from the last monitoring year. Viewed in context, there appears to be a general trend, starting in 2002, of increasing metal levels as dewatering operations proceed. Although the metal levels are higher the spatial extent is limited.

Note, in Figure 22 the reference line for potential biological effects is based on data from the joint study of the Baltimore Harbor (Baker et al., 2000). This level may not be appropriate for the main Bay in the area around HMI. Current and future toxicity tests in the area will establish better guidelines for the area.

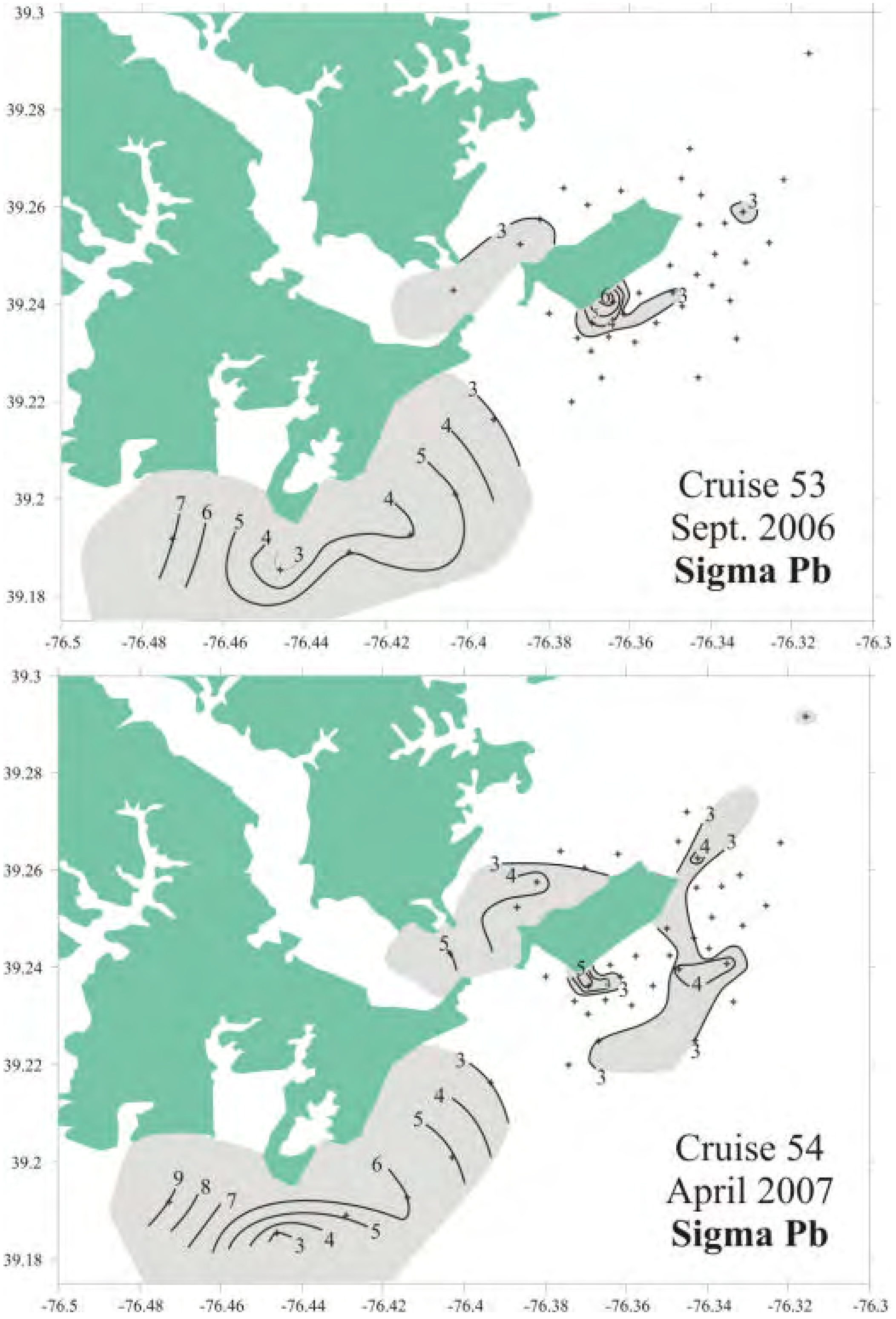


Figure 20. Distribution of Pb in the study area for the Fall and Spring sampling cruises. Units are in multiples of standard deviations - Sigma levels: 0 = baseline, +/- 2 = baseline, 2-3 = transitional(values less than 3 not shown), >3 = significantly enriched (shaded in figures).

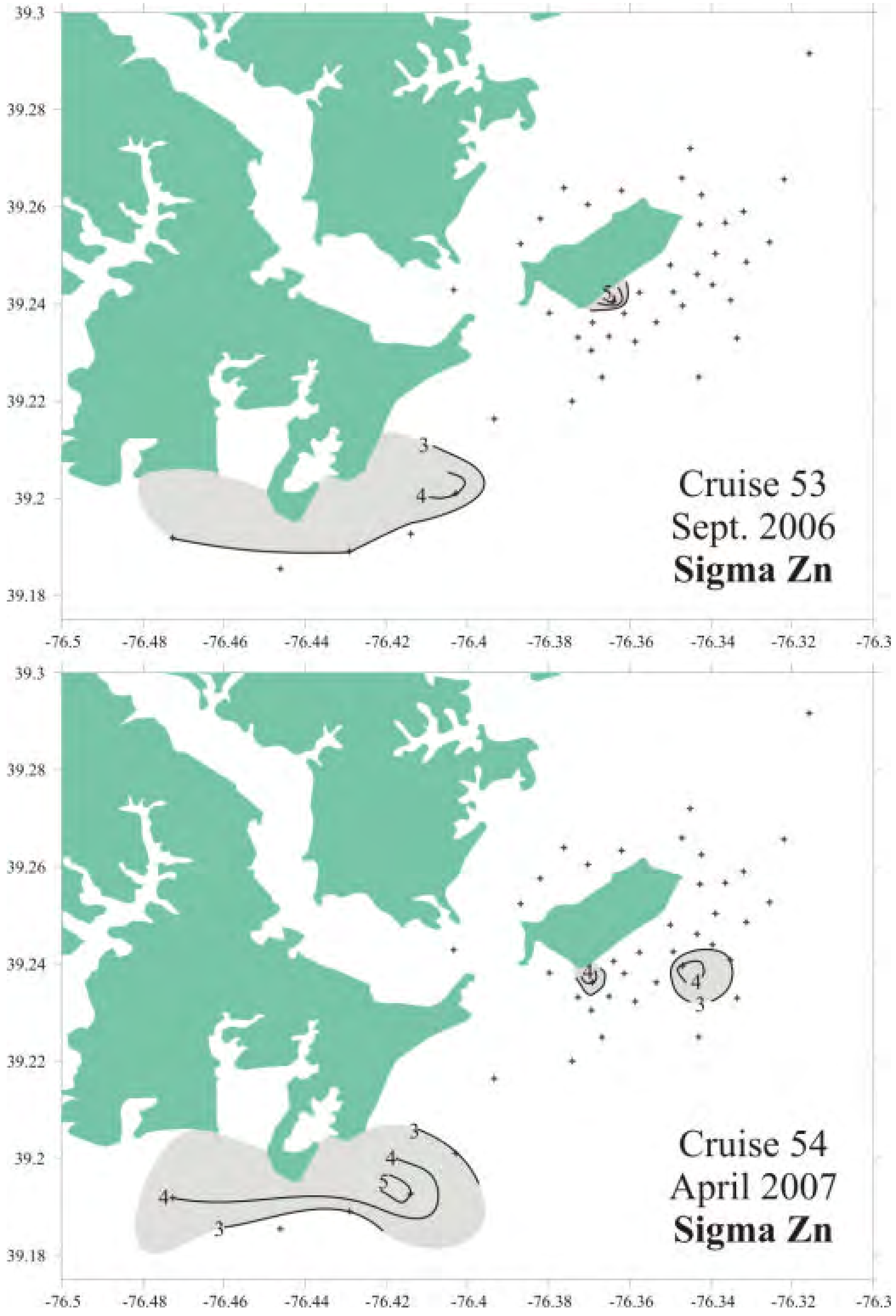


Figure 21. Distribution of Zn in the study area for the Fall and Spring sampling cruises. Units are in multiples of standard deviations - Sigma levels: 0 = baseline, +/- 2 = baseline, 2-3 = transitional(values less than 3 not shown), >3 = significantly enriched (shaded in figures).

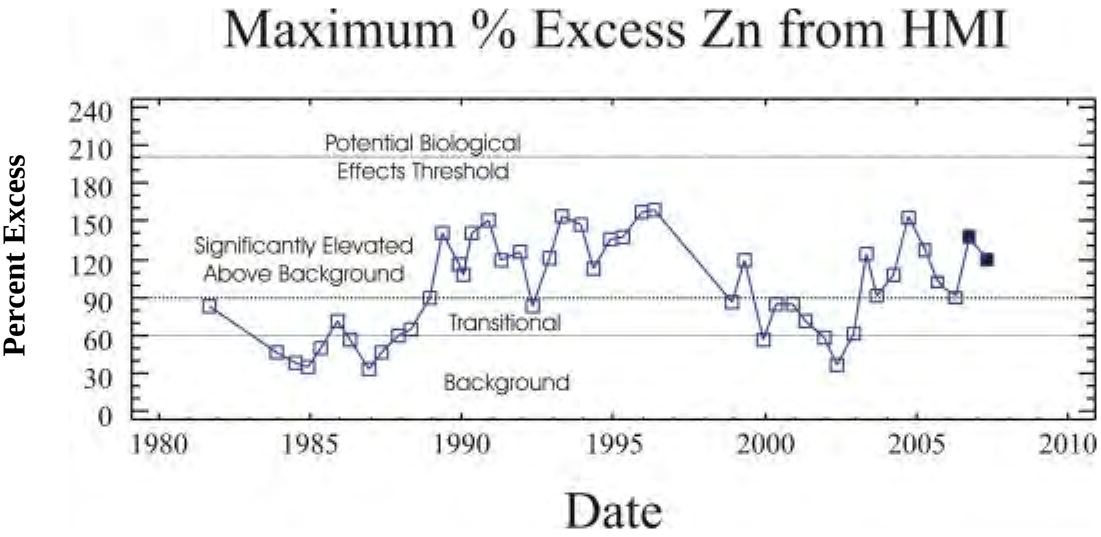


Figure 22. Record of the maximum % excess Zn for all of the cruises for which MGS analyzed the sediments. The filled points are the data from this study.

SUMMARY AND RECOMMENDATIONS

The grain size distribution of the Year 25 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 similar during Year 24 and Year 25. A slight increase in clay content at several stations across the study area resulted in a larger number of clay-rich samples in September 2006. However, this did not greatly affect the overall distribution of clay-rich areas. Several of 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 2007 at these stations and the dominate clay-rich area continued to be the area to the south of HMI with the clay-rich area being slightly smaller than in the previous three samplings. 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 25.

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 dike. In Year 25, monitoring was continued at the 3 stations added in the vicinity of Spillway 003 in April 2004. The monitoring was done in order to assess the operation of the South Cell as upland wetlands with a discharge in the area of Spillway 003. There were no significant changes at these three stations during Year 25 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 ERL values; and
2. Ni and Zn exceed the 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. Sediments with concentrations below the ERL are considered baseline concentrations with no expected adverse effects. Concentrations between the ERL and ERM may have adverse impacts to benthic organisms, while values greater than the ERM have probable adverse biological effects. These criteria are based on a statistical method of termed preponderance of evidence. The method does not allow for unique basin conditions and does not take into account grain size induced variability in metal concentrations in the sediment. The values are useful as a guide, but are limited in applicability due to regional difference. The grain size normalization procedure outlined in the previous section is a means to correct the deficiencies of the guidelines by taking into account the unique character of Chesapeake Bay sediments and eliminating grain size variability. When the data are normalized, Pb, and Zn have significantly enriched samples compared to the baseline.

In regard to potential adverse benthic effects results from this year's toxicology tests, the overlap of enrichment and concentration can be used as an indicator of potential biological impacts: based on the intensity of the effect, Zn>Ni>Pb; in regard to the number of samples, Pb>Zn>Ni. *Most* of the samples with potential benthic effects from Ni are in the Back River and Baltimore Harbor Zones of influence. From the preliminary toxicology work done this year, enrichments of Zn and Pb are most significant in influencing benthic communities as a result of HMI operations

Pb enriched samples are associated with the three local sources HMI, Baltimore Harbor and Back River. Zn on the other hand only shows enrichment from Baltimore Harbor and HMI. Material from the Harbor did not influence the sediments in the HMI zone.

In the area effected by facility operations, Pb and Zn showed enriched levels. The April sampling cruise had higher levels, and a greater areal extent as compared to the September 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.

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. 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 should 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 discharge monitoring 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 1A: HMI GROUNDWATER MONITORING WELLS 2006 (PROJECT II)

INTRODUCTION

Groundwater samples from six wells were collected in June and December 2006, as part of the on-going HMI external monitoring effort and as a continuation of the groundwater studies completed in 2003 (URS), and 2005 (Hill). The number of wells were equally divided between the North and South Cells as seen in Figure 23: North Cell 2A, 4A & 6A; South Cell 8A, 10A & 12A. The South Cell is being converted to its' ultimate use as an upland wetlands, and no longer receives dredged material.

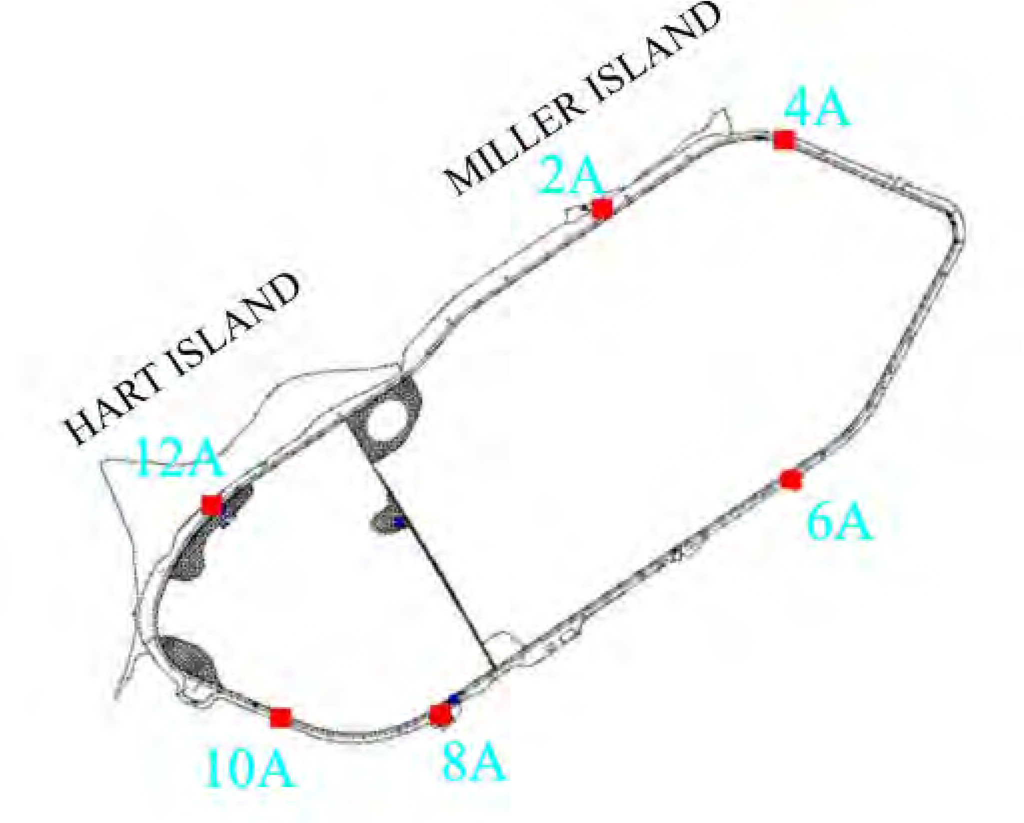

Figure 23. Groundwater sampling wells locations.

The North Cell on the other hand is actively receiving material and will continue to do so until Jan 2010. The following summarizes the data based on the interpretive methods detailed in the 2005 well study report (Hill,2005)

SUMMARY OF DATA

All Wells

1. All of the wells are anoxic or hypoxic; dissolved Oxygen levels less than 0.8mg/l. This level of oxygen may be the result of sulfide interference with the DO probe.
2. There are no sulfide measurements, due to limitations in the instrumentation used to get in situ measurements. These measurements are not absolutely necessary, but their absence limits the information on the degree of anoxia and the processes occurring. Dissolved sulfide binds with many metals and restricts their mobility, and is preferentially used as a metal ligand releasing mineralized phosphate into the water.
3. The dominant form of nitrogen in all of the wells appears to be ammonium, since nitrate is below detection. Nitrate is used preferentially once oxygen is consumed as the primary oxidant, and ammonium ion is a by-product of anaerobic respiration. This is consistent with the anoxic/hypoxic nature of the groundwaters.

North Cell Wells 2A & 6A

1. The groundwater shows a reducing environment based on the depletion in sulfate in comparison to predicted concentrations. The predicted levels are calculated from the chloride concentration based on conservative mixing between rainwater and seawater. Figure 24 shows the Chloride concentration as a function of the amount of sulfate either removed from the water as a result of sulfate reduction (- Excess Sulfate) or added to the water as the result of sulfide oxidation in the sediment solids (+ Excess Sulfate).

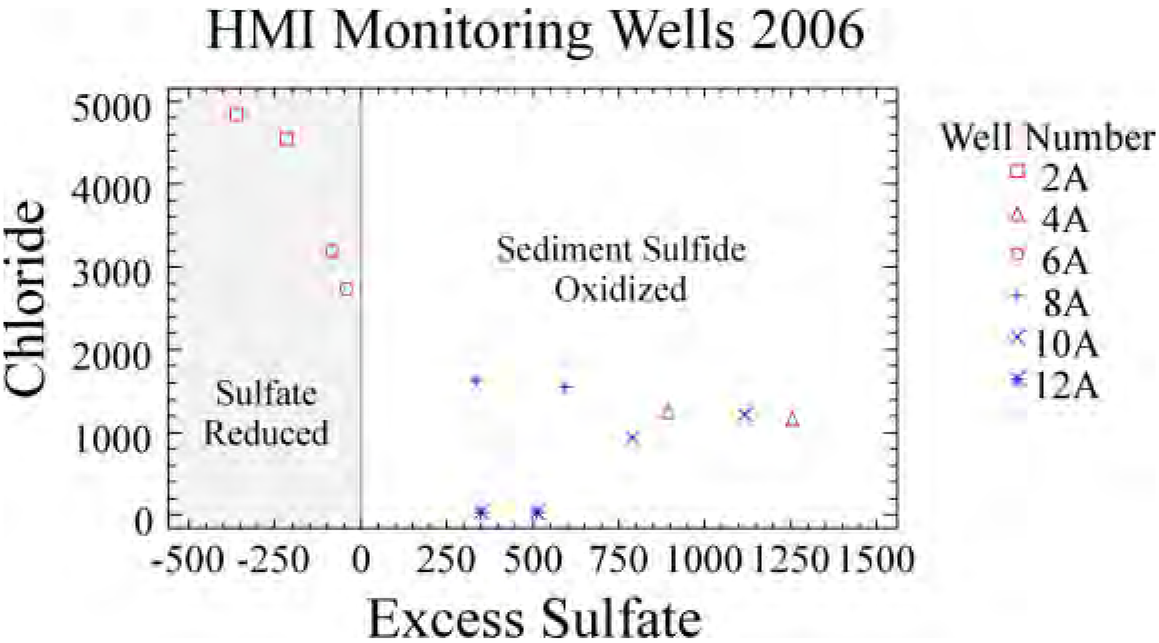

Figure 24. Groundwater Chloride concentrations as a function of Excess Sulfate (the difference of the measured sulfate concentrations minus the predicted concentrations).

2. These wells have higher salinity, as seen from the chloride concentrations (Figure 24). The higher levels are the result of replenishment of more saline water from the Bay as a result of dredging operations.

3. Alkalinity concentrations are higher than the other sites since the alkalinity has not been neutralized by acid production.
4. Metal concentrations are generally lower since they are not leeched from the sediment by acid or change in oxidation state. Acid produced by sediment oxidation can dissolve mineral species and the change in oxidation state that produced the acid can destabilize minerals and make them more soluble. Most of the metals measured [except As] were near or below the detection limit.

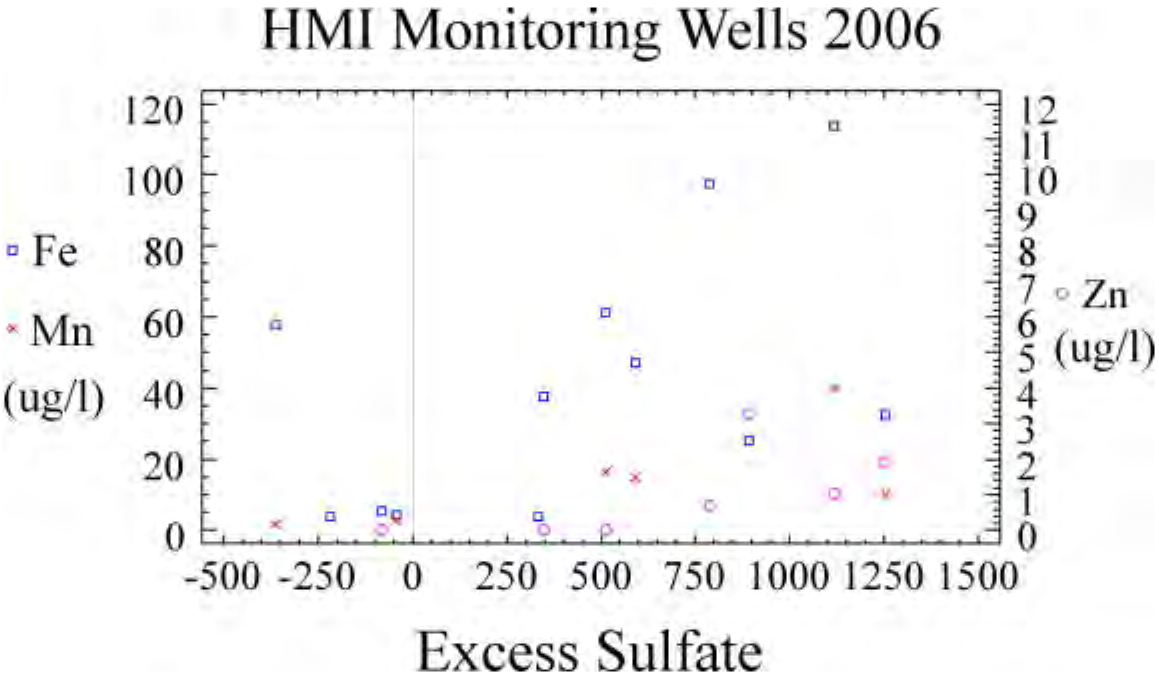

Figure 25. Fe, Mn and Zn concentrations as a function of Excess sulfate. Note samples below detection limits are not shown.

5. The major cations are near the predicted conservative mixing concentrations. Since acid is not produced there is little mineral dissolution (specifically calcium carbonate) or ion exchange. Hydrogen ion from acid is preferentially bound on ion exchange sites in the sediment releasing other adsorped cations (e.g. K+). The linear relation in the positive Excess Sulfate region is due to the process of acid production being directly related to neutralization and ion exchange.

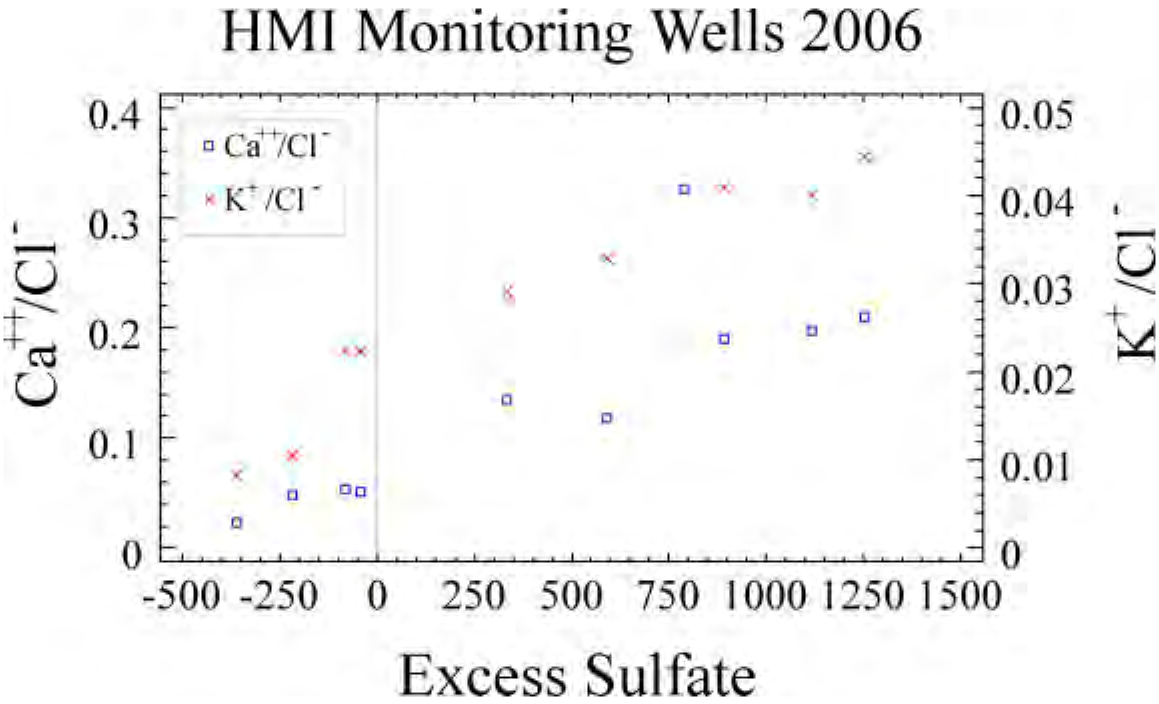

Figure 26. The ratios of K+/Cl- and Ca++/Cl- as a function of Excess Sulfate. For reference, the ratios for both of these cations in seawater is ~0.2.

6. Total dissolved nitrogen (as ammonium), on average, is about three times higher in the wells 2A and 6A compared to the other wells. This is due to the reducing processes that dominate these groundwaters. Ammonium is produced as a by-product of anaerobic respiration. Since the waters in these wells have not undergone an oxidative stage, ammonium is higher.

Overall, the North Cell wells 2A and 6A exhibit behavior typical of anoxic pore waters that have not been exposed to oxidized sediment. The ground water is replenished with water from dredged material input which maintains the anaerobic state of the sediments in these areas of the North Cell.

South Cell Wells 8A, 10A & 12A and North Cell Well 4A

1. The waters in these wells have been exposed to oxidized sediments, thus the higher levels of Excess Sulfate (Figure 24).
2. Rainwater appears to be a major source of water to these wells due to the lower Chloride concentrations that dilute the Bay concentrations.
3. Ammonium is lower, on average, by a third.
4. Metals and Cations are significantly higher.
5. Alkalinity is lower and in well 10A samples from both sampling events was below the detection limit, indicating that free acid was present at some point in its flow path.

Based on the above, rainwater appears to be a major source of water to these wells, and the sediments are to some extent exposed to the atmosphere. The exposure of the sediment is providing the oxygen to oxidize the sulfide in the sediments that are the source of water for the wells. The entire South Cell has on-going sediment oxidation, as well as the source area around North Cell well 4A.

APPENDIX 2: BENTHIC COMMUNITY STUDIES (PROJECT III)

(September 2006 – August 2007)

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-fifth consecutive year under Project III of the HMI Exterior Monitoring Program. The communities living close to the facility [Nearfield, South Cell Exterior Monitoring (formerly called 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 Exterior Monitoring stations) were sampled on September 13, 2006 and on April 13, 2007.

A total of 40 taxa of benthic macroinvertebrates were found during Year 25 of monitoring. Several of the 40 taxa were clearly dominant. The worms *Marenzelleria viridis* and *Naididae* sp.1, the clams *Rangia cuneata* and *Mytilopsis leucophaeata*, 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 Year 25 cruises was the worm *Streblospio benedicti* and the arthropod *Apocorophium lacustre*. *Streblospio benedicti* declined from the most abundant taxa in September 2006 to the 12th most abundant taxa in April 2007, while *Apochorophium lacustre* increased from a low total abundance in September 2006 to the fourth most abundant taxa in April 2007. Polychaete taxa richness was similar for the two seasons, although *Streblospio benedicti* was much less abundant in April 2007 sampling. Total abundance (excluding Bryozoa and Copepoda) was higher in April 2007 than September 2006 at most stations; this was primarily due to the spring recruitment of the worms *Naididae* sp. and *M. viridis*.

Species diversity was examined using the Shannon-Wiener diversity index. Diversity was higher in September 2006 than in April 2007 at all stations except MDE-19 and MDE-36. The proportion of pollution sensitive taxa abundance (PSTA) and pollution indicative taxa abundance (PITA) was calculated in both seasons. The PSTA percentages were much higher at all stations in September 2006 compared to April 2007. Oligohaline conditions prevailed at all stations in September 2006 and April 2007, except at MDE-13 in September 2006, where lower mesohaline conditions were measured.

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 (July 15th to September 30th timeframe) of benthic macroinvertebrates, was calculated for all stations sampled in September 2006. Overall, the B-IBI scores remained generally stable when compared to Year 24. This year, 13 stations exceeded the benchmark criteria of 3.0, and seven stations failed to meet the benchmark. All station types, including Reference, had stations that failed to meet the 3.0 benchmark.

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[1] Tubificidae sp. is now described as Naididae sp. due to a reclassification brought about by the International Commission on Zoological Nomenclature. (Case 3305)

In Year 25, there were significant differences for the ten most abundant infaunal taxa among the four station types, based on results of the nonparametric Friedman’s test. These results were primarily driven by influence of the Back River drainage on the three Back River stations, and possible unique physical or habitat factors at the South Cell stations. Cluster analysis also indicated faunal differences due to station location and habitat.

INTRODUCTION

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

As part of the environmental permitting process for dredged material containment facilities, an exterior monitoring program was developed to assess any environmental impacts associated with HMI. Various agencies have worked together since the inception of this program to monitor for possible environmental impacts resulting from facility construction 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 25th consecutive year of the benthic macroinvertebrate community monitoring since 1981. In Year 25, the Maryland Department of the Environment (MDE) was responsible for all aspects of benthic community monitoring.

The goals of the Year 25 benthic community monitoring were:

- To monitor the benthic community condition. Although benthic monitoring is no longer a permit requirement, the MPA continues the monitoring voluntarily;

- 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 monitor benthic community conditions in a transect leading away from the South Cell Spillway 003. This will help the State to assess any environmental impacts resulting from the South Cell closure and restoration.

METHODS AND MATERIALS

For the Year 25 benthic community studies, staff from the MDE's Environmental Assessment and Standards and Field Evaluation Divisions collected all macroinvertebrate and water quality samples. Field sampling cruises for both seasons were conducted from the Maryland Department of Natural Resources (DNR) vessel, the *Kerhin*. The same 20 benthic stations were monitored during both fall and spring seasons (Table 6; Figure 27). Environmental parameters recorded at the time of sample collection are included in Tables 7 through 10.

Table 6. Sampling Stations (latitudes and longitudes in degrees, decimal minutes), 7-digit codes of stations used for Year 25 benthic community monitoring, and predominant sediment type at each station for September and April.

Station #	Latitude	Longitude	Sediment Type		Maryland 7-Digit Station Designation
			Fall	Spring	
Nearfield Station					
MDE-01	39^{o} 15.3948	-76^{o} 20.5680	Sand	Sand	XIF5505
MDE-03	39^{o} 15.5436	-76^{o} 19.9026	Sand	Silt/clay	XIG5699
MDE-07	39^{o} 15.0618	-76^{o} 20.3406	Sand	Sand	XIF5302
MDE-09	39^{o} 14.7618	-76^{o} 20.5842	Shell	Silt/clay	XIF4806
MDE-16	39^{o} 14.5368	-76^{o} 21.4494	Silt/clay	Silt/clay	XIF4615
MDE-17	39^{o} 14.1690	-76^{o} 21.1860	Silt/clay	Silt/clay	XIF4285
MDE-19	39^{o} 14.1732	-76^{o} 22.1508	Shell	Silt/clay	XIF4221
MDE-24	39^{o} 14.2650	-76^{o} 22.7862	Silt/clay	Sand	XIF4372
MDE-33	39^{o} 15.9702	-76^{o} 20.8374	Sand	Sand	XIF6008
MDE-34	39^{o} 15.7650	-76^{o} 20.5392	Sand	Sand	XIF5805
MDE-35	39^{o} 16.3182	-76^{o} 20.7024	Silt/clay	Silt/clay	XIF6407
Reference Stations					
MDE-13	39^{o} 13.5102	-76^{o} 20.6028	Silt/clay	Sand	XIG3506
MDE-22	39^{o} 13.1934	-76^{o} 22.4658	Silt/clay	Silt/clay	XIF3224
MDE-36	39^{o} 17.4768	-76^{o} 18.9480	Silt/clay	Silt/clay	XIG7589
Back River/Hawk Cove Stations					
MDE-27	39^{o} 14.5770	-76^{o} 24.2112	Silt/clay	Silt/clay	XIF4642
MDE-28	39^{o} 15.3900	-76^{o} 22.7304	Silt/clay	Silt/clay	XIF5232
MDE-30	39^{o} 15.8502	-76^{o} 22.5528	Shell	Silt/clay	XIF5925
South Cell Exterior Monitoring Stations					
MDE-42	39^{o} 13.8232	-76^{o} 22.1432	Silt/clay	Silt/clay	XIF3879
MDE-43	39^{o} 13.9385	-76^{o} 21.4916	Silt/clay	Sand	XIF3985
MDE-44	39^{o} 14.4229	-76^{o} 21.8376	Silt/clay	Silt/clay	XIF4482

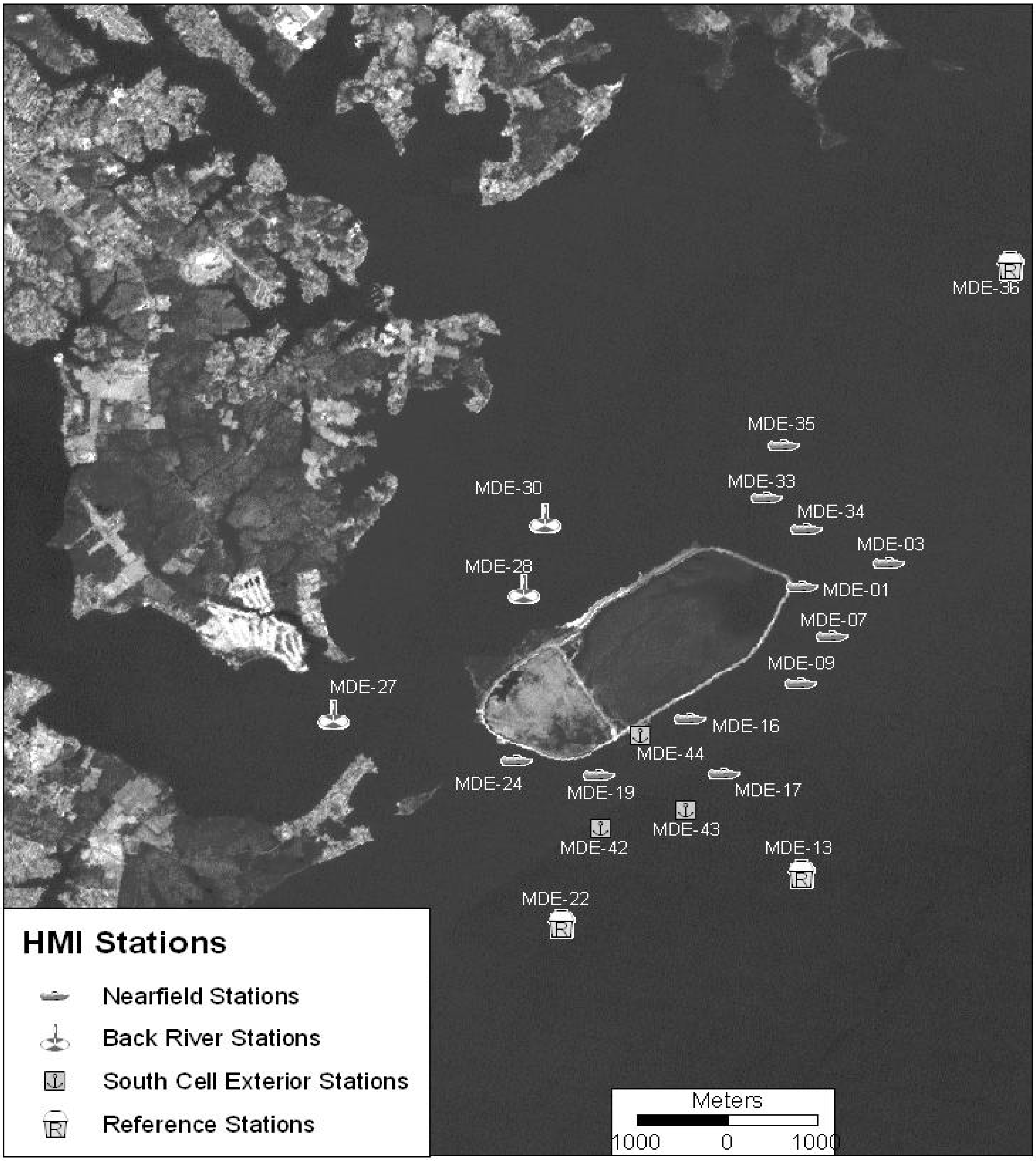

Figure 27. Year 25 Benthic Sampling Stations for the HMI Exterior Monitoring Program.

All stations sampled during Year 24 of monitoring were again sampled for Year 25. Stations were classified by location and dominant sediment type (Table 6). Stations were divided into four location groups (Nearfield stations, Reference stations, Back River/Hawk Cove stations, and South Cell Exterior Monitoring stations) and five sediment types (silt/clay, shell, detritus, gravel, and sand). All benthic community stations coincided with stations sampled by the Maryland Geological Survey (MGS) for sediment 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 IV water quality meter in September 2006 and April 2007. 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 7 and 9) 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.

Most organisms were identified to the lowest practical taxon using a stereo dissecting microscope. The number of specimens for each taxon collected in each replicate have been reported in the Year 25 Data Report. 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.

Nine 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, tolerance score, Tanypodinae to Chironomidae abundance ratio, abundance of carnivores and omnivores, taxa richness, and total abundance of all taxa (excluding Nematoda, Copepoda, and Bryozoa). Six of these measures (total infaunal abundance, relative abundance of pollution-indicative infaunal taxa, relative abundance of pollution-sensitive infaunal taxa, tolerance score, Tanypodinae to Chironomidae abundance ratio, and abundance of carnivores and omnivores) were used to calculate the B-IBI for September 2006. 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 2007 data. In addition to the above metrics, during each season the numerically dominant taxa and the length frequency distributions of the three most common clams (*R. cuneata*, *M. balthica*, and *M. mitchelli*) were examined.

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 25 Data Report*. 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).

For each station, data was converted to the base 2 logarithm in order to calculate the Shannon-Wiener Diversity Index (H') (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 combined. Infaunal taxa richness was calculated as the number of infaunal taxa found in all three replicates combined. The most abundant taxa at the reference and monitoring stations were also determined.

To evaluate the numerical similarity of the infaunal abundances among the 20 stations, a single-linkage cluster analysis was performed on a Euclidean distance matrix comprised of station infaunal abundance values for all 20 stations. This analysis was performed separately for September 2006 and April 2007 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 Exterior Monitoring stations for both September 2006 and April 2007. 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 (DO), conductivity, and pH values, indicated no water column stratification. Secchi depths were greater in September 2006 (Table 8, range=0.60 m-0.70 m, average = 0.63 m ± 0.04 m) than those in April 2007 (Table 10, range=0.30 m-0.50 m, average=0.39 m ± 0.06 m). Stations MDE-16, MDE-28, MDE-30, MDE-34, and MDE-44 had the shallowest Secchi depth (0.3 m) in April 2007. Water quality and Secchi depth measurements provide a snapshot of the conditions prevalent at the time of sampling, but do not necessarily reflect the dominant conditions for the entire season.

The following discussion will be limited to bottom values for the first four parameters as bottom water quality measurements are most relevant to benthic macroinvertebrate health. In Year 25, bottom water temperatures did not vary much between stations during both sampling seasons. The September 2006 bottom water temperatures in Year 25 (Table 8, range= 21.14°C – 22.00°C, average=21.71°C ± 0.25°C) were lower than those seen at HMI in the previous monitoring year. Bottom water temperatures were seasonably lower in April 2007 (Table 10) with a range of 8.04°C –8.94°C and an average of 8.34°C ± 0.23°C. In addition, the April 2007 bottom water temperatures were lower than those recorded in April 2006.

The bottom DO concentrations exceeded water quality standards, as given in the Maryland Code of Regulations (COMAR) during both seasons. Year 25 bottom DO concentrations were, on average, slightly higher than Year 24. Bottom DO concentrations were lower in September 2006 (Table 8, range=7.45 ppm-7.95 ppm, average=7.71 ppm ± 0.16 ppm) than in April 2007 (Table 10, range=10.76 ppm-12.00 ppm, average=11.24 ppm ± 0.26 ppm). The lowest bottom DO concentration in September 2006 was 7.45 ppm, recorded at Station MDE-43. The highest bottom DO concentration in September 2006 (7.95 ppm) was recorded at station MDE-27 and at station MDE-42. In April 2007, the lowest bottom DO concentration was 10.76 ppm, recorded at station MDE-22. The highest bottom DO concentration in April 2007 (12.00 ppm) was seen at Station MDE-28.

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). For both sampling seasons, there was a regionally dominant oligohaline environment[2]. Most stations (19 stations in September 2006 and 20 stations in April 2007) were within the oligohaline (0.5 ppt – 5 ppt) salinity regime with station MDE-13 in September 2006 as the only exception; it fell within the low mesohaline (>5ppt – 12 ppt) range. Bottom salinity varied considerably between September 2006 (Table 8, range=3.57-5.24 ppt, average=4.33 ppt ± 0.46 ppt) and April 2007 (Table 10, range=0.68-2.94 ppt, average=1.67 ppt ± 0.53 ppt). Low bottom salinity values in September 2006 and April 2007 may be attributed to the fact that Year 25 was not a drought year, unlike Year 24.

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[2] Because this was a regionally dominant oligohaline environment, all calculations were based on oligohaline metrics/parameters.

In September 2006, the highest bottom salinity was seen at Reference station MDE-13 (5.24 ppt). The highest bottom salinity in April 2007 was seen at Back River/Hawk Cove station MDE-27 (2.94 ppt). In Year 25, in both September 2006 and April 2007, the lowest salinity was seen at station MDE-36 (September—3.57 ppt; April—0.68 ppt). These relative salinities follow expectations, with the more southerly stations, which are more upgradient in the salt wedge, having a higher salinity than the stations further north and closest to freshwater flow from the Susquehanna River.

Table 7. Year 25 physical parameters measured *in situ* at all HMI stations on September 13, 2006.

MDE Station	Time	Tide	Water Depth (m)	Wave Height (m)	Wind Direction	Wind Speed (knots)		Air Temp. (°C)	Cloud Cover (%)	Weather		Observed Bottom Sediment (%)				
						Min.	Max			Past 24 hrs.	Today	silt/clay	sand	shell	gravel	detritus
MDE-01	11:13	Ebb	5.00	0.5	SSE	9	12	18.3	100	0	5	0	80	15	0	5
MDE-03	11:22	Flood	6.50	0.5	SSE	9	12	18.3	100	0	5	40	40	15	0	5
MDE-07	11:03	Ebb	6.05	0.5	SSE	9	12	18.3	100	0	5	35	40	10	0	5
MDE-09	10:46	Ebb	6.60	0.5	SSE	9	12	18.3	100	0	5	35	0	60	0	5
MDE-13	10:07	Ebb	5.80	0.8	SSE	9	12	20.6	100	0	5	75	0	20	0	5
MDE-16	10:36	Ebb	5.40	0.5	SSE	9	12	18.3	100	0	5	75	0	20	0	5
MDE-17	10:26	Ebb	5.90	0.5	SSE	9	12	19.4	100	0	5	75	0	20	0	5
MDE-19	09:00	Ebb	5.80	0.8	SSE	9	12	20.0	100	0	5	35	0	60	0	5
MDE-22	08:10	Ebb	6.00	0.8	SSE	9	12	20.0	100	0	5	95	0	5	0	0
MDE-24	08:51	Ebb	3.50	0.8	SSE	9	12	20.0	100	0	5	70	10	10	0	10
MDE-27	13:13	Flood	4.80	0.5	SSE	9	12	18.3	100	0	5	80	0	15	0	5
MDE-28	13:00	Flood	3.40	0.5	SSE	9	12	18.3	100	0	5	55	0	40	0	5
MDE-30	12:49	Flood	4.20	0.3	SSE	9	12	18.3	100	0	5	35	0	60	0	5
MDE-33	11:50	Flood	3.20	0.5	SSE	9	12	18.3	100	0	5	5	90	5	0	0
MDE-34	11:45	Flood	3.00	0.5	SSE	9	12	18.3	100	0	5	0	80	15	0	5
MDE-35	11:59	Flood	4.60	0.3	SSE	9	12	18.3	100	0	5	80	0	5	0	15
MDE-36	12:14	Flood	4.20	0.3	SSE	9	12	18.3	100	0	5	75	0	20	0	5
MDE-42	08:38	Ebb	5.80	0.8	SSE	9	12	20.0	100	0	5	95	0	5	0	0
MDE-43	09:56	Ebb	6.00	0.8	SSE	9	12	20.0	100	0	5	80	0	15	0	5
MDE-44	09:46	Ebb	5.80	0.8	SSE	9	12	20.0	100	0	5	80	0	15	0	5

Note: The Weather codes zero and five stand for, “clear with no clouds” and “light rain drizzle”, respectively.

Table 8. Year 25 water quality parameters measured *in situ* at all HMI stations on September 13, 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	0.50	3.90	21.60	7.79	7.64	0.6	7,052
		Bottom	4.50	3.90	21.60	7.75	7.68		7,010
MDE-03	XIG5699	Surface	0.50	4.45	21.90	7.66	7.60	0.6	7,945
		Bottom	6.00	4.48	22.00	7.60	7.61		7,997
MDE-07	XIF5302	Surface	0.50	4.43	22.00	7.69	7.64	0.6	7,936
		Bottom	5.55	4.56	22.00	7.66	7.81		8,146
MDE-09	XIF4806	Surface	0.50	4.61	22.00	7.65	7.61	0.6	8,253
		Bottom	6.15	4.67	22.00	7.50	7.65		8,345
MDE-16	XIF4615	Surface	0.50	4.05	21.60	7.84	7.65	0.6	7,279
		Bottom	4.87	4.06	21.58	7.80	7.63		7,293
MDE-17	XIF4285	Surface	0.50	4.81	22.00	7.67	7.64	0.6	8,576
		Bottom	5.47	4.82	22.00	7.61	7.65		8,599
MDE-19	XIF4221	Surface	0.50	4.00	21.70	7.82	7.64	0.7	7,183
		Bottom	5.30	4.17	21.50	7.58	7.86		7,448
MDE-24	XIF4372	Surface	0.50	4.24	21.58	7.79	7.70	0.7	7,609
		Bottom	3.00	4.29	21.60	7.81	7.60		7,683
MDE-33	XIF6008	Surface	0.50	3.74	21.60	7.88	7.70	0.6	6,736
		Bottom	2.77	3.74	21.60	7.83	7.71		6,735
MDE-34	XIF5805	Surface	0.50	4.00	21.67	7.79	7.66	0.6	7,167
		Bottom	2.55	4.00	21.66	7.77	7.72		7,175
MDE-35	XIF6407	Surface	0.50	3.66	21.63	7.94	7.70	0.6	6,606
		Bottom	4.10	3.69	21.63	7.85	7.70		6,653
Reference Stations									
MDE-13	XIG3506	Surface	0.50	5.24	21.90	7.50	7.59	0.7	9,301
		Bottom	5.30	5.24	21.90	7.50	7.62		9,303
MDE-22	XIF3224	Surface	0.50	5.00	22.00	7.79	7.60	0.6	8,916
		Bottom	5.50	5.00	22.00	7.74	7.56		8,902
MDE-36	XIG7589	Surface	0.50	3.56	21.12	7.94	7.70	0.6	6,423
		Bottom	3.65	3.57	21.14	7.94	7.75		6,430
Back River/Hawk Cove Stations									
MDE-27	XIF4642	Surface	0.50	4.57	**21.37**	8.06	7.74	0.6	8,171
		Bottom	4.27	4.58	21.37	7.95	7.80		8,188
MDE-28	XIF5232	Surface	0.50	4.18	21.43	7.90	7.63	0.6	7,485
		Bottom	2.88	4.44	21.47	7.60	7.65		7,960
MDE-30	XIF5925	Surface	0.50	3.93	21.67	7.93	7.60	0.6	7,055
		Bottom	3.64	3.97	21.66	7.60	7.61		7,130
South Cell Exterior Monitoring Stations									
MDE-42	XIF3879	Surface	0.50	4.44	21.90	7.70	7.70	0.7	7,937
		Bottom	5.35	4.45	21.90	7.95	7.60		7,951
MDE-43	XIF3985	Surface	0.50	4.80	22.00	7.63	7.68	0.6	8,555
		Bottom	5.50	4.80	22.00	7.45	7.80		8,555
MDE-44	XIF4482	Surface	0.50	4.04	21.50	7.85	7.68	0.7	7,253
		Bottom	5.34	4.07	21.50	7.79	7.67		7,319

Table 9. Year 25 physical parameters measured *in situ* at all HMI stations on April 13, 2007.

MDE Station	Time	Tide	Water Depth (m)	Wave Height (m)	Wind Direction	Wind Speed (knots)		Air Temp (ºC)	Cloud Cover (%)	Weather		Observed Bottom Sediment (%)				
						Min.	Max.			Past 24 hrs.	Today	silt/clay	sand	shell	gravel	detritus
MDE-01	12:32	Flood	4.30	0.9	W	15	20	13.0	80	6	2	0	95	5	0	0
MDE-03	12:42	Flood	4.60	0.9	W	15	20	13.0	80	6	2	60	10	25	0	5
MDE-07	12:22	Flood	5.50	0.9	W	15	20	13.0	80	6	2	25	40	35	0	0
MDE-09	12:09	Flood	5.50	0.9	W	15	20	13.0	80	6	2	80	0	10	0	10
MDE-13	11:02	Flood	3.25	0.9	W	15	20	13.0	80	6	2	35	40	20	0	5
MDE-16	11:59	Flood	3.40	0.9	W	15	20	13.0	80	6	2	60	10	30	0	0
MDE-17	11:40	Flood	4.58	0.9	W	15	20	13.0	100	6	2	90	0	10	0	0
MDE-19	10:02	Flood	4.55	0.9	W	12	20	13.0	80	6	2	90	0	5	0	5
MDE-22	08:58	Flood	4.80	0.9	W	12	15	13.0	80	6	2	95	0	5	0	0
MDE-24	09:49	Flood	2.69	0.9	W	12	15	13.0	80	6	2	10	70	0	0	20
MDE-27	14:05	Flood	3.96	0.9	W	15	20	13.0	75	6	2	75	5	0	0	20
MDE-28	13:51	Flood	2.71	0.9	W	15	20	13.0	75	6	2	80	5	5	0	10
MDE-30	13:36	Flood	3.50	0.9	W	15	20	13.0	80	6	2	85	0	15	0	0
MDE-33	13:10	Flood	2.71	0.9	W	15	20	13.0	80	6	2	0	95	5	0	0
MDE-34	12:59	Flood	2.34	0.9	W	15	20	13.0	80	6	2	0	90	5	0	5
MDE-35	13:18	Flood	3.57	0.9	W	15	20	13.0	80	6	2	85	0	10	0	5
MDE-36	14:52	Flood	3.48	0.9	W	15	20	13.0	60	6	2	75	0	10	0	15
MDE-42	09:25	Flood	2.95	0.9	W	12	15	13.0	80	6	2	95	0	5	0	0
MDE-43	10:51	Flood	4.50	0.9	W	15	20	13.0	80	6	2	30	60	10	0	0
MDE-44	10:39	Flood	6.04	0.9	W	12	20	13.0	80	6	2	70	0	0	0	30

Note: The Weather codes six and two stand for, “rain” and “continuous layers of clouds”, respectively.

Table 10. Year 25 water quality parameters measured *in situ* at all HMI stations on April 13, 2007.

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	0.50	1.33	8.26	11.30	7.84	0.4	2,483
		Bottom	3.81	1.34	8.25	11.32	7.83		2,494
MDE-03	XIG5699	Surface	0.50	1.56	8.52	11.34	7.71	0.4	2,900
		Bottom	4.05	1.56	8.52	11.30	7.77		2,890
MDE-07	XIF5302	Surface	0.50	1.54	8.39	11.25	7.70	0.4	2,858
		Bottom	5.03	1.55	8.38	11.25	7.71		2,862
MDE-09	XIF4806	Surface	0.50	1.59	8.43	11.25	7.67	0.4	2,948
		Bottom	5.01	1.59	8.42	11.23	7.78		2,945
MDE-16	XIF4615	Surface	0.50	1.27	8.17	11.19	7.77	0.3	2,362
		Bottom	2.94	1.27	8.17	11.19	7.82		2,419
MDE-17	XIF4285	Surface	0.50	1.66	8.38	11.18	7.65	0.5	3,062
		Bottom	4.08	1.66	8.37	11.18	7.75		3,064
MDE-19	XIF4221	Surface	0.50	1.84	8.31	11.02	7.60	0.4	3,395
		Bottom	4.05	1.89	8.27	10.95	7.64		3,490
MDE-24	XIF4372	Surface	0.50	1.75	8.27	11.10	7.66	0.4	3,220
		Bottom	2.19	1.80	8.24	11.19	7.68		3,329
MDE-33	XIF6008	Surface	0.50	1.30	8.32	11.37	7.75	0.4	2,419
		Bottom	2.21	1.28	8.28	11.41	7.86		2,387
MDE-34	XIF5805	Surface	0.50	1.35	8.30	11.31	7.80	0.3	2,510
		Bottom	1.84	1.35	8.29	11.45	7.85		2,510
MDE-35	XIF6407	Surface	0.50	1.42	8.42	11.32	7.75	0.4	2,634
		Bottom	3.07	1.42	8.40	11.40	7.82		2,633
Reference Stations									
MDE-13	XIG3506	Surface	0.50	2.03	8.13	11.03	7.57	0.4	3,731
		Bottom	2.75	2.02	8.13	11.05	7.63		3,720
MDE-22	XIF3224	Surface	0.50	2.74	8.03	10.80	7.48	0.4	4,983
		Bottom	4.30	2.74	8.04	10.76	7.45		4,985
MDE-36	XIG7589	Surface	0.50	0.67	8.92	11.15	7.99	0.4	1,273
		Bottom	2.98	0.68	8.94	11.30	8.14		1,291
Back River/Hawk Cove Stations									
MDE-27	XIF4642	Surface	0.50	1.76	8.59	11.56	7.88	0.4	3,273
		Bottom	3.46	2.94	8.40	11.20	7.70		5,364
MDE-28	XIF5232	Surface	0.50	1.36	9.04	11.89	8.03	0.3	2,534
		Bottom	2.21	1.36	8.89	12.00	8.01		2,543
MDE-30	XIF5925	Surface	0.50	1.05	8.24	11.36	7.81	0.3	1,972
		Bottom	3.00	1.06	8.23	11.44	8.02		1,978
South Cell Exterior Monitoring Stations									
MDE-42	XIF3879	Surface	0.50	2.26	8.09	10.99	7.57	0.4	4,162
		Bottom	2.45	2.28	8.09	11.02	7.59		4,171
MDE-43	XIF3985	Surface	0.50	1.72	8.27	11.15	7.65	0.5	3,183
		Bottom	4.00	1.70	8.26	11.26	7.73		3,132
MDE-44	XIF4482	Surface	0.50	1.50	8.16	11.05	7.70	0.3	2,788
		Bottom	5.54	1.82	8.18	10.88	7.69		3,351

Benthic Macroinvertebrate Community

Taxa Richness and Dominance

A total of 40 taxa were found over the two seasons of sampling during Year 25. This is a slight decrease in species richness from Year 24 (43 taxa) and similar to the number of taxa observed during the six year period from Year 19 to Year 24, where Year 23 had a total of 38 taxa, Year 22 had a total of 45 taxa, Year 21 had a total of 43 taxa, Year 20 had 41 taxa, and Year 19 had 42 taxa (mean = 42 taxa). In terms of station type, four taxa, *Piscicola* sp., Ostracoda, *Boccardiella ligerica*, and *Procladius* (*Holotanypus*) *sp.*, were found only at Silt/Clay stations and five taxa were only found at Nearfield stations. These five taxa were: *Cricotopus* sp., *Nanocladius* sp., *Chirodotea almyra*, *Piscicola* sp., and an unidentified species of Hydrozoa. 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 groups were members of the phyla Arthropoda (joint-legged organisms), Annelida (segmented worms), and Mollusca/Bivalvia (shellfish having two separate shells joined by a muscular hinge). Twenty-one species of Arthropoda were found in the course of the study. This is more than the previous monitoring year when 18 species were found, but less than Year 23 (23 species found). The most common types of arthropods were the amphipods (including *Leptocheirus plumulosus*) and the isopods (including *Cyathura polita*). Seven species of annelid worms in the Class Polychaeta were found. This is between the numbers of polychaete species found in Years 24 and 23 (8 and 6, respectively). Polychaete taxa richness was lower (5 species) in April 2007 than in September 2006 (7 species).

Glycinde solitaria, Amphicteis floridus (polychaetes), and *Balanus subalbidus* (barnacle), were not found in Year 25, while Ostracoda was absent from the fall samples, and Hydrozoa, *Boccardiella ligerica,* and *Eteone hetereopoda* (polychaetes) 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 the same as Year 24 and slightly higher than Year 23 (4 species). Overall, bivalve mollusk average abundance was higher in September 2006 than in April 2007 (Tables 11 and 12). 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 11. Average and total abundance (individuals per square meter) of each taxon found at HMI during the September 2006 sampling by substrate and station type. Depending on site salinity, taxa in bold are pollution sensitive while taxa highlighted in gray are pollution indicative.

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 Exterior Monitoring
Nemata	32.96	659.20	46.93	27.73	2.56	41.31	0.00	68.27	0.00
Carinoma tremophoros	9.60	192.00	11.73	6.40	6.40	6.98	19.20	6.40	12.80
Bivalvia (unidentified)	0.96	19.20	1.07	2.13	0.00	1.16	2.13	0.00	0.00
Macoma sp.	0.32	6.40	0.53	0.00	0.00	0.58	0.00	0.00	0.00
Macoma balthica	4.48	89.60	7.47	0.00	0.00	0.00	25.60	0.00	4.27
Macoma mitchelli	0.64	12.80	1.07	0.00	0.00	0.00	0.00	0.00	4.27
Rangia cuneata	141.12	2822.40	152.00	125.87	124.16	134.98	258.13	125.87	61.87
Ischadium recurvum	8.96	179.20	6.40	4.27	17.92	9.89	0.00	12.80	10.67
Mytilopsis leucophaeata	69.76	1395.20	47.47	10.67	158.72	86.69	66.13	27.73	53.33
Amphicteis floridus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Capitellidae	0.32	6.40	0.53	0.00	0.00	0.00	2.13	0.00	0.00
Heteromastus filiformis	24.32	486.40	33.60	4.27	14.08	16.87	53.33	12.80	34.13
Spionidae	0.64	12.80	1.07	0.00	0.00	0.00	4.27	0.00	0.00
Marenzelleria viridis	**80.00**	**1600.00**	**75.73**	**81.07**	**89.60**	**82.04**	**142.93**	**34.13**	**55.47**
Streblospio benedicti	184.96	3699.20	225.07	172.80	96.00	219.93	106.67	125.87	194.13
Polydora cornuta	15.36	307.20	22.93	4.27	3.84	19.78	14.93	2.13	12.80
Boccardiella ligerica	0.96	19.20	1.60	0.00	0.00	1.16	0.00	0.00	2.13
Nereididae	21.76	435.20	25.60	8.53	20.48	28.51	32.00	8.53	0.00
Neanthes succinea	35.20	704.00	36.80	10.67	46.08	38.40	38.40	29.87	25.60
Eteone heteropoda	6.40	128.00	9.60	2.13	1.28	7.56	6.40	2.13	6.40
Naididae sp.	129.60	2592.00	161.07	106.67	67.84	135.56	130.13	142.93	93.87
Amphipoda	3.52	70.40	4.27	4.27	1.28	1.75	2.13	4.27	10.67
Gammaridae	1.28	25.60	2.13	0.00	0.00	1.75	2.13	0.00	0.00
Ameroculodes spp complex	1.92	38.40	1.07	0.00	5.12	3.49	0.00	0.00	0.00
Leptocheirus plumulosus	32.96	659.20	42.13	44.80	3.84	27.93	53.33	49.07	14.93
Gammarus sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Melitadae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Melita nitida	4.16	83.20	4.80	2.13	3.84	3.49	8.53	2.13	4.27
Corophiidae	0.32	6.40	0.00	0.00	1.28	0.58	0.00	0.00	0.00
Apocorophium lacustre	3.52	70.40	3.20	4.27	3.84	2.91	6.40	6.40	0.00

Table 11: Continued.

			Average Abundance by Substrate			Average Abundance by Station Type			
Taxon	**Average Abundance, All stations**	**Total Abundance, All stations**	**Silt/ Clay**	**Shell**	**Sand**	**Nearfield**	**Ref.**	**Back River**	**South Cell Exterior Monitoring**
Cyathura polita	58.56	1171.20	73.07	57.60	24.32	43.05	76.80	36.27	119.47
Edotia triloba	5.44	108.80	8.00	2.13	1.28	7.56	6.40	0.00	2.13
Chiridotea almyra	**6.40**	**128.00**	**0.00**	**2.13**	**24.32**	**11.64**	**0.00**	**0.00**	**0.00**
Ciripedia	0.64	12.80	0.00	0.00	2.56	1.16	0.00	0.00	0.00
Balanus improvisus	66.56	1331.20	63.47	8.53	108.80	72.73	6.40	40.53	130.13
Balanus subalbidus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rhithropanopeus harrisii	2.88	57.60	3.73	0.00	2.56	1.16	0.00	8.53	6.40
Membranipora sp	+	+	0.00	0.00	0.00	+	+	0.00	+
Chironomidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Coelotanypus sp.	6.08	121.60	7.47	10.67	0.00	5.24	2.13	17.07	2.13
Procladius (*Holotanypus*) sp.	0.64	12.80	1.07	0.00	0.00	0.00	2.13	2.13	0.00
Mysidicea	2.24	44.80	3.73	0.00	0.00	1.16	0.00	2.13	8.53
Neanthes (*Heteroneris* Form)	0.96	19.20	1.60	0.00	0.00	0.58	2.13	0.00	2.13
Hydrozoa	0.32	6.40	0.00	0.00	1.28	0.58	0.00	0.00	0.00

Table 12. Average and total abundance (individuals per square meter) of each taxon found at HMI during Year 25 Spring sampling, April 2007, by substrate and station type. Depending on salinity, taxa in bold are pollution sensitive while taxa highlighted in gray are pollution indicative.

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 Exterior Monitoring
Nemata	32.96	659.20	49.72	0.00	1.83	30.84	0.00	106.67	0.00
Carinoma tremophoros	5.44	108.80	6.89	0.00	2.74	5.24	8.53	6.40	2.13
Bivalvia (unidentified)	16.96	339.20	8.37	0.00	32.91	24.44	12.80	4.27	6.40
Macoma sp.	1.28	25.60	1.97	0.00	0.00	0.58	0.00	0.00	6.40
Macoma balthica	1.28	25.60	1.48	0.00	0.91	1.75	0.00	0.00	2.13
Macoma mitchelli	6.08	121.60	6.40	0.00	5.49	5.24	8.53	6.40	6.40
Rangia cuneata	136.00	2720.00	111.75	0.00	181.03	144.87	151.47	200.53	23.47
Ischadium recurvum	6.40	128.00	4.92	0.00	9.14	9.89	2.13	0.00	4.27
Mytilopsis leucophaeata	37.44	748.80	38.89	0.00	34.74	63.42	8.53	0.00	8.53
Capitellidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heteromastus filiformis	21.12	422.40	16.25	0.00	30.17	22.11	32.00	0.00	27.73
Spionidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Marenzelleria viridis	**305.28**	**6105.60**	**118.65**	**0.00**	**651.89**	**478.84**	**117.33**	**134.40**	**27.73**
Steblospio benedicti	14.08	281.60	21.66	0.00	0.00	0.58	0.00	91.73	0.00
Polydora cornuta	0.32	6.40	0.49	0.00	0.00	0.00	0.00	2.13	0.00
Boccardiella ligerica	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nereididae	15.04	300.80	10.83	0.00	22.86	13.96	44.80	2.13	2.13
Neanthes succinea	28.80	576.00	20.68	0.00	43.89	25.60	64.00	14.93	19.20
Naididae sp.	743.68	14873.60	975.75	0.00	312.69	382.84	160.00	3246.93	147.20
Amphipoda	16.32	326.40	21.17	0.00	7.31	11.05	12.80	49.07	6.40
Gammaridea	18.88	377.60	22.15	0.00	12.80	12.22	19.20	32.00	29.87
Ameroculodes spp complex	16.32	326.40	10.34	0.00	27.43	19.20	12.80	12.80	12.80
Leptocheirus plumulosus	312.96	6259.20	385.48	0.00	178.29	154.18	253.87	987.73	279.47
Gammaridae	1.60	32.00	1.48	0.00	1.83	1.75	0.00	0.00	4.27
Gammarus sp	7.36	147.20	8.37	0.00	5.49	9.31	6.40	8.53	0.00
Melita nitida	9.92	198.40	11.32	0.00	7.31	8.15	4.27	21.33	10.67
Corophiidae	5.76	115.20	7.38	0.00	2.74	2.91	2.13	23.47	2.13
Apocorophium lacustre	148.48	2969.60	118.15	0.00	204.80	149.53	61.87	366.93	12.80
Cyathura polita	59.20	1184.00	63.02	0.00	52.11	44.22	89.60	59.73	83.20
Edotia triloba	7.68	153.60	6.40	0.00	10.06	5.82	4.27	19.20	6.40
Chiridotea almyra	**0.64**	**12.80**	**0.00**	**0.00**	**1.83**	**1.16**	**0.00**	**0.00**	**0.00**

Table 12: 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 Exterior Monitoring
Balanus improvisus	19.84	396.80	10.34	0.00	37.49	32.00	2.13	2.13	10.67
Balanus subalbidus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rhithropanopeus harrisii	6.08	121.60	5.42	0.00	7.31	8.15	4.27	2.13	4.27
Membranipora sp	+	+	+	0.00	+	+	+	0.00	+
Chironomidae	0.64	12.80	0.49	0.00	0.91	1.16	0.00	0.00	0.00
Coelotanypus sp.	5.76	115.20	8.37	0.00	0.91	4.65	4.27	14.93	2.13
Procladius sp.	0.32	6.40	0.49	0.00	0.00	0.00	2.13	0.00	0.00
Procladius(*Holotanypus*) sp.	1.60	32.00	2.46	0.00	0.00	0.58	8.53	0.00	0.00
Chironominae	0.32	6.40	0.00	0.00	0.91	0.58	0.00	0.00	0.00
Cricotopus sp.	0.96	19.20	0.00	0.00	2.74	1.75	0.00	0.00	0.00
Harnischia sp.	0.32	6.40	0.49	0.00	0.00	0.00	0.00	2.13	0.00
Corynoneura sp.	0.32	6.40	0.49	0.00	0.00	0.00	0.00	2.13	0.00
Nanocladius sp.	0.32	6.40	0.00	0.00	0.91	0.58	0.00	0.00	0.00
Glyptotendipes sp.	3.20	64.00	4.92	0.00	0.00	0.00	0.00	21.33	0.00
Copepoda	+	+	+	0.00	+	+	+	+	+
Piscola sp.	0.32	6.40	0.49	0.00	0.00	0.58	0.00	0.00	0.00
Ostracoda	2.24	44.80	3.45	0.00	0.00	1.75	0.00	6.40	2.13
Gobiosoma bosci	0.32	6.40	0.00	0.00	0.91	0.00	2.13	0.00	0.00
Hydrobiidae	0.96	19.20	0.49	0.00	1.83	1.16	0.00	2.13	0.00

Of the 40 taxa found in Year 25, twenty five are considered truly infaunal, nine are considered epifaunal, and the remaining six are considered too general to classify as either infaunal or epifaunal (Ranasinghe et al. 1994). The most common infaunal species found during Year 25 were the polychaete worm *M. viridis*, the bivalve *R. cuneata*, the amphipod *L. plumulosus*, worms from the family Naididae, and the isopod *C. polita.* The most common epifaunal species were the bivalve *M. leucophaeata*, the amphipod *A. lacustre*, and the barnacle *B. improvisus*.

South Cell Exterior Monitoring station MDE-44 and Nearfield station MDE-16 had the highest number of taxa in September 2006 (19 taxa). Three stations had 17 taxa (Nearfield stations MDE-7 and MDE-9 and Back River/Hawk Cove station MDE-28); one station had 15 taxa (Reference station MDE-36) (Table 13). The stations with the fewest number of taxa in September 2006 of Year 25 were Nearfield station MDE-1 with six taxa and Back River station MDE-30, and Nearfield stations MDE-33 and MDE-34 with nine taxa (Table 13). Overall, average taxa richness was highest at the South Cell Exterior Monitoring stations but did not vary greatly between stations types (average taxa richness: South Cell Exterior Monitoring=13.67 taxa, Nearfield=13.0 taxa, Reference=12.6 taxa, Back River/Hawk Cove=12.6 taxa). It is important to note that there are 11 Nearfield stations and three each of the other station types (i.e., Reference, Back River and South Cell Exterior Monitoring), so the higher taxa abundances at Nearfield stations may simply be an artifact of sample size. No trend of increasing/decreasing taxa richness associated with distance from HMI could be discerned.

Table 13. Summary of metrics for each HMI benthic station surveyed during the Year 25 fall sampling cruise, September 2006. Total Infaunal Abundance and Total Abundance, excluding Polycladida, Nematoda, and Bryozoa, are individuals per square meter.

Station	Total Infauna	Total All	All Taxa	Infaunal Taxa	Shannon-Wiener	PSTA (%)	PITA (%)	Tolerance Score	% Carnivore/ Omnivore	Tanypodinae: Chironomidae	B-IBI
Nearfield Stations											
MDE-01	236.8	236.8	6	6	2.04	54.05	8.11	6.00	45.95	0.00	4.67
MDE-03	921.6	1472	14	10	2.75	25.00	45.83	6.00	10.00	0.00	3.67
MDE-07	1126.4	2060.8	17	10	2.96	10.23	60.23	6.00	14.29	0.00	3.67
MDE-09	1056	1145.6	17	12	2.76	14.55	45.45	6.01	15.64	100.00	3.00
MDE-16	2041.6	2361.6	19	12	2.62	0.63	76.80	6.00	14.36	0.00	3.67
MDE-17	371.2	454.4	12	10	3.00	3.45	55.17	6.02	30.99	100.00	2.67
MDE-19	531.2	537.6	11	9	2.41	13.25	72.29	6.20	14.29	100.00	2.67
MDE-24	1331.2	1433.6	14	12	2.76	7.69	69.23	6.00	8.04	0.00	3.67
MDE-33	185.6	211.2	9	6	1.61	17.24	10.34	6.00	12.12	0.00	3.67
MDE-34	172.8	172.8	9	8	2.53	37.04	11.11	6.00	22.22	0.00	4.00
MDE-35	691.2	704	11	9	2.81	15.74	55.56	6.04	12.73	100.00	2.67
MEANS	**787.78**	**980.95**	**12.64**	**9.45**	**2.57**	**18.08**	**46.37**	**6.02**	**18.24**	**36.36**	**3.46**
Reference Stations											
MDE-13	409.6	454.4	12	10	3.19	3.13	54.69	6.33	30.99	100.00	2.67
MDE-22	851.2	870.4	11	10	2.89	3.76	63.16	6.00	22.06	0.00	4.00
MDE-36	1651.2	1894.4	15	12	2.48	23.26	26.74	6.00	10.47	100.00	3.00
MEANS	**970.67**	**1073.07**	**12.67**	**10.67**	**2.85**	**10.05**	**48.20**	**6.11**	**21.17**	**66.67**	**3.22**
Back River/Hawk Cove Stations											
MDE-27	825.6	825.6	12	11	2.66	4.65	79.84	6.26	14.73	100.00	2.67
MDE-28	640	921.6	17	10	2.80	6.00	45.00	6.00	15.97	0.00	4.00
MDE-30	339.2	352	9	8	2.77	7.55	58.49	6.03	10.91	100.00	2.33
MEANS	**601.60**	**699.73**	**12.67**	**9.67**	**2.74**	**6.07**	**61.11**	**6.10**	**13.87**	**66.67**	**3.00**
South Cell Exterior Monitoring Stations											
MDE-42	537.6	537.6	11	11	2.83	8.33	27.38	6.00	41.67	0.00	4.33
MDE-43	448	480	11	9	2.78	8.57	60.00	6.00	17.33	0.00	3.67
MDE-44	1004.8	1600	19	14	2.75	8.28	71.34	6.02	12.00	100.00	2.67
MEANS	**663.47**	**872.53**	**13.67**	**11.33**	**2.79**	**8.39**	**52.91**	**6.01**	**23.67**	**33.33**	**3.56**

In April 2007, the greatest taxa richness (20 taxa) occurred at Back River/Hawk Cove station MDE-28. One station had 18 taxa (Reference station MDE-13), and two stations had 17 taxa (Nearfield station MDE-17 and South Cell Exterior Monitoring station MDE-43). Overall, taxa richness increased moderately from the previous year (Year 24) when 18 taxa were recorded at one station and four stations had 17 taxa. The increase in Year 25 taxa richness may be related to the return of oligohaline salinities in this part of the Bay. The lowest taxa richness (9 taxa) from spring sampling was recorded at South Cell Exterior Monitoring Station MDE-42. Nearfield stations MDE-19 (12 taxa), MDE-33 (12 taxa), and Back River/Hawk Cove station MDE-30 (12 taxa) also had low taxa richness. Overall, in April 2007 the average taxa richness was highest at the Back River/Hawk Cove Stations, and lowest at South Cell Exterior Monitoring Stations (average taxa richness: South Cell Exterior Monitoring Stations =13 taxa, Reference=14.67 taxa, Nearfield=14.73 taxa, Back River/Hawk Cove =15 taxa).

Table 14. Summary of metrics for each HMI benthic station surveyed during the Year 25 spring sampling cruise, April 2007. Total Infaunal Abundance and Total Abundance, excluding Polycladida, Nematoda, and Bryozoa, are individuals per square meter.

Station	Total Infauna	Total All	All Taxa	Infaunal Taxa	Shannon-Wiener	PSTA (%)	PITA (%)
Nearfield Stations							
MDE-01	1900.8	2822.4	15	11	1.54	75.42	10.77
MDE-03	1241.6	1779.2	15	9	2.22	18.56	59.79
MDE-07	1062.4	1350.4	13	9	2.38	33.73	40.36
MDE-09	1139.2	1312	16	9	1.97	16.29	64.61
MDE-16	1126.4	1388.8	16	10	2.57	11.36	67.61
MDE-17	595.2	684.8	17	11	2.68	8.60	76.34
MDE-19	928	953.6	12	10	2.65	7.59	68.97
MDE-24	2342.4	2835.2	15	11	2.50	17.76	51.37
MDE-33	1011.2	1062.4	12	9	1.26	79.11	6.96
MDE-34	2662.4	3097.6	15	8	1.80	54.09	33.89
MDE-35	755.2	883.2	16	10	2.58	22.03	46.61
MEANS	**1342.25**	**1651.78**	**14.73**	**9.73**	**2.20**	**31.32**	**47.93**
Reference Stations							
MDE-13	960	1056	18	11	3.15	8.67	59.33
MDE-22	979.2	1062.4	13	10	2.75	4.58	64.71
MDE-36	1049.6	1184	13	10	2.56	21.34	35.37
MEANS	**996.27**	**1100.80**	**14.67**	**10.33**	**2.82**	**11.53**	**53.14**
Back River/Hawk Cove Stations							
MDE-27	10745.6	10809.6	13	10	0.93	0.48	97.92
MDE-28	2515.2	2835.2	20	13	2.40	2.54	65.65
MDE-30	1427.2	2387.2	12	9	2.32	20.18	63.23
MEANS	**4896.00**	**5344.00**	**15.00**	**10.67**	**1.88**	**7.73**	**75.60**
South Cell Exterior Monitoring Stations							
MDE-42	800	825.6	9	9	2.40	3.20	67.20
MDE-43	870.4	1036.8	17	10	2.76	5.15	66.91
MDE-44	358.4	390.4	13	9	2.19	3.57	85.71
MEANS	**676.27**	**750.93**	**13.00**	**9.33**	**2.45**	**3.97**	**73.27**

Since the first benthic survey studies of the Hart-Miller Island area in 1981, a small number of taxa have been dominant. Year 25 was no exception. During both seasons, seven 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 Naididae. The average abundances of these taxa were among the top ten highest both seasons of Year 25. The remaining three taxa among the top ten most abundant during both seasons were: *S. benedicti*, *B. improvisus*, and *H. filiformis*. The average abundance of each taxon (individuals per square meter) found at each station during September 2006 and April 2007 are provided in Tables 15 through 18.

Table 15. Average number of individuals collected per square meter at each station during the HMI Year 25 fall sampling, September 2006, stations MDE-1 to MDE-22. Depending on salinity, taxa in bold are pollution sensitive while taxa highlighted in gray are pollution indicative.

Taxon	Station								
	MDE-1	MDE-3	MDE-7	MDE-9	MDE-13	MDE-16	MDE-17	MDE-19	MDE-22
Nemata	0	19.2	6.4	6.4	6.4	6.4	6.4	12.8	38.4
Carinoma tremophoros	0	0	0	6.4	0	0	0	0	0
Bivalvia	0	0	0	0	0	6.4	0	0	0
Macoma sp.	0	0	0	0	0	0	0	0	76.8
Macoma balthica	0	0	0	0	0	0	0	0	0
Macoma mitchelli	76.8	185.6	179.2	294.4	57.6	211.2	51.2	0	6.4
Rangia cuneata	0	19.2	70.4	12.8	0	6.4	0	0	0
Ischadium recurvum	0	256	537.6	32	0	115.2	12.8	0	0
Mytilopsis leucophaeata	0	0	0	0	0	0	0	0	0
Amphicteis floridus	0	0	0	0	6.4	0	0	0	0
Capitellidae	6.4	6.4	57.6	0	51.2	32	12.8	12.8	83.2
Heteromastus filiformis	0	0	0	0	0	0	0	0	0
Spionidae	32	230.4	115.2	147.2	12.8	12.8	12.8	70.4	32
Marenzellaria viridis	**0**	**179.2**	**288**	**204.8**	**57.6**	**736**	**83.2**	**249.6**	**64**
Streblospio benedicti	0	6.4	12.8	6.4	38.4	192	0	0	0
Polydora cornuta	0	0	0	0	0	12.8	0	0	0
Boccardiella ligerica	0	19.2	83.2	19.2	51.2	108.8	57.6	6.4	0
Nereididae	0	64	147.2	32	19.2	108.8	32	0	0
Neanthes succinea	0	0	6.4	6.4	0	19.2	6.4	0	12.8
Eteone heteropoda	12.8	153.6	172.8	204.8	51.2	499.2	70.4	51.2	236.8
Naididae sp.	0	0	6.4	0	0	0	0	6.4	6.4
Amphipoda	0	0	0	0	0	0	0	0	0
Gammaridae	0	0	0	0	0	0	0	0	0
Ameroculodes spp complex	0	12.8	0	19.2	0	0	0	64	153.6
Leptocheirus plumulosus	0	19.2	6.4	6.4	6.4	6.4	6.4	12.8	38.4

Table 15: Continued.

Taxon	Station								
	MDE-1	MDE-3	MDE-7	MDE-9	MDE-13	MDE-16	MDE-17	MDE-19	MDE-22
Gammarus sp.	0	0	0	0	0	0	0	0	0
Melitadae	0	0	0	0	0	0	0	0	0
Melita nitida	0	0	19.2	0	12.8	6.4	0	6.4	12.8
Corophiidae	0	0	0	0	0	0	0	0	0
Apocorophium lacustre	0	6.4	0	0	0	12.8	0	0	0
Cyathura polita	12.8	44.8	51.2	96	57.6	96	32	51.2	140.8
Edotia triloba	0	0	6.4	6.4	0	12.8	0	0	0
Chiridotea almyra	**96**	**0**	**0**	**6.4**	**0**	**0**	**0**	**0**	**0**
Ciripedia	0	12.8	0	0	0	0	0	0	0
Balanus improvisus	0	256	281.6	25.6	19.2	160	70.4	0	0
Balanus subalbidus	0	0	0	0	0	0	0	0	0
Rhithropanopeus harrisii	0	0	12.8	0	0	0	0	0	0
Membranipora sp	0	0	0	0	0	+	0	0	0
Chironomidae	0	0	0	0	0	0	0	0	0
Coelotanypus sp.	0	0	0	12.8	0	0	6.4	6.4	0
Procladius (*Holotanypus*) sp.	0	0	0	0	6.4	0	0	0	0
Mysidicea	0	0	0	0	0	6.4	0	0	0
Neanthes (*Heteroneris* Form)	0	0	0	0	6.4	0	0	0	0
Hydrozoa	0	0	6.4	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 25 fall sampling, September 2006, stations MDE-24 to MDE-44. Depending on salinity, taxa in bold are pollution sensitive while taxa highlighted in gray are pollution indicative.

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	6.4	185.6	19.2	0	6.4	6.4	352	0	0	0	0
Carinoma tremophoros	12.8	19.2	0	0	6.4	0	0	12.8	19.2	6.4	12.8
Bivalvia	0	0	0	0	0	0	6.4	6.4	0	0	0
Macoma sp.	0	0	0	0	0	0	0	0	0	0	0
Macoma balthica	0	0	0	0	0	0	0	0	12.8	0	0
Macoma mitchelli	0	0	0	0	0	0	0	0	6.4	6.4	0
Rangia cuneata	160	64	230.4	83.2	121.6	57.6	147.2	710.4	57.6	76.8	51.2
Ischadium recurvum	0	0	38.4	0	0	0	0	0	0	0	32
Mytilopsis leucophaeata	0	0	83.2	0	0	0	0	198.4	0	0	160
Amphicteis floridus	0	0	0	0	0	0	0	0	0	0	0
Capitellidae	0	0	0	0	0	0	0	0	0	0	0
Heteromastus filiformis	44.8	6.4	32	0	0	0	12.8	25.6	19.2	38.4	44.8
Spionidae	0	0	0	0	0	0	0	12.8	0	0	0
Marenzellaria viridis	**102.4**	**38.4**	**38.4**	**25.6**	**32**	**38.4**	**108.8**	**384**	**44.8**	**38.4**	**83.2**
Streblospio benedicti	544	211.2	102.4	64	6.4	6.4	121.6	198.4	32	115.2	435.2
Polydora cornuta	0	0	0	6.4	0	0	0	6.4	0	0	38.4
Boccardiella ligerica	0	0	0	0	0	0	0	0	0	0	6.4
Nereididae	12.8	0	25.6	0	0	0	6.4	44.8	0	0	0
Neanthes succinea	12.8	19.2	70.4	0	12.8	6.4	6.4	96	0	25.6	51.2
Eteone heteropoda	44.8	0	6.4	0	0	0	0	6.4	0	0	19.2
Naididae sp.	172.8	307.2	57.6	64	0	0	153.6	102.4	70.4	89.6	121.6
Amphipoda	6.4	6.4	0	6.4	0	0	0	0	32	0	0
Gammaridae	19.2	0	0	0	0	0	0	6.4	0	0	0
Ameroculodes spp complex	12.8	0	0	0	0	25.6	0	0	0	0	0
Leptocheirus plumulosus	147.2	70.4	25.6	51.2	0	6.4	57.6	6.4	25.6	0	19.2

Table 16. 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
Gammarus sp.	0	0	0	0	0	0	0	0	0	0	0
Melitadae	0	0	0	0	0	0	0	0	0	0	0
Melita nitida	0	0	6.4	0	0	0	6.4	0	0	12.8	0
Corophiidae	0	0	0	0	6.4	0	0	0	0	0	0
Apocorophium lacustre	0	0	6.4	12.8	12.8	0	0	19.2	0	0	0
Cyathura polita	32	38.4	44.8	25.6	6.4	6.4	44.8	32	204.8	51.2	102.4
Edotia triloba	57.6	0	0	0	0	0	0	19.2	0	0	6.4
Chiridotea almyra	**0**	**0**	**0**	**0**	**0**	**25.6**	**0**	**0**	**0**	**0**	**0**
Ciripedia	0	0	0	0	0	0	0	0	0	0	0
Balanus improvisus	0	0	121.6	0	6.4	0	0	0	0	19.2	371.2
Balanus subalbidus	0	0	0	0	0	0	0	0	0	0	0
Rhithropanopeus harrisii	0	0	25.6	0	0	0	0	0	0	0	19.2
Membranipora sp	0	0	0	0	0	0	+	0	+	+	0
Chironomidae	0	0	0	0	0	0	0	0	0	0	0
Coelotanypus sp.	0	38.4	0	12.8	0	0	32	6.4	0	0	6.4
Procladius (*Holotanypus*) sp.	0	6.4	0	0	0	0	0	0	0	0	0
Mysidicea	6.4	0	6.4	0	0	0	0	0	12.8	0	12.8
Neanthes (*Heteroneris* Form)	6.4	0	0	0	0	0	0	0	0	0	6.4
Hydrozoa	0	0	0	0	0	0	0	0	0	0	0

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

Table 17. Average number of individuals collected per square meter at each station during the HMI Year 25 spring sampling, April 2007, stations MDE-1 to MDE-22. Depending on salinity, taxa in bold are pollution sensitive while taxa highlighted in gray are pollution indicative.

Taxon	Station								
	MDE-1	MDE-3	MDE-7	MDE-9	MDE-13	MDE-16	MDE-17	MDE-19	MDE-22
Nemata	0	0	0	0	0	0	0	0	0
Carinoma tremophoros	0	12.8	0	0	12.8	19.2	19.2	0	0
Bivalvia	0	0	0	0	0	6.4	0	6.4	32
Macoma sp.	0	0	0	0	0	0	0	0	0
Macoma balthica	0	0	0	0	0	6.4	6.4	6.4	0
Macoma mitchelli	0	0	0	0	6.4	0	0	32	19.2
Rangia cuneata	134.4	64	140.8	128	44.8	38.4	12.8	25.6	38.4
Ischadium recurvum	0	32	38.4	6.4	6.4	19.2	6.4	0	0
Mytilopsis leucophaeata	44.8	256	102.4	83.2	12.8	89.6	25.6	0	0
Capitellidae	0	0	0	0	0	0	0	0	0
Heteromastus filiformis	0	0	25.6	12.8	38.4	12.8	25.6	38.4	57.6
Spionidae	0	0	0	0	0	0	0	0	0
Marenzelleria viridis	**1427.2**	**230.4**	**358.4**	**185.6**	**83.2**	**128**	**51.2**	**70.4**	**44.8**
Steblospio benedicti	0	0	0	0	0	6.4	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	12.8	32	0	19.2	108.8	57.6	0	0	6.4
Neanthes succinea	19.2	38.4	12.8	25.6	153.6	51.2	64	0	25.6
Naididae sp.	108.8	678.4	352	672	166.4	524.8	256	185.6	147.2
Amphipoda	6.4	0	0	0	12.8	12.8	6.4	70.4	19.2
Gammaridea	6.4	12.8	6.4	0	0	19.2	6.4	12.8	51.2
Ameroculodes spp complex	25.6	19.2	51.2	19.2	32	0	12.8	0	6.4
Leptocheirus plumulosus	76.8	25.6	38.4	25.6	211.2	166.4	102.4	396.8	390.4
Gammaridae	0	0	0	0	0	0	0	19.2	0
Gammarus sp.	12.8	64	0	6.4	12.8	0	0	0	0
Melita nitida	0	38.4	0	12.8	6.4	12.8	0	12.8	6.4
Corophiidae	12.8	6.4	0	0	0	12.8	0	0	0
Apocorophium lacustre	780.8	89.6	19.2	44.8	44.8	96	19.2	6.4	38.4
Cyathura polita	38.4	64	70.4	44.8	76.8	83.2	25.6	51.2	160
Edotia triloba	0	0	0	6.4	0	0	0	0	6.4
Chiridotea almyra	**6.4**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Balanus improvisus	64	83.2	128	12.8	6.4	12.8	19.2	0	0
Balanus subalbidus	0	0	0	0	0	0	0	0	0
Rhithropanopeus harrisii	19.2	32	0	6.4	12.8	12.8	12.8	0	0
Membranipora sp.	+	+	+	+	+	+	+	+	0
Chironomidae	0	0	0	0	0	0	6.4	0	0
Coelotanypus sp.	0	0	0	0	0	0	6.4	19.2	12.8
Procladius sp.	0	0	0	0	0	0	0	0	0

Table 17. Continued

Taxon	Station								
	MDE-1	MDE-3	MDE-7	MDE-9	MDE-13	MDE-16	MDE-17	MDE-19	MDE-22
Procladius (*Holotanypus*) sp.	0	0	0	0	0	0	0	0	0
Chironominae	6.4	0	0	0	0	0	0	0	0
Cricotopus sp.	19.2	0	0	0	0	0	0	0	0
Harnischia sp.	0	0	0	0	0	0	0	0	0
Corynoneura sp.	0	0	0	0	0	0	0	0	0
Nanocladius sp.	0	0	6.4	0	0	0	0	0	0
Glyptotendipes sp.	0	0	0	0	0	0	0	0	0
Copepoda	0	0	+	+	+	+	0	+	+
Piscola sp.	0	0	0	0	0	0	0	0	0
Ostracoda	0	0	0	0	0	0	0	0	0
Gobiosoma bosci	0	0	0	0	6.4	0	0	0	0
Hydrobiidae	0	0	0	0	0	0	0	0	0

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

Table 18. Average number of individuals collected per square meter at each station during the HMI Year 25 spring sampling, April 2007, stations MDE-24 to MDE-44. Depending on salinity, taxa in bold are pollution sensitive while taxa highlighted in gray are pollution indicative.

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	12.8	224	96	0	0	0	326.4	0	0	0	0
Carinoma tremophoros	0	6.4	12.8	0	0	6.4	0	12.8	6.4	0	0
Bivalvia	172.8	0	12.8	0	0	51.2	32	6.4	12.8	6.4	0
Macoma sp.	0	0	0	0	0	0	6.4	0	12.8	0	6.4
Macoma balthica	0	0	0	0	0	0	0	0	0	6.4	0
Macoma mitchelli	25.6	19.2	0	0	0	0	0	0	6.4	6.4	6.4
Rangia cuneata	633.6	44.8	492.8	64	70.4	198.4	147.2	371.2	12.8	44.8	12.8
Ischadium recurvum	0	0	0	0	0	6.4	0	0	0	12.8	0
Mytilopsis leucophaeata	0	0	0	0	0	64	32	12.8	0	19.2	6.4
Capitellidae	0	0	0	0	0	0	0	0	0	0	0
Heteromastus filiformis	121.6	0	0	0	0	0	6.4	0	32	25.6	25.6
Spionidae	0	0	0	0	0	0	0	0	0	0	0
Marenzelleria viridis	**409.6**	**51.2**	**64**	**288**	**800**	**1440**	**166.4**	**224**	**25.6**	**44.8**	**12.8**
Steblospio benedicti	0	243.2	32	0	0	0	0	0	0	0	0
Polydora cornuta	0	0	0	6.4	0	0	0	0	0	0	0
Boccardiella ligerica	0	0	0	0	0	0	0	0	0	0	0
Nereididae	6.4	6.4	0	0	0	25.6	0	19.2	0	6.4	0
Neanthes succinea	25.6	19.2	12.8	12.8	6.4	32	6.4	12.8	0	57.6	0
Naididae sp.	569.6	8934.4	524.8	281.6	12.8	793.6	57.6	166.4	128	185.6	128
Amphipoda	0	32	108.8	6.4	0	25.6	0	6.4	12.8	6.4	0
Gammaridea	25.6	12.8	25.6	57.6	6.4	0	38.4	6.4	38.4	44.8	6.4
Ameroculodes spp complex	12.8	0	25.6	12.8	51.2	19.2	0	0	32	0	6.4
Leptocheirus plumulosus	486.4	1286.4	1075.2	601.6	44.8	76.8	256	160	377.6	313.6	147.2
Gammaridae	0	0	0	0	0	0	0	0	0	12.8	0
Gammarus sp.	6.4	0	25.6	0	6.4	0	6.4	6.4	0	0	0
Melita nitida	6.4	51.2	0	12.8	6.4	0	0	0	0	32	0
Corophiidae	0	0	0	70.4	0	0	0	6.4	0	6.4	0
Apocorophium lacustre	262.4	12.8	217.6	870.4	38.4	256	32	102.4	0	32	6.4
Cyathura polita	12.8	0	89.6	89.6	6.4	44.8	44.8	32	128	115.2	6.4
Edotia triloba	44.8	0	57.6	0	0	12.8	0	6.4	0	12.8	6.4
Chiridotea almyra	**6.4**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Balanus improvisus	0	0	6.4	0	0	32	0	0	0	32	0
Balanus subalbidus	0	0	0	0	0	0	0	0	0	0	0
Rhithropanopeus harrisii	0	0	6.4	0	0	6.4	0	0	0	12.8	0
Membranipora sp.	0	0	0	0	0	+	0	+	0	+	0
Chironomidae	6.4	0	0	0	0	0	0	0	0	0	0
Coelotanypus sp.	0	38.4	6.4	0	6.4	0	19.2	0	0	0	6.4
Procladius sp.	0	0	0	0	0	0	0	6.4	0	0	0

Table 18. 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
Procladius (*Holotanypus*) sp.	0	0	0	0	0	0	6.4	25.6	0	0	0
Chironominae	0	0	0	0	0	0	0	0	0	0	0
Cricotopus sp.	0	0	0	0	0	0	0	0	0	0	0
Harnischia sp.	0	0	6.4	0	0	0	0	0	0	0	0
Corynoneura sp.	0	0	0	6.4	0	0	0	0	0	0	0
Nanocladius sp.	0	0	0	0	0	0	0	0	0	0	0
Glyptotendipes sp.	0	51.2	12.8	0	0	0	0	0	0	0	0
Copepoda	0	0	+	+	+	+	+	+	+	+	+
Piscola sp.	0	0	0	0	0	0	6.4	0	0	0	0
Ostracoda	0	0	12.8	6.4	0	0	19.2	0	0	0	6.4
Gobiosoma bosci	0	0	0	0	0	0	0	0	0	0	0
Hydrobiidae	0	0	6.4	0	6.4	6.4	0	0	0	0	0

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

Infaunal Taxa Abundance

Average total infaunal abundance was lower in the fall (September 2006) than in the spring (April 2007) (Figure 28). This coincides with past years (excluding Year 23) and is a result of spring recruitment into the infaunal population. In September 2006, total infaunal abundance in the vicinity of HMI ranged from 172.8 to 2,041.6 organisms per square meter (individuals/m^2) and averaged 768.64 individuals/m^2 (Table 13). The highest September 2006 abundance was found at the Nearfield station MDE-16, due primarily to large numbers of the bivalve *Rangia cuneata*, the polychaetes *M. viridis* and *S. benedicti*, the amphipod *L. plumulosus*, and oligocheate worms of the family Naididae. The lowest infaunal abundance in September 2006 was found at the Nearfield station MDE-34 (Table 13). There was a moderate difference in the average total infaunal abundance between Reference stations and Nearfield stations in September 2006 (970.67 individuals/m^2 and 787.78 individuals/m^2, respectively). Total abundance was lowest at the Back River/Hawk Cove stations (601.60 individuals/m^2). Total abundance was 663.47 individuals/m^2 at the South Cell Exterior Monitoring stations. No trend of increasing/decreasing abundances associated with distance from HMI could be discerned.

In April 2007, total infaunal abundance ranged from 358.4 to 10,745.6 individuals per square meter and averaged 1,723.52 individuals/m^2. The station with the highest abundance was the Back River/Hawk Cove station MDE-27, due to very high numbers of oligocheate worms of the family Naididae. The lowest spring abundance occurred at the South Cell Exterior Monitoring station MDE-44 (Table 14). This was due in part to the low numbers of the polychaete worm *M. viridis*, which generally occurred in high numbers at other stations (Table 14). The average total infaunal abundance was lowest at the South Cell Exterior Monitoring stations (676.27 individuals/m^2) and highest at the Back River/Hawk Cove stations (4,896.0 individuals/m^2), with the Reference (996.27

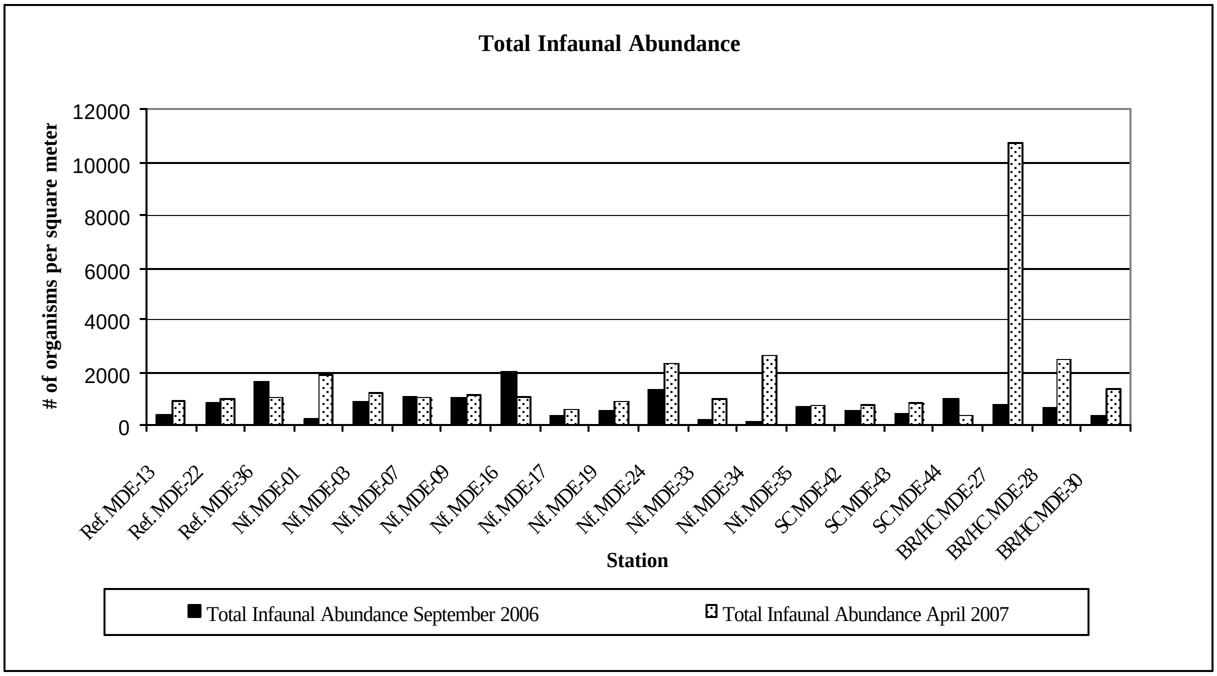

Figure 28. Total abundance of infauna taxa collected at each HMI station in Year 25, September 2006 and April 2007 grouped by stations (Ref. = Reference; Nf. = Nearfield; SC = South Cell Exterior Monitoring; BR/HC = Back River Hawk Cove).

individuals/m^2) and Nearfield stations (1,342.25individuals/m^2) falling in between. No consistent trend of increasing/decreasing abundances associated with distance from HMI could be discerned.

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 25, 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-3 (63%) and MDE-7 (55%), Back River/Hawk Cove station MDE-28 (69%), South Cell Exterior Monitoring station MDE-44 (63%) in September 2006; and, Nearfield stations MDE-1 (68%), and MDE-3 (71%), and Back River/Hawk Cove station MDE-30 (63%) in April 2007.

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. Correspondingly, diversity has often been lowest at most stations in spring (April or May) due to an influx of juveniles, especially of the dominant species (Duguay et al. 1998, Duguay et al. 1995a, Duguay et al. 1995b, Duguay 1992, Duguay 1990, Pfitzenmeyer and Tenore 1987). Diversity values for Year 25 are presented in Tables 13 & 14. In this monitoring year, on average, diversity was moderately higher in September 2006 than in April 2007. These results are similar to Year 24, where diversity values were slightly higher in the fall versus the spring.

The SWDI values in Year 25 averaged 2.67 ± 0.35 in September 2006 and 2.28 ± 0.54 in April 2007 (Figure 29). The lowest diversity value in September 2006 occurred at Nearfield station MDE-33 (1.61). This was due to the predominance of the bivalve *R. cuneata*, which accounted for 66% of total infaunal abundance at this station. The highest September 2006 diversity value (3.19) occurred at Reference station MDE-13 (the only station with a salinity high enough to merit designation as low mesohaline). The lowest diversity value in April 2007 occurred at Back River/Hawk Cove station MDE-27 (0.93); this was due to the large percentage of oligochaete worms of the family Naididae, which accounted for 83% of the total infaunal abundance at this station. The highest April 2007 diversity value also occurred at Reference station MDE-13 (3.15). On average, Nearfield stations had diversity values similar to Reference stations in September 2006 and April 2007. No trend of increasing/decreasing diversity associated with distance from HMI could be discerned.

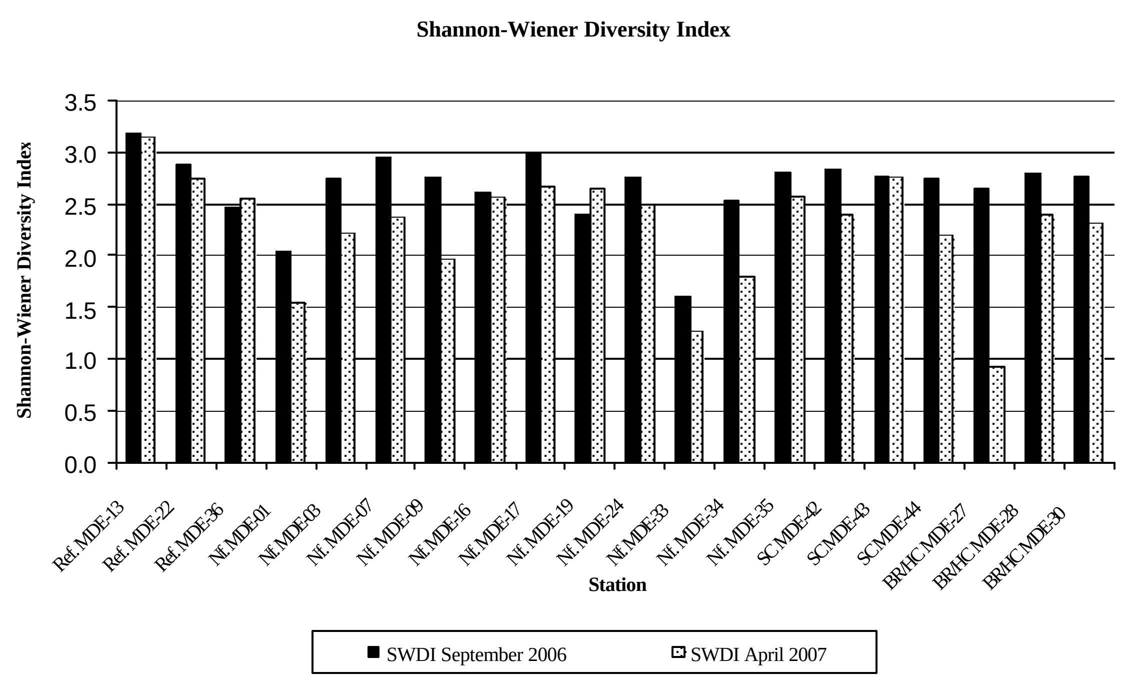

Figure 29. Shannon-Wiener Diversity Index (SWDI), HMI Year 25, September 2006 and April 2007 grouped by stations (Ref. = Reference; Nf. = Nearfield; SC = South Cell Exterior Monitoring; BR/HC = Back River Hawk Cove).

Pollution Sensitive Taxa Abundance

There were two taxa found during Year 25 benthic monitoring that are designated as "pollution-sensitive" according to Alden et al. (2002). This is because authors designated only two taxa as sensitive under Oligohaline conditions. These were the polychaete worm *M. viridis* and the isopod crustacean *C. almyra*. The calculation of the PSTA is a ratio of the relative PSTA to total infaunal abundance. In Year 25, the oligohaline salinity regime resulted in a change of the PSTA taxa from Year 24, when low mesohaline conditions prevailed. Alden, et al. (2002) designated six taxa commonly found around HMI as sensitive under mesohaline conditions. For this reason, small changes in salinity (causing conditions to be either above or below 5.0 ppt) can greatly affect the sensitivity/tolerance designation of several organisms and correspondingly alter calculated abundances.

In September 2006, PSTA ranged from 0.63% at MDE-16 (Nearfield station) to 54.05% at MDE-1 (Nearfield station - Table 13 ; Figure 30). The average PSTA for September 2006 was 13.62%. Comparing station types, the lowest average PSTA was 6.07% at the Back River/Hawk Cove stations followed by the South Cell Exterior Monitoring Stations at 8.40% and Reference stations with an average PSTA of 10.05%. The highest average PSTA occurred at the Nearfield stations at 18.08%.

In April 2007, the lowest PSTA was 0.48% at MDE-27 (Back River/Hawk Cove station) and the highest was 79.11% at MDE-33 (Nearfield station - Table 14; Figure 30). The average PSTA in April 2007 was 20.71%. The Nearfield stations had the highest average PSTA at 31.32%, followed by the Reference Stations at 11.53%, and Back River/Hawk Cove Stations at 7.73%; the South Cell Exterior Monitoring stations had the lowest average PSTA of 3.97%. Historically, the PSTA values in April are usually higher than those in September, however in Year 25 this was not the case half of the time. *M. virdis* often accounts for 50% of PSTA species within the oligohaline salinity regime. Due to very low *M. virdis* abundance this sampling year, particularly in the spring (Figure 31 and 32), PSTA values were lower than normal.

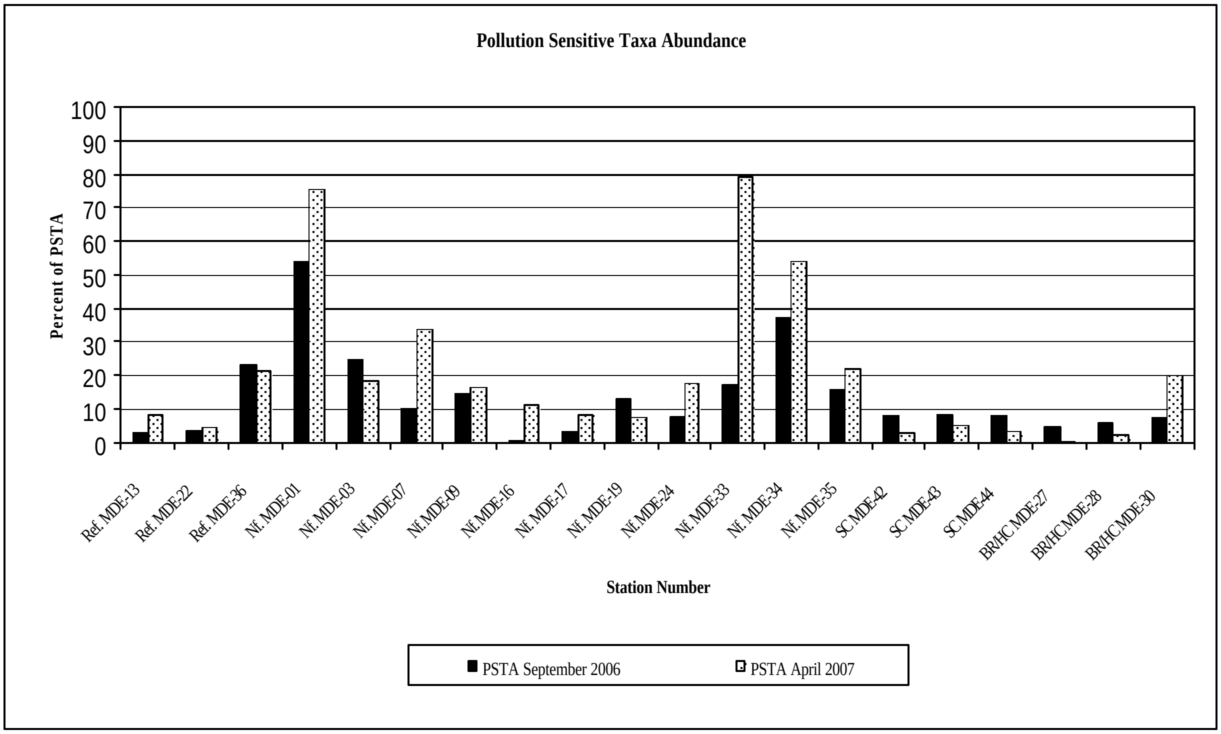

Figure 30. Percent abundance comprised of pollution sensitive species (PSTA), HMI Year 25 September 2006 and April 2007 grouped by stations (Ref. = Reference; Nf. = Nearfield; SC = South Cell Exterior Monitoring; BR/HC = Back River Hawk Cove).

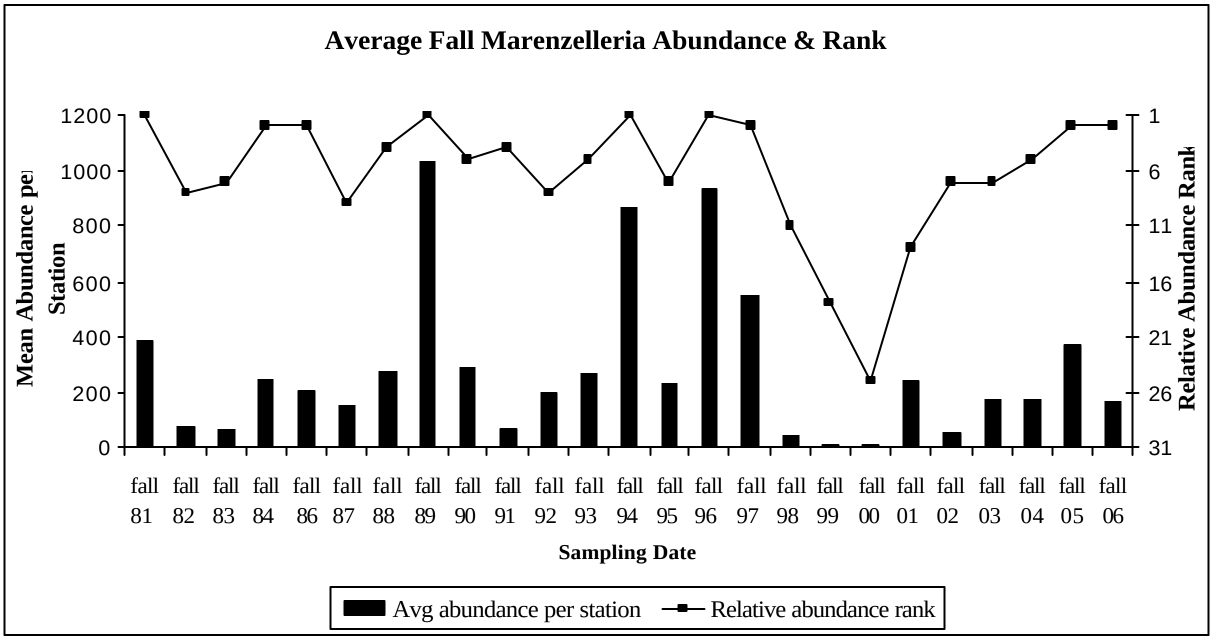

Figure 31. *Marenzelleria viridis* abundance and rank data for all fall data.

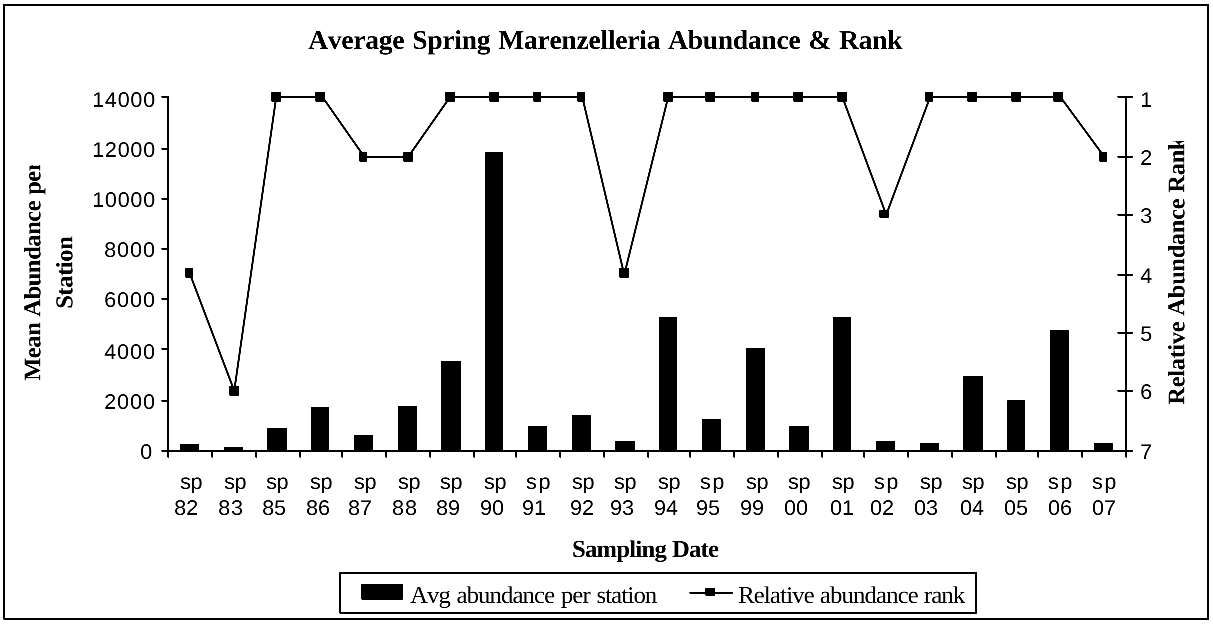

Figure 32. ***Marenzelleria viridis*** **abundance and rank data for all spring data.**

Pollution Indicative Taxa Abundance

Eight taxa found during the fall sampling of Year 25 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, P. cornuta, H. filiformis,* and *N. succinea,* the oligochaete worms of the family Naididae, and amphipod *L. plumulosus*. Relative abundance of these taxa was calculated as a proportion of total infaunal abundance.

In Year 25, PITA occurred at all station types, and the highest PITA value occurred in Back River/Hawk Cove station MDE-27 in both the fall and the spring. In September 2006, the relative abundance of PITA ranged from 8.11% at MDE-1 (Nearfield station) to 79.84% at MDE-27 (Back River/Hawk Cove station) (Table 13; Figure 33). The average PITA for September 2006, was 49.84%. In September 2006, the Nearfield stations had an average PITA of 46.37%, the Reference stations had an average of 48.20%, the Back River/Hawk Cove stations had an average PITA of 61.11%, and the average PITA was 52.91% at South Cell Exterior Monitoring stations. In April 2007, the PITA averaged 47.93% for Nearfield stations, 53.14% for Reference stations, 75.60% for Back River/Hawk Cove stations, and 73.27% at South Cell Exterior Monitoring stations. The Spring PITA values ranged from 6.96% at MDE-33 (Nearfield station) to 97.92% at MDE-27 (Back River/Hawk Cove station) (Table 14; Figure 33). The average PITA was 56.67%. This year's PITA values are higher than usual, recent monitoring years have exhibited lower average percentages of PITA taxa (i.e. Year 24 PITA average Fall: 21.7%; Spring: 3.3%.). Year 22 was the last monitoring year that had PITA values similar to this year (Year 22 PITA average Fall: 34.79%; Spring: 34.52%). The high average percentage of PITA taxa is largely the result of the general lack of heavy spring recruitment of species that are not pollution indicative, particularly *M. viridis* (Figure 31 and 32). Figure 32 shows that low spring recruitment of *M. viridis* is not highly unusual.

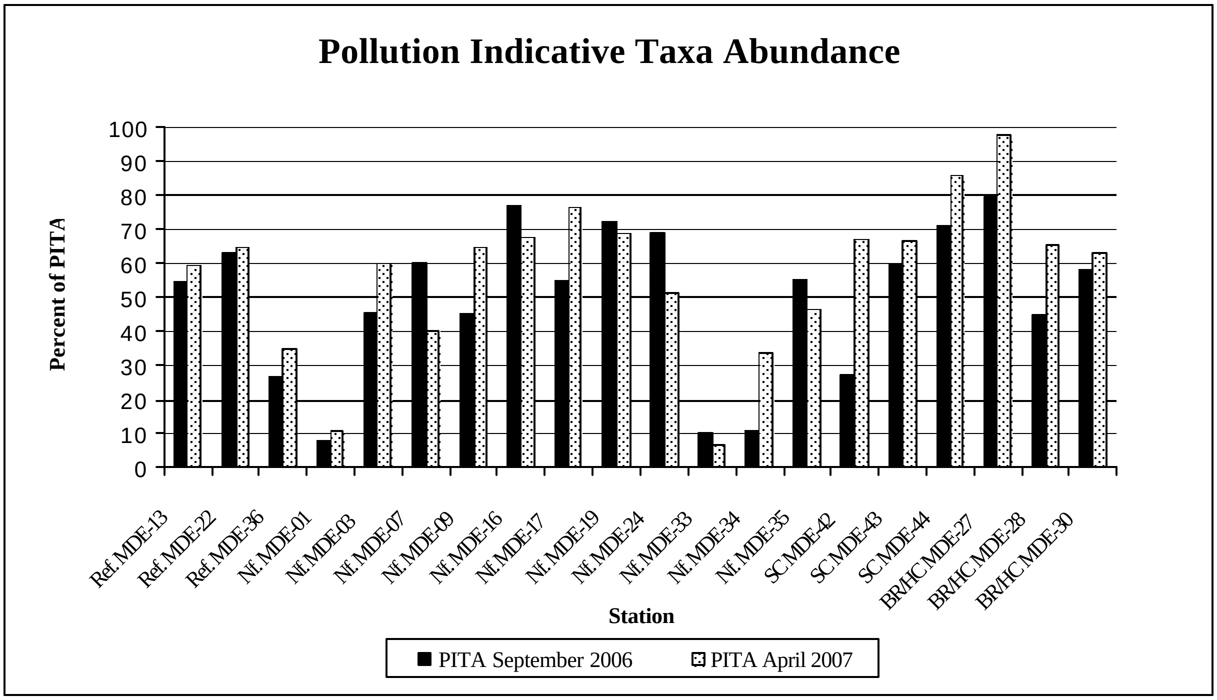

Figure 33. Percent abundance comprised of pollution indicative species, HMI year 25 September 2006 and April 2007 grouped by stations (Ref.=Reference; Nf.=Nearfield; SC=South Cell Exterior Monitoring; BR/HC=Back River Hawk Cove).

Clam Length Frequency Distribution

In September 2006, the greatest average abundance of *R. cuneata* occurred at the Nearfield stations, followed by the Reference stations, Back River/Hawk Cove stations, and the South Cell Exterior Monitoring stations. The greatest abundance of *R. cuneata* during the fall was found in the 8-12 mm size class. In April 2007, general abundance pattern by station type was repeated for this species. However, the dominant size range found during the spring was in the 25-28 mm size class.

In September 2006, *M. balthica* had the greatest average abundance at the Reference stations, followed by the South Cell Exterior Monitoring stations. No *M. balthica* were collected from any of the Nearfield or Back River/Hawk Cove stations in September 2006. The greatest abundance of *M. balthica* was found in the 22-23 mm size class in September 2006. In April 2007, *M. balthica* had the greatest average abundance at the Reference stations, followed by the South Cell Exterior Monitoring stations and Nearfield Stations. No *M. balthica* were found at Back River/Hawk Cove stations in April 2007. For all the stations in April 2007, *M. balthica* had its greatest abundance in the 14-15 mm size class.

The greatest average abundance of *M. mitchelli* in September 2006 was found at the Reference stations, followed by the South Cell Exterior Monitoring stations. No *M. mitchelli* were collected from any of the Nearfield or Back River/Hawk Cove stations in September 2006. The dominant size range for all station types was 9-10 mm. In April 2007, the greatest average abundance of *M. mitchelli* was found at the Nearfield stations, followed by the South Cell Exterior Monitoring station, Reference stations, and Back River/Hawk Cove stations. The dominant size range for all station types was 5-6 mm.

Benthic Index of Biotic Integrity

The Chesapeake Bay B-IBI was calculated for all stations based on September 2006 data only (see *Methods and Materials*). Six metrics were used to calculate the B-IBI for stations under the Oligohaline classification (= ≥0.5-5.0 ppt). These metrics were total infaunal abundance, relative abundance of pollution-sensitive taxa, relative abundance of pollution-indicative taxa, relative abundance of carnivore and omnivores, tolerance score, and Tanypodinae to Chironomidae percent abundance ratio. The specific scoring criteria for the Oligohaline metrics are presented in Table 19. The B-IBI was developed as a benchmark to determine whether any given benthic sample taken from the Bay either approximates (B-IBI score = 5), deviates slightly (B-IBI score = 3), or deviates greatly (B-IBI score = 1) from conditions at the best Reference sites (Weisberg et al., 1997). A B-IBI score greater than or equal to 3.0 represents a benthic community that is not considered stressed by *in situ* environmental conditions. The 20 benthic stations studied during Year 25 were compared to this benchmark.

Table 19..Oligohaline scoring criteria for measures used in calculating the Chespeake Bay B-IBI in September 2006 (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%

When comparing average B-IBI scores for station type Year 25 was generally lower when compared to Year 24 (Figure 34). The average B-IBI scores for the South Cell Exterior Monitoring stations did increase, and when comparing over the previous 10 years overall the averages for all station types remained fairly constant (Figure 34).

In Year 25 thirteen of the 20 stations exceeded the benchmark criteria of 3.0 and seven [MDE-13 (2.67), MDE-17 (2.67), MDE-19 (2.67), MDE-27 (2.67), MDE-30 (2.33), MDE-35 (2.67), and MDE-44 (2.67)] failed to meet this benchmark (Table 13, Figure 35). While several stations failed to meet the benchmark, the mean B-IBI for each station type (ie. Reference, Nearfield, etc.) met or exceeded the benchmark. In Year 24, 17 stations met the benchmark and three failed to meet it. In Year 24, the stations that failed to meet the benchmark were MDE-19, MDE-24, and MDE-33 (all Nearfield Stations).

The highest average B-IBI scores were at the South Cell Exterior Monitoring, Nearfield, and Reference stations, which had average B-IBI scores of 3.6, 3.5, and 3.2, respectively. The Back River/Hawk Cove stations had the lowest average B-IBI score of 3.0 (Figure 34). There is a slight (but not significant) trend of improving B-IBI scores associated with proximity to HMI in this data. However, there is a general depression in the B-IBI's over time without preference to location. The depression is not historically significant and probably is most attributable to this year's widespread use of Oligohaline metrics than to any other possible cause.

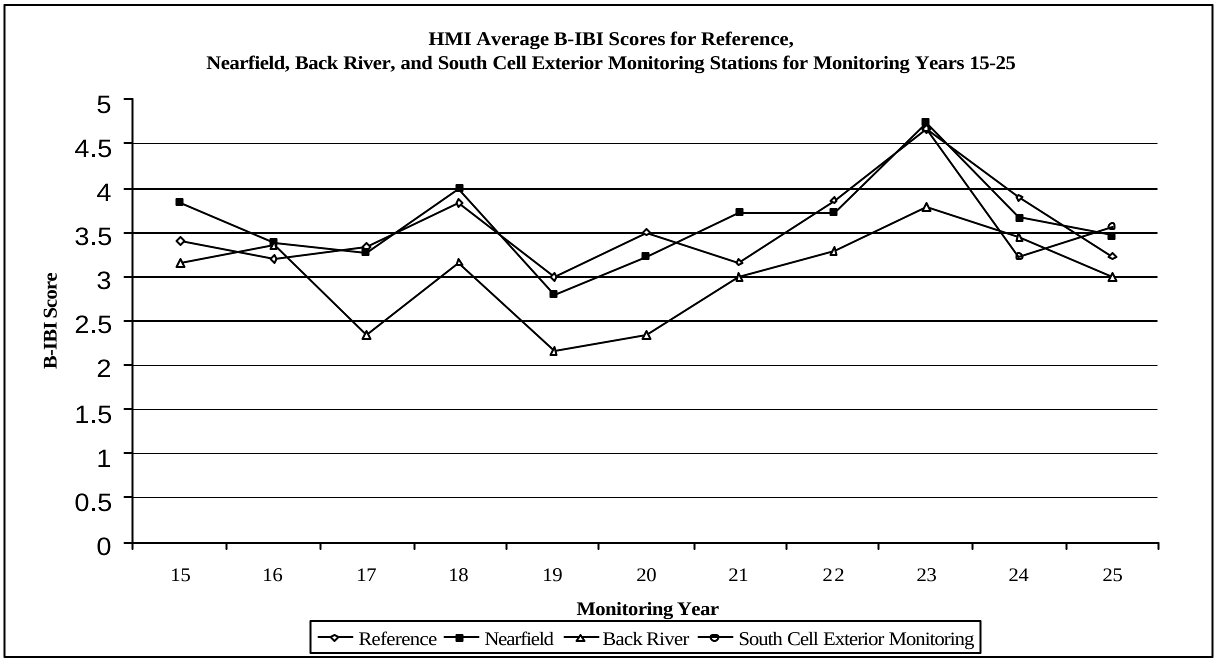

Figure 34. Average B-IBI scoes at HMI for monitoring Years 12-25.

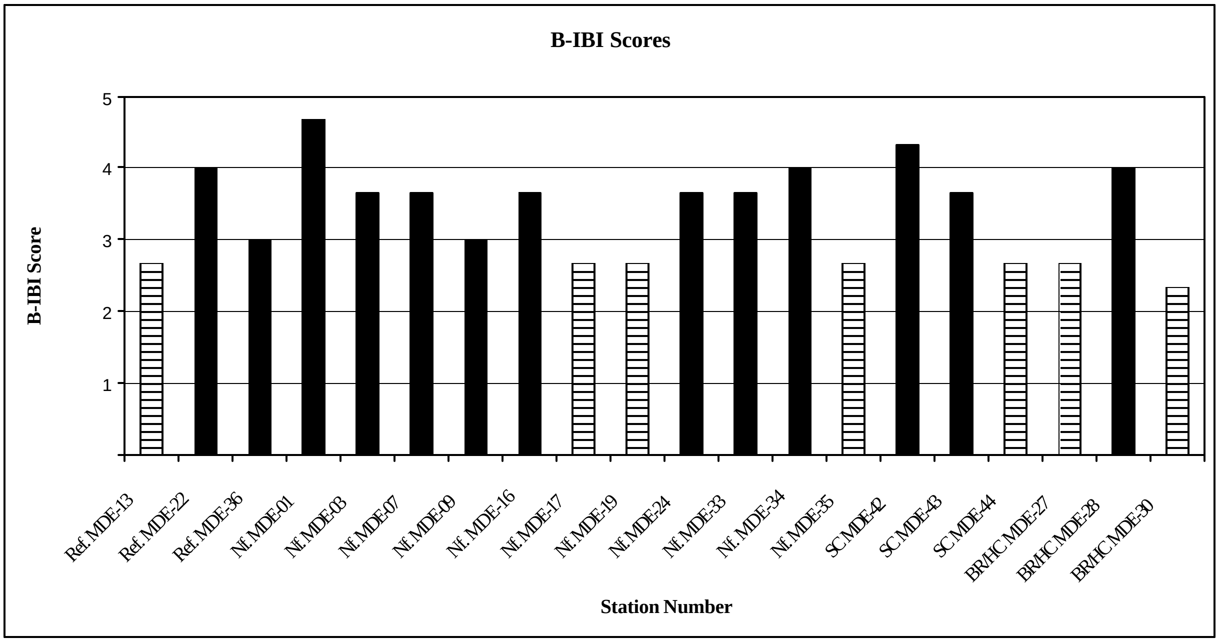

Figure 35. B-IBI Scores for all stations in September 2006 grouped by stations (Ref.=Reference; Nf=Nearfield; SC=South Cell Exterior Monitoring; BR/HC=Back River Hawk Cove).

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 36 and 37, 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 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 dendrograms in Figures 36 and 37 display visually the results of the cluster analysis in regard to the top 10 infaunal species and station type. For example, in Figure 36 stations MDE-33 and 34 become joined in a cluster with the smallest measured distance (x-axis), which means that these two stations are very similar with regard to their top 10 infaunal abundances. As the distances on the x-axis (Linkage Distance) become greater before a joining of two stations or joining of a station with an already formed cluster of stations, the more dissimilar those stations are based on their abundances of the

10 infaunal species. An example here is the linkage between stations MDE-26 and 16 with MDE-36 (Figure 36).

Both the dendrograms for September 2006 and April 2007 indicated an overall weak pattern of faunal response to sediment type. As in previous years, the examination for faunal – sediment type relationships was confounded by the predominance of silt/clay sediments (13 of 20 stations in September 2006 and 15 of 20 stations in April 2007). Grouping of stations was poorly articulated, i.e., there was not distinct separation of groups. However, it was possible to identify two distinct groups of stations in both seasons, as well as three aberrant "outlier" stations.

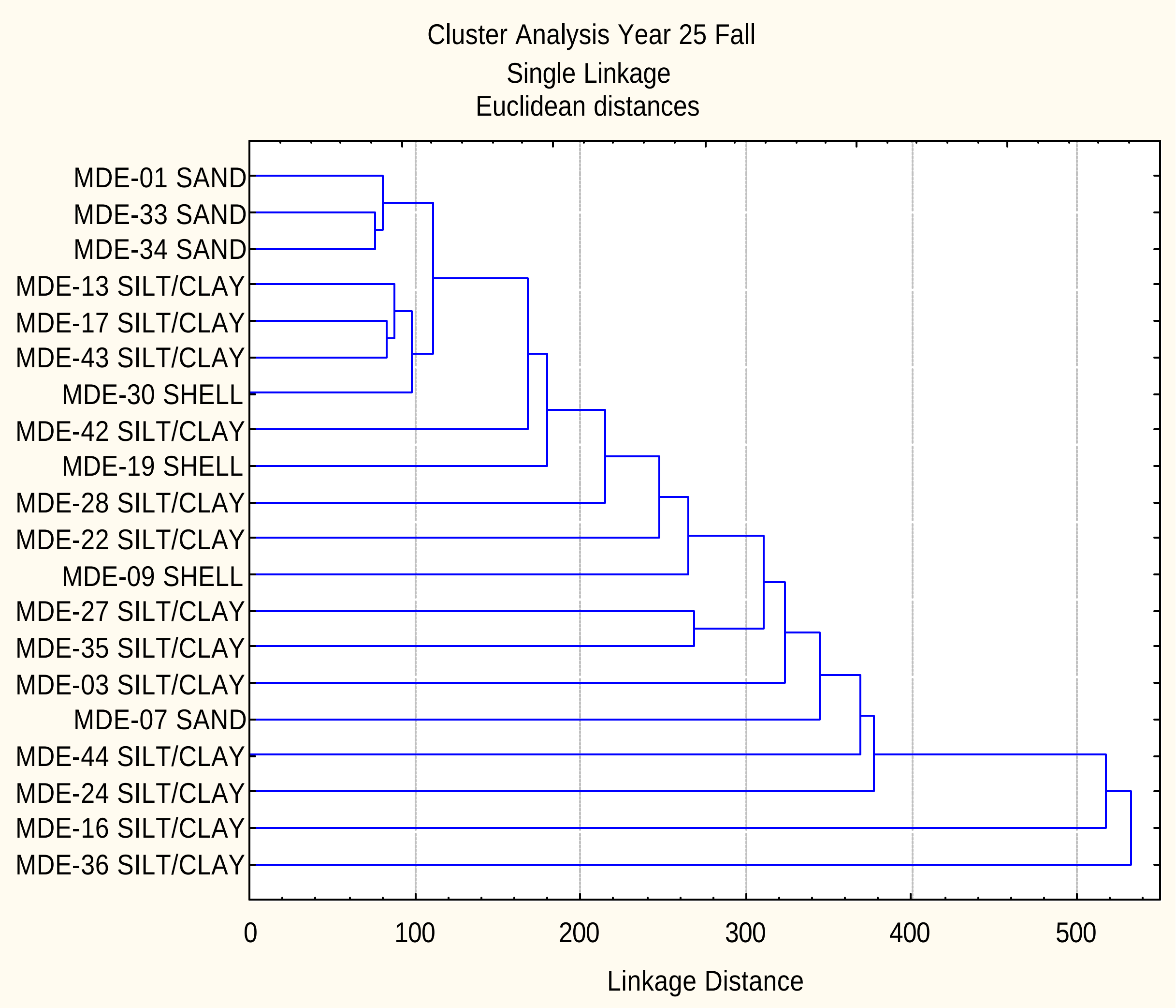

Figure 36. Cluster analysis based on Euclidean distance matrix of infaunal abundances of all HMI stations, Year 25 September 2006.

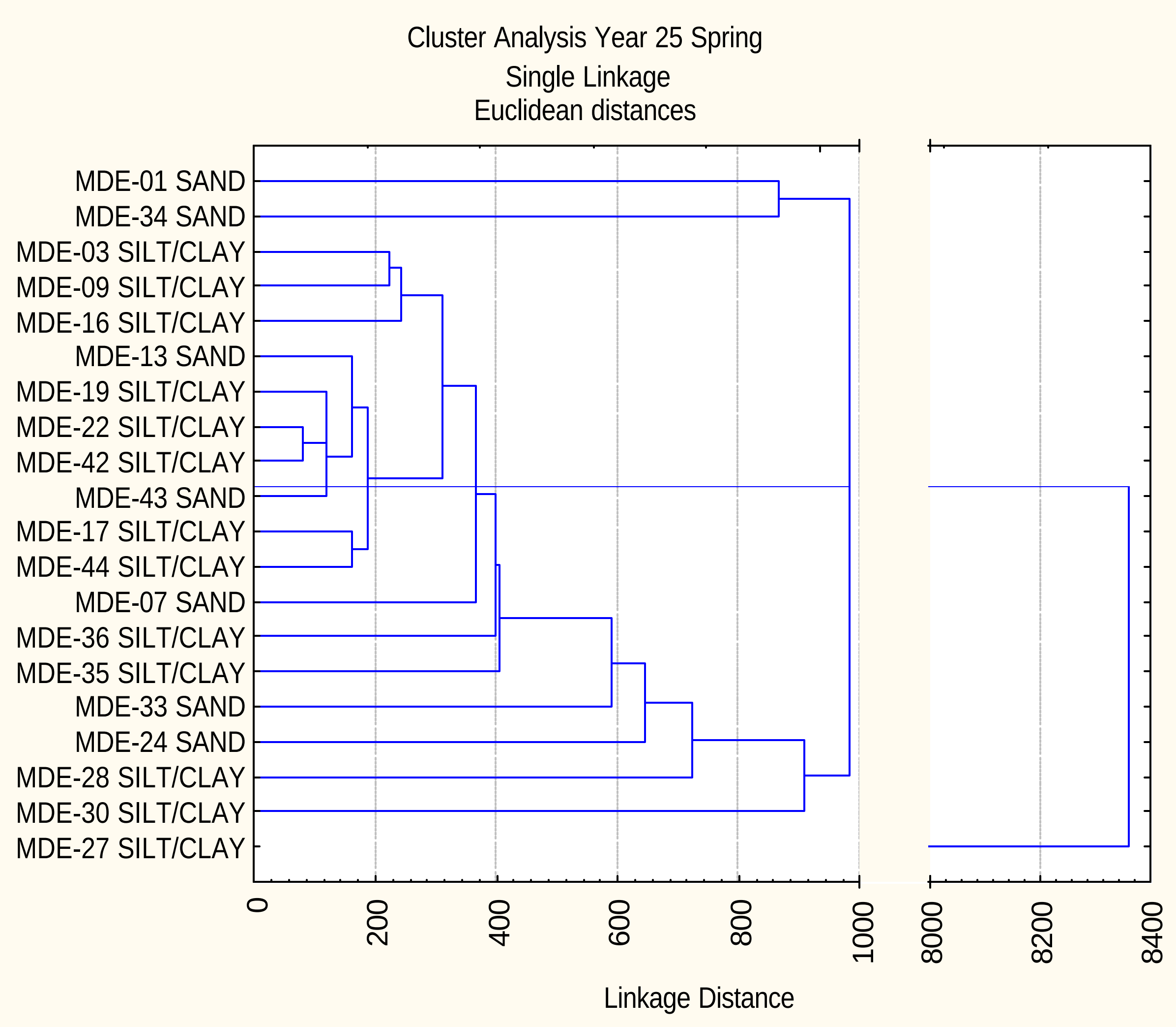

Figure 37. Cluster analysis based on Euclidean distance matrix of infaunal abundances of all HMI stations, Year 25 April 2007.

The two identifiable groups in September 2006 were each composed of a small number of stations that formed quickly (within 100 linkage distance units) and demonstrated a moderately strong response of faunal composition to bottom type, and to physical location relative to HMI. “Group 1” consisted of MDE-01, MDE-33, and MDE-34; all three had predominately sandy substrate. They were all located on the northeast end of HMI, and were no more than 1500 meters apart. Distinguishing features of the fauna at these three stations, relative to mean values, was relatively low overall faunal, with lower than average abundances of Nemata, *Mytilopsis leucophaeata*, *Heteromastus filiformis*, *Marenzelleria viridis*, *Streblospio benedicti*, *Cyathura polita*, *Polydora cornuta*, *Leptocheirus plumulosus*, *Balanus improvisus*, and Naididae in comparison to the other stations. In addition, Group 1 was also distinguished by relatively low PITA percentages (MDE-01 = 8.11, MDE-33 = 10.34, MDE-34 = 11.11) and relatively high

PSTA percentages at two of the three stations (MDE-01 = 54.05, MDE-34 = 37.04). In contrast, there was no clear-cut relationship between PITA and PSTA with the second group. The second group ("Group 2") consisted of three stations on the southeast Bay side of HMI, stations MDE-13, MDE-17, and MDE-43, and station MDE-30, on the northwest, Back River side of HMI. The three Bay side stations all had silt/clay substrate and were no more than 2000 meters apart. Station MDE-30 had a predominately shell substrate. The Group 2 stations also had lower than average overall faunal abundance, with lower than average abundances for Nemata, *Rangia cuneata*, *Mytilopsis leucophaeata*, *Streblospio benedicti*, and *Marenzelleria viridis*. There were two identifiable outlier stations in September 2006, MDE-16 and MDE-36. Neither station has occurred as an outlier in previous years of HMI cluster analyses. In contrast to Group 1 and Group 2 stations, the outlier stations had higher than average overall faunal abundance. MDE-16 had a predominately silt/clay substrate, and was located within 1000 meters of the South Unloader. The other outlier station, MDE-36, also had a predominately silt/clay substrate, and was the most distant station from HMI, located approximately 5,000 meters to the northeast. MDE-36 had higher than average abundances of *Rangia cuneata*, *Mytilopsis leucophaeata*, *Marenzelleria viridis*, *Apocorophium lacustre*, and *Edotia triloba*, and lower than average abundance of *Leptocheirus plumulosus* and Nemata. Like Group 1, outlier MDE-36 was noteworthy for having a relatively low PITA percentage (26.74 percent).

The dendrogram for April 2007 is presented in Figure 37, indicating two relatively distinct station groupings that formed within 525 linkage distance units, and one extreme outlier station. "Group 3"consisted of seven stations, five with predominately silt/clay substrate (MDE-17, MDE-19, MDE-22, MDE-42, and MDE-43) and two stations with predominately sandy substrate (MDE-43 and MDE-13). Group 3 stations had strong spatial continuity, as all the stations were located southeast of HMI, with no two stations in the group more than approximately 2700 meters apart. "Group 4" consisted of three silt/clay stations: MDE-03, MDE-09, and MDE-16. MDE-03 was located northeast of HMI, while MDE-09 and MDE-16 were located further to the south and on the east side of HMI. Groups 3 and 4 both had lower than average overall faunal abundance. All Group 3 stations had lower than average abundance of Nemata, *Rangia cuneata*, *Marenzelleria viridis*, *Streblospio benedicti*, *Apocorophium lacustre*, and Naididae. In Group 4, all three stations had lower than average abundance of Nemata, *Heteromastus filiformis*, *Marenzelleria viridis*, *Streblospio benedicti*, *Leptocheirus plumulosus*, and *Apocorophium lacustre*; and higher than average abundance of *Mytilopsis leucophaeata*. The extreme outlier station in the April 2007 dendogram was MDE-27. This silt/clay Back River station has consistently been an outlier in previous sampling years. MDE-27 required over 8000 linkage distance units before it became joined with the other stations in the dendrogram. MDE-27 had higher than average overall abundance, but this was primarily due to the extremely high abundance of Naididae, which accounted for approximately 83 percent of the infaunal abundance at this station. For individual taxa, higher than average abundance occurred for *Streblospio benedicti*, Nemata, *Macoma mitchelli*, *Leptocheirus plumulosus*, and *Melita nitida*, while lower than average abundance occurred for *Rangia cuneata*, *Mytilopsis leucophaeata*, *Heteromastus filiformis*, *Marenzelleria viridis*, *Ameroculodes* spp. complex, *Apocorophium lacustre*, *Cyathura polita*, and *Balanus improvisus*. As in previous sampling years, MDE-27 had a very high PITA percentage (97.92 percent). The consistent identification of MDE-27 as an outlier with a high PITA indicates that the faunal community is strongly influenced by the anthropogenic disturbance associated with Back River, which likely masks any impacts from HMI activities.

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 Exterior Monitoring, and Reference) for the fall and spring sampling data. The test indicated that there were significant differences in the 10 most abundant infaunal species between the four station types in September 2006 ($P < 0.16$), but not in April 2007 ($P < 0.63$) (Tables 20 and 21).

Table 20. Friedman Analysis of Variance for September 2006's 10 most abundant species among; Back River/Hawk Cove, Nearfield, South Cell Exterior Monitoring, and Reference stations. ANOVA Chi Sqr. (N = 10, df = 3) = 5.18, P < 0.16.

Station Type	Average Rank	Sum of Ranks	Mean	Std. Dev.
Nearfield	2.950000	29.50000	85.81818	62.57920
Reference	2.950000	29.50000	93.22667	71.44491
Back River	1.900000	19.00000	62.50667	48.76221
South Cell Exterior Monitoring	2.200000	22.00000	78.29333	55.97533

Table 21. Friedman Analysis of Variance for April, 2007's 10 most abundant species among; Back River/Hawk Cove, Nearfield, Reference stations, and South Cell Exterior Monitoring Stations. ANOVA Chi Sqr. (N = 10, df = 3) = 1.74, P < 0.63.

Station Type	Average rank	Sum of ranks	Mean	Std. Dev
Nearfield	2.700000	27.00000	149.7600	158.756
Reference	2.700000	27.00000	94.0800	78.387
Back River	2.550000	25.50000	501.3333	1011.135
South Cell Exterior Monitoring	2.050000	20.50000	64.0000	87.267

Comparison of average rank and mean scores indicates that Back River and South Cell Exterior Monitoring common infauna were quite different from the common infauna at Nearfield and Reference stations in September 2006. These results indicate that the faunal communities of Back River stations and South Cell Exterior Monitoring stations may be impacted by some non-random factor(s). Additional mean comparisons were examined to determine if there was other evidence indicating that the differences in the faunal communities might be due to adverse impacts in the Back River or from South Cell outfall discharges. Mean PSTA for Back River (6.07 percent) and South Cell Exterior Monitoring (8.39 percent) stations were less than half the mean values for Nearfield (18.08 percent) and Reference (19.42 percent) stations. Likewise, mean PITA values were higher at Back River (61.11 percent) and South Cell (52.91 percent) stations than at Nearfield (46.37 percent) and Reference (39.34 percent) stations. Mean total infauna was also lower at Back River and South Cell stations. However, mean number of taxa (All Taxa) and mean Shannon Wiener Diversity did not differ greatly among the station types. Mean B-IBI scores also conflicted somewhat with the mean PSTA/PITA comparisons. The South Cell Exterior Monitoring mean B-IBI (3.56) was the highest mean value among the station types. The Back River station mean B-IBI (3.00) was the lowest mean value, and was right at the accepted standard for a healthy or “passing” faunal community, but two of the three Back River stations had poor or “failing” B-IBI scores (MDE-27 = 2.66, MDE-30 = 2.33). These mean comparisons indicate that in September 2006, the significant Friedman’s test reflected adverse anthropogenic disturbance from the Back River drainage affecting the three Back River stations, but that the different faunal community at the South Cell stations were likely not due to any adverse impacts from South Cell discharges, but more likely the result of a unique combination of physical factors (wave activity, turbulence, sediment dynamics) that were affecting these three stations. The South Cell stations have consistently shown to have differences in their infaunal communities in comparison to Nearfield and Reference stations since HMI Year 22, as indicated by the Friedman’s test.

CONCLUSIONS AND RECOMMENDATIONS

The health of the benthic macroinvertebrate community for Year 25, as measured by the Chesapeake Bay B-IBI remained relatively stable and unchanged from the previous year (Year 24). However, B-IBI scores remained somewhat depressed when compared to previous monitoring years (Year 20 – Year 23). In Year 25, B-IBI scores stayed the same at 13 stations, increased at one station, and declined at six stations. Thirteen of the 20 stations exceeded the benchmark criteria of 3.0, while seven stations had “failing” scores (MDE-13, MDE-17, MDE-19, MDE-27, MDE-30, MDE-35, and MDE-44). The mean B-IBI scores indicated small differences in benthic macroinvertebrate community health between Nearfield, Reference, Back River/Hawk Cove, and South Cell Exterior Monitoring stations. However, Friedman’s nonparametric test indicated that there were significant differences in infauna among the Reference, Nearfield, South Cell Exterior Monitoring, and Back River/Hawk Cove stations. The Back River station infaunal differences were likely the result of the predominate influence of the Back River drainage on these stations. The South Cell station infaunal differences were not likely the result of adverse impacts from South Cell discharges, but likely due to a unique combination of habitat or physical factors not prevalent at Nearfield or Reference stations. The cluster analyses indicated some distinct patterns of station clustering or lack thereof (outlier stations), which was primarily associated with bottom type and station location

The HMI will continue to receive dredged material until December 31, 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 historical analysis of all HMI data might filter out real trends from background random variation. The incorporation of historical trend analysis is a primary goal for future editions of this work. 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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APPENDIX 3: ANALYTICAL SERVICES (PROJECT IV)

(September 2006 – August 2007)

Technical Report

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OBJECTIVES

The goals of the project in 2006-2007 were to continue to measure and evaluate the current levels of contaminants in the sediment in the vicinity of HMI and to relate these, as far as possible, to historical data. Continued comparison and correlation of this data with historical HMI data will indicate the extent of contamination, if any, and any trend in concentrations at the monitoring stations.

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 25th year of exterior monitoring, and to document any seasonal changes. Specific objectives were:

1. In the fall of 2006 and spring of 2007 analyze clams and associated sediment for analyses of trace metals, PAH and PCB's.

2. Relate metal and PCB concentrations to toxicity tests conducted in fall 2006 and spring 2007.

3. To determine the concentrations of target trace elements in surface sediments around HMI collected by MGS in September 2006 as part of the annual sediment survey. Metal analysis conducted by CBL focuses on those metals not measured by MGS, specifically mercury (Hg), monomethylmercury (MMHg), silver (Ag), and arsenic (As). In support of MGS analysis, CBL also conducted metal analysis on 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 25 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 25 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 stations designated by the revised sampling plan, developed by the Maryland Department of the Environment in September 2006 and April 2007. 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 cooled 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 station to avoid cross contamination between stations. The clam bodies from each station 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 both 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 HNO_3 was added and the slurry was mixed and covered with a watch glass. The sample was heated to 95^0C and allowed to reflux for 15 minutes without boiling. The samples were cooled, 5 mL of concentrated HNO_3 was added, and then they were allowed to reflux for another 30 minutes. This step was repeated to ensure complete oxidation. The watch glasses were removed and the resulting solution was allowed to evaporate to 5 mL without boiling. When evaporation was complete and the samples cooled, 2 mL of 30% H_2O_2 was added. The flasks were then covered and returned to the hot plate for warming. The samples were heated until effervescence subsided. We continually added 30% H_2O_2 in 1 mL aliquots with warming until the effervescence was minimal. No more than a total of 10 mL of H_2O_2 was added to each sample. Lastly, 5 mL of concentrated HCl and 10 mL of deionized water were added and the samples refluxed again for 15 minutes. The samples were then cooled and filtered through Whatman No. 41 filter paper by suction filtration and diluted to 50 mL with deionized water. Sediment homogenates were then analyzed using a Hewlett Packard model 4500 Inductively Coupled Plasma Mass Spectrometer for the other metals and metalloids. These techniques are similar to USEPA Method 1632.

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

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

Analytical Procedures for Organics

The sediment, clam and worm homogenates were extracted and purified using the method described by Kucklick et al. (1996). For this method, a subsample of clam homogenate, 5 g wet weight, is removed and ground with anhydrous sodium sulfate (~50 g). A perdueterated polyaromatic hydrocarbon (PAH) cocktail (d_8-napthalene, d_{10}-fluorene, d_{10}-fluoranthene, d_{12}-perylene) and a noncommercial polychlorinated biphenyl (PCB) solution (IUPAC #'s 14, 65, 166) are added as surrogates to each sample to track extraction efficiency. The mixture is then extracted in a Soxhlet apparatus with 250 mL of dichloromethane (DCM) for 24 hours. The extracts are then concentrated to 2 mL using a vacuum rotary evaporator and transferred into hexane. Each sample is transferred to a 4 mL Waters autosampler vial with sample and rinses amounting to approximately 4 mL. Gravimetric lipid analysis is performed on each sample with subsampled fractions determined gravimetrically (Kucklick et al. 1996). Samples are again concentrated in similar fashion as above, then solvent exchanged to hexane. To remove lipids the extracts are then eluted with 25 mL petroleum ether over 4 g deactivated Alumina [6% (w/w) water]. After concentrating, the extracts are spiked with a perdueterated PAH mixture (d_{10}-acenapthene, d_{10}-phenanthrene, d_{12}-benz[*a*]anthracene, d_{12}-benzo[*a*]pyrene, d_{12}-benzo[*g,h,I*]perylene) for quantification of PAH's. The samples are then analyzed using a Hewlett Packard 5890 gas chromatograph (GC) with a HP-5MS (cross linked 5% phenyl methyl siloxane) capillary column (30m x 0.25mm x 0.25um film thickness) and a HP-5972 series mass spectrometer (MS) for PAH's (Ko and Baker 1995). Each sample is separated after GC/MS analysis into two fractions with 35 mL of petroleum ether and 50 mL of DCM/PET (1:1), respectively, over 8 g of deactivated Florisil (2.5% (w/w) water (Kucklick et al.1996). The first fraction (F-1), contains PCBs and 1-100%, by weight of the less polar organochlorine pesticides [heptachlor (100%), 4,4-DDT (40%), 4,4-DDE (100%), t-nonachlor (24%), heptachlor (1%), 4,4-DDT(44%)]. The second fraction, (F-2), contains 56-100% of the more polar organochlorine pesticides [a-HCH (100%), g-HCH (100%), c-chlordane (100%), t-chlordane (100%), t-nonachlor (76%), heptachlor (99%), heptachlor epoxide (100%), dieldrin (100%), 4,4-DDD (100%), 4,4-DDT (56%)]. Both fractions are solvent exchanged to hexane and concentrated to ~ 1 mL.

PCB congeners are analyzed by gas chromatography using a J&W Scientific DB-5 capillary column (60m x 0.32mm, 0.25µm film thickness) coupled with an electron capture detector. Individual PCB congeners are identified and quantified using the method of Mullins et al. (1985) using the noncommercial PCB congeners IUPAC 30 and

204 as internal standards. After quantification of PCB congeners, the two Florisil fractions from each sample are recombined and pesticides are quantified by gas chromatography (30 m DB-5 column) with negative chemical ionization mass spectrometric (NCI-MS) detection. Chemical ionization with methane reagent gas is used. Pesticides are identified by their chromatographic retention times and confirmed by the relative abundance of negative fragments (confirmation ions) relative to the quantification fragment. Five-point calibration curves are used for each pesticide analyzed. PCB congener 204 is used as the internal standard for the pesticide quantification.

RESULTS AND DISCUSSION

Metals in Sediment

Concentrations of As, Se, Cd and Pb in the sediment collected around HMI in Year 25 (2006-2007) are similar to previous years (Figure 38 and 39) and are not substantially different than the concentrations found elsewhere in the Chesapeake Bay or in marine sediments. Concentrations of As in Year 25 sediments are typical being close to the 10 ug g^{-1} average and mean concentration observed in the previous years. Concentrations of Se in Year 25 sediments are also very close to the average of 3 ug g^{-1} observed 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 25 HMI sediments are found within this range and are typically 0.5 ug g^{-1}, and less than the average seen in pervious years (Figure 39). All the 2006 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 2006 were close to the 60 ug g^{-1} dry weight average, placing them well within this historical range. Concentrations of silver were low, and below the median values of previous years (Figure 40).

Concentrations of total mercury (T-Hg) and methylmercury (MeHg) in sediment are typical of previous years with Year 25 sediment concentrations very close to the station mean and median concentrations of previous years (Figure 41). Concentrations of T-Hg in the main stem of the Chesapeake Bay range from 0.2 to 250 ng g^{-1} dry weight and concentrations of MeHg range from 0.01 to 2.2 ng g^{-1} dry weight (Figure 41) (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}.

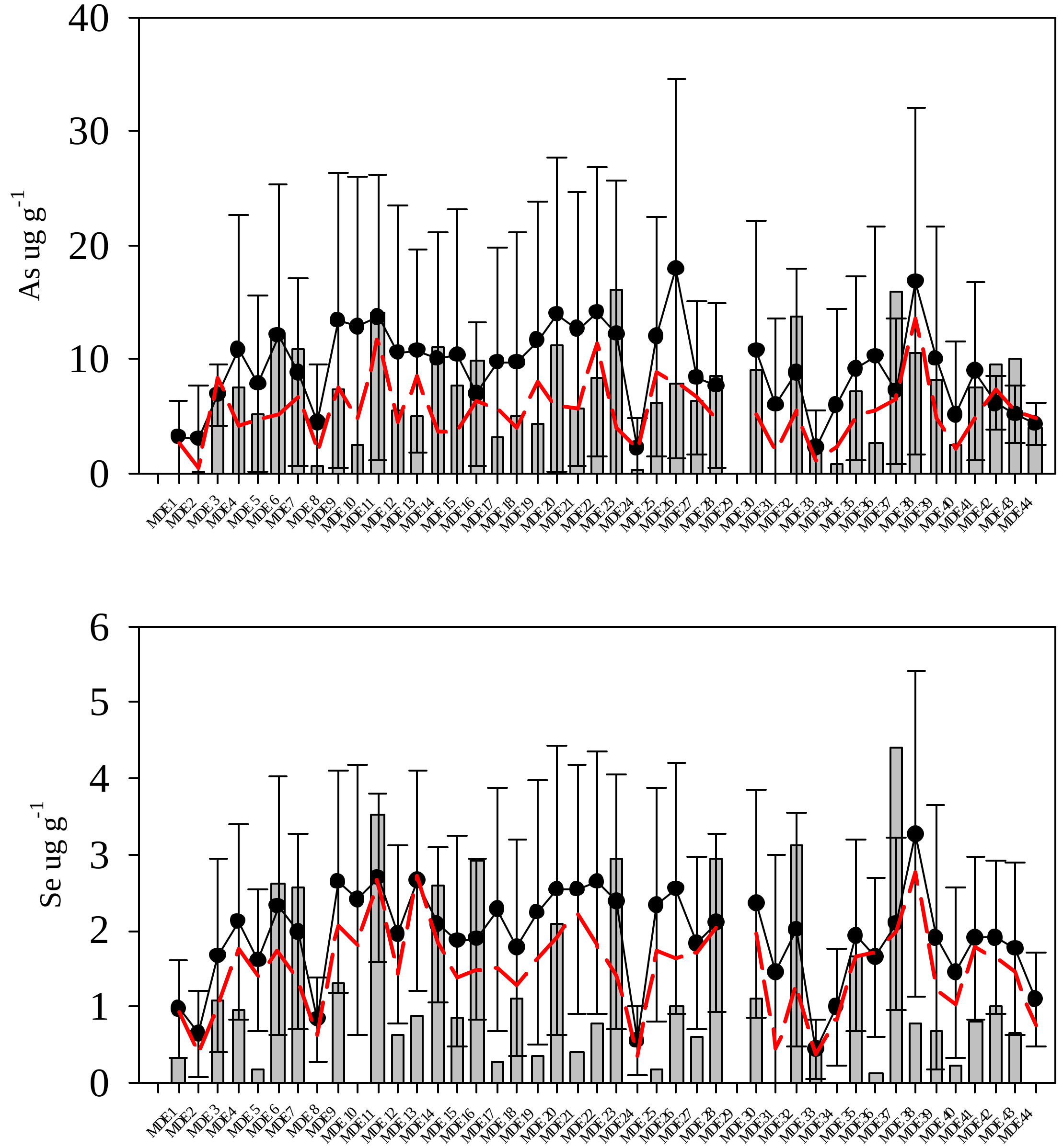


Figure 38. Arsenic (As) and selenium (Se) in sediment, expressed in dry weight concentration, from 2006 (bars) and the 1998-2005 mean (circles) with standard deviation (error bars) and the 1998-2005 median (dashed line).

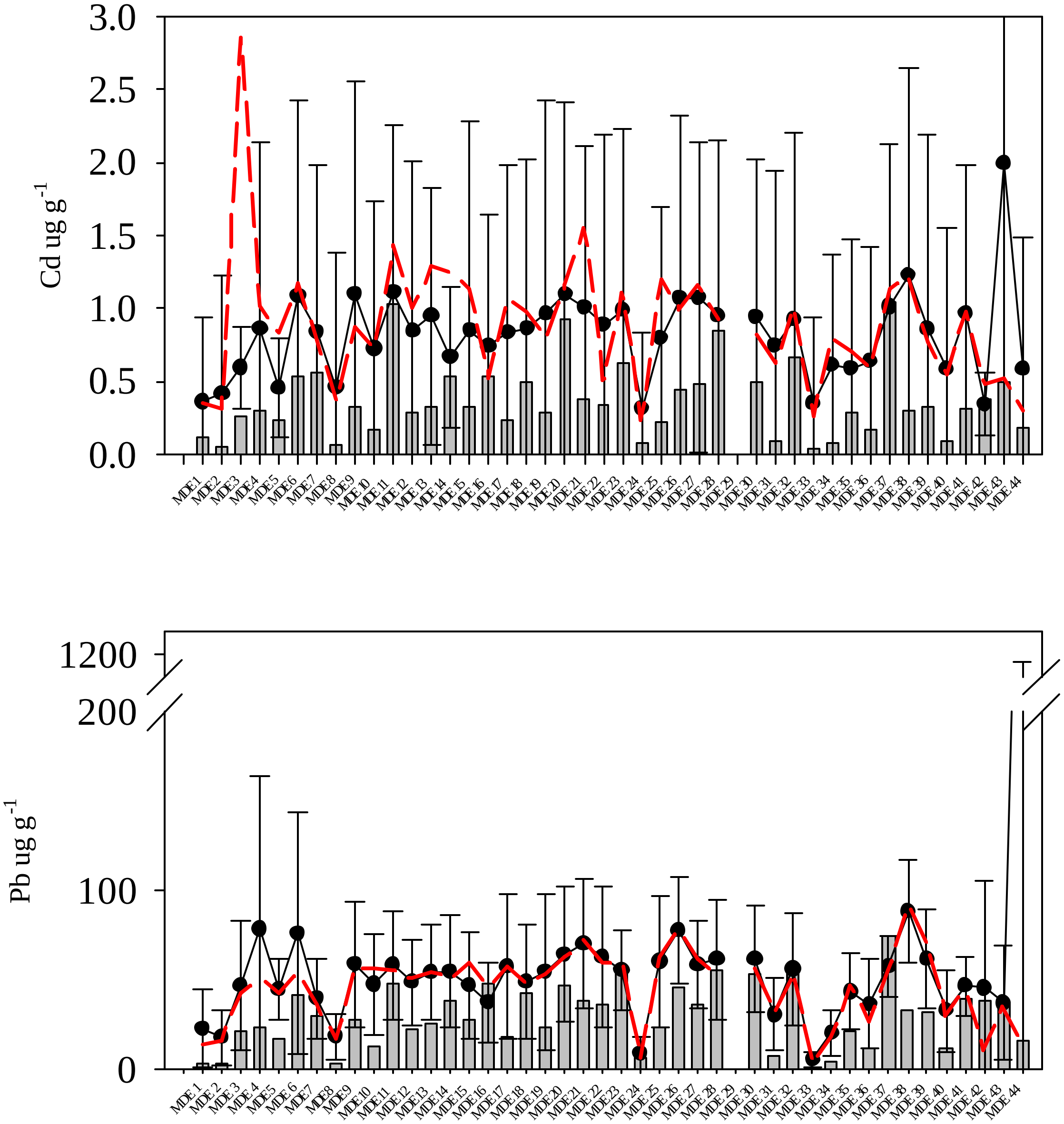


Figure 39. Cadmium (Cd) and lead (Pb) in sediment, expressed as dry weight concentration, from 2006 (bars) and the 1998-2005 mean (circles) with standard deviation (error bars) and the 1998-2005 median (dashed line).

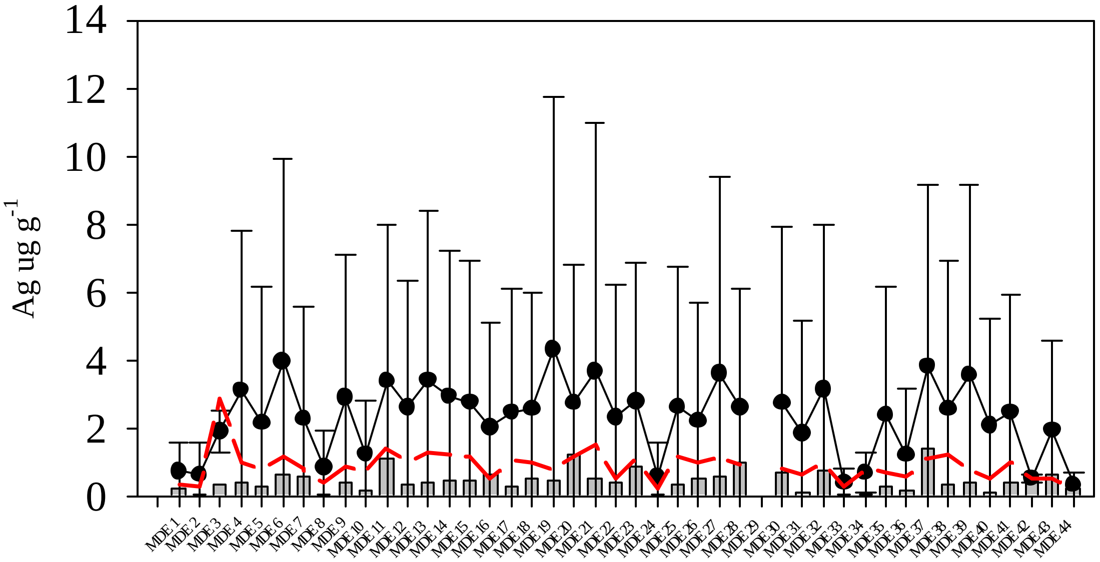


Figure 40. Silver (Ag) concentrations in sediment from 2006 (bars), expressed as dry weight concentration, and the 1998-2005 mean (circles) with standard deviation (error bars) and the 1998-2005 median (dashed line).

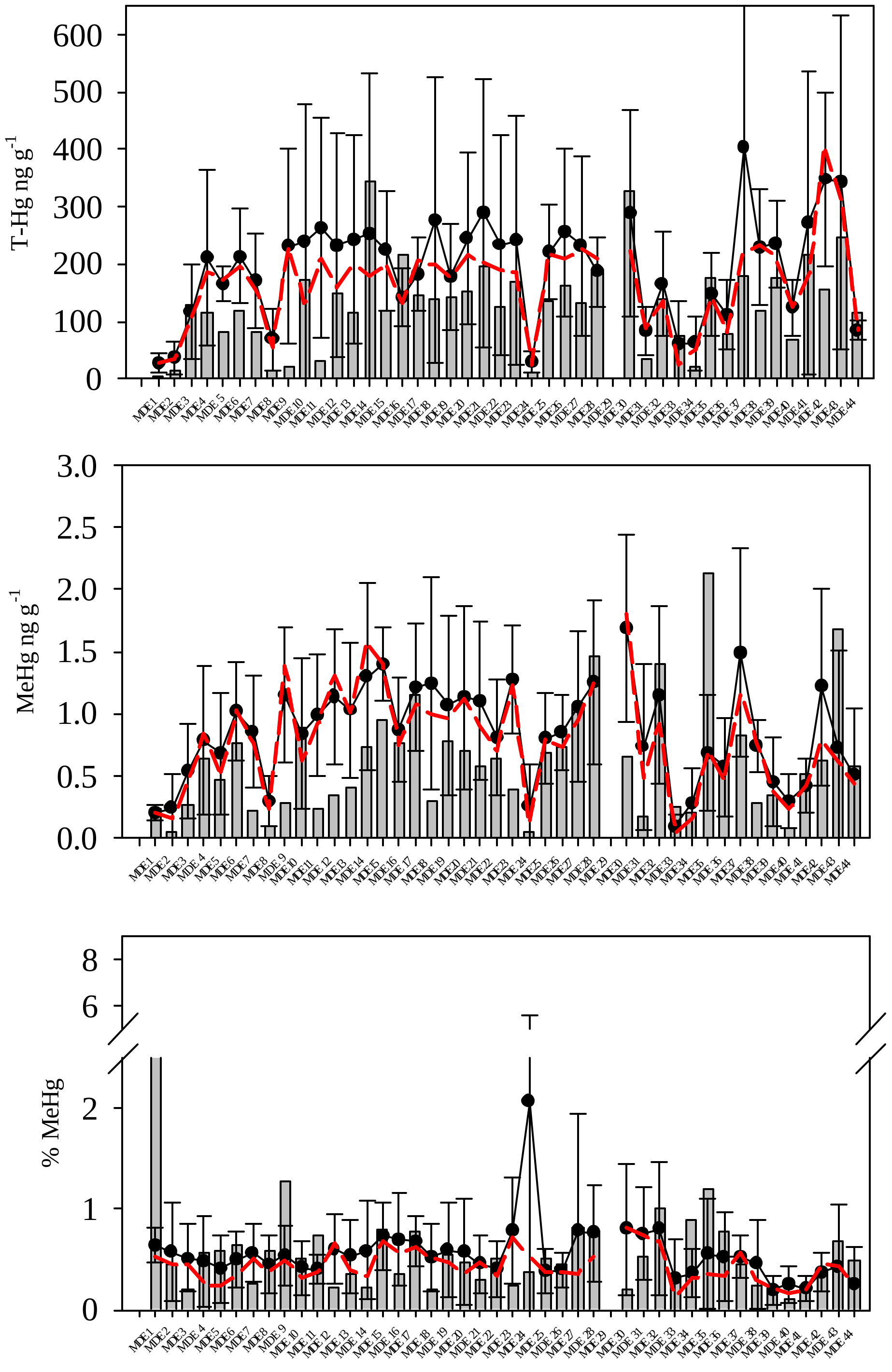


Figure 41. Mercury (Hg) and methylmercury (MeHg) expressed as dry weight concentrations, and percent Hg as MeHg, in 2006 sediment (bars) and the 1998-2005 mean (circles), median (dashed line), with standard deviation (error bars).

Stations 42, 43 and 44

To gather data on sediment in areas in proximity to Spillway 003 of the South Cell Restoration Project, where water is released as part of the annual August drawdown of the South Cell pond, three stations (MDE-42, 43 and 44) were added to the sampling plan in 2003. For the most part, results from these stations appear similar to the other stations on the southern end of the island (Figures 38, 39, and 40). The exception was in 2004, where very high concentrations of Cd, Pb and Ag were found at MDE-43, 44, and 43 respectively. Concentrations of Se and Cd were also on the high end of the concentrations observed in 2003. In subsequent sampling, including in 2006, the sediment concentrations at these stations are similar to concentrations observed elsewhere on the southern side of HMI.

Toxicity Experiment Sediments

Sediments for toxicity experiments were collected at the same time as the clams. Multiple grab samples were required and the sediment was sub-sampled and analyzed independently. Concentrations of metals in the sediments collected for toxic testing in September 2006 were similar to April 2007 with the exception of MeHg (Table 22), which was higher in September. MeHg is formed *in situ* by sulfate reducing bacteria methylating Hg. Microbial activity is temperature dependent, and therefore methylation potential was likely at its highest in September. Furthermore, disturbance often increases Hg methylation. Thus, we may have stimulated Hg methylation during the processing of the September samples. Although these concentrations are high, it would require prolonged exposure and bioaccumulation for MeHg at these concentrations to be toxic. Overall, the metal concentrations tended to be lower than the station averages, but similar to the sediment collected on a different date by MGS. What differences that exist likely reflect the variability in concentrations at the respective stations.

	As ug/g dry	Mean As ug/g dry	Se ug/g dry	Mean Se ug/g dry	Ag ug/g dry	Mean Ag ug/g dry	Cd ug/g dry	Mean Cd ug/g dry
September	2006							
MDE-3	2.26	6.90	0.20	1.67	0.19	1.91	0.18	0.59
MDE-9	7.55	13.41	1.29	2.64	0.51	2.90	0.51	1.10
MDE-13	7.96	10.80	1.15	2.65	0.54	3.42	0.40	0.95
MDE-19	13.02	11.66	1.52	2.24	0.71	4.32	0.52	0.96
MDE-22	10.51	14.16	1.78	2.64	0.63	2.33	0.45	0.89
MDE-27	6.66	8.41	0.79	1.83	0.62	3.60	0.39	1.07
MDE-36	7.86	10.27	0.86	1.65	0.42	1.22	0.26	0.64
April 2007								
MDE-3	3.76	6.90	0.75	1.67	0.27	1.91	0.25	0.59
MDE-9	12.02	13.41	1.76	2.64	0.31	2.90	0.42	1.10
MDE-13	7.71	10.80	1.57	2.65	0.58	3.42	0.48	0.95
MDE-19	9.37	11.66	1.65	2.24	0.60	4.32	0.49	0.96
MDE-22	6.80	14.16	2.75	2.64	0.30	2.33	0.28	0.89
MDE-27	6.85	8.41	1.29	1.83	1.02	3.60	0.60	1.07
MDE-36	7.93	10.27	1.76	1.65	0.49	1.22	0.41	0.64

	Pb ug/g dry	Mean Pb ug/g dry	MeHg ng/g	Mean MeHg ug/g dry	T-Hg ng/g	Mean T-Hg ug/g dry
September	2006					
MDE-3	14.60	46.95	2.56	0.54	146.98	116.29
MDE-9	36.31	58.93	3.32	1.15	38.81	231.18
MDE-13	29.78	54.31	3.00	1.03	82.20	242.56
MDE-19	46.51	54.64	4.36	1.07	43.42	178.57
MDE-22	39.86	62.82	3.44	0.81	135.54	233.85
MDE-27	33.45	58.46	2.51	1.06	290.34	232.08
MDE-36	24.54	36.51	2.30	0.57	31.28	111.59
April 2007						
MDE-3	17.11	46.95	0.14	0.54	164.22	116.29
MDE-9	26.20	58.93	0.54	1.15	227.88	231.18
MDE-13	31.05	54.31	0.16	1.03	126.98	242.56
MDE-19	36.73	54.64	0.58	1.07	41.80	178.57
MDE-22	20.72	62.82	0.63	0.81	80.68	233.85
MDE-27	43.47	58.46	1.53	1.06	119.08	232.08
MDE-36	31.65	36.51	0.93	0.57	36.16	111.59

Table 22. Metal concentrations in sediments (highlighted) collected for toxicity experiments in September 2006 and April 2007. The mean concentrations over the study period are provided for reference.

Metals in Clams

Clams were collected in both the fall of 2006 and spring of 2007 in support of the toxicity triad. Concentrations of the metals As, Se, Ag, Cd, Pb, Hg and MeHg in the clam *Rangia* displayed some variations from previous years (Figures 42 - 45). Concentrations of Hg were elevated at MDE-19 and MDE-36 being twice as high as the running mean. In the spring, As concentrations were higher than the running mean in clams from MDE-9, 19 and 27. The spring clams contained high Pb concentrations, being 5 times higher than the running mean at all the sampled stations including the reference station (MDE-36) with one exception, MDE-27 (Figure 44). MDE-27 is located at the entrance to the Back River. Elevated Pb concentrations were also seen in spring clams collected in Year 23. The fact that elevated concentrations were not observed at MDE-27, where Chesapeake Bay water is likely to mix the least and that the Pb was not observed in sediments suggests a plume of a soluble Pb-organic complex came down the Bay. Such a compound would be readily available to clams. The wide spread nature indicates HMI is not the source of the compound. In a study of Pb uptake from water by the clam *Corbicula fluminea*, Labrot et al. (1999) showed uptake was rapid, with equilibriums reached in hours, but also that depuration was also relatively fast with 86 percent of the Pb taken up depurated in 3 weeks. Therefore, very short pulses of metals may not be recorded using a biannual collection scheme. Further, Kumari et al. (2006) showed a seasonal bias in the clam *Paphia malabarica*, in the Mandovia Estuary, Goa, India. Concentrations of Pb as low as 2 ug g^{-1} were observed in the dry seasons but typical concentrations of 50 ug g^{-1} occurred in the winter monsoons. Thus, Pb concentrations vary within clams over time and are subject to seasonal pulses of Pb from runoff. In the case of clams around HMI, the source is likely runoff delivered via the Susquehanna River.

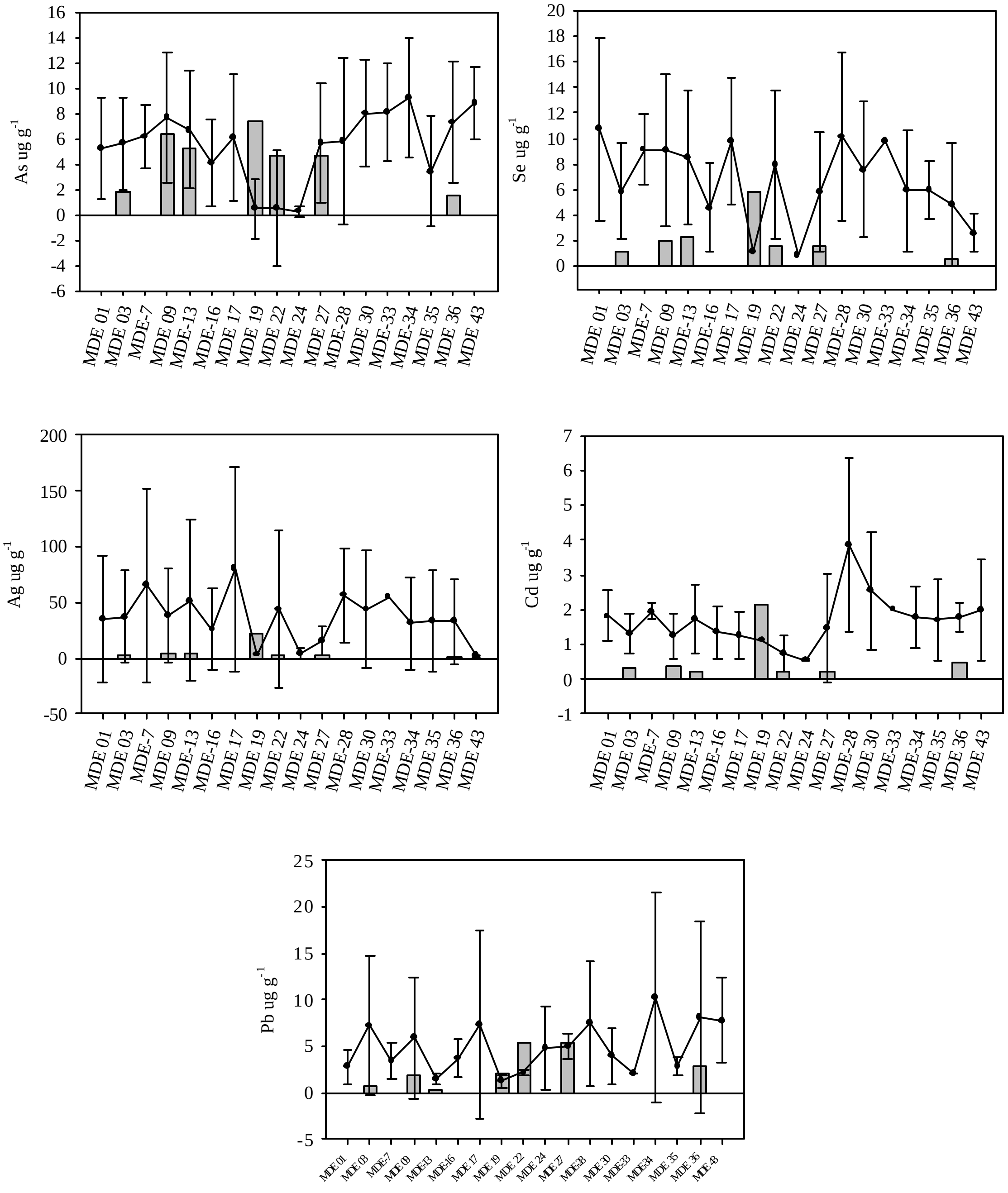


Figure 42. Concentrations of arsenic (As), selenium (Se), silver (Ag), cadmium (Cd) and lead (Pb) in clams collected in September 2006. Concentrations are expressed as dry weight, collected in September 2006 (bars) and the 1998-2005 mean (circles) with standard deviation (error bars) for the station are presented.

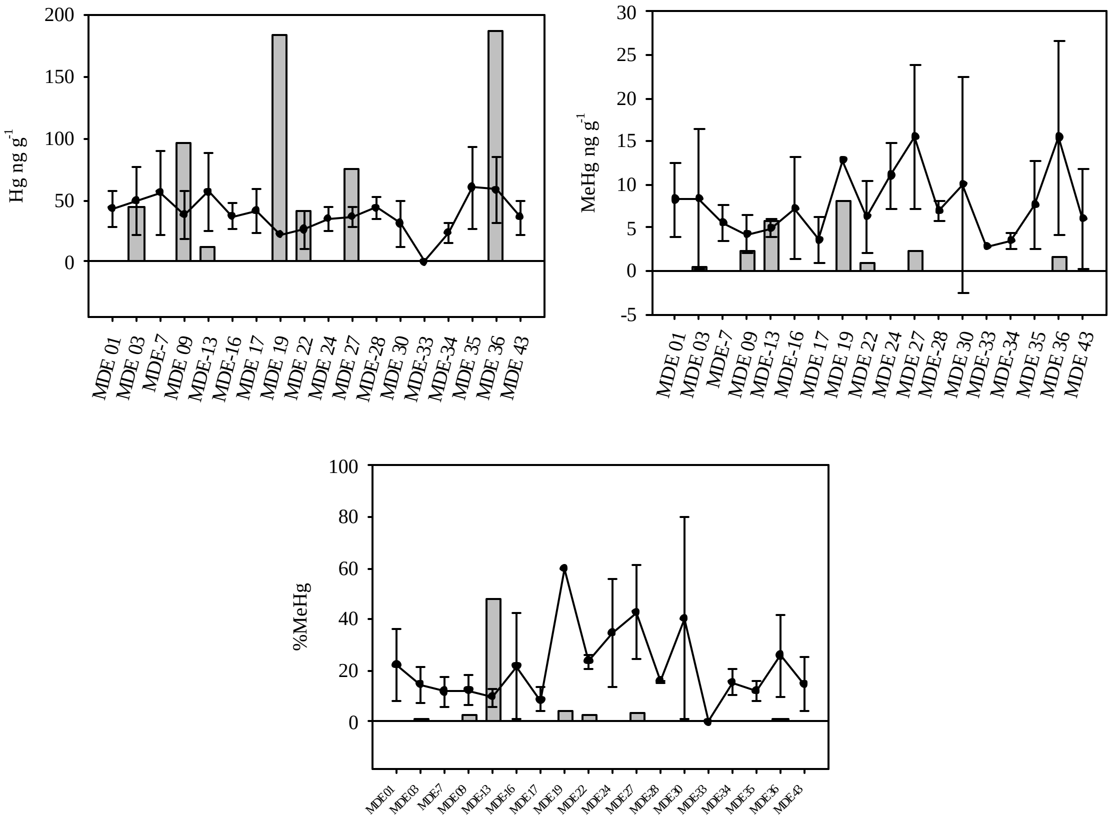


Figure 43. Mercury (Hg) and methylmercury (MeHg) concentrations, expressed on a dry weight basis, and percent of Hg that is MeHg in clams, collected in September 2006 (bars) and the 1998-2005 mean (circles) with standard deviation (error bars).

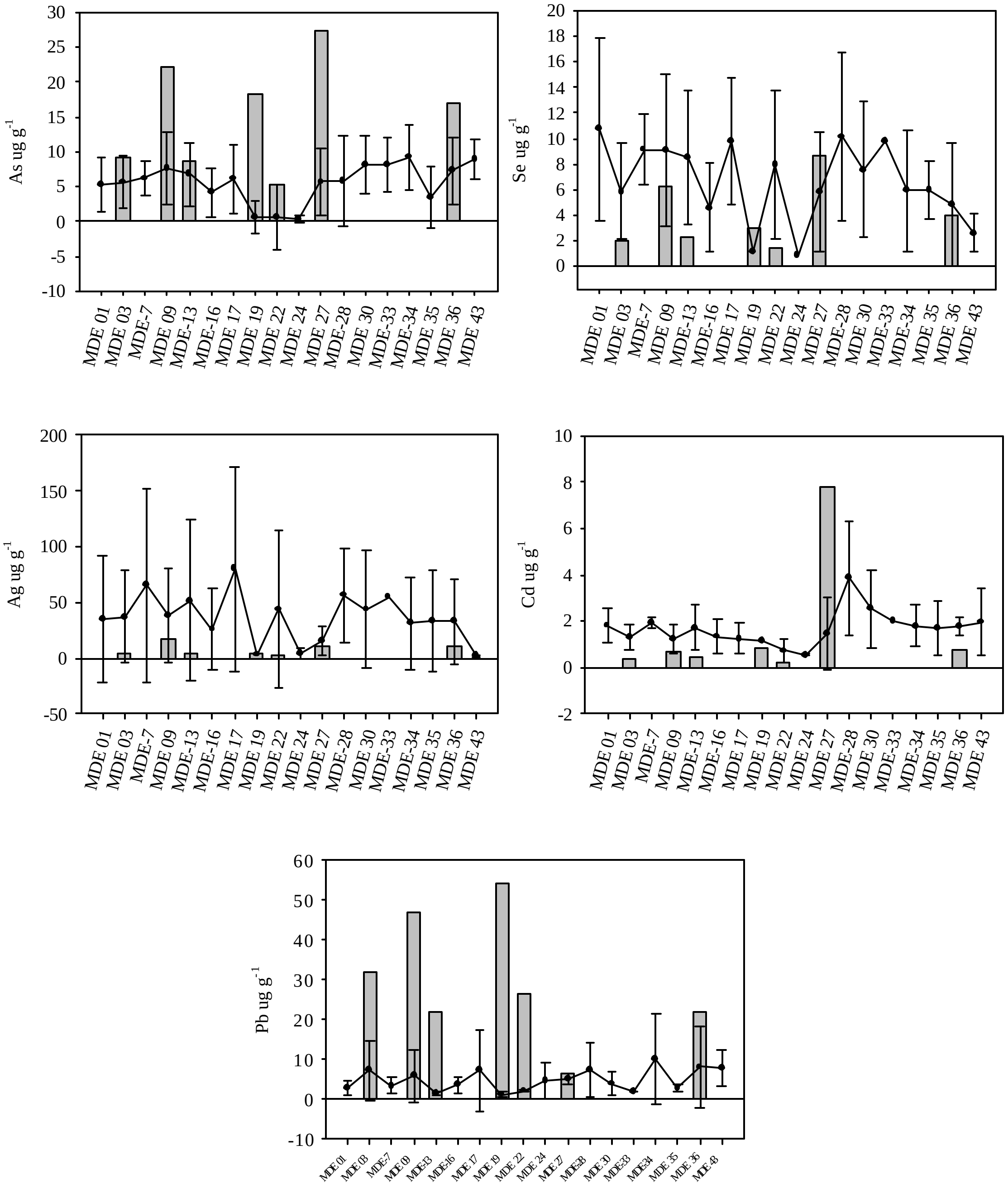


Figure 44. Concentrations of arsenic (As), selenium (Se), silver (Ag), cadmium (Cd) and lead (Pb) in the clams, expressed as dry weight, collected in April 2007 (bars) and the 1998-2005 mean (circles) with standard deviation (error bars).

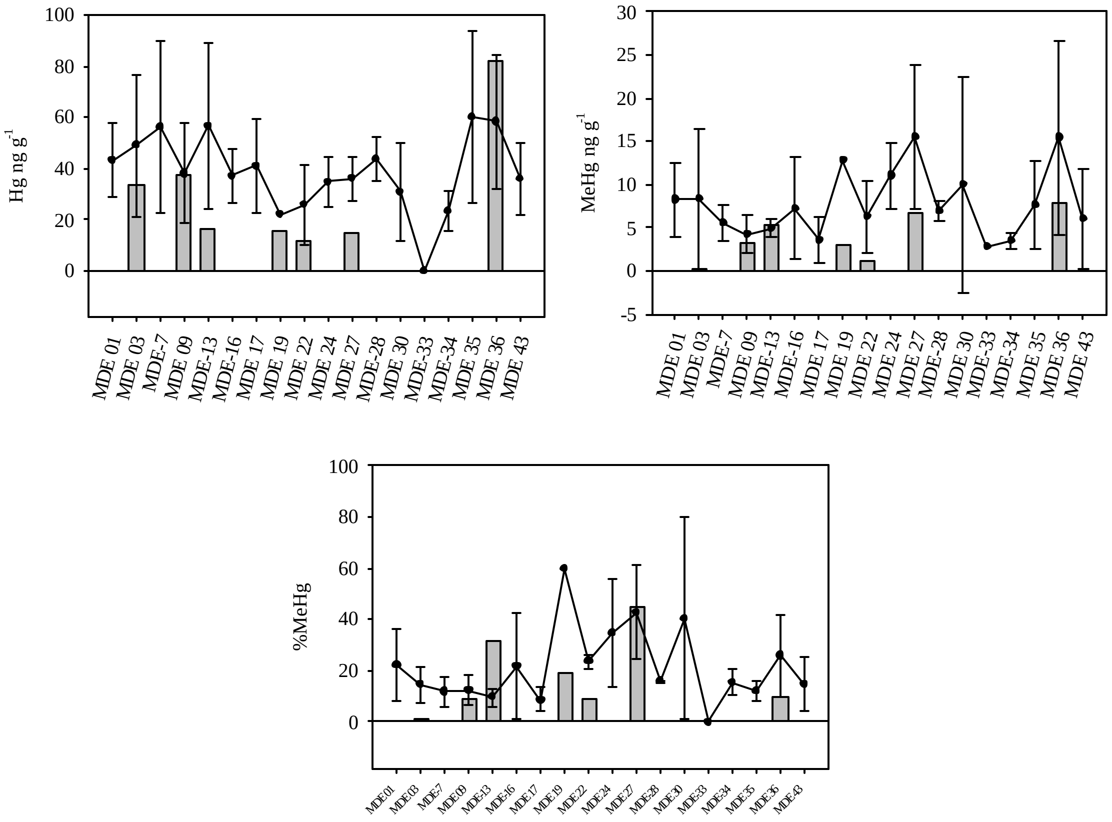


Figure 45. Mercury (Hg) and methylmercury (MeHg) concentrations, expressed on a dry weight basis, and percent of Hg that is MeHg in clams, collected in April 2007 (bars) and the 1998-2005 mean (circles) with standard deviation (error bars).

POLYCHLORINATED BIPHENYLS AND POLYCYCLIC AROMATIC HYDROCARBONS

PCB's in Sediment

The concentrations of PCB's in the sediments were sampled from 7 stations in September 2006 and April 2007. These findings are summarized in Figures 46 a-g. The sediments are typically high in the PCB congeners 40, 206 and 209. The samples collected in Year 25 are no different and generally lower than the average and close to the median when compared to sediment collected from the same stations in previous years. The six stations around HMI were also not different than what was observed at the reference station MDE-36. One abnormally high value was observed at MDE-3 for congener 40.

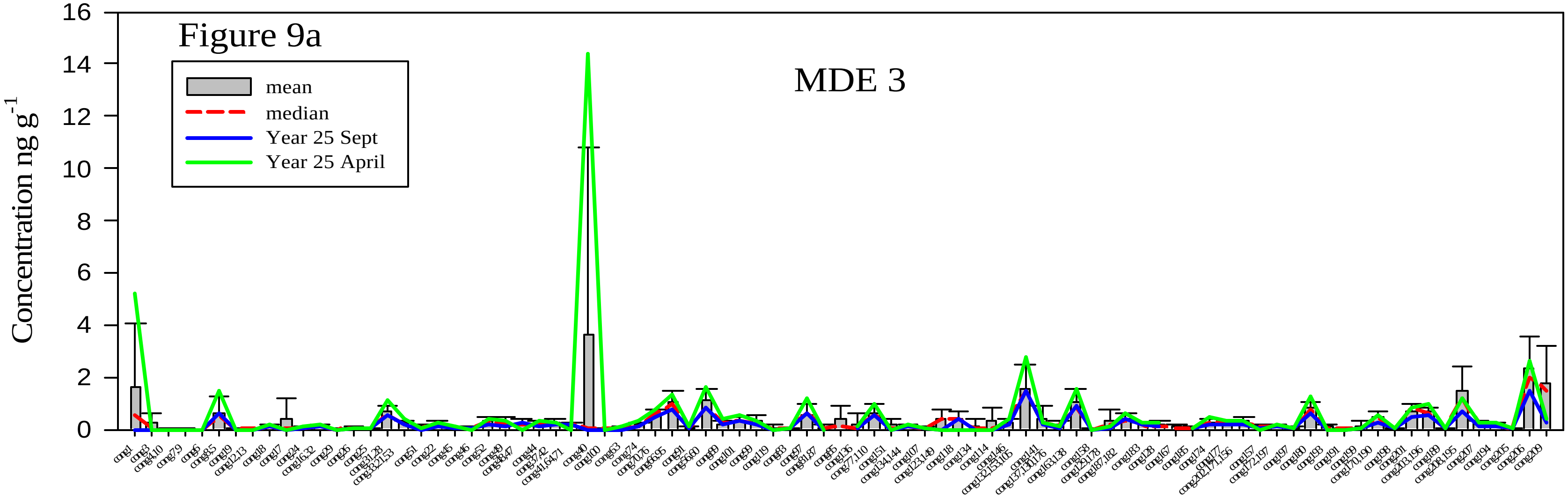


Figure 9a

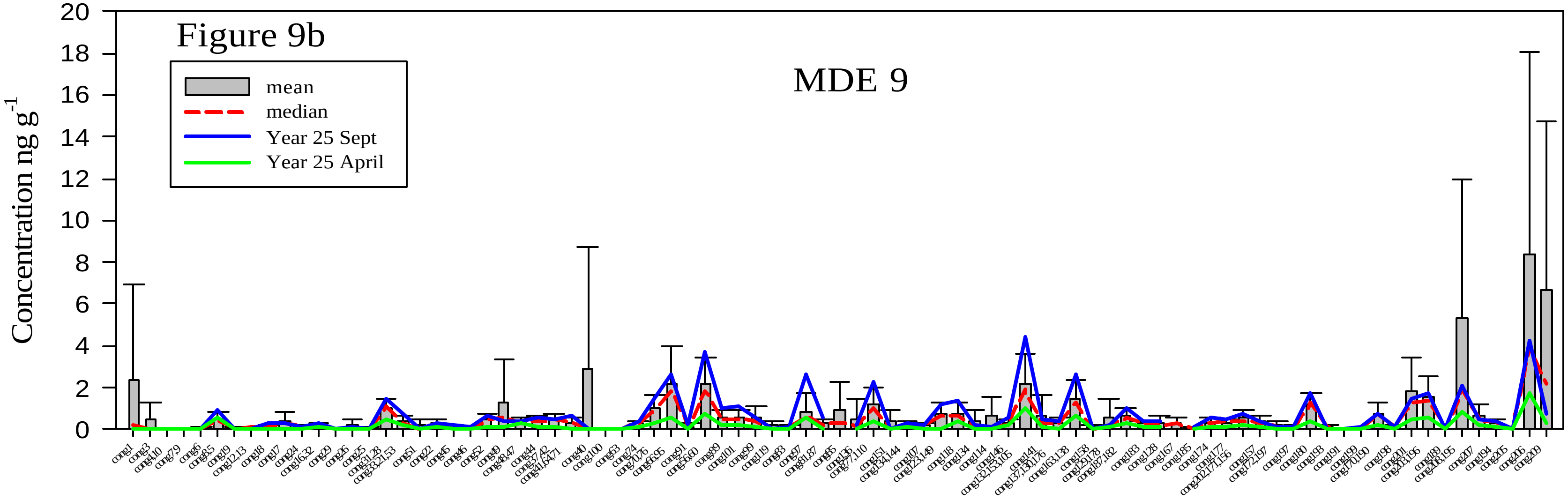


Figure 9b

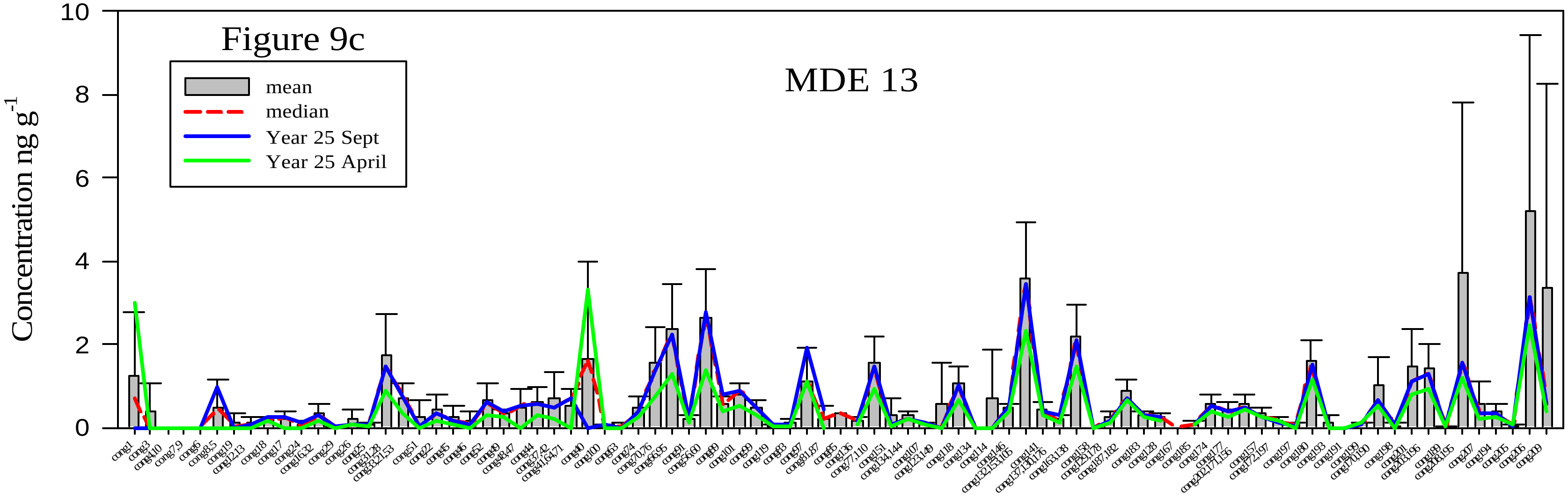


Figure 9c
MDE 13
mean
median
Year 25 Sept
Year 25 April
Concentration ng g^{-1}
0
2
4
6
8
10

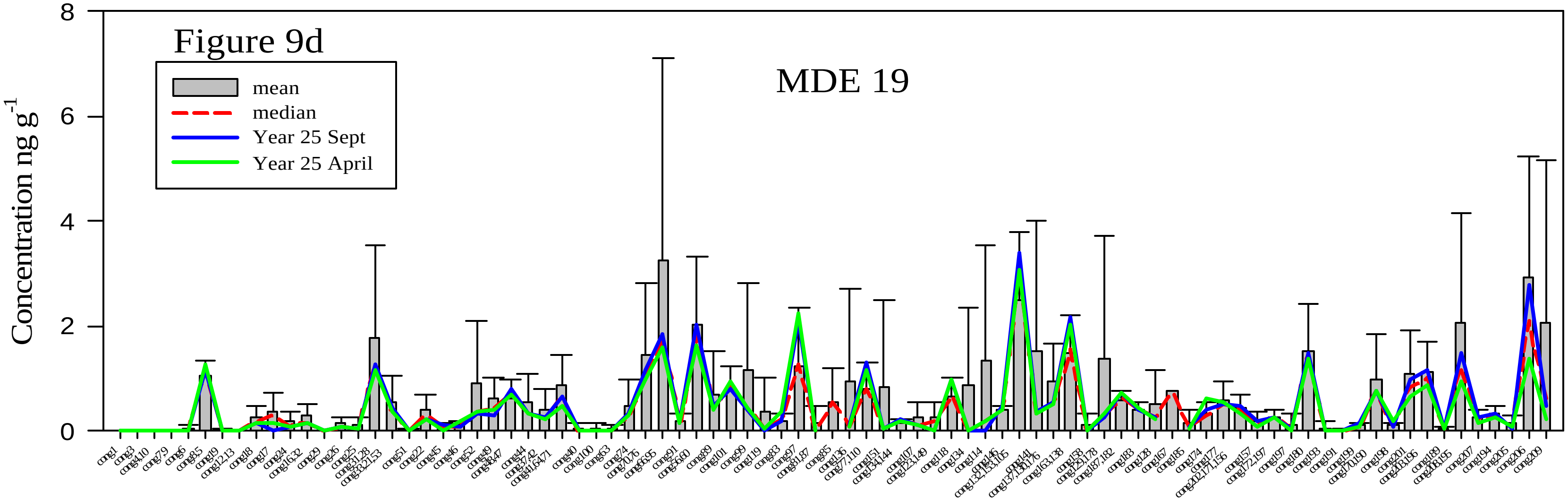


Figure 9d
MDE 19
mean
median
Year 25 Sept
Year 25 April
Concentration ng g^{-1}
0
2
4
6
8

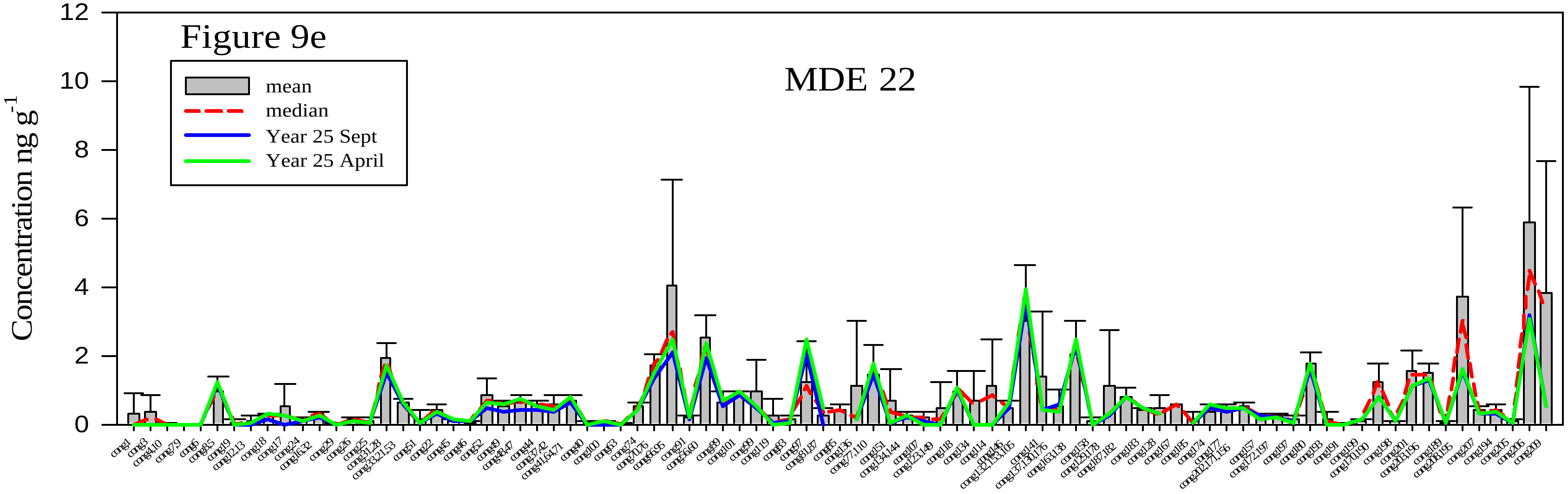


Figure 9e
MDE 22
mean
median
Year 25 Sept
Year 25 April
Concentration ng g^{-1}
0
2
4
6
8
10
12

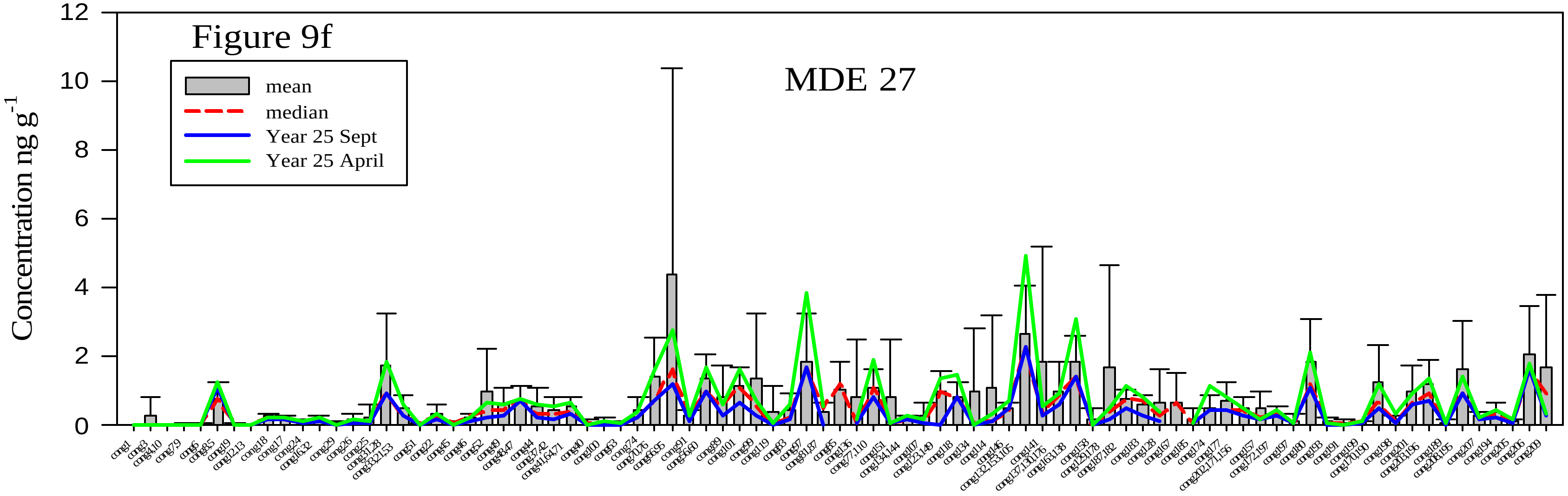
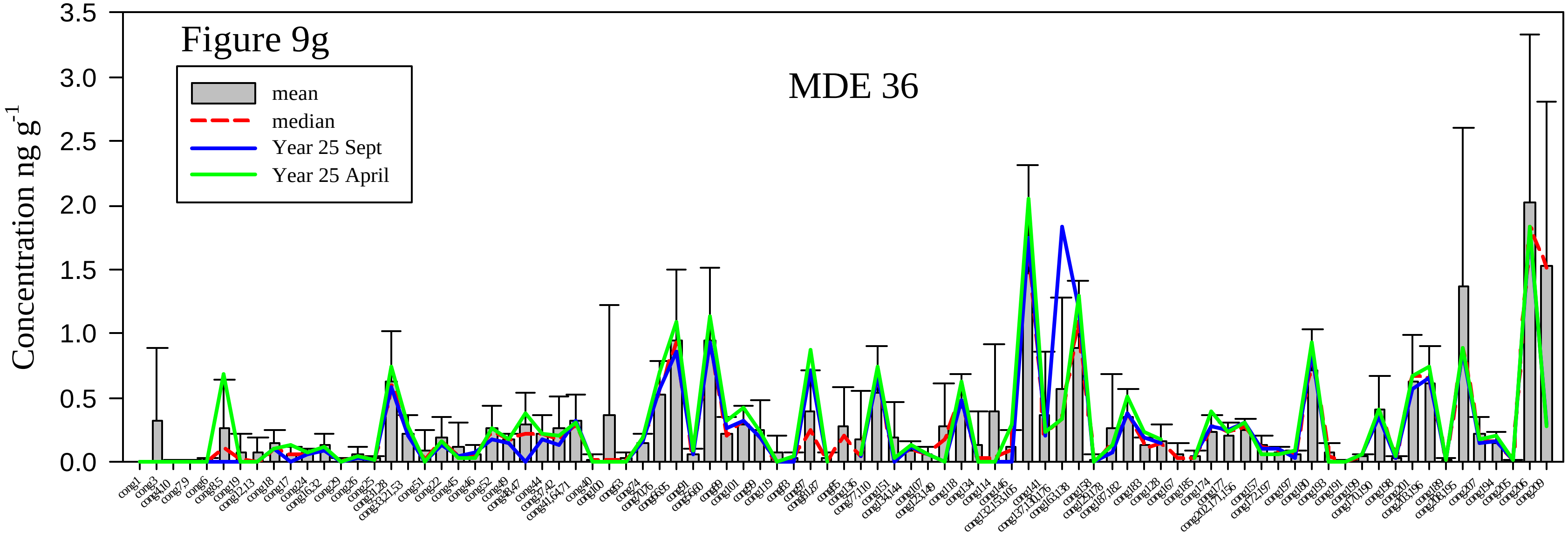


Figure 9f
MDE 27
mean
median
Year 25 Sept
Year 25 April
Concentration ng g^{-1}
0
2
4
6
8
10
12



Figures 46 (a-g). PCB concentrations in sediment expressed on a dry weight basis, collected in September 2006 (blue line), and April 2007 (green line), the 1998-2005 mean (bars) with standard deviation (error bars) and median (red dashed line).

PCB's in Clams

The concentrations of PCB's in clams were sampled from 7 stations in September 2006 and April 2007. These findings are summarized in Figures 47 a-g. Like the sediments the clams are typically high in the PCB congeners 206 and 209, but unlike the sediments contain the lighter mass 1 and 2 congeners. The samples collected in Year 25 are no different and generally lower than the average and close to the median when compared to the clams collected from the same stations in previous years. The concentrations in clams from the six stations around HMI were also not different than what was observed from the reference station MDE-36.

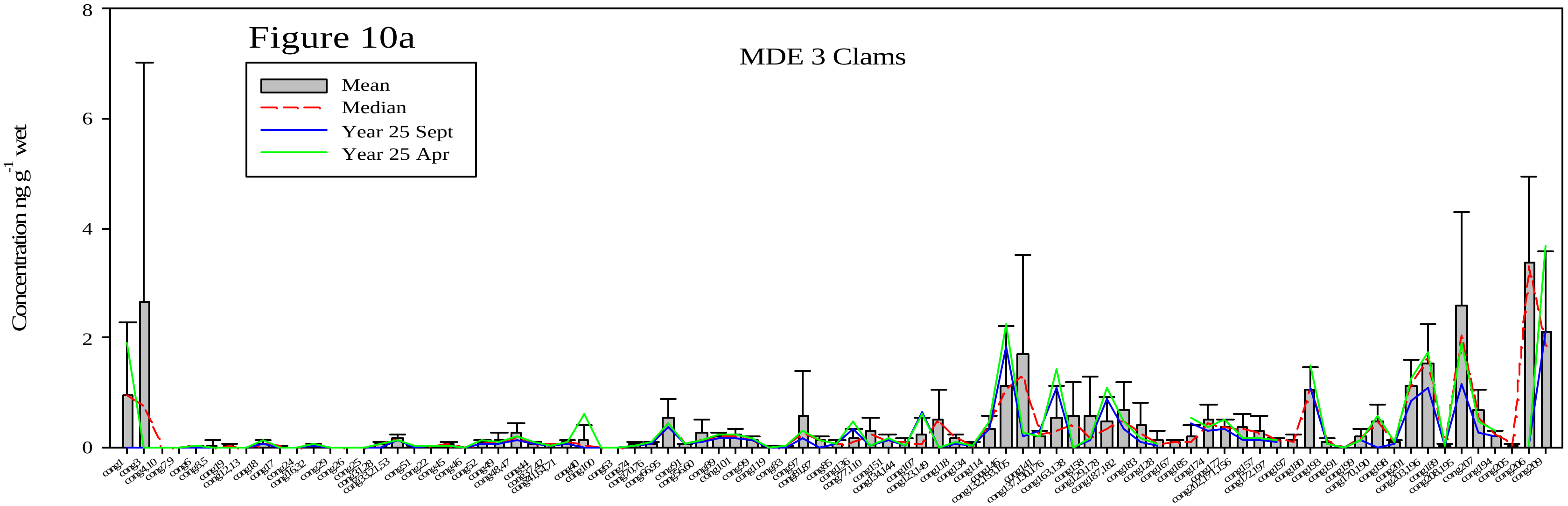


Figure 10a
MDE 3 Clams
Mean
Median
Year 25 Sept
Year 25 Apr
Concentration ng g^{-1} wet
0
2
4
6
8
cong1
cong3
cong4,10
cong7,9
cong6
cong8,5
cong19
cong12,13
cong18
cong17
cong24
cong16,32
cong29
cong26
cong25
cong31,28
cong33,21,53
cong51
cong22
cong45
cong46
cong52
cong49
cong48,47
cong44
cong37,42
cong41,64,71
cong40
cong100
cong63
cong74
cong70,76
cong66,95
cong91
cong56,60
cong89
cong101
cong99
cong119
cong83
cong97
cong81,87
cong85
cong136
cong77,110
cong151
cong134,144
cong107
cong123,149
cong118
cong134
cong114
cong146
cong132,153,105
cong141
cong137,130,176
cong163,138
cong158
cong129,178
cong187,182
cong183
cong128
cong167
cong185
cong174
cong177
cong202,171,156
cong157
cong172,197
cong197
cong180
cong193
cong191
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cong170,190
cong198
cong201
cong203,196
cong189
cong208,195
cong207
cong194
cong205
cong206
cong209

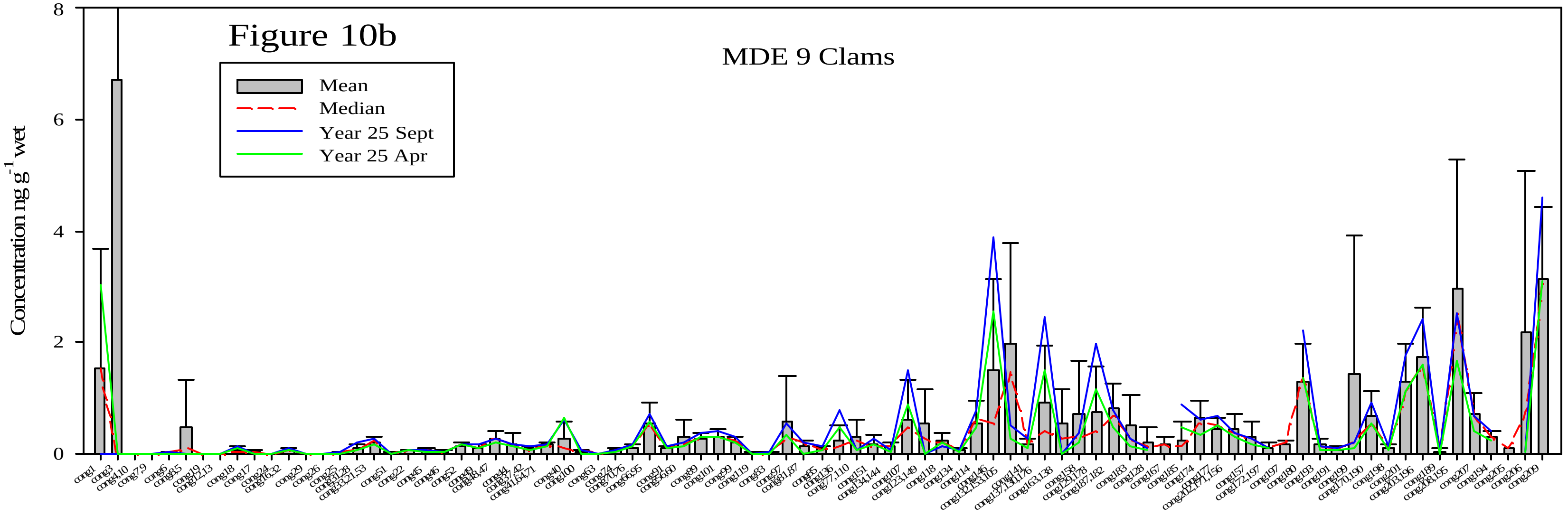


Figure 10b
MDE 9 Clams
Mean
Median
Year 25 Sept
Year 25 Apr
Concentration ng g^{-1} wet
0
2
4
6
8
cong1
cong3
cong4,10
cong7,9
cong6
cong8,5
cong19
cong12,13
cong18
cong17
cong24
cong16,32
cong29
cong26
cong25
cong31,28
cong33,21,53
cong51
cong22
cong45
cong46
cong52
cong49
cong48,47
cong44
cong37,42
cong41,64,71
cong40
cong100
cong63
cong74
cong70,76
cong66,95
cong91
cong56,60
cong89
cong101
cong99
cong119
cong83
cong97
cong81,87
cong85
cong136
cong77,110
cong151
cong134,144
cong107
cong123,149
cong118
cong134
cong114
cong146
cong132,153,105
cong141
cong137,130,176
cong163,138
cong158
cong129,178
cong187,182
cong183
cong128
cong167
cong185
cong174
cong177
cong202,171,156
cong157
cong172,197
cong197
cong180
cong193
cong191
cong199
cong170,190
cong198
cong201
cong203,196
cong189
cong208,195
cong207
cong194
cong205
cong206
cong209

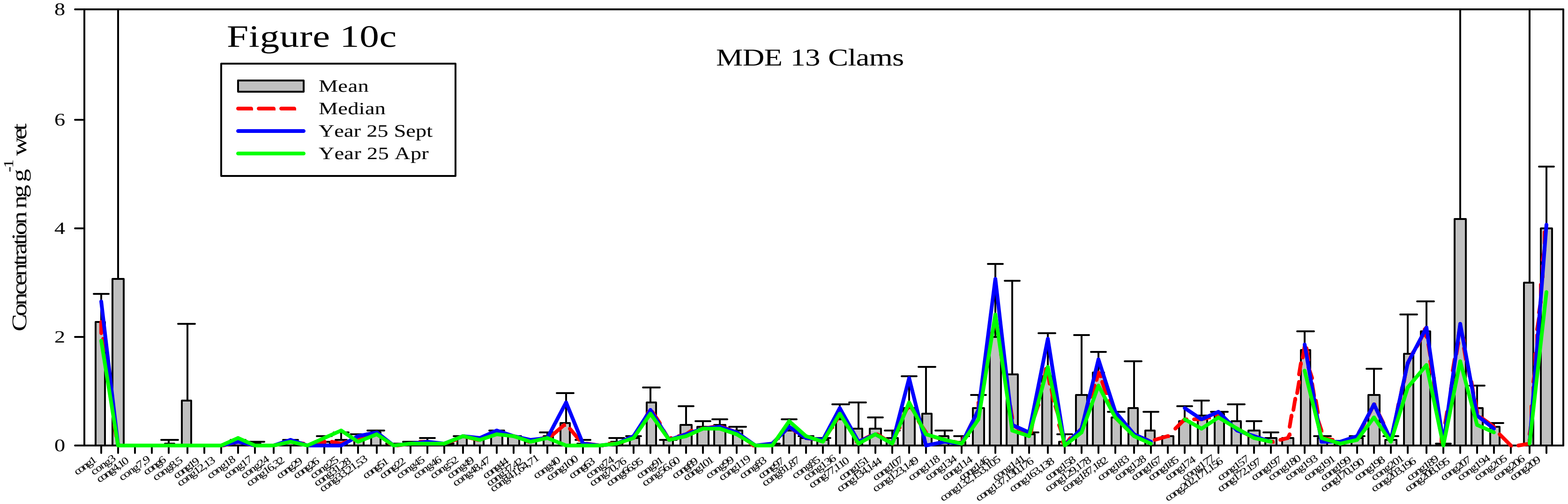


Figure 10c

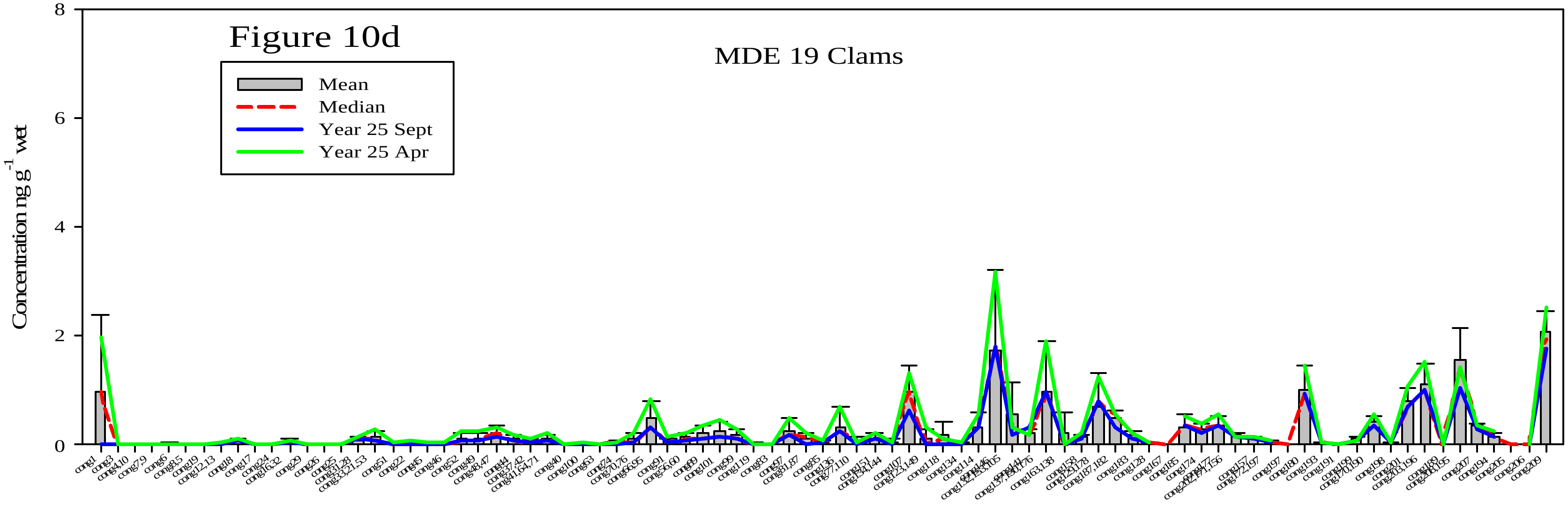


Figure 10d

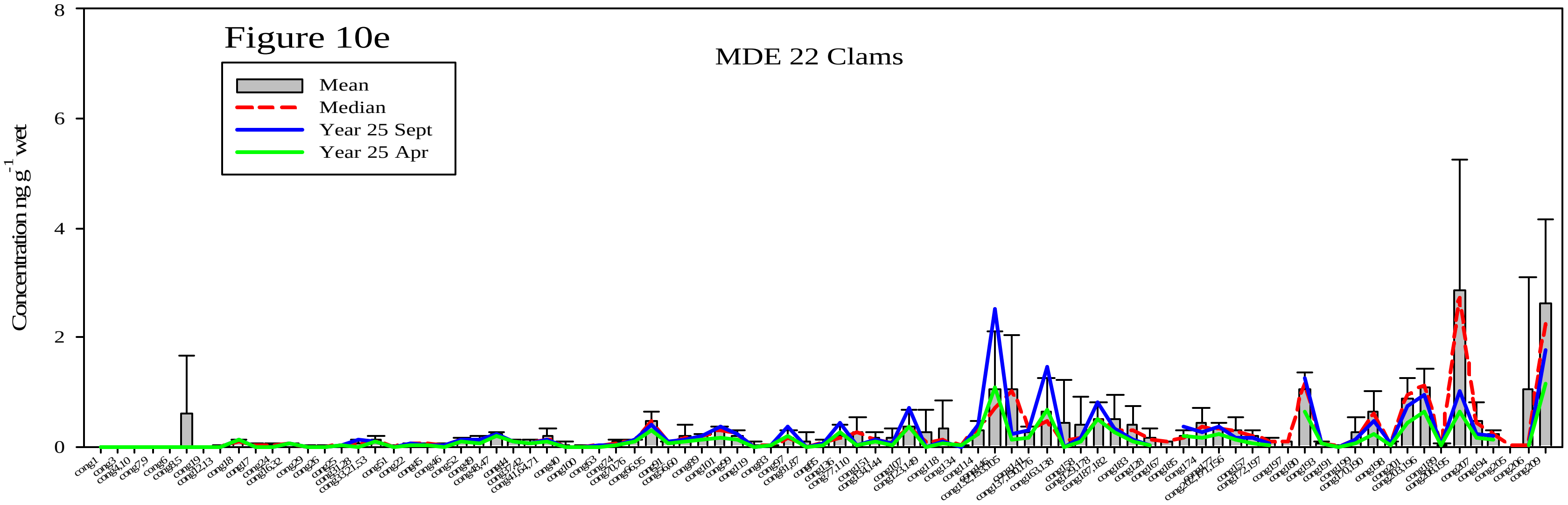


Figure 10e

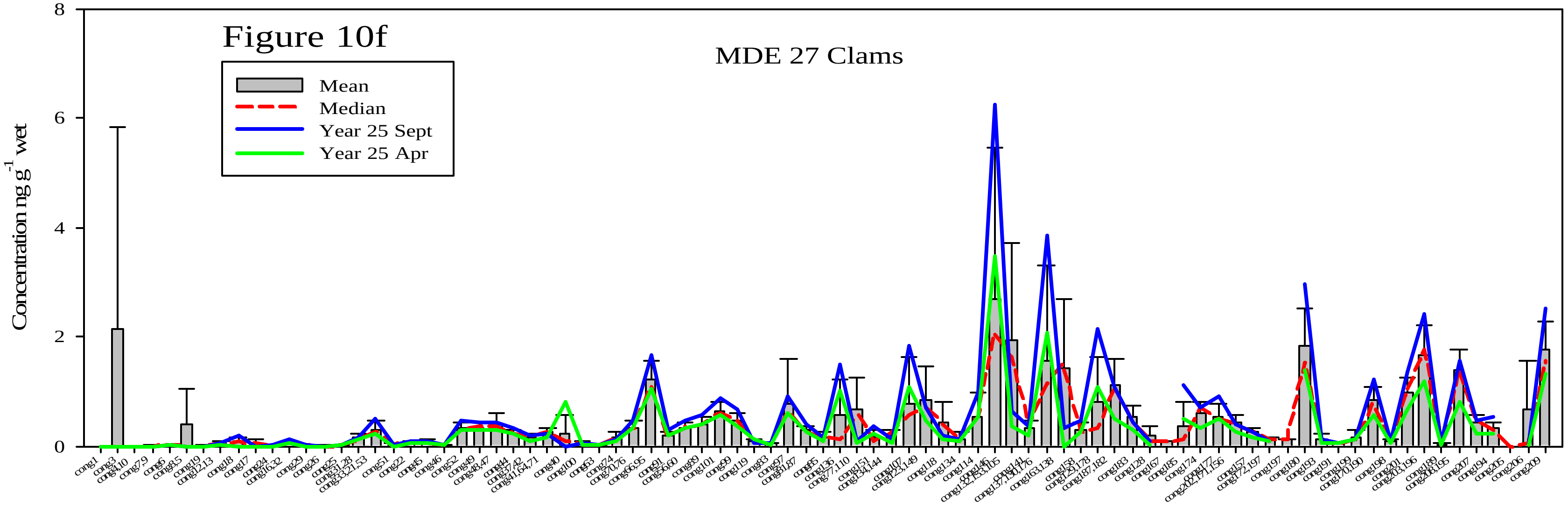
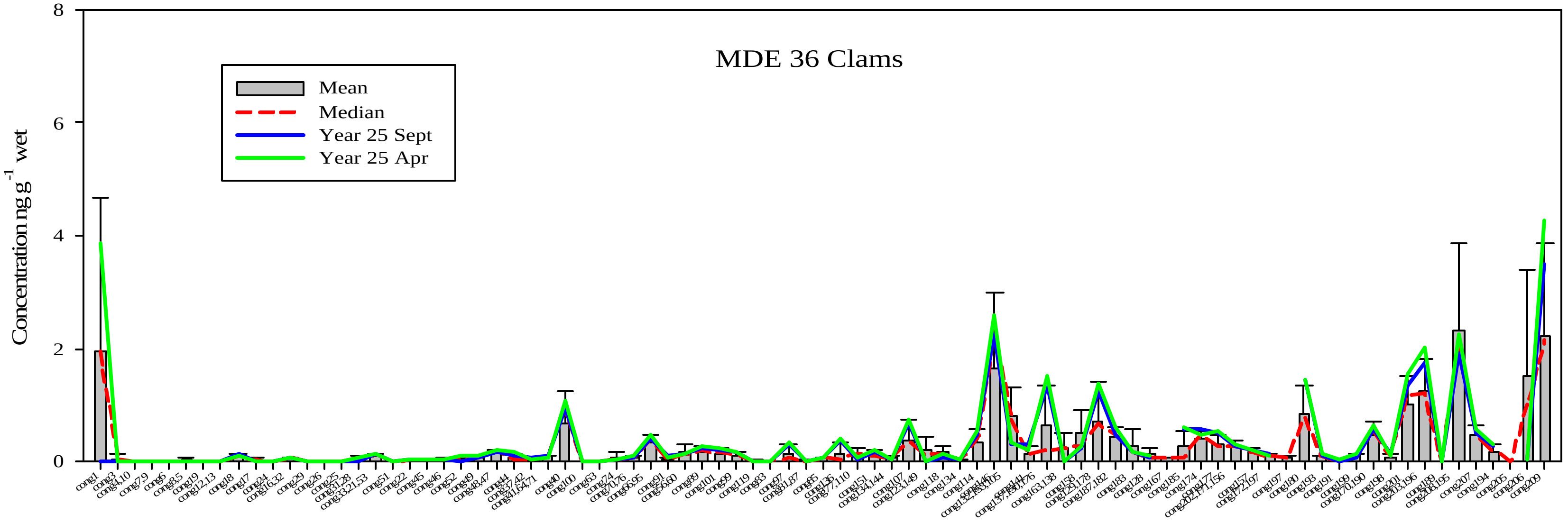


Figure 10f



Figures 47 (a-g). PCB concentrations in clams expressed on a wet weight basis, collected in September 2006 (blue line), and April 2007 (green line), the 1998-2005 mean (bars) with standard deviation (error bars) and median (red dashed line).

PAH's in Sediment

The concentrations of PAH's in sediments are presented in Figures 48 a-g. The distribution of PAH's among the stations is similar with phenanthrine and perylene often present at the highest concentrations. The concentrations at the six stations located around the HMI facility are similar to the concentrations at the reference station MDE-36. There is little variability in the distribution of PAH's between the seasons or years, as demonstrated by how closely the lines track. However, the total concentrations do vary (discussed in the toxicity section below) suggesting a regional overriding influence on these stations. Enough data has not been collected to adequately assess the impact of the South Cell discharge. MDE-9 is close to the spillway and MDE-13 is in the area, but likely out of the field of direct influence. The stations have similar concentrations and distributions of PAH's.

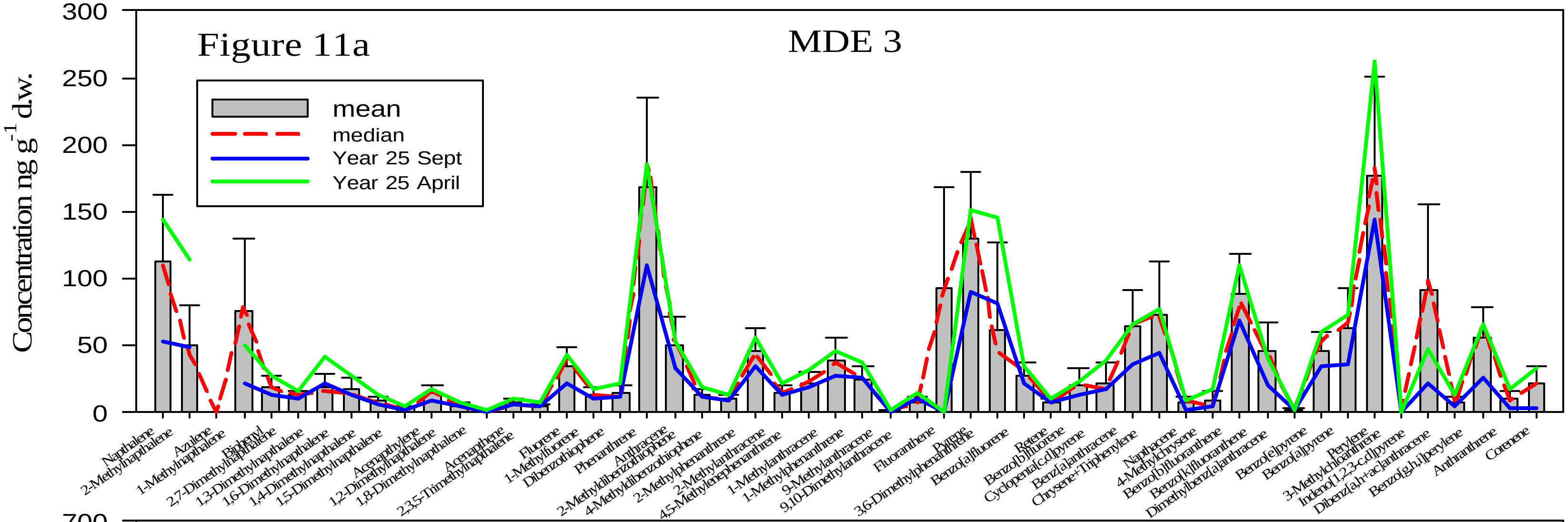


Figure 11a
MDE 3
mean
median
Year 25 Sept
Year 25 April
Concentration ng g^{-1} d.w.
0
50
100
150
200
250
300
Napthalene
2-Methylnapthalene
Azulene
1-Methylnapthalene
Biphenyl
2,7-Dimethylnapthalene
1,3-Dimethylnapthalene
1,6-Dimethylnapthalene
1,4-Dimethylnapthalene
1,5-Dimethylnapthalene
Acenapthylene
1,2-Dimethylnapthalene
1,8-Dimethylnapthalene
Acenapthene
2,3,5-Trimethylnapthalene
Fluorene
1-Methylfluorene
Dibenzothiophene
Phenanthrene
Anthracene
2-Methyldibenzothiophene
4-Methyldibenzothiophene
2-Methylphenanthrene
2-Methylanthracene
4,5-Methylenephenanthrene
1-Methylanthracene
1-Methylphenanthrene
9-Methylanthracene
9,10-Dimethylanthracene
Fluoranthene
Pyrene
3,6-Dimethylphenanthrene
Benzo[a]fluorene
Retene
Benzo[b]fluorene
Cyclopenta[c,d]pyrene
Benz[a]anthracene
Chrysene+Triphenylene
Napthacene
4-Methylchrysene
Benzo[b]fluoranthene
Benzo[k]fluoranthene
Dimethylbenz[a]anthracene
Benzo[e]pyrene
Benzo[a]pyrene
Perylene
3-Methylchloanthrene
Indeno[1,2,3-c,d]pyrene
Dibenz[a,h+a,c]anthracene
Benzo[g,h,i]perylene
Anthanthrene
Corenene

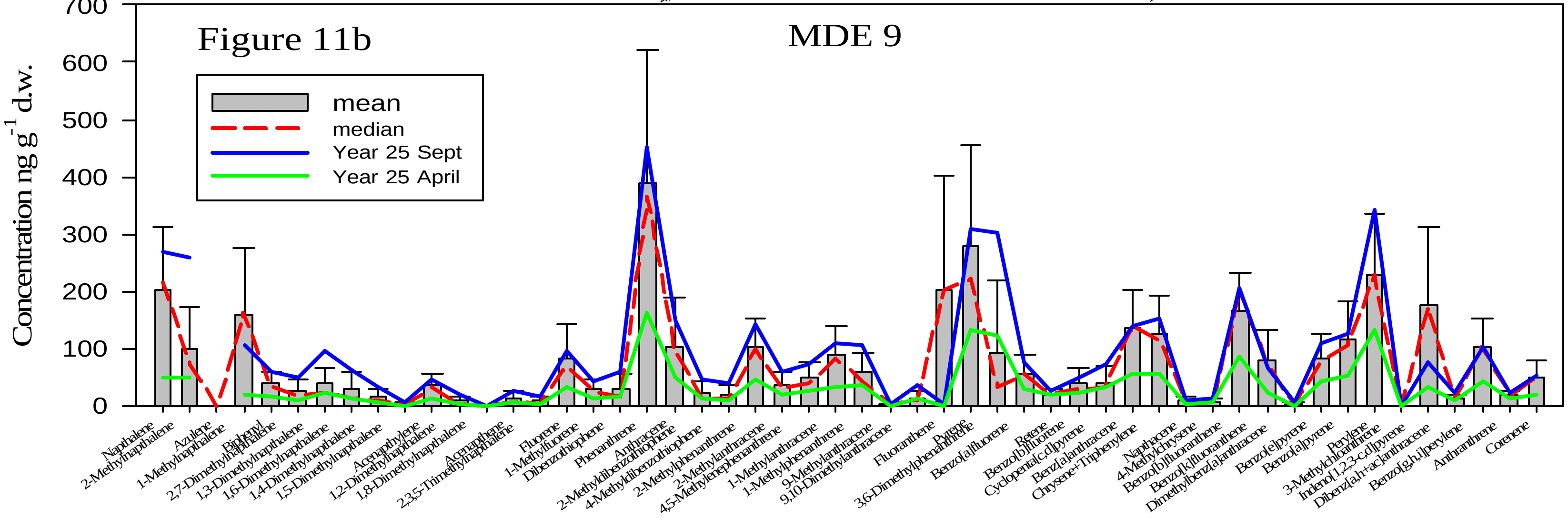


Figure 11b
MDE 9
mean
median
Year 25 Sept
Year 25 April
Concentration ng g^{-1} d.w.
0
100
200
300
400
500
600
700
Napthalene
2-Methylnapthalene
Azulene
1-Methylnapthalene
Biphenyl
2,7-Dimethylnapthalene
1,3-Dimethylnapthalene
1,6-Dimethylnapthalene
1,4-Dimethylnapthalene
1,5-Dimethylnapthalene
Acenapthylene
1,2-Dimethylnapthalene
1,8-Dimethylnapthalene
Acenapthene
2,3,5-Trimethylnapthalene
Fluorene
1-Methylfluorene
Dibenzothiophene
Phenanthrene
Anthracene
2-Methyldibenzothiophene
4-Methyldibenzothiophene
2-Methylphenanthrene
2-Methylanthracene
4,5-Methylenephenanthrene
1-Methylanthracene
1-Methylphenanthrene
9-Methylanthracene
9,10-Dimethylanthracene
Fluoranthene
Pyrene
3,6-Dimethylphenanthrene
Benzo[a]fluorene
Retene
Benzo[b]fluorene
Cyclopenta[c,d]pyrene
Benz[a]anthracene
Chrysene+Triphenylene
Napthacene
4-Methylchrysene
Benzo[b]fluoranthene
Benzo[k]fluoranthene
Dimethylbenz[a]anthracene
Benzo[e]pyrene
Benzo[a]pyrene
Perylene
3-Methylchloanthrene
Indeno[1,2,3-c,d]pyrene
Dibenz[a,h+a,c]anthracene
Benzo[g,h,i]perylene
Anthanthrene
Corenene

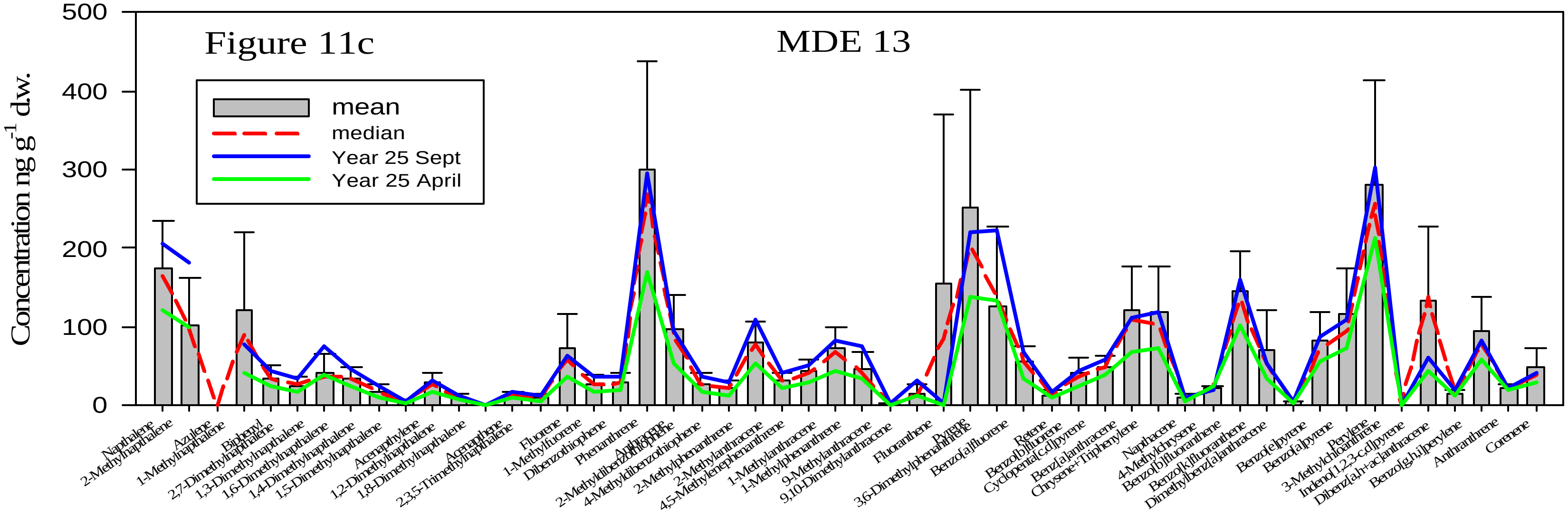


Figure 11c
MDE 13
Concentration ng g^{-1} d.w.
500
400
300
200
100
0
mean
median
Year 25 Sept
Year 25 April
Napthalene
2-Methylnapthalene
Azulene
1-Methylnapthalene
Biphenyl
2,7-Dimethylnapthalene
1,3-Dimethylnapthalene
1,6-Dimethylnapthalene
1,4-Dimethylnapthalene
1,5-Dimethylnapthalene
Acenapthylene
1,2-Dimethylnapthalene
1,8-Dimethylnapthalene
Acenapthene
2,3,5-Trimethylnapthalene
Fluorene
1-Methylfluorene
Dibenzothiophene
Phenanthrene
Anthracene
2-Methyldibenzothiophene
4-Methyldibenzothiophene
2-Methylphenanthrene
2-Methylanthracene
4,5-Methylenephenanthrene
1-Methylanthracene
1-Methylphenanthrene
9-Methylanthracene
9,10-Dimethylanthracene
Fluoranthene
Pyrene
3,6-Dimethylphenanthrene
Benzo[a]fluorene
Retene
Benzo[b]fluorene
Cyclopenta[c,d]pyrene
Benz[a]anthracene
Chrysene+Triphenylene
Napthacene
4-Methylchrysene
Benzo[b]fluoranthene
Benzo[k]fluoranthene
Dimethylbenz[a]anthracene
Benzo[e]pyrene
Benzo[a]pyrene
Perylene
3-Methylcholanthrene
Indeno[1,2,3-c,d]pyrene
Dibenz[a,h+a,c]anthracene
Benzo[g,h,i]perylene
Anthanthrene
Corenene

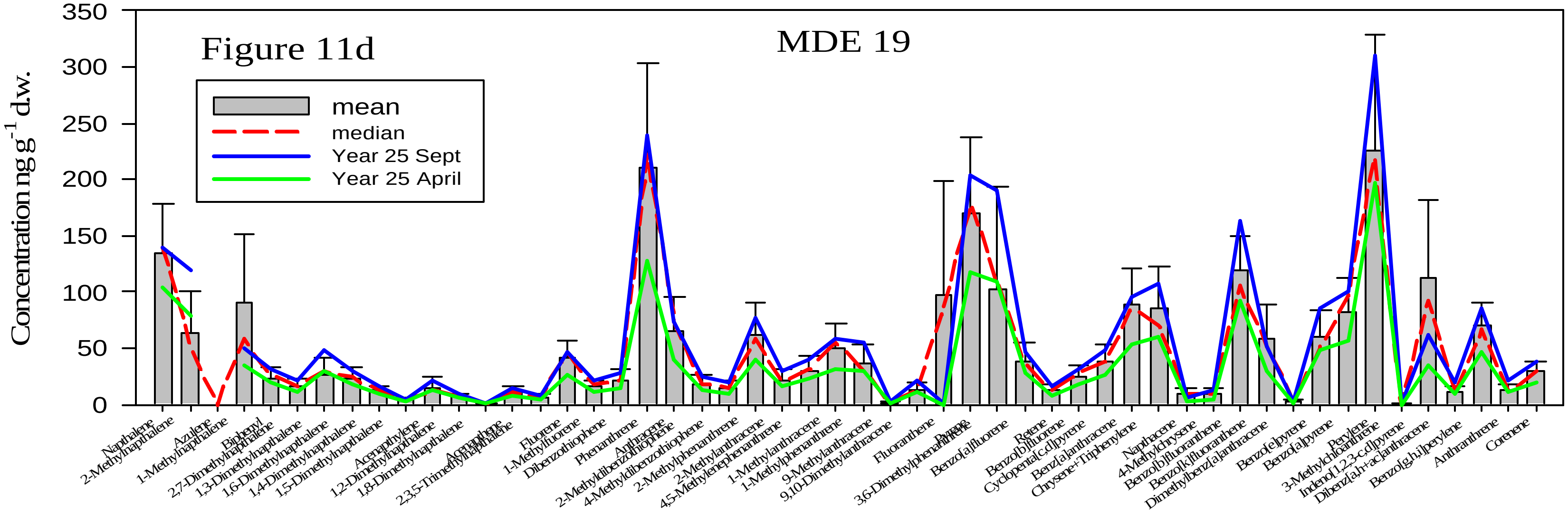


Figure 11d
MDE 19
Concentration ng g^{-1} d.w.
350
300
250
200
150
100
50
0
mean
median
Year 25 Sept
Year 25 April
Napthalene
2-Methylnapthalene
Azulene
1-Methylnapthalene
Biphenyl
2,7-Dimethylnapthalene
1,3-Dimethylnapthalene
1,6-Dimethylnapthalene
1,4-Dimethylnapthalene
1,5-Dimethylnapthalene
Acenapthylene
1,2-Dimethylnapthalene
1,8-Dimethylnapthalene
Acenapthene
2,3,5-Trimethylnapthalene
Fluorene
1-Methylfluorene
Dibenzothiophene
Phenanthrene
Anthracene
2-Methyldibenzothiophene
4-Methyldibenzothiophene
2-Methylphenanthrene
2-Methylanthracene
4,5-Methylenephenanthrene
1-Methylanthracene
1-Methylphenanthrene
9-Methylanthracene
9,10-Dimethylanthracene
Fluoranthene
Pyrene
3,6-Dimethylphenanthrene
Benzo[a]fluorene
Retene
Benzo[b]fluorene
Cyclopenta[c,d]pyrene
Benz[a]anthracene
Chrysene+Triphenylene
Napthacene
4-Methylchrysene
Benzo[b]fluoranthene
Benzo[k]fluoranthene
Dimethylbenz[a]anthracene
Benzo[e]pyrene
Benzo[a]pyrene
Perylene
3-Methylcholanthrene
Indeno[1,2,3-c,d]pyrene
Dibenz[a,h+a,c]anthracene
Benzo[g,h,i]perylene
Anthanthrene
Corenene

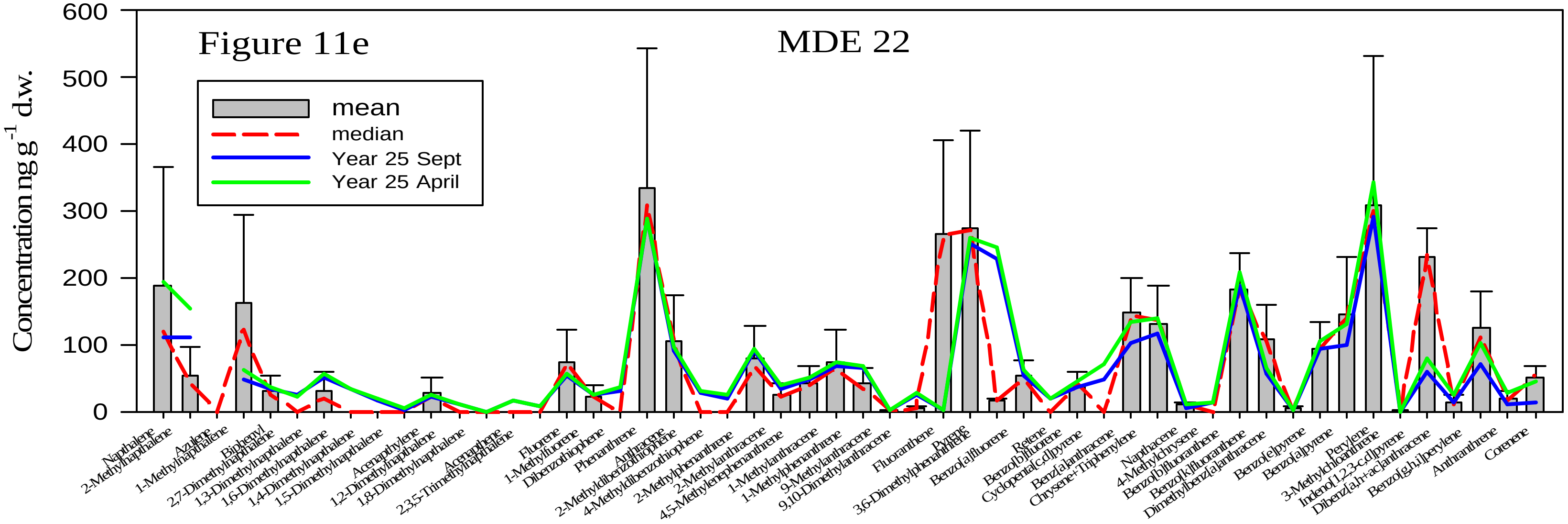


Figure 11e
MDE 22
Concentration ng g^{-1} d.w.
0
100
200
300
400
500
600
mean
median
Year 25 Sept
Year 25 April
Napthalene
2-Methylnapthalene
Azulene
1-Methylnapthalene
Biphenyl
2,7-Dimethylnapthalene
1,3-Dimethylnapthalene
1,6-Dimethylnapthalene
1,4-Dimethylnapthalene
1,5-Dimethylnapthalene
Acenapthylene
1,2-Dimethylnapthalene
1,8-Dimethylnapthalene
Acenapthene
2,3,5-Trimethylnapthalene
Fluorene
1-Methylfluorene
Dibenzothiophene
Phenanthrene
Anthracene
2-Methyldibenzothiophene
4-Methyldibenzothiophene
2-Methylphenanthrene
2-Methylanthracene
4,5-Methylenephenanthrene
1-Methylanthracene
1-Methylphenanthrene
9-Methylanthracene
9,10-Dimethylanthracene
Fluoranthene
Pyrene
3,6-Dimethylphenanthrene
Benzo[a]fluorene
Retene
Benzo[b]fluorene
Cyclopenta[c,d]pyrene
Benz[a]anthracene
Chrysene+Triphenylene
Napthacene
4-Methylchrysene
Benzo[b]fluoranthene
Benzo[k]fluoranthene
Dimethylbenz[a]anthracene
Benzo[e]pyrene
Benzo[a]pyrene
Perylene
3-Methylchloanthrene
Indeno[1,2,3-c,d]pyrene
Dibenz[a,h+ac]anthracene
Benzo[g,h,i]perylene
Anthranthrene
Corenene

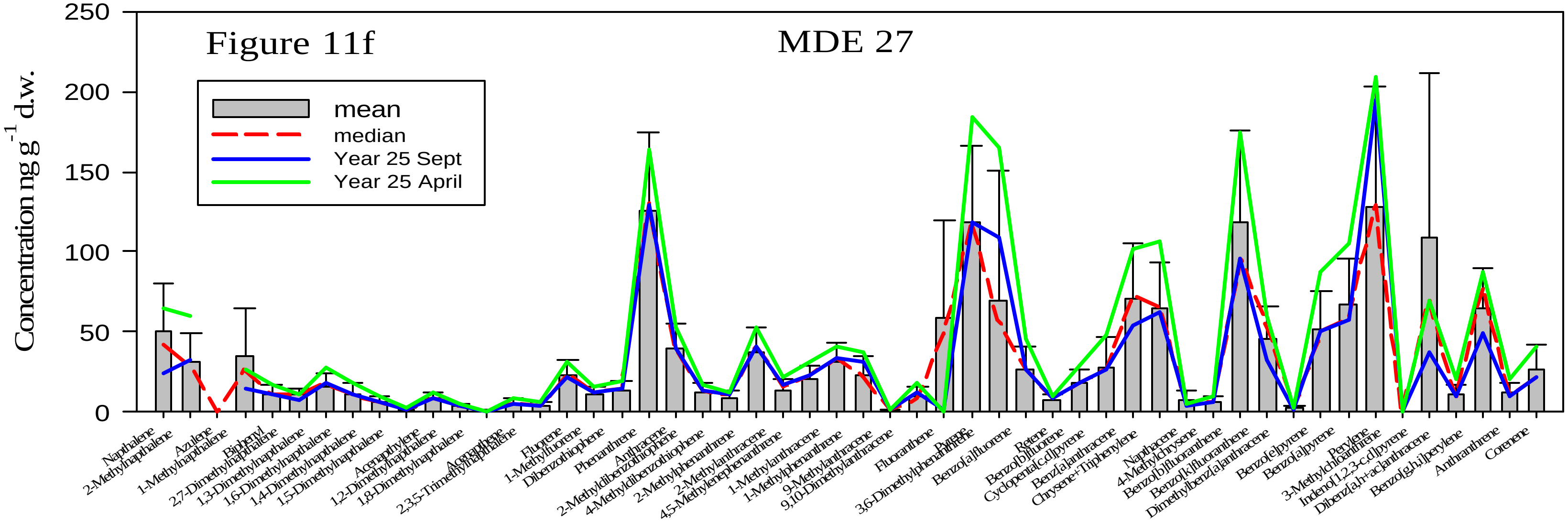
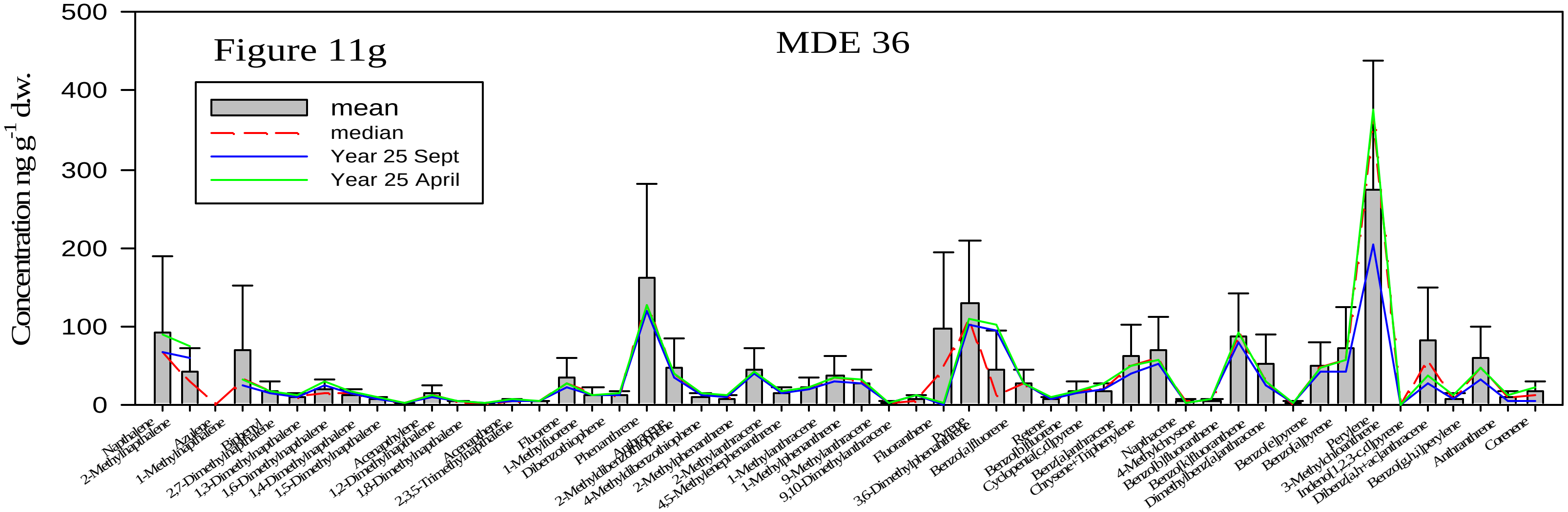


Figure 11f
MDE 27
Concentration ng g^{-1} d.w.
0
50
100
150
200
250
mean
median
Year 25 Sept
Year 25 April
Napthalene
2-Methylnapthalene
Azulene
1-Methylnapthalene
Biphenyl
2,7-Dimethylnapthalene
1,3-Dimethylnapthalene
1,6-Dimethylnapthalene
1,4-Dimethylnapthalene
1,5-Dimethylnapthalene
Acenapthylene
1,2-Dimethylnapthalene
1,8-Dimethylnapthalene
Acenapthene
2,3,5-Trimethylnapthalene
Fluorene
1-Methylfluorene
Dibenzothiophene
Phenanthrene
Anthracene
2-Methyldibenzothiophene
4-Methyldibenzothiophene
2-Methylphenanthrene
2-Methylanthracene
4,5-Methylenephenanthrene
1-Methylanthracene
1-Methylphenanthrene
9-Methylanthracene
9,10-Dimethylanthracene
Fluoranthene
Pyrene
3,6-Dimethylphenanthrene
Benzo[a]fluorene
Retene
Benzo[b]fluorene
Cyclopenta[c,d]pyrene
Benz[a]anthracene
Chrysene+Triphenylene
Napthacene
4-Methylchrysene
Benzo[b]fluoranthene
Benzo[k]fluoranthene
Dimethylbenz[a]anthracene
Benzo[e]pyrene
Benzo[a]pyrene
Perylene
3-Methylchloanthrene
Indeno[1,2,3-c,d]pyrene
Dibenz[a,h+ac]anthracene
Benzo[g,h,i]perylene
Anthranthrene
Corenene



Figures 48 (a-g). PAH concentrations in sediment expressed on a dry weight basis, collected in September 2006 (blue line), April 2007 (green line), the 1998-2005 mean (bars) with standard deviation (error bars) and median (red dashed line).

PAH's in Clams

The concentrations of PAH's in clams are presented in Figures 49 a-g. The distribution of PAH's among the stations is similar with phenanthrine and perylene often present at the highest concentrations. The concentrations at the six stations located around the HMI facility are similar to the concentrations at the reference station MDE 36. There is little variability in the distribution of PAH's between the seasons or years, as demonstrated by how closely the lines track. However, the total concentrations do vary (discussed in the toxicity section below) suggesting a regional overriding influence on these stations. Enough data has not been collected to adequately assess the impact of the South Cell discharge. MDE-9 is close to the spillway and MDE-13 is in the area, but likely out of the field of direct influence. The stations have similar concentrations and distributions of PAH's.

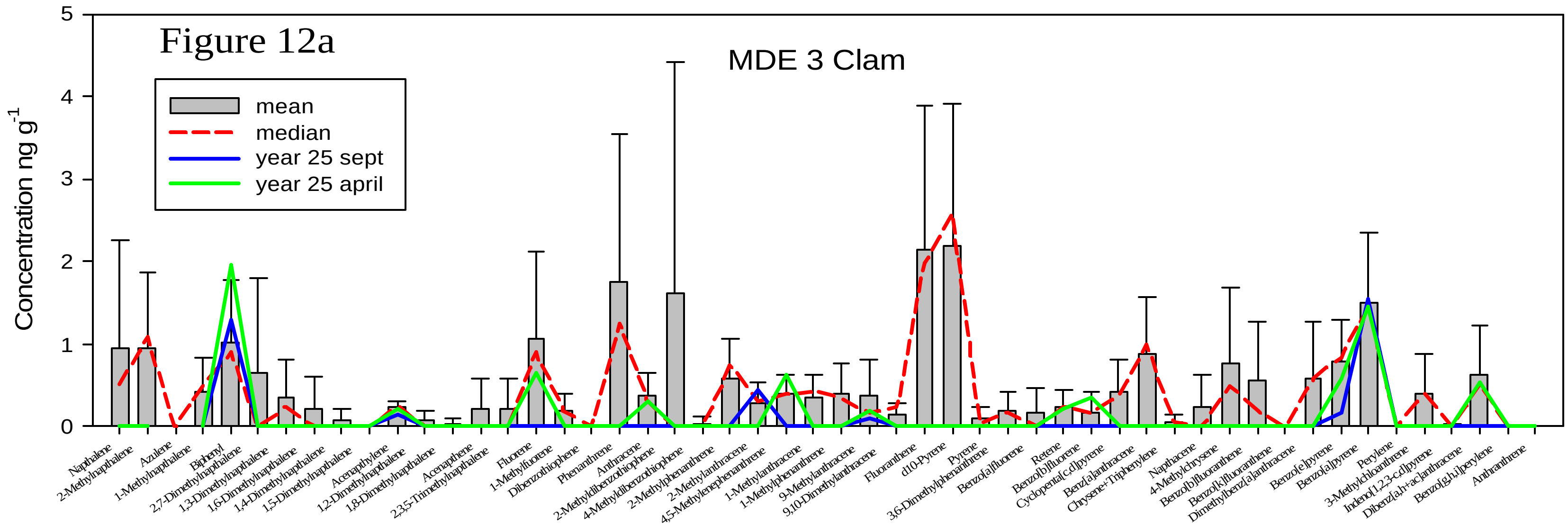


Figure 12a

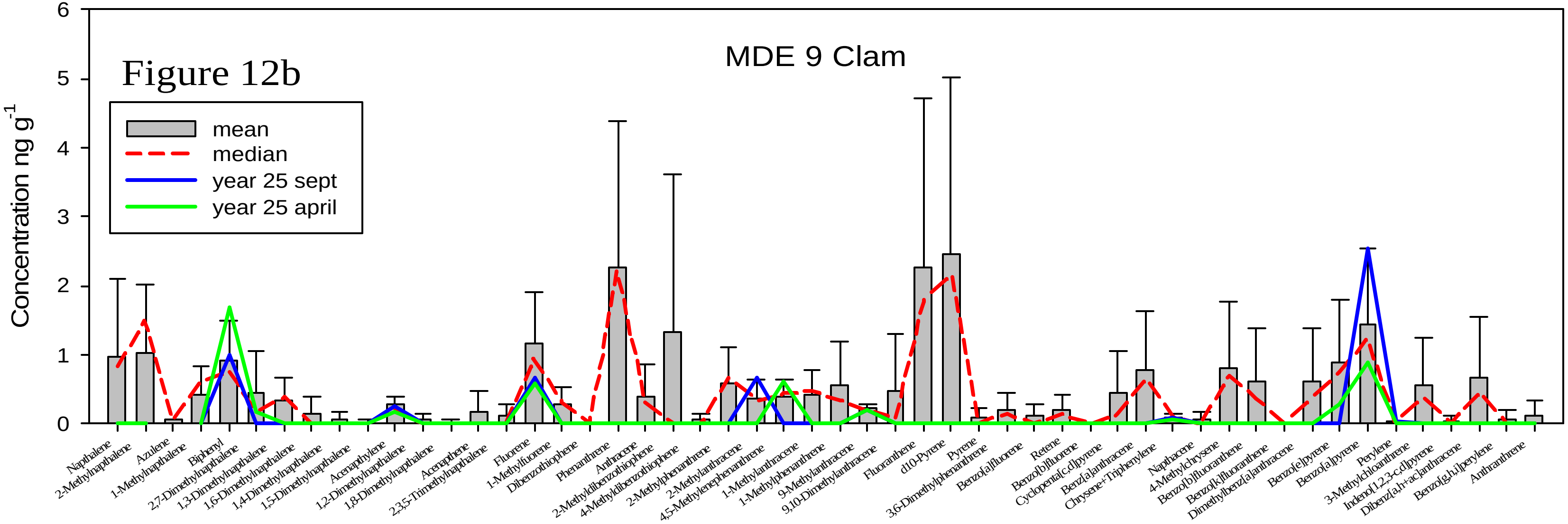


Figure 12b

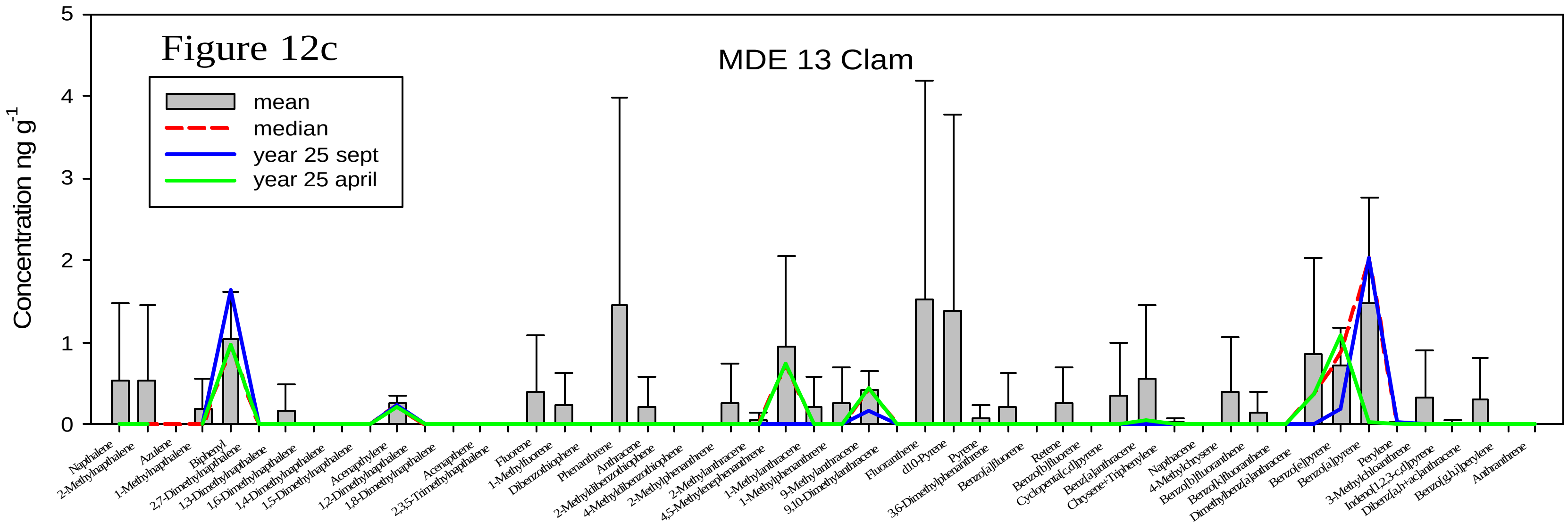


Figure 12c
MDE 13 Clam
mean
median
year 25 sept
year 25 april
Concentration ng g^{-1}
0
1
2
3
4
5
Napthalene
2-Methylnapthalene
Azulene
1-Methylnapthalene
Biphenyl
2,7-Dimethylnapthalene
1,3-Dimethylnapthalene
1,6-Dimethylnapthalene
1,4-Dimethylnapthalene
1,5-Dimethylnapthalene
Acenapthylene
1,2-Dimethylnapthalene
1,8-Dimethylnapthalene
Acenapthene
2,3,5-Trimethylnapthalene
Fluorene
1-Methylfluorene
Dibenzothiophene
Phenanthrene
Anthracene
2-Methyldibenzothiophene
4-Methyldibenzothiophene
2-Methylphenanthrene
2-Methylanthracene
4,5-Methylenephenanthrene
1-Methylanthracene
1-Methylphenanthrene
9-Methylanthracene
9,10-Dimethylanthracene
Fluoranthene
d10-Pyrene
Pyrene
3,6-Dimethylphenanthrene
Benzo[a]fluorene
Retene
Benzo[b]fluorene
Cyclopenta[c,d]pyrene
Benz[a]anthracene
Chrysene+Triphenylene
Napthacene
4-Methylchrysene
Benzo[b]fluoranthene
Benzo[k]fluoranthene
Dimethylbenz[a]anthracene
Benzo[e]pyrene
Benzo[a]pyrene
Perylene
3-Methylchloanthrene
Indeno[1,2,3-c,d]pyrene
Dibenz[a,h+a,c]anthracene
Benzo[g,h,i]perylene
Anthanthrene

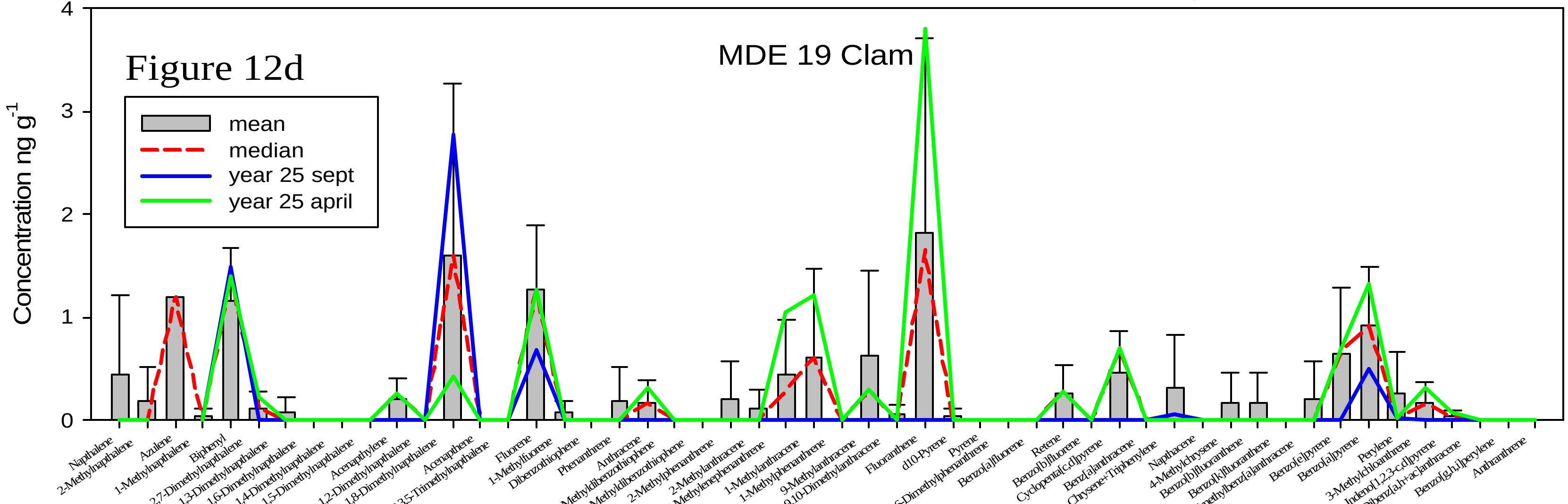


Figure 12d
MDE 19 Clam
mean
median
year 25 sept
year 25 april
Concentration ng g^{-1}
0
1
2
3
4
Napthalene
2-Methylnapthalene
Azulene
1-Methylnapthalene
Biphenyl
2,7-Dimethylnapthalene
1,3-Dimethylnapthalene
1,6-Dimethylnapthalene
1,4-Dimethylnapthalene
1,5-Dimethylnapthalene
Acenapthylene
1,2-Dimethylnapthalene
1,8-Dimethylnapthalene
Acenapthene
2,3,5-Trimethylnapthalene
Fluorene
1-Methylfluorene
Dibenzothiophene
Phenanthrene
Anthracene
2-Methyldibenzothiophene
4-Methyldibenzothiophene
2-Methylphenanthrene
2-Methylanthracene
4,5-Methylenephenanthrene
1-Methylanthracene
1-Methylphenanthrene
9-Methylanthracene
9,10-Dimethylanthracene
Fluoranthene
d10-Pyrene
Pyrene
3,6-Dimethylphenanthrene
Benzo[a]fluorene
Retene
Benzo[b]fluorene
Cyclopenta[c,d]pyrene
Benz[a]anthracene
Chrysene+Triphenylene
Napthacene
4-Methylchrysene
Benzo[b]fluoranthene
Benzo[k]fluoranthene
Dimethylbenz[a]anthracene
Benzo[e]pyrene
Benzo[a]pyrene
Perylene
3-Methylchloanthrene
Indeno[1,2,3-c,d]pyrene
Dibenz[a,h+a,c]anthracene
Benzo[g,h,i]perylene
Anthanthrene

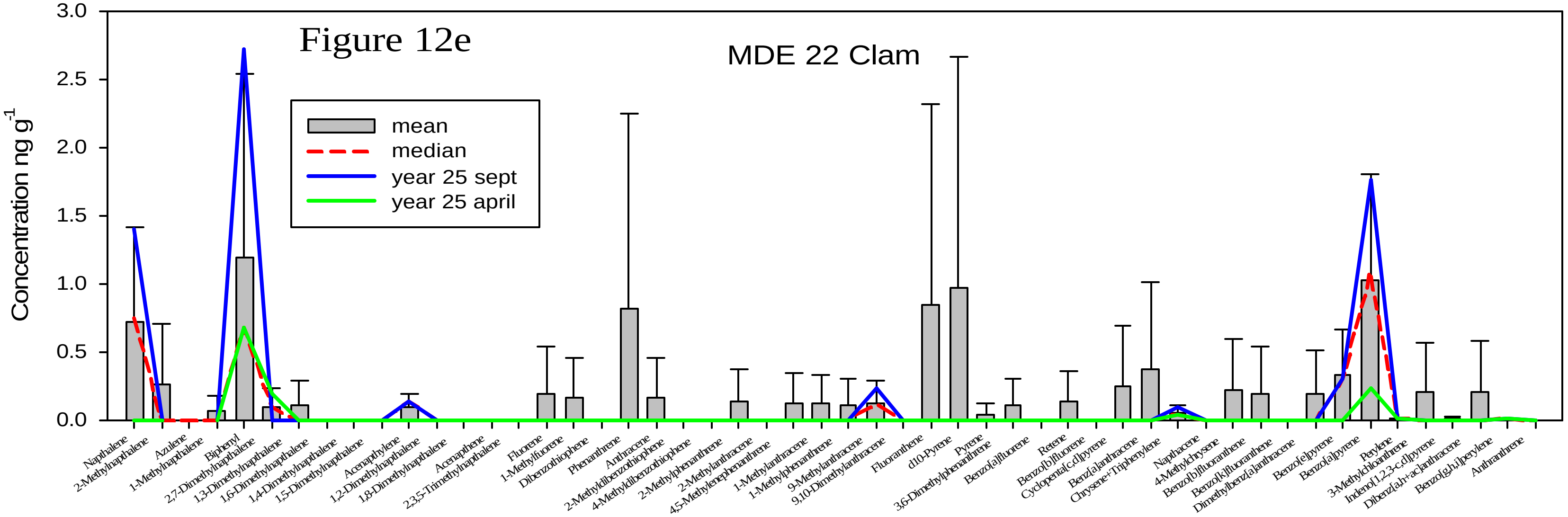


Figure 12e

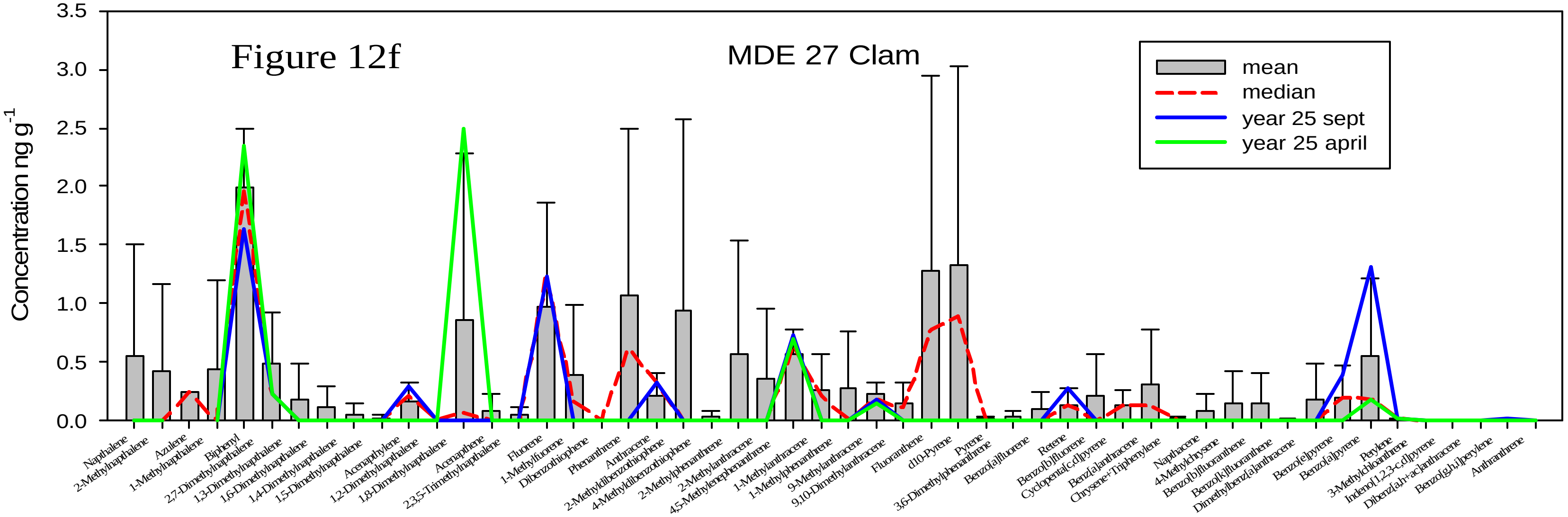
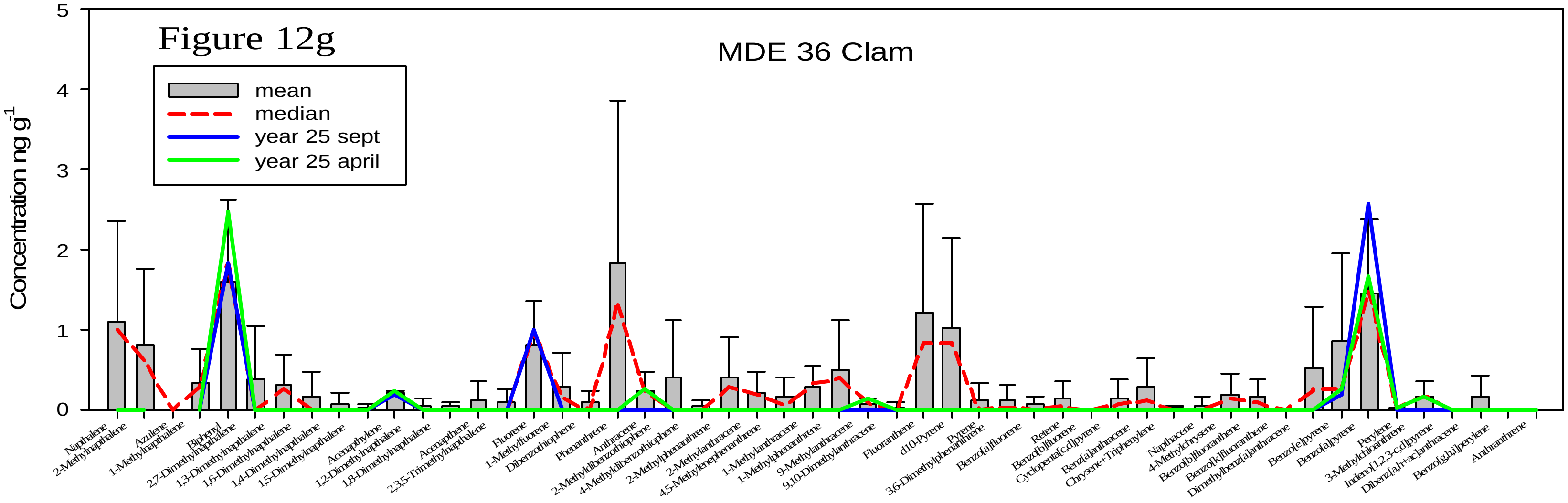


Figure 12f



Figures 49 (a-g). PAH concentrations in clams expressed on a wet weight basis, collected in September 2006 (blue line), April 2007 (green line), the 1998-2005 mean (bars) with standard deviation (error bars) and median (red dashed line).

CONCLUSIONS FROM ACUTE TOXICITY STUDIES

INTRODUCTION

In addition to CBL conducting tissue analysis, in Year 25 University of Maryland Wye River Research and Education Center (WREC) conducted a whole sediment toxicity test which is the actual third component of the Sediment Quality Triad. The test used was U.S. EPA's estuarine amphipod L. *plumulosus* 10-d acute whole sediment toxicity test method with survival as the endpoint (U.S. EPA, 1994).

Seven stations near HMI were sampled in this study. Three stations were Reference sites, two Near Field located on the east side of HMI and one located in the Back River area. Sediment samples for the study were collected both in fall and spring on September 11, 2006 and April 13, 2007, respectively. Special care was taken during sample collection to avoid possible contamination. Samples were split for sediment toxicological analysis and chemical analysis. All samples for the toxicity test were held at the WREC in refrigerators at 4°C until needed. Prior to initiating the test sediment samples were sieved through a 500 µm mesh stainless steel sieve. This process was done to make the sample more homogenous, and more importantly to remove indigenous organisms, which in a sediment toxicity study conducted in 1992 proved problematic due to predation. Sediment samples used for the controls were collected from Bay sediments near WREC which are typically clean areas. The control sediments were then tested to confirm they were clean to assure survival of the amphipods. For greater detail please see separate report included as Appendix 3A.

Water Quality

Water quality data parameters were measured to assess potential impacts on the amphipods outside of contaminants. Pore water ammonia was relatively low in all test beakers, with a highest recorded value of 3.2 mg/L for any test sediment and 2.8 mg/L for any control sediment. Overlying ammonia was also low, with a highest recorded value of 0.6 mg/L for any test sediment and 0.6 mg/L for any control sediment. These values are well below the level of 60 mg/L in pore water that would be considered a problem by the U.S. EPA for *L. plumulosus* (U.S. EPA/ACE, 2001). Values for pH were acceptable for all test and control sediments. No values for dissolved oxygen (DO) measured during the tests were below the acceptable level of 3.6 mg/L for *L. plumulosus* (U.S. EPA/ACE, 2001). The lowest recorded DO in any test beaker was 7.2 mg/L.

Sediment Toxicity Test

Performance criteria of 90% amphipod survival in control treatments was obtained for both tests.23 The fall 06 test had amphipod survival of 90% while the amphipod survival in the spring 2007 test was 94%.

Sediments from three stations around Hart-Miller Island caused significant reductions in *L. plumulosus* survival in both the fall 2006 and the spring 2007 tests (Table 23). These were stations MDE-3, MDE-9 both of which are Nearfield stations, and MDE-13, which is a reference station. All of these stations indicated more sediment toxicity in the fall of 2006 than in the spring of 2007, especially MDE-3 which saw a 52.0% reduction in survival in the fall compared to a 23.4% reduction in spring survival.

Sediments from station MDE-19 caused a statistically significant reduction in amphipod survival in the Spring of 2007 but not in the fall of 2006 (Table 23). This may be more of a reflection of less variability in the data in the spring test then in the fall test which allowed the statistics to pick up a difference from the control survival in the Spring test. The Minimum Significant Difference (MSD) detectable by the Dunnett's Test for the fall 2006 test was 20.9% while the MSD for the Spring 2007 test was 14.1%. This means that for any station amphipod survival to be statistically different from the control amphipod survival, the reduction in survival had to be greater than 20.9% for the fall test and greater than 14.1% for the spring test. Thus, the data from the spring 2007 test was a little bit "tighter" or less variable than the data from the fall 2006 test and allowed for detection of a smaller difference as being significant. This results in the somewhat contradictory finding that although survival was better in the spring test (77%) than in the fall test (72%) and that there was less of a reduction in survival in the spring test (18.1%) than the fall test (20.0%) the spring sediment was still considered statistically toxic. This is most likely a statistical anomaly rather than a true biological difference. It may be necessary to repeat this test in the future to verify this.

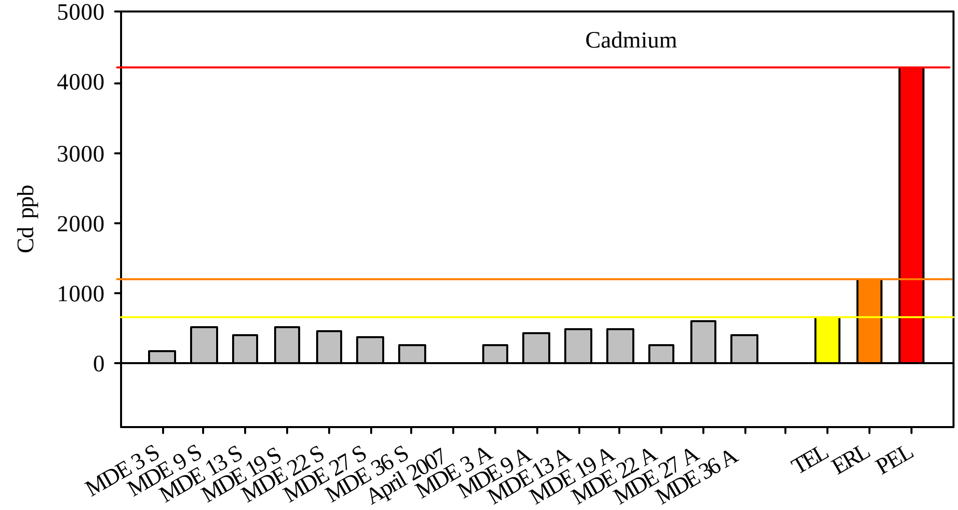
Table 23. Summary of results from the Hart-Miller Island amphipod *Leptocheirus plumulosus* 10 day acute sediment toxicity test results for fall 2006 and spring 2007 tests. Shaded treatments are significantly < the control (% = 0.05).

	Fall 2006		Spring 2007	
Station	0 Treatment % Survival (SD)	% Reduction from Control	0 Treatment % Survival (SD)	% Reduction from Control
Control	90.0 (7.91)		94.0 (5.48)	
MDE-3	**43.0 (10.95)**	**52.2**	**72.0 (13.04)**	**23.4**
MDE-9	**61.0 (15.97)**	**32.2**	**70.0 (12.75)**	**25.5**
MDE-13	**62.0 (13.04)**	**31.1**	**68.0 (17.18)**	**27.7**
MDE-19	72.0 (10.37)	20.0	**77.0 (9.75)**	**18.1**
MDE-22	80.0 (16.20)	11.1	81.0 (8.22)	13.8
MDE-27	72.0 (15.65)	20.0	91.0 (6.52)	3.20
MDE-36	72.0 (13.04)	20.0	82.0 (9.75)	12.8

Investigating Potential Metal Toxicity

From the toxicity tests performed at the Wye Research Center (Appendix 3A, a separate document in addition to this larger report) it was concluded that "sediments from stations MDE-3, 9 and 13 caused significantly reduced *L. plumulosus* survival in both the fall 2006 test and the spring 2007 test. Sediment from MDE-19 indicated reduced amphipod survival compared to control amphipod survival in the spring 2007 test, but not in the fall 2006 test".

For some metals, toxicological affects criteria have been established by NOAA. The conservative threshold effects level (TEL), effects range low (ERL) and probable effects levels (PEL) are plotted along with the data from the studied stations (Figures 50-52). The much higher effects range medium (ERM) and apparent threshold levels (AET) are not shown. An examination of sediment of concentrations of As, Se, Ag, Cd, Pb, Hg, and MeHg from stations MDE-3, 9 and 13 indicate nothing unusual compared to previous years or in relation to other stations. Cadmium concentrations do not exceed even the TEL at the seven stations, and Pb concentrations at all stations are between the TEL and ERL (Figure 50). All but MDE-27 in April were below the Ag TEL (Figure 51). The TEL and ERL are almost the same for As, and all but MDE-3 were close to these values (Figure 51). In the case of Hg, some stations exceeded the ERL but the exceeding stations were not consistent between sampling dates (Figure 52). No criteria exist for MeHg or Se. It is unlikely that of the trace metals studied, any single sediment metal concentration is responsible for the observed toxicity. Similarly, metal concentrations in clams also do not vary in a manor suggesting any differences in metal bioavailability at these stations. Furthermore, whereas Pb appears slightly enriched, concentrations of As, Cd, Hg and MeHg in sediments around HMI appear inline with more pristine or uncontaminated sediments as measured by Acevedo-Figueroa, (2005). While the criteria used are very conservative, erring on the side of having an impact on biota, the criteria do not address metal bioavailability directly. It may be that pore water metal concentrations are elevated or there is a cumulative effect of the metals.



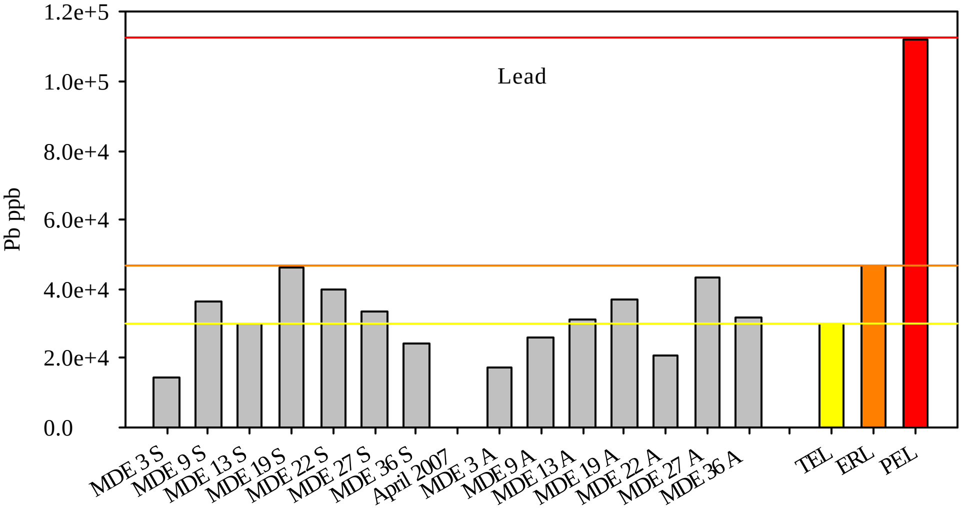


Figure 50. Cadmium (Cd) and lead (Pb) concentrations in sediment along with TEL, ERL, and PEL identified by NOAA for marine sediment.

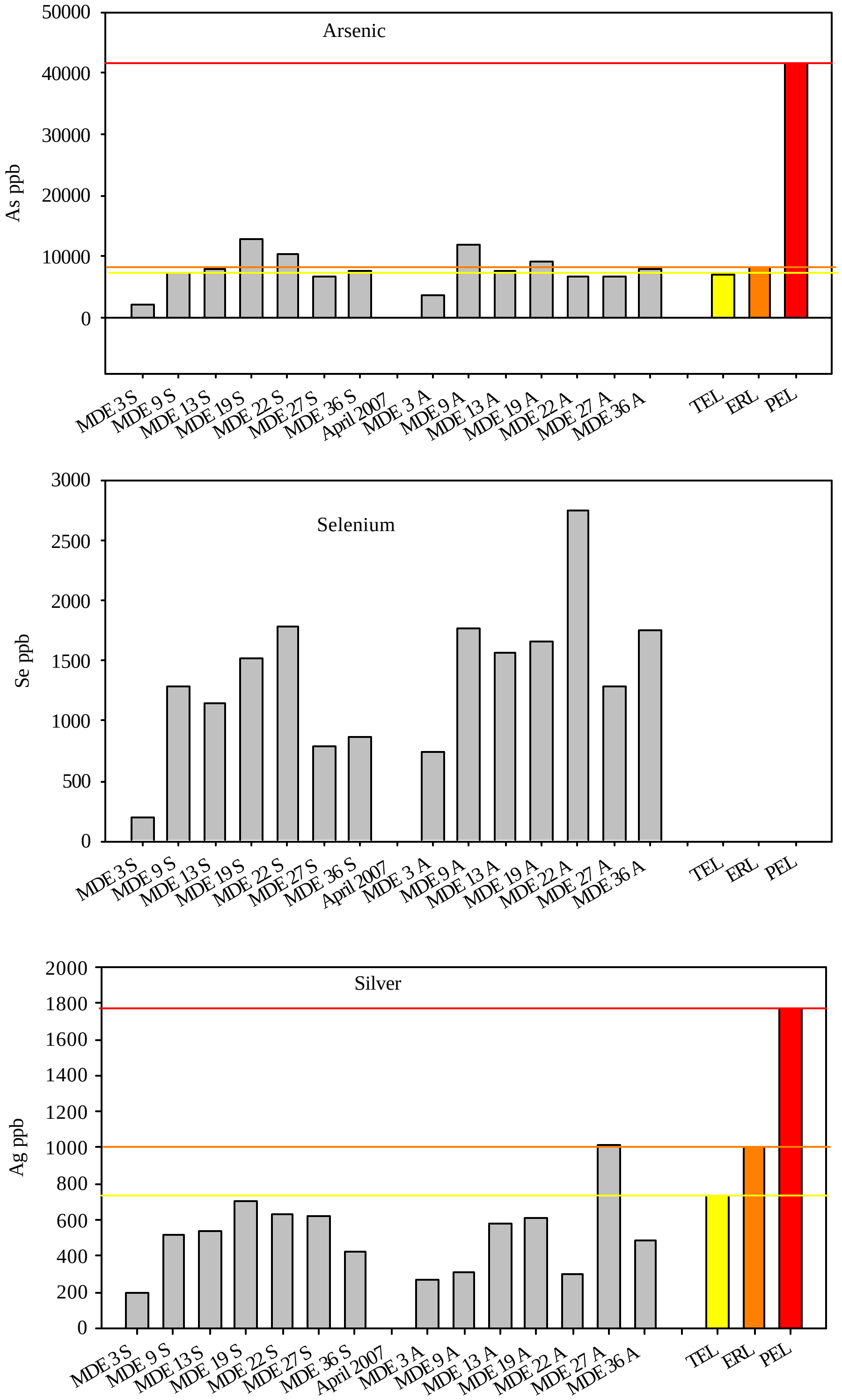
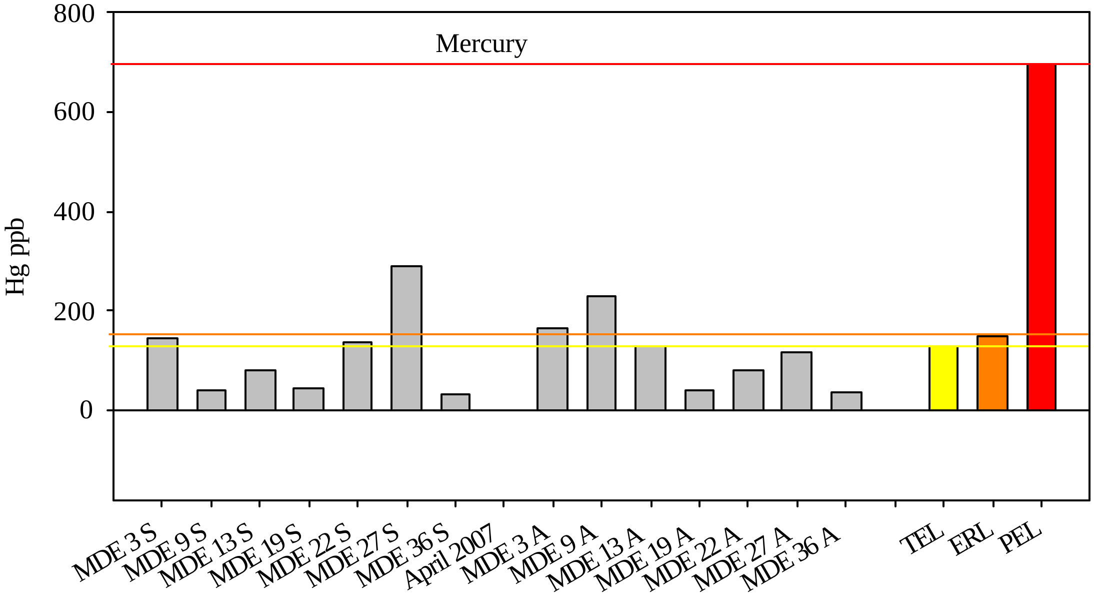


Figure 51. Arsenic (As), selenium (Se) and silver (Ag) concentrations in sediment along with TEL, ERL, and PEL identified by NOAA for marine sediment.



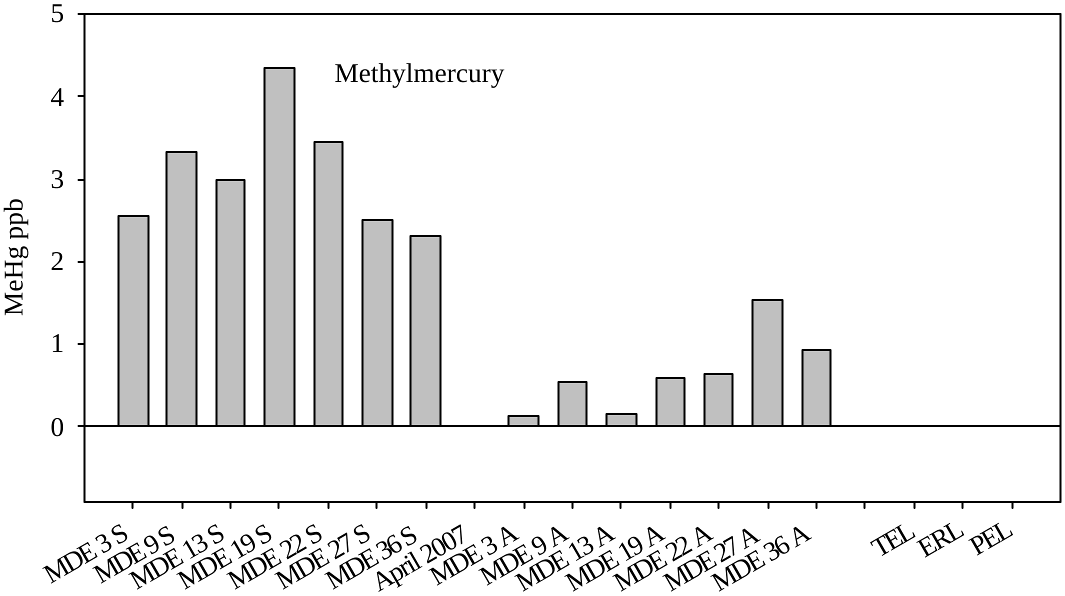


Figure 52. Mercury (Cd) and methylmercury (MeHg) concentrations in sediment along with TEL, ERL, and PEL identified by NOAA for marine sediment.

Investigating Potential Organic Contaminant Toxicity

Sediment toxicity criteria for the organic contaminants is not as well developed as it is for metals. Some PAH compounds have specific criteria but many do not. In the case of PCB's only the total PCB load is used to assess the toxicity. Many of the individual PAH concentrations are in excess of the TEL but only phenanthrene at MDE-9 approached the PEL of 543 ppb. On the whole most of the stations exceed the TEL for the total PAH concentration, including the reference station MDE-36 (Figure 53). All stations are well within the PEL. The same is true for the PCB concentrations, with most stations exceeding the TEL but well under the PEL (Figure 54).

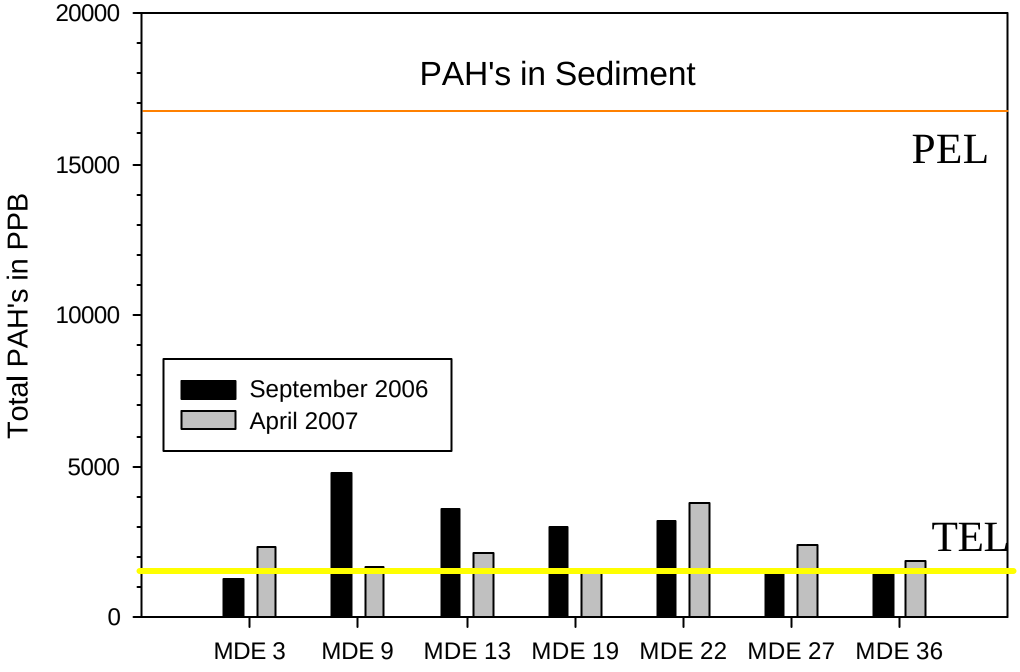


Figure 53. Total PAH concentrations in sediment along with TEL and PEL identified by NOAA for marine sediment.

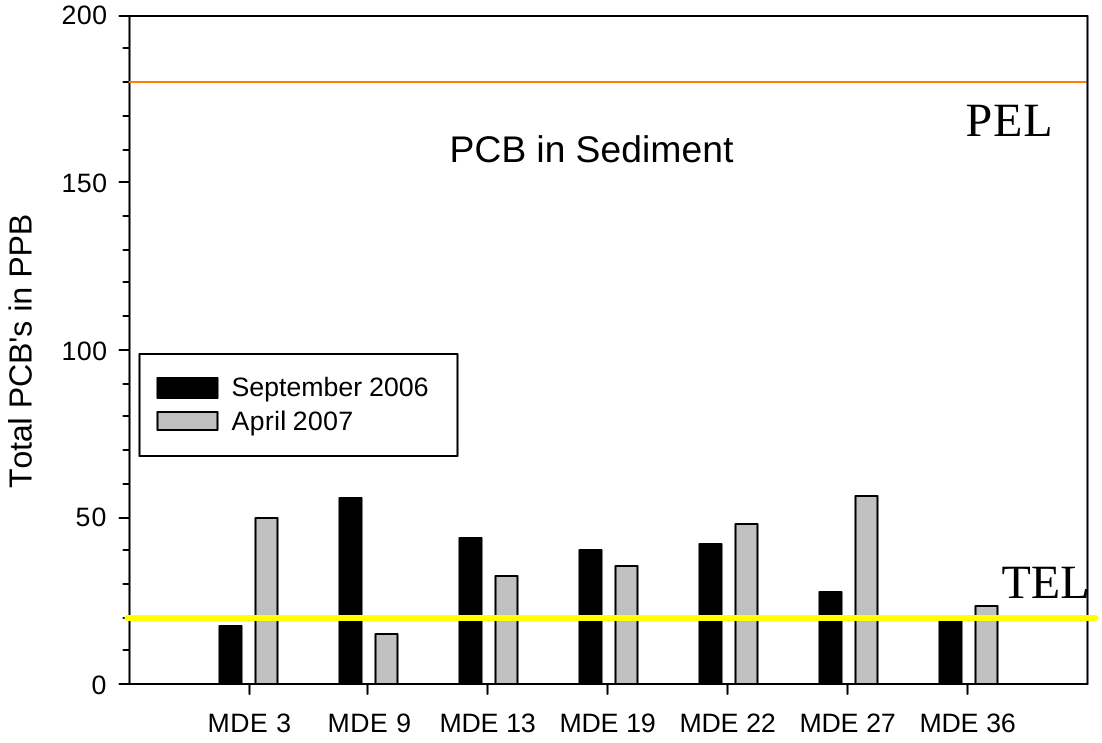


Figure 54. Total PCB concentrations in sediment along with TEL and PEL identified by NOAA for marine sediment.

While the toxicity tests performed at the Wye Research Center identified the sediments as being toxic (defined by a significant increase in mortality of amphipods) there is no single factor may explain the acute toxicity results. Since metal concentrations and organic contaminants exceed the TEL, there is a potential for an accumulated effect. Such accumulated effects are difficult to quantify and regulate.

YEAR 25 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. Stations MDE-42, 43 and 44 are located in the area where water is being discharged from the South Cell. In 2003 and 2006, the metal concentrations in sediment and clams were similar to other locations located on the south side of the island. The toxicity observed in the Wye Research center studies can not be explained by concentrations of metal As, Se, Ag, Cd, Pb Hg and MeHg alone, but may act as a stressor in combination with other factors.

RECOMMEDATIONS

The sediment around HMI reflects regional contamination and no discernable impact of island operations is apparent at the large scale. With the island ceasing to receiving sediment, we recommend the sampling design continue to be modified to address the new surficial outflows. To do this, the Principal Investigators (PIs) suggest reducing the number of far field stations and increase the sampling density in the vicinity of the outflows.

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