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

Year 26 Exterior Monitoring Technical Report
(September 2007 – August 2008)

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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-}).
Anoxic	Deplete of oxygen, (e.g., ground water that contains no dissolved oxygen).
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.
Box and Whisker Diagram	A graphical summary of the presence of outliers in data for one or two variables. This plot, which is particularly useful for comparing parallel batches of data, divides the data into four equal areas of frequency. A box encloses the middle 50 percent, where the median is represented as a vertical line inside the box. The mean may be plotted as a point. Horizontal lines, called whiskers, extend from each end of the box. The lower (left) whisker is drawn from the lower quartile to the smallest point within 1.5 interquartile ranges from the lower quartile. The other whisker is drawn from the upper quartile to the largest point within 1.5 interquartile ranges from the upper quartile. Values that fall beyond the whiskers, but within 3 interquartile ranges (suspect outliers), are plotted as individual points. Far outside points (outliers) are distinguished by a special character (a point with a + through it). Outliers are points more than 3 interquartile ranges below the lower quartile or above the upper quartile.
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+}).
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).
Depurate	To cleanse or purify something, especially by removing toxins.
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.
Dredged material: *containment*	A disposal method that isolates the dredged material from the environment. Dredged material containment is placement of dredged material within diked confined disposal facilities via pipeline or other means.
Dredged Material Containment Facility (DMCF)	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.
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.
Flocculent layer	The transition zone between water column and sediment column. The material in the layer is gelatinous and highly mobile; composed primarily of water with organic matter and fine Clay sized particles. The thickness of the layer varies seasonally and as a function of the flow of water over the sediment-water interface. In the Chesapeake Bay, the flocculent layer is generally less than a centimeter thick, and can be absent in areas of high flow.
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.
Hypoxic	A partial lack of oxygen.
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.

Mesohaline	Moderately brackish estuarine water with salinity ranging from 5 – 18 part per thousand
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.
Oligohaline	Water with salt concentrations ranging from 0.5 to 5.0 parts per thousand, due to ocean-derived salts
Open water disposal	Placement of dredged material in rivers, lakes or estuaries via pipeline or surface release from hopper dredges or barges.
Polycyclic aromatic hydrocarbons	Polycyclic aromatic hydrocarbons (PAHs) are a group of over 100 different chemicals that are formed during the incomplete burning of coal, oil and gas, garbage, or other organic substances like tobacco or charbroiled meat.
Pollution Sensitive Taxa	Organisms that are sensitive to pollution.
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.
Sigma	A measure of standard deviation away from the mean of a normally distributed data set. One sigma accounts for approximately 68 percent of the population that makes up the set. Two sigma accounts for approximately 95 percent of the population while three sigma accounts for 99 percent.
Spillway	A channel for an overflow of water.
Standard Deviation	A statistical measure of the variability of a population or data set. A high standard deviation indicates greater variance around the mean of a data set where as a low standard deviation indicates little variance around the mean.
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	A zone in a water body where turbidity is typically the

maximum	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 Water Act, that the proposed discharge of dredged material will comply with the applicable provisions of Sections 301, 303, 306 and 307 of the Clean Water Act and relevant State laws.
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.

PROJECT I : SUMMARY REPORT FOR THE HART-MILLER ISLAND DREDGED MATERIAL CONTAINMENT FACILITY YEAR 26

(September 2007 – August 2008)

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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 – 3). The following project summary and appendices discuss the results from Year 26 (September 2007 – August 2008) of exterior monitoring at HMI Dredged Material Containment Facility (DMCF).

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.

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. Summary Table 1-1 below illustrates the triad concept.

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

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

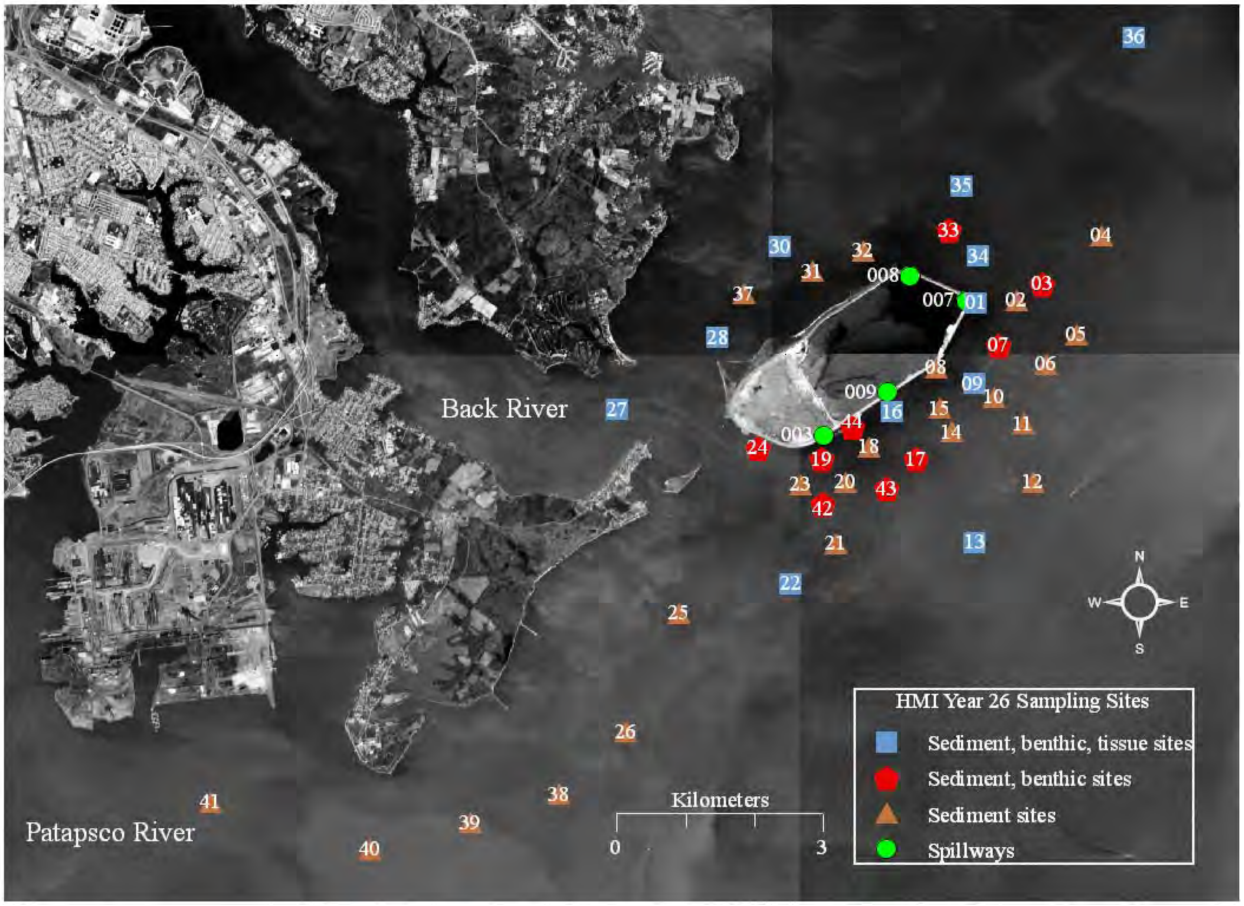
Scenario	**Sediment Contamination (Project II)**	**Toxicity (Project IV)**	**Benthic Community Impact (Project III)**	**Possible Conclusions**
				through food chain and altering the benthic community.
8.	+	-	+	Pollutants are available at chronic, non-lethal levels.

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

Scenario 1 (Summary 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 positive response to 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.

In Year 26, the organizations that were involved in Projects II, III and IV were Maryland Geological Survey (MGS), Maryland Department of the Environment (MDE), and Chesapeake Biological Laboratory (CBL), respectively. MGS collected sediment samples at 43 locations, MDE sampled the benthic communities at 20 of the same locations as MGS, and CBL collected the brackish water clam *R. rangia* for tissue analysis at 11 locations (Summary Figure 1-1).



Summary Figure 1-1. Year 26 Hart-Miller Island monitoring locations. NOTE: After breakwaters were installed on the east side of HMI monitoring of station MDE-29 was discontinued.

HMI PROJECT SUMMARIES

Project II: Sedimentary Environment

The Coastal and Estuarine Geology Program of the 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 5, 2007 (Cruise 55), and on April 9, 2008 (Cruise 56). 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).

Sediment Grain Size Composition

Changes in grain size of the exterior sediments surrounding HMI 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 25 and Year 26. The areas of high sand content are generally found around the perimeter of the dike in shallow waters and diminish with distance from HMI. The area extending off the northeast tip of HMI has the highest sand content (90 percent, MDE-01 and MDE-02) and has remained rather unchanged over the last 2 monitoring years. The elongated northwest side of HMI diminished only slightly in sand content. In September 2006 sand content in this area along the dike was at 90 percent but by April 2007 decreased to 50 percent and has since remained rather constant. The sand content remained rather consistent along the southeast and southwest side of HMI.

The mud portion of sediment is made up of very fine particles of clay, and the slightly larger particles of silt. The fine (mud) fraction of the sediments around HMI is generally richer in clay than in silt. Muddy sediments predominate around HMI; at least two-thirds of the samples contain less than 10 percent sand. Compared to the distribution of sand, the distribution of clay:mud ratios has tended to be more variable over time. The reason for this variability is due to the fact that the silt and especially the clay fractions remain suspended for longer periods of time resulting in greater opportunity to eventually settle far removed from the actual source. Also, the finer grains are more likely to become re-suspended and re-located as a result of storm events. Sand, being larger, heavier particles will settle more quickly, closer to the source, and is less likely to become re-suspended.

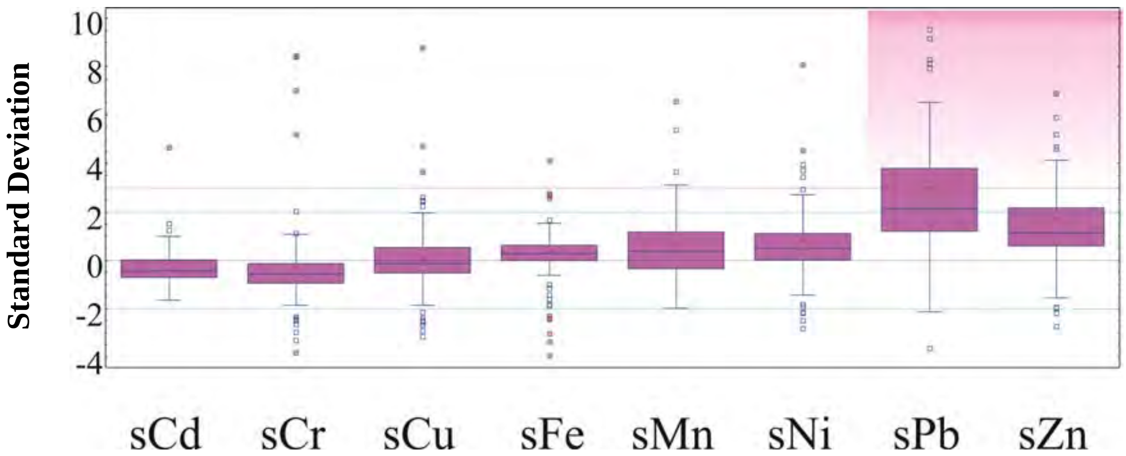
In Year 26 station MDE-41, at the mouth of Baltimore Harbor, continued to be clay-rich which is consistent with what was found in Year 25. In Year 25 a clay-rich area south of HMI was present in both September 2006 and April 2007 cruises. The September cruise resulted in nine stations with clay:mud ratios at or above 0.60, indicating the sediment is richer in clay than silt; the April 2007 cruise resulted in a slight reduction to 5 sites. For Year 26 stations MDE-10, 15, 21, and 44 remained clay-rich with the addition of MDE-5 (Summary Figure 1-1). Although more sample sites were clay-rich in Year 25 September 2006 than in the subsequent samplings, the area containing clay-rich sediments to the south of HMI did not decrease significantly. For the Year 26 September 2007 cruise, three stations south of HMI (MDE-7, 10, and 18) had clay:mud ratios at or above 0.60, to create the clay-rich area for this sampling while April 2008 resulted in two clay-rich sites (MDE-10 and MDE-44) in this area south of HMI. As stated above there is variability in the distribution of sites with high clay:mud ratios; the clay-rich pockets south of HMI were still present during the April 2008 cruise of Year 26 but their locations shifted slightly. The area north of HMI remained rather consistent over the 4 cruises with some slight variations on the northwest side of HMI.

Analysis of Trace Metals

The sediment samples collected by MGS are analyzed, and the concentrations of Fe, Mn, Zn, Cu, Cr, Ni, Cd, Pb, determined. The concentrations are then compared to the Effects Range Low (ERL) and Effects Range Median (ERM), which are proposed criteria put forward by National Oceanic and Atmospheric Administration (NOAA - Long et al. 1995) to gauge the potential for deleterious biological effects. The ERL and ERM are explained in detail in Appendix I. Basically, concentrations between the ERL and ERM may have adverse impacts to benthic organisms and those exceeding the ERM are likely to have adverse biological effects. Of the eight metals, Cd, Cr, Cu, Ni, Pb and Zn were found at some sites with concentrations that exceeded the ERL while at other sites concentrations for Zn and Ni were high enough to exceed the ERM. This comparison is somewhat useful; however, it does not take into consideration the unique characteristics and composition (i.e., grain size) of the Bay sediments around HMI.

MGS developed a mathematical procedure that normalizes the metals concentrations based on percent composition of sand and mud (clay:silt) fraction. The resulting calculations are given as multiples of sigma levels (standard deviation) above and below zero, which is a reference baseline for background levels typical of the Bay region around HMI. When the data are normalized, Pb and to a lesser extent Zn, have samples significantly enriched compared to the baseline (Summary Figure 1-2). Based on work done by the University of Maryland during Year 25 monitoring 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].



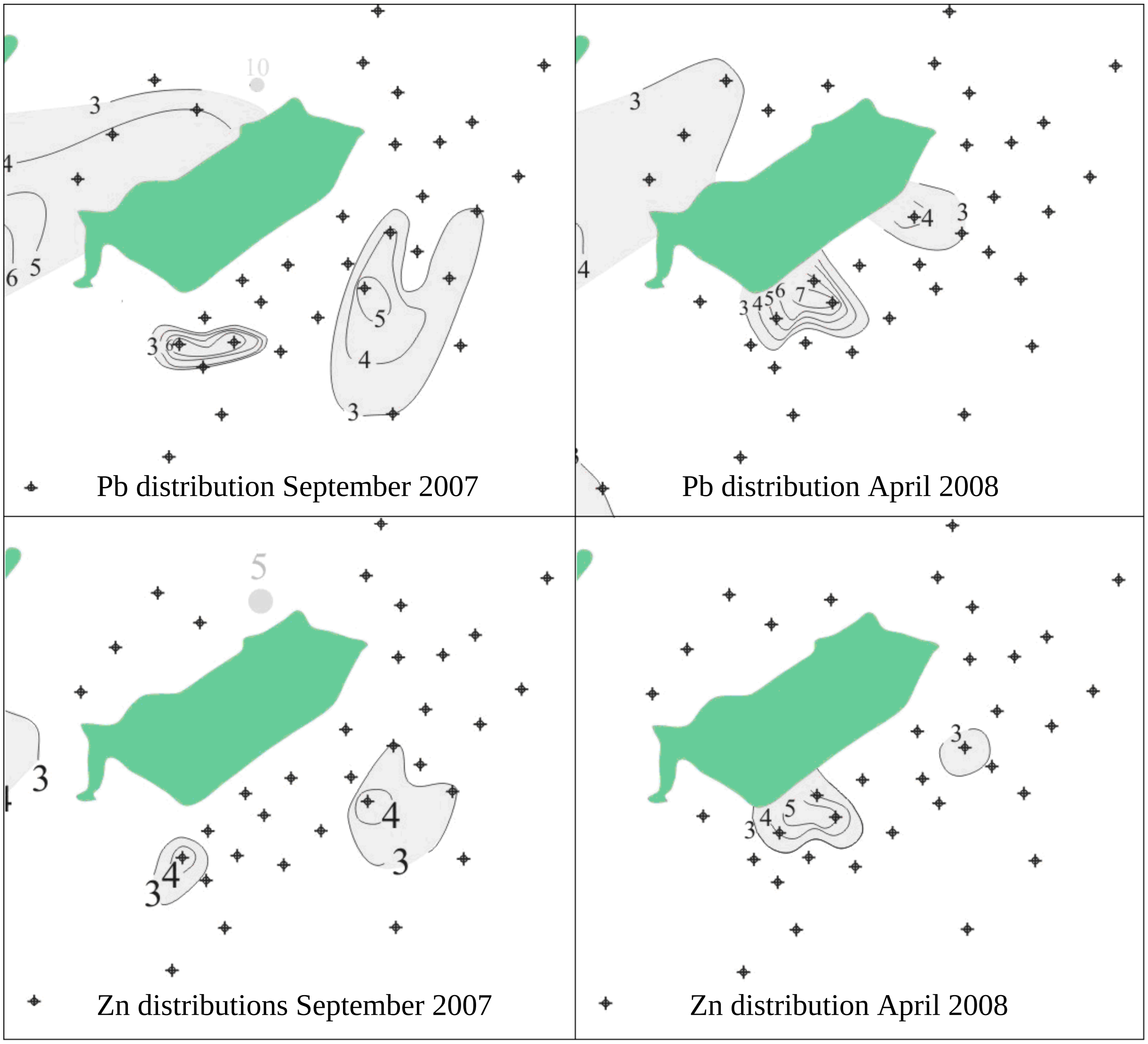
Summary Figure 1-2. Year 26 concentration of metals at HMI relative to baseline values. Metal concentrations greater than 2 standard deviations (horizontal blue lines) are considered elevated above baseline.

The results for Year 26 were similar to Year 25 where all of the metals except Pb and Zn were found to be within the range expected for normal baseline behavior in the area (Summary Figure 1-2). Approximately one half of the Pb samples, and one quarter of the Zn samples were found to be significantly enriched, which is similar to what was determined in Year 25. Most of the samples with elevated metal levels are in the Back River and Baltimore Harbor zones of influence.

Pb and Zn distribution around HMI

Since the eighth monitoring year (1988 – 89), increased metal levels (specifically Zn) have been noted in bottom sediments east and south of Spillway 007 (Summary Figure 1-1); similarly since the start of monitoring Pb in Year 15 (1995 – 96), elevated levels of Pb have been found in the same areas, but with generally higher relative loadings.

For the purpose of this summary only the distribution of Pb and Zn around HMI will be discussed; the distribution due to the contribution of Baltimore Harbor and Back River are discussed in detail in Appendix II. Summary Figure 1-3 shows the sigma levels for Pb and Zn for Year 26 fall and spring monitoring periods in the area adjacent to HMI. Data that fall within +/-2 sigma are considered within normal baseline variability. Data within the 2 to 3 sigma range are transitional, and data >3 sigma are significantly elevated above background. The shading in Summary Figure 1-3 is used to highlight the areas that are significantly elevated above baseline levels. There is one anomalous site in the fall 2007 sampling (Pb - 10 sigma; Zn - 5 sigma). There wasn't any apparent reason to reject this sample, so it was included. However, it does not fit the spatial or temporal trends. The result of a unique event, either sample handling or site specific; neither can be excluded. The area immediately around HMI this year was comparable to Year 25. Although the enriched zones were not contiguous to HMI in September



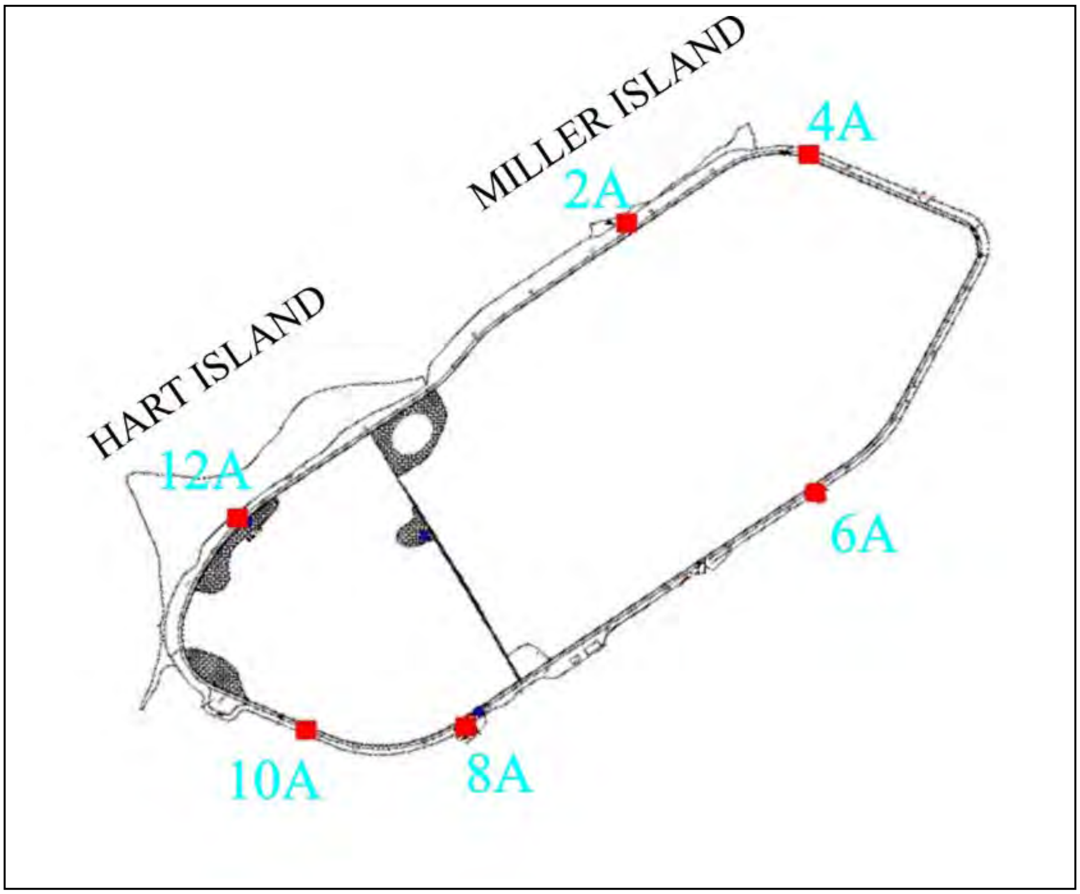
Summary Figure 1-3. Fall 2007 and spring 2008 distribution of Pb and Zn around HMI. Values are expressed in multiples of Sigma.

2007 as they were in April 2008, the area around the South Cell discharge point (Spillway 003, Summary Figure 1-1) was elevated for Pb and Zn for both cruises (Summary Figure 1-3).

MGS obtained discharge rate records from MES covering the periods April 1, 2007 - April 30, 2008. The discharge data were evaluated with respect to the enrichment of metals, specifically Pb and Zn, around HMI and the discharge points. Discharge rates less than 10 million gallons per day (MGD) and dewatering operations are conducive to the production of acidic conditions resulting from oxidation of the sediment. Based on the discharge records the South Cell discharges are conducive to the release of enriched waters into the Bay. It was MGS's evaluation that based on the operations of the HMI facility during this monitoring year, it would be expected that the facility would have statistically elevated metals from the South Cell; in contrast, the North Cell would not be expected to influence the exterior sediments, mainly because discharge rates from the North Cell were greater than 10 MGD. Based on the discharge records for the South Cell 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 the spring cruise, localized in the area of the South Cell discharge. The influence of the North Cell discharge is evident in the fall sampling and to a much lesser extent in the spring. The trend for material from the North Cell appears to be diminishing toward background levels. Comparing the last three years of Zn enrichment the highest levels in the HMI zone of influence during Year 26 are similar to Year 25; however, both cruises were higher as compared to Year 24.

Groundwater Monitoring Wells

Groundwater samples from six wells were collected in June and December 2007, 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 North and South Cells each have three monitoring wells (Summary Figure 1-4).



Summary Figure 1-4. Groundwater sampling wells locations.

All wells were found to be anoxic or hypoxic with dissolved oxygen (DO) levels less than 0.8 mg/l. However, due to sulfide interference with the DO probe it is more likely that the wells were anoxic, i.e., without oxygen. When oxygen is not available anaerobic respiration occurs with nitrates being used preferentially as the primary oxidant and ammonium is formed as a byproduct. Ammonium was found as the dominant form of nitrogen which is consistent with the anoxic nature of the groundwater. In situ sulfides were not measured due to the limitations of the instrumentation.

Chloride concentrations on average are higher in the North Cell Wells especially in 2A and 6A. The higher chloride concentrations are the result of replenishment of more saline water from active dredged material inflow operations in the North Cell and the resulting pond water perking through the sediment and infiltrating the wells. The mineral sulfides naturally found in the sediment, having been covered with pond water, are not exposed to air for significant periods of time to then oxidize and produce acidic conditions. The alkalinity of the water is not neutralized by acid production, so it is generally higher in the North Cell samples. Also, with the exception of As most of the metals were below detection limit in wells 2A and 6A. This again is a strong indication that the environmental conditions in these sites were similar to the natural surrounding Bay conditions and not altered to produce acidic conditions.

Total dissolved nitrogen (as ammonium), was found to be about three times higher in well 6A compared to the other wells. This is due to the reducing processes that dominate the groundwater infiltrating these wells. As previously stated ammonium is produced as a byproduct 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. In this area of the North Cell, the groundwater is replenished with water from dredged material input which maintains the anaerobic state of the sediments, which is necessary to keep acid from forming.

The South Cell Wells 8A, 10A and 12A, and North Cell Well 4A exhibit opposite conditions to varying degrees. On average, sulfate was found in higher concentrations in these wells (compared to 2A and 6A), especially 10A, indicating that the water infiltrating these wells has been exposed to oxidized sediments. Sediments are oxidized when exposed to air during periods of crust management or in the case of the South Cell when the pond is drained down to create mudflats, and with the upland areas (location of Well 12A) that are never submerged. This would indicate that rainwater rather than pond water is the major source of water infiltrating these wells compared to Wells 2A and 6A. This is also evident in that chloride (typically high in Bay water) is in lower concentrations in these wells.

Keeping in mind that ammonium is a byproduct of anaerobic respiration (without oxygen), ammonium was found to be lower on average by a third indicating the availability of oxygen. Also, metals and cations concentrations were found to be higher which is typical in acidic conditions again indicating the availability of oxygen, hence the oxidation of sulfides.

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 6, 2007 and on April 10, 2008 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 2007 cruise. Because of the low Mesohaline salinity regime that existed during the September time period during which HMI was sampled, three metrics were used to calculate the B-IBI scores. The three metrics used were total infaunal abundance, relative abundance of pollution-indicative taxa (PITA), and Shannon-Weiner Diversity Index (SWDI). A brief summary of these three metrics and the B-IBI results follows. For greater detail of all metrics see Appendix 2.

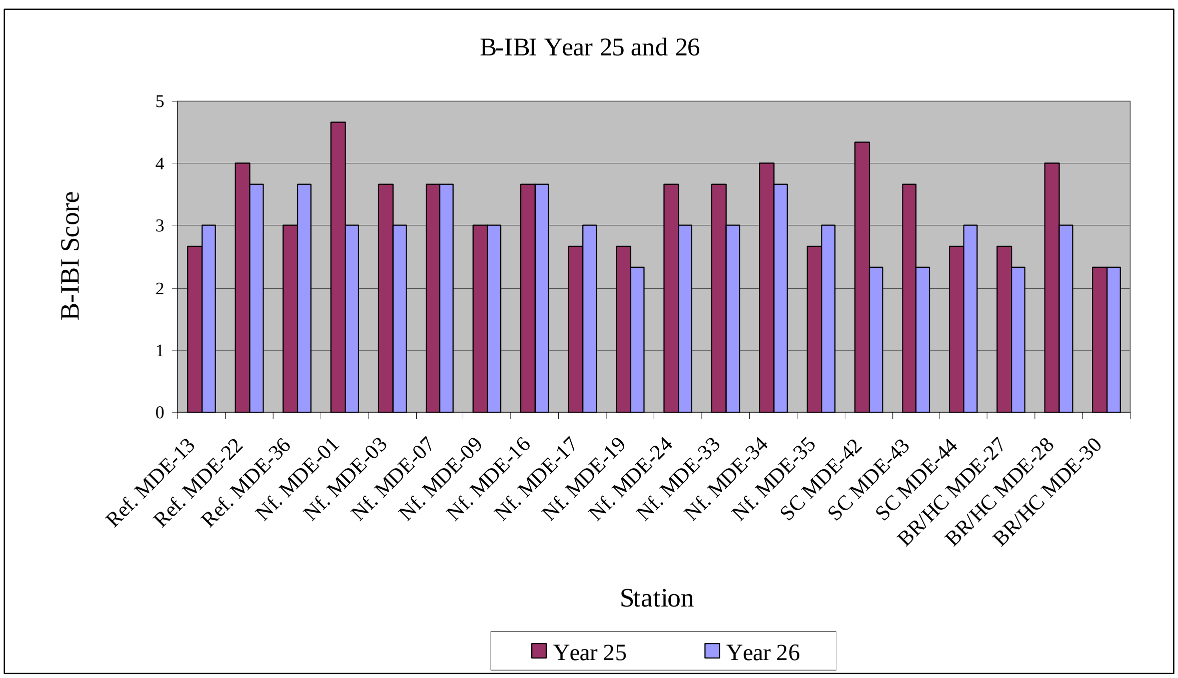
Average total infaunal abundance was lower in the fall than in the spring which is primarily a result of a greater number of organisms in the spring due to recruitment. In September 2007, total infaunal abundance ranged from 441.6 to 3737.6 organisms per square meter (individuals/m^2) and averaged 1352 individuals/m^2. The median, another measure of central tendency that is less sensitive to extreme values in the data set, was 1036.8 individuals/m^2 somewhat below the average. This would indicate that the highest abundance of 3737.6 individuals/m^2 found at the Back River station MDE-27 although real is an extreme in the dataset. The high abundance was primarily due to the large numbers of Naididae worms; some members of this family are pollution indicative. The lowest infaunal abundance in September 2007 was found at the Back River/Hawk Cove station MDE-30. The average total infaunal abundance was very similar at Reference stations and Nearfield stations in September 2007.

Four taxa found during the fall sampling of Year 26 benthic monitoring were designated as “pollution-indicative” according to Alden et al. (2002): they were Chironomids of the genus *Coelotanypus,* the polychaete worms *Streblospio benedicti* and *Eteone heteropoda,* and oligochaete worms of the family Naididae. In Year 26, pollution indicative taxa occurred at all station types ranging from 13.33 percent at MDE-22 (Nearfield station) to 72.60 percent at MDE-27 (Back River station). The average PITA for all stations in September 2007 was 42.86 percent. Comparing station types, the lowest average PITA was 36.14 percent at the Reference stations, 40.35 percent at the Nearfield stations, and 48.90 percent at Back River/Hawk Cove stations. The highest average PITA occurred at the South Cell Exterior Monitoring stations at 52.73 percent.

Species diversity was examined using the SWDI, which measures diversity on a numerical scale from 0 to 4. A lower score indicates an unbalanced benthic community dominated by only one or two species whereas a higher score suggests a balanced, diverse benthic community. In this monitoring year, average diversity was moderately higher in September 2007 than in April 2008, as would be expected; typically during the summer recruitment decreased and predation increased, thus reducing the numbers of the dominant taxa resulting in a more balanced community. SWDI values in Year 26 averaged 2.61 ± 0.39 in September 2007 and 1.94 ± 0.59 in April 2008.

The B-IBI was developed as a benchmark to determine whether any given benthic sample taken from the Bay deviated from conditions at established reference sites. B-IBI scores range from 1 to 5 with 1 considered as deviating greatly from reference conditions, and 5 approximating reference conditions. 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 26 were compared to this benchmark.

In Year 26 there was an overall decrease in B-IBI scores at individual stations when compared to Year 25. However, in Year 26 there were 15 out of 20 sites that passed the benchmark, as compared to only 13 in Year 25. The overall trend was similar (Summary Figure 1-5).



Summary Figure 1-5. Comparison of Year 25 and Year 26 B-IBI scores. Prefixes in station names are; Ref. - Reference; Nf. – Nearfield; SC – South Cell; BR/HC – Back River/Hawk Cove.

In analyzing only those sites that failed in Years 25 and 26 a number of things are apparent. There were three sites that failed both years, MDE-19, 27 and 30, which is not surprising since historically these sites have often shown poor B-IBI scores. The four sites that passed in Year 26 but failed in Year 25 did so only marginally (MDE-17, 35, 13 and 44). The two stations for which a significant difference occurs are SC MDE-42 and 43 (Summary Table 1-2). These two sites as well as SC MDE-44 were established in Year 22 to increase spatial coverage on the south side of HMI to monitor potential effects of effluent from the South Cell Spillway 003 (Summary Figure 1-1). No conclusions can be drawn at this time as to why these two sites failed and why there is such an extreme difference between sampling years. However, in the future these sites should be closely monitored, and results compared with those of Projects II and IV.

Stations	Year 25	Year 26
BR/HC MDE-27	**2.67**	**2.33**
BR/HC MDE-30	**2.33**	**2.33**
Nf. MDE-17	**2.67**	**3.00**
Nf. MDE-19	**2.67**	**2.33**
Nf. MDE-35	**2.67**	**3.00**
Ref. MDE-13	**2.67**	**3.00**
SC MDE-42	**4.33**	**2.33**
SC MDE-43	**3.67**	**2.33**
SC MDE-44	**2.67**	**3.00**

Summary Table 1-2. Comparison of failing sites in either Year 25 or Year 26.

In summary the average B-IBI score of all 20 sites monitored for Year 26 was slightly lower than Year 25 but the percentage of sites that passed was higher. The standard deviation indicates that there was less variance in the overall B-IBI scores in Year 26 when compared to Year 25 (Summary Table 1-3).

Summary of Statistics		
Stations n=20	Year 25	Year 26
Average B-IBI	3.37	3.00
Standard Deviation B-IBI	0.67	0.48
Percent Sites Passing B-IBI	65%	75%

Summary Table 1-3. Summary of statistics between HMI monitoring Years 25 and 26.

Project IV: Analytical Services

For Year 26 exterior monitoring at HMI, CBL collected clams in the fall of 2007 at 11 HMI exterior stations (Summary Figure 1-1), and associated sediments for analyses of trace metals, polycyclic aromatic hydrocarbons (PAHs), and polychlorinated biphenyls (PCBs). In addition as part of the annual sediment survey, CBL conducted analysis for concentrations of target trace elements in surface sediments collected around HMI by MGS in September. Metal analysis focuses on those metals not measured by MGS, specifically total mercury (T-Hg), methylmercury (MeHg), silver (Ag), selenium (Se) and arsenic (As).

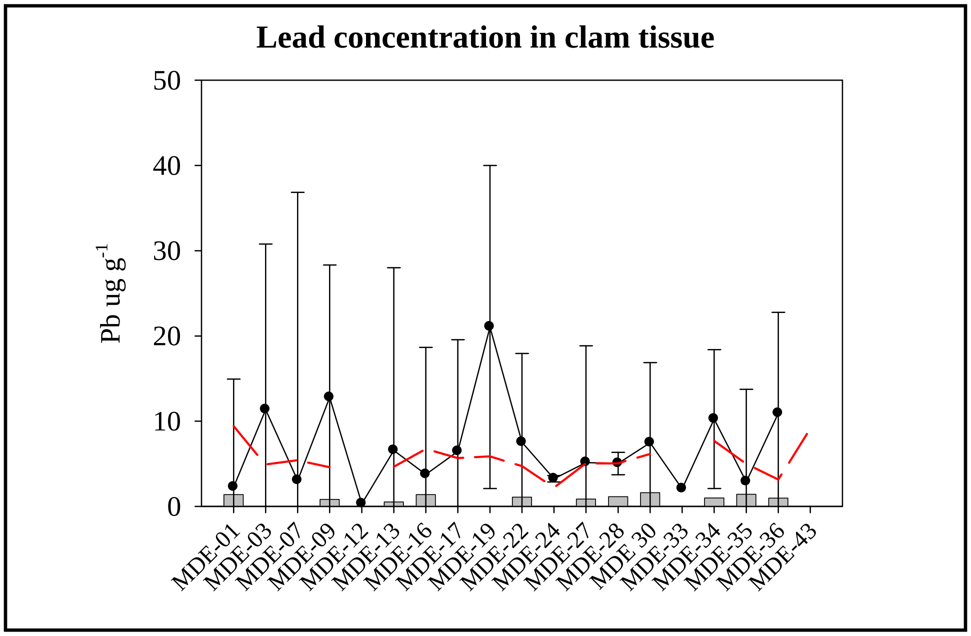
Metals in Sediment

Concentrations of As in the sediment collected around HMI in the fall 2007 were higher than the running mean at 58 percent of the stations. However, As concentration when compared to Year 25 also increased at the north reference site MDE-36, out of the influence of HMI (Summary Figure 1-1). Although As concentration increased at MDE-36 it did not exceed the running mean. Concentrations of Se in Year 26 were similar to As except that the magnitude of the increase was not as great. Concentrations of As were about 5 ug g^{-1} higher than the running mean whereas concentrations of Se at many sites were on the order of 1 ug g^{-1}.

Concentrations of both T-Hg and MeHg in sediments around HMI were lower than the running mean and median from previous years. Concentrations were also consistent with concentrations of T-Hg and MeHg found in the main stem of the Chesapeake Bay, and in the upper Bay where concentrations of T-Hg and MeHg are highest on the order of 130 ng g^{-1} and 1 ng g^{-1}, respectively.

Metals in Clam Tissue

Clams were only collected in the fall of 2007. Concentrations of the metals As, Se, Ag, Cd, Pb, Hg and MeHg in the clam *R. cuneata* displayed some variations from previous years. Concentrations of metals in clam tissue were lower at all sites with the exception of As, which was close to the average concentration observed since 1998. The percent MeHg was also close to the average mean of the study period. Concentrations of Pb and Ag in clam tissue were consistently below both the running mean and median. This was especially true for Pb at Back River sites MDE-27, 28 and 30 where MGS found a high gradient of Pb in sediment out of Back River (Summary Figures 1-6 and 1-3, respectively). A possible explanation for low concentration in clam tissue and higher concentration in the sediment is that *R. cuneata* typically live or acquire food from within the flocculent layer and the MGS analysis includes sediment from below the flocculent layer. Also, clams typically reflect a shorter or more recent time period than sediments. Clams can accumulate and depurate metals, thus concentrations in tissue can vary with time. Also, because of the rather high clay:mud ratio in this area the bioavailability of Pb might have been low. Figures for all metals are presented in Appendix 3.



Summary Figure 1-6. Concentrations of Pb in clams collected in September 2007. Concentrations are expressed as dry weight, collected in September 2007 (bars), 1998-2006 mean (circles) and median (dashed line), and standard deviation (error bars).

PCBs in Sediment

Sediment samples collected in September of 2007 were analyzed for concentrations of PCBs and found to be high in congeners 66, 90, 206, and 209. However, PCB concentrations in general were lower than the average when compared to sediment collected from the same sites in previous years. Concentrations of PCBs measured in 2007 at MDE-01, which had not been sampled in a number of years, were higher than recorded earlier but are some of the lowest when compared to the other sites. The sites around HMI were also similar to what was observed at the reference site MDE-36. Figures with concentrations for all congeners of PCBs are shown in Appendix 3.

PCBs in Clams

Tissue from clams collected in September 2007 was analyzed for concentrations of PCBs, and like the sediments found to be high in congeners 206 and 209, but unlike the sediments contain the lighter mass 1 and 2 congeners. The samples collected in Year 26 are similar and generally lower than the average PCB concentration when compared to the clams collected from the same sites in previous years, and also have less of the low mass congeners. The concentrations in clams from the 10 sites around HMI were also similar to what was observed from the reference site MDE-36.

PAHs in Sediment

The distribution of PAHs among the 10 HMI exterior stations is similar, with phenanthrene and perylene often present at the highest concentrations, and are similar to the concentrations at the reference site MDE-36. A comparison of Year 26 distribution of PAHs against the running mean shows very little variation which suggests contributions from HMI or other sources are minimal. However, the total concentrations do vary suggesting a regional overriding influence on these sites. There are not enough current data to adequately assess the impact of the South Cell Spillway 003 discharge. Greater detail is presented in Appendix 3.

PAHs in Clams

The distribution of PAHs in clam tissue among the sites is similar to those in sediment with phenanthrene and perylene often present at the highest concentrations. However, unlike concentrations in sediment, concentrations of phenanthrene and perylene were not as consistent in clam tissue. The concentrations at the 10 sites located around the HMI facility are similar to the concentrations at the reference site MDE-36. Like sediments a comparison of Year 26 distribution against the running means shows very little variation suggesting again contributions from HMI or other sources are minimal. However, the total concentrations do vary suggesting a regional overriding influence on these sites. There is not enough current data to adequately assess the impact of the South Cell Spillway 003 discharge.

PROJECT I SUMMARY AND RECOMMENDATIONS

Although a Zn as well as Pb signature in sediments surrounding HMI has been detected over the long-term record, construction and operation at the HMI-DMCF 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 effects to aquatic life. For example, site MDE-09 is located in a zone enriched for Pb and Zn (sigma 4 and sigma 3, respectively) and yet had a passing B-IBI score of 3.00. Conversely, the benthic community at sites MDE-43 and MDE-44 both were degraded from the previous year with a B-IBI score of 2.33 and yet both sites were just outside the enriched zones of influence. This would indicate that the cause(s) for these sites failing was not necessary a result of facility operations. As for site MDE-09 and other similar situations, it may be that the contaminants are chemically bound to the fine-grain silts and clays in the sediment or are in a specific chemical form that is not bioavailable.

The South Cell discharge operations did appear to have an effect on the exterior sedimentary environment, which is evident in the enrichment of Pb and Zn around the South Cell Spillway 003. This was especially true for the spring sampling when the zone of influence for both metals was contiguous to HMI and directly around Spillway 003. The zone of enrichment during the spring of 2008 extended south nearly to stations MDE-43 and 44, which also had failing benthic scores. The North Cell discharge operations did not appear to have any adverse effects to the biota or the sedimentary environment. Sampling station MDE-27, located at the mouth of Back River, and MDE-30 located east of HMI both had failing B-IBI scores. This area was also enriched for Pb both in September 2007 and April 2008, and to a lesser extent for Zn in September. However, these conditions are more attributed to the influence of Back River and not to HMI operations.

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 (Back River/Hawk Cove, Baltimore Harbor, and the HMI North and South Cell). Conversations with the Maryland Port Administration (MPA), 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. HMI exterior monitoring will continue for at least five years past facility closure (in December 2009) and then will be reevaluated on an annual basis to determine the extent of continued monitoring. Discharge at the facility spillways will continue to be monitored under the MDE issued Industrial Discharge Permit, which will have discharge limits for pH and selected metals and nutrients, until MDE deems the permit unnecessary.

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APPENDIX 1: SEDIMENTARY ENVIRONMENT (PROJECT II)

(September 2007 - August 2008)

Technical Report

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EXECUTIVE SUMMARY

The Coastal and Estuarine Geology Program of the Maryland Geological Survey (MGS) has been involved in monitoring the physical and chemical behavior of near-surface sediments around the Hart-Miller Island Dredged Material Containment Facility (HMI-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 5, 2007 and April 9, 2008. 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 2007 was performed.

For exterior bottom sediments sampled during Year 26, 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 the area effected by facility operations, Pb and Zn showed enriched levels. The September sampling cruise had higher levels, and a greater areal extent as compared to the April sampling west of the facility. This represents residual loading from the period proceeding this monitoring year, and shows a trend going to background levels. In the area adjacent to the South Cell, the behavior is the opposite with higher levels and greater areal extent in the spring as compared to the fall sampling. This reflects the input from the South Cell and 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. These conditions existed in the South Cell.

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 have 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 1-1). 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 19.2 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 groundwaters 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.

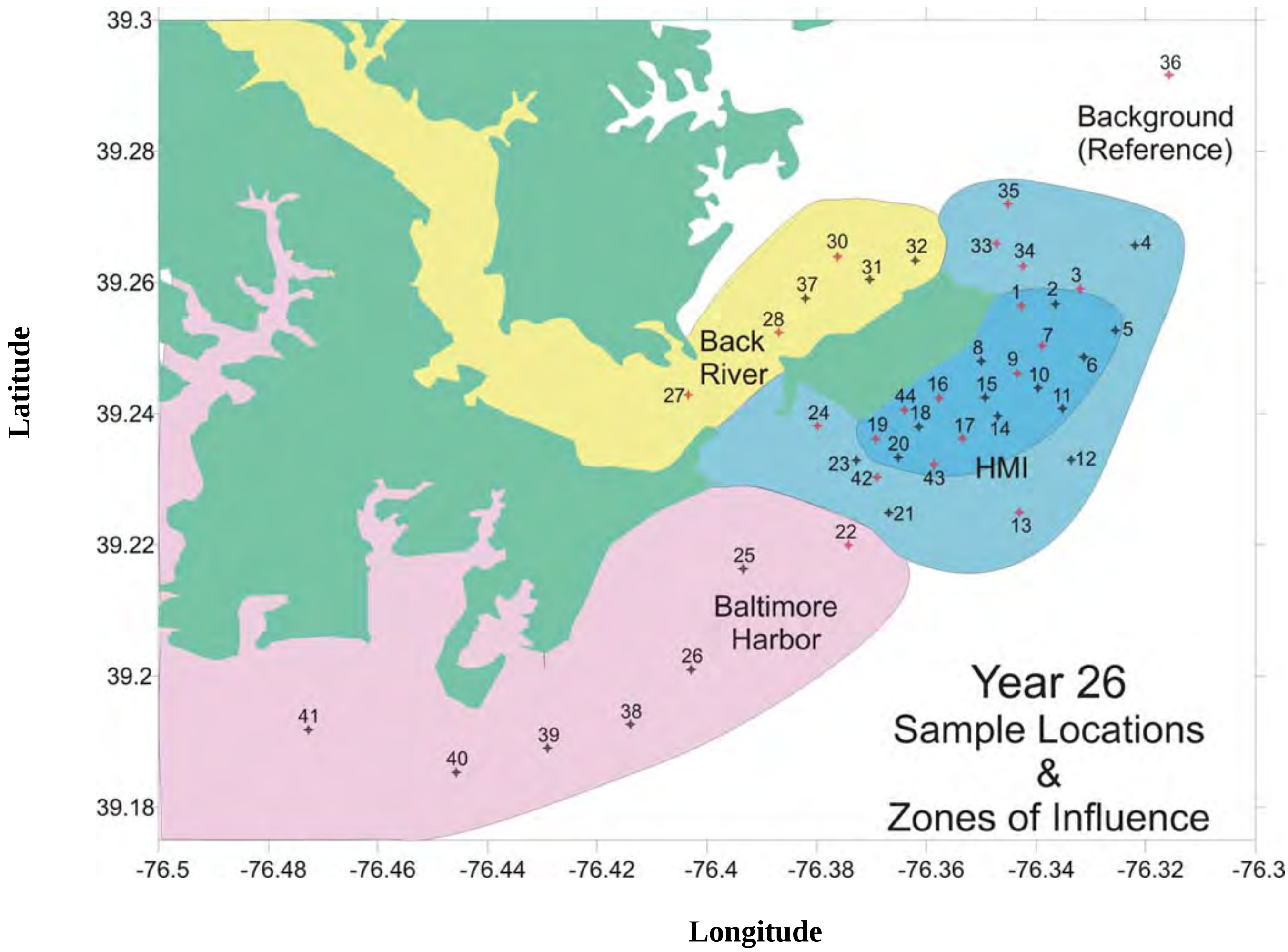


Figure 1-1. Sampling locations for Year 26. Contours show zones of influence found in previous studies. Stations 38 – 41 were added in Year 18 to measure the influence of Baltimore Harbor.

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 produces 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 1-1, in addition to showing the sampling sites for Year 26, 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 Figure 1-1 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;

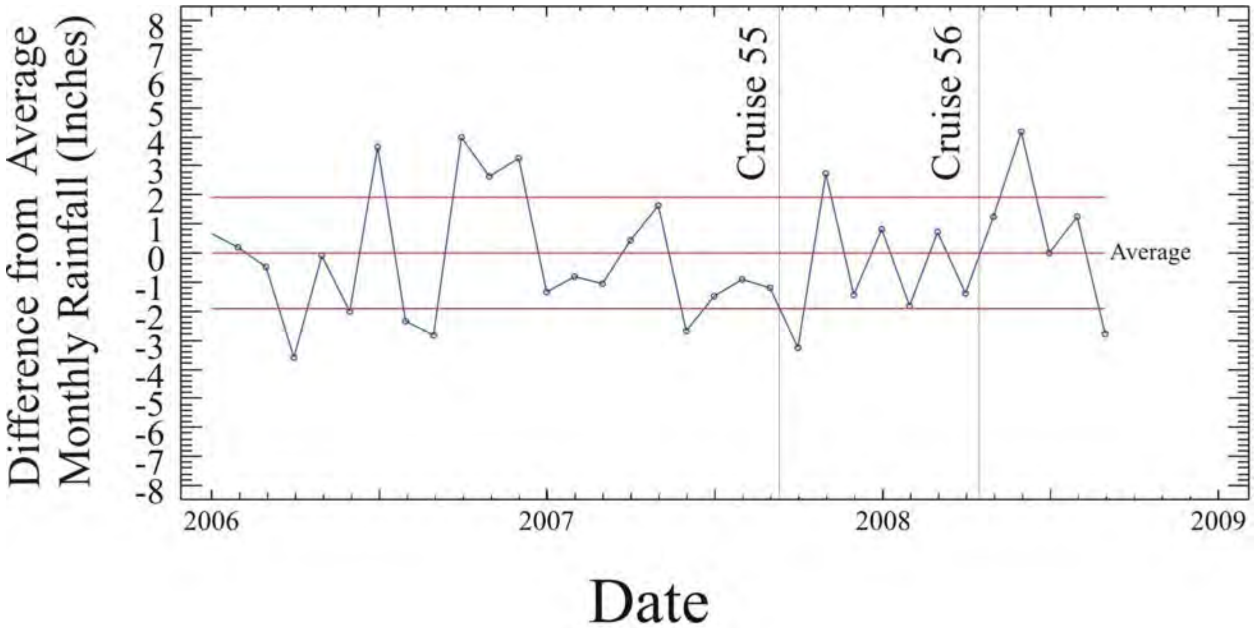
4. *Baltimore Harbor* – Sites in the southern portion of the area have consistently shown a gradient, indicating that Baltimore Harbor is a source of metals in the area south of HMI. The consistent pattern seen in the monitoring studies is base level values near HMI, which increase towards Baltimore 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 26 cruises are summarized below. Information was extracted from *Operations Reports* prepared by MES, covering the periods April 1, 2007 - April 30, 2008; a detailed synopsis of this period and digital discharge records were provided to MGS for this report by MES (pers. com. Carr)

The total amount of material accepted in the North Cell was 4.9 million cubic yards; material was accepted at a fairly uniform rate throughout the monitoring year period. Additional water input occurs from precipitation, which along with Bay water pumped from the holding pond, is the primary source of water to the South Cell. As noted earlier flow from the Susquehanna River influences the dispersion of material around HMI; this is related to rainfall totals. Figure 1-2 shows the input of dredged material and the monthly rainfall. Monthly precipitation prior to Cruise 56 was average while the months preceding Cruise 55 were below average.

Discharge from the North Cell was relatively uniform throughout the monitoring year due to the continual input of dredged material, which needed to be decanted. The South Cell discharge was not as continuous as the North Cell, but compared to previous years operations it was quite active. Water from the South Cell was discharged as needed for dewatering and to regulate the pond water levels in the South Cell habitat area. Overall, discharge from HMI was consistent, with high discharge rates from the North Cell and low, moderately consistent discharge rates from the South Cell. This is shown in Figure 1-3 which shows both the daily and cumulative discharge from the North and South Cells.



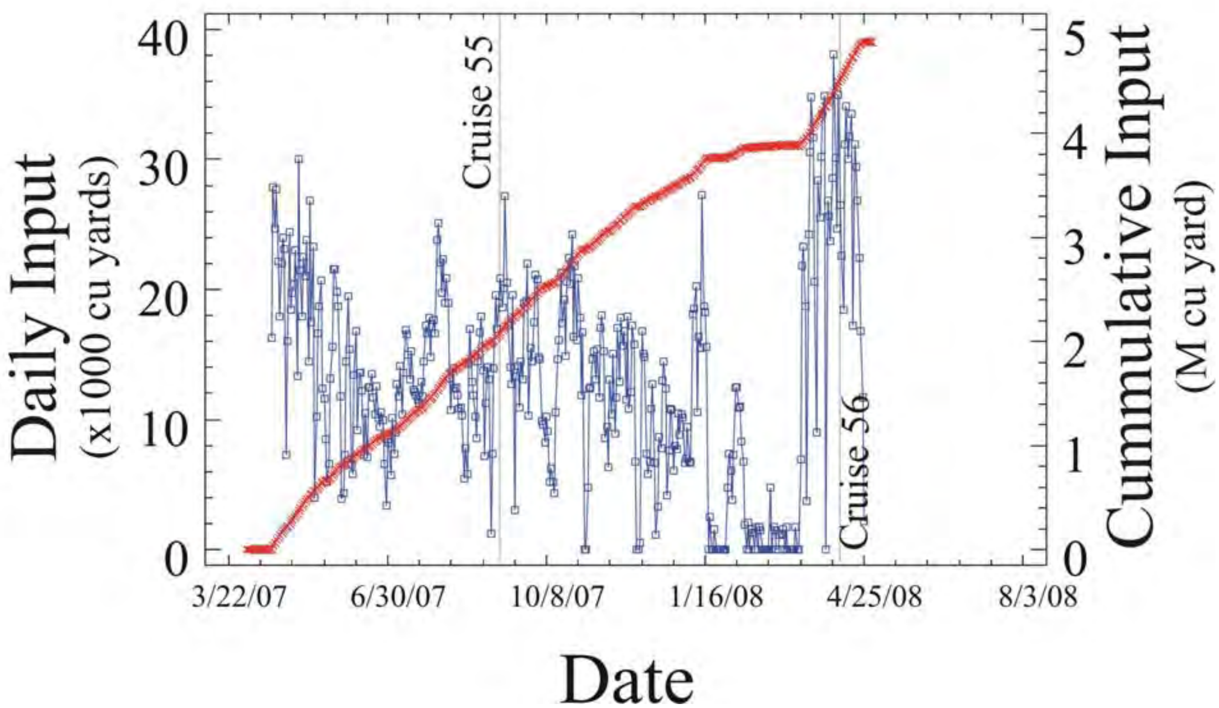


Figure 1-2. Inputs into HMI; daily precipitation and monthly dredged material input to the North Cell.

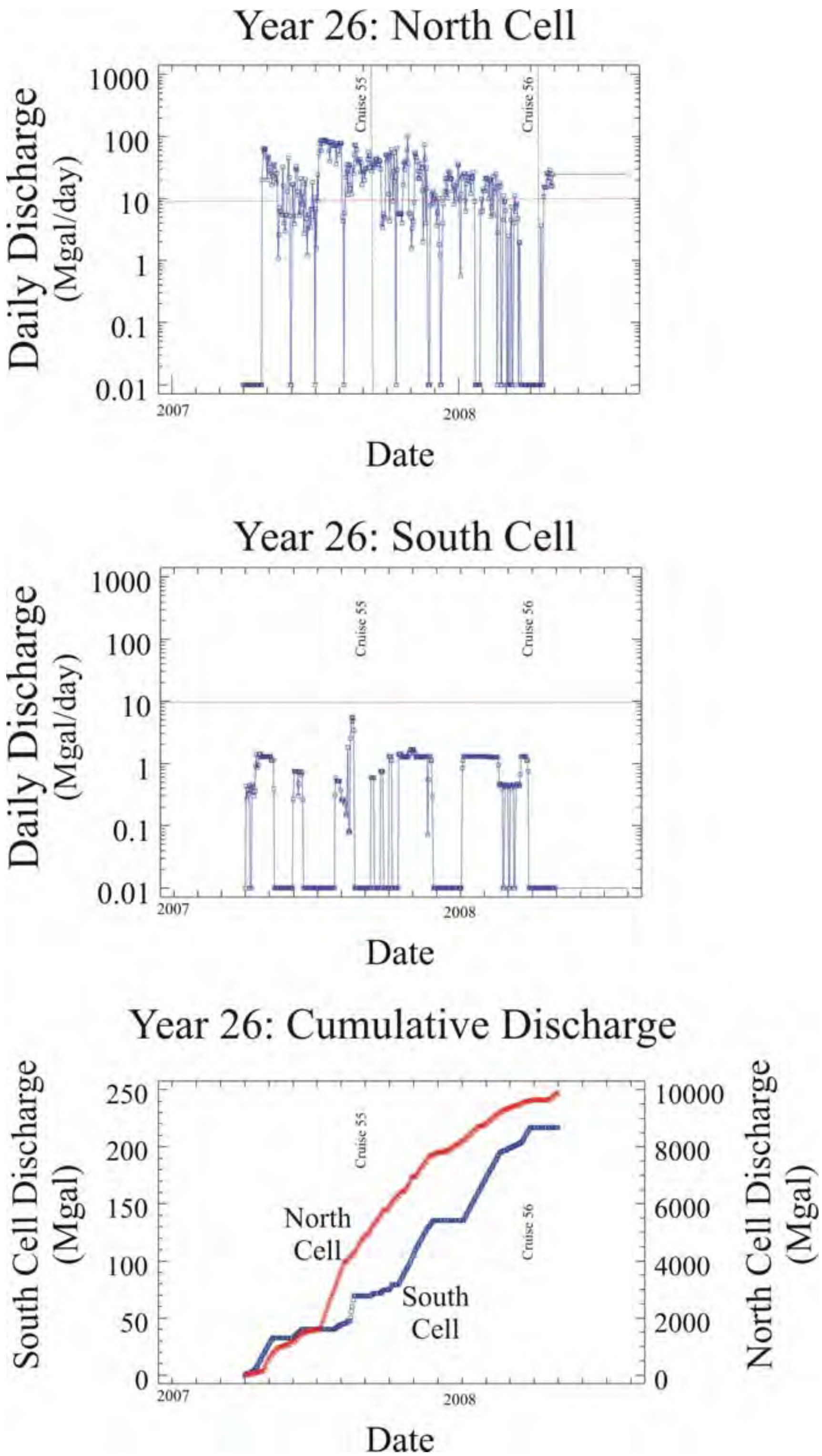


Figure 1-3. Daily and cumulative discharge from the North and South Cells. The sampling events are marked by the vertical lines.

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 1-3 (Year 26: South Cell), the South Cell discharges are conducive for the release of enriched waters into the Bay. The spring sampling period shows the higher enrichment corresponding to more days of water release from the South Cell in the months prior to sampling as compared to the fall sampling period.

Due to a change in the MDE issued discharge permit requirements, effective July 2004, methods for pH measurement were changed during the Year 23 monitoring period. 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 cannot be averaged since they are logarithmic metrics of acidity, so the range of data is an important indicator of the processes occurring. The new collection method is to collect one grab sample for each discharge event; MGS feels this is inadequate to characterize the processes operating at the facility, and believes that consequently the pH data cannot be used to corroborate the concept that low discharge rates coupled with dewatering operations that are conducive to the production of acidic conditions result in enriched waters being released into the Bay during discharge events. In addition MGS feels that with regard to the pH data the facility operations cannot be compared to previous years. 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 26 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 5, 2007, and the second, on April 9, 2008.

Sampling sites (Figure 1-1) were located in the field by means of a Leica Model MX412B differential global positioning system (GPS) with a built-in beacon receiver. According to the captain, Rick Younger, the repeatability of the navigation system, that is, the ability to return to a location at which a navigation fix has previously been obtained is between 5-10 m (16-33 ft). Where replicates were collected, the captain repositioned the vessel between samples to counteract drifting off station during sample retrieval. 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 26 sample locations are reported in the companion *Year 26 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 26 cruises. The stations were identical to those sampled during Year 25.

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 26 Data Report*.

Using plastic scoops rinsed with deionized water, the crew took sediment sub-samples from below the flocculent layer, usually several centimeters from the top, and away from the sides of the sampler to avoid possible contamination by the sampler itself. MGS's sub-samples were placed in 18-oz Whirl-Pak™ bags and refrigerated. They were maintained at $4^{o}C$ until they could be processed in the laboratory. CBL's splits were handled in much the same way, except that they included the flocculent 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 1-4).

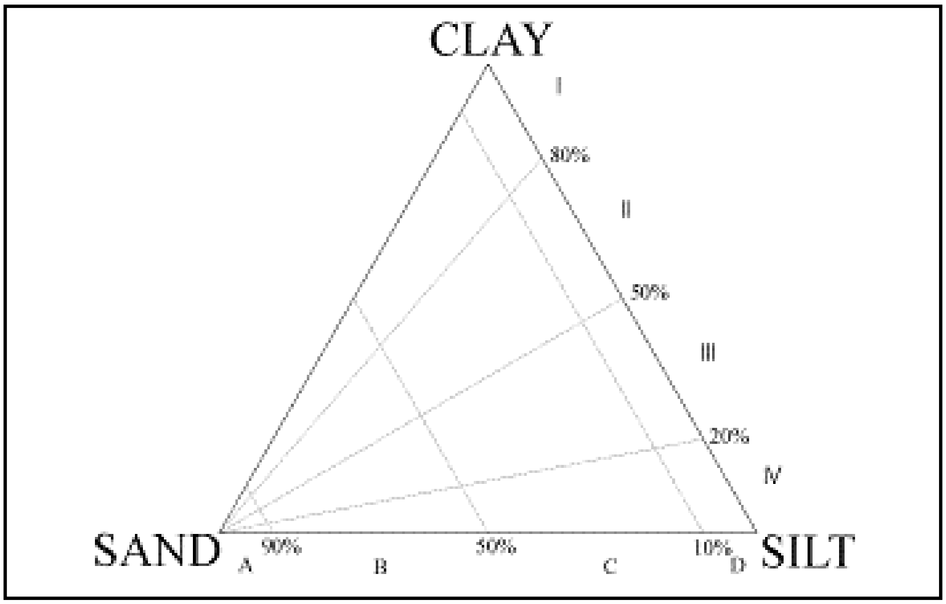


Figure 1-4. Pejrup's Diagram (1988) classification of sediment type

Pejrup's diagram, developed specifically for estuarine sediments, is a tool for graphing a three-component system summing to 100 percent. 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 percent 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), 41 additional elements were analyzed. Samples were prepared and ground in-house and sent to ActLab for analyses using both a four acid "near total" digestion technique followed by analysis on an Inductively Coupled Argon Plasma Spectrometer (ICAP), and Neutron Activation Analysis (NAA). In addition to the standards and blanks used by ActLab, National Institute 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 (SRMs) (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 six to seven 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 26 results are discussed with respect to the preceding Year 25 results.

All 43 of the sampling sites visited during Year 26 yielded results that can be compared to those measured during Year 25. 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 1-5. Within a diagram, each solid circle represents one sediment sample. Related statistics, by cruise, are presented in Table 1-1.

Table 1-1. Summary statistics for Years 25 - 26, for 43 sediment samples common to all four cruises.

Variable	Sept 2006 Cruise 53	Apr 2007 Cruise 54	Sept 2007 Cruise 55	Apr 2008 Cruise 56
Sand (%)				
Mean	24.67	23.44	22.71	22.03
Median	4.44	4.38	4.23	4.71
Minimum	0.72	0.99	0.62	0.49
Maximum	96.52	98.18	94.38	97.33
Range	95.80	97.19	93.77	96.84
Count	**43**	**43**	**43**	**43**
Clay:Mud				
Mean	0.58	0.56	0.55	0.55
Median	0.58	0.57	0.56	0.56
Minimum	0.41	0.45	0.41	0.45
Maximum	0.65	0.62	0.65	0.67
Range	0.23	0.17	0.23	0.22
Count	**43**	**43**	**43**	**43**

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

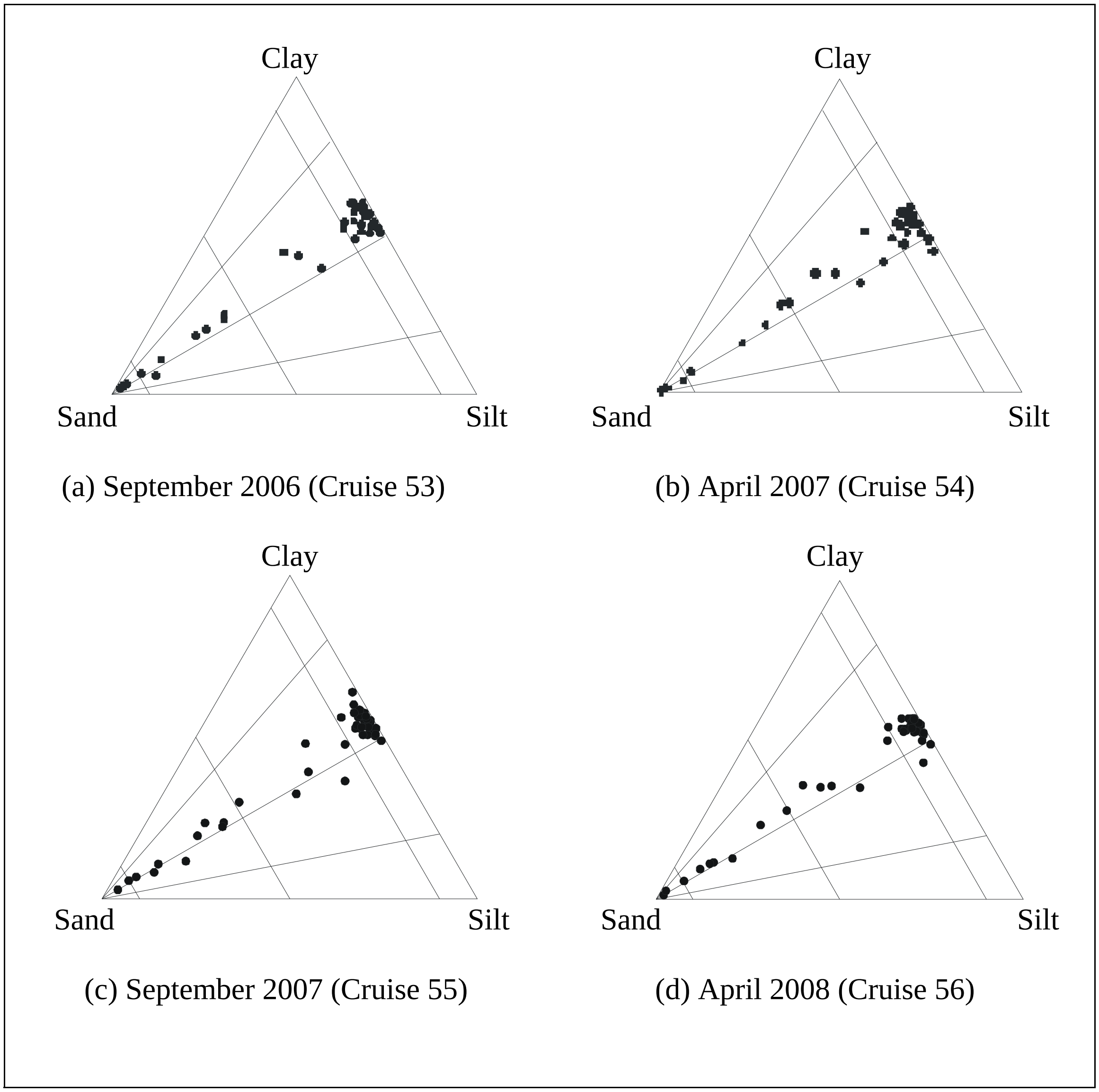


Figure 1-5. Pejrup diagrams showing the grain size composition of sediment samples collected in Years 25 and 26 from the 43 sampling sites common to all four cruises: (a) September 2006, (b) April 2007, (c) September 2007, and (d) April 2008.

Based on the summary statistics (Table 1-1), average grain size composition, reported as percent sand and as clay:mud ratios, varied little over the four sampling periods. The mean percentage of sand varied by only 2.64 percent for the four samplings. The mean clay:mud ratio was 0.58 for sampling Cruise 53 and decreased slightly to 0.56 for Cruise 54. The mean clay:mud ratio then decreased very slightly to 0.55 for sampling Cruise 55 and remained at 0.55

for sampling Cruise 56. As in the past, no clear seasonal trends are evident in either sand content or the clay:mud ratios.

The grain-size distribution of bottom sediments around HMI for the past two monitoring years is depicted in contour maps showing (1) the percentage of sand in bottom sediments and (2) the clay:mud ratios. In Figure 1-7 and Figure 1-8, three contour levels represent 10 percent, 50 percent, and 90 percent 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 percent sand) are confined to relatively shallow (<15 ft) waters (Figure 1-6).

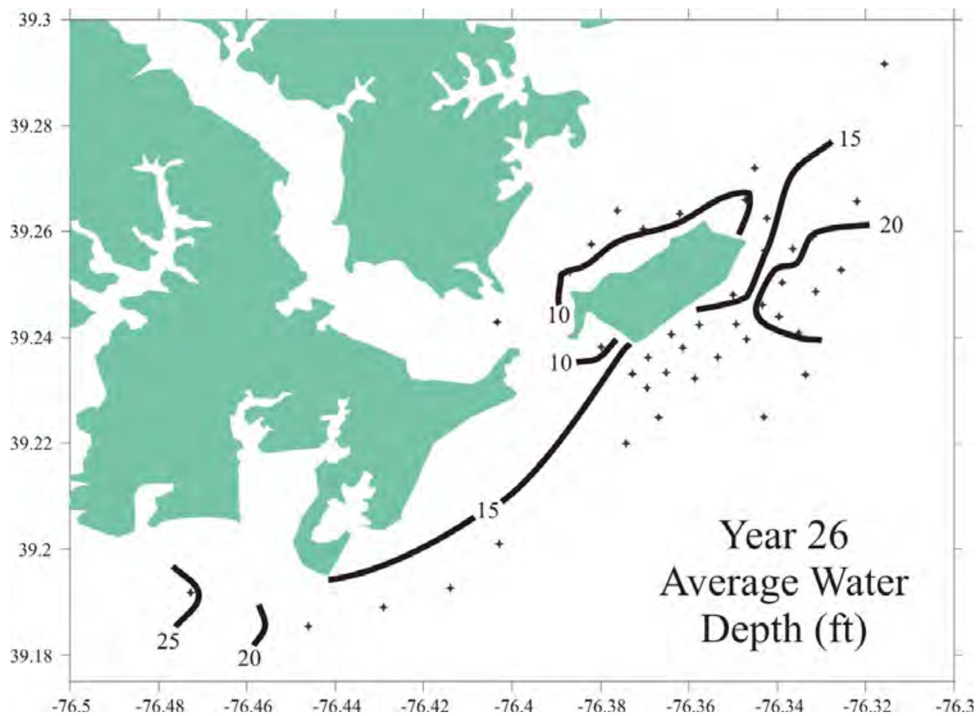


Figure 1-6. Average water depths around HMI and vacinity. Contour interval = 5 ft.

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 percent sand. Sand distribution maps for Years 25 and 26 are similar in appearance (Figures 1-7 and 1-8). 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 26. 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 Pejrup diagrams in Figure 1-5. However, slight variations in the most clay-rich (clay:mud ratio ≥ 0.60) and in the most silt-rich (clay:mud ratio < 0.50) of the fine fractions are evident (Figures 1-9 and 1-10). 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 2006 and April 2007. In September 2006, nine stations had clay:mud ratios at or above 0.60 south of HMI (MDE-10, 15, 17 through 19, 21, and 42 through 44) to create the clay-rich area for this sampling. There was also a clay-rich area along the northeast side of HMI in September 2006 due to the high clay:mud ratio seen at MDE-33 (Figure 1-9). MDE-33 is a very sandy site which makes the clay:mud ratio values here negligible as will be explained below. Five sampling sites were clay-rich south of HMI in April 2007. 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 1-9). Although more sample sites were clay-rich in September 2006 than in the subsequent samplings, the contour map shows that the size of the area containing clay-rich sediments to the south of HMI did not decrease significantly (Figure 1-9). In September 2007, three stations had clay:mud ratios at or above 0.60 south of HMI (MDE-7, 10, and 18) to create the clay-rich area for this sampling. With the decrease of the clay:mud ratio at MDE-21 to below 0.60, the three pockets seen in April 2007 was reduced to two (Figure 1-10). The following sampling in April 2008 resulted in two clay-rich sites in this area south of HMI. For this sampling, station MDE-10 remained clay-rich with the addition of MDE-44. The two clay-rich pockets south of HMI were still present in April 2008 but their locations shifted slightly (Figure 1-10).

A clay-rich area was also present to the north of HMI for two of the sampling Cruises 53 and 55 (Figure 1-9 and 1-10). Note that this area for Cruise 53 lies close to the perimeter of HMI where sand contents are consistently at or above 90 percent (Figures 1-7 and 1-8). This area is due to increased clay:mud ratios of sampling sites with high sand content. In sandy sediments, a very small increase in clay percentage will increase the clay:mud ratio above 0.60. The clay-rich site for cruise 55 was found at MDE-37 where the clay:mud ratio was 0.58 or greater for the other three sampling cruises. Therefore a very small increase in the clay content during September 2007 caused this station to be classified as clay-rich. The clay:mud ratio at MDE-27 in Back River was 0.60 in September 2006, but decreased back to below 0.60 for all subsequent samplings. There were a larger number of clay-rich sites in September 2006, from 10 stations during April 2006 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 1-9). The 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 26 are similar to those from Year 25 with no significant changes.

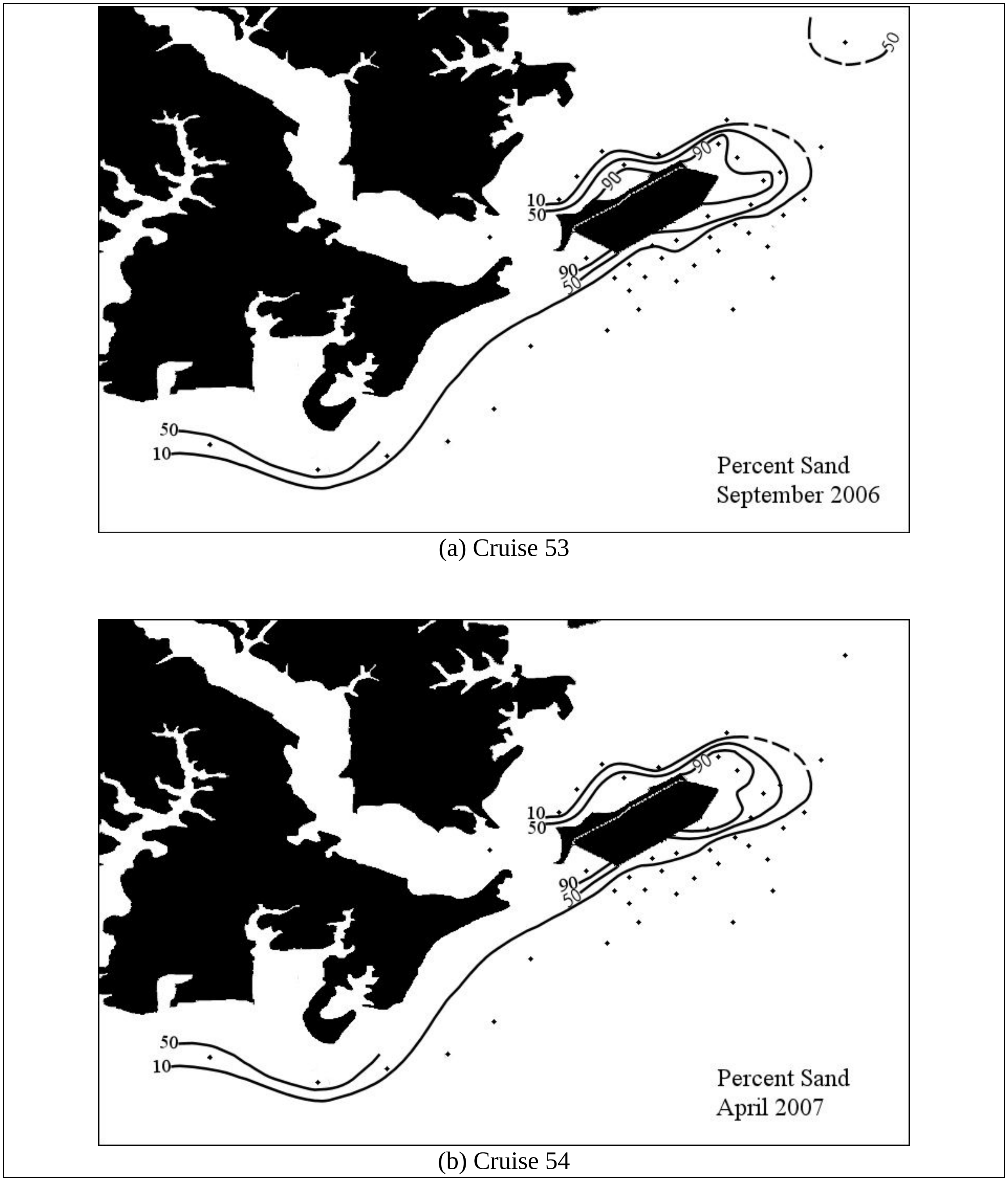
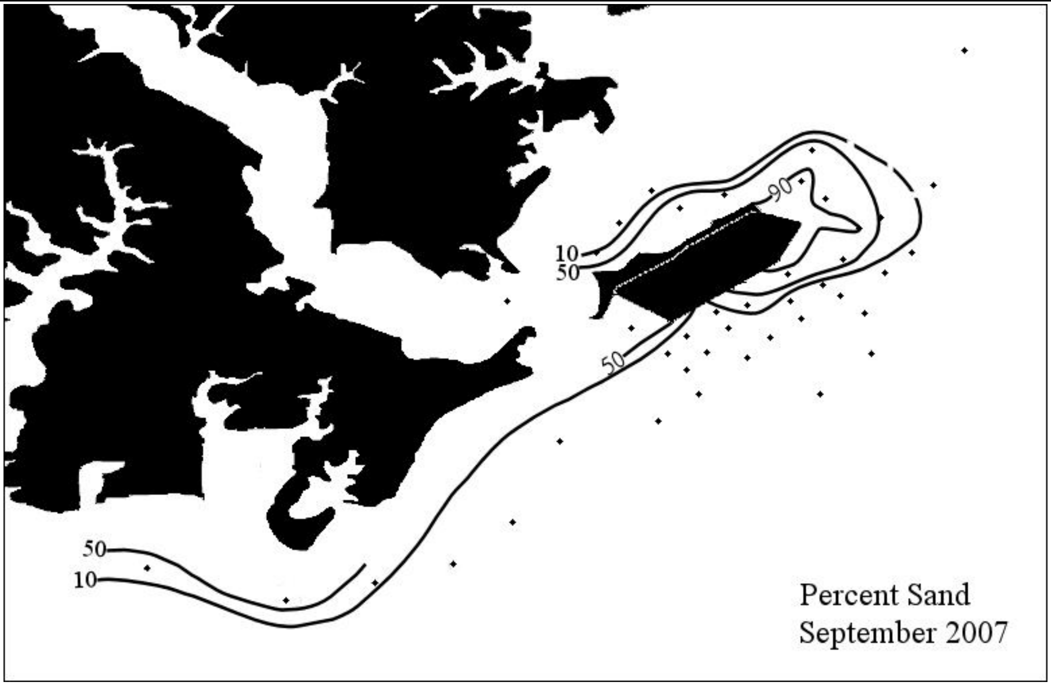
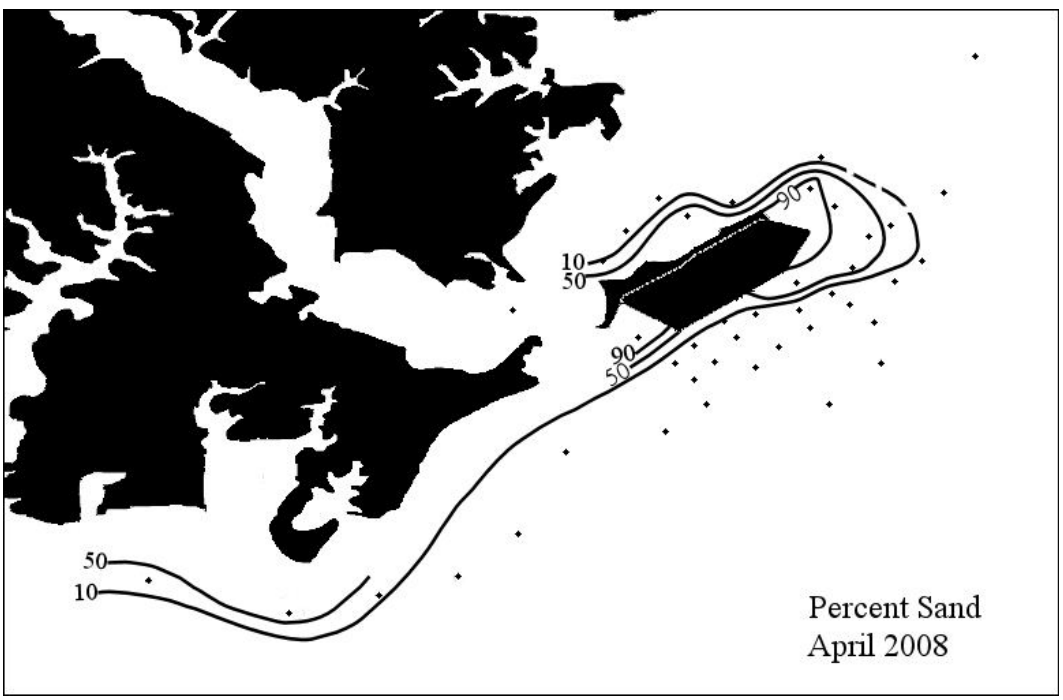


Figure 1-7. Sand distribution for Monitoring Year 25: (a) September 2006, (b) April 2007. Contour intervals are 10%, 50%, and 90% sand.

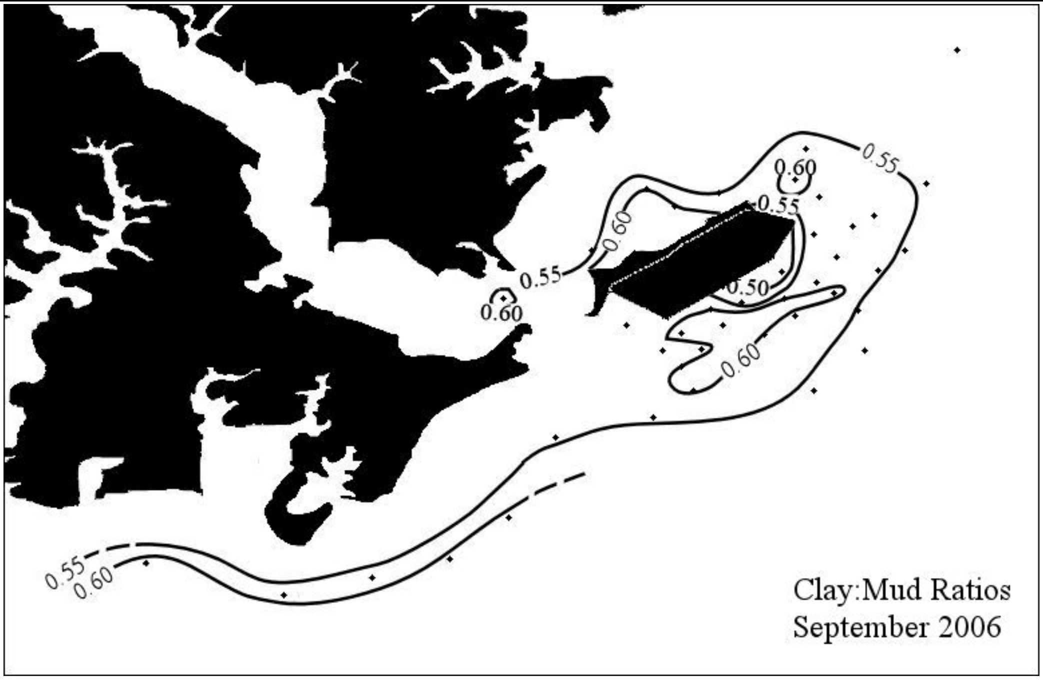


(a) Cruise 55

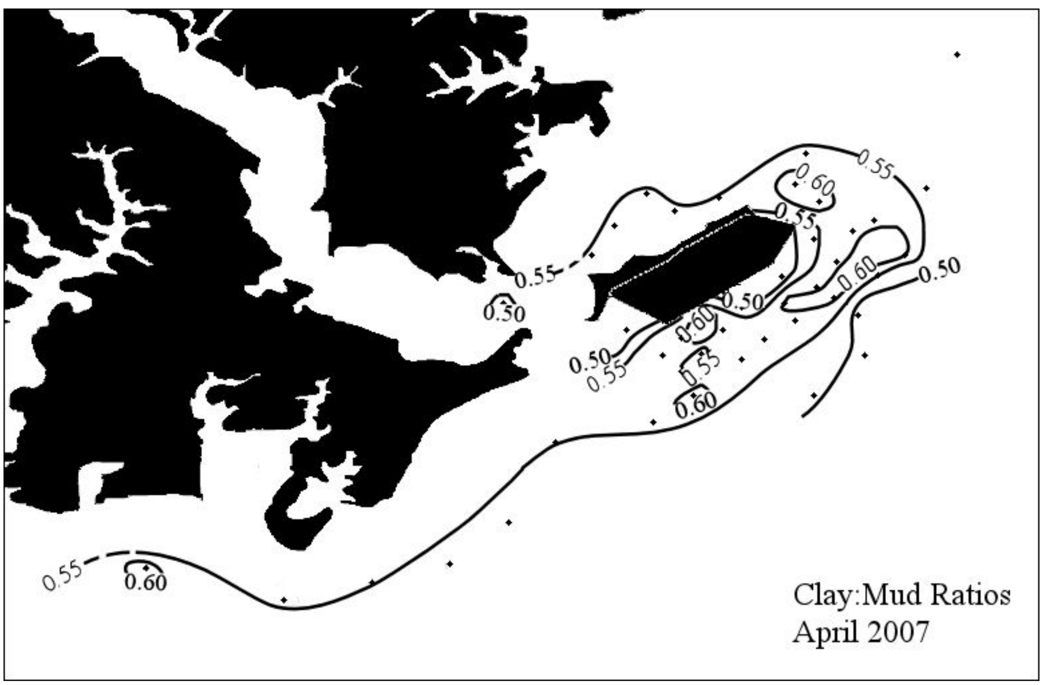


(b) Cruise 56

Figure 1-8. Sand distribution for Monitoring Year 26: (a) September 2007, (b) April 2008. Contour intervals are 10%, 50%, and 90% sand.

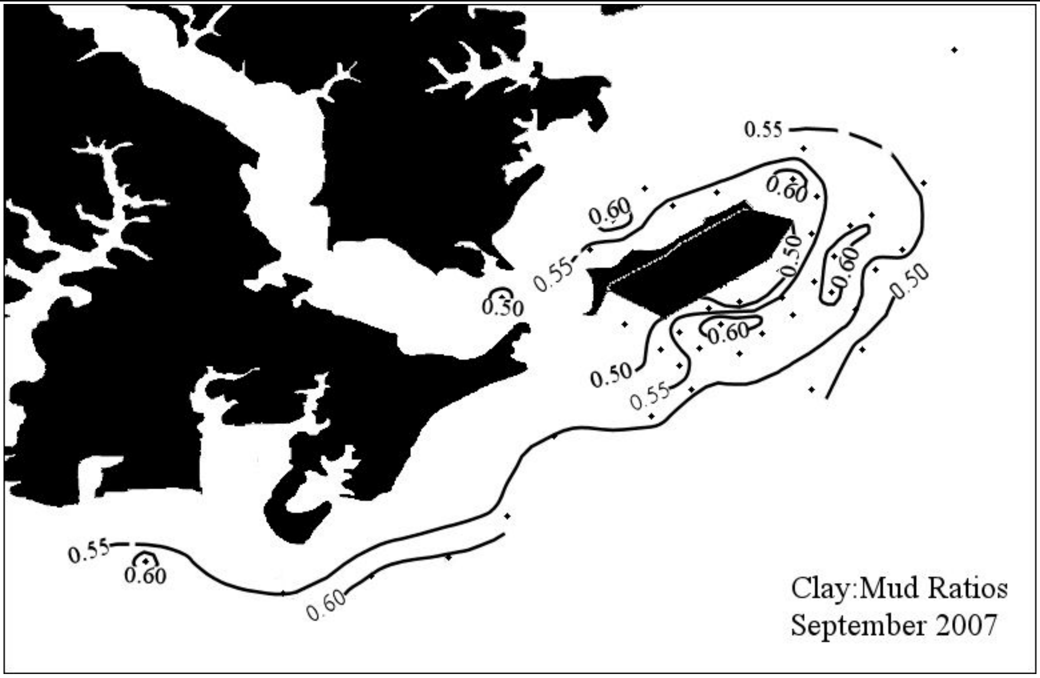


(a) Cruise 53

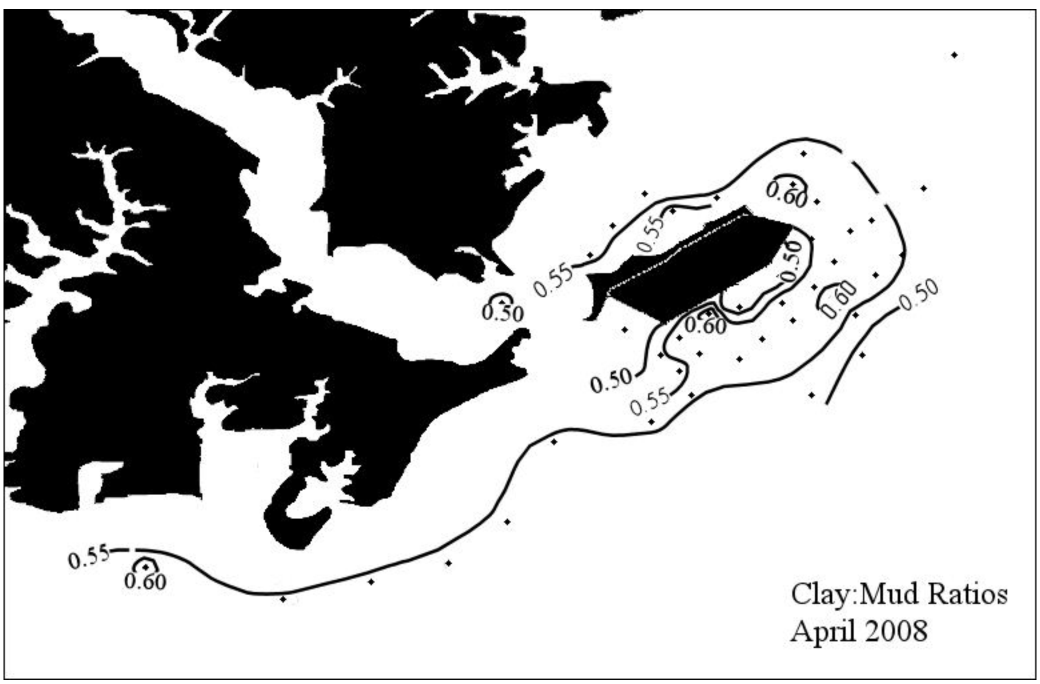


(b) Cruise 54

Figure 1-9. Clay:Mud ratios for Monitoring Year 25. Contour intervals are 0.50, 0.55, and 0.60.



(a) Cruise 55



(b) Cruise 56

Figure 1-10. Clay:Mud ratios for Monitoring Year 26. 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 2006, MDE-8, adjacent to the wall of the dike to the southeast, was the only silt-rich station for this sampling. Having only one silt-rich station in September 2006 is in direct relation to the larger number of clay-rich samples found during the same period that has been attributed to the increase rainfall during this time. In April 2007, six sites consisting of MDE-8 and MDE-16 adjacent to the wall of the dike to the southeast, MDE-24 adjacent to the south most end of the dike, MDE -11 and 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 both September 2007 and April 2008 as was MDE-27 in Back River and MDE-12. With the exception of the increase clay:mud ratio at MDE-11 to above 0.50 during September 2007 and April 2008, the silt rich sites for both of these cruises were identical to those found in April 2007. MDE-8 was silt-rich for all four samplings, while MDE-12, MDE-16, MDE-24 and MDE-27 were silt-rich for three of the four samplings. The silt-rich areas were consistent during both Year 25 and Year 26 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 25 and Year 26, one may conclude that the depositional environment in the vicinity of HMI was unchanged over this period. While there were a larger number of clay-rich sites in September 2006, there was a subsequent decrease in April 2007 that remained through April 2008. No clear trends affecting many samples from a large area are evident. The grain size distribution of Year 26 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 1-2. The correlations are excellent for Cr, Fe, Ni, Zn, and Pb, 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 1-2. Coefficients and R^2 (goodness of fit) 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	4.1	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 1-2 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 = ((measured Zn - predicted Zn)/predicted Zn) * 100   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 analytical variations must be taken into account. As a result of the normalization of the data, Gaussian statistics can be applied to the interpretation of the data. Data falling within ±2 standard deviations (±2σ) are within normal background variability for the region. Samples with a value of ±3σ 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 (σ) of the baseline data set (the data used to determine the coefficients in Equation 2) is the basis for determining the sigma level of the data. Each metal has a different standard deviation, as reflected in the R^2 values in Table 1-2. The sigma level for Zn is ~30 percent (e.g. 1σ = 30 percent, 2σ = 60 percent, etc.).

General Results

A listing of the summary statistics for the elements analyzed is given in Table 1-3. 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 1-11). Based on work done by the University of Maryland during Year 25 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 1-3. Summary statistics for elements analyzed. [All concentrations are in ug/g unless otherwise noted]

	P (%)	Cd	Cr	Cu	Fe (%)	Mn	Ni	Pb	Zn
Ave	0.0738	0.69	92	41	4.04	2520	76	57	319
Std	0.0315	0.28	42	18	1.56	1287	34	27	162
Min	0.002	bdl	7	3	0.25	322	5	5	19
Max	0.122	1.6	301	79	6.15	6460	153	134	838
n	86	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	3	63	61	n/a	n/a	77	58	73
ERM	n/a	9.5	370	270	n/a	n/a	52	218	410
#>ERM	n/a	0	0	0	n/a	n/a	67	0	17

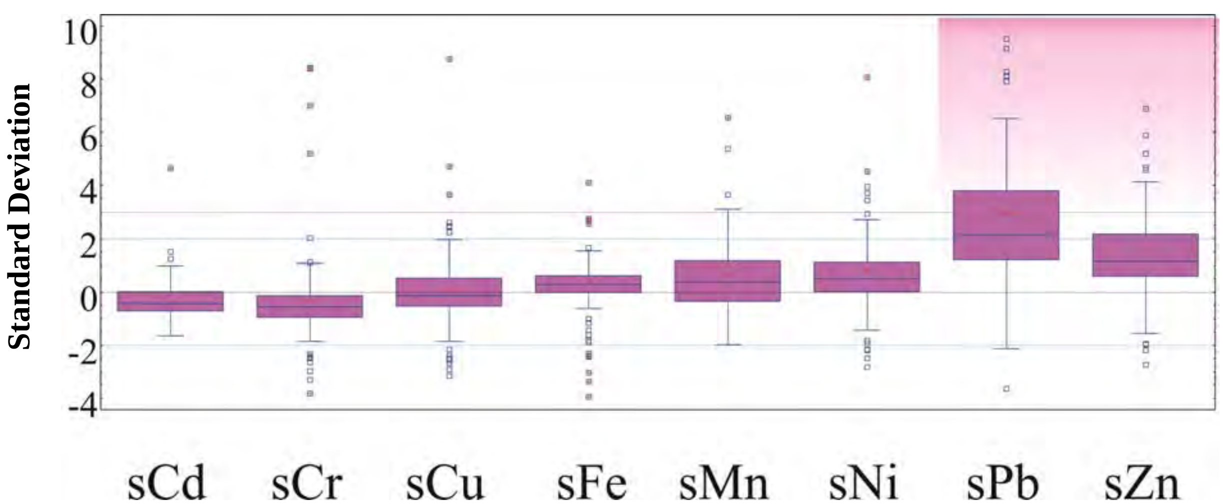


Figure 1-11. A box and whisker diagram showing the range of the data for both the fall and spring cruise.

The values presented in Table 1-3 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 1-11 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 approximately a quarter of the samples. Most of the samples with elevated metal levels 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 material inflow 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 1-12 shows the sigma levels for Pb for Year 26 monitoring periods in the study area adjacent to HMI; sigma levels for Zn are shown in Figure 1-13. 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 two to three sigma range are transitional; statistically one sample in 100 would normally be expected to occur, in a small data set. The occurrence of two or more spatially contiguous stations in this range is significant. Any sample >3 sigma is significantly elevated above background. The shading in Figures 1-12 and 1-13 is used to highlight the areas that are significantly elevated above baseline levels. As shown in Figure 1-1 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, having higher levels in the fall, compared to the spring cruise. The spatial extent is similar for both cruises. Zn concentrations were within background levels for spring cruise, but elevated in the fall. This differs from the preceding two monitoring years, where both fall and spring sampling cruises for Years 24 and 25 were at background levels.

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 elevated values as compared to Year 25. The levels diminished in the spring cruise, to levels comparable to the spring sampling in Year 25.

HMI - The area adjacent to HMI had metals (Pb and Zn) levels comparable to the two previous monitoring years (Year 24 and 25). The spatial extent this year was comparable to Year 25 with a clear separation of the zones of influence. The area around the South Cell discharge point, Spillway 003, was elevated for both metals for both cruises.

Based on the discharge operations of the HMI facility during this monitoring year, it would be expected that the facility would have statistically elevated metals from the South Cell; in contrast, the North Cell would not be expected to influence the exterior sediments (see *Facility Operations* section). Based on the discharge records for the South Cell 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 localized in the area of the South Cell discharge. The influence of the North Cell discharge is evident in the fall sampling and to a much lesser extent in the spring. The trend for material from the North Cell appears to be a trend diminishing toward background levels. The elevated area to the west of HMI in the fall sampling, which diminished in the spring, is a residual from the period prior to this year's sampling.

The spatial extent and the levels found in the Baltimore Harbor and Back River zones vary according to seasonal climatic changes, which influence the hydrodynamic conditions and sediment loading, and activity within those sources. Commonly the late summer - early fall levels are higher than the spring sampling for the Baltimore Harbor and Back River zones; this is the case for this monitoring year.

The HMI zone, prior to Year 22 monitoring, was 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 and continued through Year 26, 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, but comparable to the Year 25 monitoring. The data from this monitoring year are shown in Figure 1-14 as the solid points, which are comparable to 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 1-14 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.

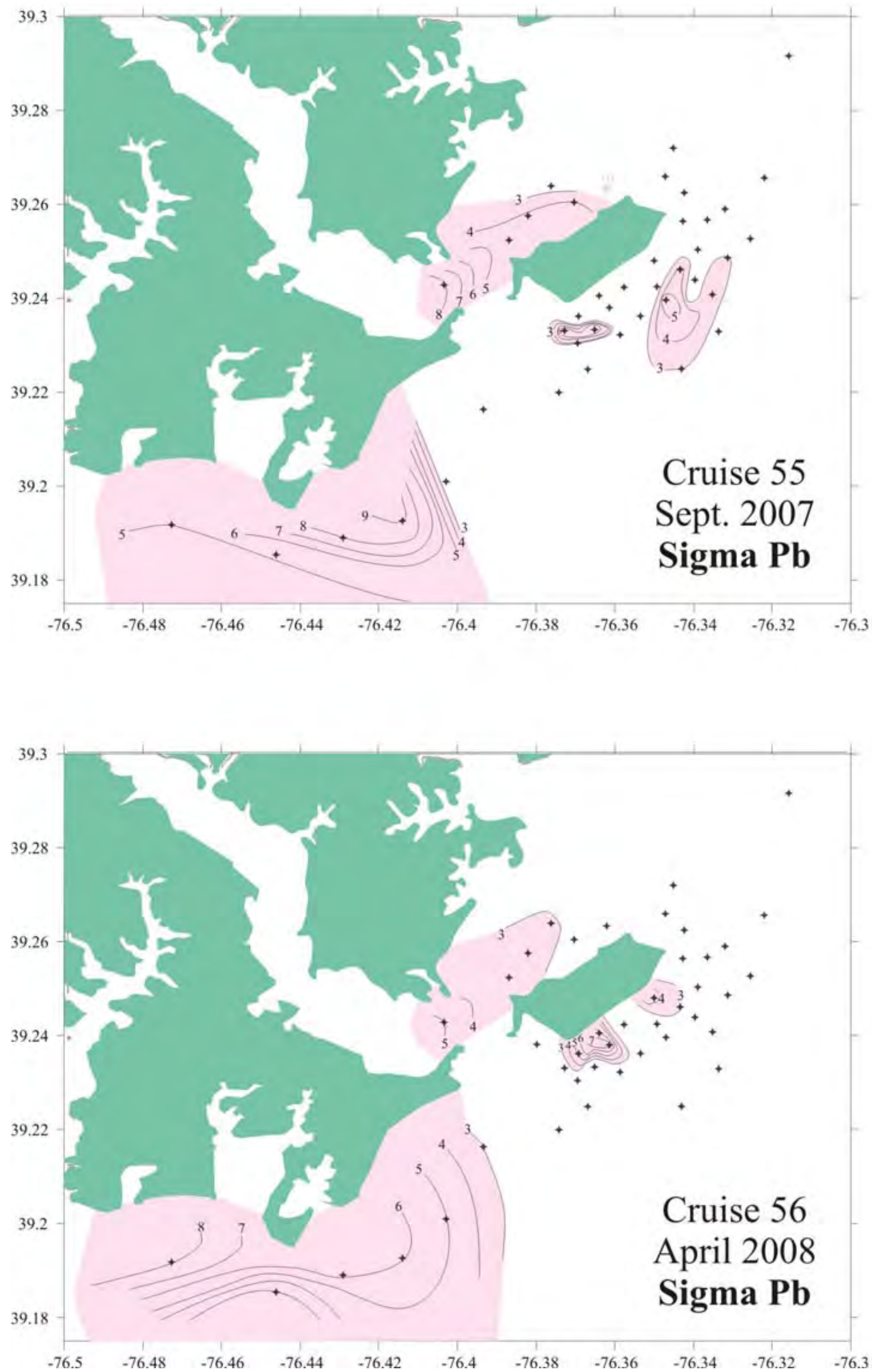


Figure 1-12. Distribution of Pb in the study area for the Fall and Spring sampling cruises. Units are in multiples of standard deviations - Sigma levels: 0 = baseline, +/- 2 = baseline, 2-3 = transitional(values less than 3 not shown), >3 = significantly enriched (shaded in figures).

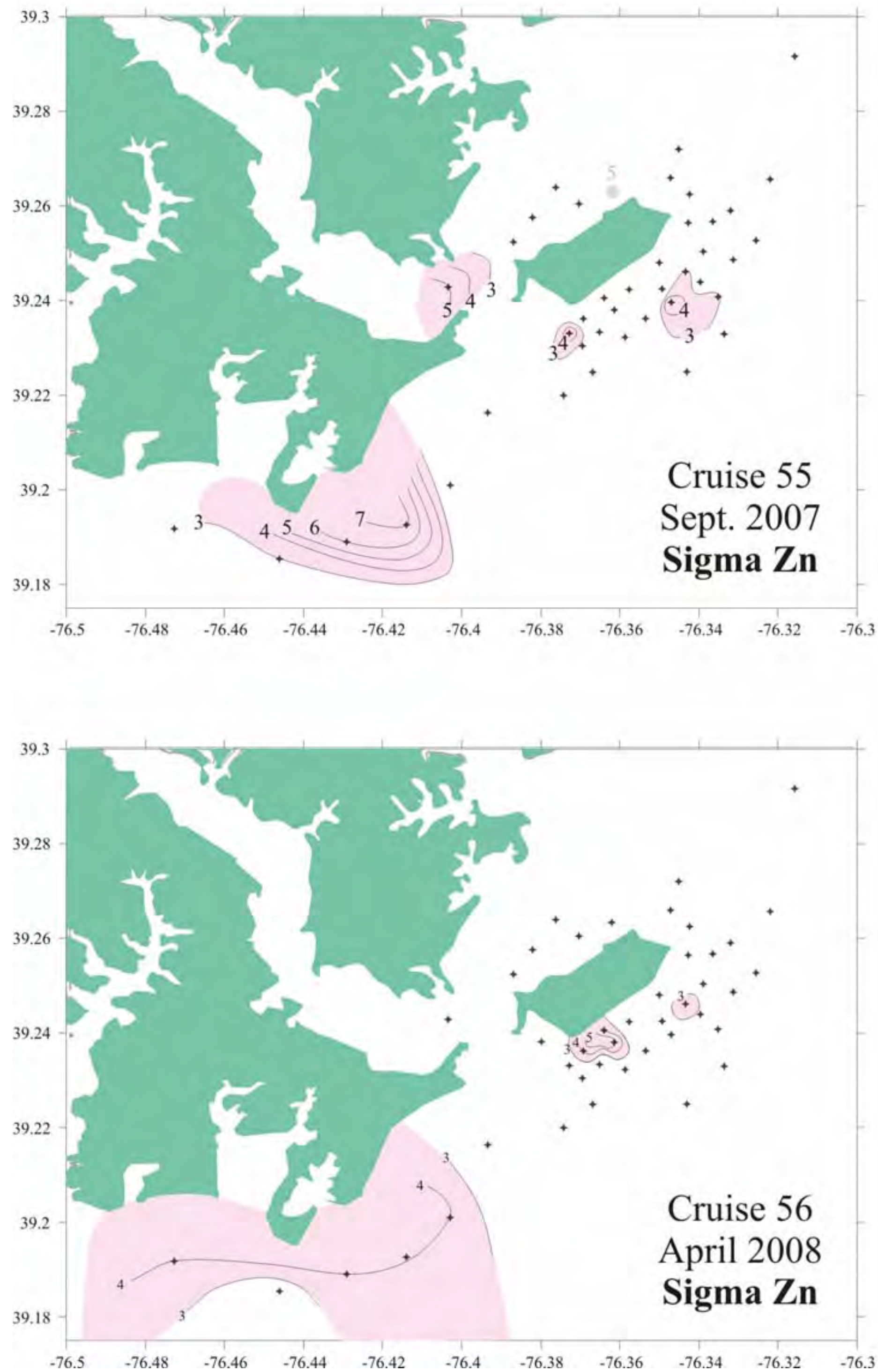


Figure 1-13. Distribution of Zn in the study area for the fall and spring sampling cruises. Units are in multiples of standard deviations - Sigma levels: 0 = baseline, +/- 2 = baseline, 2-3 = transitional(values less than 3 not shown), >3 = significantly enriched (shaded in figures).

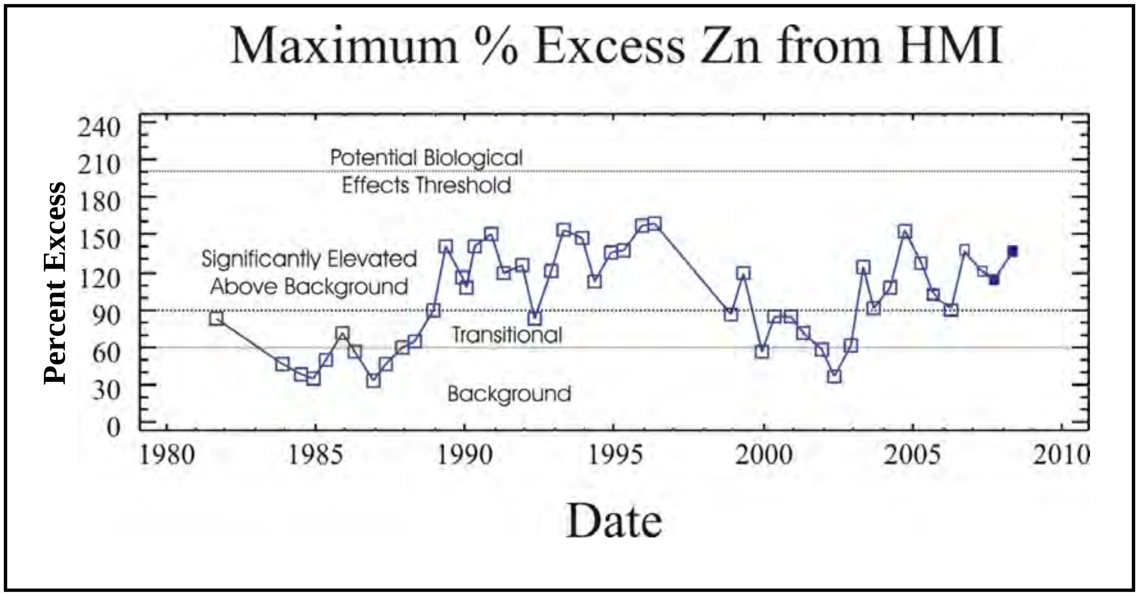


Figure 1-14. Record of the maximum % excess Zn for all of the cruises for which MGS analyzed the sediments. The filled points are the data from this study.

SUMMARY AND RECOMMENDATIONS

The grain size distribution of the Year 26 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 25 and Year 26. A slightly larger amount of clay content at several stations across the study area resulted in a larger number of clay-rich samples in September 2006 which may be attributed to the increased rainfall during this time period. 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 dominant clay-rich area continued to be the area to the south of HMI through both September 2007 and April 2008 with this 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 effluent discharge from HMI) and no significant changes occurred during Year 26.

The main reason for adding the Baltimore Harbor stations 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 26, 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 26 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 the overlap of enrichment and concentration can be used as an indicator of potential biological impacts: based on the intensity of the effect(enrichment based on sigma level, and concentrations exceeding ERL or ERM), 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 in Year 25, enrichments of Zn and Pb are probably the 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 shows enrichment from Baltimore Harbor and HMI; Back River had enriched samples in the September 2007 cruise only. Material from the Harbor did not influence the sediments in the HMI zone.

In the area affected by facility operations, Pb and Zn showed enriched levels when data is normalized to grain size. The September sampling cruise had higher levels, and a greater areal extent as compared to the April sampling west of the facility. This represents residual loading from the period proceeding this monitoring year, and shows a trend going to background levels. In the area adjacent to the South Cell, the behavior is the opposite with higher levels and greater areal extent in the spring as compared to the fall sampling. This reflects the input from the South Cell and 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. These conditions existed in the South Cell.

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 in the North Cell, but after December 31, 2009 the project will no longer accept dredged material. Consequently, the volume of effluent will decline as 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 MPA and 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 assess the potential influence of Baltimore Harbor on the HMI exterior sediments better, the additional sampling sites should be maintained, at least temporarily. Further, since the South Cell has been restored to an upland wetlands, the additional sample locations near the Spillway 003 discharge point should be maintained to assess this new operation of the facility as part of the on-going monitoring program.

In regard to discharge monitoring from the spillways, which follows the MDE discharge permit, 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 2007 (PROJECT II)

INTRODUCTION

Groundwater samples from six wells were collected in June and December 2007, 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 was equally divided between the North and South Cells as seen in Figure 1-15: North Cell 2A, 4A and 6A; South Cell 8A, 10A and 12A. The South Cell no longer receives dredged material.

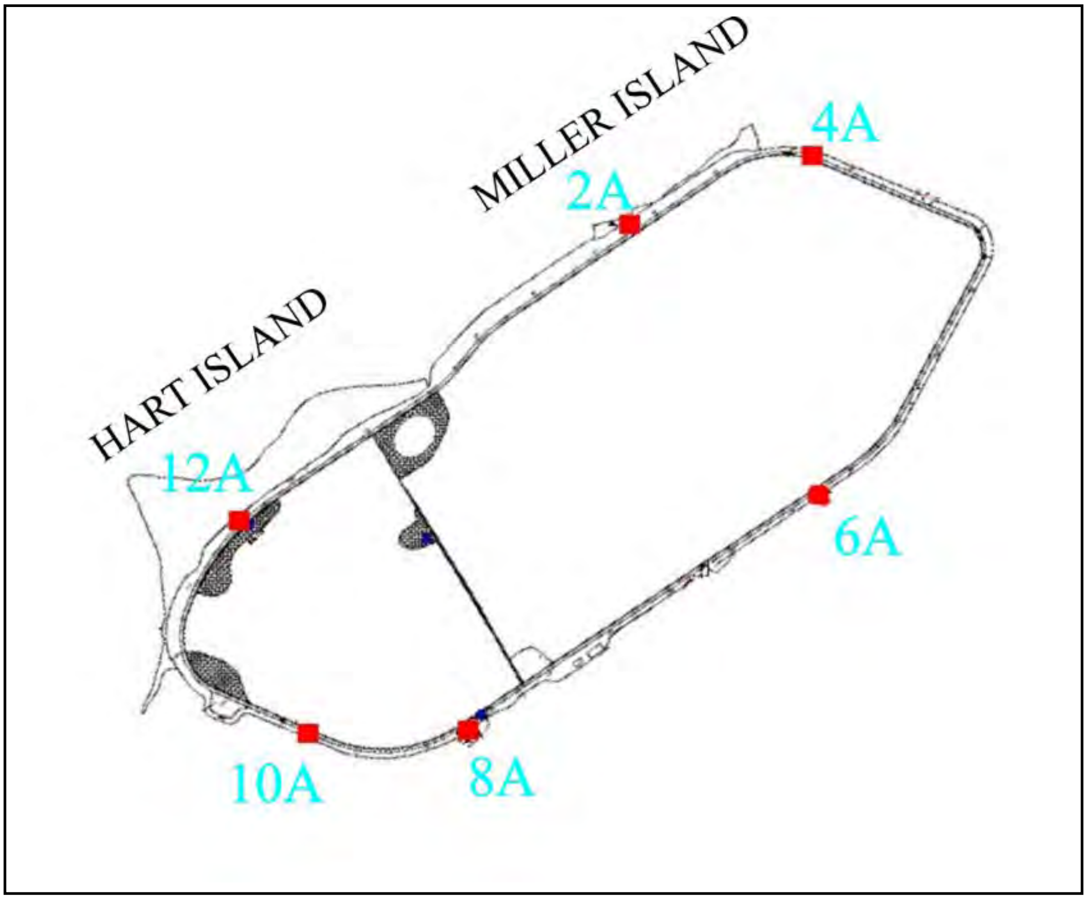

Figure 1-15. Groundwater sampling wells locations.

The North Cell on the other hand is actively receiving dredged material inflow and will continue to do so until December 31, 2009. The following report summarizes the data based on the interpretive methods detailed in the 2005 well study report (Hill,2005)

SUMMARY OF DATA

All 6 Wells

1. All of the wells are anoxic or hypoxic, with dissolved oxygen (DO) levels recorded at less than 0.8 mg/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. Sulfide 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 (<0.15 mg/L). 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 and 6A

1. The groundwater showed a reducing environment based on the depletion in sulfate in comparison to predicted concentrations. The predicted levels were calculated from the chloride concentration based on conservative mixing between rainwater and seawater. Figure 1-16 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).

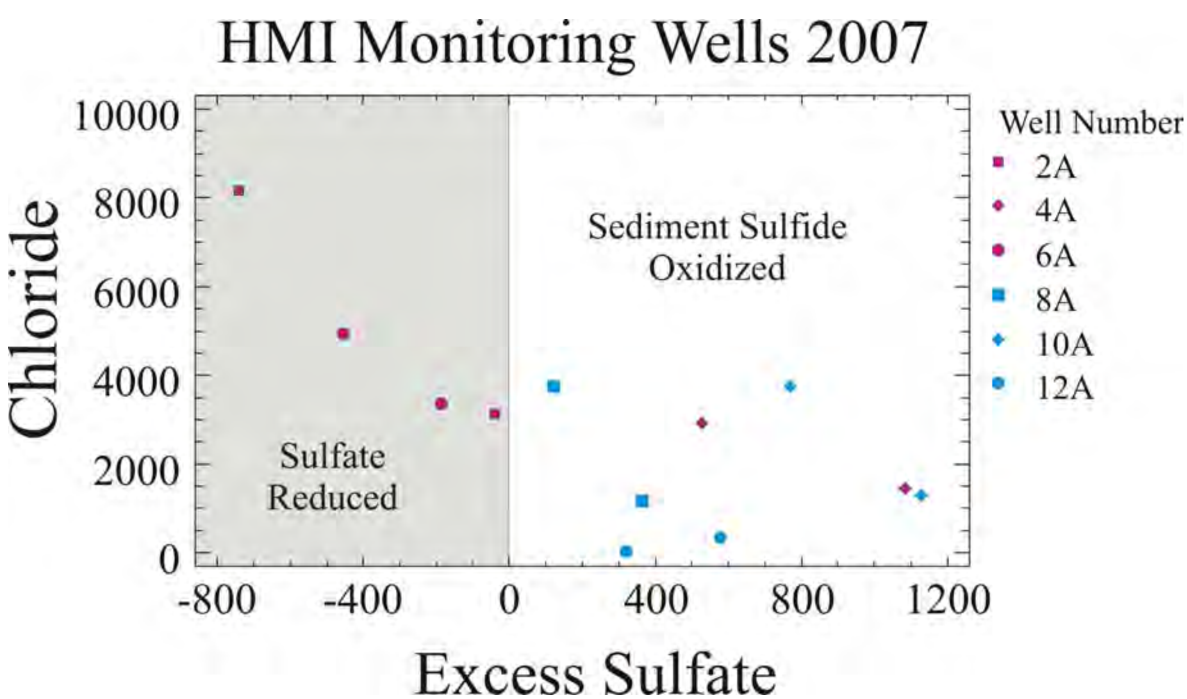

Figure 1-16. Groundwater Chloride concentrations as a function of Excess Sulfate (the difference of the measured sulfate concentrations minus the predicted concentrations).

2. These wells had higher salinity, as seen from the chloride concentrations (Figure 1-16). The higher levels are the result of replenishment of more saline water from the Bay as a result of dredged material inflow operations.
3. Alkalinity concentrations were higher than the other sites as a result of not being neutralized by acid production.
4. Metal concentrations were generally low as a result of not being leached 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 (Figure 1-17; negative Excess Sulfate). Most of the metals measured [except As] were near or below the detection limit.

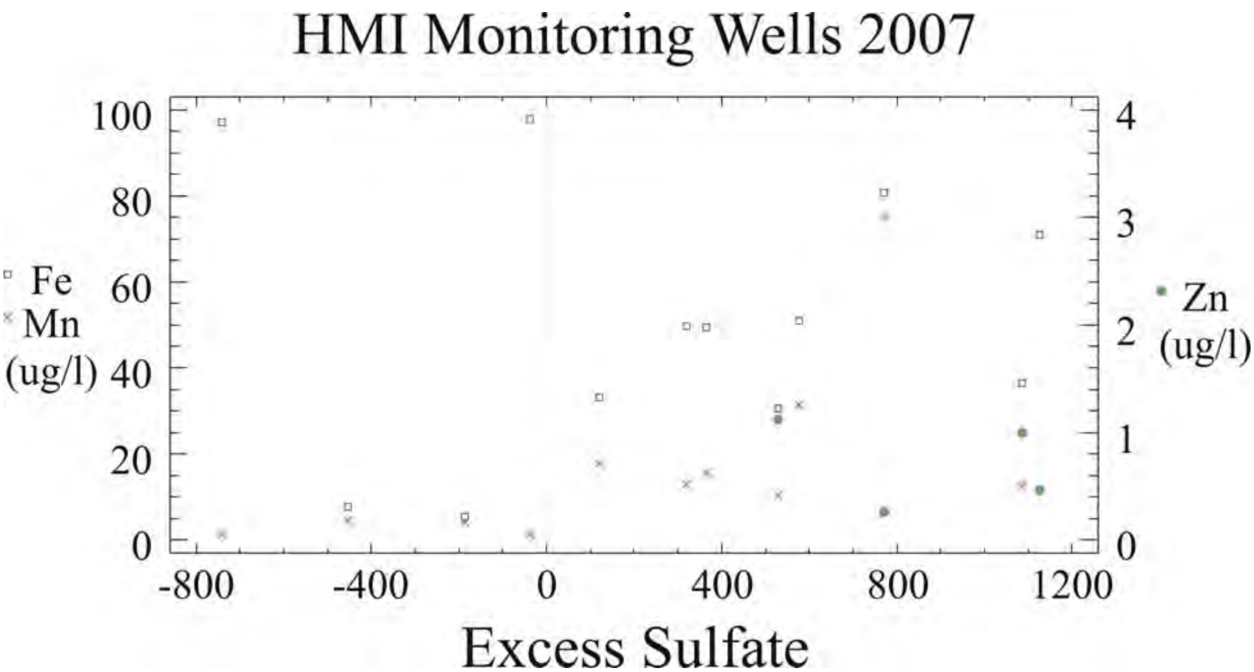

Figure 1-17. Fe, Mn and Zn concentrations as a function of Excess sulfate. Note samples below detection limits are not shown.

5. The major cations were 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 (see Figure 1-18).

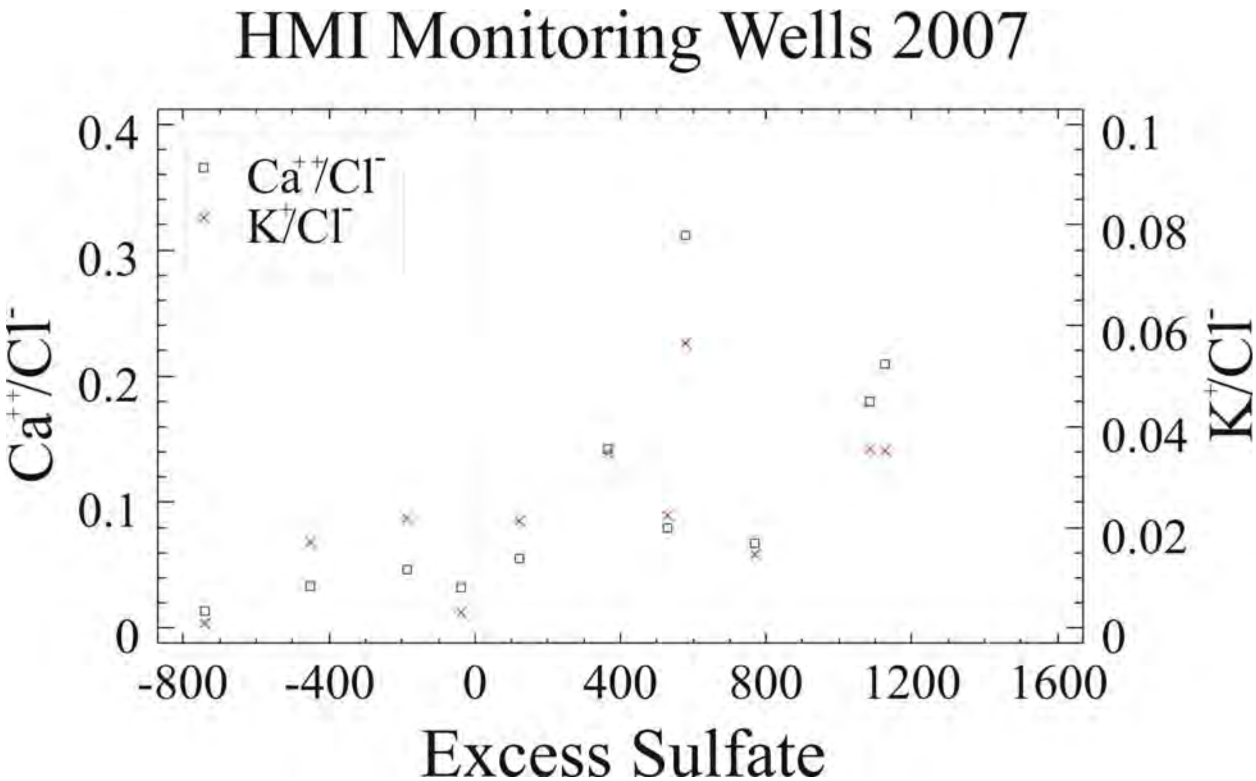

Figure 1-18. The ratios of K+/Cl- and Ca++/Cl- as a function of Excess Sulfate. For reference, the ratios for both of these cations in seawater is ~0.02.

6. Total dissolved nitrogen (as ammonium) for 6A was about three times higher in the wells 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 and 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 1-16).
2. Rainwater appeared to be a major source of water to these wells due to the lower chloride concentrations that dilute the Bay concentrations.
3. Ammonium was lower,
4. Metals and cations were greater than predicted from conservative mixing and from anoxic sulfidic pore water conditions,
5. Alkalinity was lower than in the North Cell.

Based on the above, rainwater appeared to be a major source of water to these wells, and the sediments were to some extent exposed to the atmosphere. The exposure of the sediment to ambient air provided opportunity for 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.

PROCESSES OPERATING IN HMI GROUNDWATER

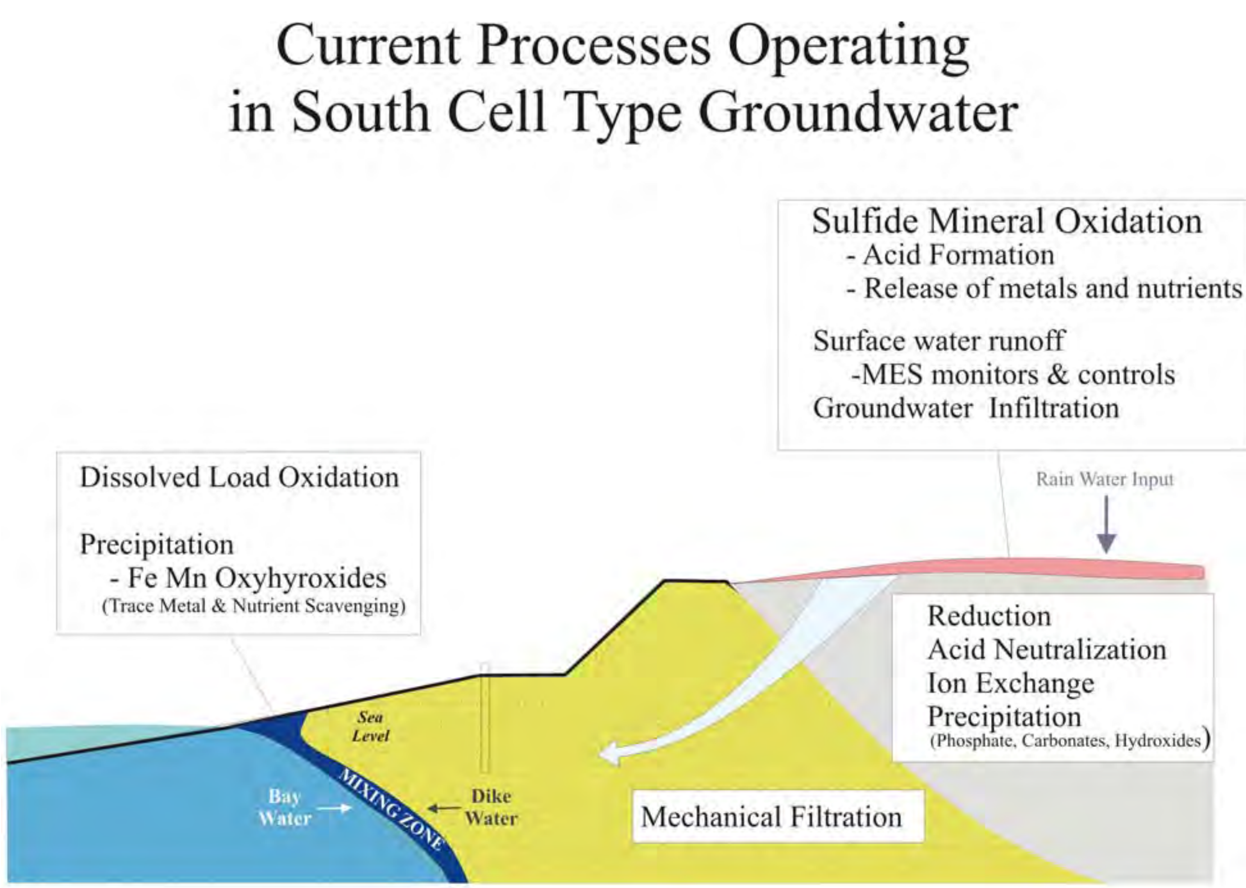

Figure 1-19. Schematic presentation of the processes which produce the ground water similar to those found in the South Cell wells.

Figure 1-19 shows a hypothetical cross section of HMI at the South Cell. Hydrodynamically, there are five areas to consider:

1. *The surface sediments of the interior of the cell*. Here ***if*** the sediment are kept inundated the sediment and the associate pore fluids would be anoxic and would have the characteristics of normal Bay sediments. This is the situation in the North Cell. However in the South Cell circumstance, the material for the most part is sub-areal with rain water being the primary source of water to the system. The occluded water native to

the dredged material is diluted by the fresh rain water; this lowers the dissolved load derived from dilution of sea water in the Bay waters. Since the hydrated sediment is exposed to atmospheric oxygen, aerobic processes are in operation. One of the most significant reactions is the oxidation of the naturally occurring sulfide minerals (primarily iron monosulfides and pyrite) that produces sulfuric acid. The acidified waters have sulfate concentrations in excess of conservative mixing. The oxidation of the sulfide minerals significantly increase the levels of Fe and Mn, and the free acid can react with the sediment to release other metals and acid soluble nutrients and trace organic compounds. This acidified water is either entrained in surface water run off or infiltrates into the sediment in the dike forming the ground water flow through the dike. The surface water is monitored and controlled by MES under an MDE issued discharge permit.

2. *Dredged sediment in the dike.* When the acidified waters infiltrate into the dredged sediment they enter an organic rich environment that is isolated from the atmosphere. Here several processes occur: the acid is neutralized by naturally occurring material such as shell material which contains calcium carbonate; acid and metals are bound by ion exchange processes; the reduction in acidity causes precipitation of insoluble metal compounds (with anions such as phosphate and carbonate); and reduction occurs which removes oxygen and changes the environmental conditions waters are in. The flow of water through the dike is relatively fast compared to the rate of reduction since the concentrations of sulfate in the groundwater are high relative to conservative mixing (this is shown as the positive Excess Sulfate in the preceding figures). If strongly reducing conditions existed all of the sulfate would be reduced and the sulfide produced would be significantly removed by sulfide mineral formation as in the North Cell.
3. *Movement through the dike walls.* The dike walls are made of clean sands, thus are relatively inert; however they act as a mechanical filter. As a filter the dike retains the fine sediment placed in the dike, and removes the precipitates that form as the water reacts in the contained sediment. Eventually as with any filter, it would be expected that the filter (i.e. the dike walls) will become plugged as material is trapped along the flow lines. This is the area where the sampling wells are located. The ground waters sampled at this point reflect changes in the water chemistry resulting from transport through the three zones outlined above.
4. *Mixing with Bay water.* As the ground water travels the dike as a result of the hydraulic gradient it will encounter and mix with Bay water within the dike wall. The water from the dike is more dilute than bay water so there will be some degree of floating, or riding over, of the less dense dike water on top of the more saline Bay water. The Bay water is aerated and slightly alkaline. This water will react with the dike water oxidizing the reduced water and precipitating iron oxy-hydroxides and other redox sensitive species. These precipitates are effective in scavenging trace metals and phosphate.

As noted the sampling wells are located in the sandy matrix of the dike walls which act as a filter for the ground water. Ground waters are anaerobic for all of the sampling wells; the South Cell type wells have undergone an initial oxidation stage that the North Cell has not. Table 1-4 is a summary of the trace metal data for the ground waters sampled in 2007; listing the number of samples, the number below detection, the maximum and minimum concentration and the EPA Maximum Concentration level in drinking water (MCL). For the most part, the concentrations of the metals are low.

Table 1-4. Monitoring Wells Trace Metal Analyses for 2007 (two sampling periods). Detection Limit (*dl*), *Min, Max and MCL* are in units of mg/l.

	North Cell Type (2A and 6A)					
	n	***n<dl***	***dl***	***Min***	***Max***	***MCL***
Al	4	4	0.05			0.05 - 0.2
As	4	0	0.01	0.016	0.038	0.05
Cd	4	4	0.002			0.005
Cr (total)	4	4	0.005			0.1
Cu	4	4	0.005			1.3
Fe	4	0		5.5	98	0.3
Pb	4	4	0.01			0.015
Mn	4	0		1.41	4.42	0.05
Zn	4	4	0.005			5
Ag	4	4	0.001			0.1
	South Cell Type (4A, 8A, 10A and 12A)					
	n	***n<dl***	***dl***	***Min***	***Max***	***MCL***
Al	8	8	0.05			0.05 - 0.2
As	8	0	0.001	0.007	0.021	0.05
Cd	8	8	0.002			0.005
Cr (total)	8	5	0.005	0.009	0.016	0.1
Cu	8	8	0.005			1.3
Fe	8	0		30.5	80.5	0.3
Pb	8	6	0.01	0.01	0.012	0.015
Mn	8	0		10.4	75	0.05
Zn	8	4	0.005	0.026	1.12	5
Ag	8	6	0.001			0.001

Note:
MCL – EPA and NOAA Maximum Concentration Level for Groundwater
North Cell Type – Maintained Pore water behavior
South Cell Type – Oxidation at Surface followed by neutralization and partial reduction

The North Cell samples were the lowest with all of the metals except Fe, Mn, and As below detection. The South Cell had more metals at detectable concentrations; however, they were still low with respect to the MCL. Fe and Mn were the only metals with concentration that exceed the MCL, these are not considered a health risk but affect the taste and quality of the water. These metals precipitate from solution in aerobic conditions, so as the water mixes with Bay water further down the flow line these metals will precipitate as metal oxyhydroxides. The metal rich precipitate will cement the sands and make the dike more impermeable with time.

APPENDIX 2: BENTHIC COMMUNITY STUDIES (PROJECT III)

(September 2007 – August 2008)

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-DMCF) was studied for the twenty-sixth consecutive year under Project III of the HMI Exterior Monitoring Program. Benthic 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, and 3 South Cell Exterior Monitoring stations) were sampled on September 6, 2007 and on April 10, 2008.

A total of 34 benthic macroinvertebrate taxa were identified during Year 26. Several taxa were clearly dominant. The worms *Marenzelleria viridis* and Naididae sp.[1], the clam *Rangia cuneata,* and the arthropods *Leptocheirus plumulosus* and *Cyathura polita* were among the dominant taxa on both sampling dates. Taxa abundance varied greatly for certain taxa between the two seasons in Year 26 (September 2007 and April 2008). The worm *Streblospio benedicti* declined from the fourth most abundant taxa in the fall to the eighteenth most abundant taxa in the spring, while *Heteromastus filiformis* increased from the twelth most abundant to the fourth most abundant taxa. Polychaete taxa richness was similar for the two cruises. Total abundance (excluding Bryozoa and Copepoda) was higher at most stations in April 2008 than September 2007, primarily due to the spring recruitment of the worms Naididae sp. and *M. viridis*.

Species diversity was examined using the Shannon-Wiener diversity index (SWDI). Diversity was higher in September 2007 than in April 2008 at all stations except MDE-19, MDE-27, MDE-35 and MDE-43. The proportion of pollution sensitive taxa (PSTA) and pollution indicative taxa (PITA) was calculated for both cruises. The PSTA and PITA percentages were similar for both cruises, even though salinity changed from low mesohaline in September 2007 to oligohaline in April 2008.

The Chesapeake Bay Benthic Index of Biotic Integrity (B-IBI, Weisberg et al. 1997, Llanso, 2002), 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 2007. Overall, the Year 26 B-IBI scores declined somewhat from Year 25. Fifteen stations met or exceeded the benchmark criteria of 3.0, and five stations failed to meet the benchmark. The five failed stations included one Nearfield station (MDE-19), two Back River stations (MDE-27 and MDE-30), and two South Cell Exterior Monitoring stations (MDE-42 and MDE-43).

There were differences in the mean B-IBI scores among the four station types (Back River/Hawk Cove, South Cell Exterior Monitoring, Nearfield, and Reference). This occurred because the Back River and South Cell Monitoring stations failed to achieve the benchmark (B-

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

IBI $\geq$3.0), while the Nearfield and Reference stations exceeded the benchmark. In contrast, the Friedman's test and cluster analysis results did not indicate significant community differences between station types. Overall, the mean B-IBI scores for each station type were slightly lower (but not significant) than their historic means.

INTRODUCTION

Annual dredging of the shipping channels leading to the Port of Baltimore is necessary to maintain safe navigation. 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-DMCF) was constructed to accommodate the dredged material management needs for the Port of Baltimore and specifically the need to manage contaminated sediments dredged from Baltimore's Inner Harbor.

HMI is a 1,140-acre artificial island surrounded by a 29,000-foot long dike constructed along the historical footprints of Hart and Miller Islands at the mouth of the Back River. A series of four spillways are located around the facility's perimeter that discharge excess water released from on-site dredged material disposal operations.

As part of the environmental permitting process for dredged material containment facilities, an exterior monitoring program was developed to assess any environmental impacts associated with HMI. Various agencies have worked together since the inception of this program to monitor for environmental impacts resulting from facility construction and operation. 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 inter-seasonal and inter-annual data. Benthic monitoring is no longer a permit requirement, but is continued voluntarily by the Maryland Port Administration (MPA). Since HMI will no longer receive dredged material as of December 31, 2009, Year 28 will represent the culmination of monitoring data collected during 28 years of dredged disposal operations, beginning with the pre-operational phase in 1981. In Year 26 (and since Year 17), the Maryland Department of the Environment (MDE) was responsible for all aspects of benthic community monitoring. Post closure monitoring is expected to begin in Year 28 and continue through at least Year 30.

The goals of the Year 26 benthic community monitoring were:

- To monitor the benthic community condition; 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 HMI monitoring studies over the operational phase of the project; 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 effects resulting from the South Cell closure and restoration.

METHODS AND MATERIALS

MDE staff collected all macroinvertebrate and water quality samples in Year 26. Field sampling cruises were conducted on board the Maryland Department of Natural Resources vessel "*R/V Kerhin*". Twenty fixed benthic stations were monitored during both fall and spring cruises (Table 2-1; Figure 2-1). Environmental parameters recorded at the time of sample collection are included in Tables 2-2 through 2-5.

Table 2-1. Sampling stations (latitudes and longitudes in degrees, decimal minutes), 7-digit codes of stations used for Year 26 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 Stations					
MDE-01	39^o 15.3948	-76^o 20.5680	Sand	Sand	XIF5505
MDE-03	39^o 15.5436	-76^o 19.9026	Silt/clay	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	Silt/clay	Silt/clay	XIF4806
MDE-16	39^o 14.5368	-76^o 21.4494	Silt/clay	Silt/clay	XIF4615
MDE-17	39^o 14.1690	-76^o 21.1860	Sand	Silt/clay	XIF4285
MDE-19	39^o 14.1732	-76^o 22.1508	Silt/clay	Silt/clay	XIF4221
MDE-24	39^o 14.2650	-76^o 22.7862	Sand	Sand	XIF4372
MDE-33	39^o 15.9702	-76^o 20.8374	Sand	Sand	XIF6008
MDE-34	39^o 15.7650	-76^o 20.5392	Sand	Sand	XIF5805
MDE-35	39^o 16.3182	-76^o 20.7024	Silt/clay	Silt/clay	XIF6407
Reference Stations					
MDE-13	39^o 13.5102	-76^o 20.6028	Silt/clay	Silt/clay	XIG3506
MDE-22	39^o 13.1934	-76^o 22.4658	Silt/clay	Silt/clay	XIF3224
MDE-36	39^o 17.4768	-76^o 18.9480	Silt/clay	Silt/clay	XIG7589
Back River/Hawk Cove Stations					
MDE-27	39^o 14.5770	-76^o 24.2112	Silt/clay	Silt/clay	XIF4642
MDE-28	39^o 15.3900	-76^o 22.7304	Silt/clay	Silt/clay	XIF5232
MDE-30	39^o 15.8502	-76^o 22.5528	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

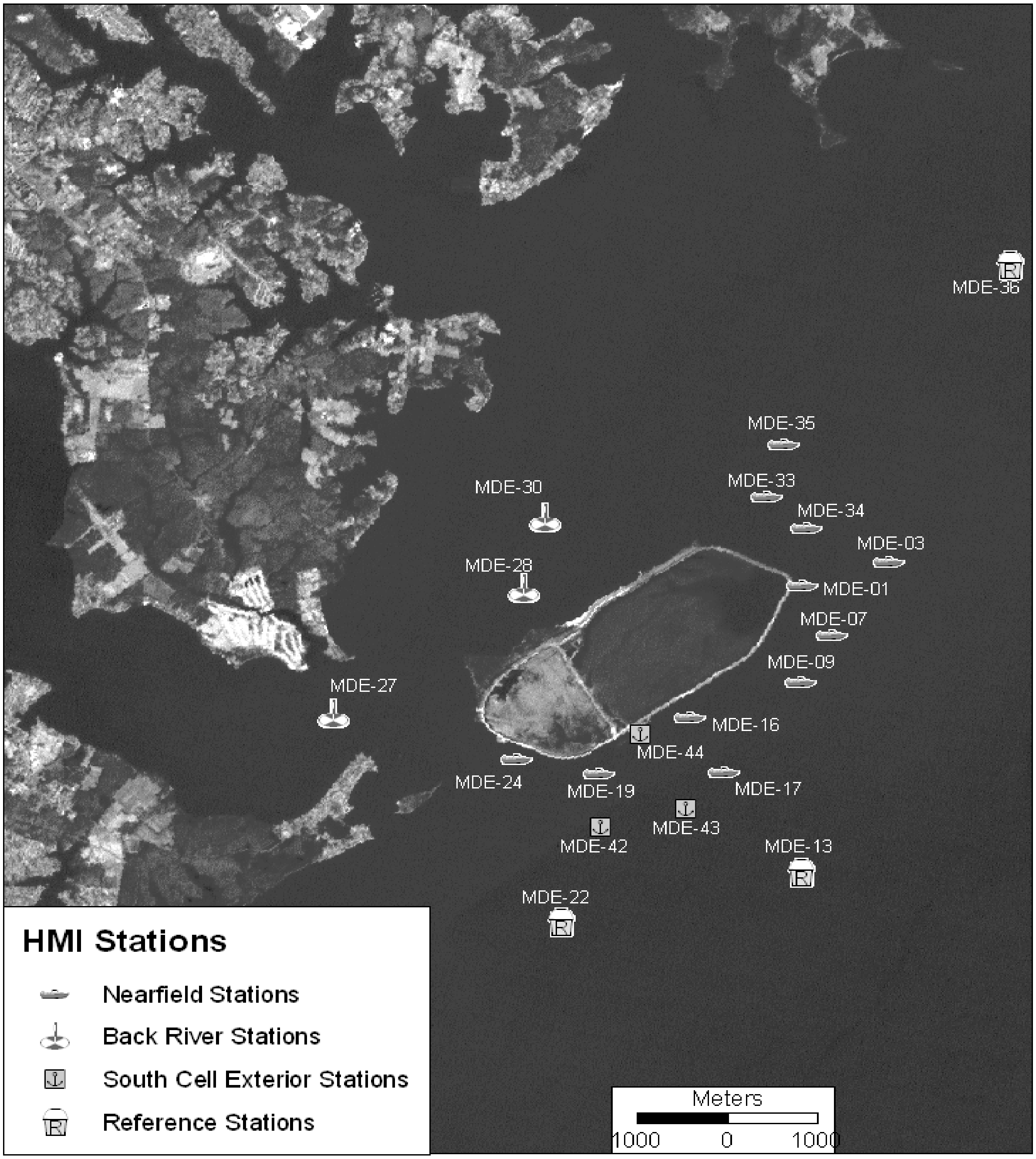

Figure 2-1. Year 26 benthic sampling stations for the HMI exterior monitoring program.

All stations sampled during Year 25 of monitoring were again sampled for Year 26. Stations were classified by location and dominant sediment type (Table 2-1). 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 Yellow Springs Instruments (YSI) multi-parameter water quality meter in September 2007 and a Hydrolab Surveyor 4a multi-parameter water quality meter in April 2008. 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 2-2 and 2-4) 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 percent 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 percent ethanol. All laboratory staff were required to achieve a minimum baseline sorting efficiency of 95 percent and quality control checks were performed for every sample to ensure a minimum 90 percent recovery of all organisms in a replicate sample.

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 (raw data) is presented in the *Year 26 Data Report.* Members of the insect family Chironomidae (midges, very small flies) 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. An independent taxonomist verified 10 percent of all samples identified.

Six 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 (SWDI), taxa richness, and total abundance of all taxa (excluding Nematoda, Copepoda, and Bryozoa). Three of these measures (total infaunal abundance, relative abundance of pollution-indicative infaunal taxa, and SWDI) were used to calculate the B-IBI for September 2007. 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 2008 data. In addition to the above metrics, the numerically dominant taxa during each season and the length frequency distributions of the three most common clams (*R. cuneata*, *M. balthica*, and *M. mitchelli*) 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 26 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 SWDI (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 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 2007 and April 2008 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 2007 and April 2008. 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 2007 (Table 2-3, range=0.80 m-1.00 m, average = 0.93 m ± 0.08 m) than those in April 2008 (Table 2-5, range=0.40 m-0.70 m, average=0.47 m ± 0.08 m). 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 three parameters as bottom water quality measurements are most relevant to benthic macroinvertebrate health. In Year 26, bottom water temperatures did not vary much between stations during both sampling seasons. The September 2007 mean bottom water temperature (Table 2-3, mean=25.62°C ± 0.40°C, range= 25.17°C – 26.25°C) was 1.15ºC higher than the 21-year fall average of 24.47ºC. Bottom water temperatures were seasonably lower in April 2008 (Table 2-5) with a range of 9.73°C –11.05°C and an average of 10.20°C ± 0.34°C. April 2008 mean temperature was 1.84ºC lower than the 10-year spring average of 12.06ºC.

The bottom DO concentrations exceeded water quality standards, as given in the Maryland Code of Regulations (COMAR), during both seasons. The September 2007 mean bottom DO (Table 2-3, range=6.82 ppm-8.19 ppm, average=7.57 ppm ± 0.37 ppm) was 0.15 ppm higher than the 10-year fall average of 7.42 ppm. The April 2008 mean bottom DO (Table 2-5, range=8.74 ppm - 11.72 ppm, average=10.66 ppm±0.55 ppm) was 0.29 ppm higher than the 10-year spring average of 10.37 ppm. Historically fall DO is 2.95 ppm lower than spring DO due to reduced oxygen solubility with elevated seasonal temperatures. The lowest DO value (6.82 ppm) occurred at Station MDE-9 in September 2007. This reading was well above the 5 ppm State standard established to protect aquatic life. This project has never observed a mean bottom DO below 6.30 ppm for any station type.

This region of the Bay typically ranges between the oligohaline (0.5 ppt – 5 ppt) and mesohaline (>5 ppt – 18 ppt) salinity regimes (Lippson and Lippson 1997). The 22-year mean bottom salinity is 6.09 ppt. Low mesohaline conditions were found during the fall 2007 sampling. Oligohaline conditions were found during the spring 2008 sampling season. During the spring sampling cruise all stations were oligohaline except MDE-33, 34, 35, and 36, all of which fell into the tidal fresh salinity regime (0 ppt - 0.5 ppt, Table 2-5).

Salinity values varied considerably between September 2007 (Table 2-3, mean=9.32 ± 1.03 ppt, range=7.76 ppt -11.24 ppt) and April 2008 (Table 2-5, mean=0.75 ppt ± 0.30 ppt, range=0.39 ppt -1.50 ppt). Both fall and spring salinities were well within the historical salinity range. This region of the Bay is subject to significant salinity fluctuations resulting from large inter-annual variation in rainfall in the watershed. High salinity values during the fall occur regularly and are caused by drier summer conditions. The low salinity values during the spring are typically the result of freshets. The 22-year mean salinity is 3.34 ppt higher in the fall than the spring.

Table 2-2. Year 26 physical parameters measured *in situ* at all HMI stations on September 6, 2007.

MDE Station	Time	Tide	Water Depth (m)	Wave Height (m)	Wind Direction	Wind Speed (knots) Min.	Max	Air Temp. (ºC)	Cloud Cover (%)	Weather Past 24 hrs.	Today	Observed Bottom Sediment (%) silt/clay	sand	shell	gravel	detritus
MDE-01	10:42	Ebb	3.85	0.3	SE	5	7	26	20	0	0	0	75	25	0	0
MDE-03	10:52	Ebb	5.47	0.3	SE	5	7	26	20	0	0	40	30	30	0	0
MDE-07	10:29	Ebb	5.16	0.3	SE	5	7	26	20	0	0	15	60	25	0	0
MDE-09	10:18	Ebb	5.27	0.3	SE	5	7	27	20	0	0	60	0	40	0	0
MDE-13	9:48	Ebb	4.83	0.3	SE	5	7	25	20	0	0	75	0	25	0	0
MDE-16	10:08	Ebb	4.50	0.3	SE	5	7	27	20	0	0	60	0	40	0	0
MDE-17	9:59	Ebb	5.23	0.3	SE	5	7	25	20	0	0	30	40	30	0	0
MDE-19	9:17	Ebb	4.73	0.3	SE	5	7	25	20	0	0	90	0	10	0	0
MDE-22	8:34	Ebb	5.47	0.3	SE	5	7	24	20	0	0	90	0	5	0	5
MDE-24	9:07	Ebb	3.15	0.3	SE	5	7	26	20	0	0	5	90	5	0	0
MDE-27	12:20	Ebb	3.53	0.3	SE	5	7	27	20	0	0	80	0	5	0	15
MDE-28	12:06	Ebb	2.86	0.3	SE	5	7	27	20	0	0	75	0	10	0	15
MDE-30	11:51	Ebb	3.40	0.3	SE	5	7	27	20	0	0	60	0	20	0	20
MDE-33	11:11	Ebb	2.52	0.3	SE	5	7	26	20	0	0	0	90	10	0	0
MDE-34	11:05	Ebb	3.01	0.3	SE	5	7	27	20	0	0	25	70	5	0	0
MDE-35	11:19	Ebb	4.10	0.3	SE	5	7	27	20	0	0	50	45	5	0	0
MDE-36	11:32	Ebb	3.34	0.3	SE	5	7	26	20	0	0	75	0	25	0	0
MDE-42	8:55	Ebb	3.63	0.3	SE	5	7	27	20	0	0	75	0	20	0	5
MDE-43	9:36	Ebb	5.03	0.3	SE	5	7	26	20	0	0	80	0	20	0	0
MDE-44	9:26	Ebb	5.10	0.3	SE	5	7	27	20	0	0	70	25	5	0	0

Note: The weather code 0 (zero) stands for “clear with no clouds”

Table 2-3. Year 26 water quality parameters measured *in situ* at all HMI stations on September 6, 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	0.5	8.19	25.60	7.91	7.74	0.8	14,160
		Bottom	3.35	8.73	25.17	7.35	7.70		15,030
MDE-03	XIG5699	Surface	0.5	9.22	25.41	7.48	7.71	1	15,800
		Bottom	4.97	9.21	25.21	7.2	7.70		15,780
MDE-07	XIF5302	Surface	0.5	8.67	25.39	7.72	7.74	0.9	14,920
		Bottom	4.66	8.97	25.11	7.01	7.62		15,400
MDE-09	XIF4806	Surface	0.5	8.16	25.58	7.81	7.77	0.9	14,120
		Bottom	4.77	9.03	25.12	6.82	7.68		15,510
MDE-16	XIF4615	Surface	0.5	8.67	25.47	7.30	7.71	0.9	14,930
		Bottom	4.00	10.58	26.02	7.70	8.04		17,930
MDE-17	XIF4285	Surface	0.5	8.34	25.40	7.74	7.78	0.9	14,400
		Bottom	4.73	10.88	26.07	7.72	8.07		18,420
MDE-19	XIF4221	Surface	0.5	9.00	25.47	7.51	7.82	0.9	15,460
		Bottom	4.23	9.92	25.69	7.41	7.93		16,970
MDE-24	XIF4372	Surface	0.5	8.35	25.59	7.22	7.77	0.8	14,430
		Bottom	2.65	8.31	25.54	7.27	7.84		14,350
MDE-33	XIF6008	Surface	0.5	8.24	25.70	8.50	7.88	1	14,250
		Bottom	2.02	8.45	25.44	7.88	7.76		14,480
MDE-34	XIF5805	Surface	0.5	8.36	25.72	8.29	7.85	1	14,440
		Bottom	2.51	8.65	25.21	7.59	7.74		14,900
MDE-35	XIF6407	Surface	0.5	8.61	25.76	8.12	7.81	1	14,840
		Bottom	3.60	8.78	25.25	7.32	7.68		15,100
Reference Stations									
MDE-13	XIG3506	Surface	0.5	9.44	25.65	8.20	8.00	1	16,150
		Bottom	4.33	10.74	25.73	7.63	8.02		18,190
MDE-22	XIF3224	Surface	0.5	11.53	26.08	8.10	8.13	1	19,430
		Bottom	4.97	9.99	25.70	7.87	8.05		17,010
MDE-36	XIG7589	Surface	0.5	8.69	25.32	7.62	7.60	1	14,960
		Bottom	2.84	8.73	25.15	7.39	7.63		15,010
Back River/Hawk Cove Stations									
MDE-27	XIF4642	Surface	0.5	8.20	26.46	8.60	8.30	0.8	14,200
		Bottom	3.03	8.21	26.25	8.16	8.31		14,230
MDE-28	XIF5232	Surface	0.5	8.13	26.19	7.70	7.89	0.8	14,080
		Bottom	2.36	8.14	26.11	7.66	7.90		14,090
MDE-30	XIF5925	Surface	0.5	7.74	25.74	8.19	7.83	0.9	13,450
		Bottom	2.90	7.76	25.60	8.19	7.84		13,470
South Cell Exterior Monitoring Stations									
MDE-42	XIF3879	Surface	0.5	8.60	25.22	7.37	7.75	1	14,820
		Bottom	3.13	9.86	25.74	7.56	7.96		16,810
MDE-43	XIF3985	Surface	0.5	8.48	25.26	8.06	7.88	1	14,620
		Bottom	4.53	11.24	26.21	8.10	8.14		18,970
MDE-44	XIF4482	Surface	0.5	8.77	25.43	7.26	7.75	0.9	15,090
		Bottom	4.60	10.14	26.01	7.70	8.05		17,320

Table 2-4. Year 26 physical parameters measured *in situ* at all HMI stations on April 10, 2008.

MDE Station	Time	Tide	Water Depth (m)	Wave Height (m)	Wind Direction	Wind Speed (knots)		Air Temp (ºC)	Cloud Cover (%)	Weather		Observed Bottom Sediment (%)				
						Min.	Max.			Past 24 hrs.	Today	silt/clay	sand	shell	gravel	detritus
MDE-01	10:28	Slack	5.01	0	N/A	0	0	13	100	2	4	0	70	30	0	0
MDE-03	10:37	Ebb	6.70	0	N/A	0	0	14	100	2	4	35	35	30	0	0
MDE-07	10:20	Slack	6.25	0	N/A	0	0	12	100	2	4	35	50	15	0	0
MDE-09	10:11	Slack	6.58	0	N/A	0	0	13	100	2	4	60	0	40	0	0
MDE-13	9:42	Slack	5.85	0	N/A	0	0	13	100	2	4	80	0	20	0	0
MDE-16	10:00	Slack	5.39	0	N/A	0	0	13	100	2	4	65	0	30	0	5
MDE-17	9:53	Slack	5.77	0	N/A	0	0	13	100	2	4	65	0	35	0	0
MDE-19	9:13	Flood	5.60	0	N/A	0	0	12	100	2	4	95	5	0	0	0
MDE-22	8:37	Flood	5.90	0	N/A	0	0	12	100	2	4	95	5	0	0	0
MDE-24	9:01	Flood	3.27	0	N/A	0	0	12	100	2	4	0	90	10	0	0
MDE-27	11:53	Ebb	4.68	0	N/A	0	0	14	100	2	4	45	0	5	0	50
MDE-28	11:45	Ebb	3.58	0	N/A	0	0	19	100	2	4	80	0	15	0	5
MDE-30	11:32	Ebb	2.99	0	N/A	0	0	14	100	2	4	65	0	35	0	0
MDE-33	10:52	Ebb	2.95	0	N/A	0	0	14	100	2	4	0	90	10	0	0
MDE-34	10:43	Ebb	4.60	0	N/A	0	0	14	100	2	4	35	35	30	0	0
MDE-35	10:58	Ebb	4.66	0	N/A	0	0	14	100	2	4	90	0	5	0	5
MDE-36	11:12	Ebb	4.25	0	N/A	0	0	13	100	2	4	70	0	25	0	5
MDE-42	8:50	Flood	5.50	0	N/A	0	0	12	100	2	4	95	5	0	0	0
MDE-43	9:30	Slack	5.87	0	N/A	0	0	13	100	2	4	90	0	10	0	0
MDE-44	9:20	Flood	5.85	0	N/A	0	0	12	100	2	4	90	0	10	0	0

Note: The weather codes 2 and 4 stand for “continuous layer of clouds” and “fog, haze or thick dust”, respectively.

Table 2-5. Water quality parameters measured *in situ* at all HMI stations on April 10, 2008.

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	0.57	10.52	10.84	7.57	0.40	1,083
		Bottom	4.51	0.57	10.46	10.88	7.76		1,082
MDE-03	XIG5699	Surface	0.50	0.59	10.12	10.81	7.63	0.40	1,130
		Bottom	6.20	0.59	10.11	10.80	7.77		1,124
MDE-07	XIF5302	Surface	0.50	0.64	10.13	10.71	7.48	0.40	1,208
		Bottom	5.75	0.64	10.07	10.70	7.56		1,217
MDE-09	XIF4806	Surface	0.50	0.70	10.04	10.72	7.57	0.40	1,328
		Bottom	6.08	0.73	10.01	10.76	7.65		1,377
MDE-16	XIF4615	Surface	0.50	0.69	10.08	10.81	7.54	0.40	1,305
		Bottom	4.89	0.69	10.07	10.82	7.65		1,303
MDE-17	XIF4285	Surface	0.50	0.89	9.95	10.74	7.53	0.45	1,671
		Bottom	5.27	1.04	9.88	10.72	7.58		1,970
MDE-19	XIF4221	Surface	0.50	0.69	10.06	10.82	7.50	0.50	1,309
		Bottom	5.13	0.73	10.06	10.74	7.50		1,385
MDE-24	XIF4372	Surface	0.50	0.60	10.23	10.88	7.47	0.45	1,145
		Bottom	2.77	0.60	10.19	10.87	7.70		1,145
MDE-33	XIF6008	Surface	0.50	0.46	10.60	10.85	7.61	0.40	885.6
		Bottom	2.45	0.47	10.45	10.77	7.72		893.6
MDE-34	XIF5805	Surface	0.50	0.48	10.56	10.75	7.68	0.40	914.4
		Bottom	4.10	0.49	10.49	10.78	7.85		938.3
MDE-35	XIF6407	Surface	0.50	0.44	10.39	10.72	7.68	0.45	847.0
		Bottom	4.16	0.44	10.33	10.81	7.90		841.6
Reference Stations									
MDE-13	XIG3506	Surface	0.50	0.94	9.78	10.65	7.49	0.45	1,711
		Bottom	5.35	1.05	9.73	9.81	7.56		1,962
MDE-22	XIF3224	Surface	0.50	0.95	10.09	10.67	7.43	0.45	1,798
		Bottom	5.40	1.30	9.84	10.58	7.33		2,423
MDE-36	XIG7589	Surface	0.50	0.36	10.14	10.69	7.77	0.45	709.8
		Bottom	3.75	0.39	10.00	10.72	7.85		751.0
Back River/Hawk Cove Stations									
MDE-27	XIF4642	Surface	0.50	0.82	11.03	11.03	7.72	0.50	1,520
		Bottom	4.18	0.83	10.84	10.64	7.70		1,551
MDE-28	XIF5232	Surface	0.50	0.64	11.35	11.54	7.91	0.70	1,213
		Bottom	3.08	0.63	10.48	10.82	7.88		1,202
MDE-30	XIF5925	Surface	0.50	0.40	11.44	11.45	7.89	0.65	776.8
		Bottom	2.49	0.57	11.05	11.72	7.85		1,082
South Cell Exterior Monitoring Stations									
MDE-42	XIF3879	Surface	0.50	0.78	10.08	10.91	7.51	0.50	1,389
		Bottom	5.01	1.50	9.95	10.74	7.50		1,754
MDE-43	XIF3985	Surface	0.50	0.79	10.12	10.52	7.56	0.55	1,435
		Bottom	5.37	1.13	9.87	8.74	7.59		2,114
MDE-44	XIF4482	Surface	0.50	0.60	10.29	10.88	7.59	0.50	1,135
		Bottom	5.35	0.61	10.17	10.86	7.63		1,151

BENTHIC MACROINVERTEBRATE COMMUNITY

Taxa Richness and Dominance

A total of 34 taxa were found over the two seasons of sampling during Year 26. This is a decrease in species richness from the 10-year average of 39.9 taxa but not the lowest number found in a given year (32 taxa in Year 17).

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). Fifteen taxa of Arthropoda were found in Year 26. This is 2.8 less than the 10-year mean of 17.8 taxa (range= 12-23 taxa). The most common types of arthropods were the amphipods (including *Leptocheirus plumulosus*) and the isopods (including *Cyathura polita*). Seven taxa of annelid worms in the Class Polychaeta were found. This is similar to the 10-year mean of 7.8 taxa (range= 6-10 taxa). Polychaete taxa richness was comparable between April and September (6 vs. 7 taxa). Five species of bivalve mollusks were found. This is similar to the 10-year mean of 5.7 taxa (range= 4-7 taxa). Overall, bivalve mollusk average abundance was lower in September 2007 than in April 2008 (Tables 2-6 and 2-7).

Glycinde solitaria, Amphicteis floridus (polychaetes), and *Balanus subalbidus* (a barnacle), were not found in Year 26. *Ischadium recurvum*, Odonata, Capitellidae, Ostracoda, and an unknown worm and leech only occurred in the spring, while *Boccardiella ligerica*, *Eteone heteropoda*, Mysidacae, Hydrozoa, and an unknown sponge species were only found in fall samples. *G. solitaria, Mya arenaria, and Mulinea lateralis* have not been observed since the Year 21 sampling season. These species (and a few rarer ones) tended to only be found at Harbor Stations (MDE-38, MDE-39, MDE-40, and MDE-41), which have not been sampled since Year 21. The cessation of sampling Harbor stations partly accounts for any recent drop in the numbers of taxa found. Additionally, small inter-annual and inter-seasonal 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 2-6. Average and total abundance (individuals per square meter) of each taxon found at HMI during the September 2007 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	40.00	800.0	64.53	N/A	3.20	15.13	2.13	206.93	2.13
Carinoma tremophoros	5.12	102.4	3.73	N/A	3.20	4.65	8.53	4.27	4.27
Bivalvia	17.92	358.4	21.33	N/A	21.33	17.45	29.87	8.53	17.07
Macoma sp.	10.24	204.8	10.13	N/A	13.87	10.47	0.00	14.93	14.93
Macoma balthica	2.24	44.8	3.20	N/A	0.00	0.00	8.53	0.00	6.40
Macoma mitchelli	18.56	371.2	18.29	N/A	19.20	15.13	6.40	23.47	38.40
Rangia cuneata	66.56	1331.2	71.77	N/A	54.40	68.65	115.20	61.87	14.93
Ischadium recurvum	0.00	0.0	0.00	N/A	0.00	0.00	0.00	0.00	0.00
Mytilopsis leucophaeata	9.92	198.4	1.60	N/A	27.73	18.04	0.00	0.00	0.00
Amphicteis floridus	0.00	0.0	0.00	N/A	0.00	0.00	0.00	0.00	0.00
Capitellidae	0.00	0.0	0.00	N/A	0.00	0.00	0.00	0.00	0.00
Heteromastus filiformis	25.60	512.0	29.33	N/A	22.4	22.69	42.67	21.33	23.47
Spionidae	0.00	0.0	0.00	N/A	0.00	0.00	0.00	0.00	0.00
Marenzelleria viridis	55.04	1100.8	40.00	N/A	81.07	72.15	51.20	25.60	25.60
Streblospio benedicti	88.00	1760.0	64.53	N/A	147.20	98.91	74.67	98.13	51.20
Polydora cornuta	4.48	89.6	5.87	N/A	3.20	8.15	0.00	0.00	0.00
Boccardiella ligerica	1.28	25.6	1.07	N/A	1.07	2.33	0.00	0.00	0.00
Nereididae	31.68	633.6	16.00	N/A	48.00	49.45	12.80	0.00	17.07
Neanthes succinea	48.32	966.4	46.4	N/A	56.53	61.09	29.87	19.20	49.07

Table 2-6. Continued.

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
Eteone heteropoda	39.04	780.8	33.07	N/A	69.33	45.96	25.60	40.53	25.60
Naididae sp.	546.56	10931.2	573.33	N/A	374.40	413.67	398.93	979.20	748.80
Amphipoda	16.00	320.0	17.07	N/A	26.67	18.62	12.80	21.33	4.27
Gammaridae	22.72	454.4	25.60	N/A	11.73	10.47	40.53	38.40	34.13
Ameroculodes spp complex	0.96	19.2	0.00	N/A	3.20	1.75	0.00	0.00	0.00
Leptocheirus plumulosus	277.44	5548.8	313.07	N/A	259.20	235.05	298.67	373.33	315.73
Gammarus sp.	0.96	19.2	0.53	N/A	2.13	1.16	0.00	2.13	0.00
Melitadae	1.92	38.4	2.13	N/A	0.00	1.75	2.13	0.00	4.27
Melita nitida	29.12	582.4	30.93	N/A	22.40	25.60	23.47	27.73	49.07
Corophiidae	0.32	6.4	0.00	N/A	0.00	0.58	0.00	0.00	0.00
Apocorophium lacustre	38.08	761.6	7.47	N/A	107.73	65.16	4.27	0.00	10.67
Cyathura polita	96.00	1920.0	93.87	N/A	60.80	86.11	125.87	66.13	132.27
Edotia triloba	16.96	339.2	15.47	N/A	35.20	21.53	8.53	8.53	17.07
Chiridotea almyra	0.32	6.4	0.00	N/A	1.07	0.58	0.00	0.00	0.00
Ciripedia	0.00	0	0.00	N/A	0.00	0.00	0.00	0.00	0.00
Balanus improvisus	4.48	89.6	3.73	N/A	8.53	5.24	8.53	0.00	2.13
Balanus subalbidus	0.00	0.0	0.00	N/A	0.00	0.00	0.00	0.00	0.00
Rhithropanopeus harrisii	1.28	25.6	0.00	N/A	3.20	2.33	0.00	0.00	0.00
Membranipora sp.	+	+	+	N/A	+	+	+	0.00	+
Chironomidae	0.00	0.0	0.00	N/A	0.00	0.00	0.00	0.00	0.00

Table 2-6. Continued.

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
Coelotanypus sp.	3.20	64.0	4.27	N/A	0.00	1.16	2.13	14.93	0.00
Procladius (*Holotanypus*) sp.	0.00	0.0	0.00	N/A	0.00	0.00	0.00	0.00	0.00
Mysidacae	1.60	32.0	2.13	N/A	0.00	1.75	0.00	4.27	0.00
Neanthes (*Heteroneris* Form)	0.00	0.0	0.00	N/A	0.00	0.00	0.00	0.00	0.00
Hydrozoa	6.40	128.0	0.00	N/A	21.33	11.64	0.00	0.00	0.00
Unknown sponge	0.32	6.4	0.53	N/A	0.00	0.00	2.13	0.00	0.00
Unknown worm	0.64	12.8	0.53	N/A	0.00	0.00	0.00	2.13	2.13

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

Table 2-7. Average and total abundance (individuals per square meter) of each taxon found at HMI during Year 26 spring sampling, April 2008, 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 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	26.24	524.80	34.99	N/A	0.00	12.80	2.13	121.6	4.27
Carinoma tremophoros	1.28	25.60	1.71	N/A	0.00	0.00	2.13	0.00	6.40
Bivalvia	75.52	1510.40	93.01	N/A	23.04	56.44	29.87	44.80	221.87
Macoma sp.	61.44	1228.80	74.24	N/A	23.04	24.44	234.67	25.60	59.73
Macoma balthica	34.24	684.80	43.52	N/A	6.40	18.62	27.73	10.67	121.60
Macoma mitchelli	75.20	1504.00	84.91	N/A	46.08	50.62	91.73	81.07	142.93
Rangia cuneata	68.16	1363.20	68.27	N/A	67.84	72.15	106.67	70.40	12.80
Ischadium recurvum	1.92	38.40	0.85	N/A	5.12	3.49	0.00	0.00	0.00
Mytilopsis leucophaeata	6.40	128.00	1.71	N/A	20.48	11.05	2.13	0.00	0.00
Capitellidae	0.64	12.80	0.85	N/A	0.00	0.00	2.13	2.13	0.00
Heteromastus filiformis	159.68	3193.60	149.33	N/A	190.72	146.62	288.00	46.93	192.00
Spionidae	0.00	0.00	0.00	N/A	0.00	0.00	0.00	0.00	0.00
Marenzelleria viridis	1882.88	37657.60	953.17	N/A	4672.00	2843.93	746.67	759.47	618.67
Steblospio benedicti	8.32	166.40	10.67	N/A	1.28	2.91	2.13	14.93	27.73
Polydora cornuta	0.64	12.80	0.00	N/A	2.56	1.16	0.00	0.00	0.00
Boccardiella ligerica	0.00	0.00	0.00	N/A	0.00	0.00	0.00	0.00	0.00

Table 2-7: Continued.

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
Nereididae	5.76	115.20	4.27	N/A	10.24	9.89	2.13	0.00	0.00
Neanthes succinea	35.84	716.80	43.09	N/A	14.08	48.29	12.8	19.20	29.87
Naididae sp.	951.36	19027.20	1084.59	N/A	551.68	518.40	1555.2	1015.47	1870.93
Amphipoda	41.28	825.60	36.69	N/A	55.04	36.65	98.13	29.87	12.80
Gammaridea	9.28	185.60	11.09	N/A	3.84	6.98	0.00	2.13	34.13
Ameroculodes spp complex	17.60	352.00	17.49	N/A	17.92	18.04	17.07	4.27	29.87
Leptocheirus plumulosus	557.44	11148.80	471.89	N/A	814.08	498.62	733.87	605.87	548.27
Gammaridae	0.00	0.00	0.00	N/A	0.00	0.00	0.00	0.00	0.00
Gammarus sp.	11.84	236.80	13.23	N/A	7.68	16.87	12.80	0.00	4.27
Melitadae	1.28	25.60	1.71	N/A	0.00	1.16	0.00	2.13	2.13
Melita nitida	20.80	416.00	26.45	N/A	3.84	16.87	32.00	32.00	12.80
Corophiidae	0.32	6.40	0.00	N/A	1.28	0.58	0.00	0.00	0.00
Apocorophium sp.	0.32	6.40	0.43	N/A	0.00	0.00	0.00	2.13	0.00
Apocorophium lacustre	24.64	492.80	15.79	N/A	51.20	30.84	36.27	6.40	8.53
Cyathura polita	59.84	1196.80	58.45	N/A	64.00	62.84	74.67	25.60	68.27
Edotia triloba	19.84	396.80	13.23	N/A	39.68	21.53	36.27	10.67	6.40
Chiridotea almyra	2.56	51.20	0.43	N/A	8.96	4.65	0.00	0.00	0.00
Balanus improvisus	4.48	89.60	0.85	N/A	15.36	8.15	0.00	0.00	0.00
Balanus subalbidus	0.00	0.00	0.00	N/A	0.00	0.00	0.00	0.00	0.00

Table 2-7: Continued.

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
Rhithropanopeus harrisii	0.64	12.80	0.85	N/A	0.00	0.58	0.00	0.00	2.13
Membranipora sp.	+	+	+	N/A	+	+	+	0.00	+
Chironomidae	0	0.00	0.00	N/A	0.00	0	0.00	0.00	0.00
Coelotanypus sp.	1.28	25.60	1.71	N/A	0.00	0.58	0.00	6.40	0.00
Procladius(*Holotanypus*) sp.	0.00	0.00	0.00	N/A	0.00	0.00	0.00	0.00	0.00
Ostracoda	14.08	281.6	18.77	N/A	0.00	1.16	4.27	83.20	2.13
Odonata	0.32	6.40	0.00	N/A	1.28	0.58	0.00	0.00	0.00
Unknown leech	0.32	6.40	0.00	N/A	1.28	0.58	0.00	0.00	0.00

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

Of the 34 taxa found in Year 26, seventeen were considered truly infaunal, nine were considered epifaunal, and the remaining eight were considered too general to classify as either infaunal or epifaunal (see Ranasinghe et al. 1994). The most common infaunal species found during Year 26 were worms from the family Naididae, the amphipod *L. plumulosus*, the polychaete worm *M. viridis*, the bivalve *R. cuneata* , and the isopod *C. polita*. The most common epifaunal species were the amphipods *A. lacustre* and *M. nitida*, and the isopod *E. triloba*.

Nearfield stations MDE-01 and MDE-03 had the highest number of taxa in September 2007 (18 and 17 taxa, respectively, Table 2-8). Two Nearfield stations had 16 taxa (MDE-09 and MDE-34). The stations with the fewest number of taxa (12 taxa) in September were Back River station MDE-30, Reference station MDE-36, and South Cell Exterior Monitoring station MDE-42 (Table 2-8). Overall, average taxa richness was highest at the Nearfield stations but did not vary greatly between station types (average taxa richness: Nearfield=15 taxa, South Cell Exterior Monitoring=13 taxa, Reference=13 taxa, Back River/Hawk Cove=13 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 2-8. Summary of metrics for each HMI benthic station surveyed during the Year 26 September 2007 cruise. 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 (%)	B-IBI
Nearfield Stations								
MDE-01	832.0	1670.4	18	11	3.09	16.15	31.54	3.00
MDE-03	1113.6	1222.4	17	14	2.98	16.09	49.43	3.00
MDE-07	2316.8	2438.4	15	11	2.74	12.98	56.63	3.67
MDE-09	1907.2	1990.4	16	11	2.41	20.81	56.71	3.00
MDE-16	672.0	736.0	15	11	3.15	20.95	20.00	3.67
MDE-17	659.2	736.0	15	9	2.58	15.53	38.83	3.00
MDE-19	1350.4	1433.6	13	11	2.24	16.59	48.34	2.33
MDE-24	940.8	1126.4	13	9	2.57	5.44	27.89	3.00
MDE-33	646.4	729.6	14	10	2.62	15.84	33.66	3.00
MDE-34	2073.6	2336.0	16	11	2.73	23.46	59.57	3.67
MDE-35	902.4	972.8	14	12	2.62	41.84	21.28	3.00
MEANS	**1219.5**	**1399.3**	**15**	**11**	**2.70**	**18.70**	**40.35**	**3.12**
HISTORIC MEAN, n=26								**3.35**
Reference Stations								
MDE-13	940.8	1030.4	15	11	2.88	21.09	42.86	3.00
MDE-22	960.0	1056.0	13	11	2.63	24.67	13.33	3.67
MDE-36	1862.4	1913.6	12	9	2.55	25.09	52.23	3.67
MEANS	**1254.4**	**1333.3**	**13**	**10**	**2.69**	**23.62**	**36.14**	**3.45**
HISTORIC MEAN, n=26								**3.53**
Back River/Hawk Cove Stations								
MDE-27	3737.6	3865.6	15	12	1.81	3.08	72.60	2.33
MDE-28	1209.6	1222.4	13	12	2.62	19.68	46.56	3.00
MDE-30	441.6	486.4	12	10	3.10	24.64	27.54	2.33
MEANS	**1796.3**	**1858.1**	**13**	**11**	**2.51**	**15.80**	**48.90**	**2.55**
HISTORIC MEAN, n=26								**2.99**
South Cell Exterior Monitoring Stations								
MDE-42	2278.4	2348.8	12	10	1.67	9.27	67.70	2.33
MDE-43	1491.2	1638.4	14	12	2.35	14.16	37.77	2.33
MDE-44	704.0	838.4	13	9	2.89	16.36	52.73	3.00
MEANS	**1491.2**	**1608.5**	**13**	**10**	**2.30**	**13.26**	**52.73**	**2.55**
HISTORIC MEAN, n=4								**3.56**

In April 2008, the greatest taxa richness (17 taxa) occurred at Nearfield station MDE-19. Six stations had 16 taxa (four Nearfield stations, one each Back River/Hawk Cove and Reference station). Overall, taxa richness decreased from the previous year (Year 25) when 20 spring taxa were recorded at one station and two stations had 18 taxa. The lowest taxa richness (10 taxa) from spring 2008 sampling was recorded at Nearfield stations MDE-24 and MDE-35. Overall, the average taxa richness was highest at Reference stations (15 taxa), while Nearfield, Back River/Hawk Cove, and South Cell Exterior Monitoring stations all averaged 14 taxa.

Table 2-9. Summary of metrics for each HMI benthic station surveyed during the Year 26 April 2008 cruise. 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	11488.0	11808.0	16	10	0.95	85.68	11.70
MDE-03	1772.8	1881.6	16	12	2.47	50.54	33.94
MDE-07	4819.2	4915.2	16	11	1.91	62.82	29.61
MDE-09	2880.0	2982.4	15	11	2.20	55.78	32.00
MDE-16	4352.0	4384.0	14	10	1.16	82.50	12.21
MDE-17	2643.2	2880.0	16	11	2.20	54.48	36.56
MDE-19	2816.0	3257.6	17	10	2.28	7.50	76.59
MDE-24	6880.0	7104.0	10	7	1.38	56.65	40.19
MDE-33	2118.4	2163.2	11	8	0.63	91.54	5.44
MDE-34	7315.2	7526.4	14	11	1.64	64.22	30.36
MDE-35	800.0	902.4	10	8	2.63	23.20	41.60
MEANS	**4353.2**	**4527.7**	**14**	**10**	**1.77**	**57.72**	**31.84**
Reference Stations							
MDE-13	2003.2	2227.2	13	10	2.56	11.50	71.57
MDE-22	5216.0	5939.2	16	12	1.76	2.09	90.67
MDE-36	4006.4	4192.0	15	10	2.07	47.44	40.26
MEANS	**3741.9**	**4119.5**	**15**	**11**	**2.13**	**20.34**	**67.50**
Back River/Hawk Cove Stations							
MDE-27	4972.8	5388.8	16	10	1.90	25.61	70.66
MDE-28	2323.2	2515.2	15	10	2.45	30.30	55.65
MDE-30	716.8	748.8	12	9	2.36	41.96	44.64
MEANS	**2670.9**	**2884.3**	**14**	**10**	**2.24**	**32.62**	**56.98**
South Cell Exterior Monitoring Stations							
MDE-42	6816.0	7264.0	12	10	1.53	1.88	90.52
MDE-43	1862.4	2284.8	15	12	2.90	13.06	59.11
MDE-44	2380.8	2457.6	15	11	1.89	62.37	30.91
MEANS	**3686.4**	**4002.1**	**14**	**11**	**2.11**	**25.77**	**60.18**

Since the first benthic survey studies of the Hart-Miller Island area in 1981, a small number of taxa have been dominant. Year 26 was no exception. During both seasons, 10 taxa were consistently dominant: oligochaete worms of the family Naididae, the amphipods *L. plumulosus*, *A. lacustre*, and *M. nitida*, the bivalve mollusk *R. cuneata*, the isopod *C. polita*, the polychaete worms *M. viridis, H. filiformis, and N. succinea,* and nematode worms (Nemata). The average abundances of these taxa were among the top 12 highest in both seasons.

Several other taxa were among the most dominant in only one season. In September 2007, the polychaetes *S. benedicti* and *E. heteropoda* were the fourth and ninth most dominant taxa, but not in the top 12 in April 2008. Likewise, in April 2008, the bivalves *M. mitchelli* and *M. balthica* were the fifth and ninth most abundant taxa, but neither was among the 12 most dominant in September 2008. The average abundance of each taxon (individuals per square meter) found at each station during September and April are provided in Tables 2-10 through 2-13. These trends, both in overall abundance and seasonal variation are historically established. Seven of the 12 most dominant species from fall of Year 26 are in the 12 most dominant taxa historically. Eight of the 12 most dominant species from spring of Year 26 are in the 12 most dominant taxa historically.

Table 2-10. Average number of individuals collected per square meter at each station during HMI Year 26 late summer sampling, September 2007, stations MDE-1 to MDE-24. Depending on salinity, taxa in bold are pollution sensitive while taxa highlighted in gray are pollution indicative.

	Station									
Taxon	MDE-01	MDE-03	MDE-07	MDE-09	MDE-13	MDE-16	MDE-17	MDE-19	MDE-22	MDE-24
Nemata	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.4	0.0	6.4
Carinoma tremophoros	0.0	6.4	0.0	0.0	6.4	0.0	0.0	19.2	19.2	0.0
Bivalvia	0.0	12.8	12.8	32.0	38.4	6.4	0.0	6.4	25.6	76.8
Macoma sp.	6.4	6.4	0.0	0.0	0.0	0.0	6.4	19.2	0.0	19.2
Macoma balthica	0.0	0.0	0.0	0.0	6.4	0.0	0.0	0.0	19.2	0.0
Macoma mitchelli	0.0	6.4	25.6	12.8	6.4	0.0	0.0	32.0	12.8	51.2
Rangia cuneata	19.2	121.6	83.2	96.0	51.2	76.8	32.0	19.2	12.8	32.0
Ischadium recurvum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mytilopsis leucophaeata	83.2	19.2	32.0	6.4	0.0	6.4	12.8	0.0	0.0	0.0
Amphicteis floridus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Capitellidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Heteromastus filiformis	0.0	51.2	51.2	25.6	64.0	19.2	12.8	12.8	64.0	64.0
Spionidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Marenzellaria viridis	38.4	12.8	121.6	57.6	19.2	25.6	6.4	51.2	19.2	6.4
Streblospio benedicti	121.6	83.2	300.8	51.2	70.4	32.0	12.8	25.6	38.4	83.2
Polydora cornuta	19.2	0.0	0.0	0.0	0.0	70.4	0.0	0.0	0.0	0.0
Boccardiella ligerica	6.4	6.4	0.0	0.0	0.0	12.8	0.0	0.0	0.0	0.0
Nereididae	230.4	89.6	38.4	64.0	25.6	102.4	0.0	0.0	0.0	0.0
Neanthes succinea	128.0	83.2	115.2	51.2	38.4	179.2	70.4	6.4	0.0	0.0
Eteone heteropoda	38.4	32.0	32.0	38.4	0.0	19.2	12.8	0.0	12.8	102.4
Naididae sp.	102.4	435.2	979.2	992.0	332.8	83.2	230.4	620.8	76.8	76.8
Amphipoda	6.4	6.4	25.6	0.0	0.0	6.4	19.2	19.2	0.0	64.0
Gammaridea	6.4	6.4	32.0	32.0	32.0	0.0	12.8	6.4	89.6	6.4

Table 2-10: Continued.

	Station									
Taxon	MDE-01	MDE-03	MDE-07	MDE-09	MDE-13	MDE-16	MDE-17	MDE-19	MDE-22	MDE-24
Ameroculodes spp complex	0.0	0.0	19.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Leptocheirus plumulosus	25.6	121.6	396.8	243.2	166.4	0.0	185.6	377.6	409.6	441.6
Gammarus sp.	12.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Melitadae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.8	6.4	0.0
Melita nitida	51.2	12.8	44.8	12.8	6.4	25.6	25.6	44.8	57.6	6.4
Corophiidae	0.0	6.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Apocorophium lacustre	518.4	44.8	25.6	6.4	12.8	19.2	12.8	0.0	0.0	12.8
Cyathura polita	76.8	44.8	96.0	243.2	121.6	38.4	64 .0	153.6	185.6	12.8
Edotea triloba	0.0	0.0	6.4	19.2	6.4	6.4	6.4	0.0	0.0	70.4
Chiridotea almyra	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ciripedia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Balanus improvisus	32.0	6.4	0.0	0.0	25.6	0.0	12.8	0.0	0.0	0.0
Balanus subalbidus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rhithropanopeus harrisii	19.2	0.0	0.0	6.4	0.0	0.0	0.0	0.0	0.0	0.0
Membranipora sp	+	+	+	+	+	0.0	+	+	0.0	0.0
Chironomidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Coelotanypus sp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.4	0.0	0.0
Procladius (Holotanypus) sp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mysidacea	0.0	6.4	0.0	0.0	0.0	6.4	0.0	0.0	0.0	0.0
Neanthes (Heteroneris Form)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hydrozoa	128.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Unknown sponge	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.4	0.0
Unknown worm	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

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

Table 2-11. Average number of individuals collected per square meter at each station during the HMI Year 26 late summer sampling, September 2007, stations MDE-27 to MDE-44. Depending on salinity, taxa in bold are pollution sensitive while taxa highlighted in gray are pollution indicative.

	Station									
Taxon	MDE-27	MDE-28	MDE-30	MDE-33	MDE-34	MDE-35	MDE-36	MDE-42	MDE-43	MDE-44
Nemata	83.2	531.2	6.4	12.8	0.0	140.8	6.4	6.4	0.0	0.0
Carinoma tremophoros	0.0	0.0	12.8	19.2	0.0	6.4	0.0	6.4	6.4	0.0
Bivalvia	19.2	6.4	0.0	12.8	25.6	6.4	25.6	6.4	25.6	19.2
Macoma sp.	38.4	6.4	0.0	25.6	25.6	6.4	0.0	0.0	12.8	32.0
Macoma balthica	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.4	12.8	0.0
Macoma mitchelli	70.4	0.0	0.0	12.8	25.6	0.0	0.0	57.6	32.0	25.6
Rangia cuneata	44.8	121.6	19.2	25.6	134.4	115.2	281.6	25.6	6.4	12.8
Ischadium recurvum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mytilopsis leucophaeata	0.0	0.0	0.0	19.2	19.2	0.0	0.0	0.0	0.0	0.0
Amphicteis floridus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Capitellidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Heteromastus filiformis	44.8	6.4	12.8	0.0	6.4	6.4	0.0	38.4	32.0	0.0
Spionidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Marenzellaria viridis	38.4	12.8	25.6	51.2	262.4	160.0	115.2	0.0	25.6	51.2
Streblospio benedicti	147.2	108.8	38.4	108.8	256.0	12.8	115.2	25.6	57.6	70.4
Polydora cornuta	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Boccardiella ligerica	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nereididae	0.0	0.0	0.0	6.4	12.8	0.0	12.8	6.4	0.0	44.8
Neanthes succinea	44.8	12.8	0.0	0.0	25.6	12.8	51.2	0.0	19.2	128.0
Eteone heteropoda	76.8	32.0	12.8	89.6	140.8	0.0	64.0	0.0	6.4	70.4
Naididae sp.	2470.4	403.2	64.0	19.2	838.4	172.8	787.2	1516.8	499.2	230.4
Amphipoda	51.2	0.0	12.8	6.4	38.4	12.8	38.4	0.0	0.0	12.8
Gammaridea	32	32.0	51.2	6.4	6.4	0.0	0.0	44.8	57.6	0.0

Table 2-11: Continued

Taxon	Station									
	MDE-27	MDE-28	MDE-30	MDE-33	MDE-34	MDE-35	MDE-36	MDE-42	MDE-43	MDE-44
Ameroculodes spp complex	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Leptocheirus plumulosus	652.8	345.6	121.6	275.2	230.4	288.0	320.0	371.2	569.6	6.4
Gammarus sp.	0.0	6.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Melitadae	0.0	0.0	0.0	0.0	0.0	6.4	0.0	6.4	6.4	0.0
Melita nitida	44.8	0.0	38.4	0.0	6.4	51.2	6.4	51.2	83.2	12.8
Corophiidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Apocorophium lacustre	0.0	0.0	0.0	19.2	57.6	0.0	0.0	0.0	0.0	32.0
Cyathura polita	32.0	102.4	64.0	25.6	89.6	102.4	70.4	179.2	166.4	51.2
Edotea triloba	25.6	0.0	0.0	6.4	121.6	0.0	19.2	0.0	19.2	32.0
Chiridotea almyra	0.0	0.0	0.0	0.0	6.4	0.0	0.0	0.0	0.0	0.0
Ciripedia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Balanus improvisus	0.0	0.0	0.0	0.0	6.4	0.0	0.0	0.0	0.0	6.4
Balanus subalbidus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rhithropanopeus harrisii	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Membranipora sp	0.0	0.0	0.0	0.0	+	0.0	0.0	+	+	+
Chironomidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Coelotanypus sp.	19.2	19.2	6.4	0.0	0.0	6.4	6.4	0.0	0.0	0.0
Procladius (Holotanypus) sp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mysidacea	12.8	0.0	0.0	0.0	0.0	6.4	0.0	0.0	0.0	0.0
Neanthes (Heteroneris Form)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hydrozoa	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Unknown sponge	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Unknown worm	0.0	0.0	6.4	0.0	0.0	0.0	0.0	6.4	0.0	0.0

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

Table 2-12. Average number of individuals collected per square meter at each station during the HMI Year 26 spring sampling, April 2008, stations MDE-1 to MDE-24. Depending on salinity, taxa in bold are pollution sensitive while taxa highlighted in gray are pollution indicative.

	Station									
Taxon	MDE-01	MDE-03	MDE-07	MDE-09	MDE-13	MDE-16	MDE-17	MDE-19	MDE-22	MDE-24
Nemata	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.4	6.4	0.0
Carinoma tremophoros	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.4	0.0
Bivalvia	51.2	44.8	0.0	64.0	83.2	0.0	70.4	230.4	0.0	32.0
Macoma sp.	6.4	19.2	57.6	0.0	83.2	0.0	6.4	128.0	620.8	51.2
Macoma balthica	0.0	12.8	25.6	19.2	12.8	12.8	6.4	121.6	70.4	6.4
Macoma mitchelli	25.6	6.4	57.6	25.6	147.2	0.0	12.8	217.6	115.2	51.2
Rangia cuneata	83.2	83.2	102.4	140.8	32.0	38.4	12.8	25.6	6.4	57.6
Ischadium recurvum	25.6	0.0	0.0	6.4	0.0	0.0	6.4	0.0	0.0	0.0
Mytilopsis leucophaeata	89.6	6.4	6.4	6.4	0.0	0.0	6.4	0.0	0.0	0.0
Capitellidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Heteromastus filiformis	377.6	121.6	435.2	198.4	288.0	12.8	166.4	160.0	556.8	57.6
Spionidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Marenzellaria viridis	9843.2	896.0	3027.2	1606.4	230.4	3590.4	1440.0	204.8	108.8	3859.2
Streblospio benedicti	0.0	6.4	0.0	12.8	0.0	0.0	0.0	6.4	6.4	0.0
Polydora cornuta	12.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Boccardiella ligerica	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nereididae	12.8	0.0	38.4	0.0	6.4	57.6	0.0	0.0	0.0	0.0
Neanthes succinea	32.0	51.2	19.2	32.0	19.2	198.4	153.6	19.2	6.4	0.0
Naididae sp.	582.4	243.2	659.2	512.0	307.2	230.4	480.0	1350.4	3315.2	96.0
Amphipoda	25.6	12.8	6.4	25.6	140.8	12.8	57.6	6.4	64.0	140.8
Gammaridea	0.0	12.8	6.4	38.4	0.0	6.4	0.0	0.0	0.0	0.0

Table 2-12: Continued

	Station									
Taxon	MDE-01	MDE-03	MDE-07	MDE-09	MDE-13	MDE-16	MDE-17	MDE-19	MDE-22	MDE-24
Ameroculodes spp complex	0.0	12.8	44.8	32.0	19.2	12.8	25.6	0.0	12.8	0.0
Leptocheirus plumulosus	339.2	179.2	313.6	166.4	819.2	89.6	166.4	614.4	844.8	2611.2
Gammaridae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gammarus sp	6.4	19.2	25.6	19.2	6.4	51.2	57.6	0.0	0.0	0.0
Melitadae	0.0	12.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Melita nitida	12.8	6.4	0.0	0.0	25.6	6.4	108.8	44.8	64.0	0.0
Corophiidae	6.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Apocorophium sp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Apocorophium lacustre	115.2	19.2	12.8	19.2	25.6	12.8	25.6	6.4	32.0	64
Cyathura polita	147.2	96.0	64.0	57.6	57.6	38.4	64.0	89.6	102.4	0.0
Edotea triloba	12.8	0.0	6.4	6.4	6.4	6.4	12.8	6.4	0.0	38.4
Chiridotea almyra	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.4	0.0	38.4
Balanus improvisus	76.8	12.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rhithropanopeus harrisii	0.0	0.0	0.0	0.0	0.0	6.4	0.0	0.0	0.0	0.0
Membranipora sp	+	+	+	+	+	+	+	+	0.0	0.0
Chironomidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Coelotanypus sp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.4	0.0	0.0
Procladius (Holotanypus) sp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Copepoda	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ostracoda	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.8	6.4	0.0
Odonata	0.0	0.0	6.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Unknown Leech	0.0	0.0	6.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0

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

Table 2-13. Average number of individuals collected per square meter at each station during the HMI Year 26 spring sampling, April 2008, stations MDE-27 to MDE-44. Depending on salinity, taxa in bold are pollution sensitive while taxa highlighted in gray are pollution indicative.

	Station									
Taxon	MDE-27	MDE-28	MDE-30	MDE-33	MDE-34	MDE-35	MDE-36	MDE-42	MDE-43	MDE-44
Nemata	179.2	185.6	0.0	0.0	0.0	134.4	0.0	0.0	6.4	6.4
Carinoma tremophoros	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	19.2	0.0
Bivalvia	76.8	57.6	0.0	12.8	19.2	96.0	6.4	428.8	224	12.8
Macoma sp.	76.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	172.8	6.4
Macoma balthica	19.2	12.8	0.0	0.0	0.0	0.0	0.0	166.4	179.2	19.2
Macoma mitchelli	166.4	76.8	0.0	12.8	83.2	64.0	12.8	166.4	236.8	25.6
Rangia cuneata	51.2	121.6	38.4	19.2	76.8	153.6	281.6	19.2	12.8	6.4
Ischadium recurvum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mytilopsis leucophaeata	0.0	0.0	0.0	0.0	6.4	0.0	6.4	0.0	0.0	0.0
Capitellidae	0.0	0.0	6.4	0.0	0.0	0.0	6.4	0.0	0.0	0.0
Heteromastus filiformis	70.4	64.0	6.4	25.6	57.6	0.0	19.2	377.6	153.6	44.8
Spionidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Marenzellaria viridis	1273.6	704.0	300.8	1932.8	4697.6	185.6	1900.8	128.0	243.2	1484.8
Streblospio benedicti	6.4	19.2	19.2	0.0	6.4	0.0	0.0	70.4	12.8	0.0
Polydora cornuta	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Boccardiella ligerica	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nereididae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Neanthes succinea	44.8	0.0	12.8	6.4	12.8	6.4	12.8	0.0	6.4	83.2
Naididae sp.	2310.4	550.4	185.6	0.0	1420.8	128	1043.2	4992	352.0	268.8
Amphipoda	0.0	70.4	19.2	0.0	102.4	12.8	89.6	19.2	12.8	6.4
Gammaridea	0.0	6.4	0.0	0.0	12.8	0.0	0.0	25.6	19.2	57.6

Table 2-13: Continued

Taxon	MDE-27	MDE-28	MDE-30	MDE-33	MDE-34	MDE-35	MDE-36	MDE-42	MDE-43	MDE-44
Ameroculodes spp complex	0.0	0.0	12.8	25.6	19.2	25.6	19.2	0.0	70.4	19.2
Leptocheirus plumulosus	1068.8	652.8	96.0	83.2	723.2	198.4	537.6	729.6	576.0	339.2
Gammaridae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gammarus sp	0.0	0.0	0.0	0.0	6.4	0.0	32.0	6.4	0.0	6.4
Melitadae	0.0	0.0	6.4	0.0	0.0	0.0	0.0	0.0	0.0	6.4
Melita nitida	76.8	12.8	6.4	6.4	0.0	0.0	6.4	12.8	6.4	19.2
Corophiidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Apocorophium sp.	0.0	6.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Apocorophium lacustre	12.8	0.0	6.4	19.2	44.8	0.0	51.2	0.0	0.0	25.6
Cyathura polita	6.4	44.8	25.6	12.8	96.0	25.6	64.0	115.2	76.8	12.8
Edotea triloba	12.8	12.8	6.4	0.0	140.8	6.4	102.4	0.0	19.2	0.0
Chiridotea almyra	0.0	0.0	0.0	6.4	0.0	0.0	0.0	0.0	0.0	0.0
Balanus improvisus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rhithropanopeus harrisii	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.4
Membranipora sp	0.0	0.0	0.0	0.0	+	0.0	0.0	0.0	+	+
Chironomidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Coelotanypus sp.	12.8	6.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Procladius (Holotanypus) sp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Copepoda	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ostracoda	147.2	102.4	0.0	0.0	0.0	0.0	6.4	6.4	0.0	0.0
Odonata	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Unknown Leech	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

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

Infaunal Taxa Abundance

Average total infaunal abundance was lower in the fall (September 2007) than in the spring (April 2008) (Figure 2-2), which is primarily a result of a greater number of organisms in the spring due to recruitment. This has occurred in each of the past 10 years (excluding Year 23, which had an unusually large winter die-off of *R. cuneata*). In September 2007, total infaunal abundance ranged from 441.6 to 3,737.6 organisms per square meter (individuals/m^2) and averaged 1,352 individuals/m^2 (Table 2-8). The highest September 2007 abundance was found at the Back River/ Hawk Cove station MDE-27, due primarily to large numbers of Naididae worms. The lowest infaunal abundance in September 2007 was found at the Back River/Hawk Cove station MDE-30 (Table 2-8). The average total infaunal abundance was very similar at Reference stations and Nearfield stations in September 2007 (1,254.4 individuals/m^2 and 1,219.5 individuals/m^2, respectively). Higher fall average infaunal abundances occurred at South Cell Exterior Monitoring stations (1,491.2 individuals/m^2) and Back River/Hawk Cove stations (1,796.3 individuals/m^2, primarily due to higher abundance of Naididae). No trend of increasing/decreasing abundances associated with distance from HMI could be discerned. These abundances are comparable to historical averages. The 26-year mean (4,904 individuals/m^2) of fall abundance for the Back River stations is much higher than the Reference (1,982 individuals/m^2) and Nearfield (2,194 individuals/m^2) means. Mean abundance in the South Cell stations has a four-year average of 1,000 individuals/m^2.

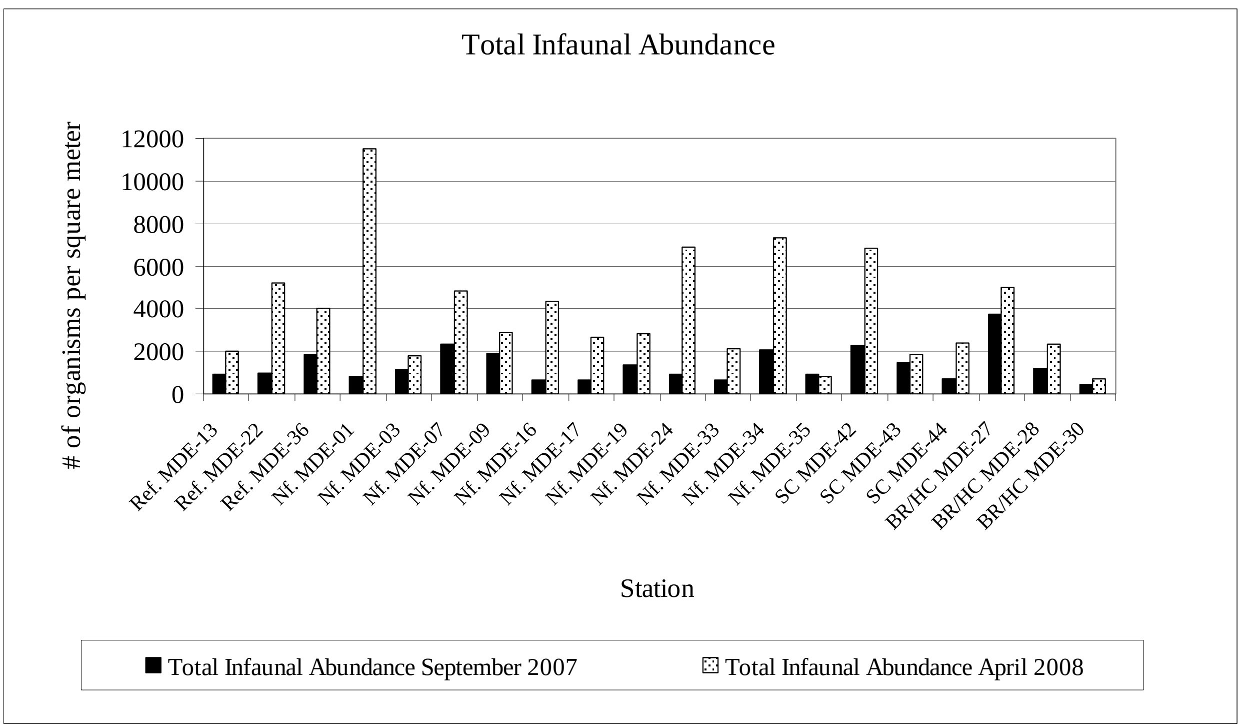

Figure 2-2. Total abundance of infauna taxa collected at each HMI station in Year 26, September 2007 and April 2008 grouped by stations (Ref. = Reference; Nf. = Nearfield; SC = South Cell Exterior Monitoring; BR/HC = Back River Hawk Cove).

In April 2008, total infaunal abundance ranged from 716.8 to 11,488.0 individuals/m^2 and averaged 3,909.1 individuals/m^2. The station with the highest abundance was the Nearfield station MDE-01, due to very high numbers of the polychaete *M. viridis*. The lowest spring abundance occurred at the Back River/Hawk Cove station MDE-30 (Table 2-9). This was due to depressed abundances of many common species (Tables 2-9, 2-12, 2-13). The average total infaunal abundance was lowest at Back River/Hawk Cove stations (2,670.9 individuals/m^2) and highest at Nearfield stations (4,353.2 individuals/m^2). Reference stations (3,741.9 individuals/m2) and South Cell Exterior Monitoring stations (3,686.4 individuals/m2) had similar moderate average infaunal abundances. No consistent trend of increasing/decreasing abundances associated with distance from HMI could be discerned. Comparisons of mean spring station type abundances to historical averages were not made. Due to highly variable and often intense spring recruitment, spring benthic data yields variability that does not lend itself to historic analyses and is an unreliable indicator of community health.

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 26, total infaunal abundance was similar to total abundance, accounting for ≥75 percent of all organisms at most stations during both seasons. The only exception where infaunal abundance fell below 75 percent was at Nearfield station MDE-01 (50 percent in the fall sampling). MDE-01 had a substrate of 30 percent oyster shell resulting in an increase in epifaunal species.

Diversity

Species diversity was examined using the Shannon-Wiener Diversity Index (SWDI), which measures diversity on a numerical scale from zero to four. A lower score indicates an unbalanced benthic 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 SWDI, would be higher in the summer when recruitment decreased and predation increased as opposed to spring, 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 26 are presented in Tables 2-8 and 2-9. In this monitoring year, average diversity was moderately higher in September 2007 than in April 2008.

SWDI values in Year 26 averaged 2.61 ± 0.39 in September 2007 and 1.94 ± 0.59 in April 2008. The fall average diversity of 2.61 was slightly higher than the 10-year mean fall diversity of 2.54. The lowest diversity value in September 2007 occurred at South Cell Exterior Monitoring station MDE-42 (1.67, Figure 2-3). This was due to the large percentage of oligochaete worms of the family Naididae, which accounted for 67 percent of total infaunal abundance at this station. The highest September 2007 diversity value (3.15) occurred at Nearfield station MDE-16.

The lowest diversity value in April 2008 occurred at Nearfield station MDE-33 (0.63); this was due to the large percentage of *M. viridis,* which accounted for 91 percent of the total infaunal abundance at this station. The highest April 2008 diversity value occurred at South Cell Exterior Monitoring station MDE-43 (2.90). Comparisons of mean spring diversity values to historical averages were not made. Due to highly variable and often intense spring recruitment, spring benthic data yields variability that does not lend itself to historic analyses and is an unreliable indicator of community health.

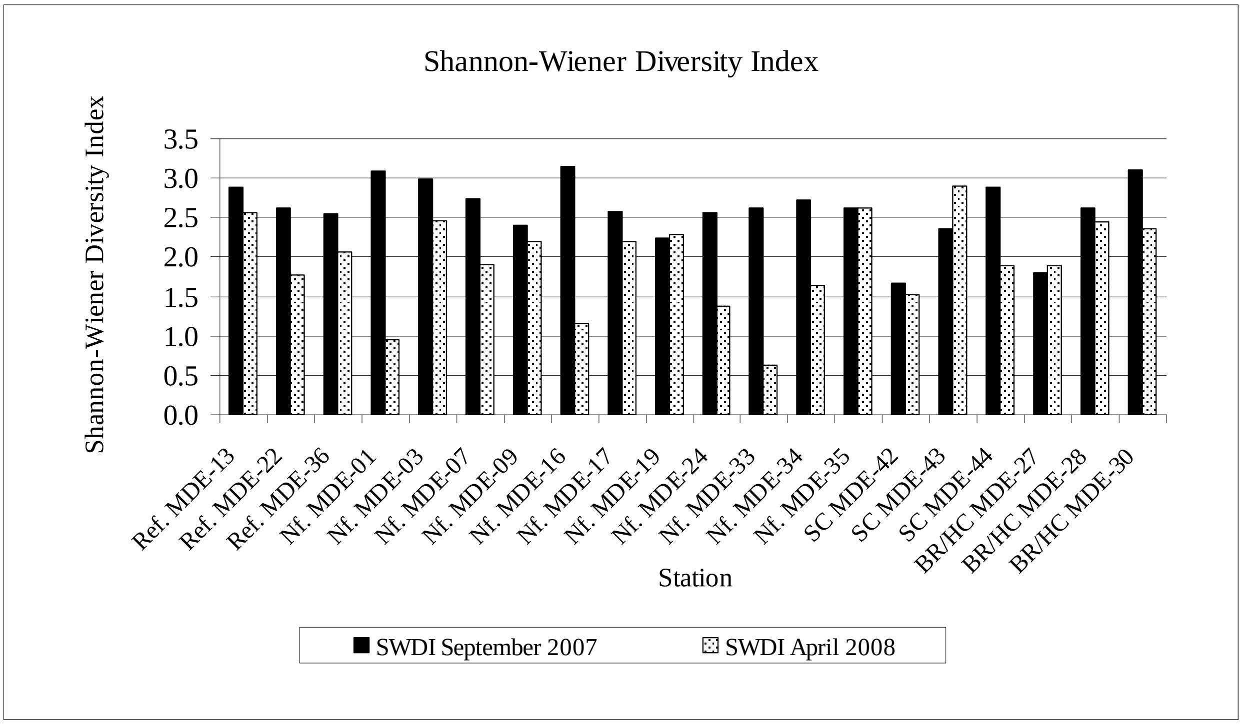

Figure 2-3. Shannon-Wiener Diversity Index (SWDI), HMI Year 26, September 2007 and April 2008 grouped by stations (Ref. = Reference; Nf. = Nearfield; SC = South Cell; BR/HC = Back River Hawk Cove).

On average, Nearfield stations had diversity values similar to Reference stations in September 2007 and April 2008. Comparing station types from the fall only, the lowest average SWDI was 2.30 at the South Cell Exterior Monitoring stations followed by the Back River/Hawk Cove stations at 2.51, and Reference stations at 2.69. The highest average SWDI occurred at the Nearfield stations at 2.70 (Table 2-8). Historically, the 20-year mean SWDI values, ranked from lowest to highest, are associated with the following station types: Back River/Hawk Cove (2.12), Nearfield (2.27), Reference (2.34), and South Cell Exterior Monitoring (2.50, n=4 yrs). No trend of increasing/decreasing diversity associated with distance from HMI could be discerned.

Pollution Sensitive Taxa Abundance (PSTA)

Four taxa found during Year 26 were designated as "pollution-sensitive" according to Alden et al. (2002). These were the polychaete worm *M. viridis*, the bivalves' *R. cuneata* and *M. balthica,* and the isopod crustacean *C. polita.* The calculation of the PSTA is a ratio of the relative PSTA abundance to total infaunal abundance.

In Year 26, the low mesohaline salinity regime resulted in a change of the PSTA taxa from Year 25, when oligohaline conditions prevailed. In contrast, Alden, et al. (2002) designated only two taxa commonly found around HMI as sensitive under oligohaline 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. Because this metric is salinity driven, and salinity varies from year to year, salinity must be controlled for prior to some historical analyses of PSTA fall data.

In Year 26, pollution sensitive taxa occurred at all station types. In September, PSTA ranged from 3.08 percent at MDE-27 (Back River/Hawk Cove station) to 41.84 percent at MDE-35 (Nearfield station - Table 2-8; Figure 2-4). The average PSTA for all stations in September 2007 was 18.18 percent. Comparing station types, the lowest average PSTA was 13.26 percent at the South Cell Exterior Monitoring stations followed by the Back River/Hawk Cove at 15.77 percent and Nearfield stations at 18.70 percent. The highest average PSTA occurred at the Reference stations at 23.62 percent.[2] Historically, the 26-year mean fall PSTA values, ranked from lowest to highest, are associated with the following station types: Back River/Hawk Cove (32.71 percent), South Cell Exterior Monitoring (34.79 percent, n=3 years), Nearfield (41.28 percent), and Reference (44.50 percent).

In April 2008, the lowest PSTA was 1.88 percent at MDE-42 (South Cell Exterior Monitoring station) and the highest was 91.54 percent at MDE-33 (Nearfield station - Table 2-9; Figure 2-4). The average PSTA for all stations in April was 40.30 percent. In contrast to the fall data, Reference stations had the lowest average PSTA at 20.34 percent, followed by the South Cell Exterior Monitoring stations at 25.77 percent, and the Back River/Hawk Cove stations at 32.62 percent; the Nearfield stations had the highest average PSTA of 57.72 percent.

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[2] These calculations were not used for the B-IBI scores for September 2007 due to the salinity falling in the Low Mesohaline regime. PSTA is not a metric that contributes to the overall B-IBI score during Mesohaline conditions.

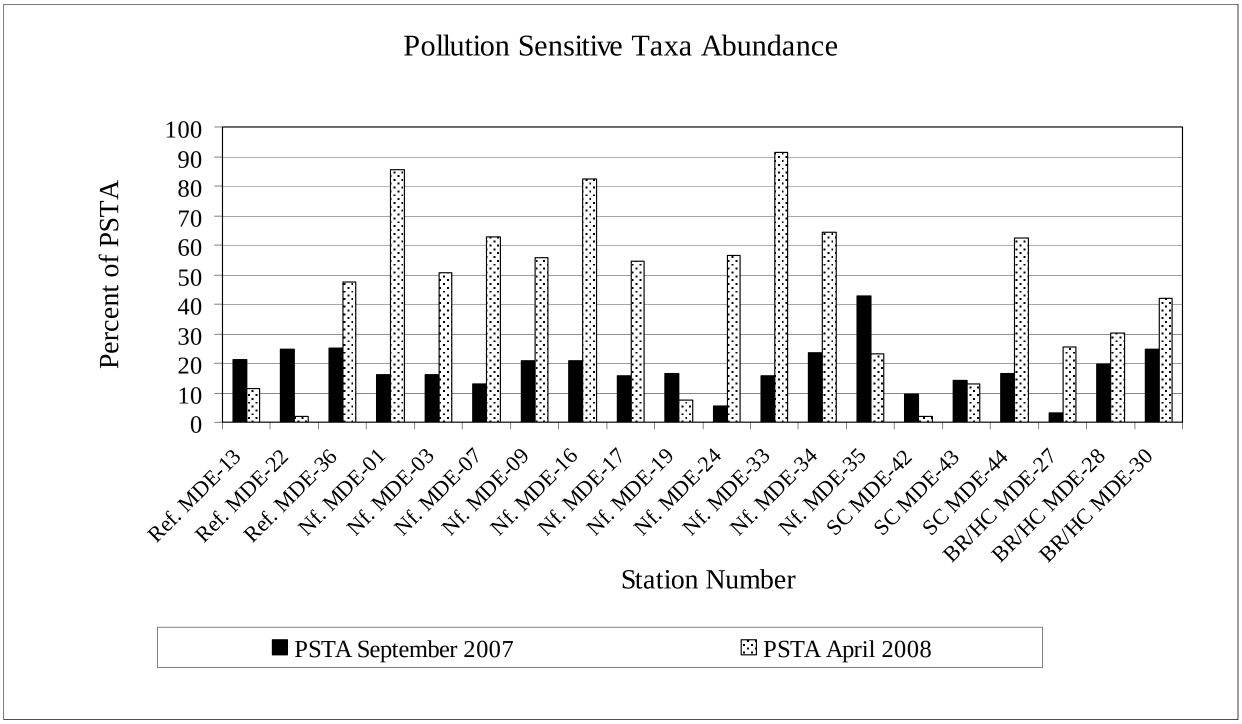

Figure 2-4. Percent abundance comprised of pollution sensitive species (PSTA), HMI Year 26 September 2007 and April 2008 grouped by stations (Ref. = Reference; Nf. = Nearfield; SC = South Cell Exterior Monitoring; BR/HC = Back River Hawk Cove).

Pollution Indicative Taxa Abundance (PITA)

Four taxa found during the fall sampling of Year 26 benthic monitoring were designated as "pollution-indicative" according to Alden et al. (2002): they were Chironomids of the Genus *Coelotanypus*, the polychaete worms *S. benedicti* and *E. heteropoda,* and oligochaete worms of the family Naididae. The calculation of the PITA is a ratio of the relative PITA abundance to total infaunal abundance. Those species which are designated "pollution indicative" are constant throughout all salinity regimes. Therefore salinity does not drive this metric.

In Year 26, pollution indicative taxa occurred at all station types. In September, the PITA ranged from 13.33 percent at MDE-22 (Nearfield station) to 72.60 percent at MDE-27 (Back River/Hawk Cove station) (Table 2-8; Figure 2-5). The average PITA for all stations in September 2007 was 42.86 percent. Comparing station types, the lowest average PITA was 36.14 percent at the Reference stations, followed by 40.35 percent at the Nearfield stations, and 48.90 percent at Back River/Hawk Cove stations. The highest average PITA occurred at the South Cell Exterior Monitoring stations at 52.73 percent. Historically, the 26-year mean fall PITA values, ranked lowest to highest, are associated with the following station types: Reference (20.82 percent), Nearfield (23.22 percent), Back River/Hawk Cove (35.16 percent), and South Cell Exterior Monitoring (42.21 percent, n = 3 years). The fall data for Year-26 followed the historical trend in terms of station type ranking order.

In April 2008, the lowest PITA was 5.44 percent at MDE-33 (Nearfield station) and the highest was 90.67 percent at MDE-22 (Reference station - Table 2-9; Figure 2-5). The average PITA for all stations in April was 43.60 percent. Nearfield stations had the lowest average PITA at 31.84 percent, followed by the Back River/Hawk Cove stations at 56.98 percent, and the South Cell Exterior Monitoring stations at 60.18 percent; the Reference stations had the highest average PITA of 67.50 percent.

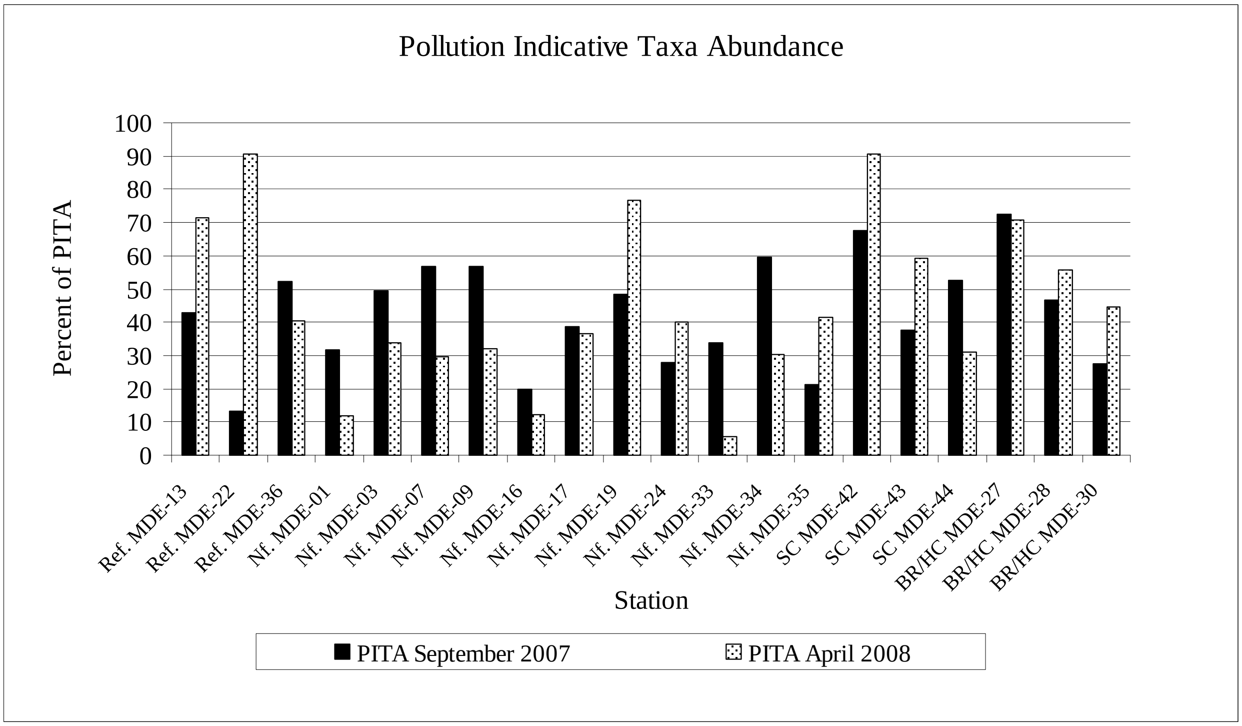

Figure 2-5. Percent abundance comprised of pollution indicative species (PITA), HMI year 26 September 2007 and April 2008 grouped by stations (Ref.=Reference; Nf.=Nearfield; SC=South Cell Exterior Monitoring; BR/HC=Back River Hawk Cove).

Clam Length Frequency Distribution

In September 2007, 208 *R. cuneata* were collected. The greatest average abundance of *R. cuneata* occurred at the Reference stations (18.0 clams/station), followed by the Nearfield stations (10.7 clams/station), the Back River/Hawk Cove stations (9.7 clams/station), and the South Cell Exterior Monitoring stations (2.3 clams/station). The greatest abundance of *R. cuneata* during the fall was found in the 31-35 mm size class. In April 2008, 213 *R. cuneata* were collected. The greatest average abundance for this species occurred at the Reference stations (16.7 clams/station), followed by the Nearfield and Back River/Hawk Cove stations (10.7 clams/station), and the South Cell Exterior Monitoring stations (1.7 clams/station). The dominant size range found during the spring was also in the 31-35 mm size class.

R. cuneata has always been the most abundant bivalve mollusk found in this benthic monitoring project. It is classified as pollution sensitive during higher salinity years ($\geq$5ppt). The population has historically been very dynamic in terms of overall abundance and distribution by size or station type. There are no consistent trends except that the South Cell Exterior Monitoring stations have had the lowest abundances in every season since they were established four years ago. The main drivers of *R. cuneata* variability appear to be temperature and salinity. In the Chesapeake Bay, this species exists at the northern extent of its range. Because of this, it is subject to high winter mortality during cold winters (Hopkins, et al., 1973). Additionally, ideal salinity conditions for reproduction and recruitment do not occur regularly. In Maryland, *R. cuneata* rarely if ever reaches its reported maximum age (15-20 years) or size (79 mm). Looking at 10 years of historical HMI frequency distribution data, it is difficult to identify more than four age classes of clams in any one season. This implies very few clams survive longer than five years.

In September 2007, only seven *M. balthica* were collected, with four coming from Reference stations and three coming from South Cell Exterior Monitoring stations. All of these clams were 15 mm or larger. In April 2008, 107 *M. balthica* were collected with 57 coming from South Cell Exterior Monitoring stations, 32 from Nearfield stations, 13 from Reference stations, and 5 from Back River/Hawk Cove stations. Ninety-one were in the 1-2 mm size class and 8 were in the 3-4 mm class, which is indicative of recruitment.

M. balthica has been common and found in low to moderate abundance throughout this benthic monitoring project. It is classified as pollution sensitive during higher salinity years ($\geq$ 5 ppt). The population has historically been somewhat dynamic in terms of overall abundance and size distribution. The main driver of *M. balthica* variability appears to be salinity. In the Chesapeake Bay, this species exists at salinities as low as about 5 ppt (Gosner, 1978), and is generally not found much more than 10-15 miles north of HMI. Looking at 10 years of historical HMI frequency distribution data, the strong freshet in Year 23 appears to have caused high mortality in this species, which has yet to recover to previous densities. Year 26 recruitment may be a sign of recovery.

In September 2007, 58 *M. mitchelli* were collected, with 26 coming from Nearfield stations, 18 from South Cell Exterior Monitoring stations, 11 from Back River/Hawk Cove stations, and 3 from Reference stations. These clams were fairly evenly distributed from 3-15 mm. In April, 235 *M. mitchelli* were collected with 67 coming from South Cell Exterior Monitoring stations, 87 from Nearfield stations, 43 from Reference stations, and 38 from Back River/Hawk Cove stations. Ninety were in the 1-4 mm size classes, which is indicative of recruitment. Similar to *M. balthica*, *M. mitchelli* populations declined in the spring of Year 22 and remained depressed for several years. Year 26 recruitment may be a sign of recovery.

Benthic Index of Biotic Integrity

The B-IBI was calculated for all stations based on September 2007 data only (see *Methods and Materials*). Three metrics were used to calculate the B-IBI for stations under the low mesohaline classification (5.0 -12 ppt). These metrics were total infaunal abundance, relative abundance of pollution-indicative taxa, and SWDI. The specific scoring criteria for the low mesohaline metrics are presented in Table 2-14. 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 26 were compared to this benchmark.

Table 2-14. Low mesohaline scoring criteria for measures used in calculating the Chesapeake Bay B-IBI in September 2007 (Weisberg et al. 1997).

Measure	**Score**		
	5	**3**	**1**
Total Abundance (individuals per square meter)	≥ 1500-2500	500-1500 **or > 2500-6000**	< 500 **or** ≥ 6000
% Pollution-indicative Taxa	≤ 10%	10-20%	> 20%
Shannon-Wiener Diversity Index	≥2.5	1.7-2.5	<1.7

The vast majority of the individual station B-IBI scores for Year 26 either decreased or remained the same when compared to Year 25 (Table 2-8). Scores decreased at 11 stations, remained the same at 4, and increased at 5 stations. Despite this, 15 of the 20 stations met or exceeded the benchmark criteria of 3.0 in Year 26, while only 13 did so in Year 25. In Year 26, five stations [Nearfield station MDE-19 (2.33), Back River/Hawk Cove stations MDE-27 (2.33) and MDE-30 (2.33), and South Cell Exterior Monitoring Stations MDE-42 (2.33) and MDE-43 (2.33)] failed to meet this benchmark (Table 2-8, Figure 2-6). Seventeen stations were below historic averages, while three (two Reference and one Back River) were above.

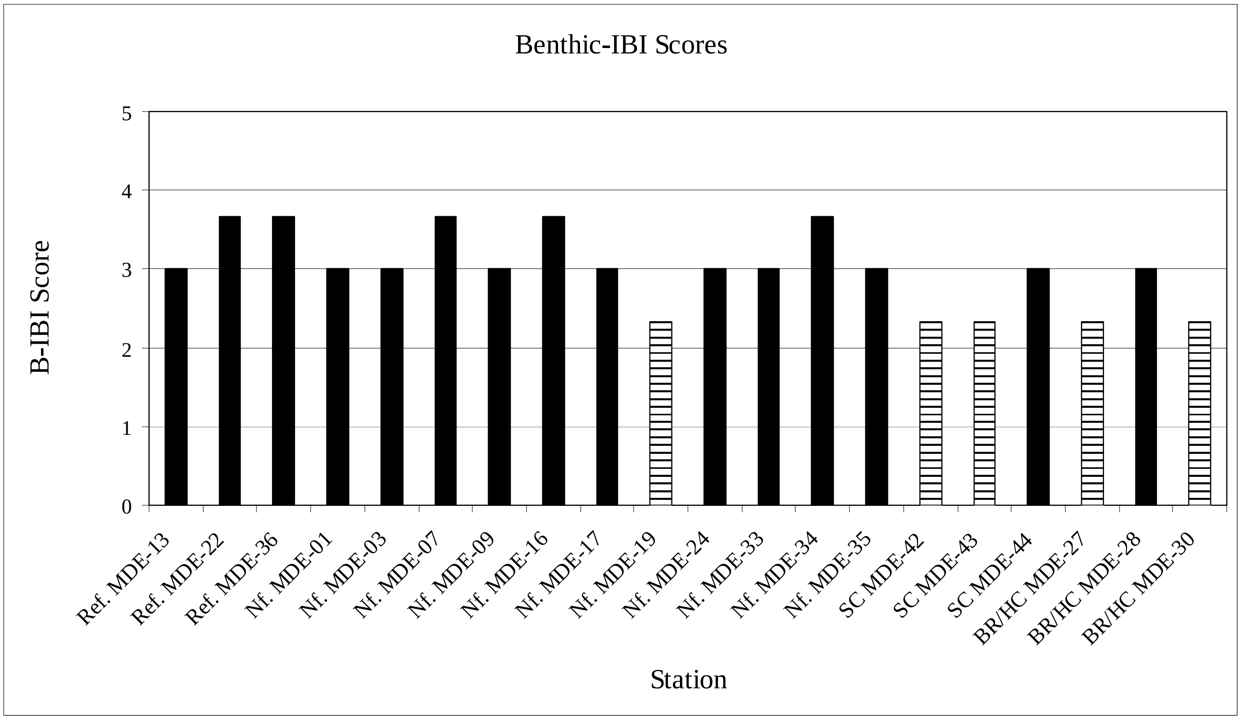

Figure 2-6. B-IBI Scores for all stations in September 2007 grouped by stations (Ref.=Reference; Nf.=Nearfield; SC=South Cell Exterior Monitoring; BR/HC=Back River Hawk Cove).

While this implies a negative trend, only three “long established” stations (having at least 10 years of data) were the same as their historical low. No new lows were set for these stations. Two South Cell Exterior Monitoring stations set new historical lows. However, these stations have only been monitored for four years.

The mean B-IBI for Nearfield and Reference stations met or exceeded the benchmark. The mean B-IBI for Back River/Hawk Cove and South Cell Exterior Monitoring stations failed to meet the benchmark. Average B-IBI scores by station type are shown in Figure 2-7. Compared to Year 25, the mean B-IBI for Reference stations increased, while the mean B-IBI decreased for the other station types. The Year 26 mean B-IBIs for all station types were below their 26-year historic averages (four year average for South Cell Exterior Monitoring Stations, Table 2-8). However, none of the Year 26 station type means for “long established” stations were within 0.5 units of their historic lows. The South Cell Exterior Monitoring stations mean B-IBI set a new historic low, however only four years of data exists for this station type.

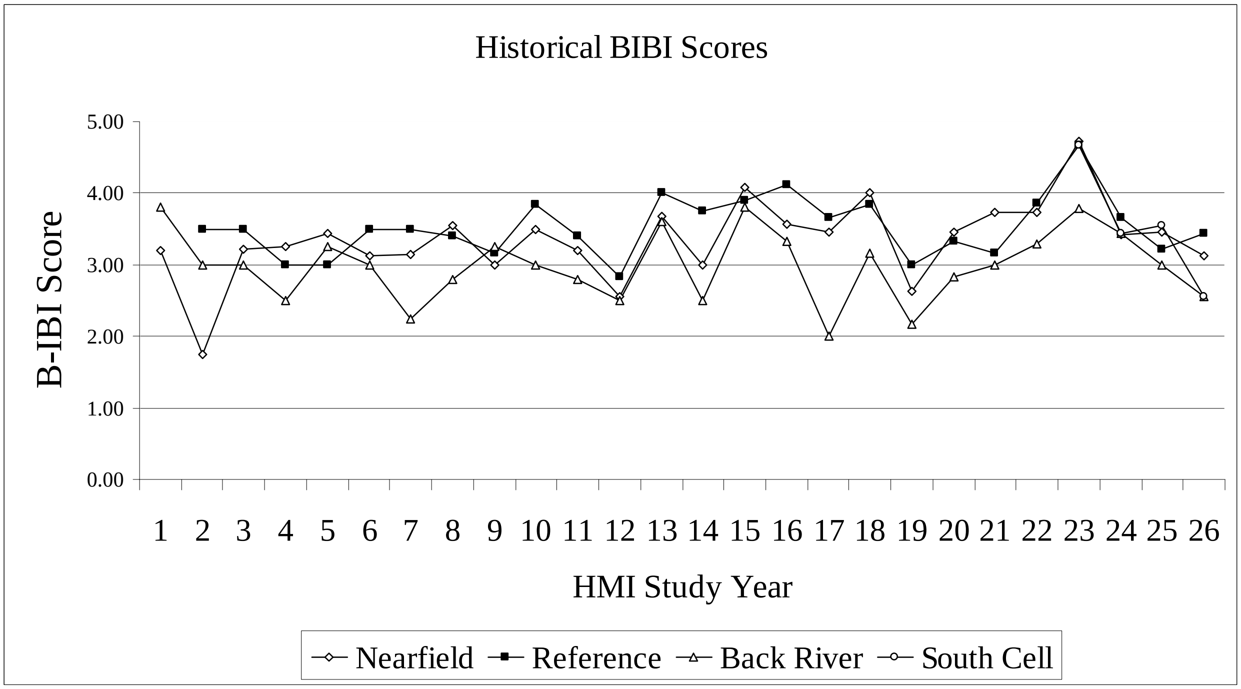

Figure 2-7. Average B-IBI Scores at HMI for Monitoring Years 1-26.

There is a slight trend of decreasing B-IBI scores associated with proximity to HMI in Year 26. However the tendency for lower B-IBIs nearer to HMI is not a historical trend. While the 26-year mean for Reference stations (3.53) is slightly higher than that for Nearfield stations (3.35), the difference is not statistically significant. Through the last 25 years, Reference stations have had higher mean B-IBIs than Nearfield stations 15 times; Nearfield stations have been higher ten times.

STATISTICAL ANALYSIS

Cluster analysis was employed to examine relationships among the stations based upon the presence, abundance and distribution of species. In Figures 2-8 and 2-9, the stations with faunal similarity (based on a Euclidean distance matrix comprised of station infaunal abundance values for all 20 stations) are linked by vertical connections in the dendrograms. Essentially, each station was considered to be a cluster of its own, and at each step the clusters with the shortest distance between them were combined (amalgamated) and treated as one cluster. Identification of station groups from the dendrograms is a subjective exercise. In an effort to verify the identified groups, several other metric variables were examined (total infaunal abundance, number of infaunal taxa, Shannon-Wiener diversity, PSTA score, PITA score, and B-IBI score) to see if there was good agreement among the stations within the identified groups for these variables, in relation to the overall means (all stations) for each of these variables, e.g., all Group 1 (see below) stations had infaunal abundances below the overall mean for all stations, thus the infaunal abundance metric strongly verifies the identified Group 1.

Cluster analysis in past studies at HMI has clearly indicated a faunal response to bottom type (Pfitzenmeyer, 1985; Duguay et al, 1999). Thus, any grouping of stations not correlated to bottom type suggests unidentified factors, warranting further examination of these groups. 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.

Both the dendrograms for September 2007 and April 2008 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 (14 of 20 stations in September 2007 and 15 of 20 stations in April 2008). Grouping of stations in the dendrograms were poorly articulated, i.e., there was not distinct separation of groups. However, it was possible to identify three distinct groups of stations and one outlier station from both the September 2007 and April 2008 cluster dendrograms.

Station clustering occurred early on the x axis of the dendrogram in September 2007 with 16 stations joined within 380 linkage units (Figure 2-8). These 16 stations were initially viewed as one group because of the tight linkage, but a comparison of the individual station metric values against their means at all stations (as discussed above) indicated that a two group interpretation was more valid. Group 1, the more strongly related station group, was composed of ten stations that are joined from 160 to 270 linkage units (Reference station MDE-13, Nearfield stations MDE-17, MDE-03, MDE-33, MDE-16, MDE-24, MDE-22, and MDE-35, Back River station MDE-30, and South Cell Exterior Monitoring station MDE-44). The Group 2 station cluster consisted of six stations that joined from 300 to 360 linkage units (Nearfield stations MDE-19, MDE-34, MDE-07, and MDE-09, South Cell Monitoring station MDE-43, and Reference station MDE-36). Clustering of stations was poorly correlated to station type. In addition, physical nearness or proximity of stations for both Group 1 and Group 2 were poor. Median distance between Group 1 stations was 2,952 meters, while Group 2 median distance was 3,018 meters. Thus, the two groups did not exhibit distinct spatial clustering. However, the benthic macroinvertebrate metrics did reliably separate and contrast the two groups. For the metric total infaunal abundance, all Group 1 stations had values below the overall mean for this variable, while in Group 2 five of six stations had values above the overall mean. Group 1 stations generally had lower than average abundances of *M. viridis*, *S. benedicti*, Naididae sp., and *L. plumulosus*. Group 2 stations generally had higher than average abundances of *R. cuneata*, *M. viridis*, Naididae sp., *L. plumulosus*, and *C. polita*. For the SWDI, eight of ten Group 1 stations were above the overall mean, while five of six Group 2 stations were below the overall mean. For the PITA variables, seven of ten Group 1 stations were below the overall mean, while five of six Group 2 stations were above the overall mean. For the PSTA metric, number of infaunal taxa metric and BIBI score, the contrast between Group 1 and Group 2 was not as powerful. In both Group 1 and Group 2, half of the stations had PSTA scores below the overall mean and half had PSTA scores above the overall mean. For the number of infaunal taxa metric, half of the Group 1 stations were above the overall mean and half were below the overall mean, while in Group 2 five of six stations were above the overall mean. For the B-IBI score, seven of ten Group 1 stations were equal to the overall mean, while in Group 2, one station was equal to the overall mean, three stations were above the overall mean, and two stations were below the overall mean. This analysis indicates that the two groups do not differ in terms of overall community health as measured by the key indicators of impairment. The underlying causes are not likely adverse conditions.

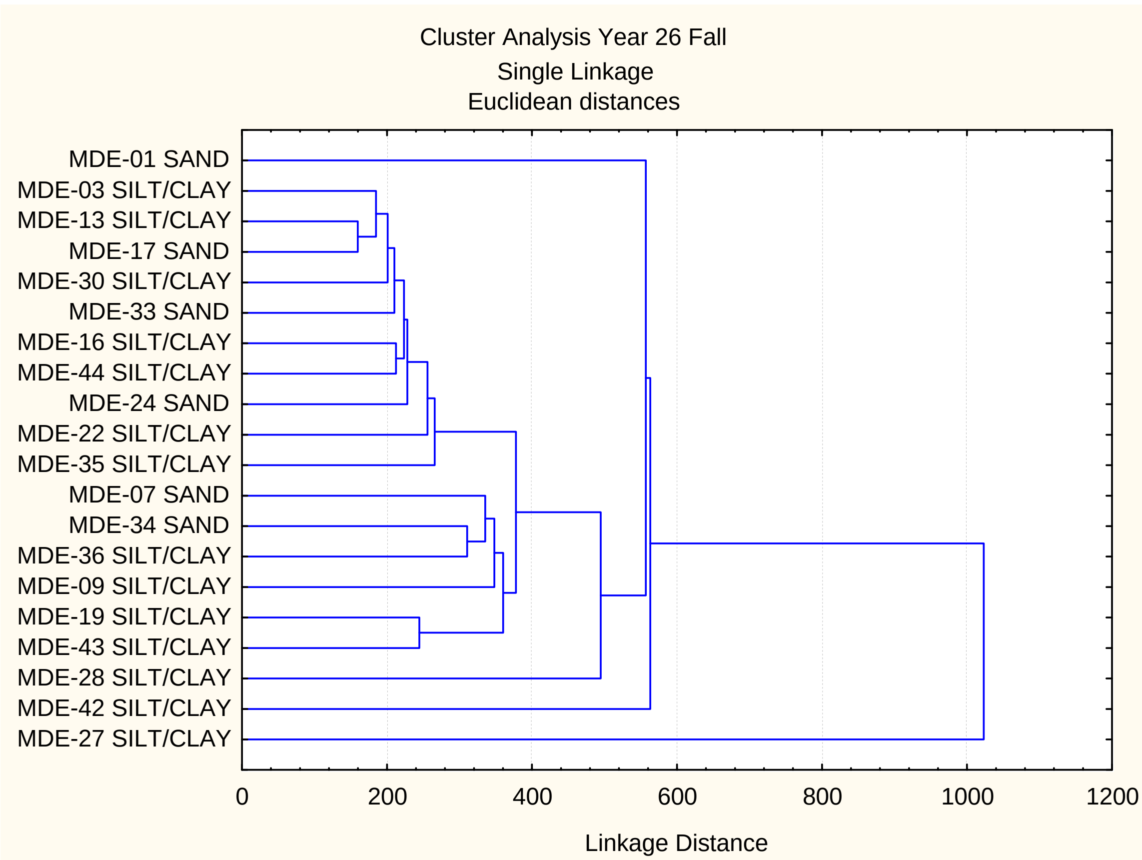

Figure 2-8. Cluster analysis based on Euclidean distance matrix of infaunal abundances of all HMI stations, Year 26 September 2007.

The third group identified in the September dendrogram was composed of three stations that joined from 500 to 570 linkage units (Nearfield station MDE-01, Back River station MDE-28, and South Cell Exterior Monitoring station MDE-42). Group 3 also lacked correlation to station type and to spatial continuity (median distance between stations = 3,054 meters), and exhibited poor continuity with respect to the six metrics. As with Groups 1 and 2, this analysis does not identify any unique impairments or stressors in Group 3.

The one outlier station in September 2007 was Back River station MDE-27. This station required over 1,000 linkage units to join with the other stations in the dendrogram. Historically, MDE-27 has regularly been identified as an outlier. MDE-27 is a silt/clay Back River station with relatively low diversity and high infaunal abundance. Infaunal abundance was dominated by a high percentage of pollution indicative Naiad worms (66 percent of total infaunal abundance, PITA = 72.60 percent), and a lack of pollution sensitive taxa (PSTA =32.08 percent).

The dendrogram for April 2008 (Figure 2-9) exhibited poor clustering, but three weakly associated groups were identified. Grouping of stations was weaker compared to the September 2007 cluster dendrogram. Group 1 consisted of ten stations that joined between 300 and 630 linkage units (Nearfield stations MDE-03, MDE-09, MDE-17, MDE-33, MDE-35, Reference station MDE-13, Back River stations MDE-28 and MDE-30, and South Cell Exterior Monitoring stations MDE-43 and MDE-44). Group 2 consisted of four stations that were joined from 800 to 1,300 linkage units (Nearfield stations MDE-07, MDE-16, and MDE-19, and Reference station MDE-36). Group 3 was composed of five stations that joined from 1,570 to 2,250 linkage units (Nearfield stations MDE-24 and MDE-34, Reference station MDE-22, Back River station MDE-27, and South Cell Exterior Monitoring station MDE-42). The identified clusters exhibited weak to no correlation with station type, and all three groups had poor spatial continuity. Median distance between Group 1 April stations was 2,836 meters, 3,745 meters for Group 2 stations, and 3,273 meters for Group 3 stations.

The lack of spatial separation of groups identified by the cluster procedure in both September 2007 and April 2008 indicates that the habitat diversity driving most natural community differences is likely at a much finer scale (meters) than the sampling effort scale (hundreds of meters). However, the lack of spatial separation also implies an absence of severe impacts associated with HMI operations.

The macroinvertebrate metrics did not affirm the clustering results in April 2008 as strongly as occurred for the September 2007 results. However, total infaunal abundance validated the three groups. All ten stations of Group1 had lower than the overall average infaunal abundance, while three of the four Group 2 stations and all five Group 3 stations had higher than average infaunal abundance. Other strong correlations between the metrics and the cluster results were: nine of ten Group 1 stations with higher than average Shannon/Wiener Diversity, five of five Group 3 stations with less than average Shannon/Wiener Diversity, three of four Group 2 stations with less than average number of infaunal taxa, seven of ten Group 1 stations with less than average PITA scores, three of four Group 2 stations with higher than average PITA scores, and three of four Group 2 stations with less than average PITA scores. In contrast, there were six metric-group combinations that exhibited poor within group coincidence:

number of infaunal taxa within Group 1, number of infaunal taxa within Group 3, Shannon/Wiener Diversity within Group 2, PSTA scores within Group 1, PSTA scores within Group 3, and PITA scores within Group 3.

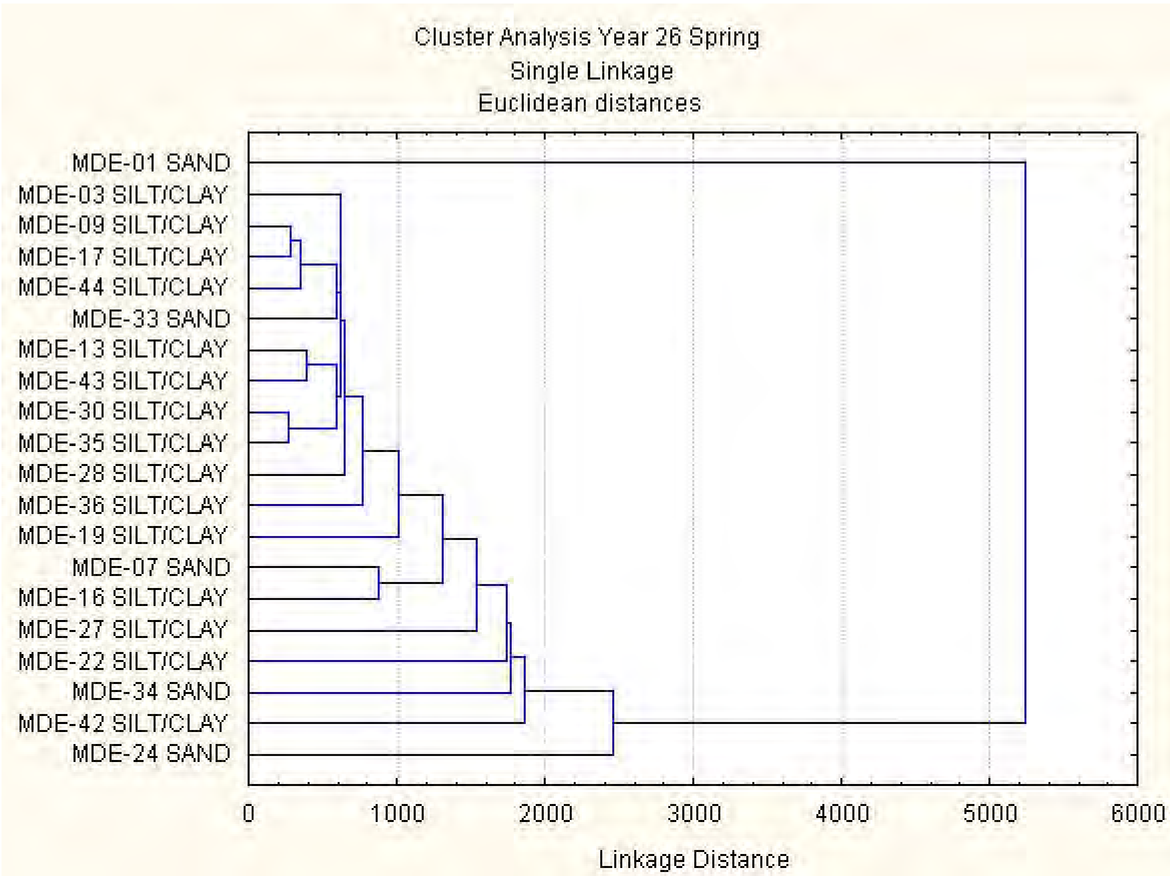

Figure 2-9. Cluster analysis based on Euclidean distance matrix of infaunal abundances of all HMI stations, Year 26 April 2008.

The one outlier station identified by the cluster dendrogram in April 2008 was Nearfield station MDE-01. This station did not join to any other stations until 5,300 linkage units. Station MDE-01 was characterized by a very high infaunal abundance; almost triple the overall station average for this variable. Shannon/Wiener Diversity at MDE-01 was lower than average, but the PSTA score was higher than average (likely due to very high *M. viridis* abundance), while the PITA score was lower than the overall average. This station was unique because of a high epifaunal population. For April 2008, MDE-01 had the highest number of epifauna taxa (5 taxa), and the greatest abundance of the epifauna species *A. lacustre*, *M. leucophaeata*, *B. improvisus*, and *I. recurvum*. In addition, this station had higher than average abundances of the infaunal species *M. viridis* (9,843.2 individuals, the highest recorded station value), *H. filiformis*, and *C. polita*, and lower than average abundance of Naiad worms. Station MDE-01 has unique habitat. It is one of only five stations classified as having a sand dominated substrate and has the highest percentage of oyster shell of all stations sampled.

In conclusion, the Year 26 dendrograms show that clustering was primarily due to small-scale patch dynamics. The variables (station type, sediment type, proximity of stations within a cluster, and proximity to HMI) did not correlate with the clustering patterns, however several of the calculated metrics did correlate well with the identified groups (as discussed above). In the future, the station group identification process of the dendrogram analysis could be improved with the implementation of a quantitative method to replace the current subjective qualitative analysis.

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 no significant differences in the 10 most abundant infaunal species between the four station types in either September 2007 ($P < 0.36$), or April 2008 ($P < 0.52$). Comparisons of means by station type to the overall mean (all stations) for the following metrics: number of infaunal taxa, Shannon/Wiener Index value, PSTA score, and PITA score, were examined to determine if they supported the Friedman's test results. In most cases station type means for these variables did not vary greatly from the overall means, with only two exceptions. In September 2007, the Reference stations mean of 25.82 percent for the PITA score was quite lower than the overall mean of 42.86 percent. Likewise, in April 2008, the PSTA mean of 20.34 percent for Reference stations was quite lower than the overall mean of 43.56 percent. The apparent uniqueness of reference stations with regard to PSTA and PITA scores was not reflected in the outcome of the Friedman's Test.

Table 2-15. Friedman Analysis of Variance for September 2007's 10 most abundant species among: Back River/Hawk Cove, Nearfield, South Cell Exterior Monitoring, and Reference stations. ANOVA Chi Sqr. ($N = 10$, $df = 3$) = 3.19, $P < 0.36$.

Station Type	Average Rank	Sum of Ranks	Mean	Std. Dev.
Nearfield	3.100000	31.00000	116.1891	119.6350
Reference	2.200000	22.00000	112.6400	133.4799
Back River	2.450000	24.50000	187.0933	300.2760
South Cell Exterior Monitoring	2.250000	22.50000	137.6000	234.5745

Table 2-16. Friedman Analysis of Variance for April 2008'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) = 2.28, P < 0.52.

Station Type	Average rank	Sum of ranks	Mean	Std. Dev
Nearfield	2.200000	22.00000	427.3455	870.2017
Reference	2.900000	29.00000	360.9600	507.3067
Back River	2.200000	22.00000	273.9200	372.9657
South Cell Exterior Monitoring	2.700000	27.00000	357.5467	575.0486

CONCLUSIONS AND RECOMMENDATIONS

The health of the benthic macroinvertebrate community was marginally acceptable in Year 26 as measured by the B-IBI scores, which declined overall for the third consecutive year (Figure 2-7). Compared to Year 25, B-IBI scores stayed the same at four stations, increased at five stations, and declined at eleven stations. However, the B-IBI scores were comparable to historical values. Fifteen of the twenty stations met or exceeded the benchmark criteria of 3.0, while five stations had failing scores (MDE-19, MDE-27, MDE-30, MDE-42, and MDE-43). B-IBI scores tend to fluctuate naturally (Figure 2-7), thus it is too soon to discern whether this most recent decline is environmentally significant. The last major low for B-IBI scores occurred in Year 19, which was followed by an increasing trend for several years prior to the most recent decline.

Reference and Nearfield stations had mean B-IBI scores of 3.4 and 3.1 respectively, which indicated relatively healthy benthic macroinvertebrate communities for these sites, but the mean B-IBI scores for Back River and South Cell Exterior Monitoring stations were 2.6, indicating that these sites had relatively impaired benthic communities. Although the Year 26 mean B-IBI scores indicated differences in benthic macroinvertebrate community composition between the passing Nearfield/Reference stations and failing Back River/South Cell stations, the Friedman's nonparametric test results and the cluster analysis results did not lend statistical validity to these differences. The Friedman's test found no significant differences in the infauna among the four station types, while the dendrograms produced by the cluster procedure found little or no correlation of clusters to station type. The lack of agreement between the B-IBI results and the Friedman's cluster test results is not unexpected, as the B-IBI scores are calculated from a number of metrics, including infaunal abundance, Shannon-Wiener Diversity, and PITA score, while the Friedman's test and the cluster analysis examine differences in faunal abundance only. The comparison of mean B-IBI scores among the station types are a more robust measure of differences between them because they are multi-metric indices, which are fine-tuned to the predominant salinity regime at the time of sampling.

Various explanations can be used to account for relatively depauperate benthic communities in the Back River and South Cell Exterior Monitoring Stations. For instance, lower B-IBI scores at the Back River stations is historically documented and most likely due to conditions intrinsic to the Back River drainage. However, the depressed B-IBI scores near the South Cell discharge identify a need for closer examination. Various biological stress factors may be involved, including potential localized impacts from the South Cell discharge. Possible explanations may include habitat or physical conditions unique to the South Cell Exterior Monitoring stations, or the fact that the group of three South Cell stations is largely new (established in Year 24 to gain a baseline dataset prior to closure of the South Cell). Characterizing the year's poor result for the South Cell stations is difficult without a strong historical context. In some recent years, South Cell Exterior Monitoring stations have been better than other station types and above the benchmark. With this in mind, further data will be needed to determine if the depressed mean B-IBI was coincidental or attributable to any of the above candidate causes.

The Hart-Miller Island Dredged Material Containment Facility will cease to received dredged material on December 31, 2009. To date, there have been no conclusive impacts from HMI on the benthic community in the adjacent area. This report incorporates some comprehensive historical analysis of present year data against historic HMI data. Consequently, Year 26 results more effectively filter out real trends from background random variation. The preparation and dissemination of a comprehensive historical analysis of HMI data (without the focus on a single years monitoring) is a primary goal for future work. That goal is largely fulfilled at this time with regard to data management but a thoughtful analysis remains to be written for many details. 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 2007 –August 2008)

Technical Report

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OBJECTIVES

The goals of the project in 2007-2008 were to continue to measure and evaluate the current levels of contaminants in the sediment in the vicinity of Hart-Miller Island (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 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 the twenty-sixth year of exterior monitoring, and to document any seasonal changes. Specific objectives were:

1. In the fall of 2007 collect clams and associated sediment for analyses of trace metals, polycyclic aromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs).

2. To determine the concentrations of target trace elements in surface sediments around HMI collected by Maryland Geological Survey (MGS) in September 2007 as part of the annual sediment survey. Metal analysis focuses on those metals not measured by MGS, specifically mercury (Hg), monomethylmercury (MMHg), silver (Ag), selenium (Se), and arsenic (As).

The results of the quality assurance (QA/QC) procedures and the description of the analytical and field protocols are contained in the *Year 26 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 26 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 (MDE) 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 whole clams where placed in plastic bags with surface water and held on ice. The clams were frozen to allow easy shucking the next day. For metals analysis, clams were removed whole from their shells with a Teflon-coated spatula. Most of the water and body fluids were allowed to drain. The spatula was acid rinsed between each site to avoid cross contamination between sites. The clam bodies from each site were homogenized in a plastic blender with a stainless steel blade. Unused samples were returned to their respective bags and stored in the freezer until further analysis.

Analytical Procedures for Metals

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

Sediment and clam tissue were treated the same with regard to analysis. A sub-sample of sediment (5 g wet weight) was placed in acid-cleaned flasks for further digestion, using United States Environmental Protection Agency (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 percent 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. Thirty percent H_2O_2 was repeatedly added in 1 mL aliquots with warming until the effervescence was minimal. No more than a total of 10 mL of H_2O_2 was added to each sample. Lastly, 5 mL of concentrated HCl and 10 mL of deionized water were added and the samples refluxed for 15 minutes. The samples were then cooled and filtered through Whatman No. 41 filter paper by suction filtration and diluted to 50 mL with deionized water. Sediment homogenates were then analyzed using a Hewlett Packard model 4500 Inductively Coupled Plasma Mass Spectrometer for the other metals and metalloids. These techniques follow USEPA Method 3050b.

Samples for mercury (1-3 g wet weight) were digested in a solution of 70 percent sulfuric/30 percent 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 percent 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 percent sulfuric acid solution and a 20 percent 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 and clam 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 PAH cocktail (d_8-napthalene, d_{10}-fluorene, d_{10}-fluoranthene, d_{12}-perylene) and a noncommercial PCB solution (IUPAC #'s 14, 65, 166) are added as surrogates to each sample to track extraction efficiency. 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 percent (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 PAHs. The samples are then analyzed using a Hewlett Packard 5890 gas chromatograph (GC) with a HP-5MS (cross linked 5 percent phenyl methyl siloxane) capillary column (30m x 0.25mm x 0.25um film thickness) and a HP-5972 series mass spectrometer (MS) for PAHs (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 percent [w/w] water) (Kucklick et al.1996). The first fraction (F-1), contains PCBs and 1-100 percent, by weight, of the less polar organochlorine pesticides [heptachlor (100 percent), 4,4-DDT (40 percent), 4,4-DDE (100 percent), t-nonachlor (24 percent), heptachlor (1 percent), 4,4-DDT(44 percent)]. The second extracted fraction, (F-2), contains 56-100 percent of the more polar organochlorine pesticides [a-HCH (100 percent), g-HCH (100 percent), c-chlordane (100 percent), t-chlordane (100 percent), t-nonachlor (76 percent), heptachlor (99 percent), heptachlor epoxide (100 percent), dieldrin (100 percent), 4,4-DDD (100 percent), 4,4-DDT (56 percent)]. 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

RESULTS AND DISCUSSION

Metals in Sediment

Concentrations of As and Se in the sediment collected around HMI in Year 26 (fall 2007) are toward the higher side of concentrations seen in previous years (Figure 3-1). The concentrations of As are about 5 ug g^{-1} higher than the running mean at the majority of the sampling locations, but this increase was also seen at the reference site MDE-36. An increase in As was not observed at all sites. For example sites MDE-42, 43 and 44, located within the observed zone of influence showed no deviation from past concentrations. Concentrations of Se in Year 26 sediments displayed a similar pattern as As. The increase in concentration at many sites was on the order of 1 ug g^{-1}. The reference site also showed above average concentrations and as in the case of Se, some sites in close proximity to HMI showed concentrations consistent with most years. Concentrations of Ag were consistent with the median value and well below the average concentrations observed around HMI.

Concentrations of both total mercury (T-Hg) and methylmercury (MeHg) in sediment are lower than the running mean and median from previous years (Figure 3-2 and 3-3). Concentrations of T-Hg in the main stem of the Chesapeake Bay range from 0.2 to 250 ng g^{-1} dry weight and concentrations of MeHg range from 0.01 to 2.2 ng g^{-1} dry weight (Heyes et al. 2006). Concentrations of both T-Hg and MeHg are highest in the upper Bay, with T-Hg concentrations on the order of 130 ng g^{-1} and MeHg concentrations 1 ng g^{-1}. The concentrations around HMI are consistent with this observation.

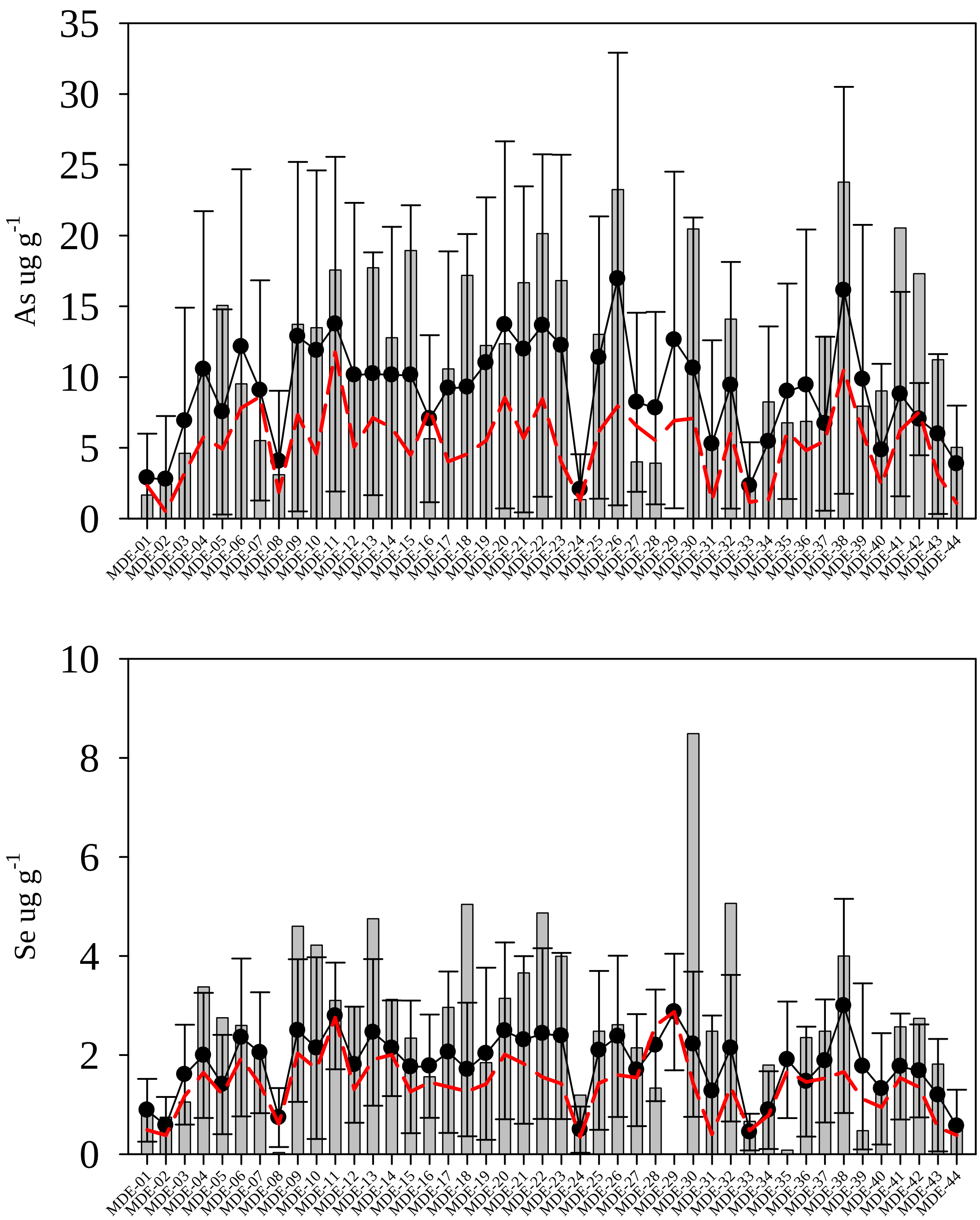

Figure 3-1. As and Se in sediment, expressed in dry weight concentration, from 2007 (bars) and the 1998-2006 mean (circles) with standard deviation (error bars) and the 1998-2006 median (dashed line).

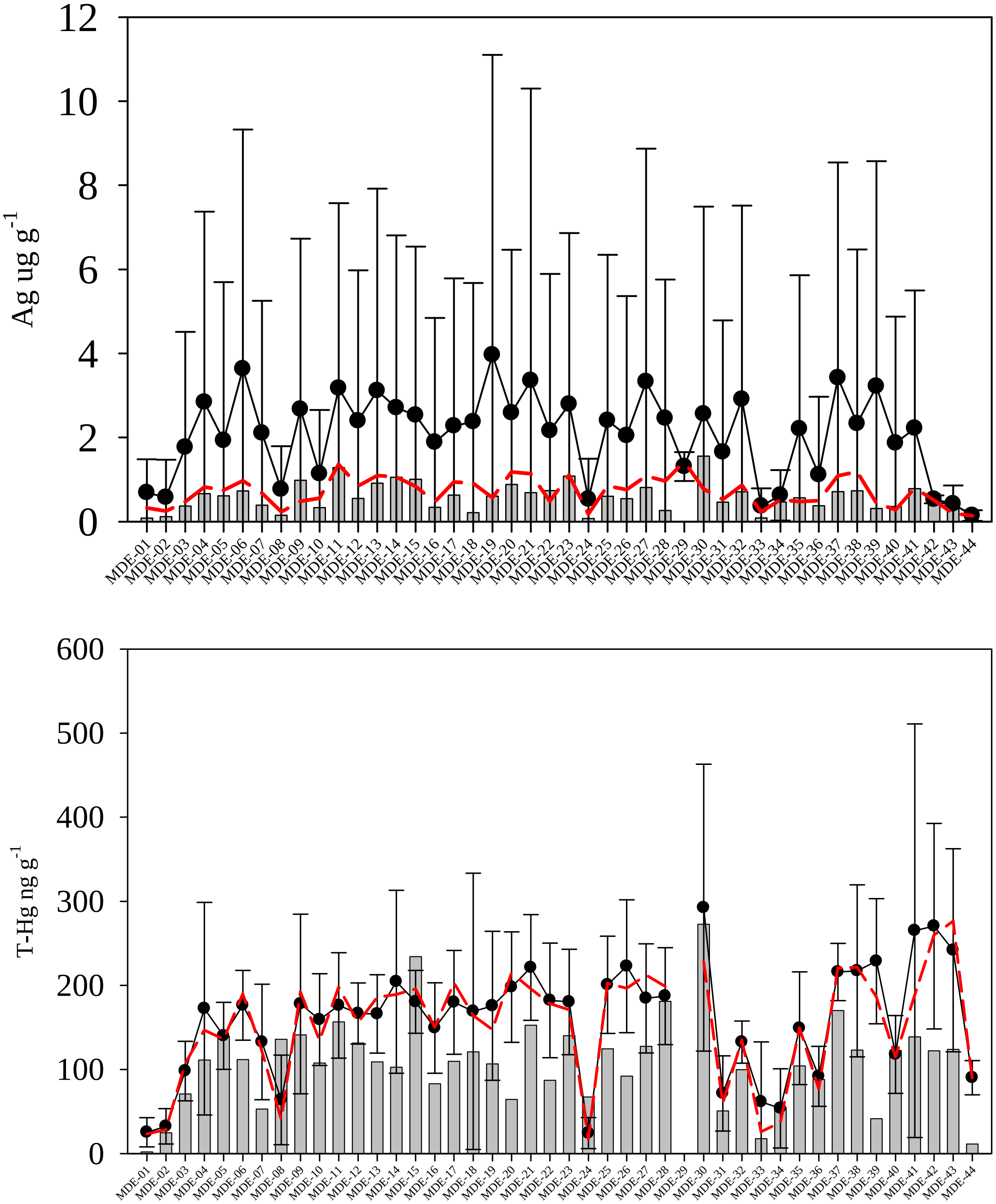

Figure 3-2. Ag and T-Hg concentrations in sediment from 2007 (bars), expressed as dry weight concentration, and the 1998-2006 mean (circles) with standard deviation (error bars) and the 1998-2006 median (dashed line).

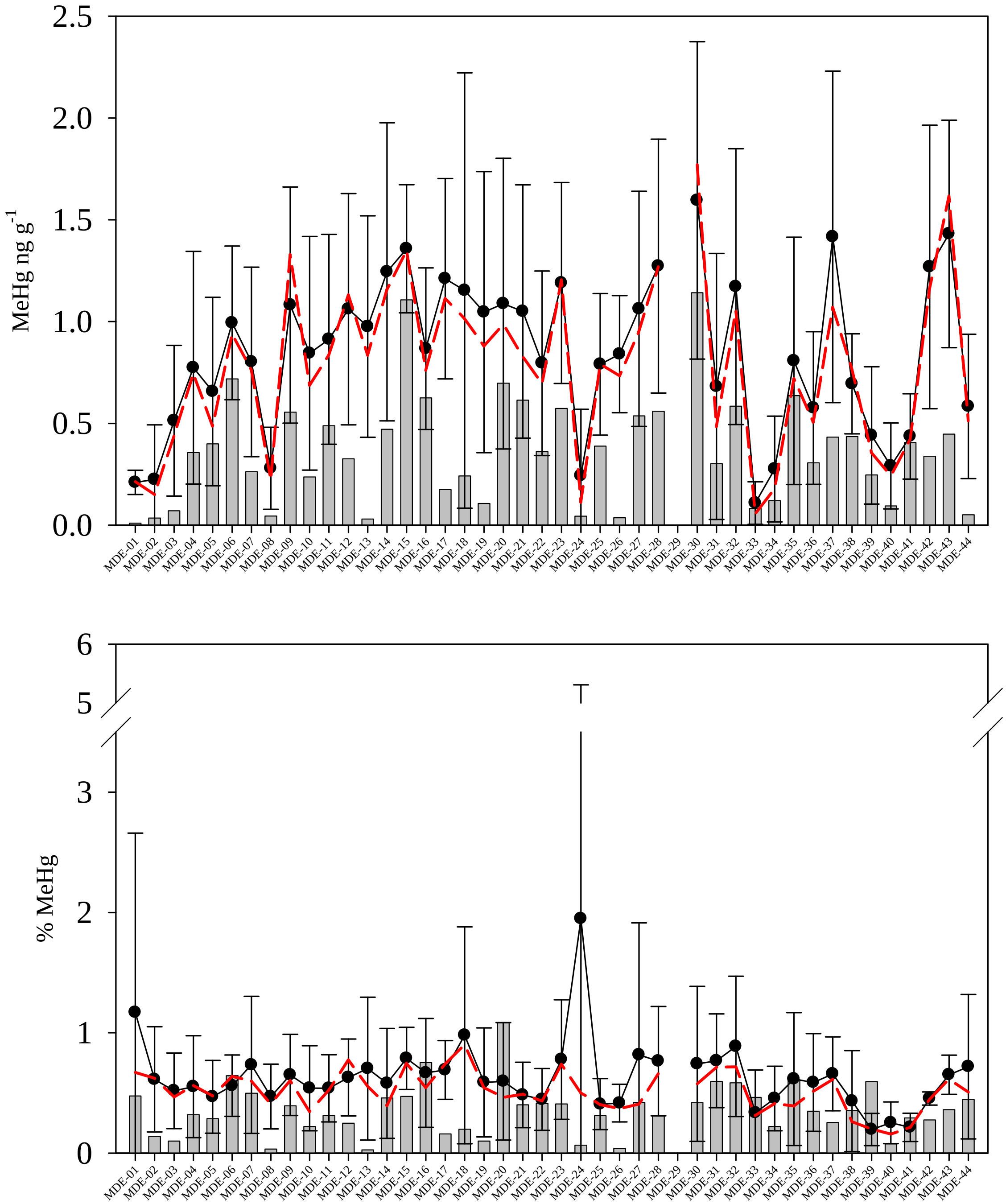

Figure 3-3. MeHg expressed as dry weight concentrations, and percent Hg as MeHg in 2007 sediment (bars), and the 1998-2006 mean (circles), median (dashed line), with standard deviation (error bars).

Stations MDE-42, 43 and 44

Monitoring stations MDE-42, 43 and 44 were added to the sampling plan in the spring of Year 22. The stations were added to gather baseline data in the Bay area east of the South Cell Spillway 003, which was put back into use in 2006 after the restoration of the South Cell was completed in August of 2005 (HMI Year 24). For the most part, these sites appear similar to the sites on the southern end of HMI (Figures 3-1, 3-2, 3-3). In 2007, T-Hg and MeHg concentrations at sites 42, 43 and 44 were similar to the other sites and lower than observed in previous years. The concentrations of As and Se were elevated at these sites when compared to the running mean. These elevated levels were observed at the majority of sites including the reference sites and reflects some larger scale influence, not HMI operations. Concentrations of Ag were low in 2007 as observed in previous years.

Metals in Clams

Clams were only collected in the fall of 2007. Concentrations of the metals As, Se, Ag, Cd, Pb, Hg and MeHg in the clam *Rangia cuneata* displayed some variations from previous years (Figures 3-4 and 3-5). Metals where lower in concentration at all sites with the exception of As, which was close to the average concentration observed since 1998. The percent MeHg was also close to the average mean of the study period. In general, clams collected in September often have lower Ag and Pb concentrations than April.

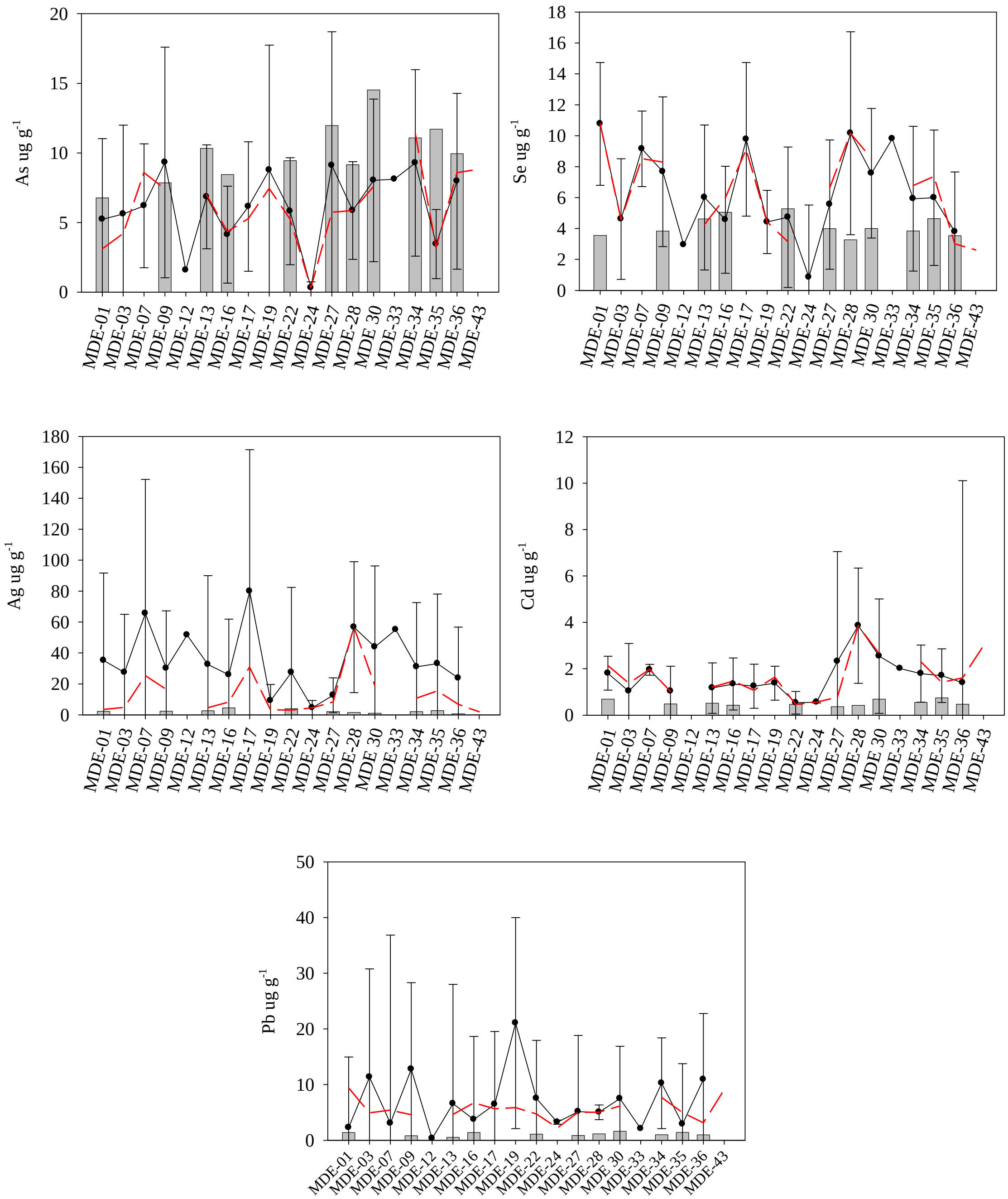

Figure 3-4. Concentrations of Pb, Cd, As, Se, Ag in clams collected in September 2007. Concentrations are expressed as dry weight, collected in September 2007 (bars) and the 1998-2006 mean (circles) and median (dashed line) with standard deviation (error bars) for the sites are presented.

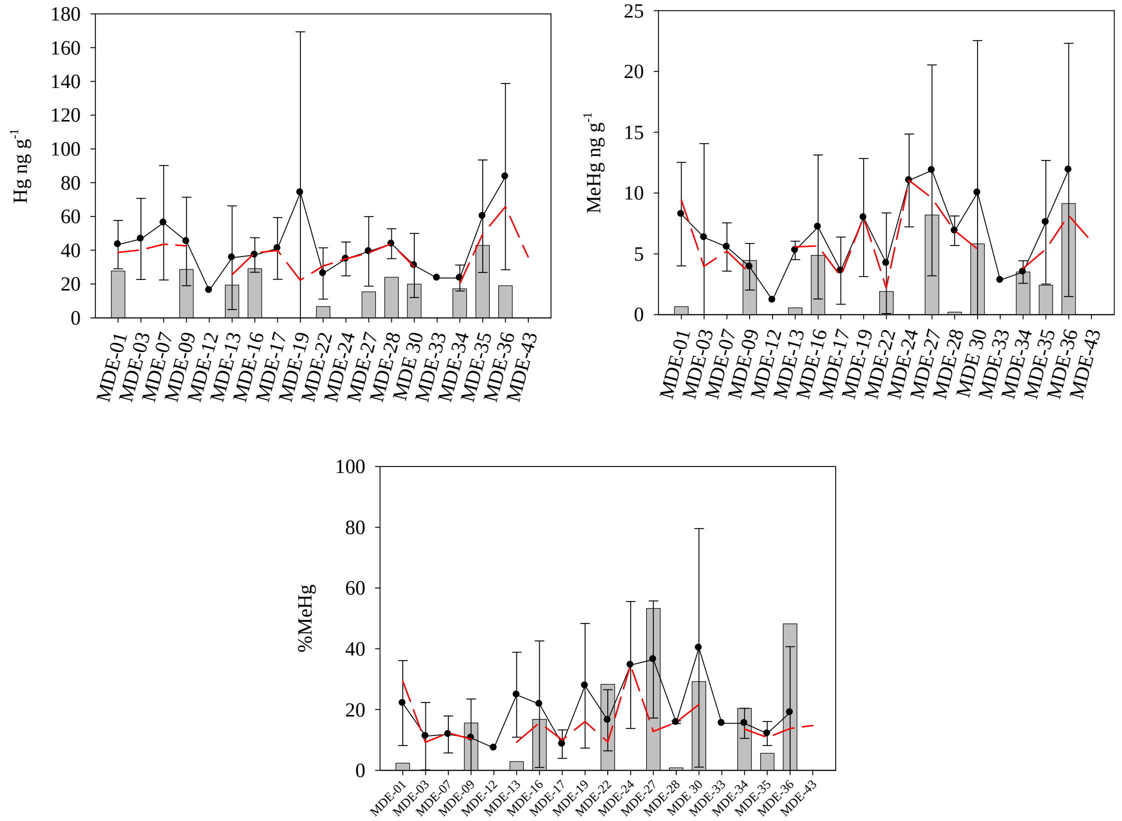

Figure 3-5. Mercury (Hg) and methylmercury (MeHg) concentrations, expressed on a dry weight basis, and percent of Hg that is MeHg in clams, collected in September 2007 (bars) and the 1998-2006 mean (circles) and median (dashed line) with standard deviation (error bars).

Bioaccumulation Factors

The bioaccumulation factors (BAFs) were calculated for the trace metals, Cd, Pb, As, Ag, Se, Hg, and MeHg (Figure 3-6) using the sediment concentration data in Table 3-1. The BAFs for Pb (not shown) are less than one at all sites sampled. BAFs of less than 1 for Pb have been occurring for the duration of the study. Little bioaccumulation of As, Cd and Hg was observed. Some bioaccumulation was indicated at site MDE-01, but this is driven by low sediment concentrations of these metals (Table 3-1) not elevated tissue levels (Figure 3-4 and 3-5). Moderate bioaccumulation was observed for Se at a number of sites, which had BAFs <5 except for site MDE-35 where very low Se concentrations in sediment skew the result. In the case of MeHg, some bioaccumulation is occurring which is expected, but the BAF vary among the sites, driven mostly by the sediment MeHg concentration. At site MDE-01, sediment MeHg was at the detection limit thus the BAF of 65 for that site is biased high compared to other locations.

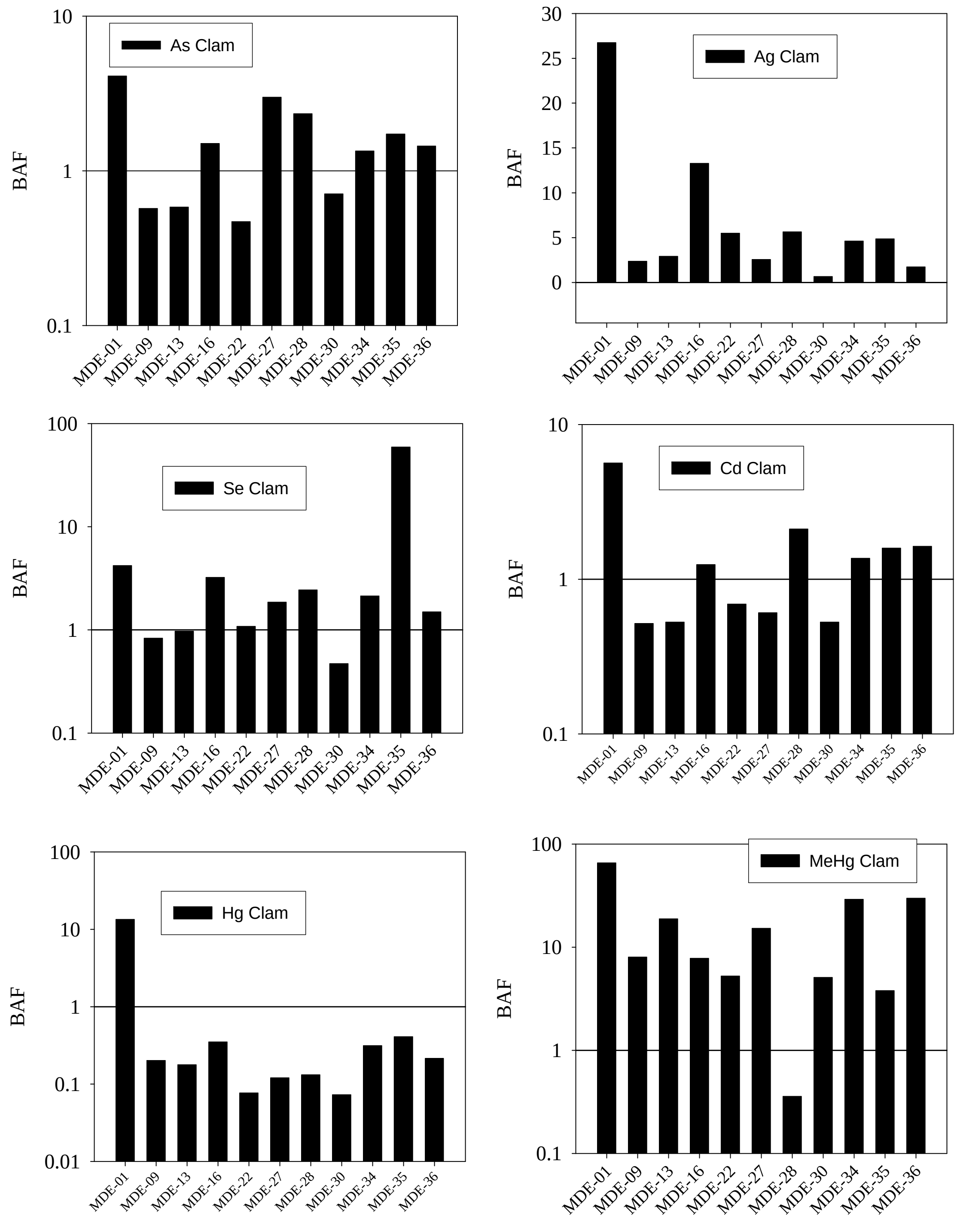

Figure 3-6. Bioaccumulation factors for the metals As, Ag, Se, Cd, Hg and MeHg.

Station	As ug/g dry	Se ug/g dry	Ag ug/g dry	Cd ug/g dry	Pb ug/g dry	T-Hg ug/g dry	MeHg ug/g dry
MDE-01	1.65	0.84	0.09	0.12	6.89	2.06	0.01
MDE-09	13.72	4.60	0.98	0.93	62.38	141.21	0.55
MDE-13	17.17	4.75	0.91	0.97	66.69	108.95	0.03
MDE-16	5.63	1.56	0.34	0.35	31.45	83.05	0.62
MDE-22	20.13	4.87	0.74	0.67	71.37	87.14	0.36
MDE-27	4.00	2.15	0.81	0.60	51.03	127.40	0.54
MDE-28	3.91	1.33	0.27	0.20	21.28	180.96	0.56
MDE-30	20.47	8.49	1.56	1.30	101.20	272.73	1.14
MDE-34	8.23	1.80	0.46	0.40	31.27	54.64	0.12
MDE-35	6.77	0.08	0.56	0.47	49.02	104.20	0.64
MDE-36	6.87	2.35	0.38	0.29	28.87	88.26	0.31

Table 3-1. Trace metal concentrations in sediment at HMI sites where clams were collected.

POLYCHLORINATED BIPHENYLS AND POLYCYCLIC AROMATIC HYDROCARBONS

PCBs in Sediment

The concentrations of PCBs in the sediments were sampled in September of 2007 (Table 3-2). These findings are summarized in Figure 3-7 a-k. The sediments are typically high in the PCB congeners 66, 95, 206 and 209. The samples collected in Year 26 are similar. In general PCB concentrations were lower than the average and close to the median when compared to sediment collected from the same sites in previous years. Site MDE-01, which had not been sampled in a number of years, was sampled in 2007. Concentrations of PCBs measured in 2007 at MDE-01 were higher than recorded earlier but are some of the lowest when compared to the other sites. The sites around HMI were also similar to what was observed at the Reference site MDE 36.

Polychlorinated Biphenyls											
1	cong1	16	cong31,28	30	cong63	44	cong136	58	cong158	72	cong193
2	cong3	17	cong33,21,53	31	cong74	45	cong110,77	59	cong129,178	73	cong191
3	cong4,10	18	cong51	32	cong70,76	46	cong82,151	60	cong187,182	74	cong200
4	cong7,9	19	cong22	33	cong66,95	47	cong135,144	61	cong183	75	cong170,190
5	cong6	20	cong45	34	cong91	48	cong107	62	cong128,167	76	cong198
6	cong8,5	21	cong46	35	cong56,60,92	49	cong123,149	63	Cong167	77	cong199
7	cong19	22	cong52	36	cong84	50	cong118	64	cong185	78	cong203,196
8	cong12,13	23	cong49	37	cong101,89	51	cong134	65	cong174	79	cong189
9	cong18	24	cong47,48	38	cong99	52	cong114	66	cong177	80	cong208,195
10	cong17	25	cong44	39	cong119	53	cong146	67	cong202,171,156	81	cong207
11	cong24	26	cong37,42	40	cong83	54	cong132,153,105	68	cong157,201	82	cong194
12	cong16,32	27	cong41,64,71	41	cong97	55	cong141	69	cong172	83	cong205
13	cong29	28	cong40	42	cong81,87	56	cong137,176	70	cong197	84	cong206
14	cong26	29	cong100	43	Cong85	57	cong163,138	71	cong180	85	cong209

Table 3-2. Polychlorinated biphenyls given in the same order as presented in Figure 3-7 a-k, and Figure 3-8 a-k.

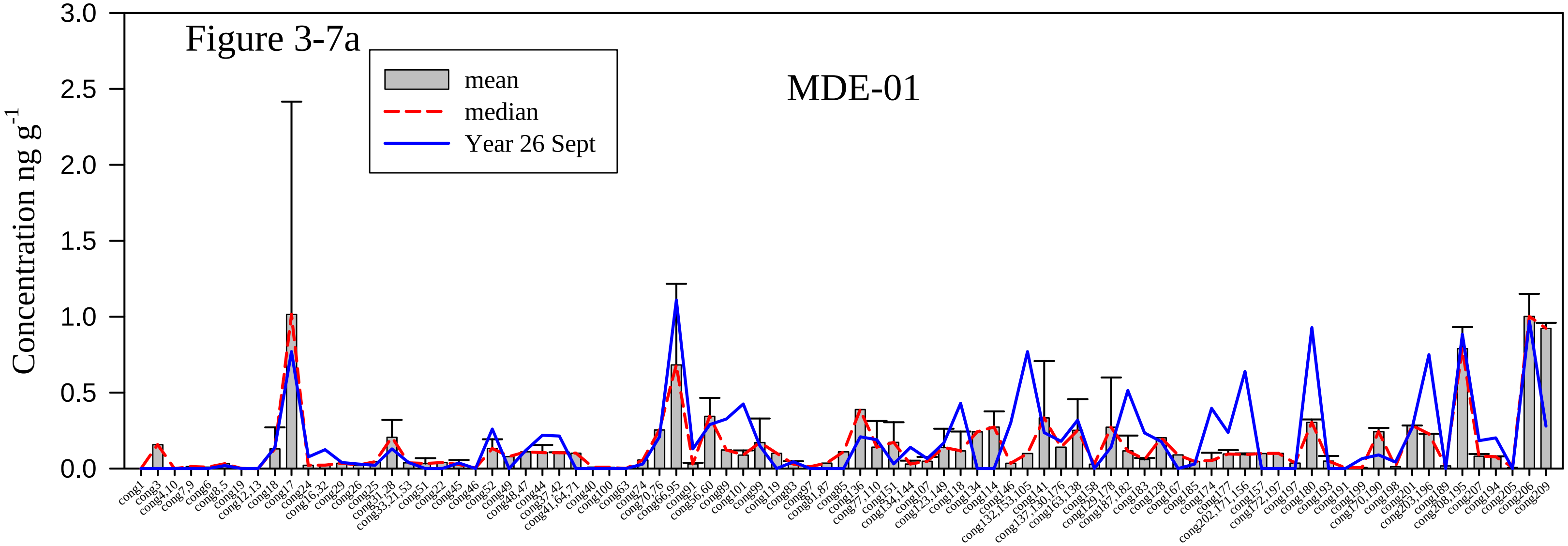
Figure 3-7a
MDE-01
mean
median
Year 26 Sept
Concentration ng g-1

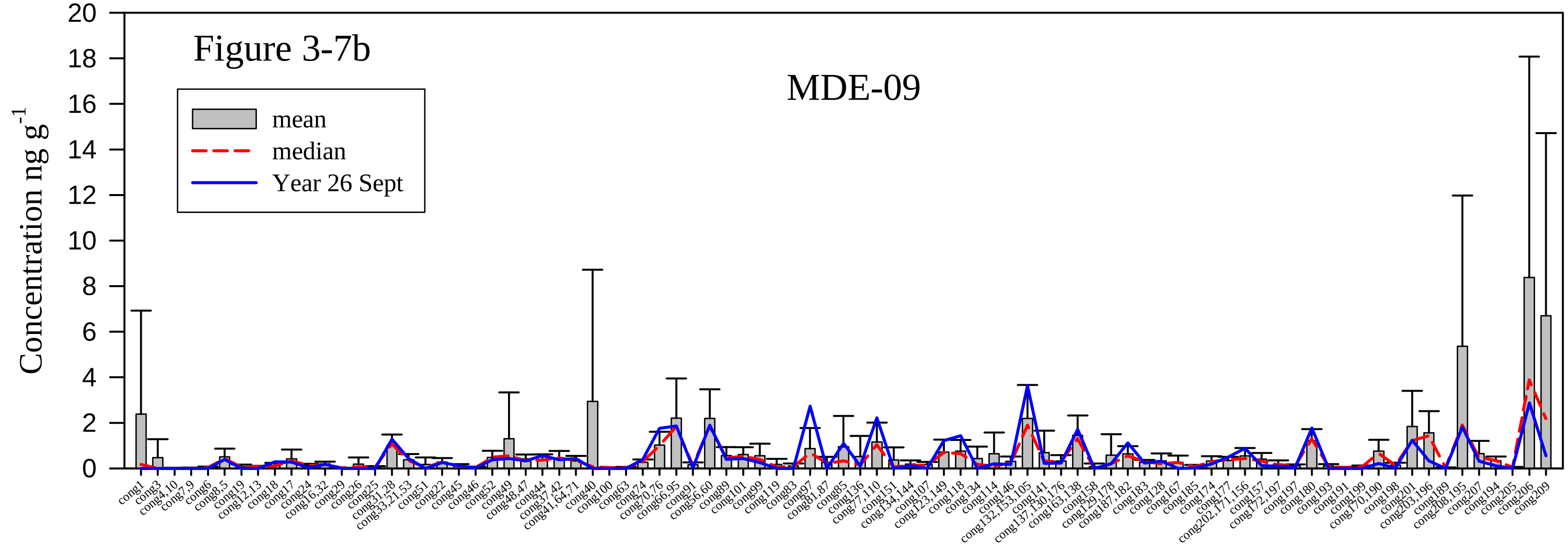
Figure 3-7b
MDE-09
mean
median
Year 26 Sept
Concentration ng g-1

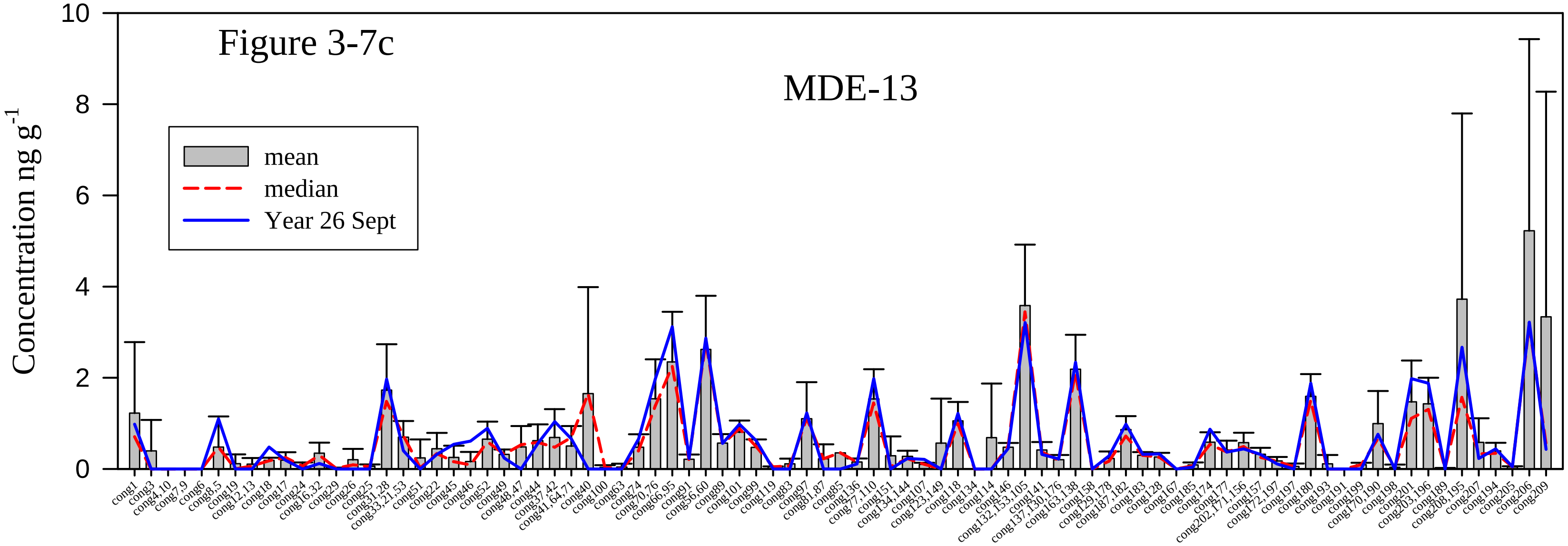
Figure 3-7c
MDE-13
Concentration ng g-1
mean
median
Year 26 Sept
0
2
4
6
8
10

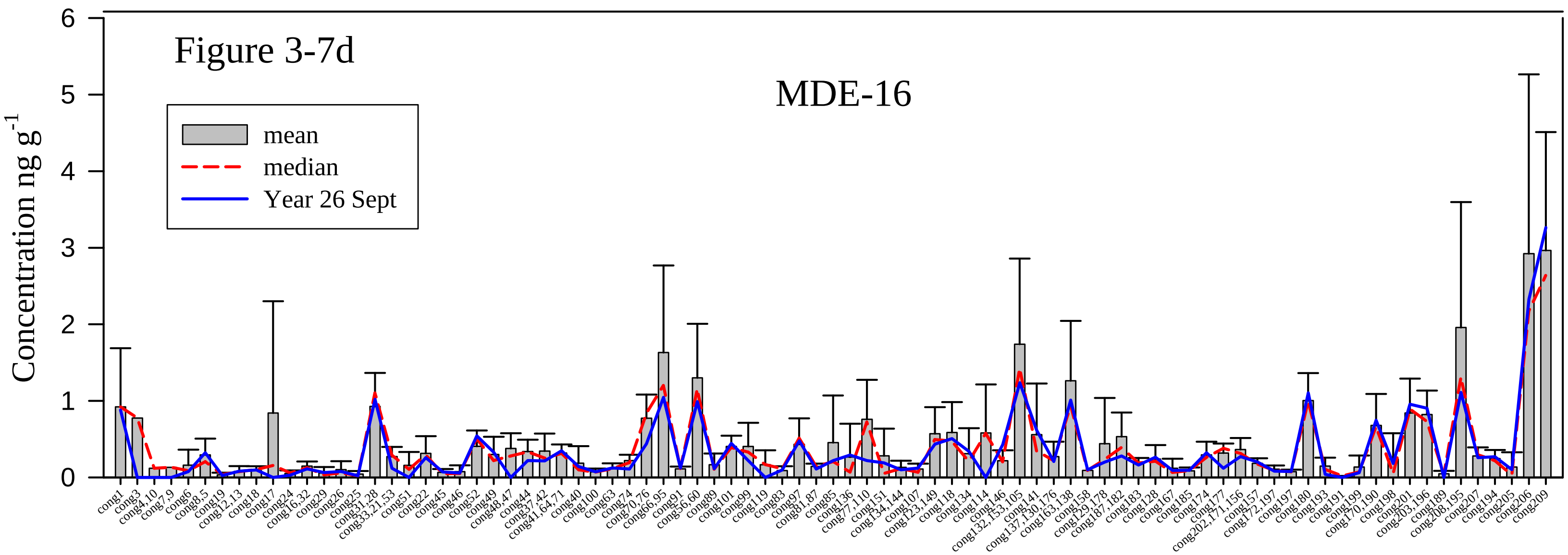
Figure 3-7d
MDE-16
Concentration ng g-1
mean
median
Year 26 Sept
0
1
2
3
4
5
6

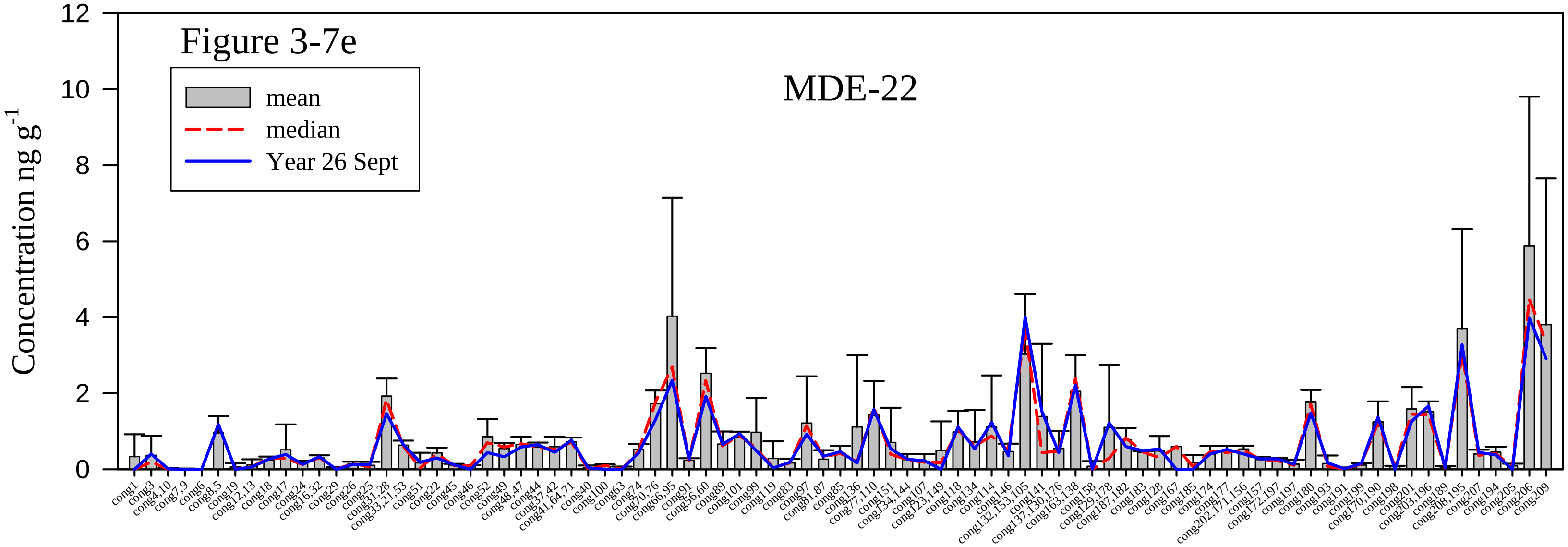
Figure 3-7e
MDE-22
mean
median
Year 26 Sept
Concentration ng g-1

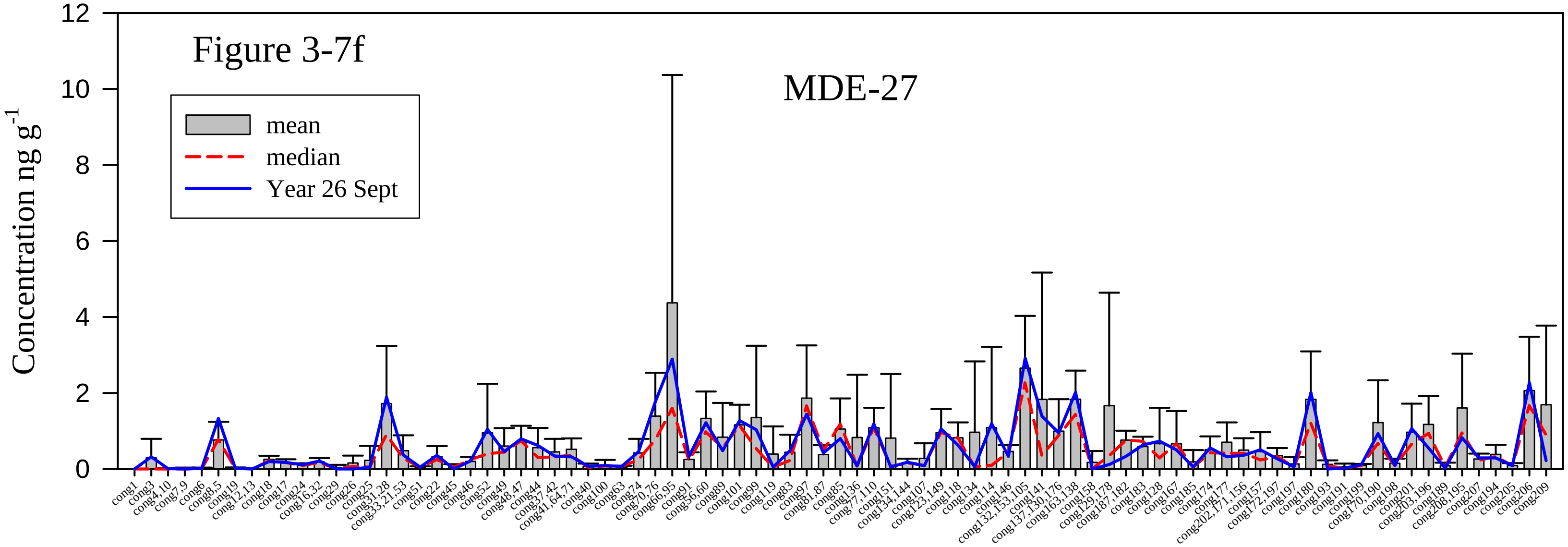
Figure 3-7f
MDE-27
mean
median
Year 26 Sept
Concentration ng g-1

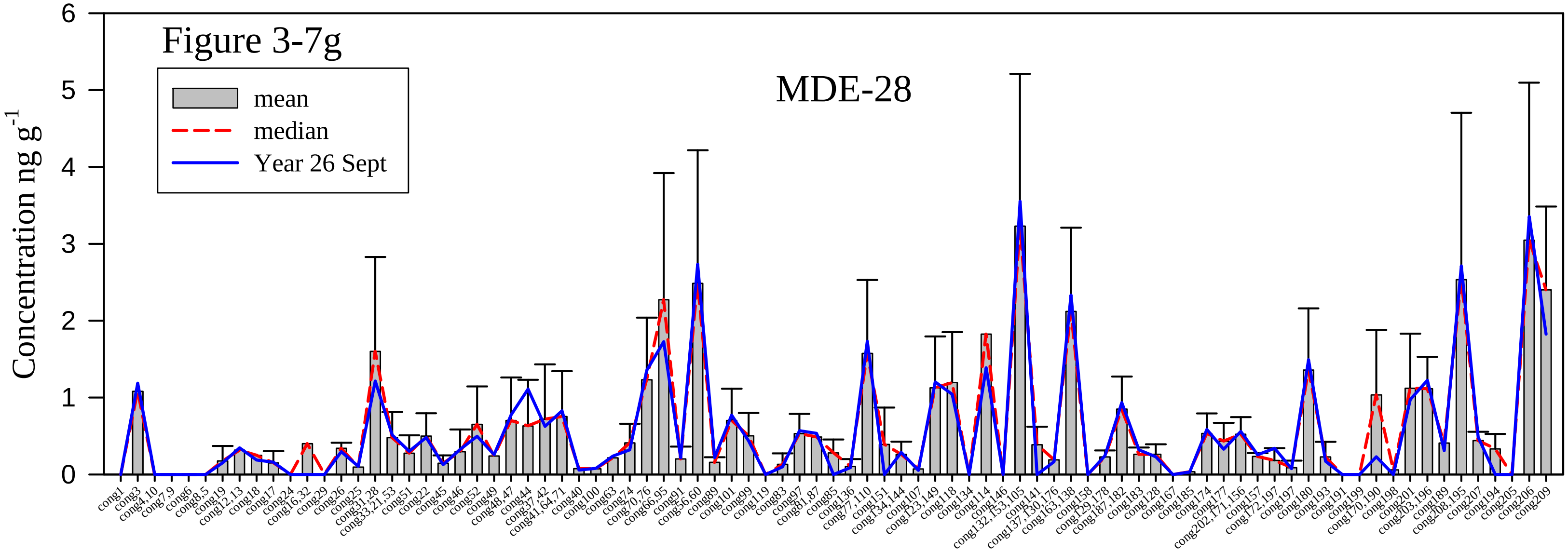
Figure 3-7g
MDE-28
mean
median
Year 26 Sept
Concentration ng g-1
0
1
2
3
4
5
6

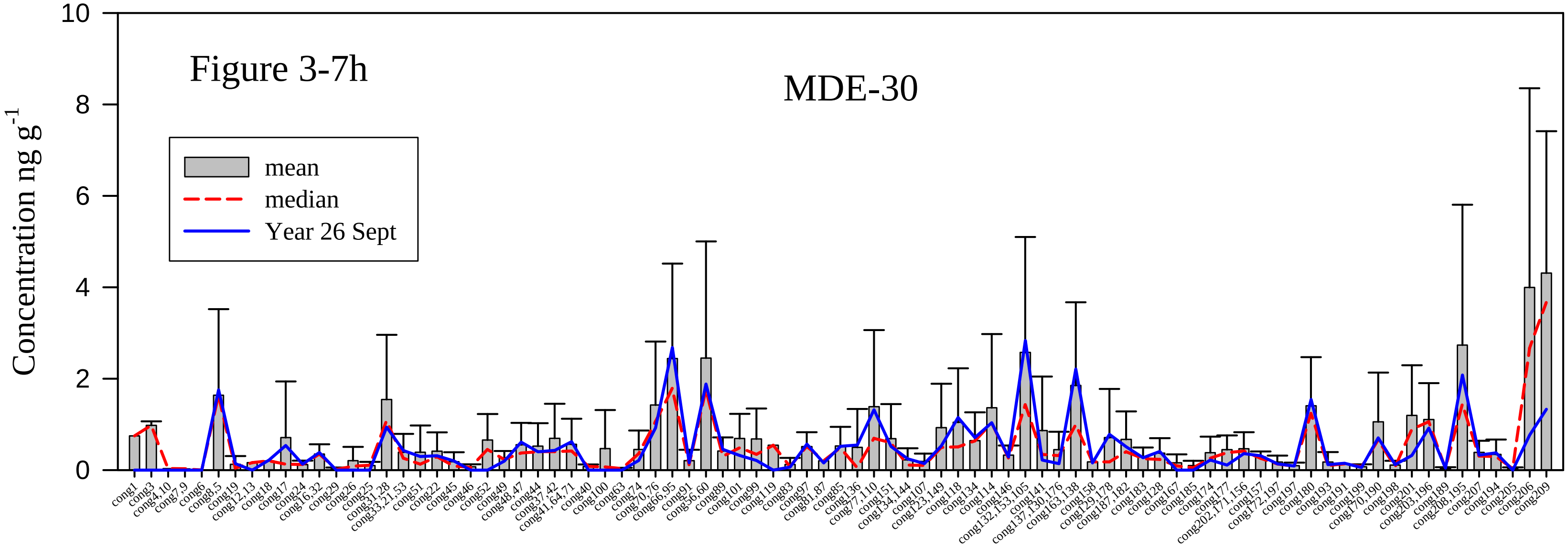
Figure 3-7h
MDE-30
mean
median
Year 26 Sept
Concentration ng g-1
0
2
4
6
8
10

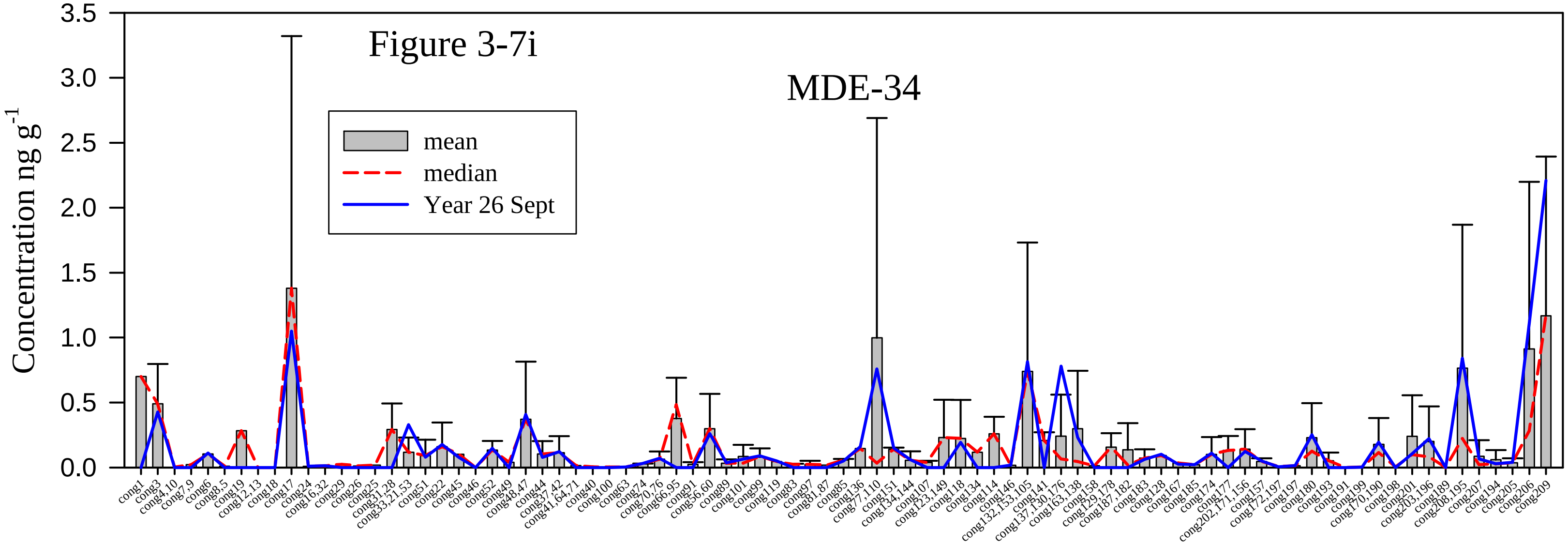

Figure 3-7i
MDE-34
mean
median
Year 26 Sept
Concentration ng g-1

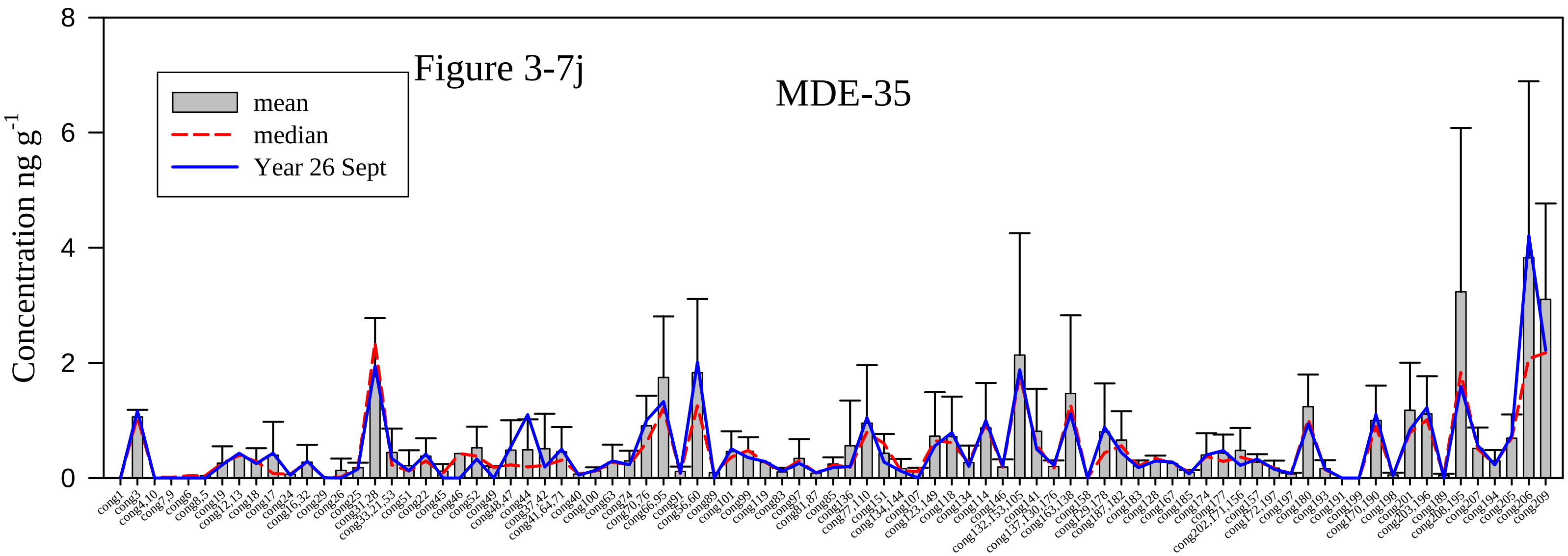

Figure 3-7j
MDE-35
mean
median
Year 26 Sept
Concentration ng g-1

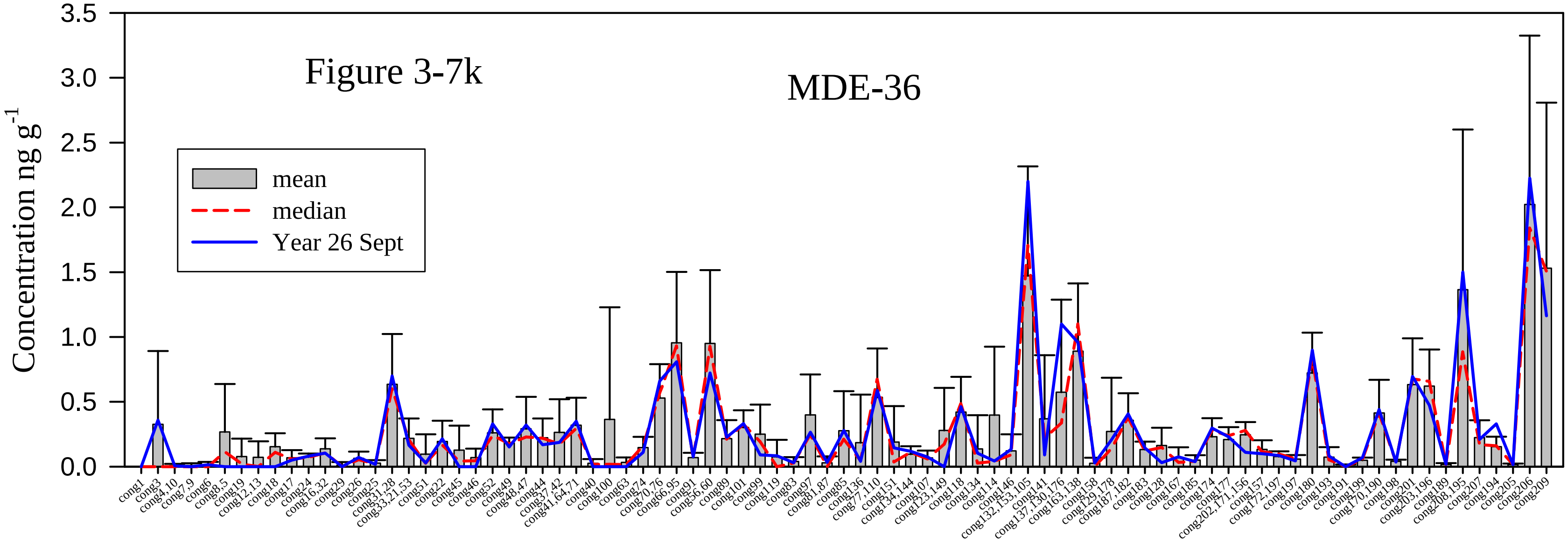

Figure 3-7 a-k. PCB concentrations in sediment expressed on a dry weight basis, collected in September 2007 (blue line), the 1998-2006 mean (bars) with standard deviation (error bars) and median (red dashed line).

PCBs in Clams

The concentrations of PCBs in clams were sampled in September 2007. These findings are summarized in Figure 3-8 a-k. 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 such as in clams from MDE-09. The samples collected in Year 26 are similar to, and generally lower than the average and close to the median when compared to the clams collected from the same sites in previous years. They also have less of the low mass congeners. The concentrations in clams from the 10 sites around HMI were also similar to what was observed from the Reference site MDE-36.

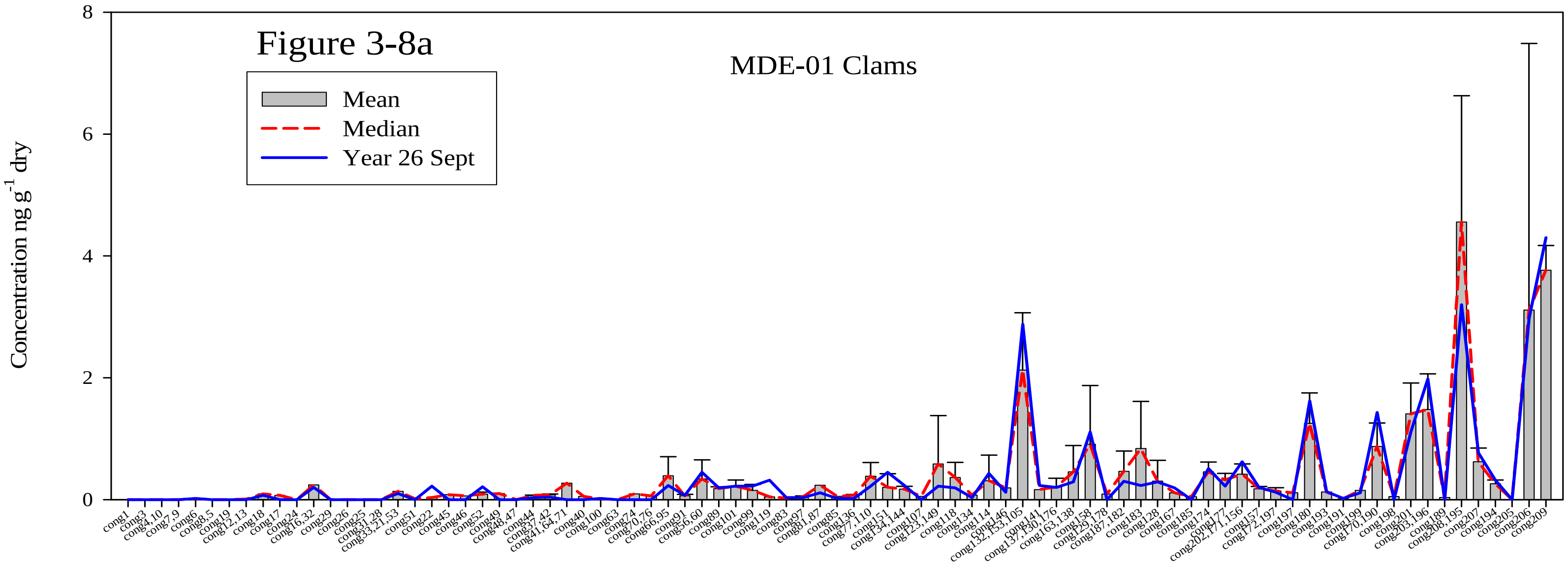
Figure 3-8a
MDE-01 Clams
Mean
Median
Year 26 Sept
Concentration ng g-1 dry

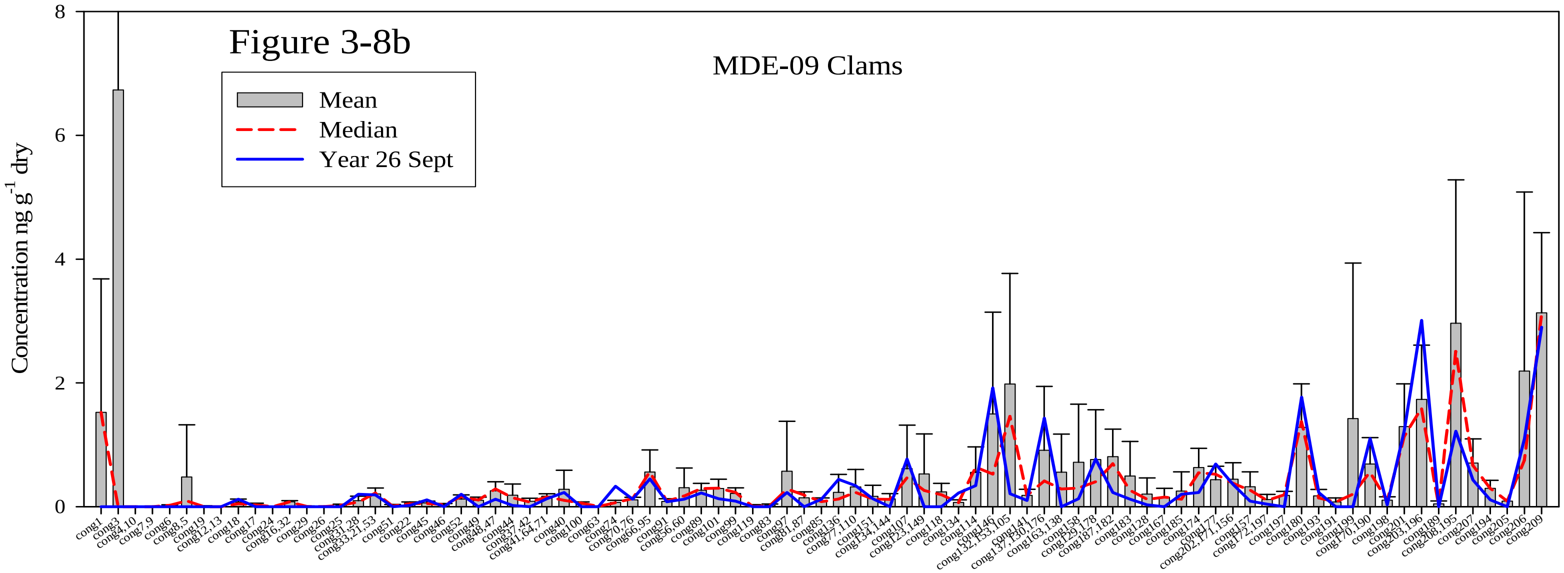
Figure 3-8b
MDE-09 Clams
Mean
Median
Year 26 Sept
Concentration ng g-1 dry

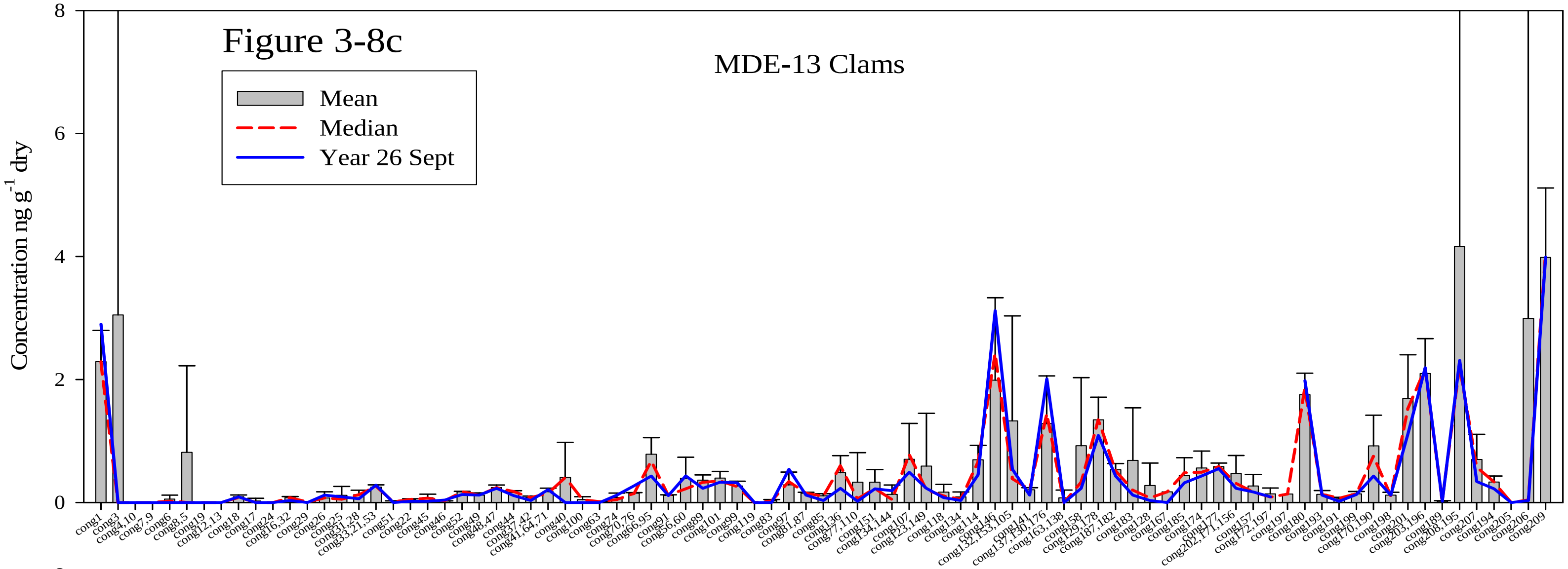
Figure 3-8c
MDE-13 Clams
Mean
Median
Year 26 Sept
Concentration ng g-1 dry
0
2
4
6
8

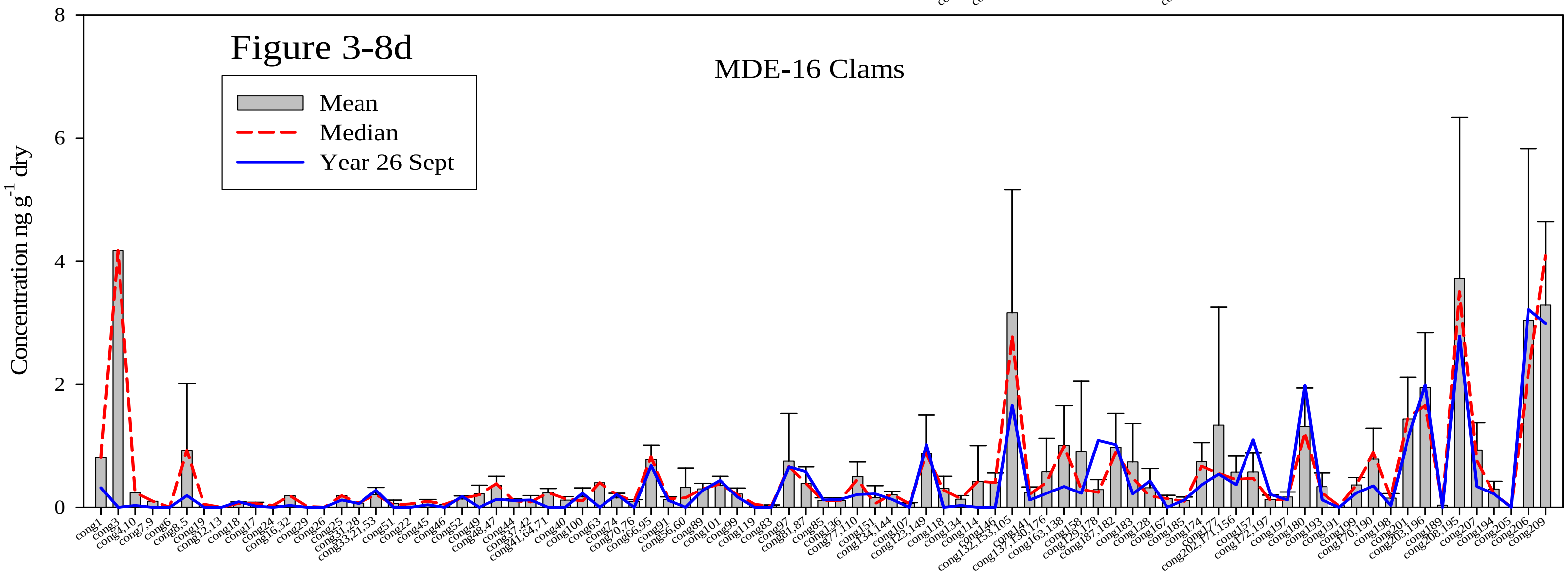
Figure 3-8d
MDE-16 Clams
Mean
Median
Year 26 Sept
Concentration ng g-1 dry
0
2
4
6
8

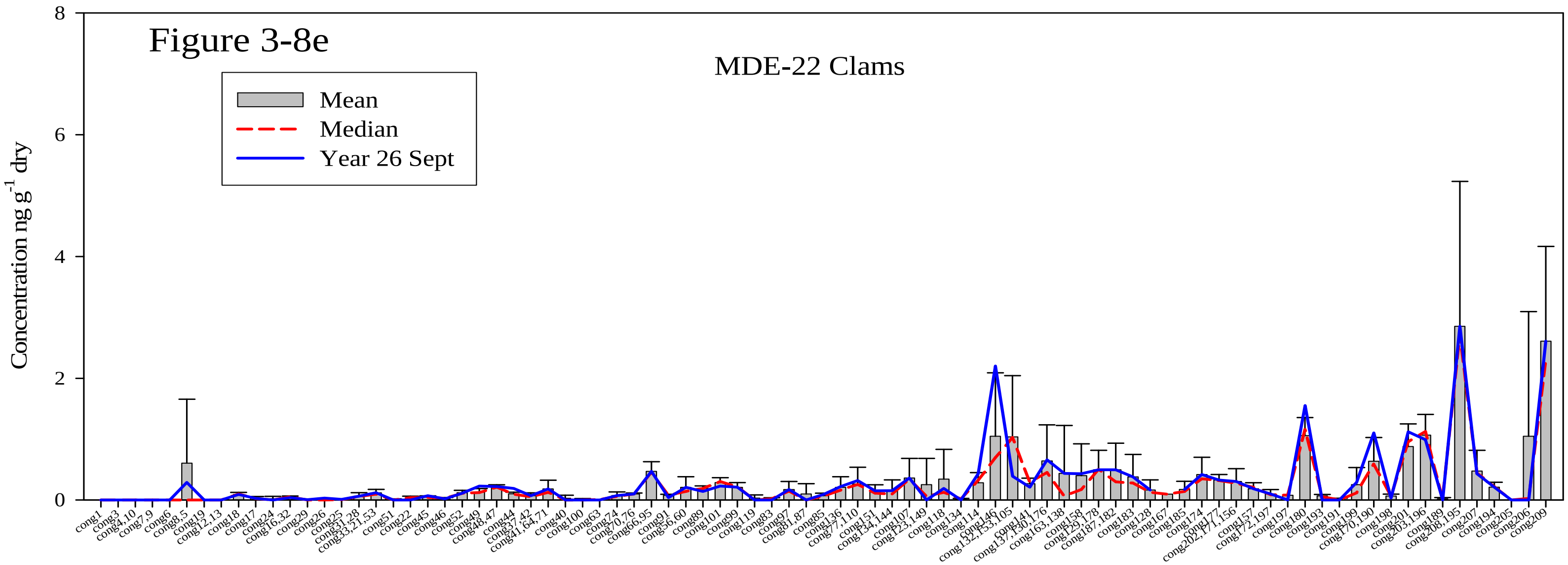
Figure 3-8e
MDE-22 Clams
Mean
Median
Year 26 Sept
Concentration ng g-1 dry

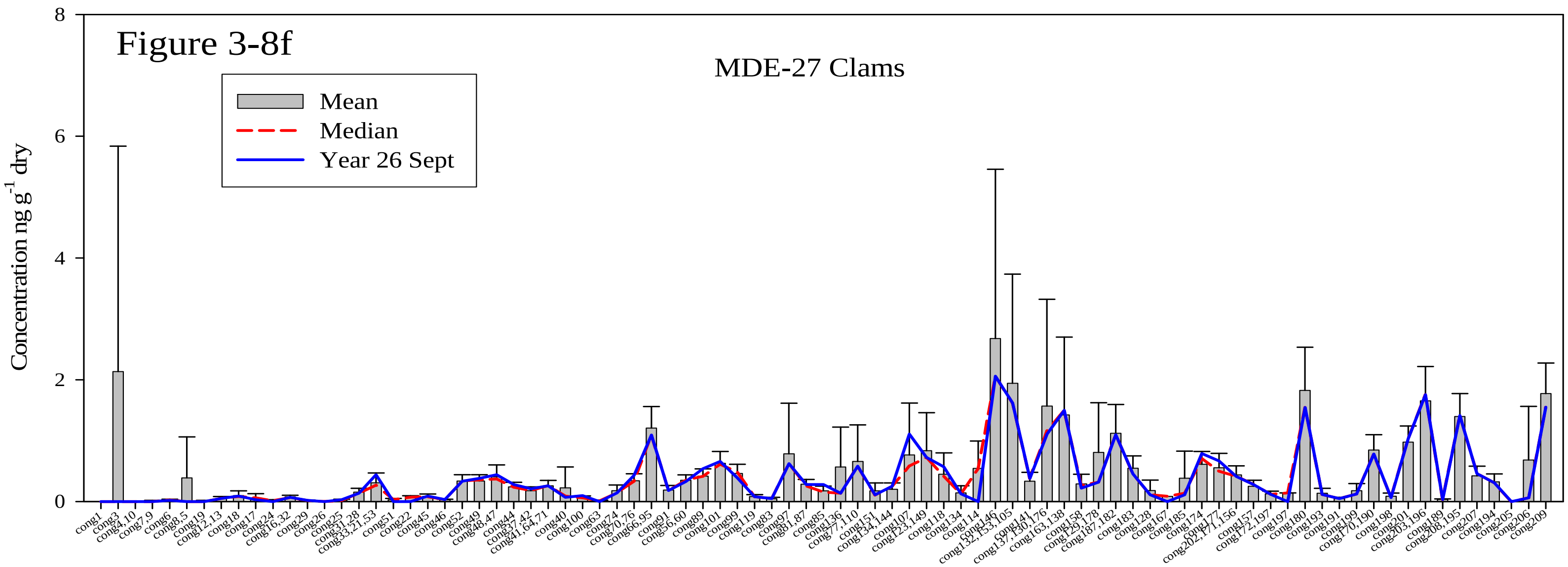
Figure 3-8f
MDE-27 Clams
Mean
Median
Year 26 Sept
Concentration ng g-1 dry

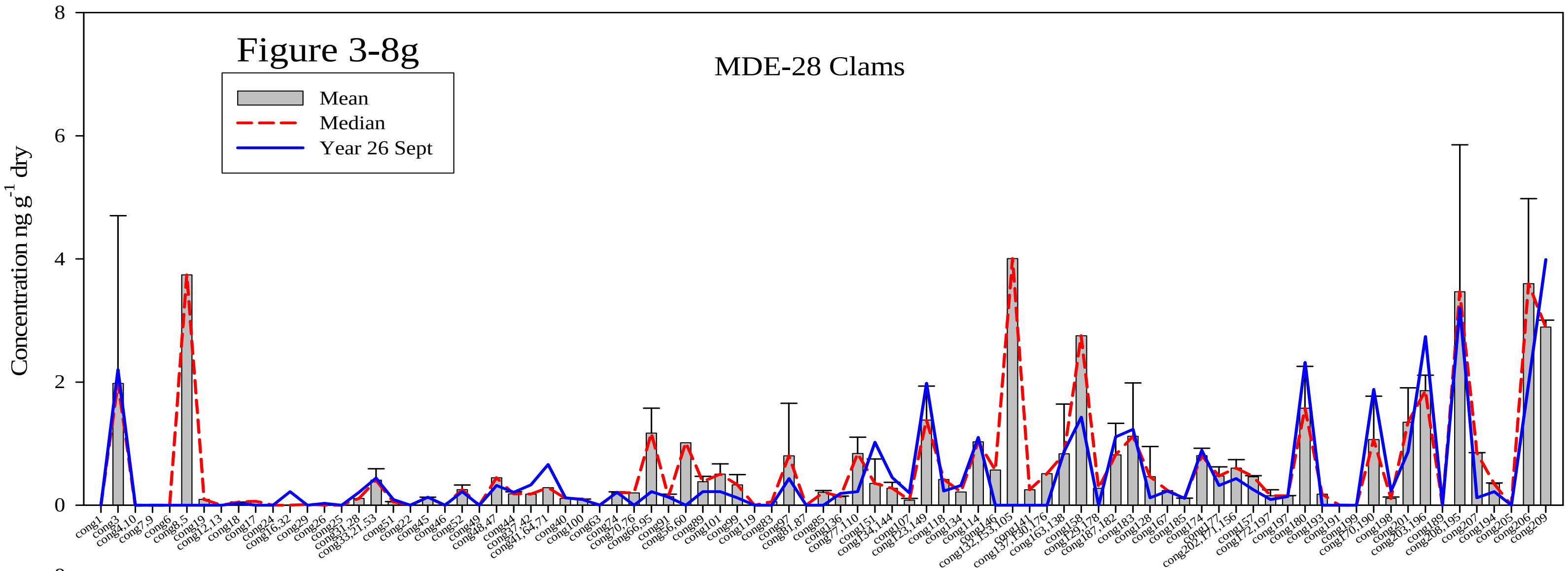
Figure 3-8g
MDE-28 Clams
Mean
Median
Year 26 Sept
Concentration ng g-1 dry

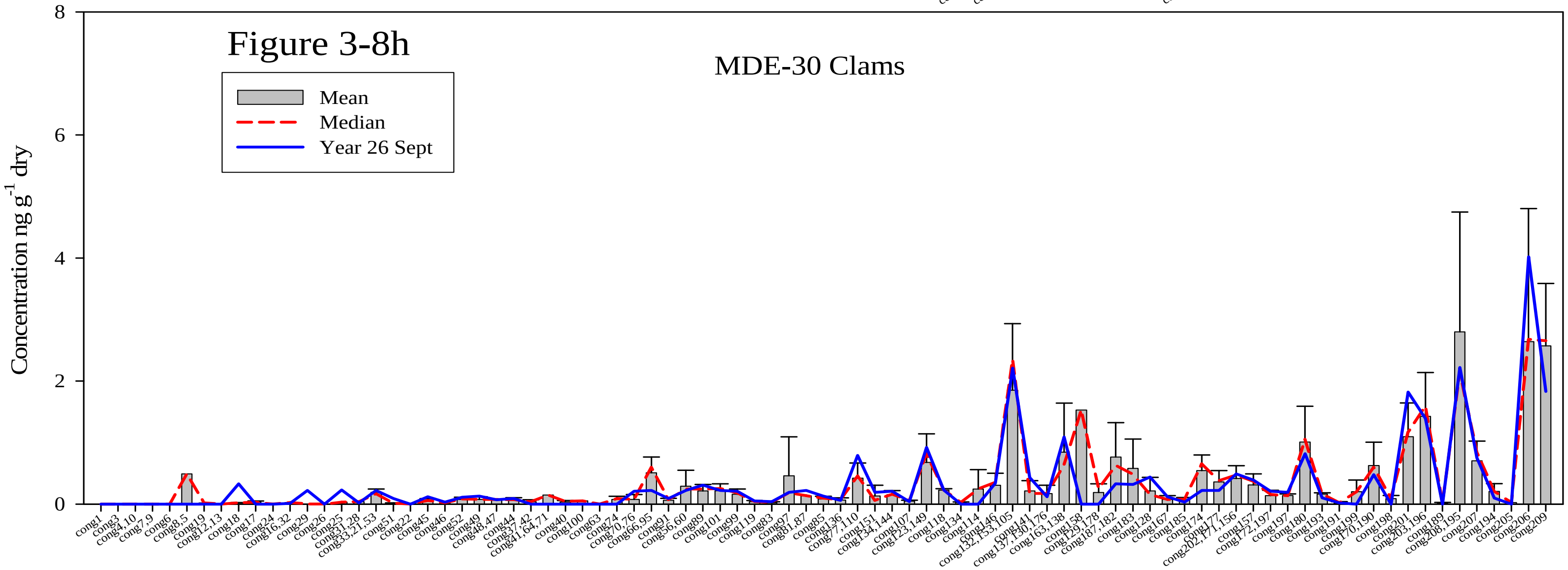
Figure 3-8h
MDE-30 Clams
Mean
Median
Year 26 Sept
Concentration ng g-1 dry

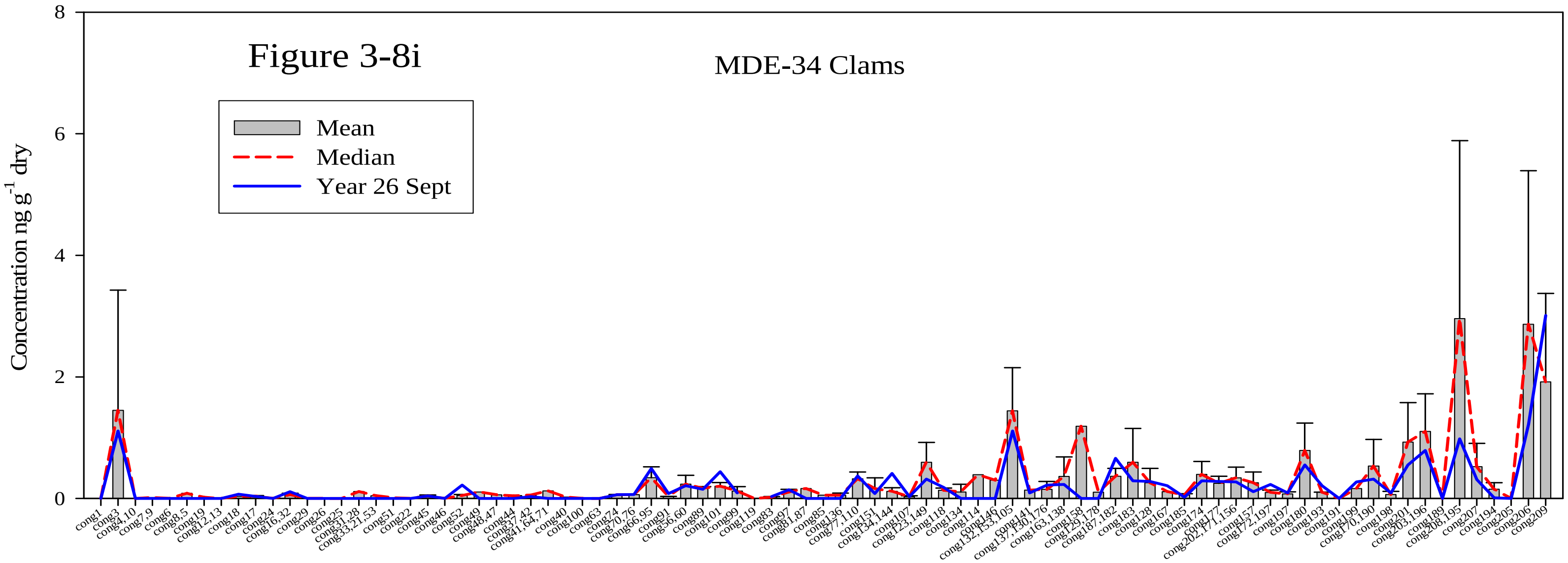
Figure 3-8i
MDE-34 Clams
Mean
Median
Year 26 Sept
Concentration ng g-1 dry
0
2
4
6
8

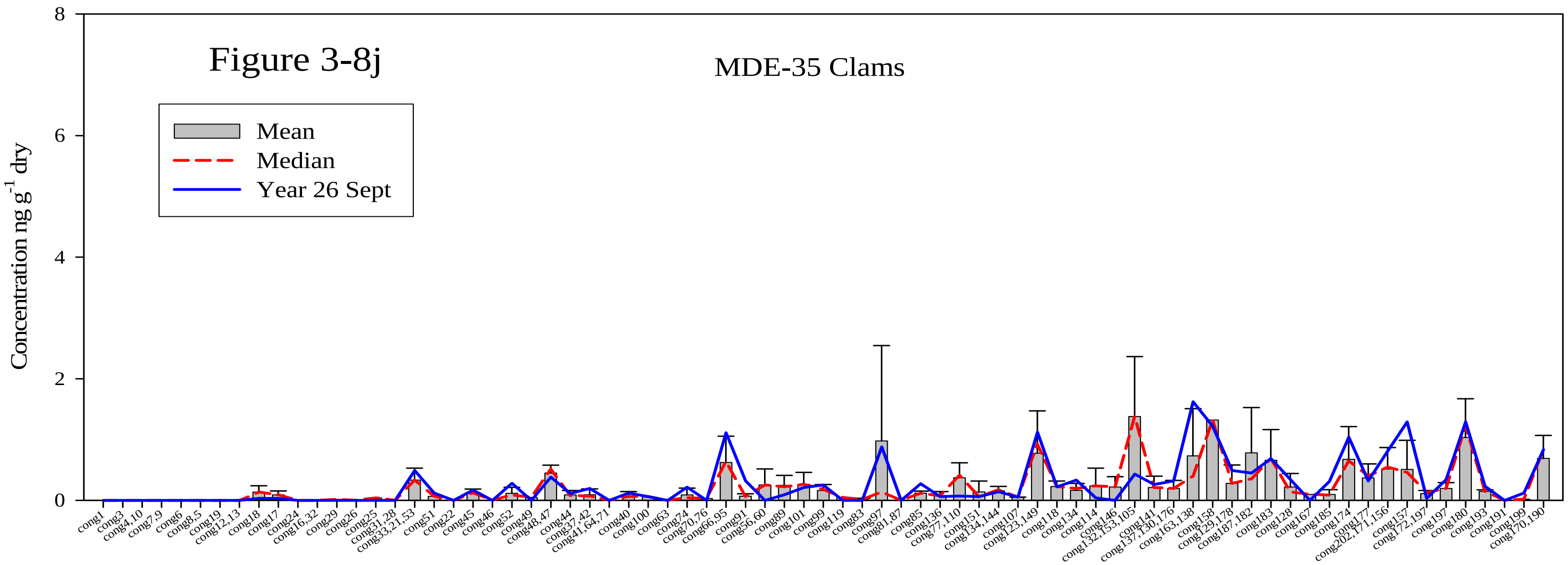
Figure 3-8j
MDE-35 Clams
Mean
Median
Year 26 Sept
Concentration ng g-1 dry
0
2
4
6
8

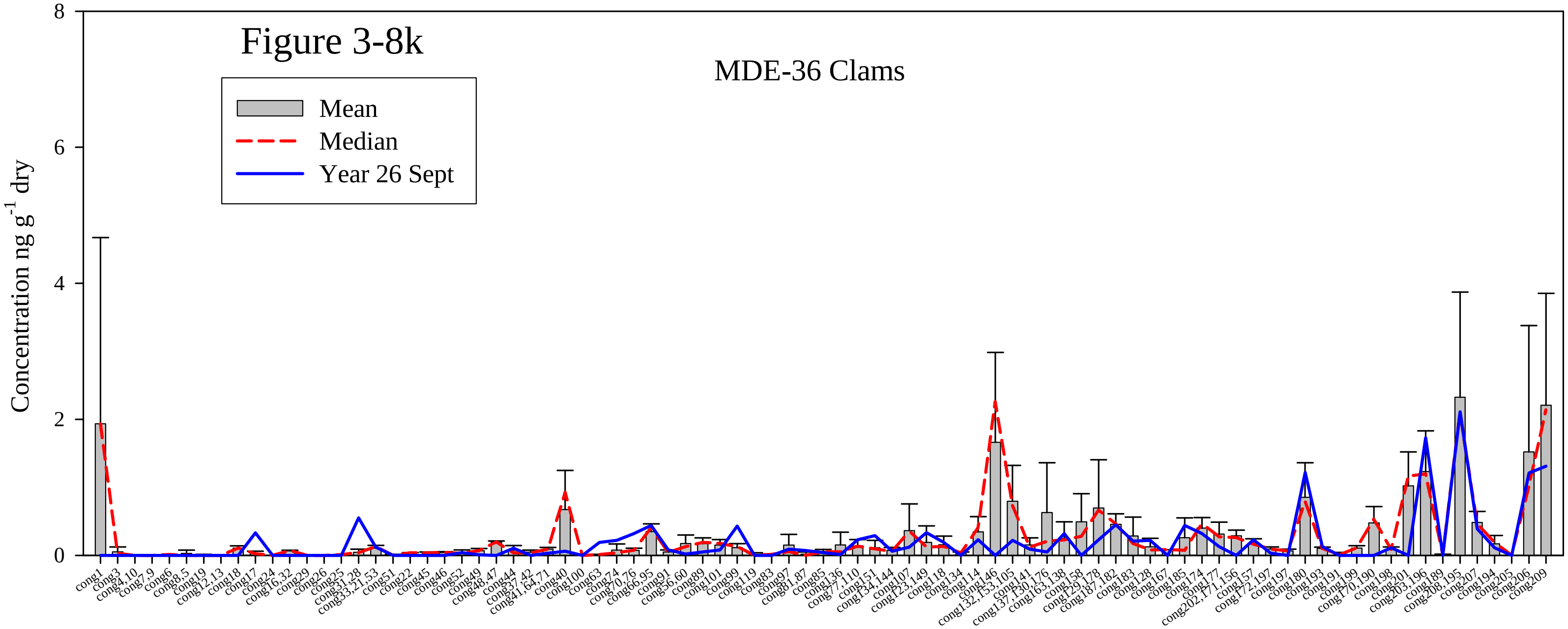

Figure 3-8 a-k. PCB concentrations in clams expressed on a dry weight basis, collected in September 2007 (blue line), the 1998-2006 mean (bars) with standard deviation (error bars) and median (red dashed line).

PAHs in Sediment

The concentrations of PAHs in sediments are presented in Figure 3-9 a-k and listed in Table 3-3. The distribution of PAHs among the sites is similar with phenanthrene and perylene often present at the highest concentrations. The concentrations at the six sites located around the HMI facility are similar to the concentrations at the Reference site MDE-36. There is little variability in the distribution of PAHs between the seasons or years, as demonstrated by how closely the lines track. However, the total concentrations do vary (discussed in the toxicity potential section below) suggesting a regional overriding influence on these sites. There is not enough data to adequately assess the impact of the South Cell Spillway 003 discharge. Site MDE-19 is close to the spillway and MDE-13 is in the area but likely out of the field of direct influence. The sites have similar concentrations and distributions of PAHs.

Polycyclic Aromatic Hydrocarbons								
1	Napthalene	14	2,3,5-Trimethylnapthalene	27	9-Methylanthracene	40	Benzo[b]fluoranthene	
2	2-Methylnapthalene	15	Fluorene	28	3,6-dimethylphenanthrene	41	Benzo[k]fluoranthene	
3	1-Methylnapthalene	16	1-Methylfuorene	29	9,10-Dimethylanthracene	42	Dimethylbenz[a]anthracene	
4	Biphenyl	17	Dibenzothiophene	30	Fluoranthene	43	Benzo[e]pyrene	
5	2,7-Dimethylnapthalene	18	Phenanthrene	31	Pyrene	44	Benzo[a]pyrene	
6	1,3-Dimethylnapthalene	19	Anthracene	32	Benzo[a]fluorene	45	Perylene	
7	1,6-Dimethylnapthalene	20	2-Methyldibenzothiophene	33	Retene	46	3-Methylchloanthrene	
8	1,4-Dimethylnapthalene	21	4-Methyldibenzothiophene	34	Benzo[b]fluorene	47	Indeno[1,2,3-c,d]pyrene	
9	1,5-Dimethylnapthalene	22	2-Methylphenanthrene	35	Cyclopenta[c,d]pyrene	48	Dibenz[a,h+ac]anthracene	
10	Acenapthylene	23	2-Methylanthracene	36	Benz[a]anthracene	49	Benzo[g,h,i]perylene	
11	1,2-Dimethylnapthalene	24	4,5-Methylenephenanthrene	37	Chrysene+Triphenylene	50	Anthanthrene	
12	1,8-Dimethylnapthalene	25	1-Methylanthracene	38	Napthacene	51	Corenene	
13	Acenapthene	26	1-Methylphenanthrene	39	4-Methylchrysene			

Table 3-3. Polycyclic aromatic hydrocarbons given in the same order as presented in Figure 3-9 a-k and Figure 3-10 a-k.

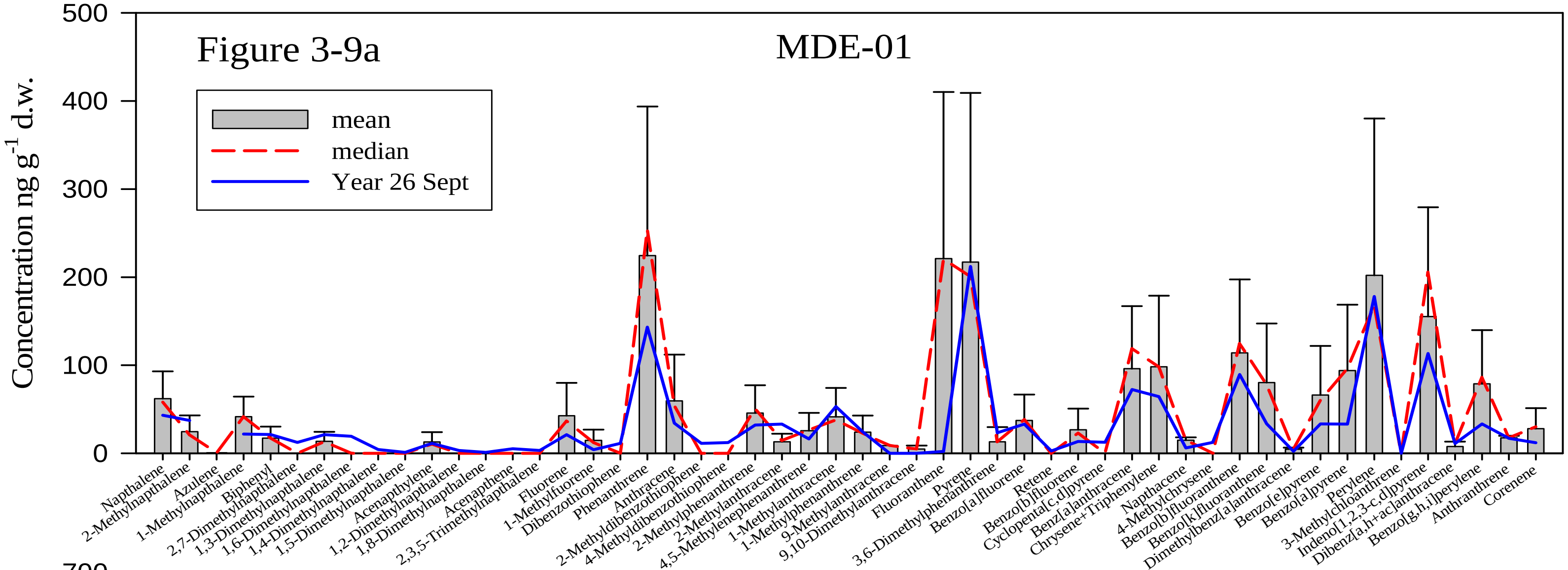
Figure 3-9a
MDE-01
mean
median
Year 26 Sept
Concentration ng g-1 d.w.
0
100
200
300
400
500

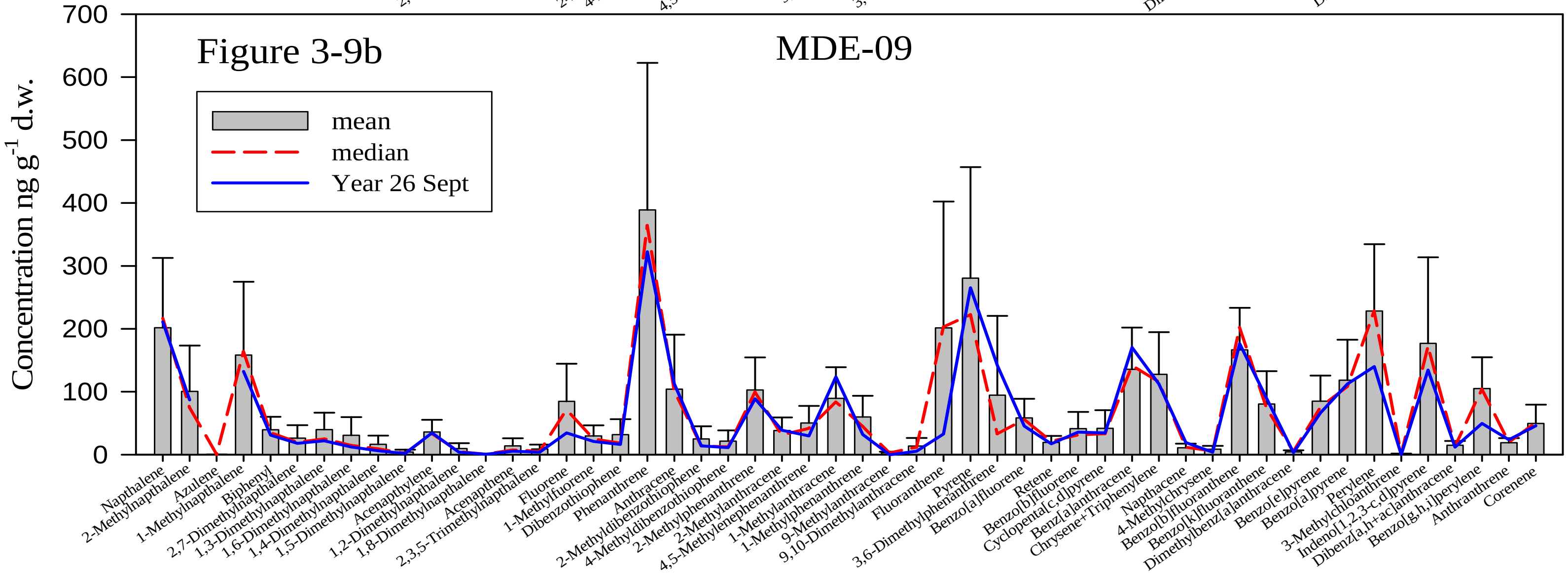
Figure 3-9b
MDE-09
mean
median
Year 26 Sept
Concentration ng g-1 d.w.
0
100
200
300
400
500
600
700

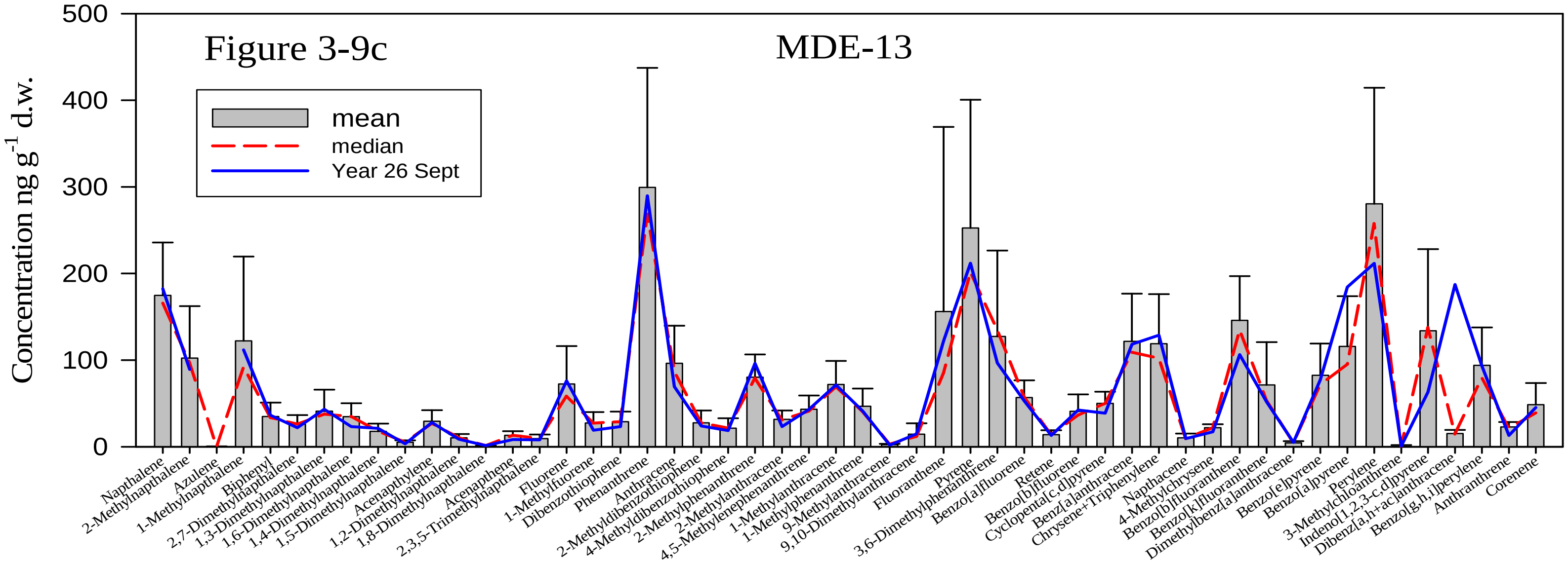
Figure 3-9c
MDE-13
Concentration ng g^{-1} d.w.
0
100
200
300
400
500
mean
median
Year 26 Sept
Napthalene
2-Methylnapthalene
Azulene
1-Methylnapthalene
Biphenyl
2,7-Dimethylnapthalene
1,3-Dimethylnapthalene
1,6-Dimethylnapthalene
1,4-Dimethylnapthalene
1,5-Dimethylnapthalene
Acenapthylene
1,2-Dimethylnapthalene
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

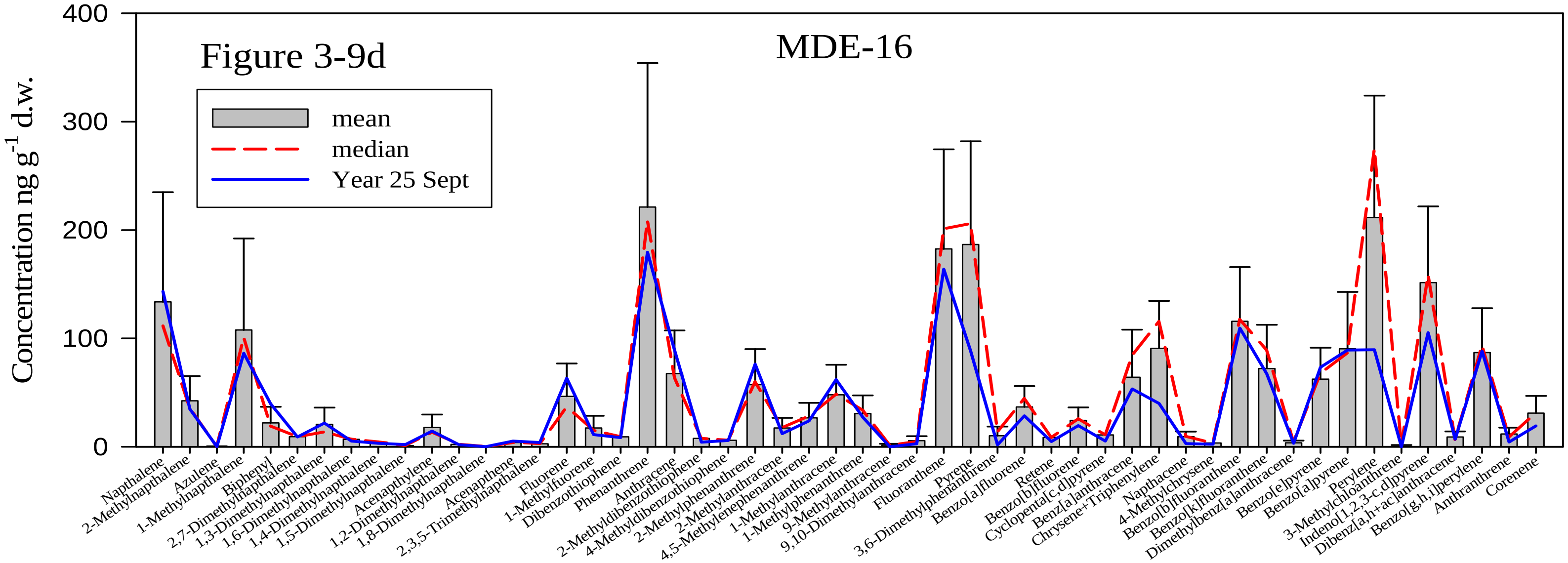
Figure 3-9d
MDE-16
Concentration ng g^{-1} d.w.
0
100
200
300
400
mean
median
Year 25 Sept
Napthalene
2-Methylnapthalene
Azulene
1-Methylnapthalene
Biphenyl
2,7-Dimethylnapthalene
1,3-Dimethylnapthalene
1,6-Dimethylnapthalene
1,4-Dimethylnapthalene
1,5-Dimethylnapthalene
Acenapthylene
1,2-Dimethylnapthalene
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

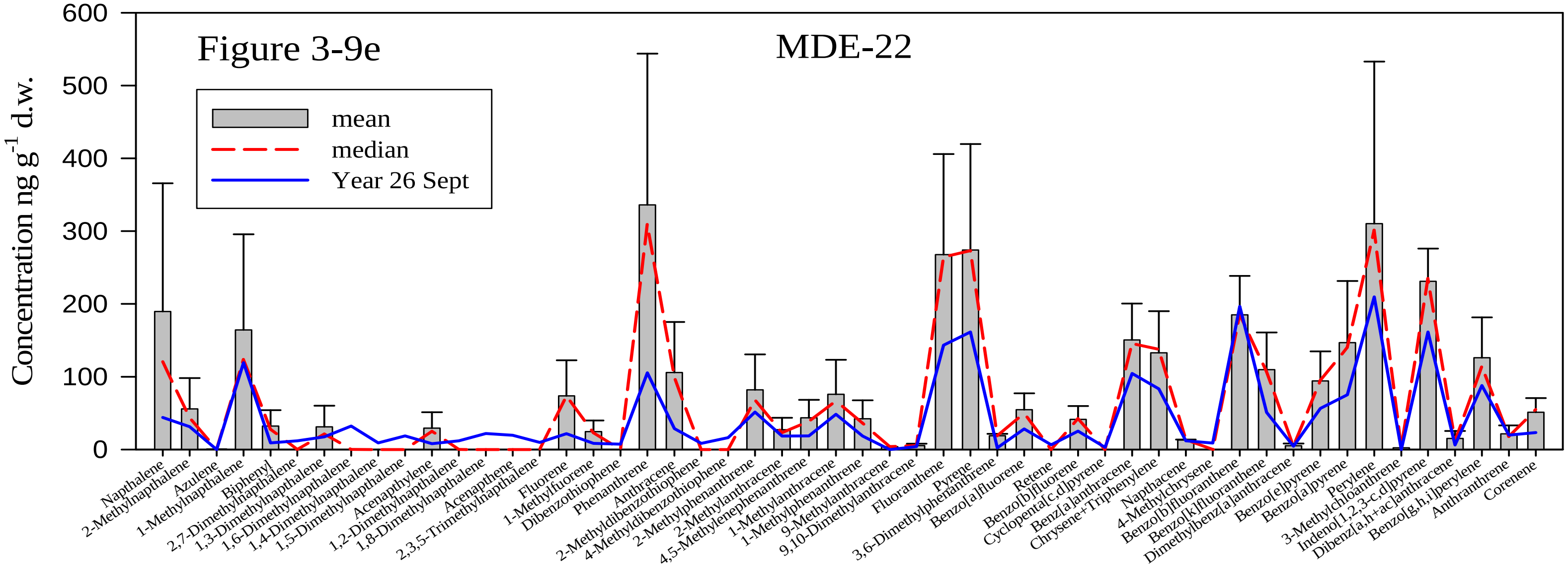
Figure 3-9e
MDE-22
mean
median
Year 26 Sept
Concentration ng g-1 d.w.

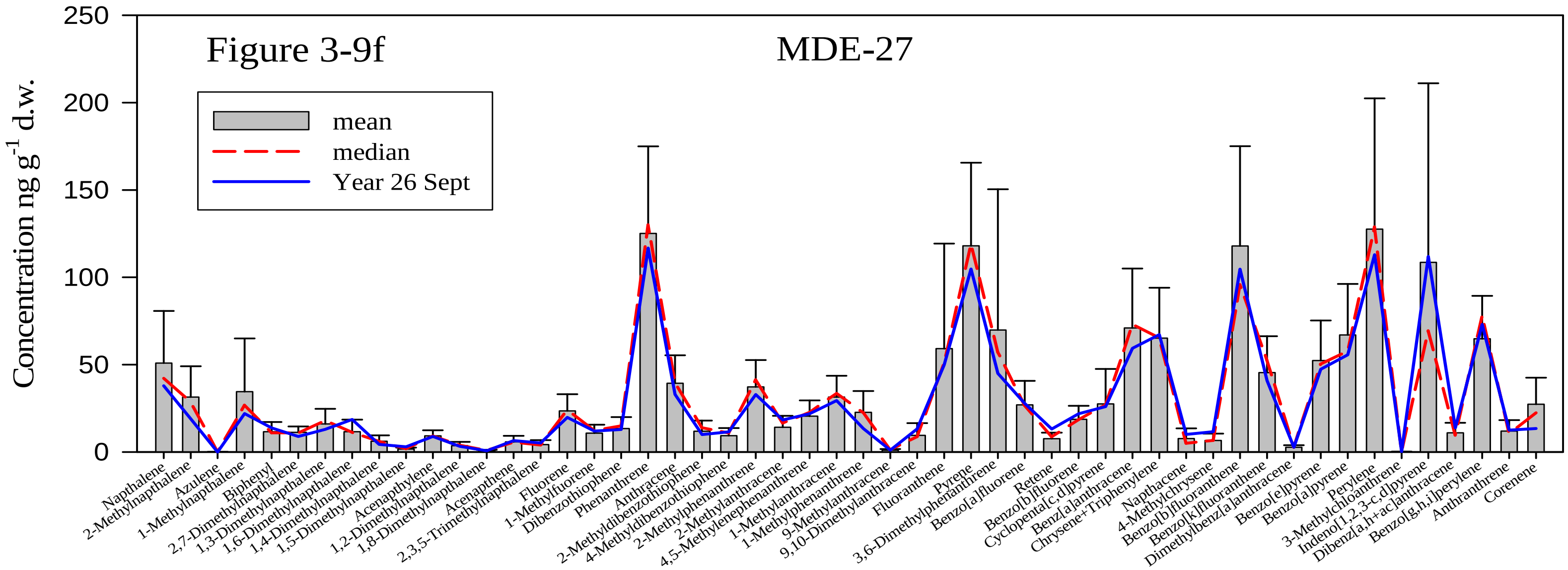
Figure 3-9f
MDE-27
mean
median
Year 26 Sept
Concentration ng g-1 d.w.

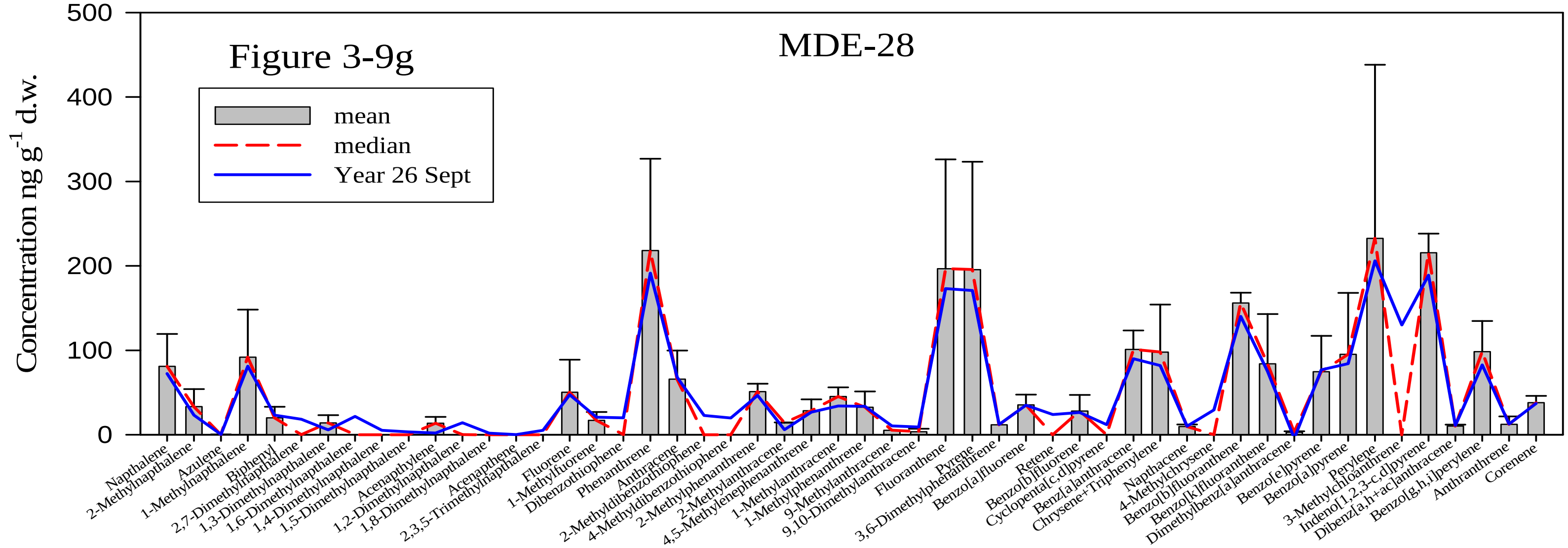

Figure 3-9g
MDE-28
mean
median
Year 26 Sept
Concentration ng g^{-1} d.w.
0
100
200
300
400
500
Napthalene
2-Methylnapthalene
Azulene
1-Methylnapthalene
Biphenyl
2,7-Dimethylnapthalene
1,3-Dimethylnapthalene
1,6-Dimethylnapthalene
1,4-Dimethylnapthalene
1,5-Dimethylnapthalene
Acenapthylene
1,2-Dimethylnapthalene
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

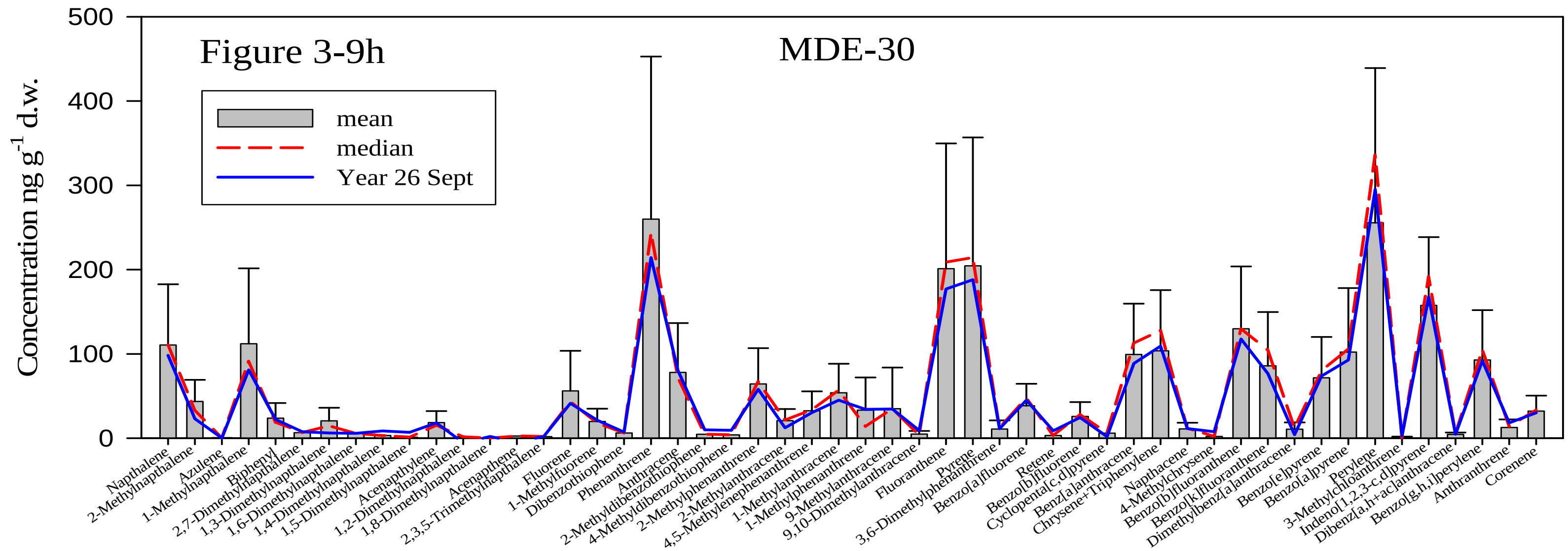

Figure 3-9h
MDE-30
mean
median
Year 26 Sept
Concentration ng g^{-1} d.w.
0
100
200
300
400
500
Napthalene
2-Methylnapthalene
Azulene
1-Methylnapthalene
Biphenyl
2,7-Dimethylnapthalene
1,3-Dimethylnapthalene
1,6-Dimethylnapthalene
1,4-Dimethylnapthalene
1,5-Dimethylnapthalene
Acenapthylene
1,2-Dimethylnapthalene
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

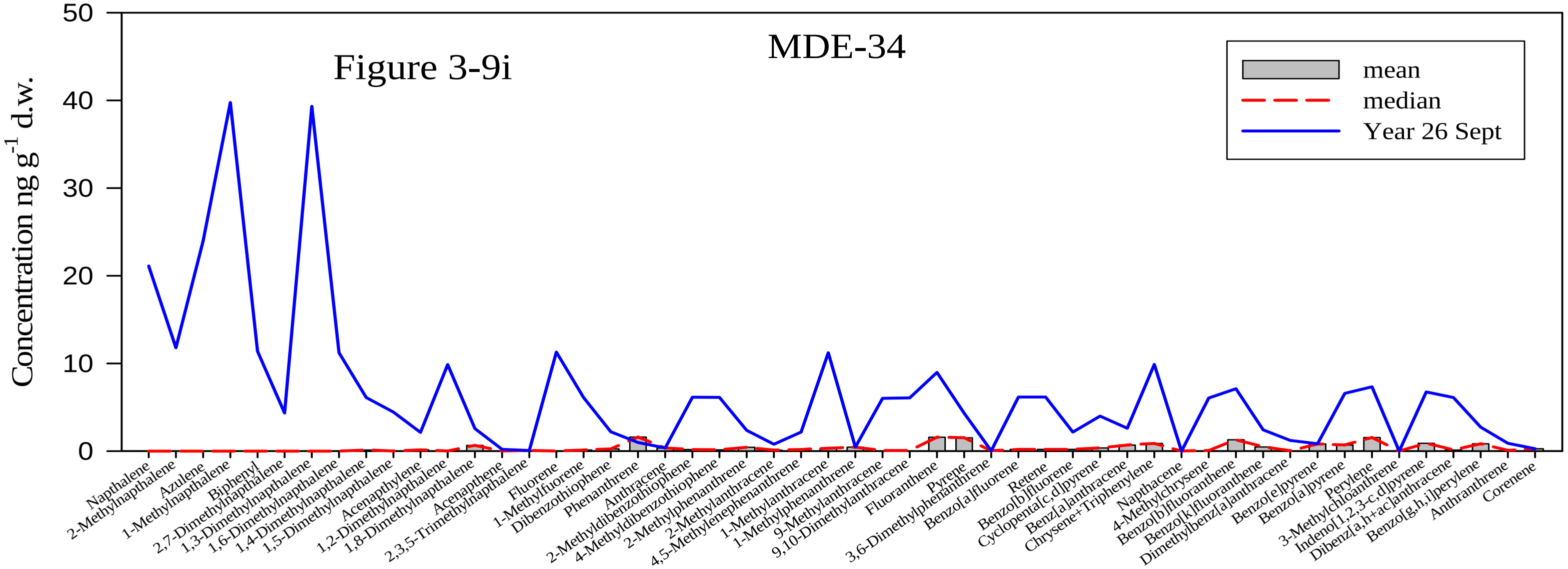

Figure 3-9i
MDE-34
mean
median
Year 26 Sept
Concentration ng g-1 d.w.

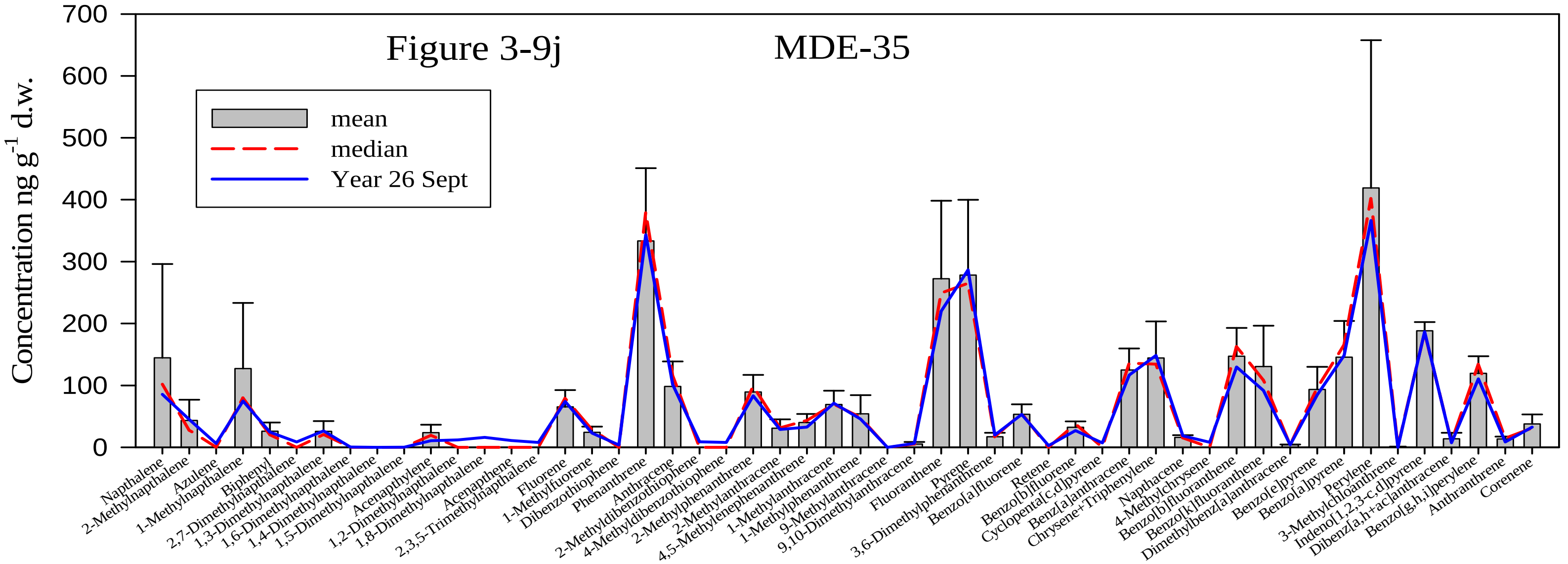

Figure 3-9j
MDE-35
mean
median
Year 26 Sept
Concentration ng g-1 d.w.

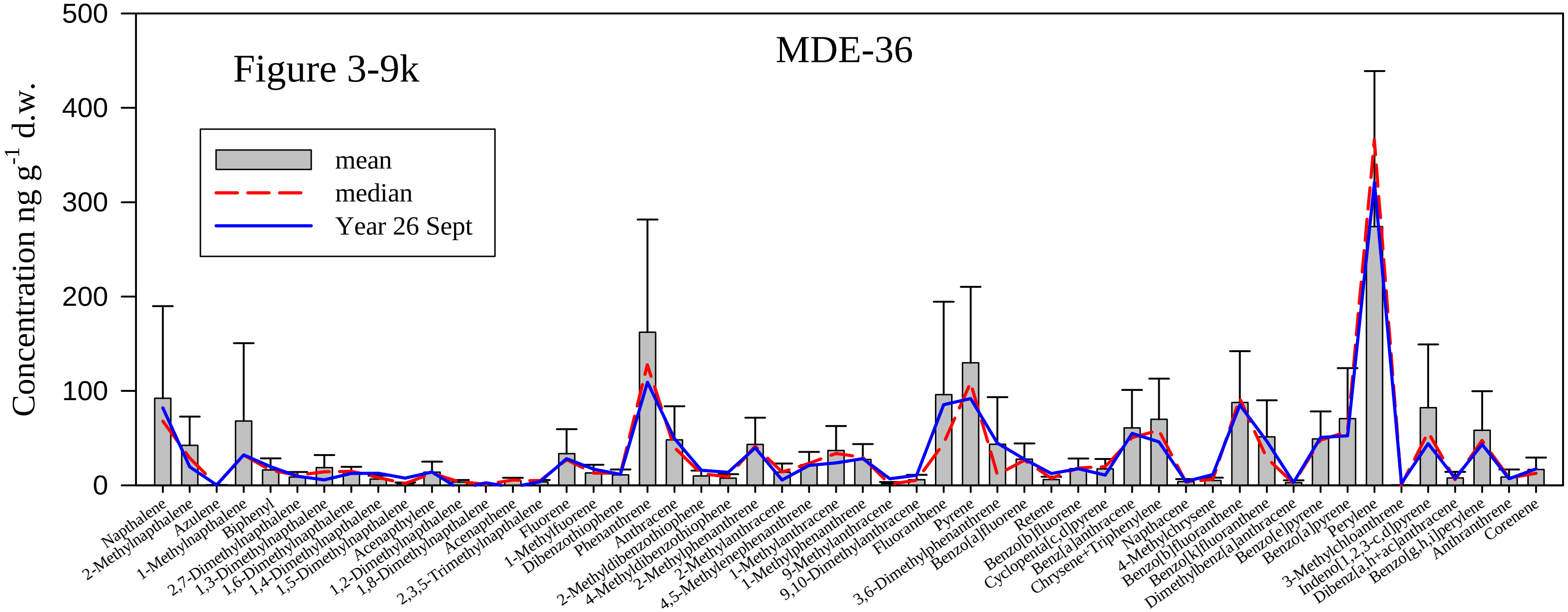

Figure 3-9 a-k. PAH concentrations in sediment expressed on a dry weight basis, collected in September 2007 (blue line), the 1998-2006 mean (bars) with standard deviation (error bars) and median (red dashed line).

PAHs in Clams

The concentrations of PAHs in clams are presented in Figure 3-10 a-k. The distribution of PAHs among the sites is similar with phenanthrene and perylene often present at the highest concentrations. The concentrations at the sites located around the HMI facility are similar to the concentrations at the Reference site MDE-36. There is little variability in the distribution of PAHs between the seasons or years, as demonstrated by how closely the lines track. However, the total concentrations do vary (discussed in the toxicity potential section below) suggesting a regional overriding influence on these sites. There isn't enough data to adequately assess the impact of the South Cell Spillway 003 discharge. Site MDE-19 is close to the spillway and MDE-13 is in the area but likely out of the field of direct influence. The sites have similar concentrations and distributions of PAHs.

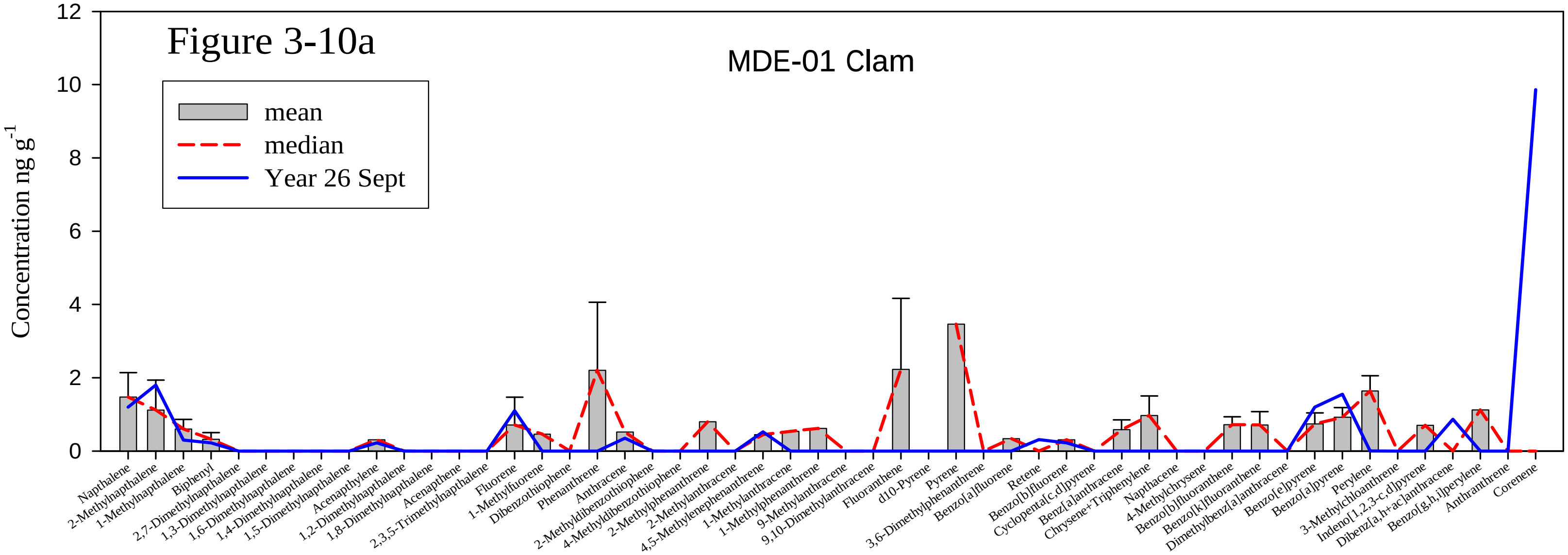
Figure 3-10a
MDE-01 Clam
mean
median
Year 26 Sept
Concentration ng g-1
0
2
4
6
8
10
12

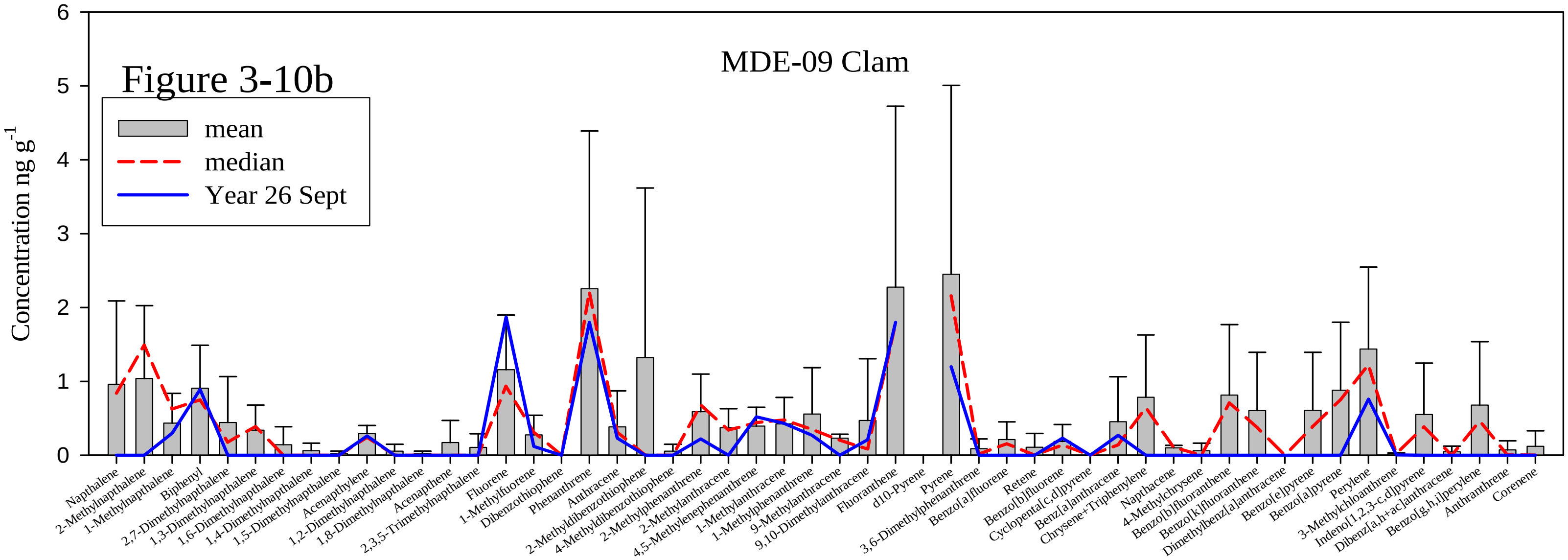
Figure 3-10b
MDE-09 Clam
mean
median
Year 26 Sept
Concentration ng g-1
0
1
2
3
4
5
6

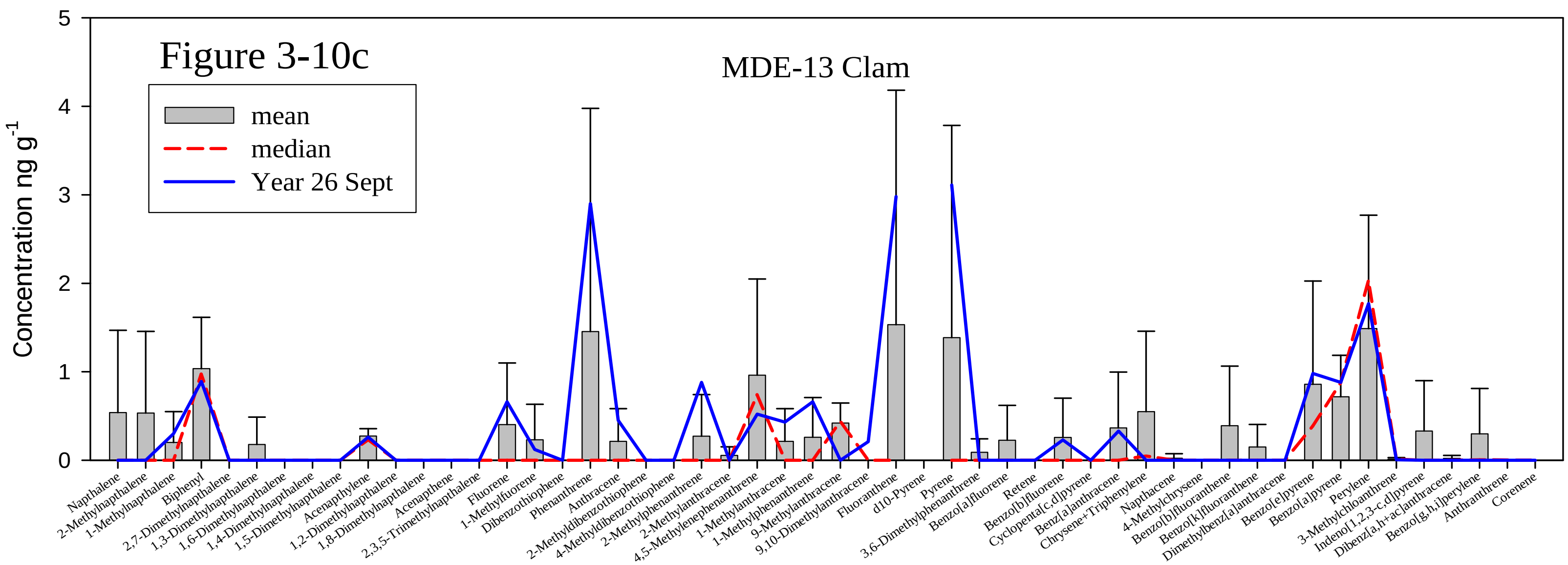
Figure 3-10c
MDE-13 Clam
mean
median
Year 26 Sept
Concentration ng g-1

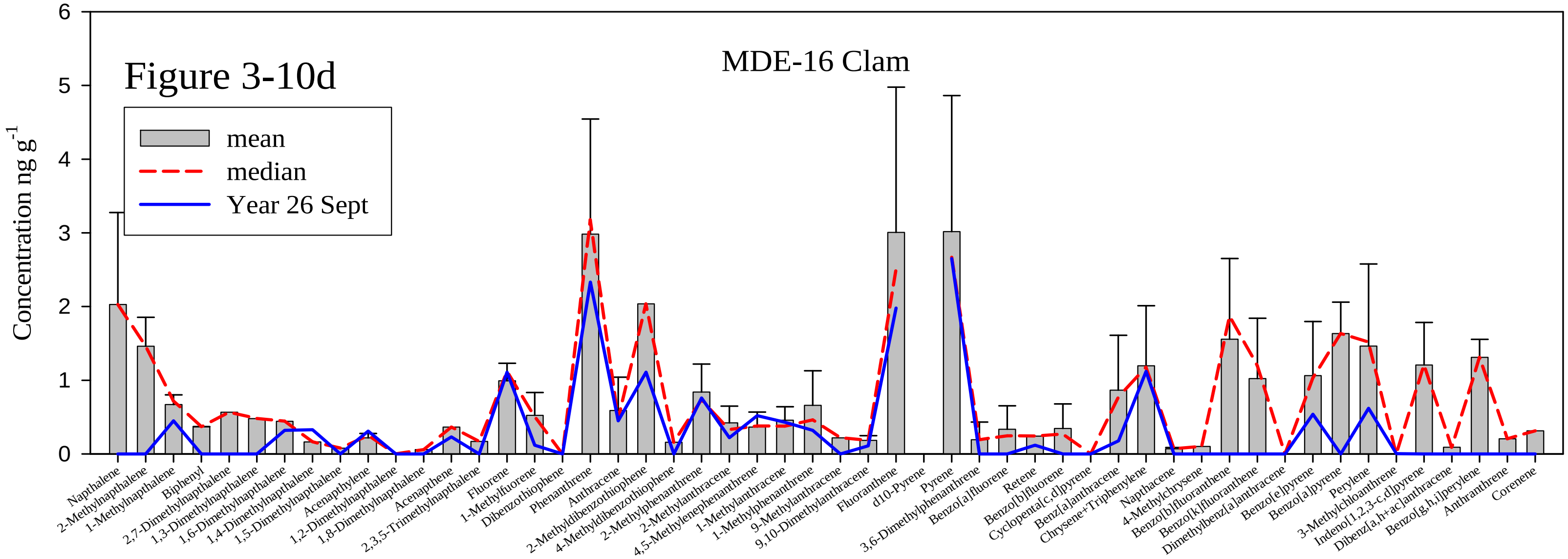
Figure 3-10d
MDE-16 Clam
mean
median
Year 26 Sept
Concentration ng g-1

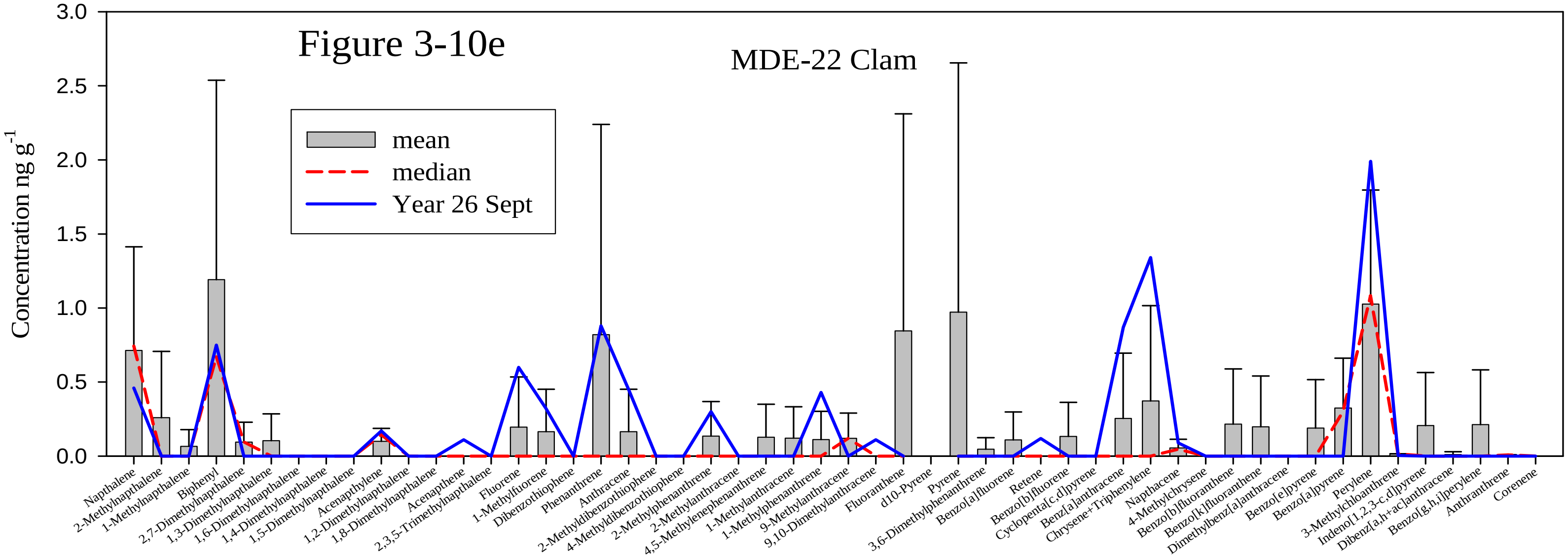
Figure 3-10e
MDE-22 Clam
mean
median
Year 26 Sept
Concentration ng g-1

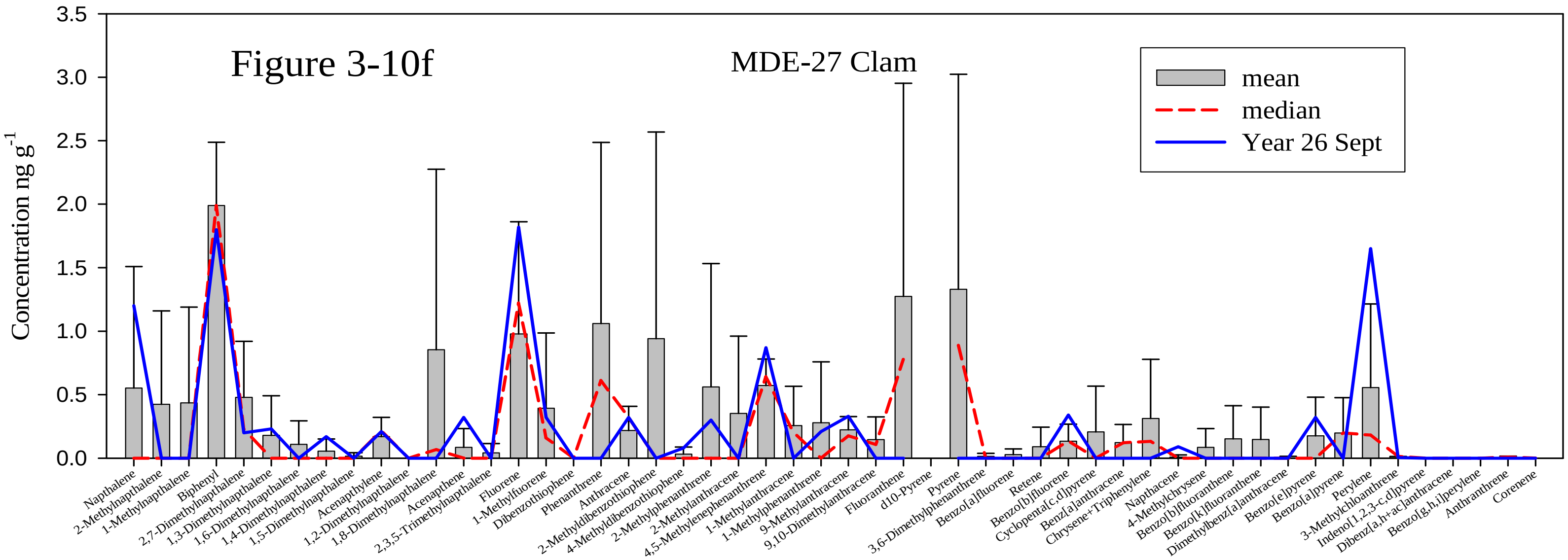
Figure 3-10f
MDE-27 Clam
mean
median
Year 26 Sept
Concentration ng g-1

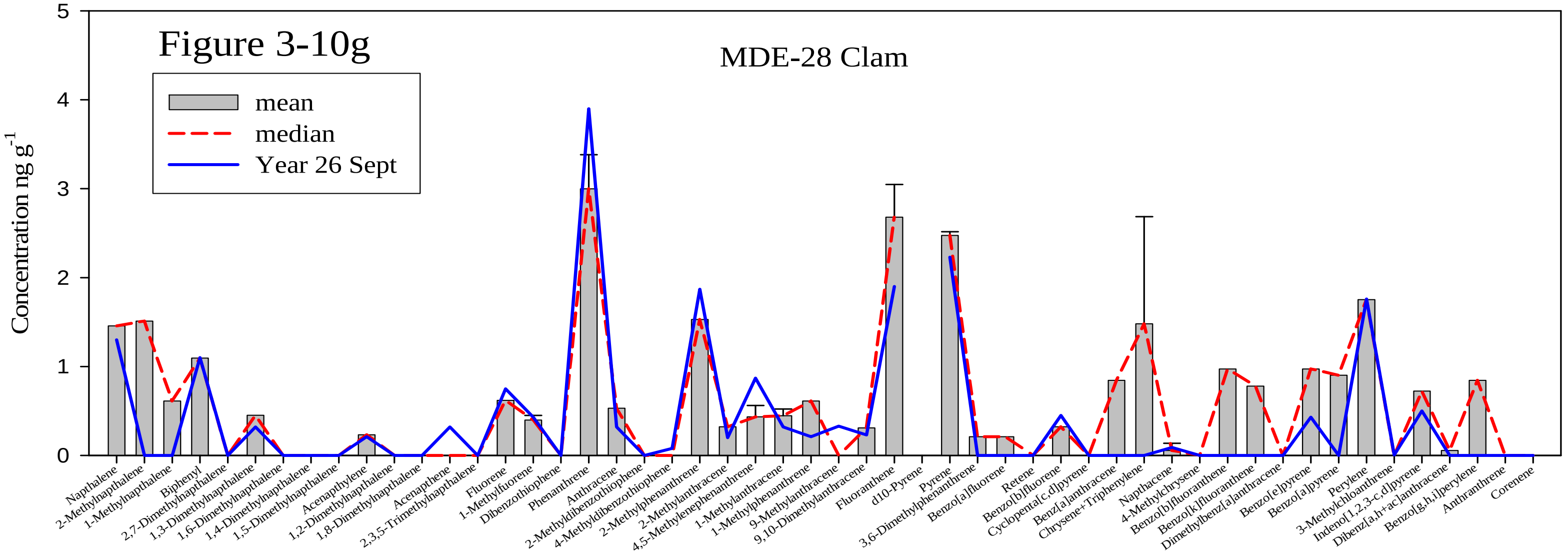
Figure 3-10g
MDE-28 Clam
mean
median
Year 26 Sept
Concentration ng g^{-1}
0
1
2
3
4
5
Napthalene
2-Methylnapthalene
1-Methylnapthalene
Biphenyl
2,7-Dimethylnapthalene
1,3-Dimethylnapthalene
1,6-Dimethylnapthalene
1,4-Dimethylnapthalene
1,5-Dimethylnapthalene
Acenapthylene
1,2-Dimethylnapthalene
1,8-Dimethylnapthalene
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+ac]anthracene
Benzo[g,h,i]perylene
Anthranthrene
Corenene

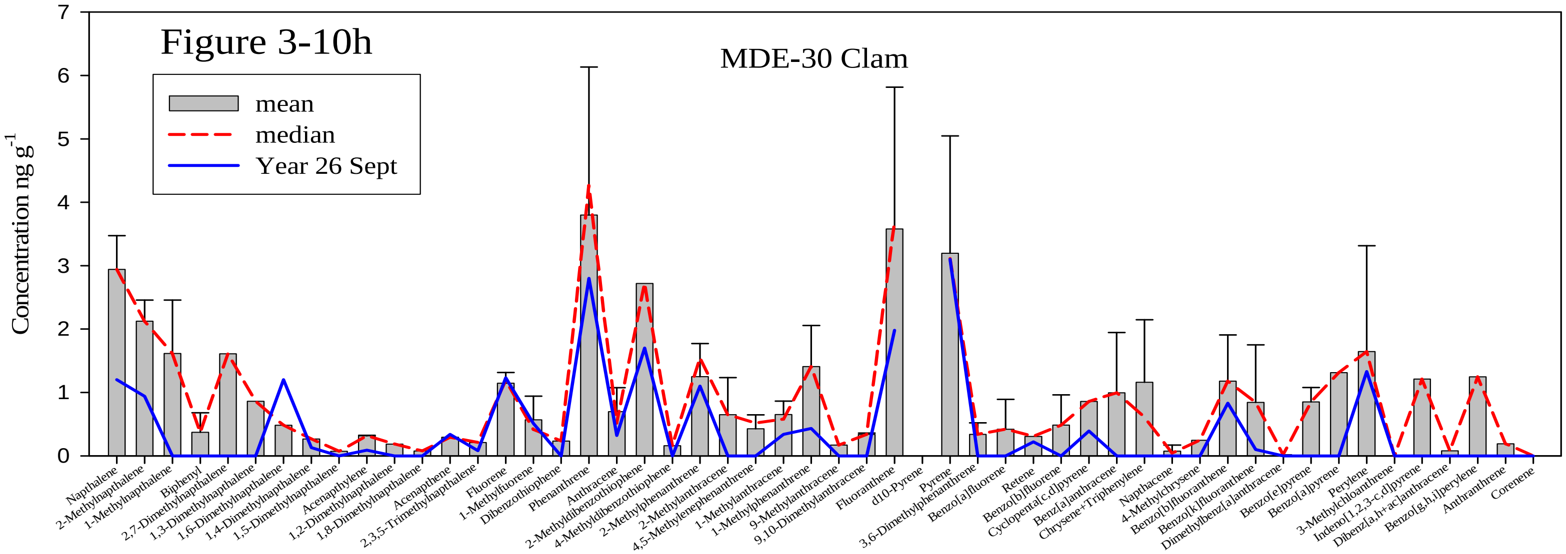
Figure 3-10h
MDE-30 Clam
mean
median
Year 26 Sept
Concentration ng g^{-1}
0
1
2
3
4
5
6
7
Napthalene
2-Methylnapthalene
1-Methylnapthalene
Biphenyl
2,7-Dimethylnapthalene
1,3-Dimethylnapthalene
1,6-Dimethylnapthalene
1,4-Dimethylnapthalene
1,5-Dimethylnapthalene
Acenapthylene
1,2-Dimethylnapthalene
1,8-Dimethylnapthalene
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+ac]anthracene
Benzo[g,h,i]perylene
Anthranthrene
Corenene

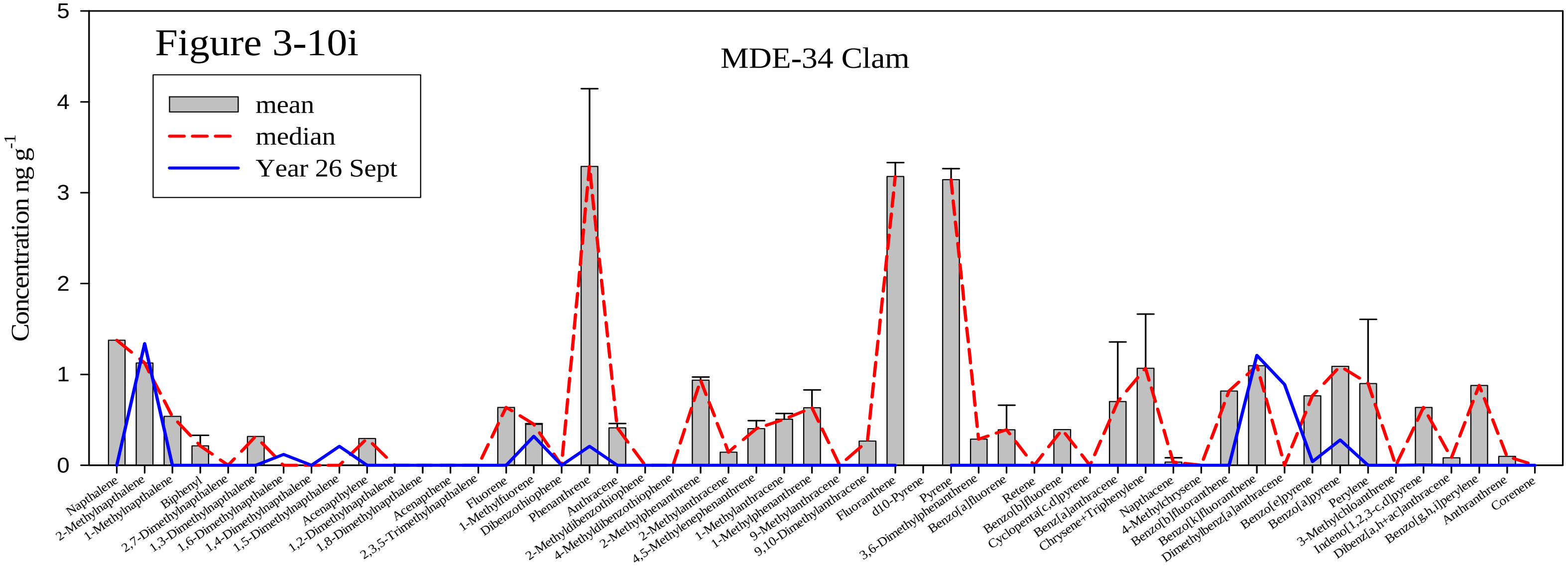
Figure 3-10i
MDE-34 Clam
mean
median
Year 26 Sept
Concentration ng g-1

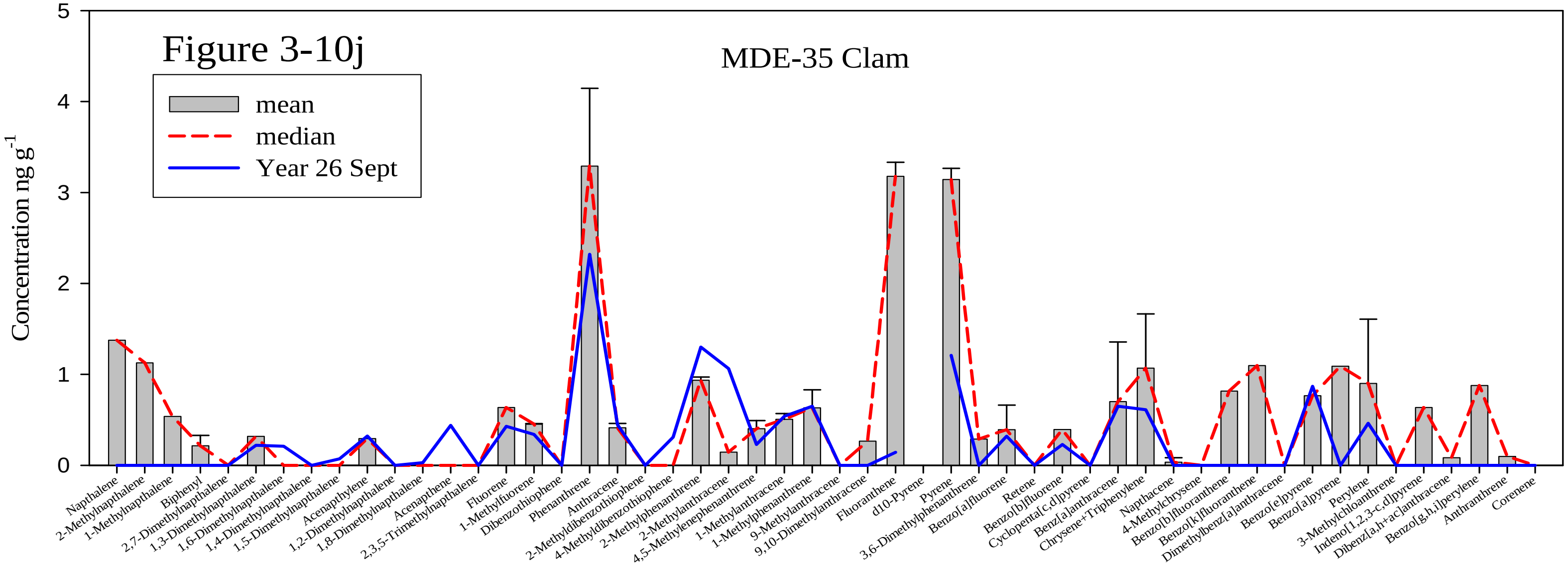
Figure 3-10j
MDE-35 Clam
mean
median
Year 26 Sept
Concentration ng g-1

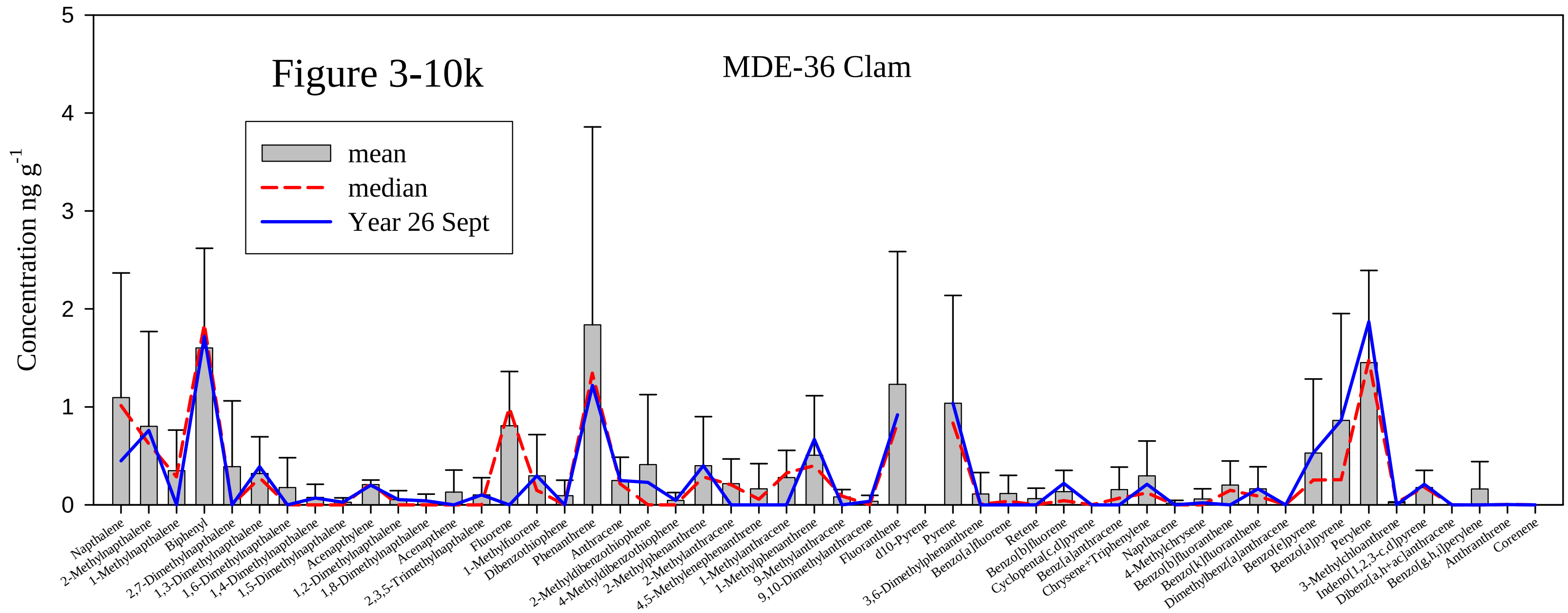

Figure 3-10 a-k. PAH concentrations in clams expressed on a wet weight basis, collected in September 2007 (blue line), the 1998-2006 mean (bars) with standard deviation (error bars) and median (red dashed line).

TOXICITY POTENTIAL

Investigating Potential Metal Toxicity

For some metals, toxicological effects criteria have been established by National Oceanic and Atmospheric Administration (NOAA). The conservative Threshold Effects Level (TEL), Probable Effects Levels (PEL) and Apparent Effects Threshold (AET) are plotted along with the data from the studied sites (Figures 3-11 and 3-12). For the metals As, Ag, and Hg, sediment concentrations are around the TEL. At MDE-30 the sediment concentration approaches the PEL. In the case of Se, the majority of sediment concentrations exceed the AET. Even concentrations at the reference site exceed the AET level. The average sediment concentration observed during the study period is on the order of 2,000 ppb thus the sediment concentrations exceed the criteria on a regular basis. The data used to create the criteria for Se is the most limited of the metals studied. Although sediment Se concentrations exceed the advised level, it is not because of HMI activities, and the basis for the criteria is extremely limited.

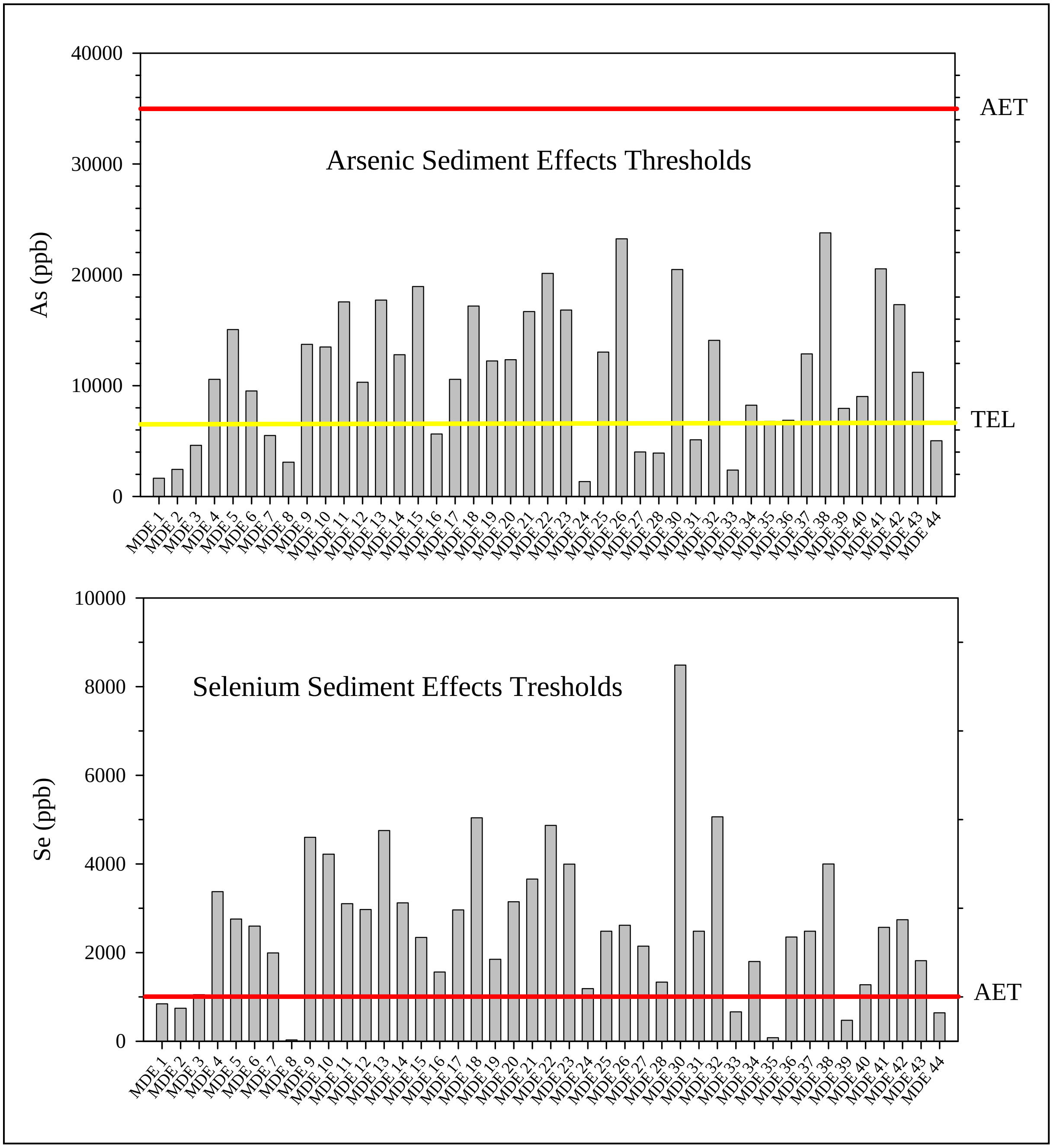

Figure 3-11. As and Se concentrations in sediment along with TEL, and AET identified by NOAA for marine sediment.

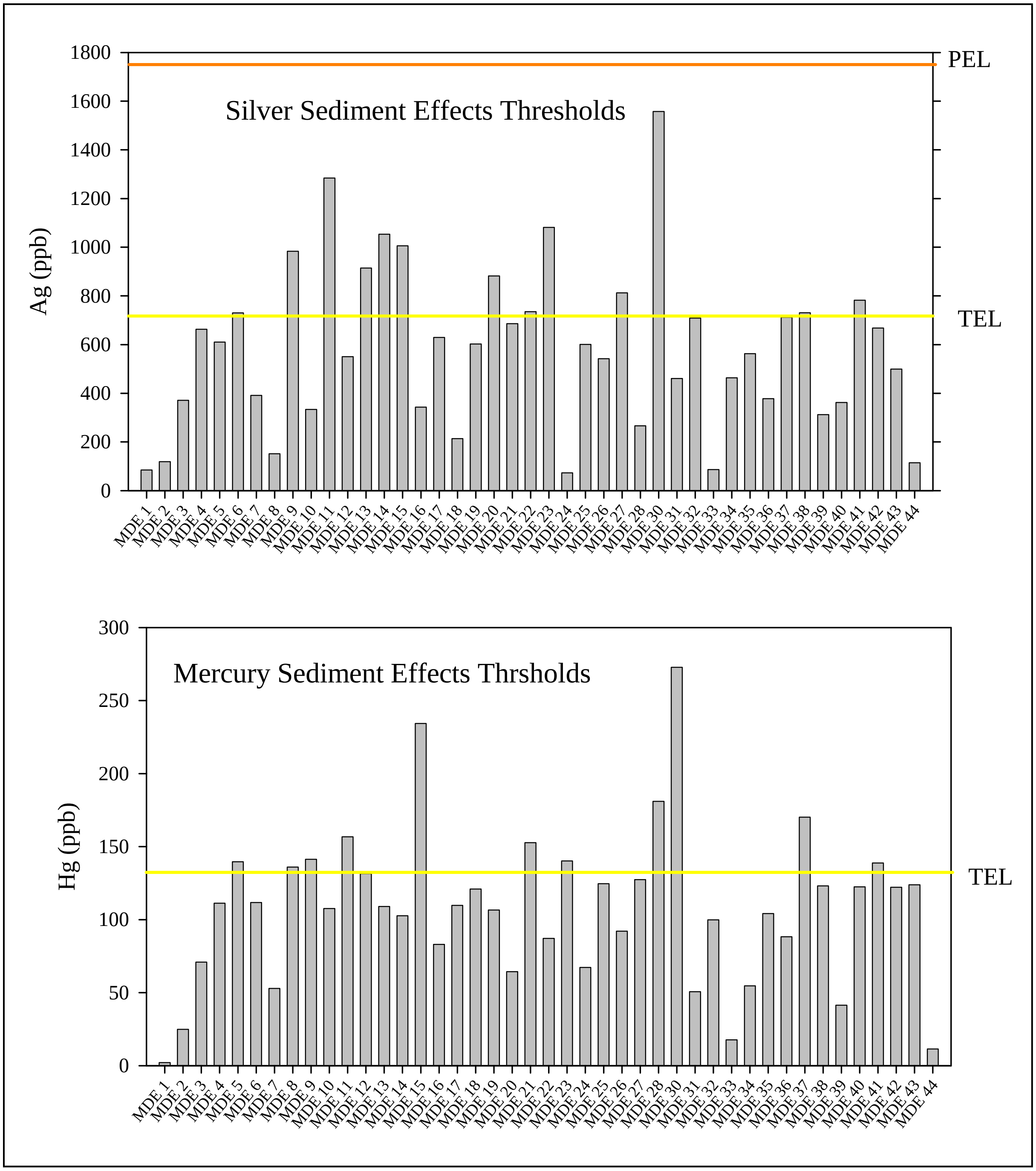

Figure 3-12. Ag and Hg concentrations in sediment along with TEL, and PEL identified by NOAA for marine sediment.

Investigating Potential Organic Contaminant Toxicity

Sediment toxicity criteria for the organic contaminants are not as well developed as they are 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. On the whole most of the sites exceed the NOAA TEL for the total PAH concentrations in sediment, including MDE-36, the Reference site (Figure 3-13). All sites are well within the PEL. The same is true for the PCB concentrations, with most sites exceeding the TEL, but well under the PEL (Figure 3-14).

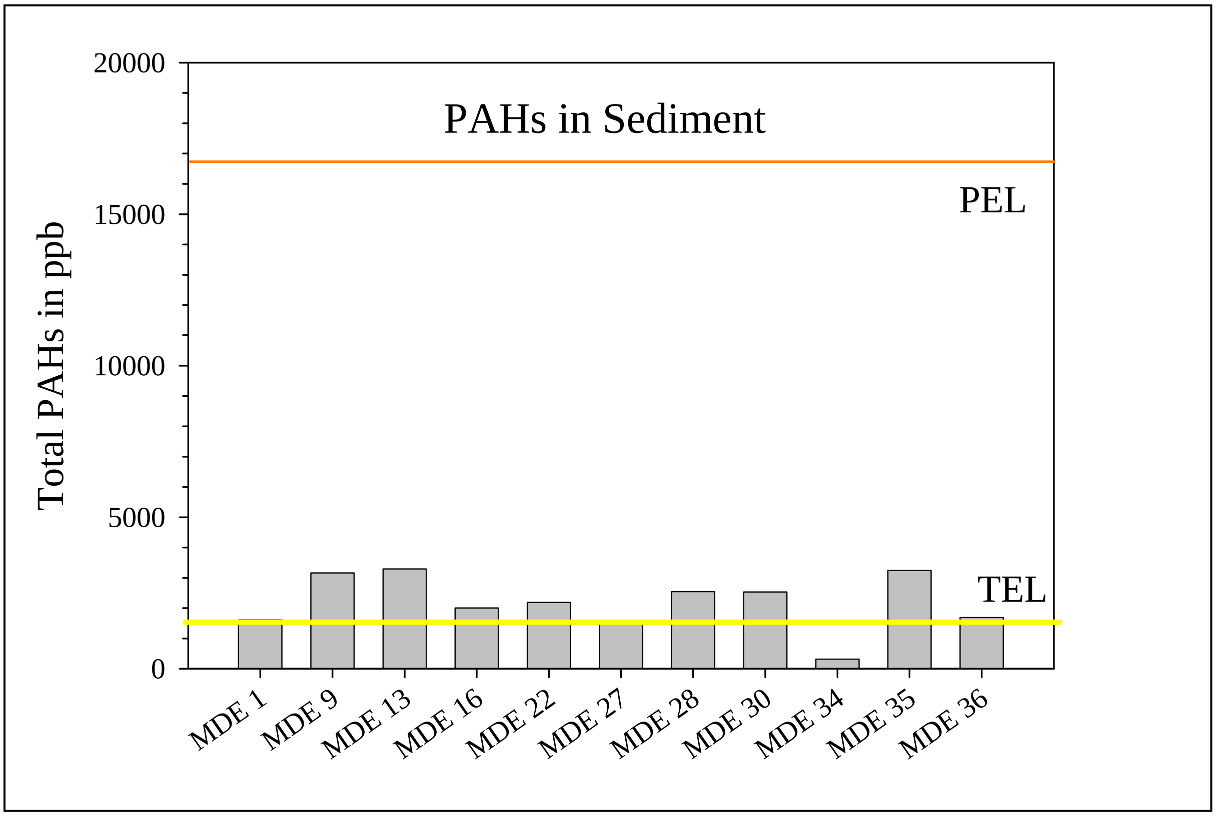

Figure 3-13. Total PAH concentrations in sediment along with Threshold Effects Level (TEL) and Probable Effects Level (PEL) identified by NOAA for marine sediment.

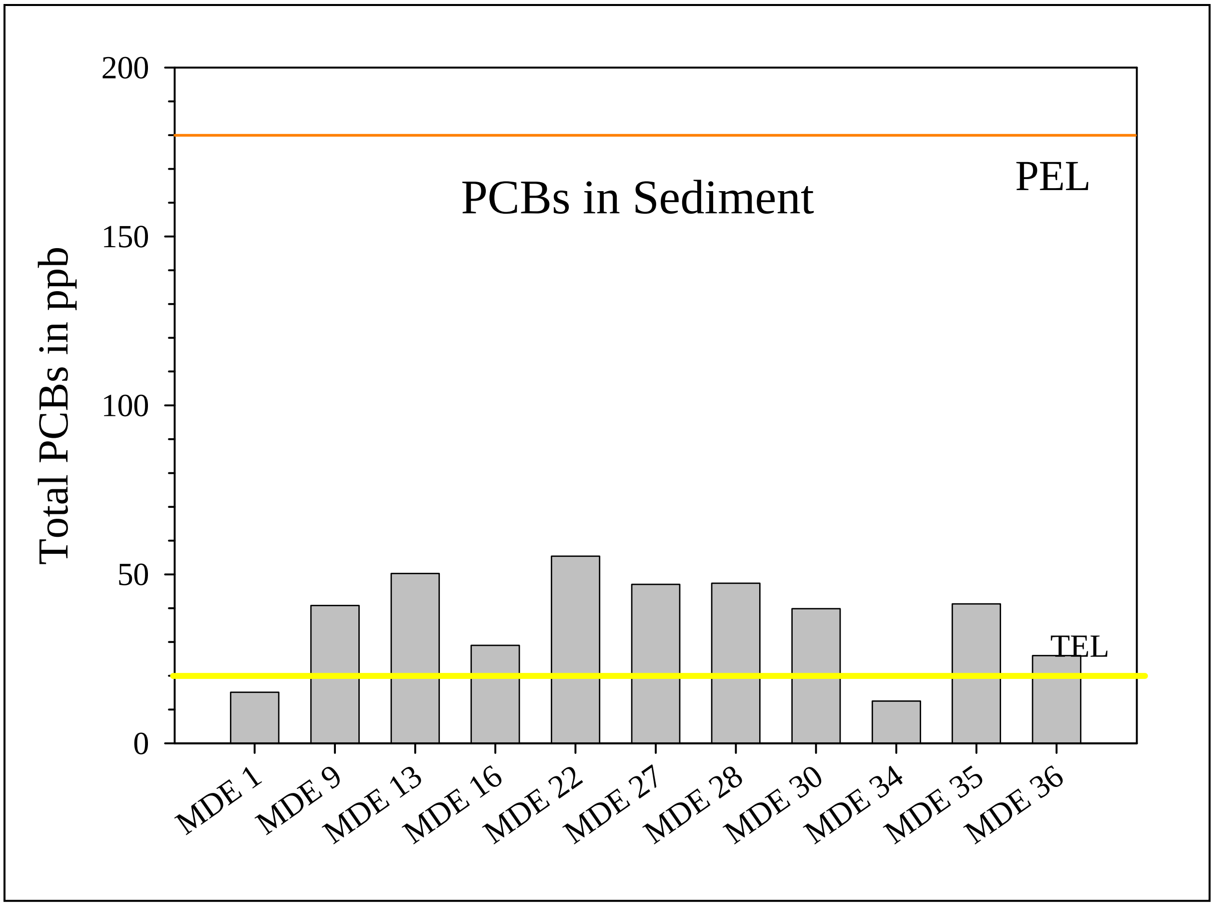

Figure 3-14. Total PCB concentrations in sediment along with TEL and PEL identified by NOAA for marine sediment.

YEAR 26 SUMMARY

Concentrations of the trace metals As, Se, Ag, Cd, Pb, Hg, and MeHg in both sediments and clams are similar to the concentrations observed in previous years. Three new stations (MDE-42, 43, and 44) have been sampled since 2003. The stations, located east of the South Cell discharged, appear similar to other HMI sites including the reference sites. From 2003 through 2007, the metal concentrations in clams have also been similar to other monitoring locations on the south side of the island. Of the sites located near the South Cell discharge, only MDE-16 was sampled for PCB and PAH analysis in 2007. Total PCB and PAH concentrations at MDE-16 were similar to the other sites sampled in 2007.

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