ASSESSMENT OF THE ENVIRONMENTAL IMPACTS OF CONSTRUCTION AND OPERATION OF THE HART AND MILLER ISLANDS CONTAINMENT FACILITY

SECOND INTERPRETIVE REPORT

AUGUST 1982 - AUGUST 1983

TO

WATER RESOURCES ADMINISTRATION

MARYLAND DEPARTMENT OF NATURAL RESOURCES

UNDER MPA CONTRACT 12477-S

AMONG

CHESAPEAKE RESEARCH CONSORTIUM, INC.

WATER RESOURCES ADMINISTRATION, MARYLAND DEPARTMENT OF NATURAL RESOURCES

MARYLAND PORT ADMINISTRATION, MARYLAND DEPARTMENT OF TRANSPORTATION

CHESAPEAKE RESEARCH CONSORTIUM

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1982-83 INTERPRETIVE REPORT

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SECOND INTERPRETIVE REPORT

EXECUTIVE SUMMARY

* Under contract among the Maryland Port Administration, Maryland Water Resources Administration and Chesapeake Research Consortium, extensive and intensive studies were conducted for a second consecutive year in the area around the Hart and Miller Islands diked spoil containment facilities. These studies, from August 1982 to August 1983, continue those reported in the First Interpretive Report.

* Scientists from the University of Maryland, The Johns Hopkins University, the Maryland Geological Survey and the Chesapeake Research Consortium designed, conducted and interpreted the studies, with administration, contract approval and report review by the Maryland Port Administration and Water Resources Administration with participation by other Maryland agencies.

* The schedule for most studies was quarterly, in August 1982 when the dike was approximately 70% completed, in November near completion, and in February and May of 1983 following completion of the primary structure of the dike. Several studies utilized different schedules appropriate to their topic.

* Studies were directed toward currents in the area; nutrients and productivity in the water column; sediments; animals in the bottom (benthos); fish and crabs; aquatic vegetation; and trace metals and organic contaminants in the water, sediments and organisms.

* Previous reports for 1981-1983 include:
  - Quarterly Progress Reports
  - Historical Summary of Environmental Data for the Area of the Hart and Miller Islands. 1982. 128 p.
  - Hart and Miller Islands Data Report, 1981-1982. 1982. 272 p.
  - First Interpretive Report, August 1981-August 1982. 1982. 341 p.
  - Recommendations. 1983. 11 p.
  - Hart and Miller Islands Data Report,1982-1983. 1984. 249 p.
  - Graphical Data Report on Currents, Vicinity of Hart and Miller Islands 1981-1983. 1984. 158 p.

TIDAL CURRENTS

* Most of the time, the flow of the Susquehanna River dominates circulation near the facility, and there is a stable counter-current up-estuary near the Islands.

* Local and regional wind conditions can alter or eliminate the counter-current for short periods.

* Currents are weak and variable.

* More intensive sampling in November of 1982 disclosed that the fluid mud extended 480 meters (525 yards) to the east and 1 kilometer (1090 yards) to the south of the dike and ranged in thickness from 10-38 cm (3.9-15 inches). Approximately 490,000 cubic meters (641,000 cubic yards) had been deposited between March and November.

* The fluid mud was very probably from dike construction, and apparently resulted from comparitively fast deposition.

* The new mud changed little through May 1983 and contained very few indications that the area was recolonized by animals, and those were in the surface sediments.

* Extensive data on the sediments, associated living organisms and chemical content are now available for future comparisons.

BENTHIC ANIMALS

* In the two years of seasonal sampling around the site of the containment dike, thirty-nine species of readily visable animals have been found in and on the bottom sediments.

* Nine species provided over 90% of the number of animals present, including one annelid worm, two small crustaceans, two species of barnacles, a false mussel and the non-commercial Macoma clam.

* Strong seasonal patterns occur in species composition and abundance, with the highest number of individuals in February and the lowest in August.

* Species diversity is highest in August.

* The average number of organisms was about 22% higher in 1982-1983 than in 1981-82, probably in response to higher salinities.

* Significant differences occur among stations, related to depth and to bottom type.

* In the new deposit of fluid mud, less than 1% of the number of organisms previously observed were present in August.

* In numbers, the animals in the fluid mud recovered about 11% in four months and 85% in ten months after the mud was deposited.

* Most of the invading animals were juveniles, and the total biomass may lag behind other areas for about two years.

* Detailed descriptions and analyses are now available for comparison in future years and after any significant change.

* Variability is wide in the amount of contaminants found in animals, affected by individual variability, seasonal changes, salinity, river run-off, growth rates and variation in location.

* Analysis of many individuals proved that at least 15-20 must be tested to determine the correct average within ±10%. Occasional "outliers", individuals far above average chemical burden, should be identified and taken into account.

* For oysters and mussels, which can contain outliers, at least 20 animals should be sampled annually at the same season from about 6 well-placed sites.

* Oysters and Macoma clams showed a November low for several metals and a summer high in May or August which can be ten times as high in metal concentration.

* Seasonal sampling of the Macoma clam is an important monitoring method for this area.

* Several species should be collected and banked for future reference, with present analysis of a single seasonally-matched sample.

* It is essential to learn more about the effects of external factors like salinity and internal factors like growth rate and body size on trace metal contamination - and to have continuity in the long-term sampling program.

* Highly useful reference data are now available for the two year period and the requirements of an effective and efficient annual monitoring program are established.

ORGANIC CONTAMINANTS

* Forty-four trace organic contaminant compounds were determined in samples of water, sediment and several animals from the Hart and Miller Islands area.

* Levels were extremely low in water but several orders of magnitude (10-1,000x) higher in sediments.

* Concentrations of many compounds were higher in 1982-83 than in 1981-82, particularly in the water during construction and in benthic animals.

* In invertebrates, concentrations ranged from about the same as in the sediments to 10,000 times as high. Such bioconcentration is normal and animals provide an excellent way of detecting low levels of new pollutants entering the system.

* High variability exists and seriously complicates the interpretation of data.

CHAPTER 1

INTRODUCTION

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This report summarizes and interprets the second year of studies of possible environmental impacts of construction and operation of the Hart and Miller Islands diked spoil containment facility. The program was carried out under MPA Contract 12477-S among the Chesapeake Research Consortium, Inc., Maryland Water Resources Administration and Maryland Port Authority. The program for two years of study was designed to provide historical summary and detailed present baseline description of the area which might be affected and to detect and measure any impacts from construction during this period.

Under the Contract, the Consortium conducted the program in cooperation with the state agencies and is responsible for interpreting the results; with participation by The Johns Hopkins University, the University of Maryland, the Maryland Geological Survey, the Maryland Tidewater Administration and the office of the Consortium. The Water Resources Administration reviewed the work proposed, certified the necessity of such work, supervised performance of the contract, reviewed all bills and invoices and reported the status of the work to the Maryland Port Administration. The Maryland Port Administration is the contracting agency and pays all costs upon certification by WRA and approval of the work performed.

The Facility (Figure 1) is now an 1100 acre enclosure behind a dike 18 feet above mean low water constructed from sand deposits within and underlying the enclosure site. Typical side slopes are 3 : 1 (three horizontal to one vertical) on the exposed outside face, 5 : 1 on the inside and 10 : 1 on the Back River side. The Bayside face is riprapped with stone over filter cloth. The completed dike is about 29,000 feet long and contains 5,800,000 cubic yards of stone. Detailed description is provided in several documents of the State of Maryland and U.S. Army Corps of Engineers and the 1981-1982 program is briefly described in CRC Publication No. 106 "Assessment of the Environmental Impacts of Construction of the Hart and Miller Islands Containment Facility", a pamphlet for public information.

The program involved year-round observation of water currents, the water column, the sediments, the biota and the chemical content of water, sediments and organisms. Each project was designed and then refined to provide appropriate data which can be statistically and qualitatively compared with further observations.

Specific project responsibilities and objectives were as follows:

Project I Coordination and Interpretation - Dr. L. Eugene Cronin and associates, CRC

1. Coordination of projects, budgets, administration and reporting.

2. Preparation of a special report "Historical Summary of Environmental Data for the area of Hart and Miller Islands in Maryland".

3. Preparation of Quarterly Progress Reports. All Project Leaders contribute to this Report.

4. Preparation of an annual Interpretive Report to summarize and interpret all observations and other information on the environment around the Islands.

5. To assure that all data are of high quality and are placed in the permanent data system of the State of Maryland, for current and future use, Mr. Charles Bostater of the Maryland Tidewater Administration and the principal investigators have developed a QUALITY ASSURANCE PROGRAM and a DATA MANAGEMENT PROGRAM. The Tidewater Administration is responsible for data entry and storage in computer files. In addition, WRA provides data from the other sources to investigators, data analysis by various schemes, and other assistance.

Project II Current Studies - Dr. William C. Boicourt and associates JHU-CBI, later UM-HPEL

Objectives:

(1) To determine the general circulation patterns around the area to be diked to assist design of studies and provide a reliable baseline.

(2) To determine the nature and magnitude of relatively long-term hydrographic variations in the vicinity of the area to be diked.

Project III Water Column - Dr. David A. Wright and associates - UM-CBL

Objectives:

(1) To monitor chemical and physical parameters associated with water quality to quantitate changes caused by construction.

(2) To measure inorganic and organic material of potentially toxic nature to detect any release caused by construction of the dike.

2. An Interim Report for discussion with the Technical Committee on Hart and Miller Islands. March 1982.

3. Report of Progress and Proposal. July 1982.

4. Special Report No. 1. HISTORICAL SUMMARY OF ENVIRONMENTAL DATA FOR THE AREA OF THE HART AND MILLER ISLANDS IN MARYLAND. CRC Publication No. 108. October 1982. 128 p.

5. HART AND MILLER ISLANDS DATA REPORT, 1981-1982. CRC Publication No. 109. October 1982. 272 p.

6. FIRST INTERPRETIVE REPORT, AUGUST 1981-AUGUST 1982. CRC Publication No. 110. December 1982. 341 p.

7. HART AND MILLER ISLANDS DATA REPORT, 1982-1983. CRC Publication No. 115. January 1984. 249 p.

8. GRAPHICAL DATA REPORT ON CURRENTS, VICINITY OF HART AND MILLER ISLANDS 1981-1983. January 1984. 158 p.

This Report summarizes and interprets all observations in 1982-83 with appropriate references to earlier studies and to those elsewhere which assist in these interpretations, with special emphasis on the uses of these reports as the basis of comparison with environmental observations in the future. Each chapter has been prepared by the person or persons responsible and each is approached from the position of an experienced investigator who is a specialist on the topic. The chapters, therefore, vary in style and content, but may gain in relevance.

It is appropriate to note several inherent and unavoidable constraints. The budget of the program was substantial but still required conservatism in the number of samples. Communications among all of the investigators and agency personnel has not always been easy.

This has, however, been a productive, extensive and intensive study over two full years by collaborating scientists at several research institutions in cooperation with several state agencies. It provides valuable new knowledge of an important part of the Chesapeake Bay system and unprecedented detail related to a specific site and engineering alterations. The product will be useful for many purposes, most especially the primary function of documenting and assessing impacts of construction and operation of the Hart and Miller Islands Containment Facility.

We acknowledge with appreciation the continuing constructive efforts of Mr. Lee Zeni, Mr. Thomas Andrews and Mr. Harold Cassell of the Maryland Department of Natural Resources and Mr. Frank Hamons of the Maryland Port Authority. They have provided effective cooperation and conscientious attention to the interests of the public of the State of Maryland and to the responsibilities of their agencies. The Citizens Oversight Committee and Governor's Advisory Board provided important suggestions, which are appreciated.

The Consortium acknowledges the excellent professional work, cooperation and, in most cases, timely analysis and reporting by the scientists and institutions participating. They have brought both high professional capability and concern for the health of Chesapeake Bay to their performance.

INTRODUCTION AND REVIEW

At the outset of the present study on the environmental impacts of the dredged material containment facility, the goals of the current measurement component were simple and clear: 1) to describe the details of the circulation in the vicinity of the Island and 2) to detect any change in the circulation induced by the presence of the containment dike. A possible approach to the problem would be to deploy a large, extensive array of moored instrumentation, and to maintain the array at least through one annual cycle of variation in the fresh water inflow from the Susquehanna River and through one annual cycle in the variation of meteorological forcing. The expense and effort required for such an approach, however, was not warranted, especially for a first look at the local circulation. An alternate approach was chosen that was designed to address both the spatial details of the flow, and the time variation over the annual cycle. The field program consisted of 1) two spatially extensive experiments, 2) two long-term moorings, and 3) a special experiment to determine the exchange of water between the region northwest of Hart and Miller Islands (Back River - Hawk Cove) and the Bay proper through Pleasure Island Channel. The interpretation of both the spatial experiments and the long-term current measurements was aided greatly by the concurrent program of long-term salinity and current measurements in the Upper Bay conducted by The Chesapeake Bay Institute and Science Applications, Inc. (Hamilton and Boicourt, 1983). Three long-term moorings were deployed in the main channel of the Upper Bay between July 1981 and August 1982, providing substantial overlap with the Hart and Miller Island measurements. As will be seen from the analysis of the currents in the vicinity of the Islands, the degree of coupling between the circulation along the boundaries and the circulation over the main channel of the estuary varies widely in time. For this reason, the complementary current measurements over the main channel of the Upper Bay proved invaluable.

The October 1981 spatially intense measurement program, in combination with other recent measurements in the Chesapeake Bay have served to modify the simple circulation picture of low salinity waters in the upper layers of the Bay moving steadily seaward over the incoming salt water from the ocean in the lower layer. Wang and Elliott (1978) show that the estuary above Pooles Island may be dominated over time scales of 5 days or more by either the wind or the discharge from the Susquehanna River. The Upper Bay measurements of Grano and Pritchard (1982) are of particular interest here because they show that there is significant lateral variation in the circulation. At the latitude of Hart and Miller Islands, the majority of the longitudinal estuarine transport occurs over the deep channel, near the eastern shore. Over the broad shallow regions off Hart and Miller Islands on the western side of the Bay, the mean longitudinal flows are small, of the order 1 cm/s or less. The October 1981 spatially intense measurement array data were consistent with Grano and Pritchard's findings in that the flows were weak near the Islands, but the new data also suggested that there was a reverse flow or countercurrent with up-estuary flow, perhaps connected with a lateral eddy in the downstream lee of Pooles Island (Figure 1). The existence of this countercurrent shown schematically in Figure 2, was not surprising in light of recent measurements in the Potomac River (Boicourt, 1982) or in the St. Lawrence estuary, where lateral

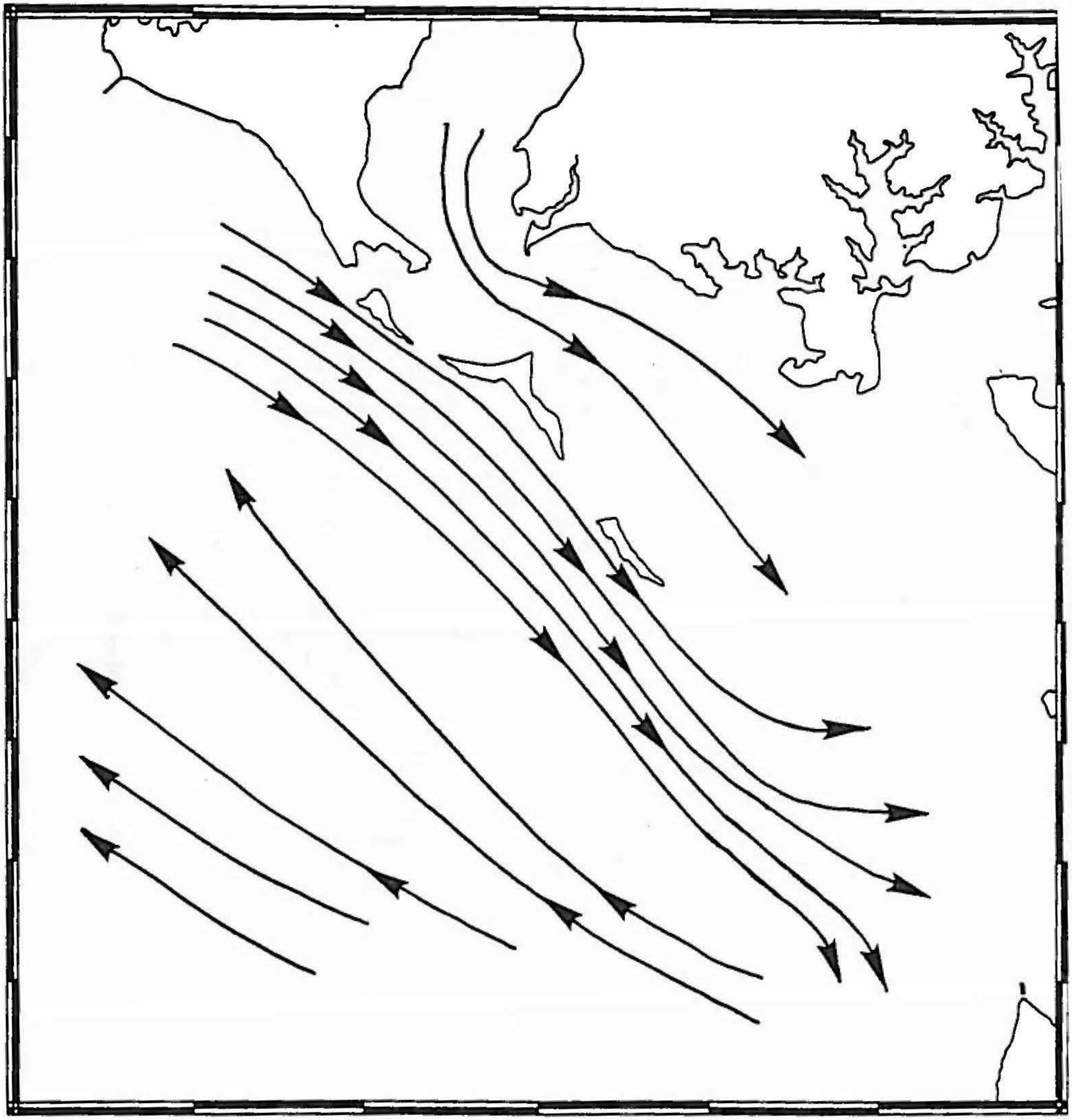

Figure 2. Schematic residual current streamlines.

through the large section between Wells Point and Miller Island. A direct measure of the flow through the Pleasure Island Channel was deemed desirable, however, to provide a quantitative comparison between the flux through the Wells Point-Miller Island section and the flux through the Island openings.

EXPERIMENTS

The current measurement component of the Hart and Miller Island study can be separated into four experiments:

1) October 1981 spatially intense measurement array

2) Two long-term moorings at Station LT-4 and LT-5

3) The July-August 1983 spatial experiment

4) The July, 1983 Pleasure Island Channel experiment

The details of the October 1981 spatially intense measurement experiment have been described in the First Interpretive Report and in the Data Report 1981-1982 (CRC publication No. 109). Instrument malfunction was restricted to the three moorings in the vicinity of Black Marsh and Pleasure Island, so that an additional spatial experiment was planned for this region in July-August 1983. The long-term moorings LT-4 and LT-5 were placed 2.5 km and 6 km, respectively, offshore of Hart and Miller Island (Figure 3). These instruments were designed to monitor the flow in the offing of the Islands and to provide a connection to the quantative circulation over the main chamber of the Upper Bay. In addition, these moorings provided a fortuitous connection to the larger-scale long-term array of the Chesapeake Bay Institute and Science Application, Inc. addressing the salinity structure in the Upper Bay (Figure 4). Four moorings were deployed during July and August 1983 with two purposes. The first purpose was to provide spatial coverage in a region where the October 1981 array lacked coverage, and the second purpose was to provide regional circulation information during the Pleasure Island Channel experiment.

SEASONAL VARIABILITY OF THE CIRCULATION

Separating the circulation effects of the Susquehanna River flow, the wind, and the influence of the bottom topography (including the containment dike) in the Hart and Miller Island region requires the aid of long-term measurements. For this purpose, the combination of the records from moorings LT-4 and LT-5 and the records from the CBI-SAI long-term salinity study in the Upper Bay is especially appropriate.

The first clues to the effects of the wind and the river flow on the circulation appear in the simple statistics of the low-frequency, monthly mean variabilities of flows at the long-term moorings LT-4 and LT-5. Figure 5 shows the mean longitudinal (parallel to the axis of the estuary) component of the flow at LT-4 and LT-5, with positive velocities directed up the estuary. The existence of the topographic eddy, or countercurrent observed in the October, 1981 spatially intense array is expressed in Figure 5 as a seaward mean flow at LT-5 and a weak up-estuary

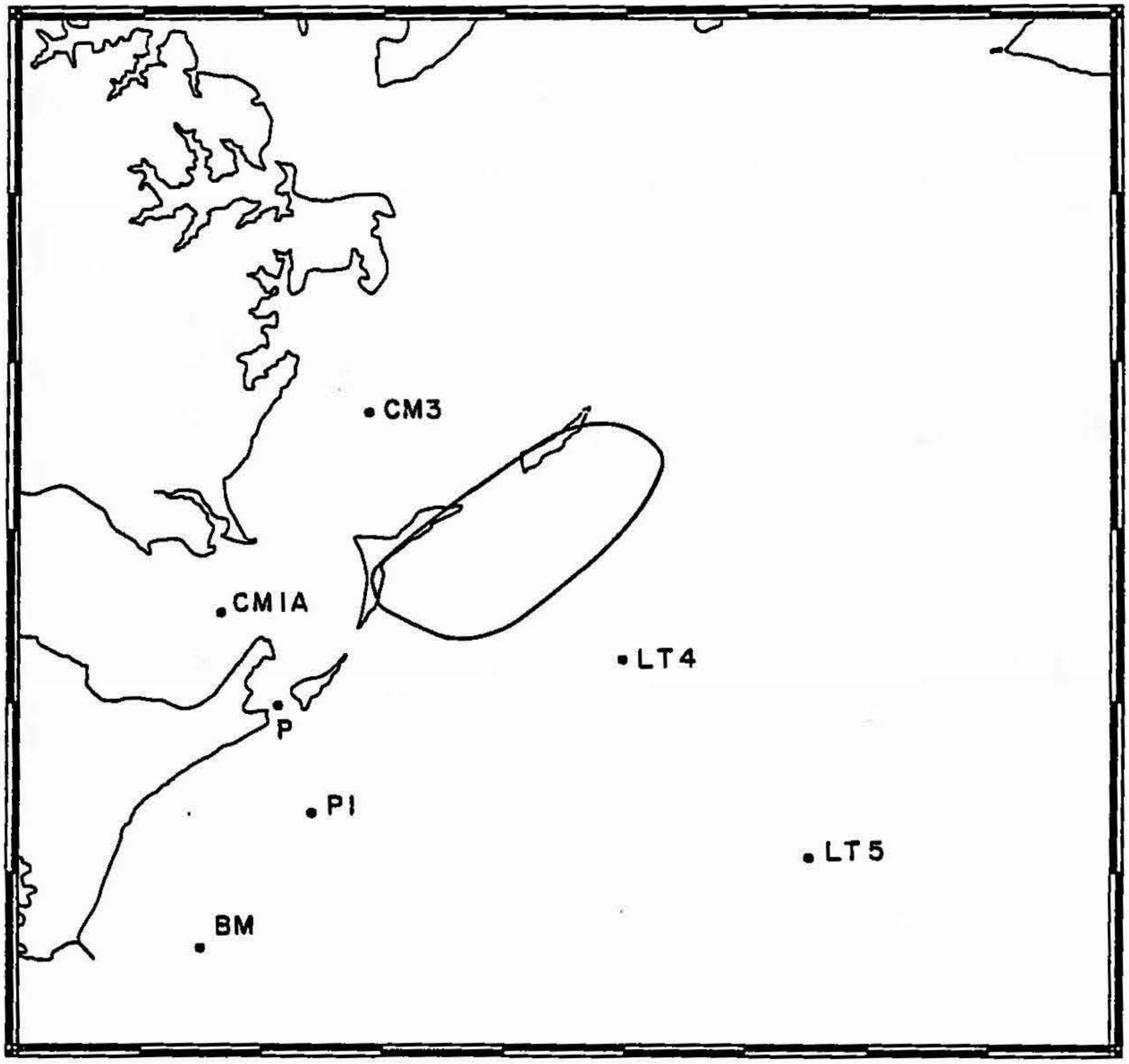

Figure 4. July 1983 spatial array mooring positions. The anchor station for the R/V D.W. Pritchard is shown at Pleasure Island channel.

flow at LT-4. The other current meter showed that LT-4 was near the nodal point in the longitudinal velocity profile and that the countercurrent increased in velocity shoreward, toward Hart and Miller Islands. Were the countercurrent or eddy structure to remain stationary, or at least a constant component of superposed circulations, then we would expect that the mean velocity at LT-4 would remain a relatively constant amount more positive than that of LT-5 (Figure 5). Although the majority of measurement intervals show the longitudinal component of velocity at LT-4 to be more positive that at LT-5, there are clear exceptions. Figure 5 can be interpreted in the light of three circulation processes:

1) There is a tendency for the low-frequency component of the circulation in the vicinity of Hart and Miller Islands to form a countercurrent or even a closed gyre or eddy set up by the large lateral embayment from Pooles Island to North Point.

2) The mean seaward flow in the upper layers of Chesapeake Bay is stronger over the deep channel than over the shallows along the side boundaries, and

3) the shallows along the side boundaries are more prone to wind-stress dominance because the gravitational component of the circulation is weak, and the water column is shallow.

The times, therefore, when the flow at LT-4 is directed seaward and is moving faster than the flow at LT-5, such as in November and December 1981, are likely to be the result of the strong northwesterly winds driving the shallows faster than the slightly deeper waters offshore. The interval October through November 1982 may seem a puzzle until we realize our ability to measure mean flows accurately when the mean flow is small is probably no better than 1 cm/s. In addition, the instrument position was usually at a depth of 2.4 m on a mooring in typically 4.6 m of water. While for the <u>gravitational</u> component of the circulation 2.4 m is in the seaward flowing upper layer, for the wind-driven component of the circulation, it turns out that, for the shallows, 2.4 m may be either slightly above or slightly below the nodal point on the vertical velocity profile, especially for cross-estuary flows. This behavior is evident in the higher-frequency variability, which will be discussed later. The conclusion for the October-December 1982 interval is that northwest winds may cause the flow at LT-4 to be slightly less positive than of LT-5, but certainly, the <u>mean</u> flows are weak. The interval July-August 1982 shows the effect of the prevailing southwesterly winds augmenting the countercurrent near the Islands.

The strong seaward flows in March-April 1981, and in March-April 1982 (Figure 5) are the results of the high discharge of the Susquehanna River during the spring runoff. At these times, the low-salinity water, the cross-estuary slope of the pycnocline is large as the result of the large transport in the gravitational circulation, and the seaward flowing water in the upper layer dominates the Hart and Miller Island region. At this time, the countercurrent or eddy is expected to be very narrow, close to the shore, or to be entirely eliminated. The monthly mean Susquehanna flows (Figure 6) show that the large discharges coincide with the large seaward means at LT-4 and LT-5. Of interest is the large monthly discharge in July 1982 that is not reflected in a correspondingly large seaward mean in the current at the long-term moorings (Figure 5). There is clearly not a linear relationship between the Susquehanna discharge and the mean flows at LT-4 and LT-5.

Do the mean flows reveal any influence of the containment dike such as increasing the longitudinal currents or moving the countercurrent offshore, toward the main channel? The flows are in general, weak, the variability sufficiently large, and the record length inadequate to detect the presence of the containment dike in this low-frequency component of the flows, measured at 2-1/2 km and 6 km from the Island, before dike construction. Given the weakness and variability of the currents, at least 3 years of record prior to dike construction would be required for detection of change induced by the dike. The weakness and variability of these means however, suggest that any change would not be significant.

Low-Frequency Variability

Records of currents and tidal heights were subjected to a set of Lanczos digital filters to separate the fluctuations into high frequency, tidal band-passed frequency, and low frequency components. The low-passed filter has a half power point at the 34-hour period, which effectively removes both the semidiurnal and the diurnal tides. The resultant current and tide records reflect the fluctuations driven by fluctuations in wind and river flow. Two measurement intervals have been chosen for comparison of low frequency variability at the two long-term mooring sites LT-4 and LT-5. Figure 7 contains the filtered longitudinal component of velocity from the two long-term moorings during the October 1981 spatially intense measurement array. A first look reveals the 2-1/2 day oscillations that have been observed elsewhere (Wang, 1979; Hamilton and Boicourt, 1983) in the Bay. They have been described by Wang and Elliott (1978) and Wang (1979) as seiche oscillations of the Bay. With Merian's formula predicting a 24 hr free-oscillation period of the Bay, however, the observed 2 to 2-1/2 day period must reflect the forced nature of the oscillations. Of special interest here is the coherence between the two long-term stations (Figure 7). While there are departures from strict coherence between the two records, there are no apparent systematic differences.

An indication of the wind-driven component of the fluctuations can be obtained by a comparison of the wind records (Figure 8) and the resulting currents (Figure 7). Winds measured at two meteorological stations are shown to provide an idea of the high spatial coherence in the wind field, despite the differences in location and anemometer height between the Craighill Channel Range Light and Baltimore-Washington International Airport weather stations. The direct wind driving is especially evident during the strong wind fluctuations in the interval 15-21 October. A progressive vector diagram of the October wind record from the Craighill Channel Range Light (Figure 9) reveals the sharp direction changes during this period. One trend that is not coherent with the wind driving in the October 1981 long-term current records is the increase in seaward velocity at the end (28 Oct. - 1 Nov., Figure 7). The reason for this increase can be found by comparing the flow at LT-4 and LT-5 with the upper layer flow of Fairlee Creek, as measured by Hamilton and Boicourt (1983), and with the Susquehanna River flow at this time. Figure 10 shows a stackplot of Hamilton and

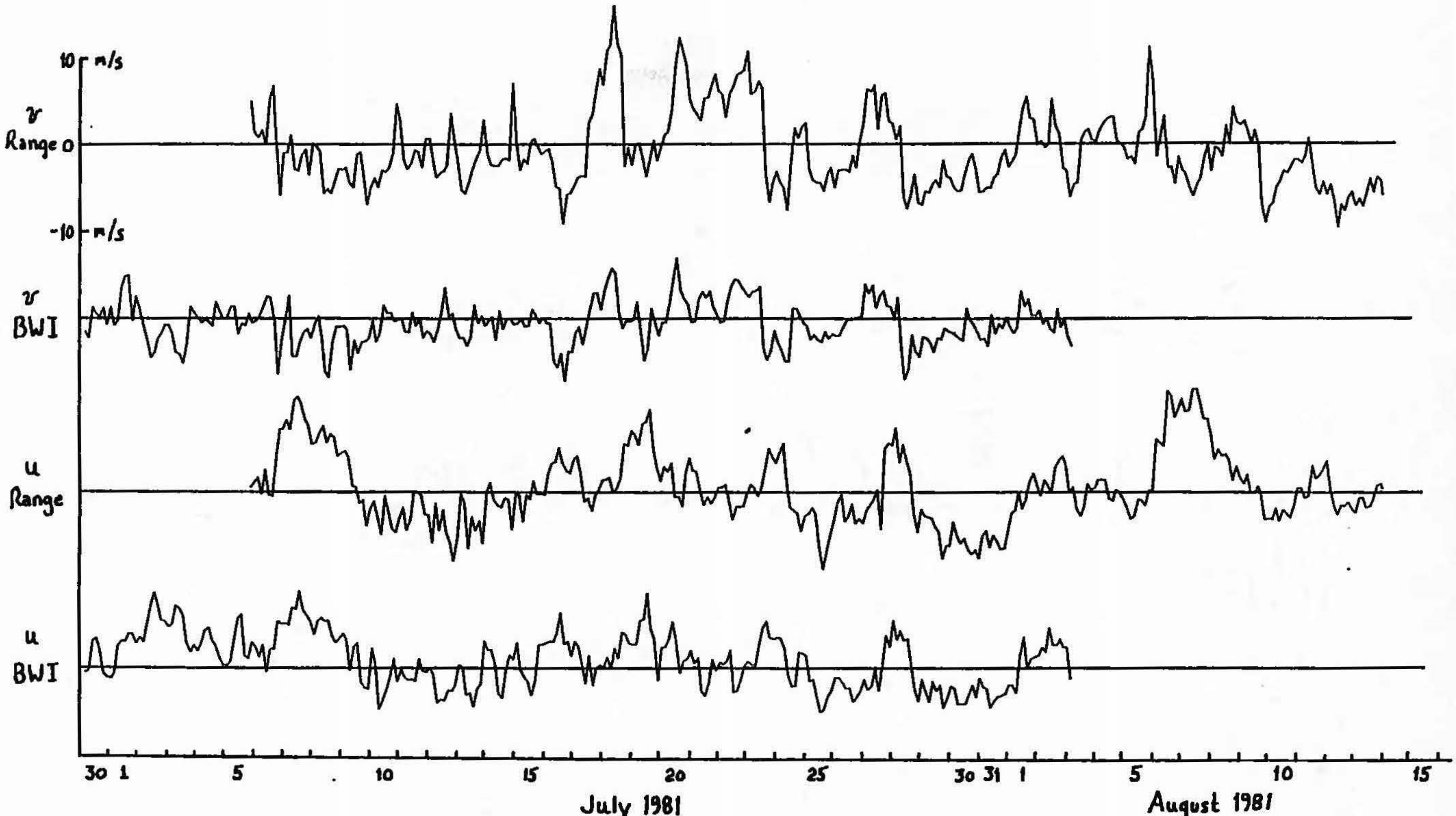

Figure 8. North (v) and east (u) components of wind velocity as measured at Baltimore-Washington International Airport (BWI) and at Craighill Channel Range Light (Range).

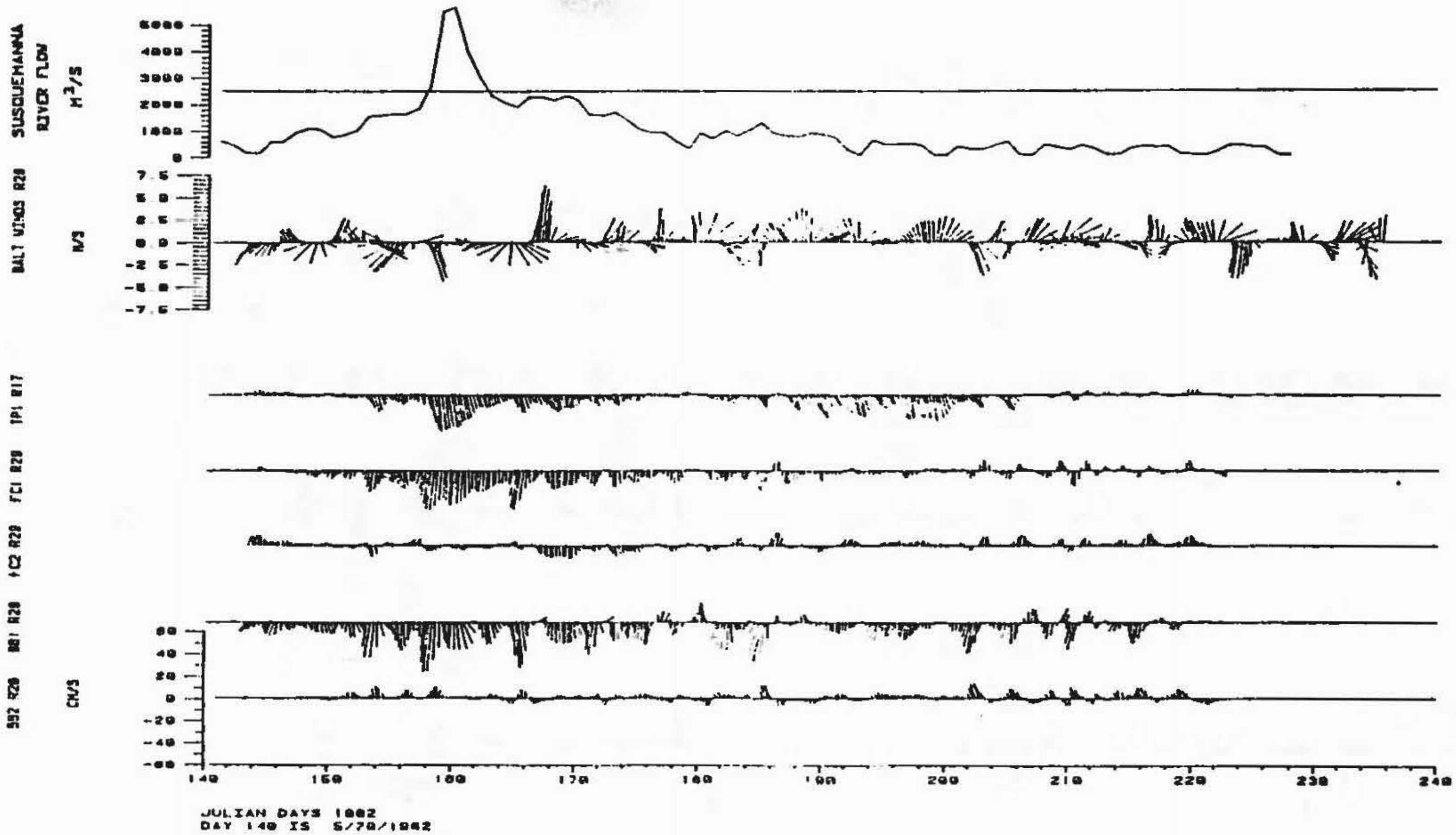

Figure 11. Time series plot of 40 HLP currents and daily averaged riverflow during late spring-summer, 1982. Hamilton and Boicourt (1983).

Two tide gauges were placed on either side of the Islands, at Wells Point (30° 16' 30" N, 76° 23' 06" W) and at Bethlehem Steel (39° 12' 50" N, 76° 25' 08" W). The current measurements were remarkably consistent with the October 1981 measurement array, given the variability of the wind and river flow. The flow out of Back River in the upper layer is of the order 2 cm/s (Figure 13). The flow in Hawk Cove is weak and variable, and dominated by the wind (Figures 14 and 15). Two reasons could be given for the gravitational component's appearance at the mouth of Back River, and not in Hawk Cove. The most likely explanation is that the 2 cm/s measured in the Rocky Point - Cuckold Point cross section is reduced by continuity in the wide cross section between Hart Island and Back River Neck to the point where the local wind-driven circulation easily dominates. The other possible reason is that the upper layer flow from Back River is discharged through Pleasure Island Channel and the shallow opening between Hart Island and Pleasure Island. This possibility will be discussed in the section on the Pleasure Island Channel Experiment.

The countercurrent at Station PI was well-developed, with a steady 3 cm/s flow toward the head of the estuary (Figure 16). That this flow is stronger than any flow in the countercurrent during the October 1981 array is probably not an effect of the containment dike so much as it is a reflection of the prevailing southwesterly winds in July and the westerly winds in October.

PLEASURE ISLAND CHANNEL EXPERIMENT

The mean flows from the October 1981 array (Figure 1) in combination with simple continuity arguments led to the deduction that the primary exchange of Back River with the Bay proper occurs via the Wells Point-Miller Island section near the mouth of Middle River and not via the Pleasure Island Channel and the opening between Hart Island and Pleasure Island. Although these openings experience tidal currents of the order 1 kt, their cross sectional areas appeared insufficient to allow a significant amount of transport during a half tidal cycle. The low mean flow measured in Hawk Cove and the uncertainty in the transport through the openings led to the Pleasure Island Channel Experiment in July 1983, where currents were measured at three stations over a 13-hour tidal cycle in the cross section between the Ramona's Cafe and Pleasure Island. The research vessel D. W. Pritchard was anchored fore-and-aft at a position 39° 13' 52" N, 76° 23' 51" W in the dredged navigation channel at 0600 on 26 July 1983. The moorings and tide gauges for the July 1983 spatial array (Figure 4) had been in place since 12 July. Two additional anchor stations were established, one on either side of the channel anchor station. Measurements of currents, temperature and salinity were made from the Pritchard every 30 minutes for 13 hours. Every hour, the two lateral stations were occupied with a smaller vessel, and current measurements were made at one depth in the shallow water column.

A current record from the channel anchor position is shown in Figure 17. The ebb velocities reached a higher peak than the flood velocity during this measurement interval. An estimate of the tidal flow through

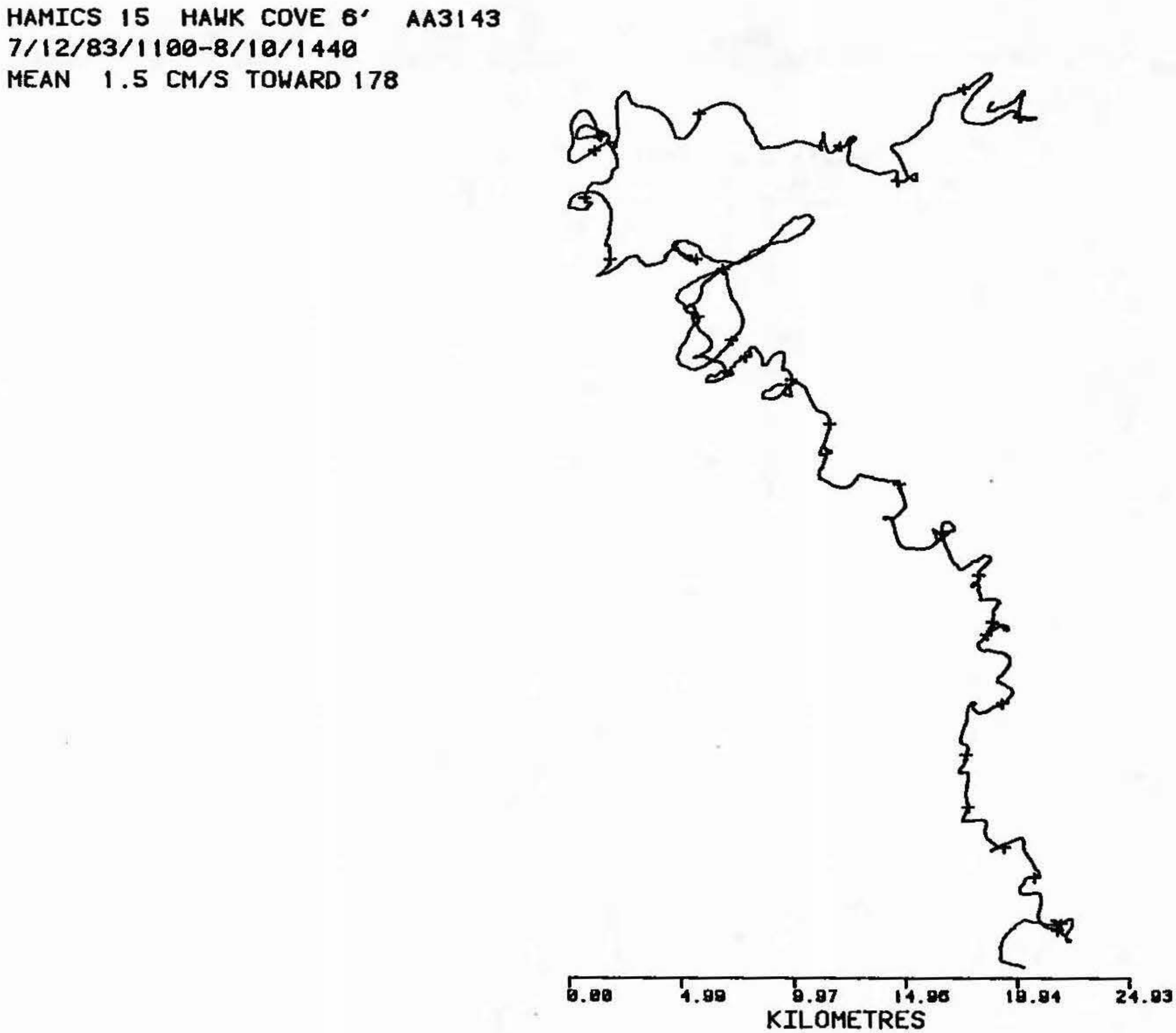

Figure 14. Progressive vector diagram constructed from a current meter record from Station CM3 in July 1983.

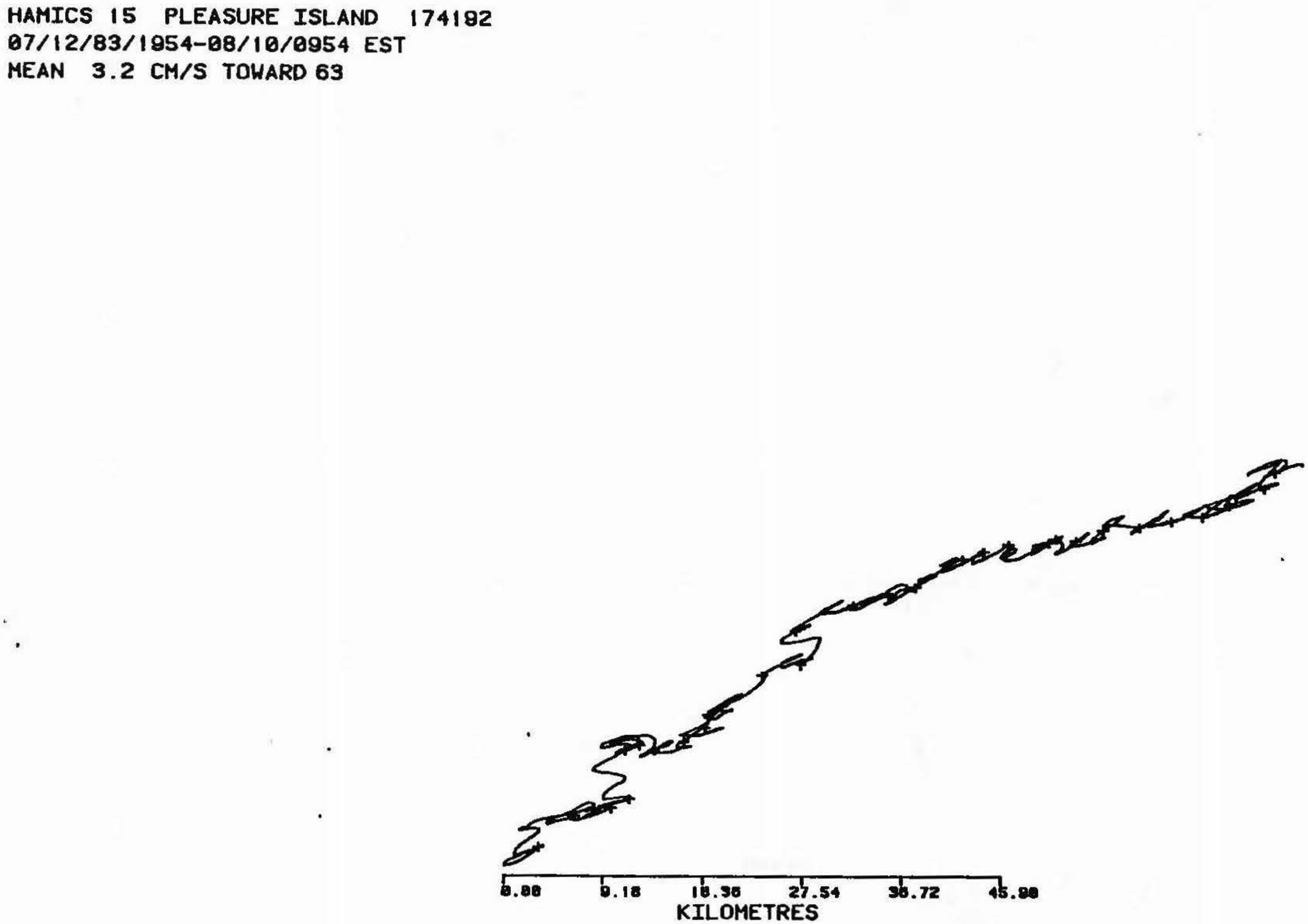

Figure 16. Progressive vector diagram constructed from a current meter record of Station PI in July 1983.

the Pleasure Island Channel could be constructed by segmenting the cross-section into areas that are represented by a current measurement point in space and then integrating the individual products of flow times segment area throughout the half tidal cycle. The consistency and coherence of the lateral station measurements with the channel stations measurements provides confidence that a simple procedure will suffice for the tidal flux estimate. The procedure is to assign the current measurements at the channel station to the entire cross section, and to assume that the flow variation is sinusoidal in time. The cross sectional area of the channel section is 490 m^2. The mean of a sinusoidal signal over a cycle is $\frac{2a}{\pi}$ where a is the amplitude of the signal. With a = 60 cm/s, the flux during the 7-1/2 hour ebb tide shown in Figure 14 is:

$$\frac{2x(.6m/s)}{\pi} \times 7.5 \text{ hrs} \times 490m =$$

$$= 187\ m^3/_s \times 2.7 \times 10^4 s = 5 \times 10^6 m^3$$

The question here is how does this flux compare with the tidal transport through the Cedar Point - Cuckold Point Section (CM1A, Figure 4) and through the Ralliston Point - Hart Island transect (CM3, Figure 4)? The transect across the mouth of Back River (Cedar Point - Cuckold Point) has a cross sectional area of 2800m^2 and the Hawk Cove cross section has an area of 5300m^2. While the tidal velocities through the Back River mouth are clearly evident, the tidal component of the flow through Hawk Cove (CM3) is often masked by the wind-driven component of the velocity. If the tidal flux through Pleasure Island Channel were flowing through the Hawk Cove section, then peak velocities would be an order of magnitude less than in the Channel, but certainly detectable at 6 cm/s. This comparison suggests that the Pleasure Island Channel provides at least the same order of magnitude of exchange between Back River - Hawk Cove and the Bay proper that the opening between Wells Point and Miller Island provides.

If the Pleasure Island Channel represents a significant exchange route between Back River - Hawk Cove and the Bay, will the closing of the opening between Hart and Miller Island significantly alter the exchange processes between Hawk Cove and the Bay? The answer to this question is no, because the amplitude of the tidal pressure gradient driving flow through the opening is much smaller than the pressure gradient through the Pleasure Island Channel and the transport and diffusion distances are considerably shorter. The tidal wave propagates up Chesapeake Bay at a phase velocity of approximately 15 kt. Locally, it propagates around Miller Island and into Hawk Cove. The phase difference of approximately 25 minutes across the Pleasure Island Channel is sufficient to allow a driving pressure gradient to be established. Across the Hart-Miller Island opening before dike construction, the phase difference was only approximately 8 minutes. In addition, the transport pathway between waters connected by the Pleasure Island Channel would be approximately 10 km without the Channel, whereas the pathway would only be 3.5 km around Miller Island.

Continuously pumped dye from release locations at the existing spillways would serve to reveal the resulting plumes under a variety of meteorological and river flow conditions. If the dye were Rhodamine-WT, then both the near-field (1-km space scale) and the mid-field (2-10 km scale) regions could be examined with the same experimental release. Rhodamine-WT can be tracked fluorometrically via the Chesapeake Bay Institute technique, which has a detectable concentration limit of .04 parts per billion of dye.

Dye transport experiments should be designed carefully to ensure that adequate resolution and coverage are achieved for both the near-field and the mid-field regions. In addition, two reference moorings of current meters should be deployed at the long-term sites LT-4 and LT-5. These measurements would provide a connection to the previously gathered intense instrument array measurements.

The recommendation to archive the current measurement and meteorological information also constitutes an endorsement of planned activities. The reason for explicitly mentioning this suggestion is to emphasize that future experiments and monitoring can build on the present data set without the necessity of launching large, expensive arrays of recording instruments. The intensive array measurements in October 1981 and the two long term moorings provide both spatial and temporal coverage. Future experiments can appeal to this information by placing instruments at the long-term mooring positions and by making local meteorological measurements.

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INTRODUCTION

In order to determine the degree of environmental impact occurring during construction of the Hart and Miller Islands containment facility, a broad monitoring program was initiated in August 1981. The water column portion of this program had as its prime objective the continuation of the monitoring program conducted in this area by the Maryland Water Resources Administration (WRA) from 1972 to 1978 (Allison and Butler, 1981). After the August 1981 sampling cruise, during which the WRA design was employed, the study was modified to more intensively describe water quality, nutrient concentrations and primary production rates in the vicinity of Hart and Miller Islands and to determine if changes occurred in these variables attributable to construction activities and the containment facility itself.

Included in this report are descriptions of the study area and construction sequence, the study design, the methods utilized and the results and interpretation of findings to date. The complete data sets are included in Wood and Keefe, (1982) and Wood et al. (1983).

Study Area and Construction Sequence

The upper Chesapeake Bay is strongly influenced by the Susquehanna River which supplies 90% of the freshwater to this portion of the Bay. The flow usually exhibits a seasonal pattern of a spring freshet with lower flow during late summer, fall and early winter (United States Geological Survey, 1972-1983). In addition, freshwater flow supplies significant amounts of nitrogen, phosphorus, sediments and organic matter to the upper Bay (Guide and Villa, 1972) and concentrations of nitrogen and phosphorus as well as chlorophyll _a_ have increased in the upper Bay over the past 25 years in response to changes in population, land uses and agricultural practices (Taft, 1982).

The study area is shallow with depths less than 5m. Seston distribution has been found to be controlled by the Susquehanna during periods of high discharge and by tidal and wind-induced resuspension during other periods (Schubel and Biggs, 1969). To these normal sources of suspended sediments, the effects of dredging activity have been added starting in September 1981. By the time of our sampling cruise on 19-20 November 1981 (Table 1) the dike was approximately 0.6 miles long at the northeast end of Miller Island (Fig. 1). On the 25-26 March 1982 cruise some construction had begun between the islands and the northeast span was about 1 mile long. During the November and March cruises very little actual dredging activity was observed. However, construction activity during the 30 June-1 July 1982 cruise was quite extensive and resulted in a visible sediment plume in the area at the southeast end of the dike (Keefe and Wood, 1982). Maryland Geological Survey's sampling of the sedimentary environment in July and November 1982 noted recently deposited sediments in an area along the southeast side of the dike. The probable source of the sediments was dredged material which had been resuspended during dike construction in June and July 1982 (Wells and Kerhin, 1983). They also found fluid mud in the surficial sediments in a

Figure 1. Extent of Completion of the dike on the sampling dates shown.

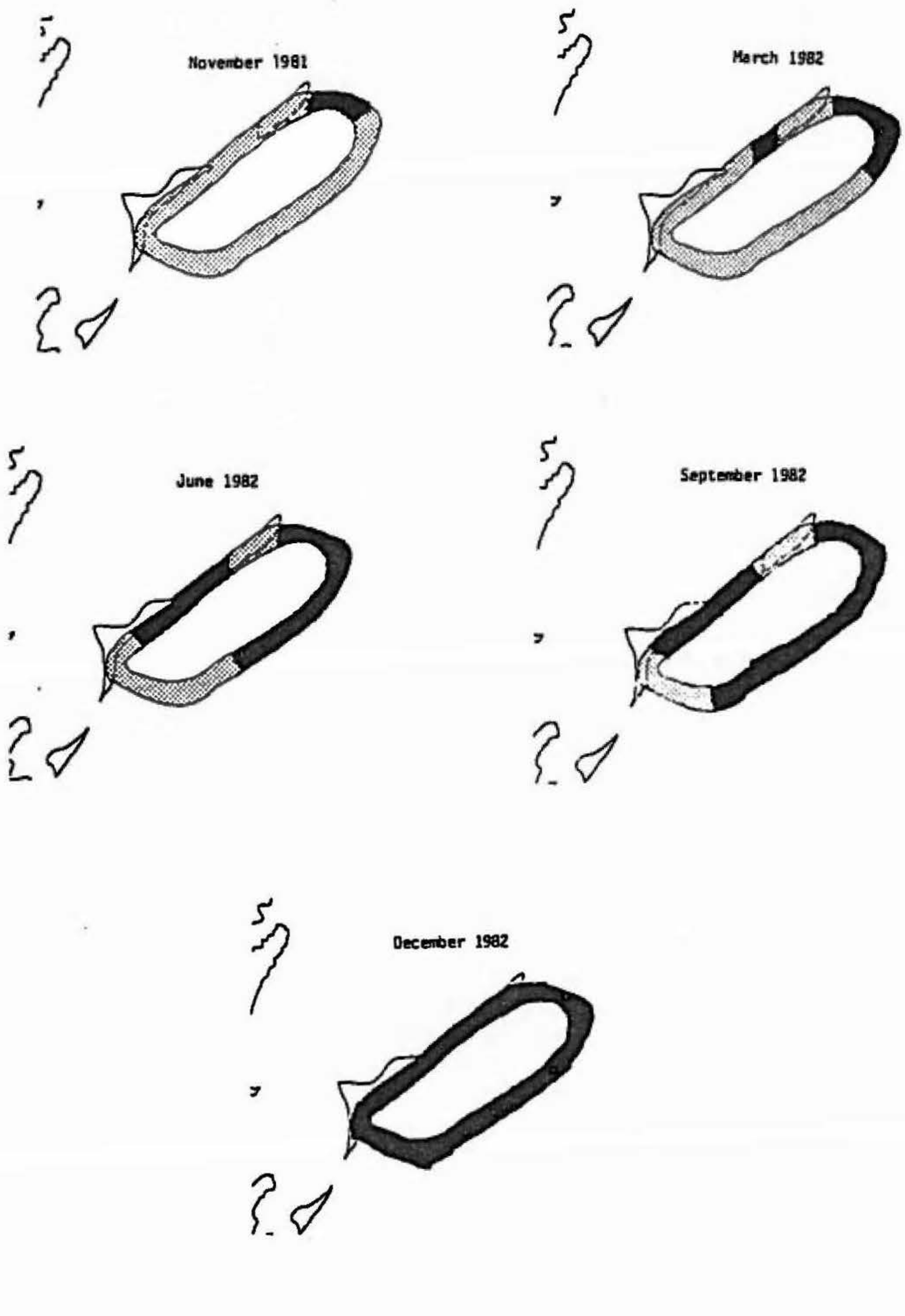
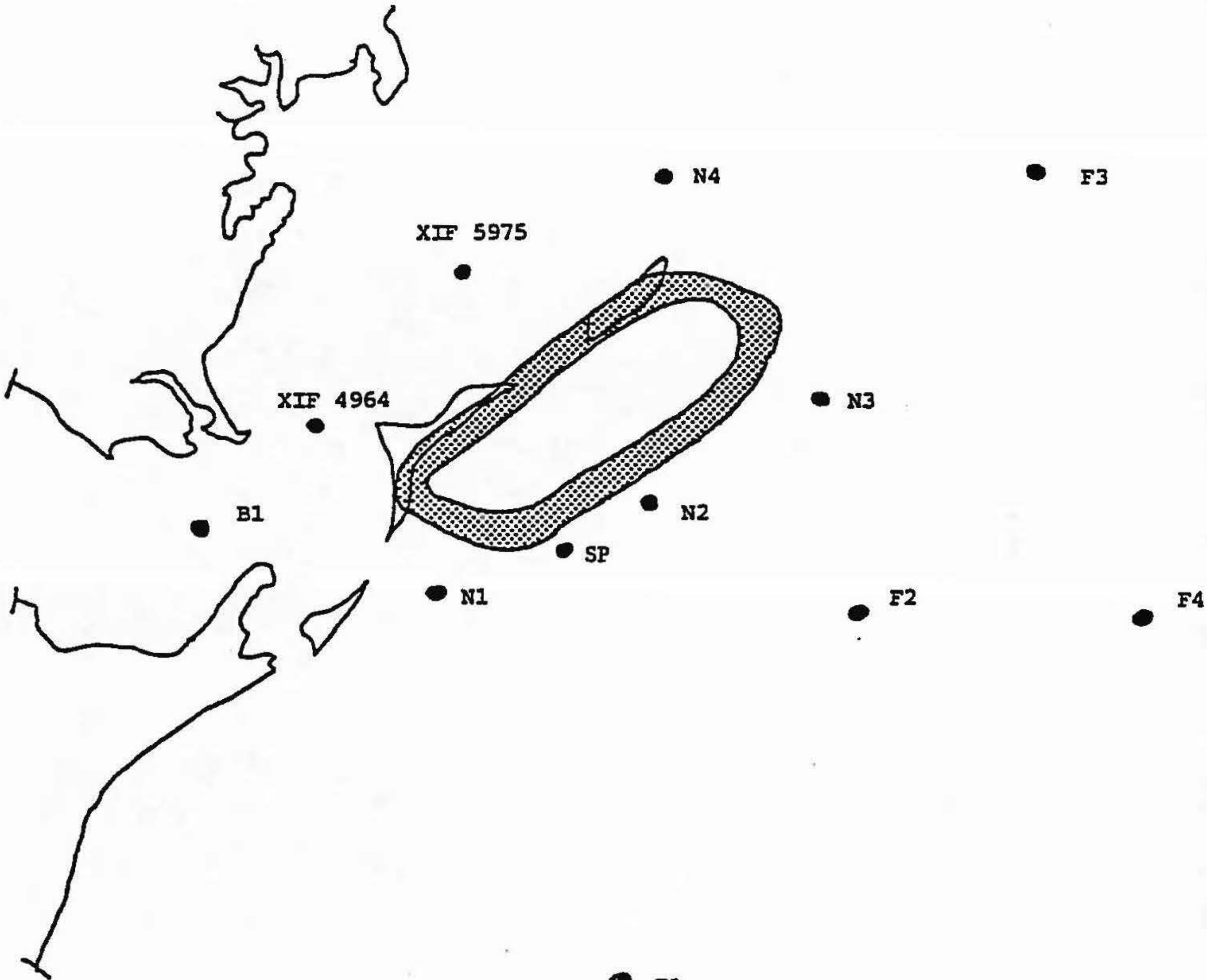


Figure 2. Water column nutrient and productivity station locations. "SP" marks the location of an extra set of samples taken on 9 September 1982 in a visible dredging plume.



Secchi disc depth was measured and light attenuation measurements were made with a Li-Cor Corporation Underwater Quantum Sensor (Model LI-193SB). A two-liter pumped water sample was taken at the surface and another at a depth approximately 1m from the bottom. These samples were immediately filtered and the filtrate frozen for ammonium, nitrite, nitrate and phosphate analyses. The filter pads (Whatman GF/C) with the suspended material on them were frozen for chlorophyll a and total suspended solids analyses.

Frozen samples were returned to the laboratory for analysis. The fluorometric technique described by Strickland and Parsons (1972) was used for chlorophyll a determinations. The dissolved nutrients and total suspended solids were analyzed using the methods of USEPA (1979).

On cruises 1, 2, 3, 4 and 7, in situ estimates of phytoplanktonic productivity were made at stations N1, N2, F2, F3 and F4 each day and on 8 December 1982, at N1, F2 and F3. The oxygen light-dark bottle method was used (Gaarder and Gran, 1927). Water from the surface was used to fill light bottles which were then suspended in duplicate from a buoyed rack at the surface and at 0.5m, 1.0m and 1.5m below the surface. A set of duplicate dark bottles was also suspended at 1.5m. A duplicate sample from the surface water was taken to establish initial dissolved oxygen concentration at the start of the incubation period. The samples were incubated for approximately six hours at mid-day after which final oxygen determinations were made.

A quality assurance evaluation was performed through U.S. Environmental Protection Agency (USEPA), Region III, Annapolis. The results were within acceptance limits and no further action was required.

Several types of statistical tests were employed for various purposes in the analysis of each cruise data set (Snedecor and Cochran, 1967). Since one of our major goals was to determine if there were significant water quality differences among stations in the study area, a one-way analysis of variance (ANOVA) was applied to the data. In the ANOVA, the eight stations were the treatments and the six measurements of each water quality variable were the replicates, yielding 47 degrees of freedom for each ANOVA. Surface and bottom measurements were treated separately. Another type of ANOVA was applied to the data taken each day of a cruise. All data from the N stations were compared to all data from the F stations for surface variables and Secchi disc visibility, k and $Z_{1\%}$. Each treatment (N or F) had 12 replicates (4 stations x 3 samples per day) yielding 23 degrees of freedom. This type of ANOVA eliminated some temporal variability and thus was more sensitive to spatial (near-field vs far-field) differences. Data subjected to analysis of variance were also examined to determine if distributional properties were appropriate for parametric testing. These tests included Bartlett's Box F, Cochran's C, and the F-max test. Of the 315 ANOVAs conducted, 71% met these criteria. In those cases where the criteria were not met, a non-parametric test (Kruskal-Wallis; L. Douglass, personal communication) was applied to confirm the results of the parametric ANOVAs. In all cases non-parametric tests yielded results consistant with those obtained from parametric testing. Each cruise data

Figure 3. Mean temperature, salinity and dissolved oxygen values for the N and F stations for each sampling cruise in the vicinity of Hart and Miller Islands, 1981-1983.

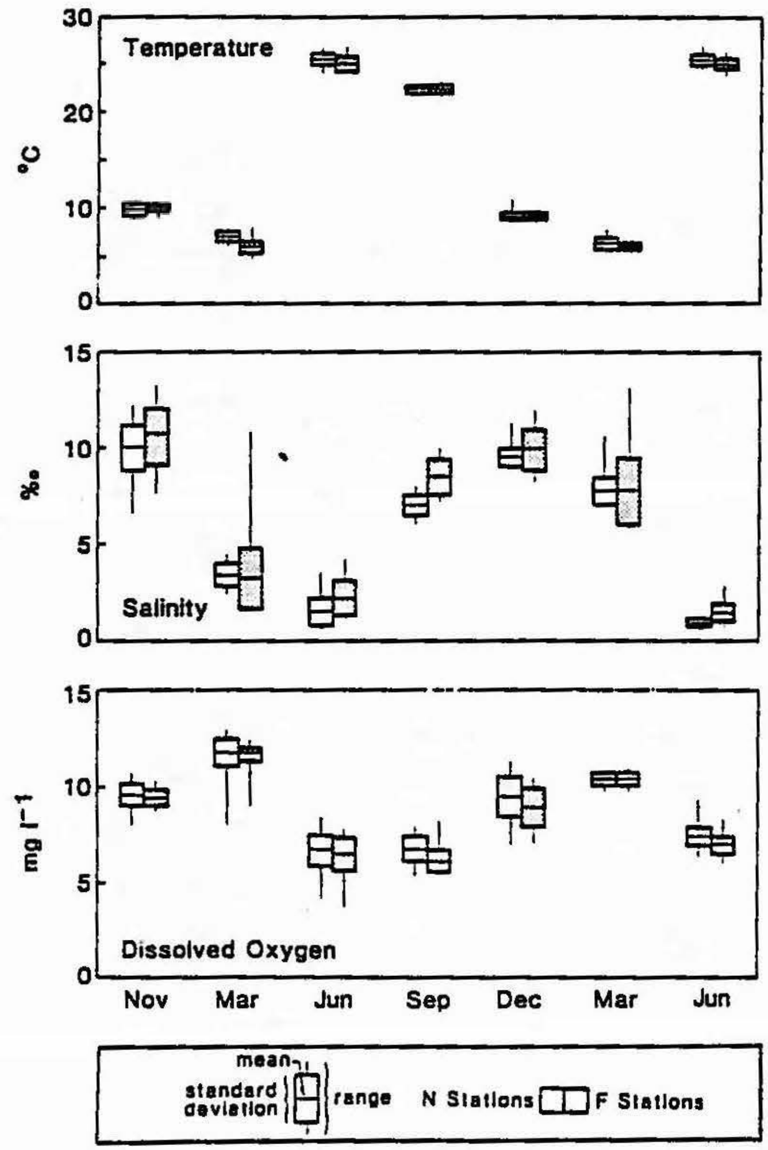


Figure 5. Mean chlorophyll a, phytoplankton production, seston and extinction coefficient values for the N and F stations for each sampling cruise in the vicinity of Hart and Miller Islands, 1981-1983.

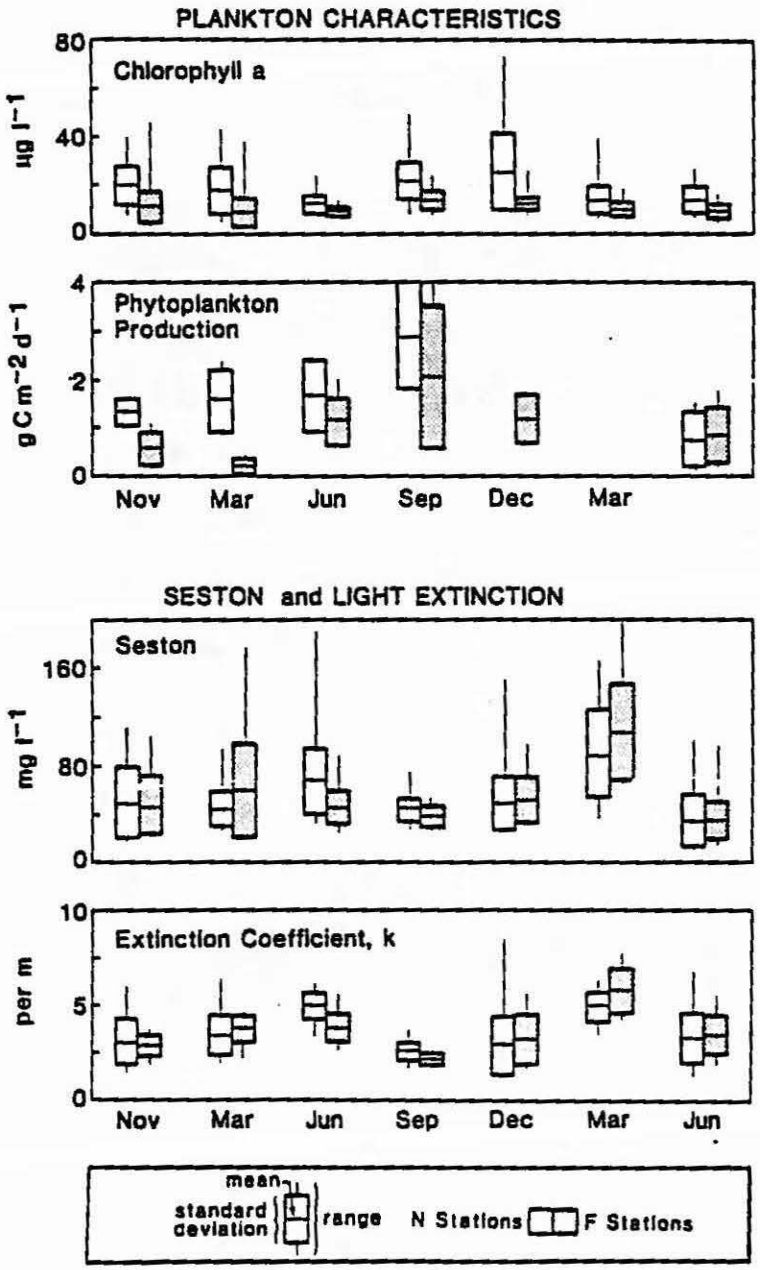


Table 3. Results of analysis of variance tests on data collected each day of each cruise. Surface values from all N stations were compared to values from all the F stations yielding 23 degrees of freedom for each analysis. Means with identical superscripts are not significantly different at the p = .05 level.

		19 Nov 1981	20 Nov 1981	25 Mar 1982	26 Mar 1982	30 Jun 1982	1 Jul 1982	8 Sep 1982	9 Sep 1982	8 Dec 1982	9 Dec 1982	22 Mar 1983	23 Mar 1983	21 Jun 1983	22 Jun 1983
NH_4	N	8.2^{a}	10.2^{a}	7.2^{b}	5.5^{b}	2.8^{a}	2.0^{a}	0.5^{b}	1.7^{b}	4.1^{a}	3.5^{a}	14.6^{a}	27.3^{a}	1.4^{b}	3.1^{a}
	F	8.2^{a}	8.0^{a}	10.7^{a}	9.2^{a}	3.2^{a}	3.2^{a}	2.6^{a}	4.3^{a}	6.5^{a}	6.1^{a}	10.5^{a}	11.0^{b}	3.0^{a}	4.0^{a}
NO_2	N	0.56^{a}	0.56^{a}	0.79^{a}	0.81^{a}	0.82^{a}	0.72^{a}	0.16^{b}	0.28^{b}	0.35^{a}	0.32^{a}	0.75^{a}	0.88^{a}	0.41^{a}	0.36^{a}
	F	0.64^{a}	0.57^{a}	0.73^{a}	0.78^{a}	0.64^{a}	0.62^{a}	0.58^{a}	0.67^{a}	0.38^{a}	0.45^{a}	0.73^{a}	0.78^{a}	0.44^{a}	0.42^{a}
NO_3	N	24.5^{a}	24.7^{a}	75.3^{a}	75.5^{a}	65.7^{b}	64.5^{b}	0.6^{b}	1.2^{b}	21.7^{b}	21.0^{b}	73.7^{a}	72.4^{b}	44.0^{b}	46.3^{b}
	F	27.1^{a}	2[illegible].9^{a}	72.1^{b}	73.3^{b}	76.9^{a}	78.5^{a}	4.0^{a}	4.2^{a}	26.7^{a}	27.1^{a}	72.2^{a}	76.5^{a}	51.2^{a}	54.6^{a}
DIP	N	0.23^{b}	0.21^{b}	0.10^{b}	0.08^{b}	0.59^{a}	0.59^{b}	0.25^{b}	0.43^{b}	0.08^{b}	0.08^{b}	0.34^{a}	0.42^{a}	0.18^{b}	0.31^{b}
	F	0.39^{a}	0.38^{a}	0.23^{a}	0.24^{a}	0.66^{a}	0.69^{a}	0.68^{a}	0.82^{a}	0.23^{a}	0.25^{a}	0.37^{a}	0.39^{a}	0.46^{a}	0.60^{a}
Chlor	N	24.8^{a}	19.5^{a}	18.4^{a}	18.3^{a}	13.6^{a}	14.4^{a}	28.3^{a}	23.2^{a}	30.6^{a}	28.4^{a}	12.8^{a}	13.5^{a}	17.8^{a}	10.3^{a}
	F	13.3^{b}	12.6^{a}	9.9^{a}	11.4^{b}	9.5^{b}	9.7^{b}	16.1^{b}	15.9^{b}	13.9^{b}	12.6^{b}	11.9^{a}	8.7^{b}	11.5^{b}	7.1^{b}
Ses	N	23.0^{a}	66.7^{a}	33.1^{b}	50.7^{a}	66.4^{a}	54.2^{a}	44.0^{a}	37.1^{a}	37.4^{a}	54.6^{a}	85.0^{b}	80.7^{a}	48.3^{a}	18.6^{a}
	F	24.9^{a}	62.4^{a}	38.3^{a}	75.6^{a}	35.9^{b}	34.4^{b}	35.2^{b}	32.6^{a}	35.8^{a}	67.1^{a}	149.8^{a}	84.2^{a}	43.8^{b}	24.0^{a}
Temp	N	9.8^{a}	9.7^{b}	7.2^{a}	7.2^{a}	25.9^{a}	25.5^{a}	22.6^{a}	22.2^{a}	9.6^{a}	8.8^{b}	7.0^{a}	5.9^{a}	25.7^{a}	25.6^{a}
	F	10.2^{a}	10.0^{a}	6.3^{b}	6.3^{b}	25.4^{a}	25.2^{a}	22.5^{a}	22.3^{a}	9.6^{a}	9.0^{a}	6.9^{a}	6.0^{a}	25.2^{b}	25.4^{a}
Sal	N	8.8^{a}	9.7^{b}	3.2^{a}	3.3^{a}	1.1^{b}	1.3^{b}	6.7^{b}	6.7^{b}	9.4^{a}	9.3^{a}	7.5^{a}	7.7^{a}	0.9^{b}	0.9^{b}
	F	9.3^{a}	10.6^{a}	2.9^{a}	2.9^{a}	1.8^{a}	1.9^{a}	8.3^{a}	8.4^{a}	9.5^{a}	9.6^{a}	8.0^{a}	7.3^{a}	1.6^{a}	1.3^{a}
DO	N	9.8^{a}	9.9^{a}	11.8^{a}	12.1^{a}	7.0^{a}	7.2^{a}	6.9^{a}	7.0^{a}	9.0^{a}	10.5^{a}	10.4^{a}	10.6^{a}	7.4^{a}	7.8^{a}
	F	9.6^{a}	9.7^{a}	11.7^{a}	12.0^{a}	6.9^{a}	7.0^{a}	6.3^{a}	6.4^{a}	8.6^{a}	9.9^{a}	10.2^{a}	10.7^{a}	7.1^{a}	7.4^{a}
Secc	N	0.65^{a}	0.64^{a}	0.59^{a}	0.45^{a}	0.22^{b}	0.24^{b}	0.50^{b}	0.54^{b}	0.59^{b}	0.49^{a}	-	0.29^{a}	0.41^{a}	0.65^{a}
	F	0.66^{a}	0.71^{a}	0.55^{a}	0.34^{a}	0.38^{a}	0.39^{a}	0.66^{a}	0.68^{a}	0.74^{a}	0.38^{b}	-	0.27^{a}	0.42^{a}	0.55^{a}
k	N	2.89^{a}	3.10^{a}	2.70^{b}	3.88^{a}	4.95^{a}	4.78^{a}	2.66^{a}	2.42^{a}	2.22^{a}	3.31^{a}	-	5.13^{a}	4.29^{a}	2.30^{a}
	F	2.98^{a}	2.40^{a}	3.50^{a}	4.28^{a}	3.97^{b}	3.44^{b}	2.12^{b}	2.09^{b}	2.23^{a}	4.38^{a}	-	5.63^{a}	4.17^{a}	2.65^{a}
$Z_{1\%}$	N	1.74^{a}	1.62^{a}	1.67^{a}	1.20^{a}	0.89^{b}	0.93^{b}	1.72^{b}	1.90^{a}	2.03^{a}	1.58^{a}	-	0.86^{a}	1.12^{a}	2.27^{a}
	F	1.56^{a}	1.87^{a}	1.33^{b}	1.02^{a}	1.21^{a}	1.31^{a}	2.11^{a}	2.14^{a}	2.03^{a}	1.12^{a}	-	0.80^{a}	1.14^{a}	1.88^{a}

To determine if differences in water quality variables existed among sampling stations (as opposed to between N and F station groups) ANOVAs and Student-Newman-Keuls tests were performed on each variable. Surface and bottom data were treated separately (Tables 5-11). In general these tests indicated that there were few strong trends such that any one station or station group was consistently different from the others. For example, dissolved inorganic phosphorus values were significantly higher at F2, F3 and F4 than at the other stations in November 1981, March 1982 and December 1982 but not during the other four cruises. Significantly different ammonium concentrations were detected among some stations on each cruise, but no single station or station group was consistantly higher or lower than others.

A possible exception to this pattern may have existed at station N1. For example, ammonium values were significantly higher than all others in November 1981, but significantly lower than all others in March 1982. N1 also displayed significantly higher surface DO, surface NO_2 and surface and bottom chlorophyll *a* in November 1981; high surface and bottom chlorophyll *a* in March 1982; and higher surface and bottom NO_2 and surface chlorophyll *a* in June 1982. It is doubtful that the tendency for N1 to display occassional differences from the other seven stations was due to construction activities alone because differences were inconsistent and when they did occur were often not consistent with the direction of change expected due to dredging activities. A more likely cause is the proximity of station N1 to the mouth of Back River, where nutrient and chlorophyll *a* concentrations were generally also somewhat higher (Wood and Keefe, 1982; Wood et al., 1983).

Evaluation of Monitoring Strategy

In planning monitoring strategy, a pertinent issue concerns the number of samples needed to adequately characterize the water column at each station. For that purpose, paired t-tests of each water quality variable at each station were used to determine if there were statistically significant differences between surface and bottom water samples. Of the 72 t-tests conducted for each cruise the percentage of variables showing no significant surface to bottom differences ranged from 67% for Cruise 3 to 96% for Cruise 2 (Table 12). Dissolved oxygen showed no significant surface to bottom differences in only 55% of the sampling sets, probably since surface DO concentrations tend toward saturation due to atmospheric aeration while bottom values are depressed due to water column and sediment respiration. Salinity and seston concentrations exhibited no surface to bottom differences in 78% and 65% of the sets, respectively, but there was no pattern from sampling cruise to sampling cruise concerning which stations exhibited differences. Likewise, there was no station that consistently exhibited surface to bottom differences for any other variables. Our analysis suggests that for the most part the water column in the shallow upper Bay can be adequately characterized with a single water column sample.

Table 6. Results of analysis of variance and Student-Newman-Keuls multiple range tests on data collected in the vicinity of Hart and Miller Islands on 25-26 March 1982. Means with identical superscripts are not significantly different at the 5% level. The degrees of freedom were 47 for each analysis.

		Station							
Variable	Depth	N1	N2	N3	N4	F1	F2	F3	F4
NH_4	Surface	4.0^{c}	6.9^{b}	8.0^{ab}	6.3^{b}	9.2^{a}	10.1^{a}	9.3^{a}	10.1^{a}
ug-at l^{-1}	Bottom	2.9^{c}	6.8^{b}	6.8^{b}	5.5^{b}	10.4^{a}	10.6^{a}	9.6^{a}	10.3^{a}
NO_2	Surface	0.86^{a}	0.86^{a}	0.81^{a}	0.83^{a}	0.86^{a}	0.79^{a}	0.76^{a}	0.75^{a}
ug-at l^{-1}	Bottom	0.84^{ab}	0.86^{ab}	0.83^{ab}	0.80^{ab}	0.88^{a}	0.82^{ab}	0.80^{ab}	0.76^{b}
NO_3	Surface	74.5^{ab}	75.5^{a}	75.8^{a}	75.8^{a}	71.2^{d}	73.0^{bc}	74.6^{ab}	72.0^{cd}
ug-at l^{-1}	Bottom	74.4^{a}	75.5^{a}	75.8^{a}	74.8^{a}	69.9^{c}	73.1^{ab}	74.9^{a}	71.0^{bc}
DIP	Surface	0.08^{c}	0.14^{bc}	0.17^{b}	0.18^{b}	0.19^{b}	0.31^{a}	0.31^{a}	0.32^{a}
ug-at l^{-1}	Bottom	0.07^{b}	0.16^{b}	0.14^{b}	0.11^{b}	0.16^{b}	0.33^{a}	0.28^{a}	0.33^{a}
Chlorophyll	Surface	32.1^{a}	17.6^{b}	9.9^{b}	13.9^{b}	12.0^{b}	12.8^{b}	9.7^{b}	8.0^{b}
ug l^{-1}	Bottom	30.6^{a}	15.2^{b}	11.3^{b}	14.0^{b}	11.6^{b}	7.6^{b}	7.7^{b}	7.4^{b}
Seston	Surface	37.3^{a}	40.8^{a}	43.1^{a}	46.2^{a}	43.6^{a}	66.4^{a}	55.3^{a}	62.5^{a}
mg l^{-1}	Bottom	40.7^{a}	47.2^{a}	44.9^{a}	50.7^{a}	51.9^{a}	66.8^{a}	59.6^{a}	69.1^{a}
Temperature	Surface	7.6^{a}	7.0^{ab}	6.9^{abc}	7.3^{ab}	6.5^{bcd}	6.1^{cd}	6.4^{bcd}	6.0^{d}
°C	Bottom	7.6^{a}	6.8^{ab}	6.1^{bc}	6.9^{ab}	6.0^{bc}	5.8^{bc}	6.1^{bc}	5.6^{c}
Salinity	Surface	3.8^{a}	3.5^{ab}	3.0^{b}	2.8^{bc}	3.9^{a}	2.8^{bc}	2.2^{c}	2.6^{bc}
‰	Bottom	4.0^{b}	3.5^{b}	3.2^{b}	3.5^{b}	6.0^{a}	3.0^{b}	2.5^{b}	2.9^{b}
DO	Surface	12.4^{a}	11.8^{b}	11.7^{b}	11.8^{b}	11.9^{b}	11.8^{b}	11.9^{b}	11.9^{b}
mg l^{-1}	Bottom	12.5^{a}	11.7^{ab}	11.7^{ab}	11.1^{b}	10.9^{b}	11.7^{ab}	11.8^{ab}	11.8^{ab}
Secchi, m		0.55^{a}	0.54^{a}	0.53^{a}	0.53^{a}	0.54^{a}	0.47^{a}	0.41^{a}	0.43^{a}
k, per m		3.11^{a}	3.36^{a}	3.66^{a}	3.22^{a}	3.23^{a}	4.16^{a}	3.82^{a}	3.74^{a}
$Z_{1\%}$, m		1.55^{a}	1.62^{a}	1.36^{a}	1.55^{a}	1.37^{a}	1.09^{a}	1.17^{a}	1.21^{a}

Table 8. Results of analysis of variance and Student-Newman-Keuls multiple range tests on data collected in the vicinity of Hart and Miller Islands on 8-9 September 1982. Means with identical superscripts are not significantly different at the 5% level. The degrees of freedom were 47 for each analysis.

		Station							
Variable	Depth	N1	N2	N3	N4	F1	F2	F3	F4
NH_4 ug-at l^{-1}	Surface	1.1^{bc}	1.6^{bc}	1.0^{bc}	0.5^{c}	5.0^{a}	2.7^{b}	1.6^{bc}	4.8^{a}
	Bottom	2.4^{bc}	2.6^{bc}	2.2^{bc}	0.6^{c}	5.6^{a}	3.7^{ab}	2.0^{bc}	5.8^{a}
NO_2 ug-at l^{-1}	Surface	0.33^{bc}	0.28^{bc}	0.15^{c}	0.10^{c}	0.73^{a}	0.52^{b}	0.50^{b}	0.75^{a}
	Bottom	0.43^{c}	0.28^{cd}	0.30^{cd}	0.08^{d}	0.78^{ab}	0.55^{bc}	0.53^{bc}	0.88^{a}
NO_3 ug-at l^{-1}	Surface	1.12^{b}	1.05^{b}	1.10^{b}	0.32^{b}	3.52^{a}	4.12^{a}	4.50^{a}	4.32^{a}
	Bottom	1.25^{c}	1.73^{c}	1.85^{c}	0.73^{c}	3.22^{b}	4.32^{ab}	5.07^{a}	4.25^{ab}
DIP ug-at l^{-1}	Surface	0.33^{d}	0.43^{d}	0.35^{d}	0.25^{d}	0.82^{ab}	0.68^{bc}	0.62^{c}	0.87^{a}
	Bottom	0.42^{d}	0.50^{d}	0.55^{cd}	0.27^{e}	0.80^{ab}	0.73^{b}	0.68^{bc}	0.92^{a}
Chlorophyll ug l^{-1}	Surface	32.0^{a}	23.3^{bc}	22.6^{bc}	25.2^{ab}	16.0^{bc}	15.2^{bc}	19.2^{bc}	13.6^{c}
	Bottom	21.1^{a}	14.9^{ab}	15.5^{ab}	20.6^{a}	14.9^{ab}	12.3^{b}	12.5^{b}	9.2^{b}
Seston mg l^{-1}	Surface	43.9^{ab}	47.2^{a}	38.3^{ab}	33.5^{b}	31.5^{b}	37.8^{ab}	33.5^{b}	32.6^{b}
	Bottom	52.8^{a}	49.6^{ab}	49.5^{ab}	34.2^{b}	42.2^{ab}	43.1^{ab}	39.3^{ab}	41.1^{ab}
Temperature °C	Surface	22.3^{a}	22.3^{a}	22.4^{a}	22.4^{a}	22.5^{a}	22.3^{a}	22.4^{a}	22.5^{a}
	Bottom	22.4^{a}	22.4^{a}	22.4^{a}	22.4^{a}	22.5^{a}	22.3^{a}	22.2^{a}	22.4^{a}
Salinity °/₀₀	Surface	6.9^{d}	7.0^{d}	6.8^{d}	6.2^{e}	9.2^{a}	8.0^{b}	7.4^{c}	8.8^{a}
	Bottom	7.6^{c}	7.7^{bc}	7.4^{c}	6.4^{d}	9.4^{a}	8.2^{b}	7.5^{c}	9.2^{a}
DO mg l^{-1}	Surface	7.1^{a}	6.5^{ab}	7.0^{a}	7.2^{a}	5.9^{b}	6.6^{ab}	6.7^{ab}	6.1^{b}
	Bottom	6.0^{bcd}	6.1^{bc}	6.4^{b}	7.0^{a}	5.7^{cd}	6.0^{bcd}	6.3^{bc}	5.6^{d}
Secchi, m		0.50^{de}	0.47^{e}	0.55^{cde}	0.57^{cd}	0.70^{ab}	0.63^{abc}	0.62^{bc}	0.72^{a}
k, per m		2.75^{a}	2.77^{a}	2.27^{ab}	2.37^{ab}	2.07^{b}	2.33^{ab}	2.15^{b}	1.88^{b}
$Z_{1\%}$, m		1.65^{b}	1.62^{b}	2.05^{ab}	1.92^{ab}	2.15^{a}	1.88^{ab}	2.10^{ab}	2.37^{a}

Table 10. Results of analysis of variance and Student-Newman-Keuls multiple range tests on data collected in the vicinity of Hart and Miller Islands on 22-23 March 1983. Means with identical superscripts are not significantly different at the 5% level. The degrees of freedom were 36 for each analysis.

Variable	Depth	Station N1	N2	N3	N4	F1	F2	F3	F4
NH_4	Surface	40.1 ^{a}	19.6 ^{ab}	16.7 ^{ab}	12.4 ^{b}	13.2 ^{ab}	10.8 ^{b}	8.2 ^{b}	12.5 ^{ab}
ug-at l^{-1}	Bottom	28.4 ^{a}	17.6 ^{ab}	16.0 ^{ab}	12.6 ^{ab}	16.9 ^{ab}	11.0 ^{b}	7.6 ^{b}	12.2 ^{ab}
NO_2	Surface	1.00^{a}	0.80^{ab}	0.78^{ab}	0.74^{b}	0.80^{ab}	0.78^{ab}	0.70^{b}	0.90^{ab}
ug-at l^{-1}	Bottom	0.88^{a}	0.78^{a}	0.80^{a}	0.76^{a}	0.90^{a}	0.80^{a}	0.63^{a}	0.90^{a}
NO_3	Surface	68.0 ^{b}	73.9 ^{a}	74.7 ^{a}	75.1 ^{a}	70.2 ^{ab}	79.4 ^{a}	75.7 ^{a}	81.0 ^{a}
ug-at l^{-1}	Bottom	66.4 ^{b}	74.1 ^{a}	73.8 ^{a}	74.3 ^{a}	59.5 ^{c}	78.5 ^{a}	76.3 ^{a}	72.6 ^{ab}
DIP	Surface	0.42^{a}	0.38^{a}	0.40^{a}	0.34^{a}	0.40^{a}	0.40^{a}	0.35^{a}	0.40^{a}
ug-at l^{-1}	Bottom	0.44^{a}	0.36^{a}	0.40^{a}	0.34^{a}	0.35^{a}	0.40^{a}	0.35^{a}	0.40^{a}
Chlorophyll	Surface	17.0 ^{a}	13.4 ^{a}	12.1 ^{a}	10.6 ^{a}	8.2 ^{a}	8.3 ^{a}	11.9 ^{a}	8.8 ^{a}
ug l^{-1}	Bottom	22.4 ^{a}	12.6 ^{ab}	11.9 ^{ab}	11.1 ^{ab}	10.0 ^{ab}	8.9 ^{b}	12.6 ^{ab}	9.0 ^{ab}
Seston	Surface	78.7 ^{a}	79.8 ^{a}	84.2 ^{a}	86.9 ^{a}	89.5 ^{a}	93.9 ^{a}	121.2 ^{a}	73.5 ^{a}
mg l^{-1}	Bottom	80.8 ^{a}	91.1 ^{a}	92.9 ^{a}	92.4 ^{a}	117.1 ^{a}	114.4 ^{a}	130.4 ^{a}	83.5 ^{a}
Temperature	Surface	6.3 ^{a}	6.3 ^{a}	6.3 ^{a}	6.5 ^{a}	6.2 ^{a}	6.1 ^{a}	6.4 ^{a}	6.1 ^{a}
°C	Bottom	6.4 ^{a}	6.4 ^{a}	6.4 ^{a}	6.4 ^{a}	6.1 ^{a}	6.2 ^{a}	6.3 ^{a}	5.9 ^{a}
Salinity	Surface	8.3 ^{ab}	7.6 ^{bc}	7.4 ^{bc}	7.3 ^{bc}	9.0 ^{a}	6.9 ^{c}	6.7 ^{c}	6.1 ^{c}
°/oo	Bottom	8.8 ^{b}	7.5 ^{b}	7.6 ^{b}	7.3 ^{b}	10.7 ^{a}	7.0 ^{b}	6.7 ^{b}	6.2 ^{b}
DO	Surface	10.3 ^{a}	10.6 ^{a}	10.6 ^{a}	10.6 ^{a}	10.4 ^{a}	10.6 ^{a}	10.7 ^{a}	10.9 ^{a}
mg l^{-1}	Bottom	10.0 ^{b}	10.3 ^{ab}	10.4 ^{ab}	10.4 ^{a}	10.0 ^{b}	10.3 ^{ab}	10.5 ^{a}	10.4 ^{ab}
Secchi, m		0.32^{a}	0.30^{a}	0.35^{a}	0.32^{a}	0.33^{a}	0.23^{a}	0.23^{a}	0.30^{a}
k, per m		4.85^{a}	5.15^{a}	4.55^{a}	4.85^{a}	4.33^{a}	6.43^{a}	6.13^{a}	5.60^{a}
$Z_{1\%}$, m		0.90^{a}	0.85^{a}	1.00^{a}	0.90^{a}	1.00^{a}	0.70^{a}	0.70^{a}	0.80^{a}

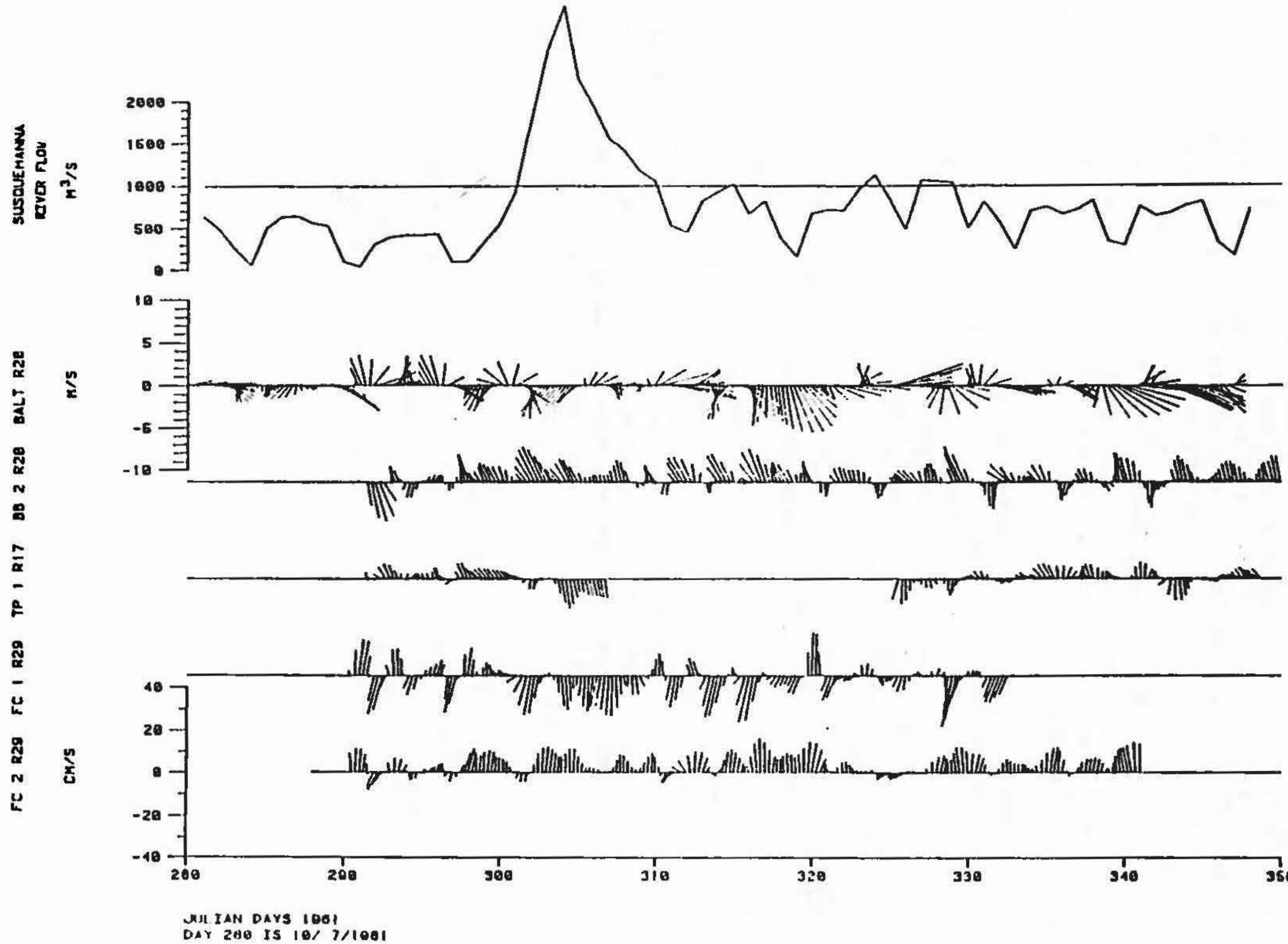
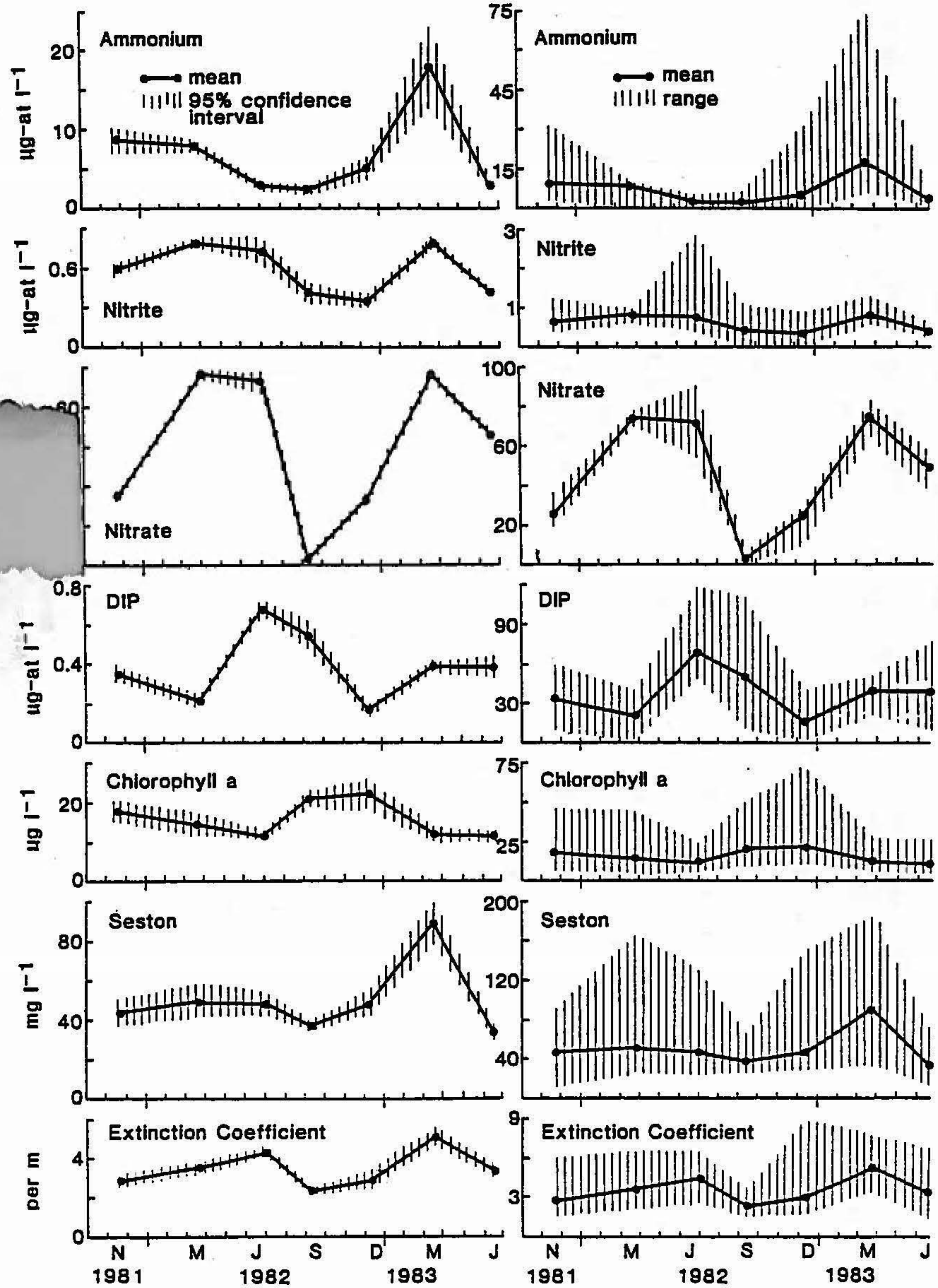


Figure 10. Time series plot of 40 HLP currents and daily averaged riverflow during fall, 1981. Hamilton and Boicourt.

Table 12. Results of paired t-tests on data collected in the vicinity of Hart and Miller Islands 1981-1983 showing where there were significant differences between surface and bottom values. The degrees of freedom were 5 for each analysis.

Date	Variable	Station
November 1981	Salinity	F1, F2, F4, N4
	DO	F1, F2, F3, N4
	Seston	F2
March 1982	NH_4	F2
	Seston	N1, N4
June 1982	Temperature	N1, N3
	Salinity	F1, N1, N2
	DO	F1, F3, N1, N2, N4
	NH_4	F3, N3
	NO_2	F3
	NO_3	F1
	DIP	F1, F2, F3
	Chlorophyll *a*	N1
	Seston	F2, F3, F4, N2, N3, N4
September 1982	Temperature	F3, F4
	Salinity	F3, N1, N2, N3
	DO	F1, F4, N1, N2, N3
	NH_4	N3
	NO_3	N3
	DIP	N3
	Chlorophyll *a*	F3, N1, N2, N3, N4
	Seston	F1, F4, N3
December 1982	Salinity	F4
	DO	F3
	NO_3	F1
	DIP	F1, F2
	Seston	N1, N3
March 1983	Temperature	N2
	DO	F1, F2, N1, N2, N3, N4
June 1983	DO	N4, F1, F2, F4
	NH_4	F3
	NO_2	N4, F3
	Chlorophyll *a*	F2, F3
	Seston	N2, N3, F2, F3, F4

Figure 6. Cruise means, ranges and 95% confidence interval of the means for surface data from all stations (n=48) in the vicinity of Hart and Miller Islands, 1981-1983. Means and 95% confidence intervals are shown in the left-hand column. Means and ranges are shown in the right-hand column.



In addition, we have found that few errors would result if only a single water column sample were taken at a station. Effort might more appropriately be expended in determining spatial and temporal patterns of water quality variables.

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decrease in enrichment factor, common for modern Chesapeake Bay sediments.

Low bioturbation levels were observed in the cores collected spring 1983 and were consistent with those collected during the first year monitoring. However, at the station adjacent to the dike structure, thick accumulation of unbioturbated sediments were noted, a contrast from the more bioturbated sediments observed in fall 1981. Only recent biogenic recolonization and biogenic activity was evident in the upper few cm of the sediments at these sites.

An accurate evaluation of the potential changes in the sedimentary environment requires a point of reference for comparison. Historical information and data have been reviewed and are presented in a historical summary document (Kerhin et al., 1982a). Complementing the historical information is knowledge of the bathymetric configuration of the surrounding area. Bathymetric charts from NOAA provide an information data base, but more recently, in 1981, a bathymetric survey was completed to document the nearshore bathymetry prior to dike construction (Zoltan and Kerhin, 1981).

Monitoring and assessment of the sedimentary environment in the vicinity of Hart-Miller Islands has begun. Interpretation of observations and data collected between August 1981 and August 1982 are presented in an interpretative report (Kerhin et al., 1982b). These data covered the period from which dike construction began to approximately the time of seventy percent completion. The information covered were the physical characteristics and areal distribution of the sediments, trace metals, and physical and biogenic sedimentary structures found in the upper 50 cm of the sediments and pathological conditions of the bivalve *Macoma balthica*.

The second year interpretative report includes data collected from a period between August, 1982 and June, 1983.

METHODOLOGY

Field

Field sampling was conducted five times during the second year of the project: 1) October, 1982, 2) November, 1982, 3) December, 1982, 4) February, 1983, and 5) June, 1983. The November, 1982 sampling represents two cruises which were conducted to determine the thickness and areal extent of the unusually light-colored fluid mud discovered during the first year monitoring. Figure 1 illustrates the sampling locations for the su rficial and gravity core stations.

The sediments were collected using a Van Veen type sampler for the surficial sediments. The cores were collected using a Benthos-type gravity corer (Model #2171) with clear cellulose acetate butyrate (CAB) liners (diameter of 6.3 cm). The Van Veen sampler collected a relatively undisturbed cut of the top 6-8 centimeters of sediments. Once the sediment sample was on board, its physical appearance was described and a subsample for grain size analysis was taken. However, during the November cruises, the surficial samples were collected, their physical appearances noted and then discarded.

The gravity cores were capped immediately after collection, and transported back to the Maryland Geological Survey where they were refrigerated at 4°C until they could be X-rayed.

In May, 1983, cores were collected at the seven box core stations established during the first year monitoring. One sediment core was taken at each station for radiographic analysis, dissection and visual observations, as well as to provide subsamples for sediment textural and trace metal information. The station locations (identified by prefix BC) are shown in Figure 1 and all pertinent field data are presented in the Second Year Data Report.

Brief descriptions and an interpretative summary of the initial sampling are documented in Kerhin and others, 1982b. At that time, a modified spade box corer was utilized to extract a sediment surface of 0.063 cm (21x30 cm) with a maximum penetration of 60 cm. During the later cruise, a Benthos-type gravity corer with an areal surface of $0.0035m^2$ (r=3.35 cm) and maximum depth of penetration of ≈100 cm was employed since the box core sampler was unavailable. Although the box corer yielded a greater cross-sectional sample area, the gravity corer provided a longer sediment record by deeper penetration of the substratum. Only Station BC-5 of the first sampling period, part of a remnant oyster reef, was impenetrable by the gravity corer and was consequently relocated and reclassified to Station BC-5A (Figure 1).

Laboratory

Sediment Analyses

In the laboratory, the subsamples from both the surficial and box core samples were analyzed for water content and sand, silt, and clay percentages. Water content was determined as a percentage of the weight of water to the total wet weight of the sample as expressed by equation 1.

$$Wc = \frac{Ww}{Wt} \times 100 \qquad \text{eq 1}$$

where: Wc = water %
Ww = weight of water
Wt = water and solids total weight.

The weight of the water was determined by drying the sediment at 65°C and recording the dry weight of the sample. The total wet weight minus the dry weight represented the weight of water.

The percentages of sand, silt, and clay were determined using standard sedimentological procedures. Detailed procedures may be found in Kerhin and others (1982b). First, the sediment samples were cleaned with hydrochloric acid to remove carbonates (shell fragments) and hydrogen peroxide to remove organic matter. The cleaned sample was wet sieved through a 62μm sieve to separate the sand from the mud fraction. Silt and clay components were determined by pipette analysis of the mud fraction. The sediments were classified according to Shepard's (1954) classification based on the percentages of sand, silt, and clay (Figure 2).

Radiographic Procedures

The radiographic processing techniques outlined by Howard and Frey (1975) have been applied to the gravity core sections as well as the box core samples. Each core was cut and capped at the original level of the sediment-water interface that was marked at the time of sampling. The original level of this interface is represented by zero depth and measurements are given with respect to this reference point. Many cores underwent some shortening during sampling. Factors contributing to this alteration of the samples include 1) compression of the sample due to progressively increasing sediment accumulation in the coring tube (gravity cores), 2) loss of sample from the core tube (gravity cores), and 3) subsequent radiographic trimming in most cores (box and gravity cores).

A reference line (0°) was scratched along the length of each core tube. This line served to orient the core for xeroradiography and X-ray radiography. The cores were first xeroradiographed at 0° and 90° (from reference line). The cores were later sawed at 0° and 180° (from reference line), the disturbed outer layer of the sediment trimmed and the top cut flat, inverted and emplaced in a 100 cm (l) x 5 cm (w) x 1.5 cm (d) tray (inner diameters), and trimmed again (to 1.5 cm) for X-ray radiograhic analysis. Caps at the surface and at depth held the sample in the shallow tray. This method of cutting the core tube and treating the sample prevents the typical compression of the sediment by the traditional extraction method, namely by forcing the sediment through the tube via a plunger.

<u>Xeroradiography vs. X-ray radiography</u>

Radiography is a general X-ray technique which allows us to readily identify sedimentary structures not discernible in slabbed cores. Variations in the composition of the sediment produce corresponding differences in X-ray attenuation which is then recorded on some hardcopy format. Using the cylindrical gravity cores enables us to make the most of two different techniques: xeroradiography and X-ray radiography. The xeroradiographic process is primarily physical whereas X-ray radiography uses film which responds photochemically.

The essential functional unit of xeroradiography is a reusable photoreceptor plate, consisting of a thin layer of charged photoconductive semiconductor material deposited on a rigid metal backing sheet. When exposed to X-ray energy (or any form of light), the semiconductor material increases its conductivty causing the surface to discharge. The result is that an electric charge pattern, which is representative of the density of the object being exposed, is imprinted upon the plate. The CTR 150 Kv X-ray unit at Johns Hopkins Hospital, Baltimore, Maryland, was used, and the following exposures employed: focal distance, 115 cm; amperage, 90 ma; voltage 50-55 kv; time 4.5 sec. An image of the exposed xeroradiographic plate is produced by a special non-photosensitive powder which is sprayed onto the plate where it is attracted to the charge pattern. The developed image is made permanent by transferring and fixing it to white paper. Hardcopies were obtained from the Xerox 125 Xeroradiographic Conditioner and Processor.

X-ray radiography is a more straightforward process than xeroradiography. Basically, a photosensitive film enclosed in a light proof cassette is X-rayed. Kodak AA-5 industrial X-ray film was available (refer to Bouma, 1969 for advantages) and exposed by a Torr 120 Kv X-ray unit. Only a 1.5 cm deep section (rather than the optimal 2.0 cm) was X-rayed to obtain high resolution of existing sedimentary features because of the limiting volume of material in the gravity core. The

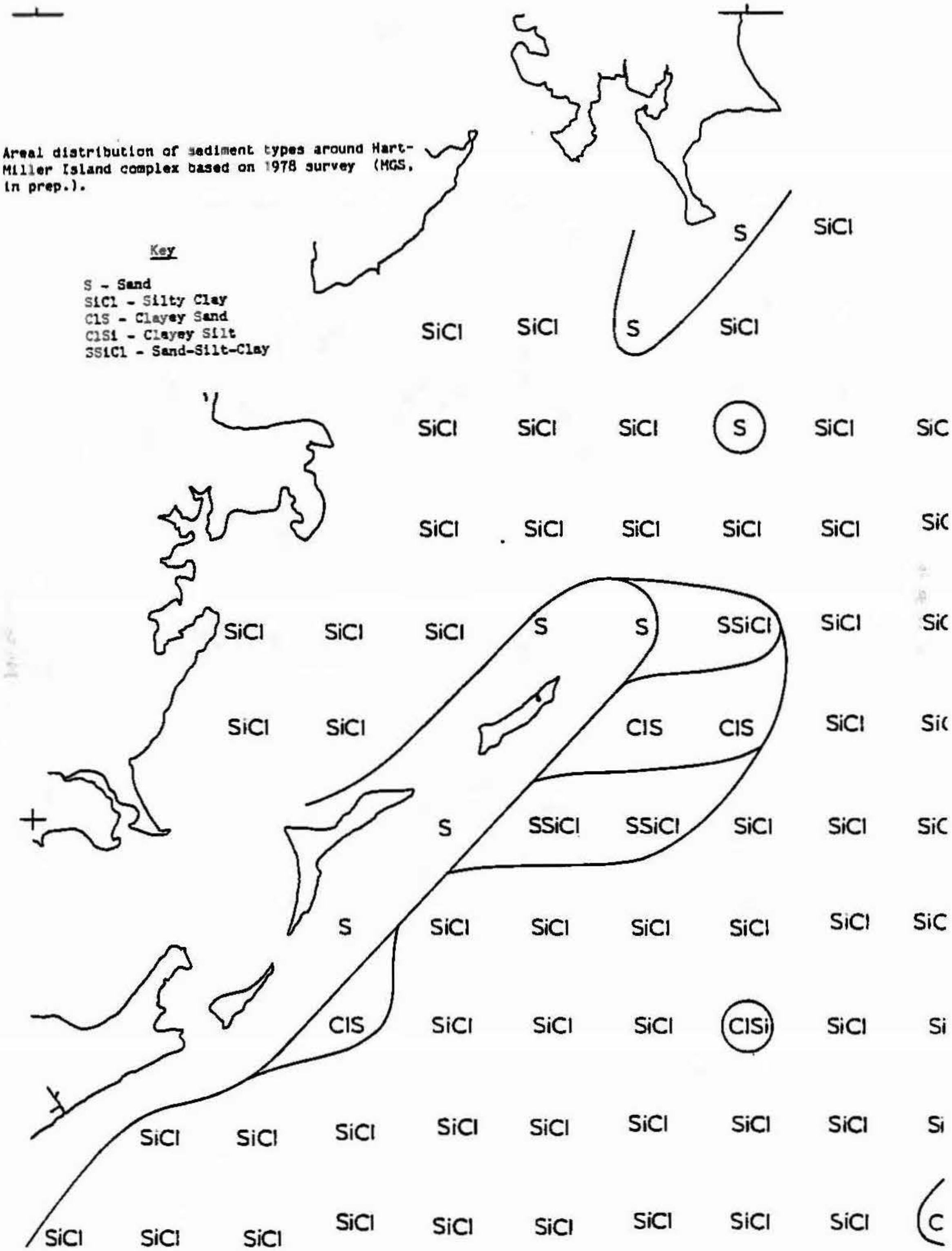

Figure 3 Areal distribution of sediment types around Hart-Miller Island complex based on 1978 survey (MGS, in prep.).

Key

S - Sand
SiCl - Silty Clay
ClS - Clayey Sand
ClSi - Clayey Silt
SSiCl - Sand-Silt-Clay

and containing shell fragments. However, at stations 4 and 5, the July descriptions were that of very fluid, smooth mud, light grey to pink in color and containing no shells. The light grey to pink fine grained material resembled certain Coastal Plain sediments which may have been dredged for dike material. The absence of shell fragments suggested that the sediment had accumulated very rapidly. Also, there was a sudden depletion in the overall percentages of organics and carbonate material in the sediments collected in July. It was concluded that these gross changes in the sediments were related to the dredging activities and dike construction (Kerhin et al., 1982b).

Second year observations (August 1982-May 1983)

October, 1982

Based on the samples collected in October, 1982 cruise, there was little change in the sand, silt, clay percentages of the sediments as compared to the July cruise. Stations 3,. 4, and 5 showed a slight increase in silt. Construction of the dike had progressed to the vicinity near station 4 at this time. Station 21 did exhibit a gross change in sand, silt, clay percentage, changing from clayey silt in July to a silty sand. There is no explanation for this except for the station's close proximity to the dike structure. The light colored fluid muds first noted in July were still noted at stations 4 and 5 and first noted at station 8 (see physical descriptions, October 1982, Wells and Kerhin, 1983b). The areal distribution of the sediment type for October are shown in Figure 5a.

November, 1982

Two sampling cruises were conducted in November to document the areal extent of the light grey to pink fluid muds which had first appeared in July 1982. Over 30 surficial sediment samples were collected at locations other than the 21 established surficial sediment stations (Figure 1). Based on the physical descriptions of these sediments, the areal extent of the light colored fluid muds were found adjacent to the eastern and southern flank of the dike structure extending out to approximately 480 meters just north of station 21, gradually widening to approximately 1 km in the vicinity of station 5 .

In addition to the surficial samples, nine gravity cores were collected to measure the thickness of the fluid muds. Four of the nine cores were immediately extruded and described on board. The descriptions are presented in Table 1. The remaining five cores were brought back to the laboratory, and X-rayed using the xeroradiographic method. Figure 6 shows the locations of the surficial sediment samples and the cores taken and depicts the areal extent of the fluid muds based on the descriptions of the surficial samples.

Information from the gravity cores extruded on board and the five brought back to the laboratory further supported the noted changes in the bayside sediments. Visual examination of the cores revealed several features common to all the cores. The most striking feature was the change in color and texture of the sediments down core. The top sediments were soft light colored whereas the sediments down core agreed with those fine-grained

Core Descriptions

6	Length 72 cm
0-2 cm	Brown, oxidized surface layer
2-14	High water (fluid) light grey mud; no shell fragment of infauna
14-72	Dark grey to black mud; shell fragments; Rangia at 14 cm, burrows throughout
6A	Length 94 cm
0-2 cm	Brown oxidized surface layer
2-19	Light grey mud; very fluid, no shell fragment
19-70	Dark grey to black mud; cohesive, shell fragments, burrow
70-94	Light to dark grey mud; very cohesive, burrows
5	Length 100 cm
0-4 cm	Brown surface layer
4-46	Light grey to tan mud; very fluid, no shell fragment
46-67	Dark grey to black mud; Macoma shells; cohesive
67-100	Light grey to dark grey mud; very cohesive, shells, burrow
5A1	Length 95 cm
0-2 cm	Brown surface layer
2-17	Light grey to tan mud; very fluid, no shell
17-25	Light to dark grey mud; cohesive, mottled, shells
25-95	Dark grey to black mud; cohesive, shells, burrows

Table 1 - Core descriptions (taken on-board, November 1982).

sediments found bayside of Hart-Miller Islands prior to the July, 1982 sampling cruise. Also, in each of the cores, shells (Rangia cuneata) were found several centimeters below the boundary between the two different sediment types. These shelly layers correlated well with the shell layers found in the box cores collected August 1981 and mark the sediment surface before the active dike construction. Based on xeroradiographic interpretations, the thickness of the upper sediments ranged from 10 cm (Station BC-3, Plate 1, Appendix I) to 38 cm (Station #5, Plate II, Appendix I).

Xeroradiographic observations revealed well developed laminations which were found exclusively in the upper portion of the cores (i.e. the most recently deposited sediments). These laminations are interpreted as subtle textural variation in the sediments as a result of settling and reworking under the influence of tidal cycles. Such sedimentary structures are indicative of events in which anomalously high concentrations of suspended sediments existed (Zabawa and Schubel, 1974). In this case, the increased sediments load was certain to be from material resuspended during the dike construction, as indicated by the conspicuous difference in color between the overlying and down core sediments. Visual examination of this upper sediment layer revealed bands or streaks of different colored sediments, ranging from brown to red to grey muds. This "banding" was particularly noticeable at Stations 8 and 21 (see Appendix I, Plates IV and V). These variations in color may not represent the same structural features as seen by the laminations in the xeroradiographs, but rather reflect color changes in the material introduced from dike construction. In a letter from Mr. Holback (pers. comm.) to the Director of Maryland Environmental Services, Mr. Holback included a condensation of dredge discharge records (Table 2), which report, for a two week period in June, 1982, the changes in color and texture of the material being pumped into place on the dike. From this record it can be seen that the discharge material contained silts and clays, the colors of which correspond to those found in the gravity cores.

In the same communication, boring logs of cores taken along the southwestern dike wall were included (Table 3). These logs show that only relatively small amounts of silt and clay were found in the dike, suggesting that much of the fine material introduced in dike construction did not stay on the dike but was "washed out" and resuspended during placement. This information along with the reported accidents in which dredge material was pumped outside the proposed diked area between dike stations 184 and 190 and between 221 and 225 (Figure 7) explains the origin of the relatively thick layer of light colored sediments noted in the surficial samples and gravity cores.

The gravity cores taken on the bayside of Hart and Miller Islands provide a visual record of the very recent sedimentological history of the area. The co res reveal that a considerably thick layer (up to 38 cm) of sediments not characteristic of sediments previously found in the Hart-Miller Islands area has accumulated since the construction of the dike began, and most probably since March, 1982. Volumetrically, 490,000 cubic meters of fine-grained,

Table 3 - Log reports for dike borings (D-83, D-89, D-54, D-93, D-96, D-104) (Holback, pers comm.).

Thickness in feet	Lithology
D-83 Elevation at +20 mlw Station 107+00	
0-2	Loose red-brown, coarse to fine sand, trace clay
2-6	Medium dense, red-brown sand, trace gravel and clay
6-9.5	Medium dense, tan fine sand with little clay
9.5-17	Medium dense, light brown coarse to fine sand, gravel, trace clay
17-22	Medium dense, brown wet coarse to fine sand, gravel, trace clay
22-30	Medium dense, brown wet coarse to fine sand, gravel, trace red clay
30-42.5	Wet medium dense fine sand
D-89 Elevation at +20 mlw Station 182+00	
0-5	Loose tan fine sand
5-11	Dense clay to fine sand with brown silt
11-13	Wet grey silty fine sand
13-18	Medium dense tan coarse to fine sand, gravel, trace white clay
18-22	Wet dense, tan mostly fine sand, trace gravel
22-43	Wet dense, tan/grey coarse to fine sand, trace gravel
43-44.5	Very stiff grey fine sandy silt
D-54 Elevation at +20 mlw Station 191+00	
0-13	Tan coarse to medium sand with gravel
13-18	Tan coarse to medium sand with gravel and clay; water encountered at 16
18-23	Light tan coarse to medium sand
23-27	Tan-white ;coarse to medium sand with clay
27-31	Grey medium sand with silt
31-39	Medium to fine grey sand with trace silt
D-93 Elevation at +20 mlw Station 202+00	
0-5	Moist loose brown fine sand, trace gravel and silt
5-7	Loose brown coarse to fine sand and gravel
7-12	Dense white, grey and brown fine sand, trace silt
12-15	Dense, multi-colored coarse to fine sand and gravel, trace silt
15-19	Same as 12-15 with trace white clay; water encountered at 18
19-26	Wet tan dense fine sand
26-30	Same as 19-26 but loose
30-37	Same as 19-26 but medium dense
37-38	Same as 19-26 but trace silt, shells
38-41	Very loose tan fine sand, very soft grey clayey silt

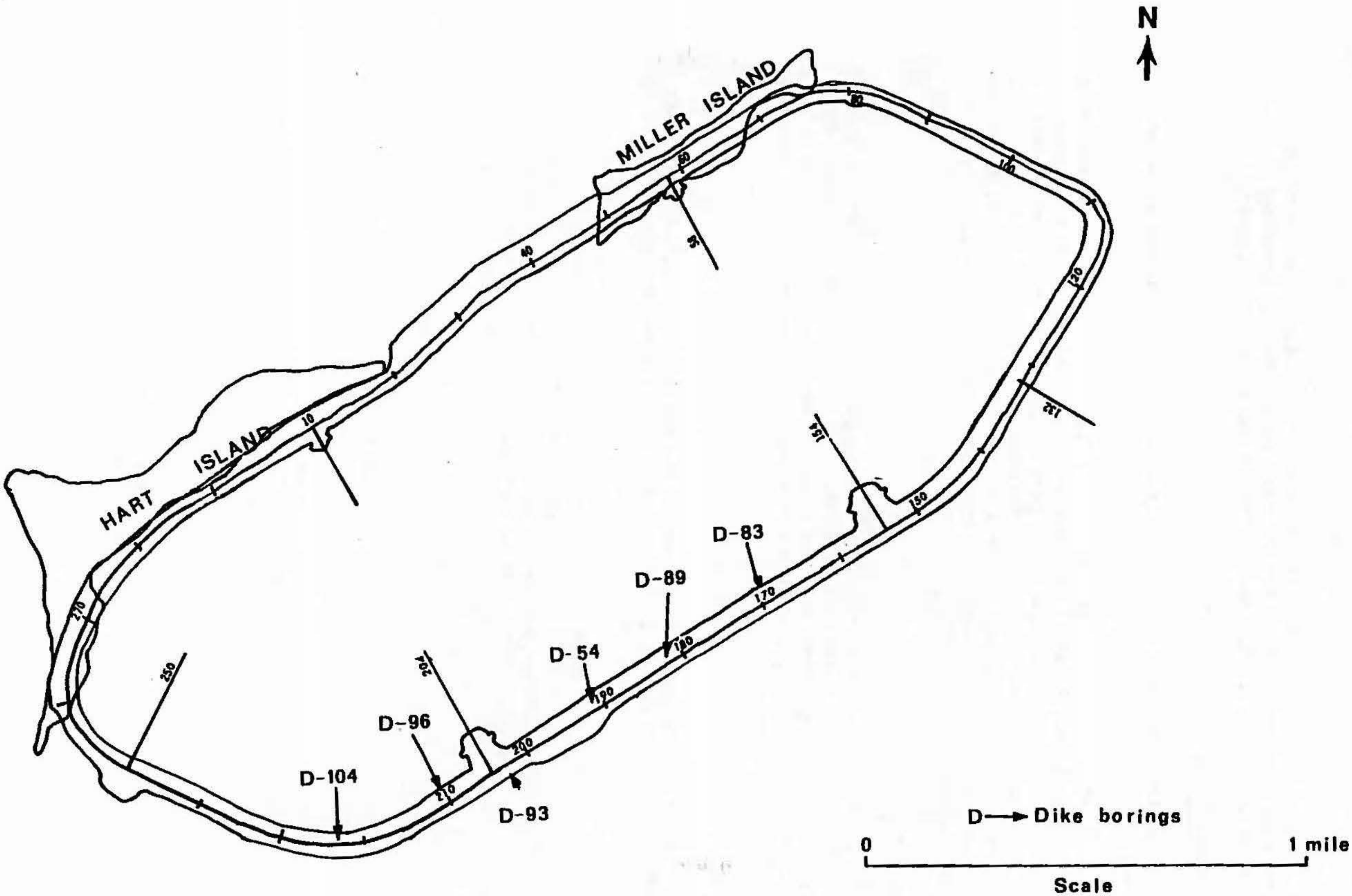

Figure 7 Dike template showing locations of dike borings and dike wall stations.

considerable variance between the methods employed. Another problem encountered in using raw concentration data is the association of the trace elements with the sediment. Trace elements are generally associated with fine grain sediments and organic material. Variations in bulk sediment analyses may simply reflect fundamental variations in chemical environments or the influences of man. The use of enrichment factors can be used to circumvent these problems by removing the influence of sediment grain size and organic matter (Zoller et al., 1974; Sinex and Helz, 1981).

An enrichment factor (EF) is a ratio of a trace element to an element whose source can be considered solely a result of normal weathering processes. This ratio is in turn normalized to the same ratio calculated from a standard material. The elements generally on which enrichment factors are based are iron (Fe) and aluminum (Al). The standards used for normalization are either an average crustal abundance of the elements or an average shale composition. In this report the enrichment factors are based on Fe and are normalized to an average shale (Turekian and Wedepohl, 1961). Thus, the enrichment factors are calculated as:

$$EF_{Fe}(X)shale = \frac{(X/Fe)sample}{(X/Fe)shale}$$

where: x is the element of interest;
(X/Fe)sample is the analytically determined ratio of X's concentration to Fe concentration (both expressed as dry weight of sample);
(X/Fe)shale is the ratio of X to Fe in the average shale of Turekian and Wedepohl (1961).

An enrichment factor of one indicates no enrichment over the average shale values. Values which differ from one may be explained by a variety of hypotheses, but the more important aspect of the values is that they are a relative indicator referenced to a known fixed material. This may show artificial variations, due to sediment type, or reflect differences in methodologies, not in the nature of the sediment. This approach is particularly useful in examining spatial distribution of elements in the sediment.

Table 4 lists the average enrichment factors for Ni, Zn, Cd, Cr, Cu, and Pb for samples from the 1981 and 1983 studies. Comparisons of the two studies show lower enrichment factors for Ni, Zn, Cr, and Pb with elevated enrichment factors for Cd and Cu. Except for Pb, the enrichment factors are in closer agreement to the main Bay enrichment factors for the same metals as reported by Helz and others (1982).

Table 5. Enrichment Factors for Zn, 1981 and 1983 Studies

Station	Enrichment Factors $EF_{Fe}Zn$ 1981	1983
1	2.94	3.84
2	3.50	3.10
3	4.20	3.19
4	-	3.72
5	2.95	3.63
6	3.28	3.34
7	4.01	2.78
8	7.32	1.53
9	5.90	2.60
10	3.22	3.10
11	1.56	3.29
12	3.22	-
13	4.01	1.47
14	4.31	1.77
15	2.83	3.30
16	3.34	3.73
17	3.59	-
18	3.23	2.62
19	3.96	5.00
20	4.81	4.92
BC-1	4.99	1.80
BC-2	3.63	4.73
BC-3	3.35	1.60
BC-4	3.97	7.16
BC-5	2.56	3.43
BC-6	3.46	5.14
BC-7	5.99	5.14

Table 6: Classification of sedimentary structures found(or *expected to be found) in the Hart-Miller Islands area.

General Physical Structures

Type	Description	Mode of Origin
Lamina	Stratified formation ∠1 cm deep.	Laminae are generally the result of differential settling rates of various sediment types to the depositional basin. The most common cause of laminations in silt-clay deposits is due to alternating flocculated (random orientation of particles) and non-flocculated (parallel orientation of particles) layers. This layering is primarily controlled by the following conditions (Coleman, 1966): (a) rapidly changing pH; (b) types of cations present; and/or, (c) variations in sediment concentration.
Bed	Stratified formation ≥1 cm deep.	Bed formation are typically a consequence of the following events: (a) high sediment concentrations; (b) rapid deposition from suspension; (c) lack of a tractional phase during deposition; (d) extensive bioturbation (Blatt et al., 1972); and/or, (e) turbulence at the sediment-water interface (Krinitsky, 1970).
*Parallel laminations or bedding	Alternating layers of differing composition, textures, and colors where upper and lower contacts of layers are flat.	Parallel layering characteristically form because of (a) sediment movement by traction, indicating a transition between various energy regimes, or (b) settling of sediment from suspension during low energy conditions. Changes in current or tidal velocities produce textural variations whereas changes in water chemistry produce color changes.
Wavy laminations or bedding	Alternating layers of differing composition, texture, or color where upper and lower contacts are wavy.	Wavy layering forms under similar conditions as parallel layering but may be related to minor irregularities on the depositional surface. This structure is the most abundant in muddy, low energy environments.

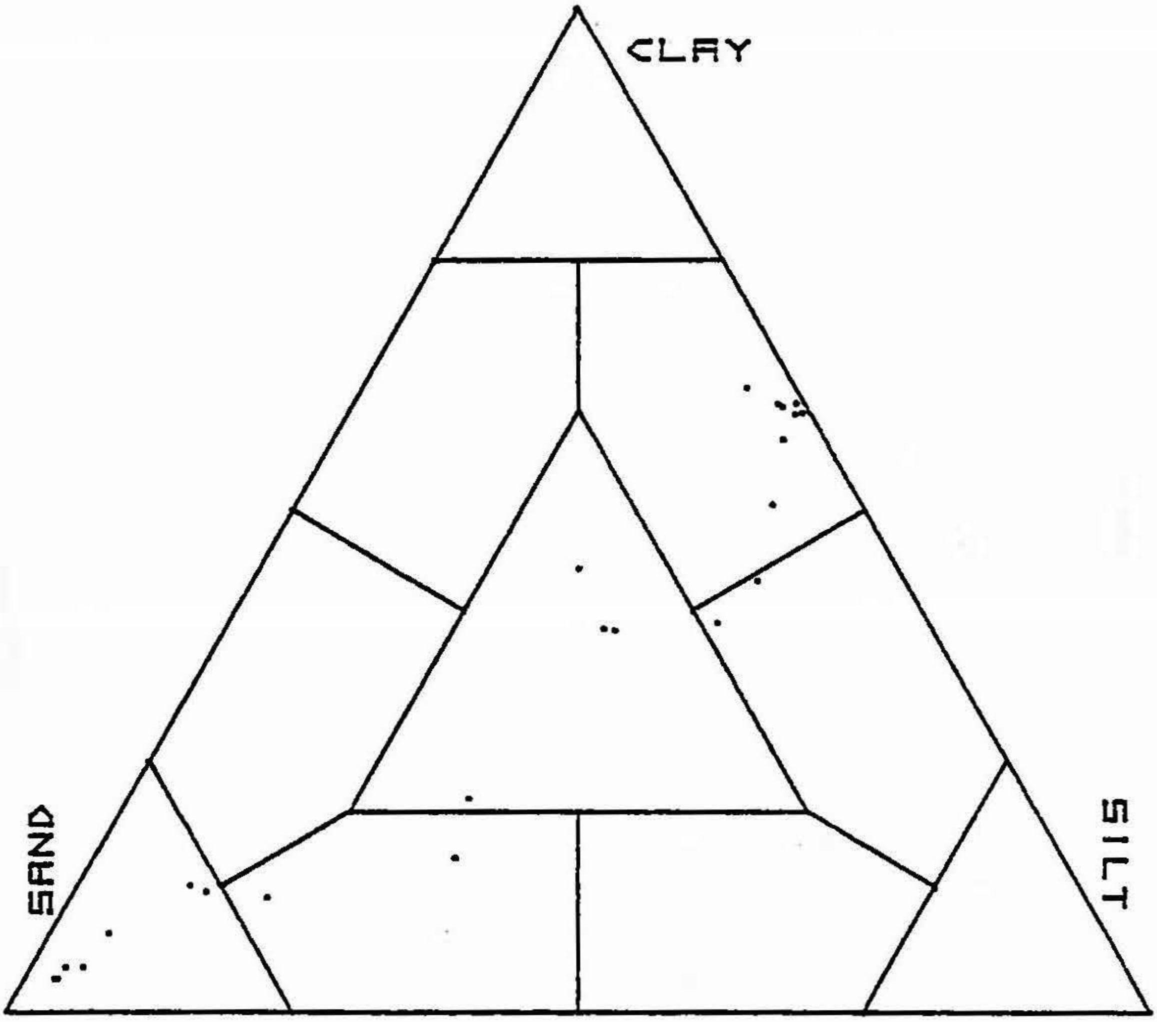

Figure 10

Tertiary plot of surficial sediment samples collected February 24, 1982.

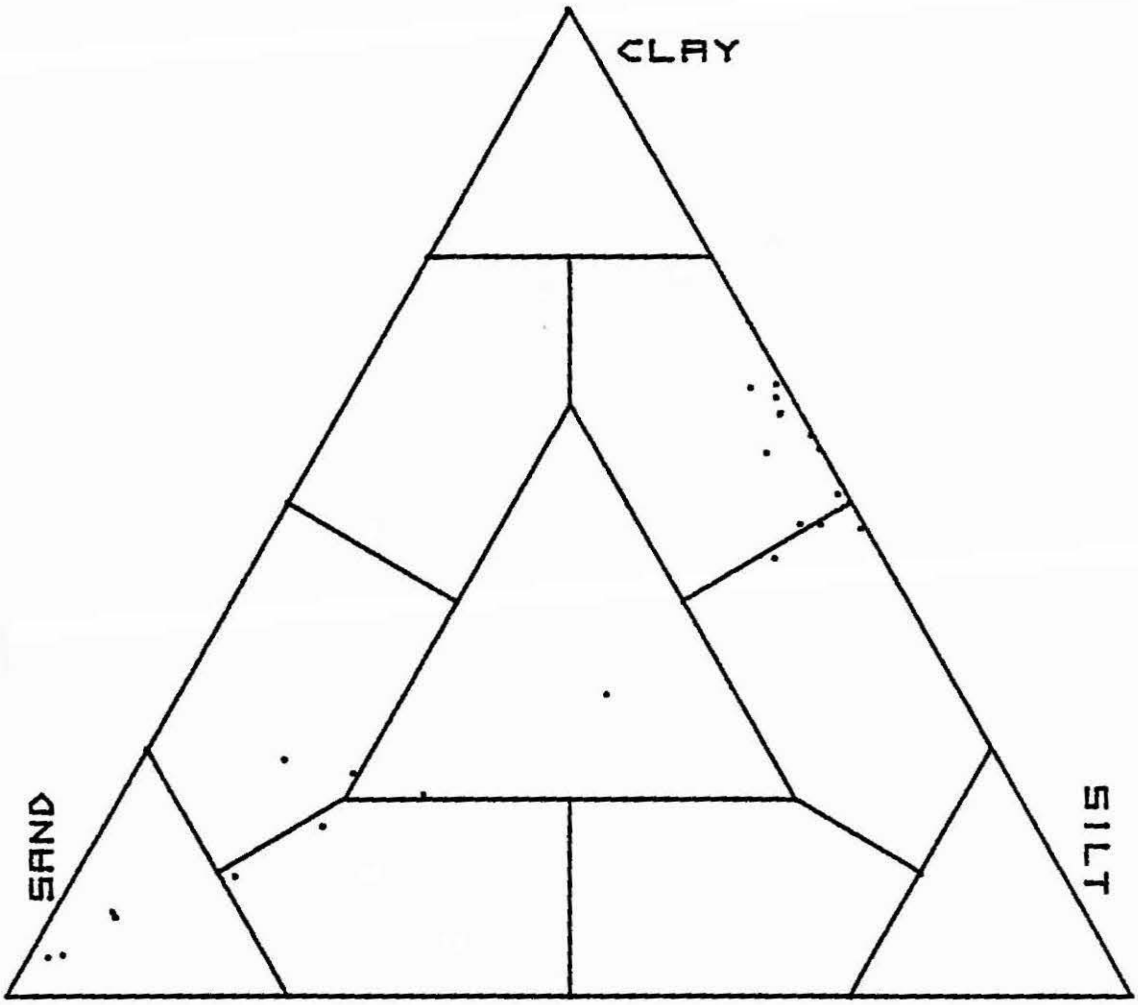

Figure 12

Tertiary plot of surficial sediment samples collected October 6, 1982.

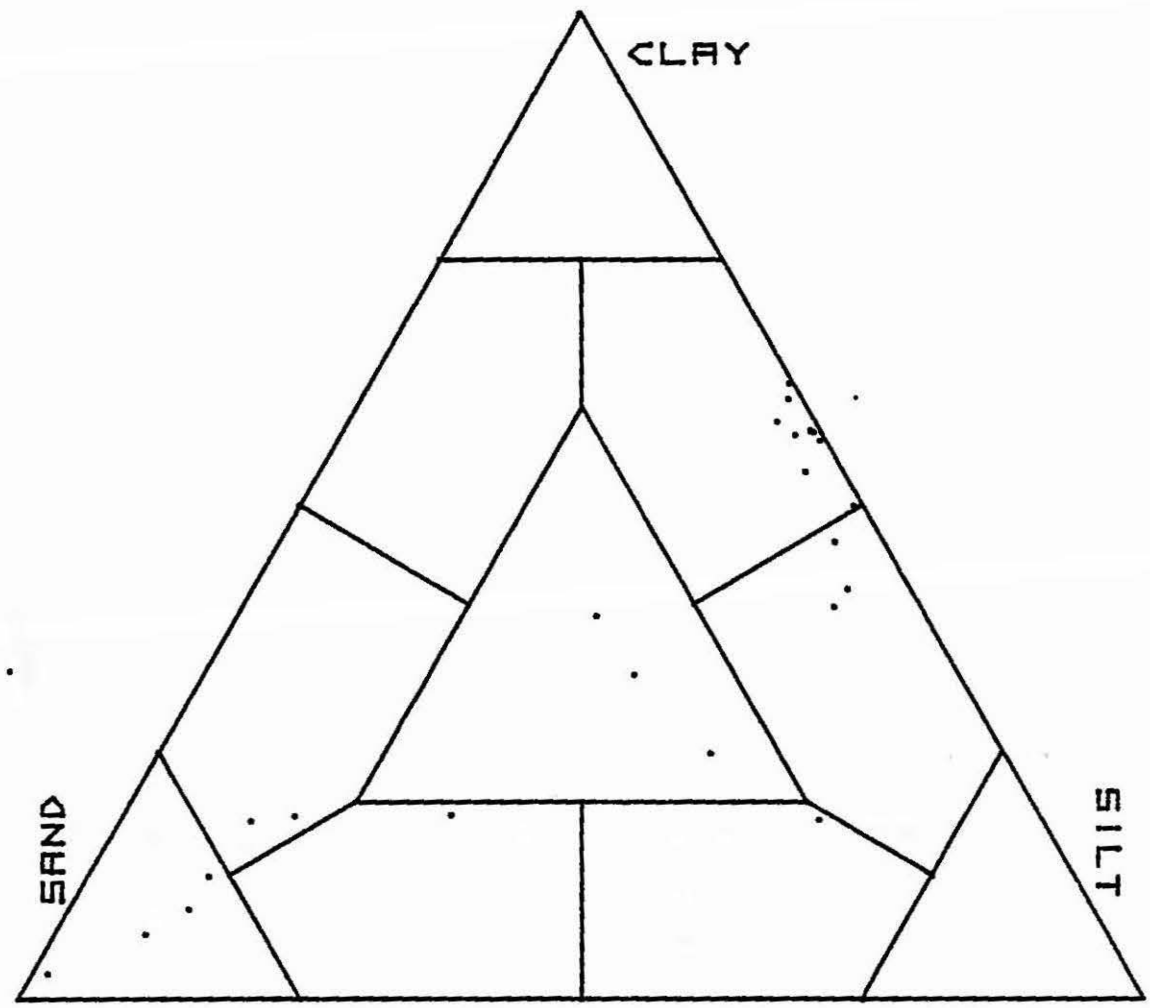

Figure 14

Tertiary plot of surficial sediment samples collected February 24, 1983.

reported accidents in which dredge material was pumped outside the proposed diked area between stations 6 and 4 explain the origin (Wells and Kerhin, 1983a). Based on thicknesses revealed in the gravity cores and areal extent determined by the surficial sediments, it has been estimated that approximately 490,000 cubic meters of the fluid light grey to pink mud have accumulated offshore of the dike structure since Spring 1982.

After the completion of the dike structure, continued monitoring revealed little change in the characteristics of the sediments. In addition, there appeared to be no reversal of the trends observed in the first year monitoring. Whether or not the sediment environment "recovers" from the effects of the dike construction remains to be seen. As seen from the gravity cores collected in November and May, 1983, the newly deposited sediments are relatively clean of shells and organics and they remain so after the end of construction (Figures 16a, b, c, d).

Physical and Biogenic Sedimentary Structures

Generally, higher biotic reworking of the sediments conveys increased biogenic diversity in most areas of the Chesapeake Bay (Nilsen et al., 1981; Reinharz and O'Connell, 1981; Diaz and Schaffner, 1982; Reinharz et al., 1982; Reinharz, 1983). Identifying types of organisms by their imprints is extremely difficult because of the continued reworking of the substratum by benthic individuals. However, bioturbation in the Hart-Miller area can be attributed to the amount of time available for biogenic activity per unit of sediment deposition rather than the result of high species densities. The biotic patterns in the region supports this model (Allison and Butler, 1981; Pfitzenmeyer et al., 1982). Such observations are common in protected vicinities where reworking of the bottom sediments far exceeds the incorporation of new material.

Although much of the substratum at the Hart and Miller Islands area is highly reworked, most of the organisms do not move extensively throughout the sediment matrix. Instead, many organisms secure themselves at or near the sediment-water interface. The bottom is highly anoxic, making the organisms dependent on overlying waters for respiration as well as food. Even the few deep dwelling species are somehow related to the sediment surface by a form of permanent structure. The resulting sediment fabric is a complex geometry of biogenic traces. Although biological activity is high at the remnant oyster reef, northeast of Miller Island, such a shell matrix precludes any potential imprints by the existing biota. At the Back River-Hawk Cove area, there are relatively few benthic traces, indicating an unstable, highly fluid and periodically anoxic environment.

Anthropogenic effects

Abrupt boundaries as well as animal traces can serve as markers in determining potential future sedimentary successions. The former indicator, although helpful, is not very reliable since natural phenomena (i.e. - storms) and anthropogenic activities (i.e. - dredging and spoil disposal) may create similarly marked boundaries. Biogenic traces can be of stratigraphic value only if they are widely distributed and leave a record of their activity within the sedimentary framework. The structures of certain soft-bodied benthic species have been used to characterize certain environments (Howard and Frey, 1972 & 1975). These biotic traces were not used in the analysis of this study because of the post-depositional deformation and destruction of such features. The skeletal remains of the bivalve mollusc, Rangia cuneata, meet the above criteria and proved especially useful in delineating short-range correlations for depositional episodes.

Comparative time analysis at stations relatively remote from the Hart and Miller Islands complex revealed minimal amounts of natural sediment accumulation above the Rangia shell layer, supporting the notion of a low energy regime. However, stations close to dike construction at the islands contained heavy accumulations (≥30 cm) of sediment (Stations BC-1 and BC-3). The physical structures, textures and coloration at these sites point to an anthropogenic origin. Two distinct distorted bedding sequences are found here which suggest variable but fast deposition of the material. The breaks in time are recorded by bedding planes. Rapid deposition of sediments may form two structural types: 1. an unbioturbated homogenous bed arising to a high rate of deposition in which the sediment accumulates too fast to be sorted out (Station BC-1), or 2. alternating layers of different sizes or variable oriented textures and colors as a consequence of changing physical or chemical conditions (Station BC-3). The second structural type is correlated specifically with the wash-out and resuspension of highly concentrated dredged material in the water column (Holback, pers. comm.; Keefe, pers. comm.), which later settled on the bottom. The lack of bioturbation in these distorted beds strongly indicates that such intense deposition occurred in a short period of time, possibly within 2 to 4 weeks. Only recent biogenic recolonization and biogenic activity is evidenced in the upper few cm of the sediment at these sites.

Potential effects of dredging and dike construction on the biota

The environmental effects of dredging for dike construction and potential disposal activities on the biota of the Hart and Miller Islands are not yet completely understood because of the many physical and chemical variables involved. Nevertheless, the major factor in dredging operations always focuses on the composition and constitution of the biological community, including the resistance and resilience of its individual members to such stressful events. Three consequences of dredging must be considered: 1. physical disruption of the bottom environment, 2. generation of suspended sediments, and 3. contaminant load of sediments and their effective redistribution.

The physical disturbance of the bottom environment in the Hart-Miller complex area can have immediate or long-term effects on the benthic realm. Direct outcomes involve both the removal and burial of established habitats and their populations. Long-term effects involve the recovery (resistance and resilience aspects) of the biotic community. Recently deposited sediment creates a new environment that may or may not resemble the original substratum. The bottom plume resulting from the Hart-Miller Islands dike construction is considerably different from the natural sediment and may be of enduring significance in this low energy regime where such mounds persist.

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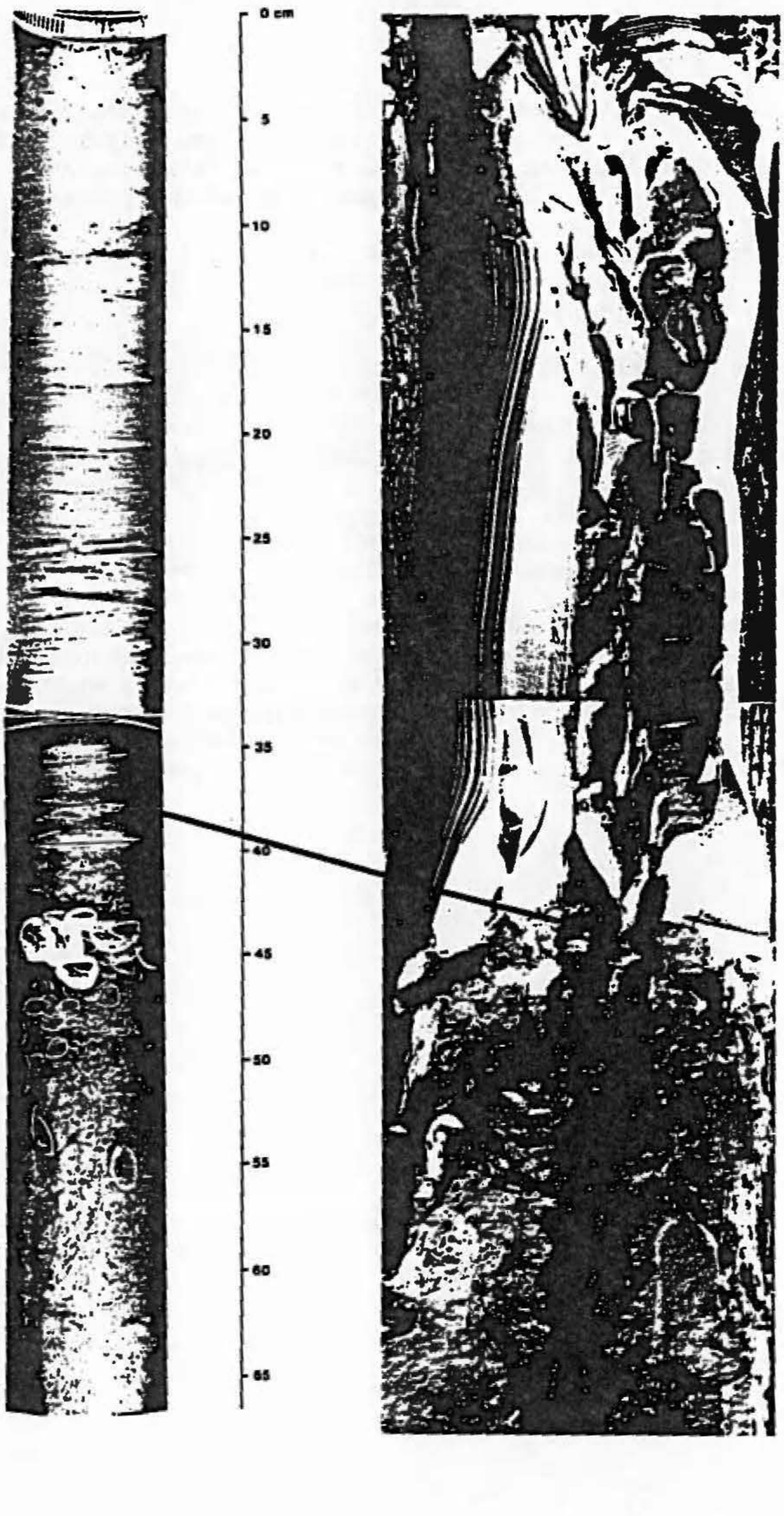

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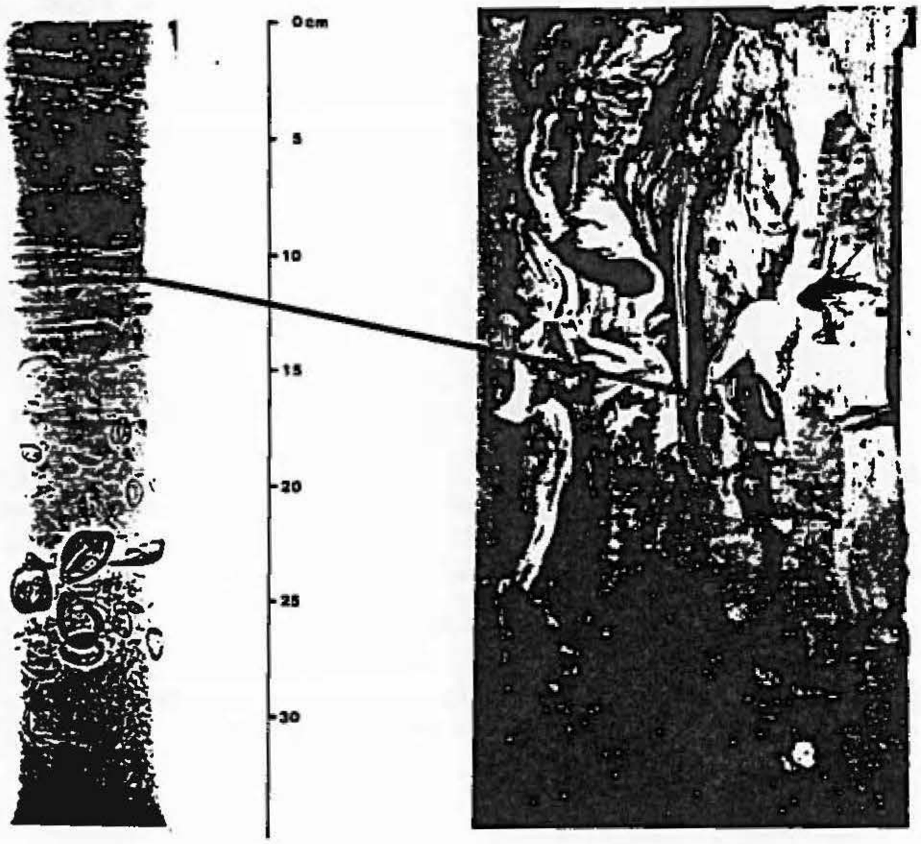

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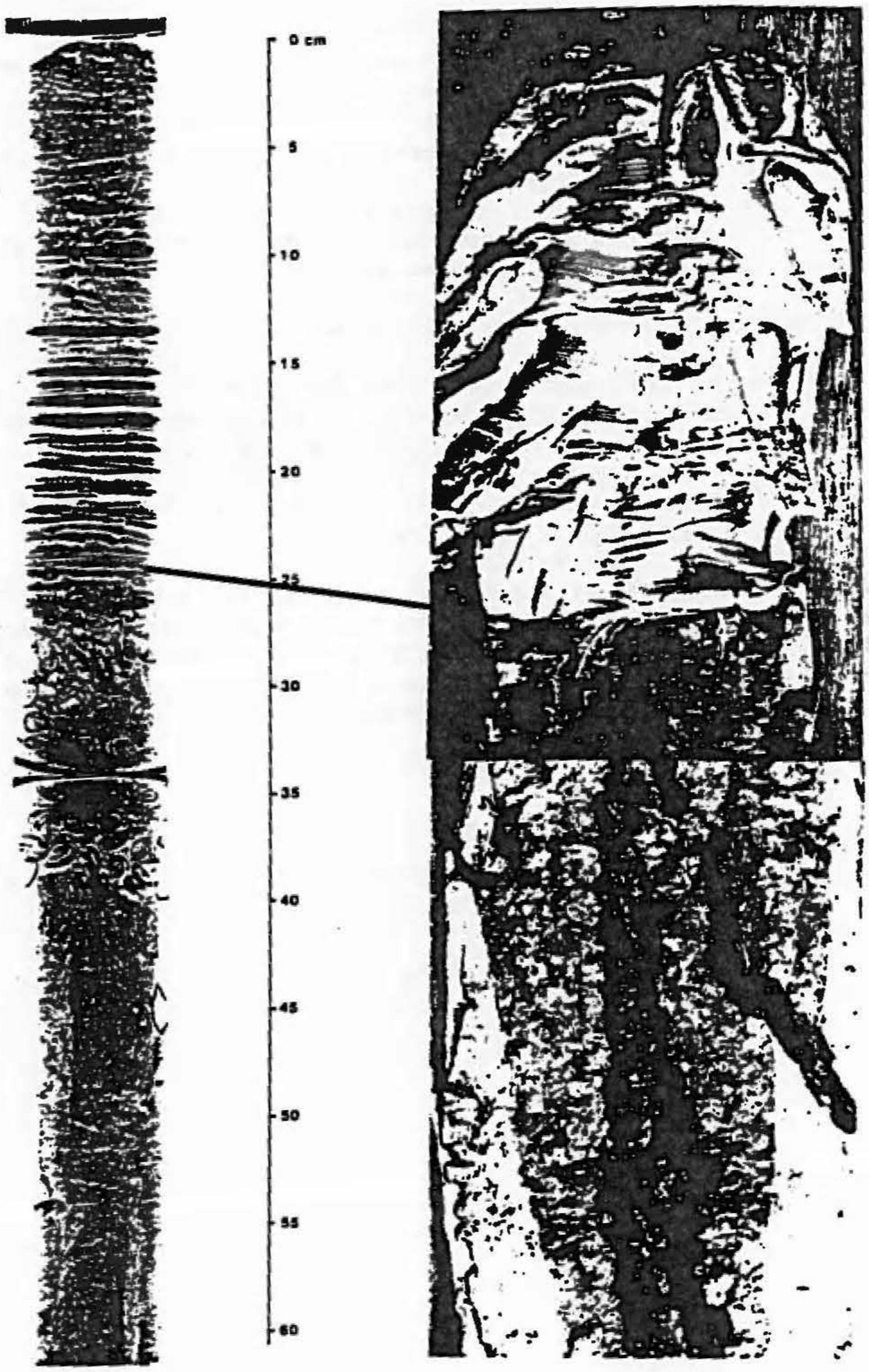

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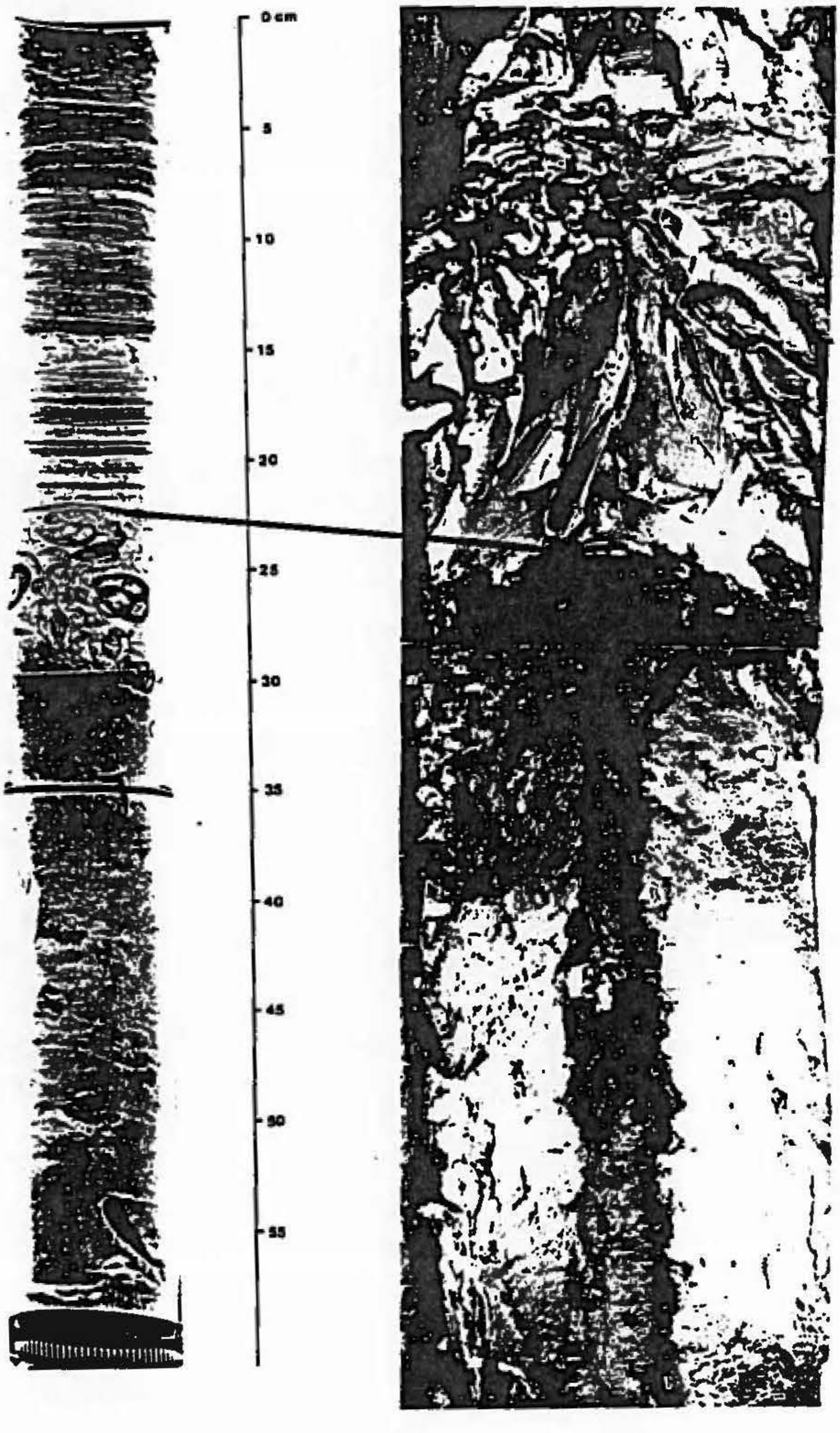
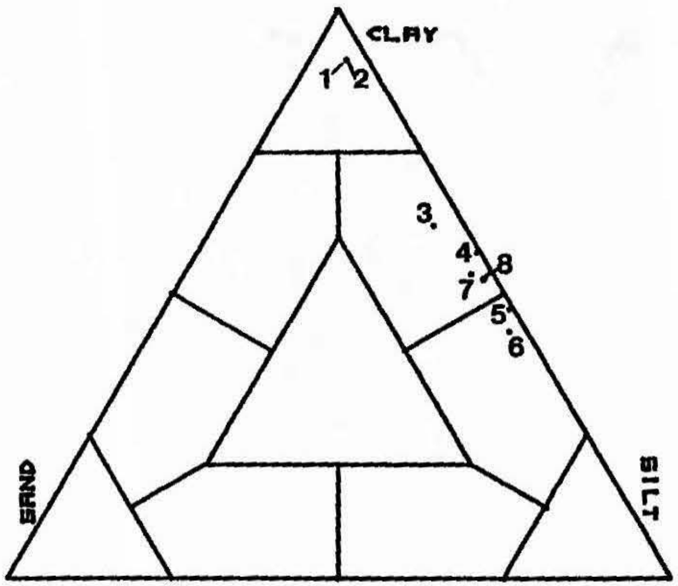


APPENDIX II

Tertiary Plots of the Sand-Silt-Clay percentage at each sampling station.

The plots are labeled as follows:

Number	Sampling Date
1	August 27, 1981
2	December 2, 1981
3	February 24, 1982
4	July 2, 1982
5	October 6, 1982
6	December 7, 1982
7	February 24, 1983
8	June 2, 1983



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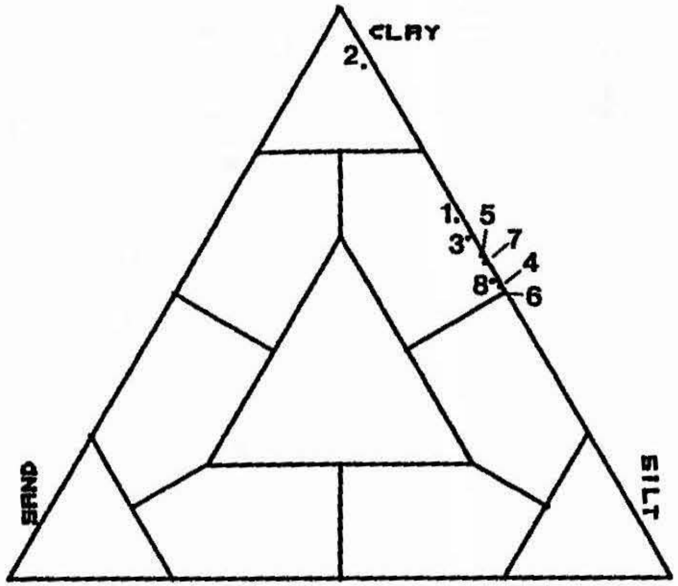

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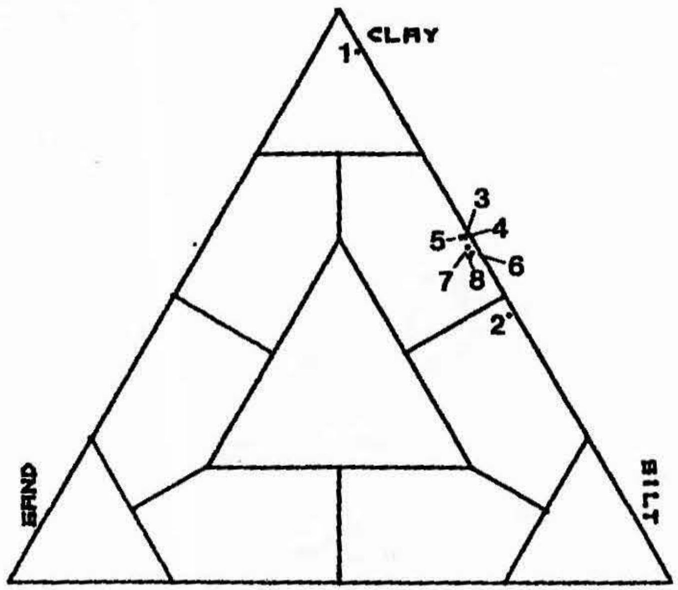

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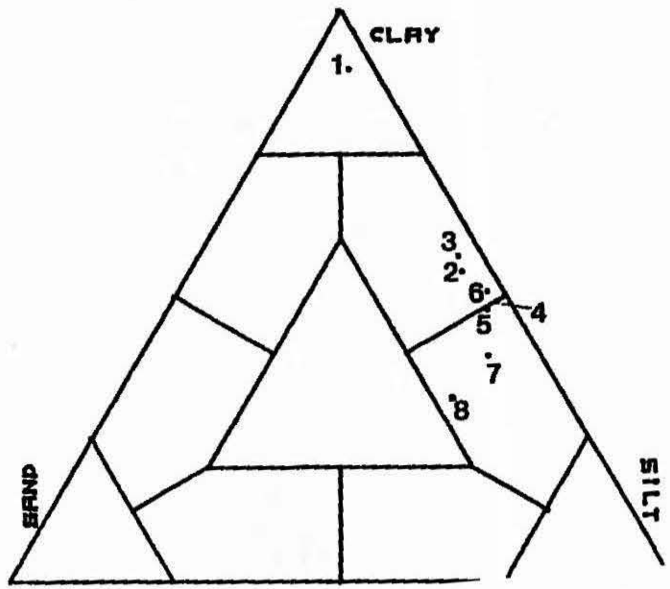

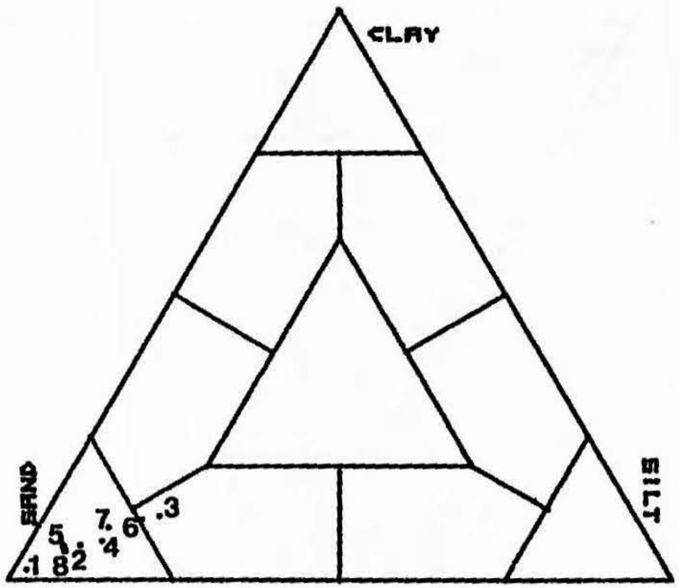

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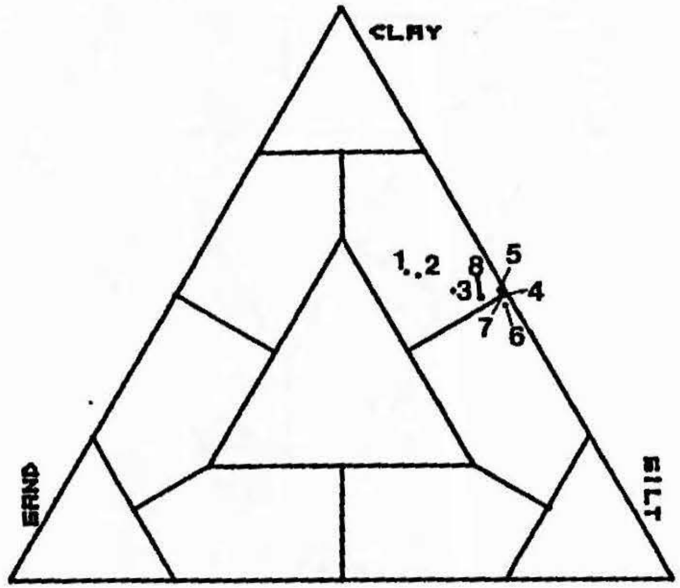

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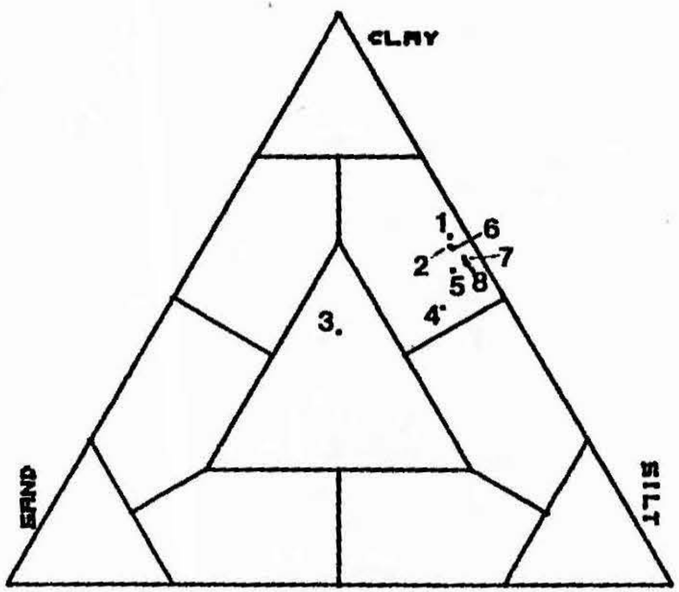

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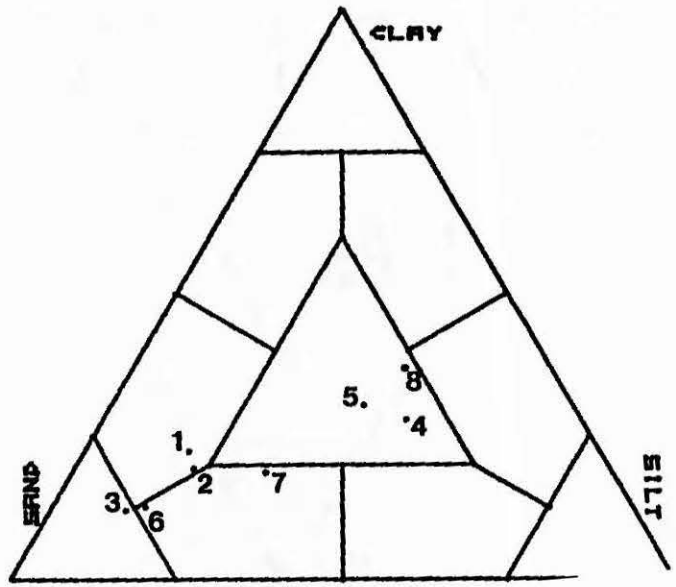

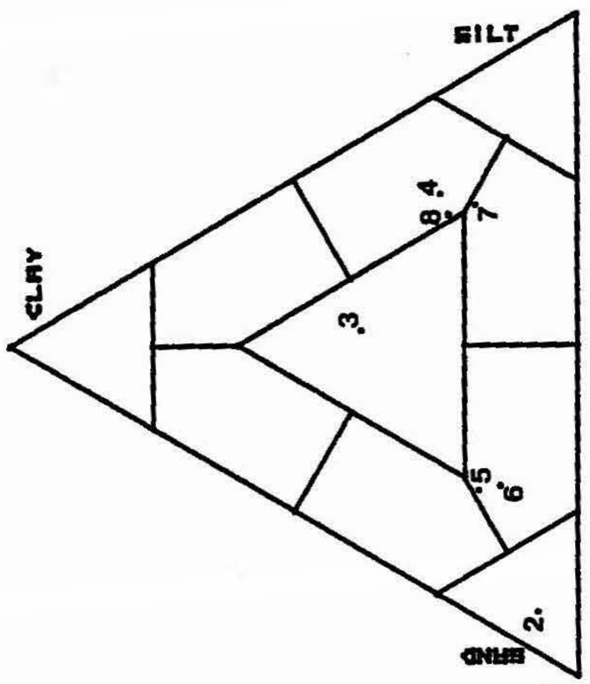

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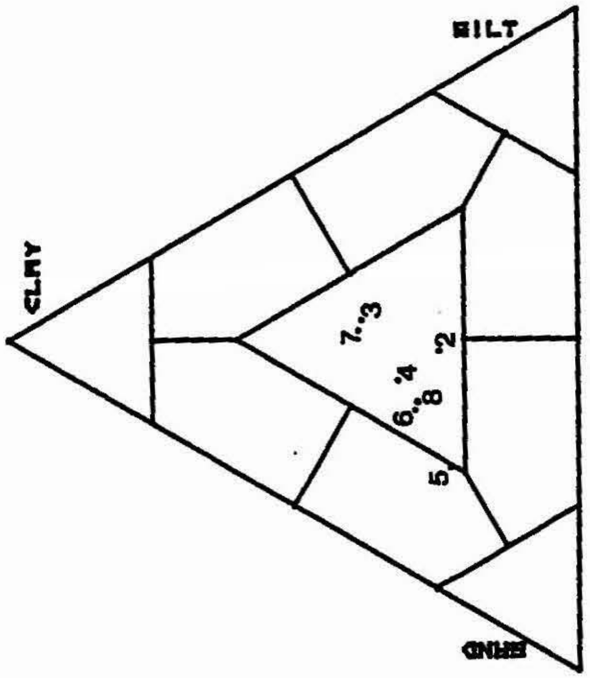

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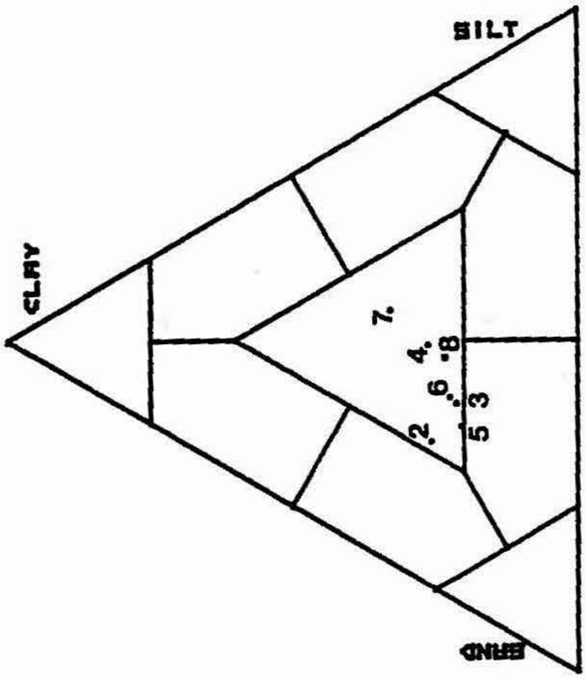


Sta. 23

2. Station BC-2 (Appendix III, Plates 3 & 4; Appendix IV, Graphs 3 & 4)

Several distinctive shell strata, differentiated principally by their size classifications, are found here. Some of the surface shell layering in the gravity core was inadvertantly cut off during X-ray radiographic processing. Both cores demonstrate similar textural and coloration properties. Highly bioturbated mottled bedding characterizes this area. Evidence of wavy lamination and diffuse wavy bedding is also present. Clay and shell inclusions are found at depth.

3. Station BC-3 (Appendix III, Plates 5 & 6; Appendix IV, Graphs 5 & 6)

The distinctive layer shell pattern evident at Station BC-2 is also apparent at this site. The shell layering is manifested more clearly in the box core X-ray radiograph, showing minimal sediment accumulation above the shell zone. The gravity corer seems to have penetrated a non-shell crevice and the sample reveals some physical disruption created by an apparent episodic event (marked by the abrupt contact at ≈36 cm). Highly bioturbated, mottled bedding prevails below the abrupt contact, but becomes more honest with depth (refer to Plate 6, Graph 6). A wavy bed is also evident in the lower sediment stratum of the gravity core. Both box and gravity cores demonstrate similar color and only slightly dissimilar textural characteristics below the original horizons, indicating the natural sediment fabric.

The upper 36 cm of the gravity core (Plate 6, Graph 6) contains new, relatively non-bioturbated, fluid, distorted laminations (0-26 cm) overlying a more compact, physically distorted bed (26-36 cm). Color and textural patterns are distinctly different from the natural sediments, suggesting an anthropogenic source as in Station BC-1. Lamina in the upper 4 cm of the sediment are less distinct due to recent biogenic activity.

4. Station BC-4 (Appendix III, Plates 7 & 8; Appendix IV, Graphs 7 & 8)

Comparative analysis between the box and gravity core samples at this locality reveals slight sediment accumulation above the Rangia cuneata shell layer over time. The radiographs of both cores demonstrate mottled bedding, showing a tendency to become homogenous at depth (refer to Plate 8, Graph 8). Clay and shell inclusions are sparse. The xeroradiograph also manifests some gas production at the bottom 10 cm of the sediment, however this phenomenon is not apparent in the X-ray radiograph of the gravity core.

5. Station BC-5 (Appendix III, Plate 9; Appendix IV, Graph 9)

This area represents a remnant Crassostrea virginica oyster reef assemblage. No subsequent gravity core was taken here because of the impenetrable substratum. Some shells of Rangia cuneata were present at the surface whereas shells of Macoma balthica were strewn throughout the shell matrix.

6. Station 5A (Appendix III, P late 10; Appendix IV, Graph 10)

The sedimentary sequence at this location changes from a fluid (0-12 cm) to more cohesive zones (>12 cm). Some sediment accumulation is evident above the Rangia cuneata shell layer. The mottled bedding throughout the core is the result of moderately high bioturbation activities and heavy contribution of organic detrital material, especially in the upper sediment stratum. A diffuse section of a wavy bed in the X-ray radiograph is more clearly evident in the xeroradiograph. Random shell inclusions are apparent at depth.

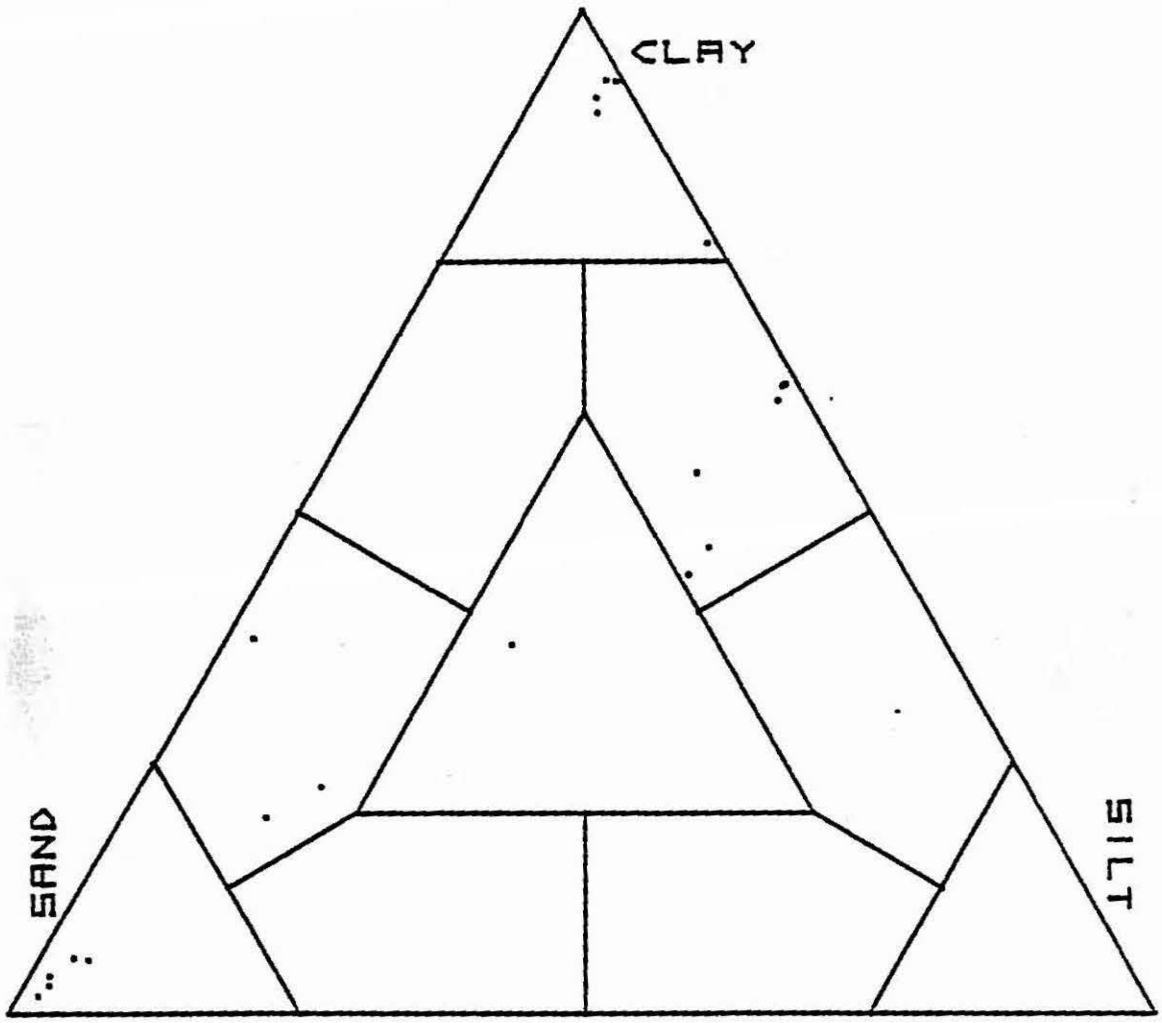


Figure 8

Tertiary plot of surficial samples collected during the first quarter (August 27, 1981), prior to the onset of dike construction.

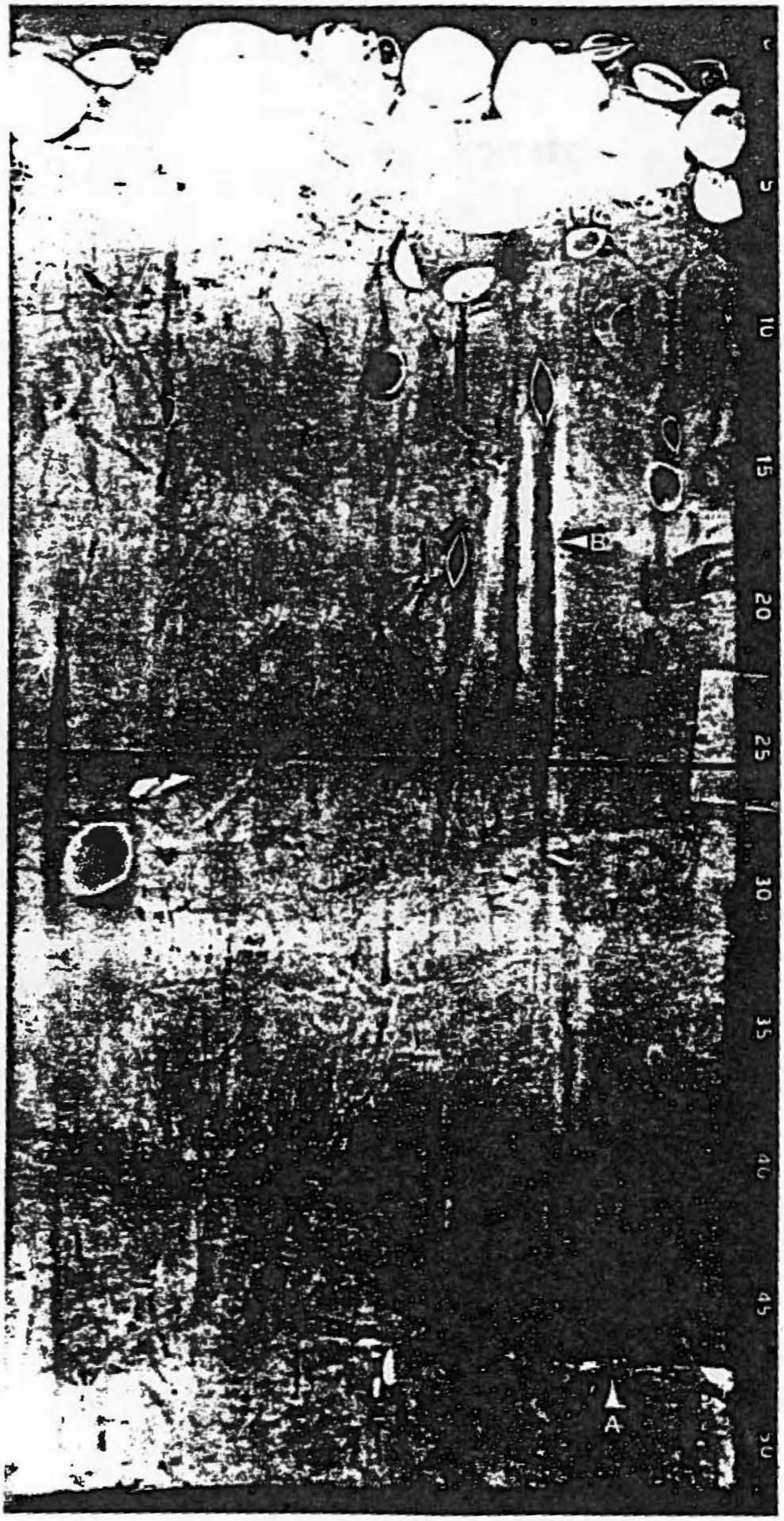


Plate 1

STATION BC-1

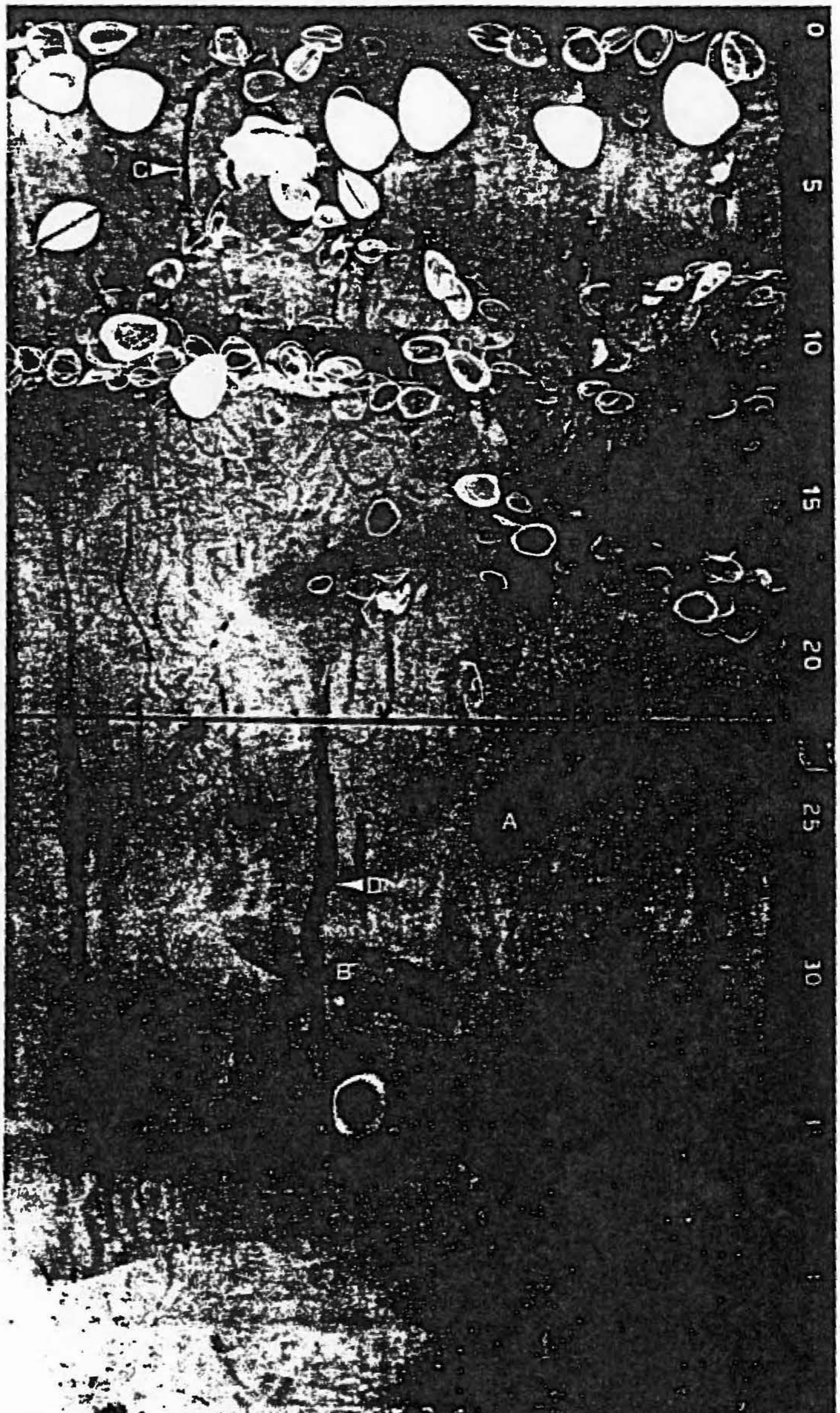


Plate 3

STATION BC-

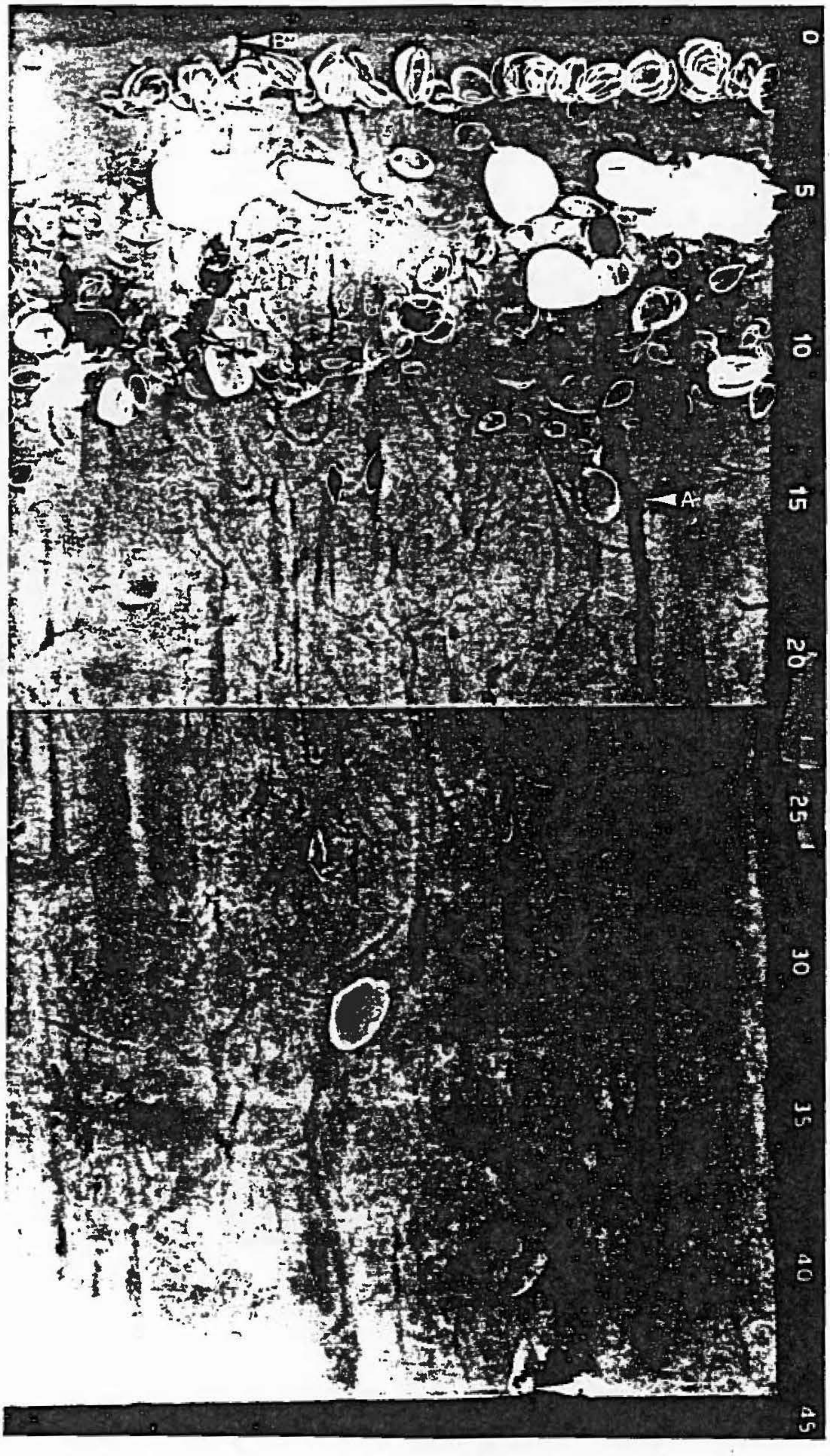


Plate 5

STATION BC-3

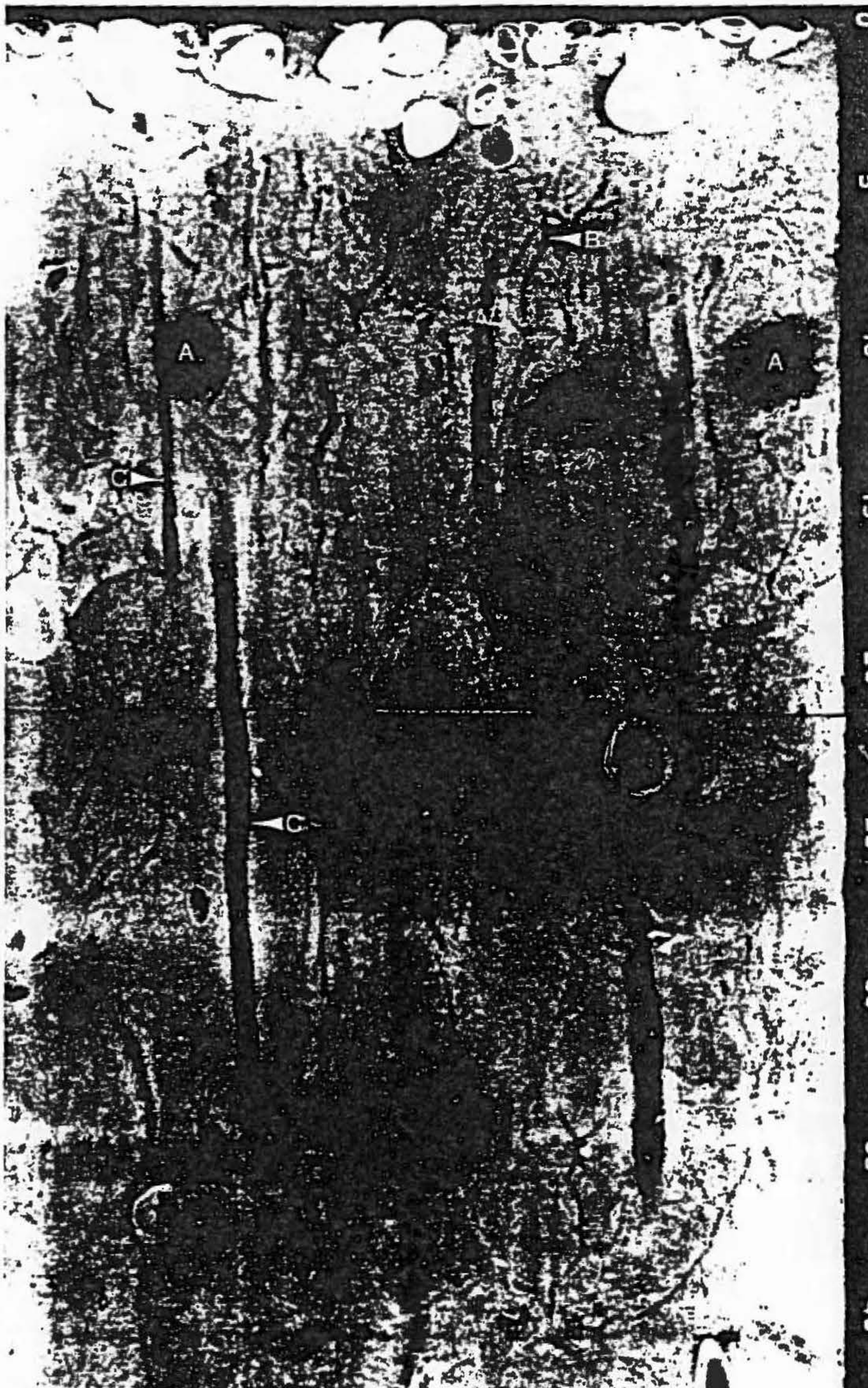


Plate 7

STATION BC-

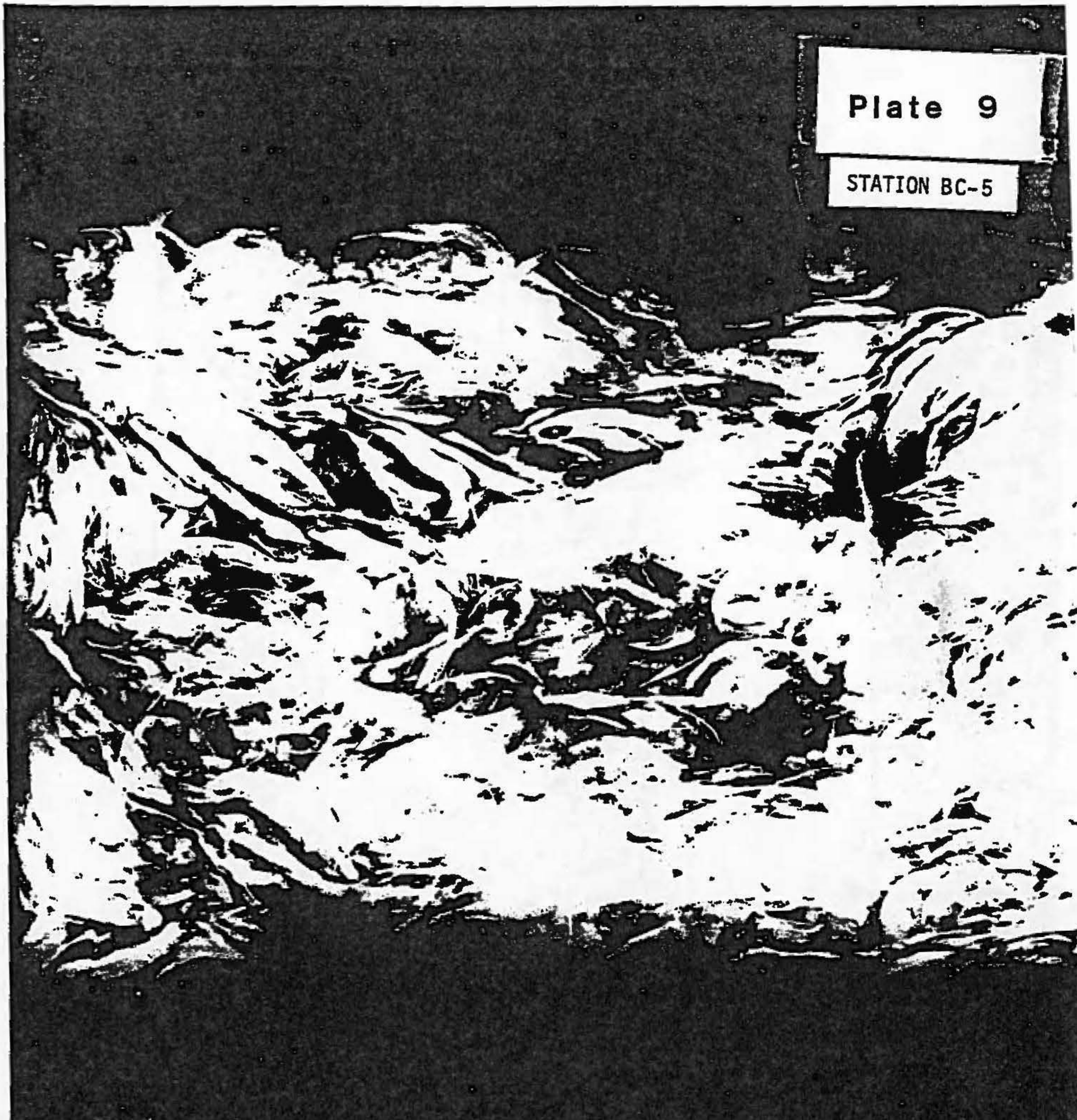


Plate 9
STATION BC-5

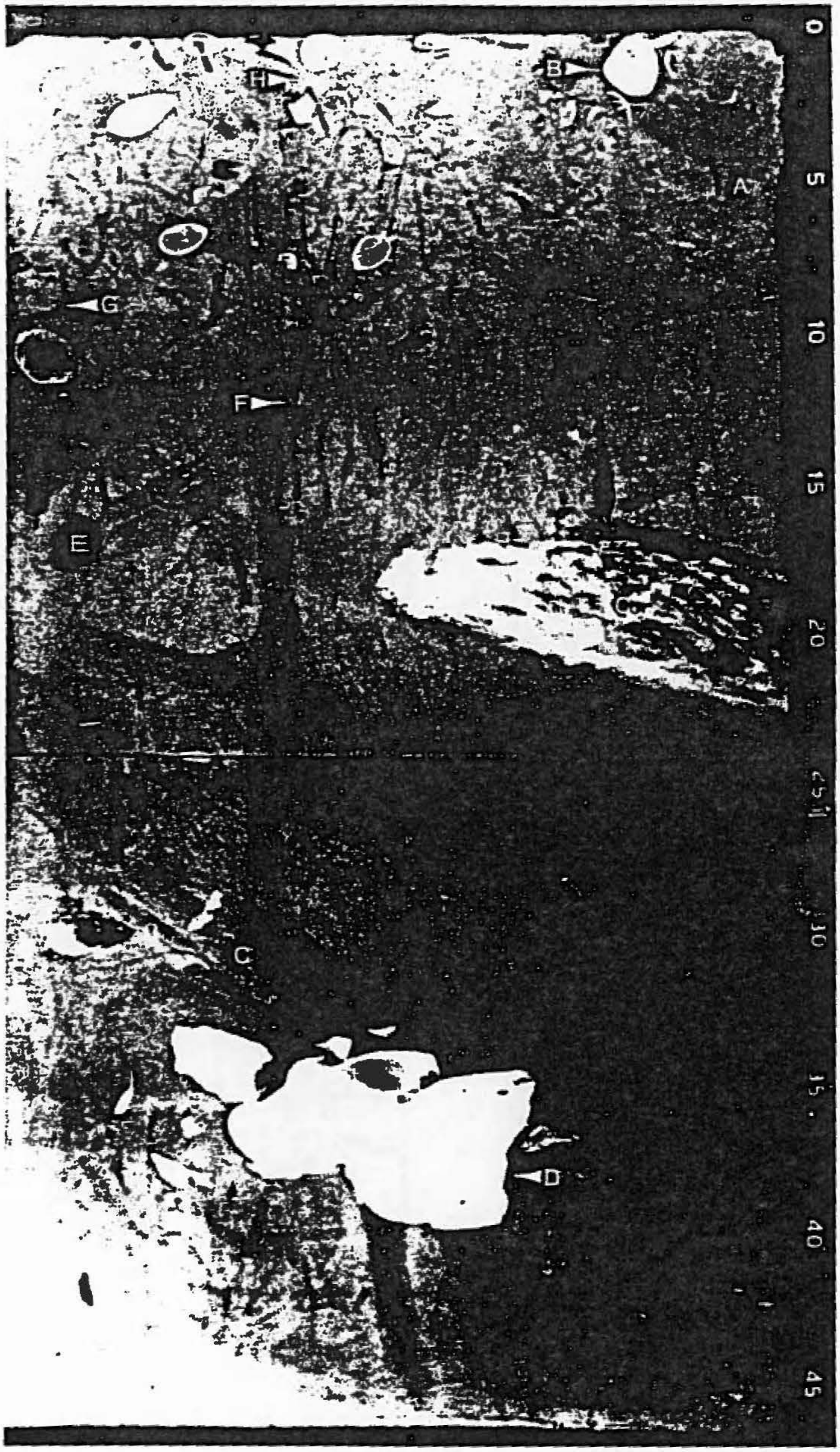


Plate 1

STATION BC-6

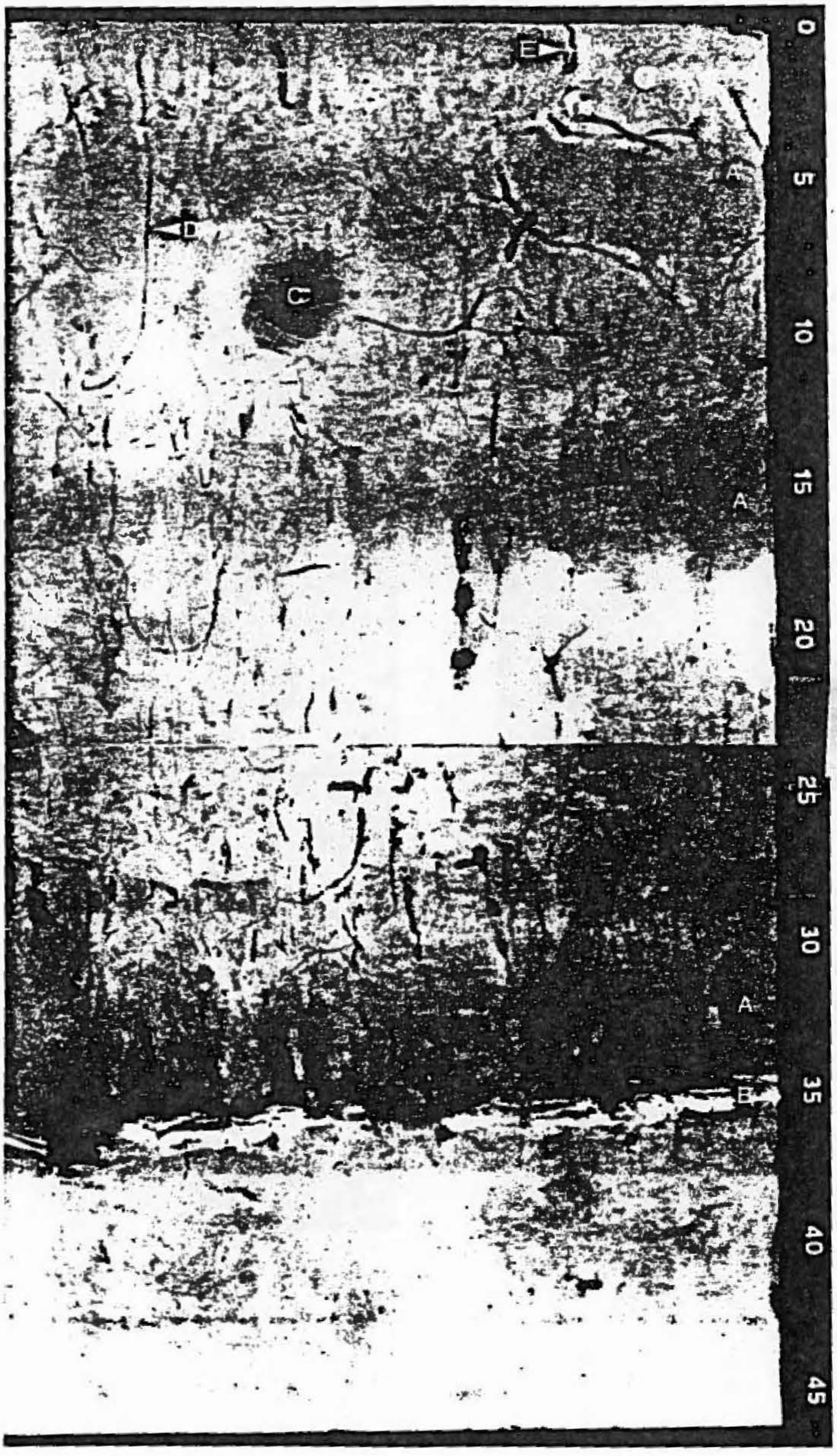
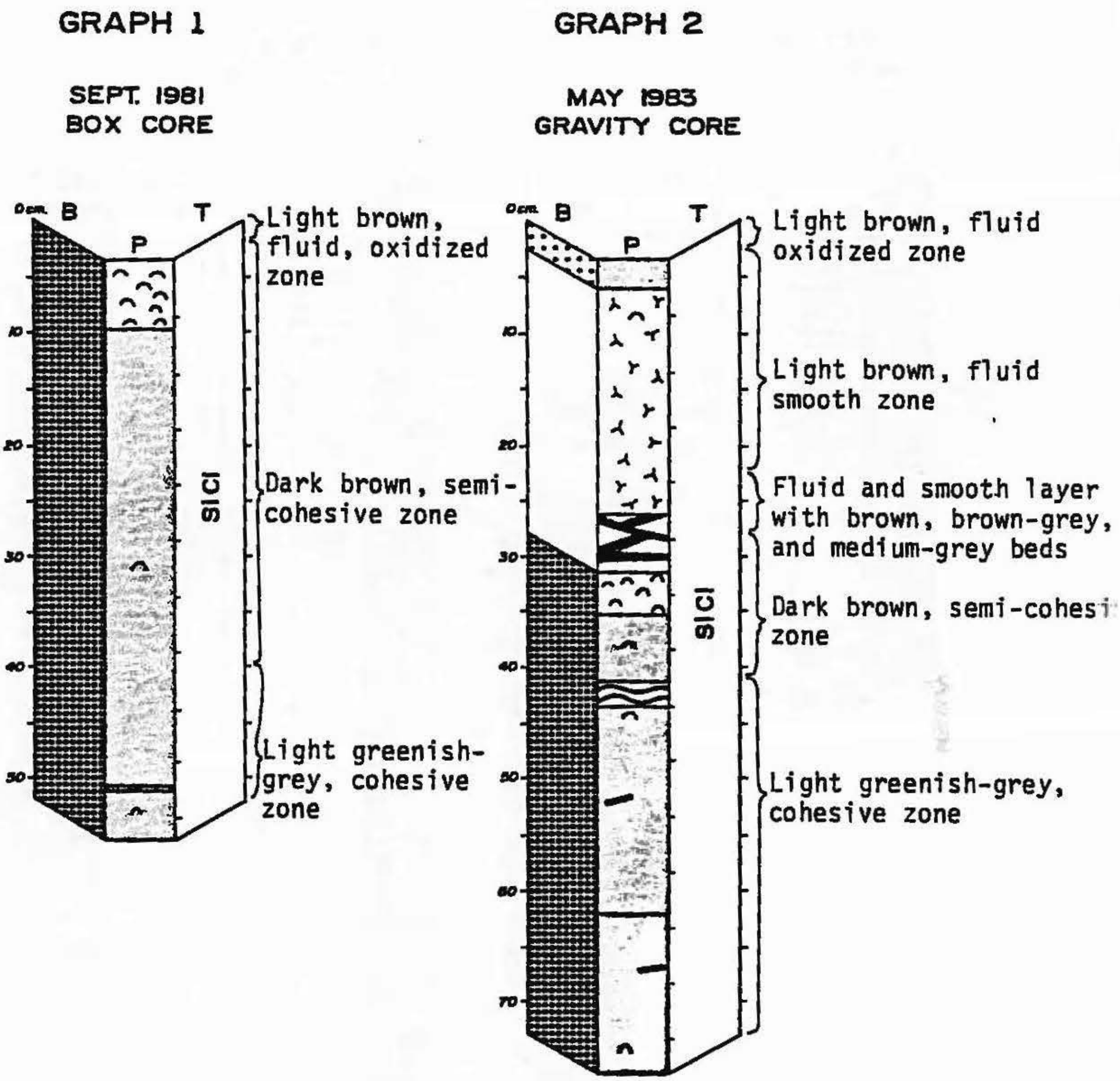


Plate 1

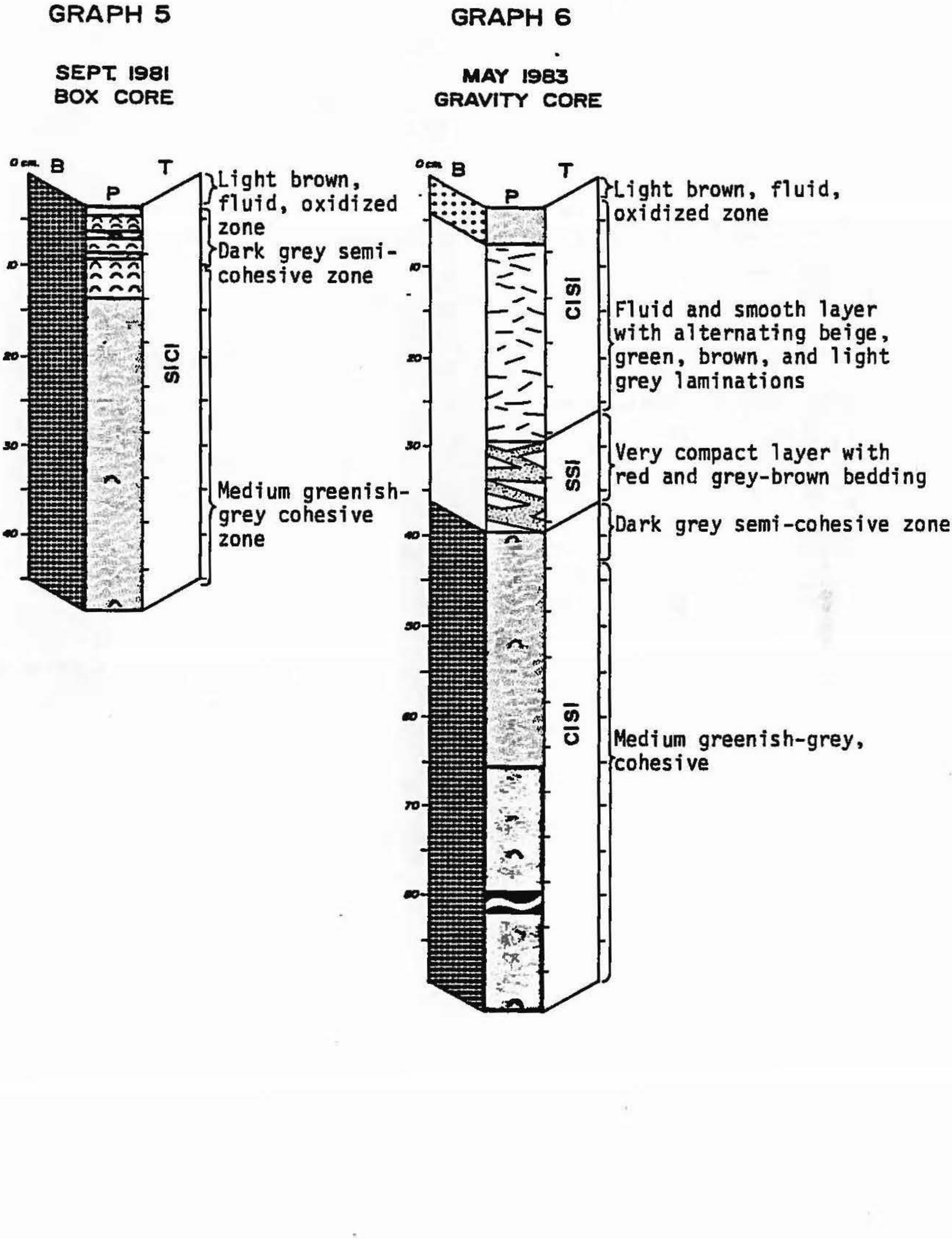
STATION BC-

Appendix IV: Graphical representations of box and gravity cores (Sept., 1981 and May, 1983).

STATION BC-1


GRAPH 1
SEPT. 1981
BOX CORE
B
P
T
SICI
Light brown, fluid, oxidized zone
Dark brown, semi-cohesive zone
Light greenish-grey, cohesive zone
GRAPH 2
MAY 1983
GRAVITY CORE
B
P
T
SICI
Light brown, fluid oxidized zone
Light brown, fluid smooth zone
Fluid and smooth layer with brown, brown-grey, and medium-grey beds
Dark brown, semi-cohesi
zone
Light greenish-grey, cohesive zone

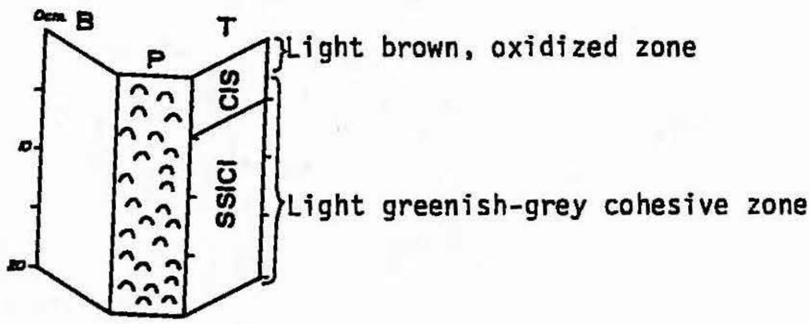
STATION BC-3


GRAPH 5
SEPT. 1981
BOX CORE
0 cm.
B
P
T
10
20
30
40
SICI
Light brown, fluid, oxidized zone
Dark grey semi-cohesive zone
Medium greenish-grey cohesive zone
GRAPH 6
MAY 1983
GRAVITY CORE
0 cm.
B
P
T
10
20
30
40
50
60
70
80
CISI
SSI
CISI
Light brown, fluid, oxidized zone
Fluid and smooth layer with alternating beige, green, brown, and light grey laminations
Very compact layer with red and grey-brown bedding
Dark grey semi-cohesive zone
Medium greenish-grey, cohesive

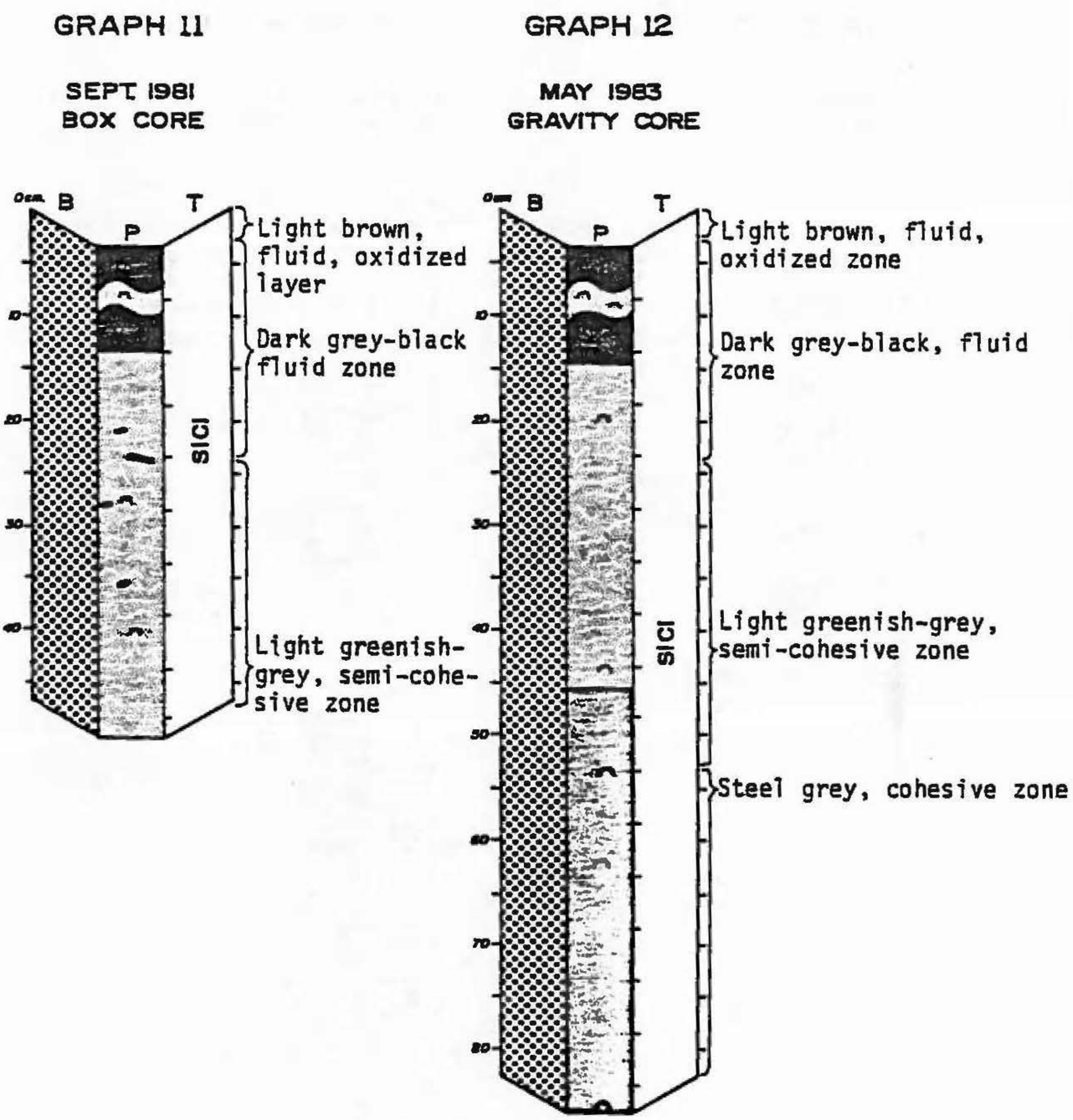
STATION BC-5

GRAPH 9

SEPT. 1981
BOX CORE



STATION BC-6


GRAPH 11
SEPT. 1981
BOX CORE
B
P
T
SICI
10
20
30
40
Light brown, fluid, oxidized layer
Dark grey-black fluid zone
Light greenish-grey, semi-cohesive zone
GRAPH 12
MAY 1983
GRAVITY CORE
B
P
T
SICI
10
20
30
40
50
60
70
80
Light brown, fluid, oxidized zone
Dark grey-black, fluid zone
Light greenish-grey, semi-cohesive zone
Steel grey, cohesive zone

CHAPTER 5

BENTHOS

HAYES T. PFITZENMEYER
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SUMMARY

The second year of a two year monitoring study of benthic macroinvertebrates surrounding Hart and Miller Islands in the upper Chesapeake Bay has been completed. The primary objectives for this year's study were to survey the species, abundance, and distribution of benthic species in this area and to determine the effects of construction of the diked disposal facility on this fauna. A brief view of past benthic studies in the area is included in this report with a comparison of the extensive Maryland Water Resources Administration study of 1972 to 1978.

The number of species sampled over the present two year period totaled 39. Only four new species were added during the second year. Nine species comprised over 90% of the fauna during both years. The most numerically dominant species were the amphipod *Leptocheirus plumulosus*, in all sediments, and the annelid *Scolecolepides viridis* which preferred sand bottoms. On oyster shell substrates the barnacles *Balanus improvisus* and *subalbidus*, and the false mussel *Congeria leucophaeta* were very abundant. The isopod *Cyarthura polita* and the clam *Macoma balthica* were also dominant in silt/clay sediments.

The number of benthic individuals was lowest during the August sampling period and highest during February. While the reduced numbers corresponds to that period of the year when predatory fish and crabs were most abundant, it was believed that population reductions from natural or environmental events also contributed to this yearly cycle. Species diversity was also highest during August because of the reduced dominance. Generally, species diversity decreased with water depth at each season of the year.

INTRODUCTION

The proposed objectives for this phase of the study were to survey the species, density and distribution of the benthic invertebrates in the vicinity of Hart and Miller Islands, and to determine the effects of construction of the diked disposal facility on these components of the biota. To further assist in accomplishing these stated objectives, sediment grain size samples at each benthic station were taken and related to natural biotic distributions and any changes from the facility activity.

In an uncontrolled and variable environment, such as the upper Chesapeake Bay, it is important to achieve as broad a data base as possible to confidently separate natural from extraneous occurrences. These monitoring efforts were a continuation of the first year's study. The methods remained essentially the same and may be referred to in the first interpretive report or the first and second data reports.

REVIEW

Our knowledge on the fauna surrounding Hart and Miller Islands has been greatly increased since the initiation of this project in August 1981. It wasn't until relatively recently that any scientific approach was begun towards understanding the benthic environment in this part of the bay (Pfitzenmeyer 1970). This initial dredge and spoil disposal study, which encompassed a large portion of the upper bay, had one sampling station located near Miller Island. Here, 21 benthic species were found and the dominant was the amphipod Leptocheirus. In anticipation that someday a spoil disposal diked area would be constructed, Water Resources Administration of the State of Maryland, began an intensive sampling effort of the benthic biota surrounding Hart and Miller Islands (Allison and Butler 1981). The data from their study has been summarized for comparison with our present survey (Table 1). The species list and sample size in both studies have been equated.

One series of samples was obtained in March 1971 prior to the arrival of tropical storm Agnes. Probably because of inexperienced field and laboratory personnel the data obtained on the first cruise is limited. This was unfortunate since it served as the only data prior to the deluge of fresh water from tropical storm Agnes (June 1972) which affected the benthos. For example, the most abundant amphipod in the area Leptocheirus was identified as Gammarus and a second abundant species Scolecolepides was not reported. It does illustrate the decrease in species and density of benthos following the storm and the gradual repopulation in succeeding years. Most obvious was the population increase of the clam Rangia cuneata two years following the 1972 storm. This species is a common inhabitant of brackish water and can rapidly spread with low salinity conditions. The average number of individuals per square meter ranged from a low of 104 in 1973 to a high of 1927 in 1977. These values were derived from densities reported in the original report. Densities of benthos in our present survey ranged from 1831 to 3954 per square meter which is considerably higher than the earlier years. Also from the results of these initial studies it was not difficult to conclude that benthic spatial distribution was highly variable and also seasonal and yearly environmental changes play an important part in the faunal make-up.

Outside the immediate area of Hart and Miller Islands, the construction of a power plant about four miles to the north between Seneca and Saltpeter Creeks, and the often-sampled Patapsco River an equal distance to the south, provided numerous studies on environmental impacts. These studies though removed from Hart and Miller Islands generally substantiated each others findings in concluding that the benthic fauna is limited in species richness, variable in numbers, and responsive to salinity changes and sediment types. (Chesapeake Research Consortium, 1982).

Most recently, we have reported upon the findings of the first year's investigation of the benthic fauna surrounding Hart and Miller Islands and the effects of dike construction (Pfitzenmeyer et al. 1982). Species composition and dominance had shifted somewhat since the earlier study by Allison and Butler (1981) because of changing environmental conditions. The earlier 1972-78 study was conducted over comparatively low salinity (.8-7 ‰) conditions whereas 1981-82 fauna reflected a period of higher salinity (8-10 ‰). During the last sampling period, May 83, salinities averaged about 1‰. This present study found more species but not necessarily greater species diversity because of the numerical abundance of a few dominant forms. Statistical analysis further substantiated the theories that stations could be grouped in response to bottom types and water depths but that stations of similar bottom types and water depths could not be significantly differentiated. It was further concluded that no effects were observed on the surrounding benthic fauna during the first year of construction activities. It was recommended that monitoring be continued through another year which would follow the construction of the diked facility to completion. The following discussion is a report upon the continuation of the benthic monitoring activities through May 1983 at the stations shown in Fig. 1.

RESULTS

The components of the benthic macroinvertebrate fauna upon which we base most of our determination are those forms sufficiently large enough to be retained upon a 1.0 mm mesh screen. One sample of the triplicates taken at each sampling station was further collected on a .5 mm mesh screen and will also be included in the non-quantitative discussions.

Studies over a two year period at Hart and Miller Islands have sampled a total of 39 species of macroinvertebrates (Table 2). Five new species were added during the second year (annelids, *Melinna* sp., *Polydora ligni*, and *Capitella capitata*; nudibranch mollusk, *Doridella obscura* and the amphipod *Gammarus mucronatus*) while two species were not resampled (annelid, *Scoloplos fragilis*, and crustacean *Leucon americanus*). One species of barnacle, *Balanus subalbidus*, was present during the first year

Table 2. Taxonomic list of species collected August 1981 through May 1983.

CNIDARIA (Anemones) - 1
- Anthozoa
  - Diadumene leucolena

RHYNCHOCOELA (Ribbon worms) - 1
- Anopla
  - Micrura leidyi

ANNELIDA (Worms) - 11
- Polychaeta
  - Heteromastus filiformis
  - Nereis succinea
  - Scoloplos fragilis
  - Eteone heteropoda
  - Polydora ligni*
  - Scolecolepides viridis
  - Streblospio benedicti
  - Captella capitata*
  - Melinna sp.*
- Oligochaeta
  - Peloscolex sp.
  - Limnodrilus hoffmeisteri

MOLLUSCA (Mollusks) - 9
- Pelecypoda
  - Ischadium recurvum
  - Congeria leucophaeta
  - Rangia cuneata
  - Macoma balthica
  - Macoma mitchelli
  - Mya arenaria
- Gastropoda
  - Hydrobia sp.
  - Littoridinops sp.
  - Doridella obscura*

ARTHROPODA (Arthropods) - 17
- Crustacea
  - Balanus improvisus
  - Balanus subalbidus
  - Leucon americanus
  - Cyathura polita
  - Cassidinidea lunifrons
  - Chirodotea almyra
  - Edotea triloba
  - Leptocheirus plumulosus
  - Corophium lacustre
  - Gammarus daiberi
  - Gammarus tigrinus
  - Gammarus mucronatus*
  - Melita nitida
  - Neohaustorius biarticulatus
  - Monoculodes edwardsi
  - Rithropanopeus harrisii
- Insecta
  - Chironomid sp.

* Found during second year.

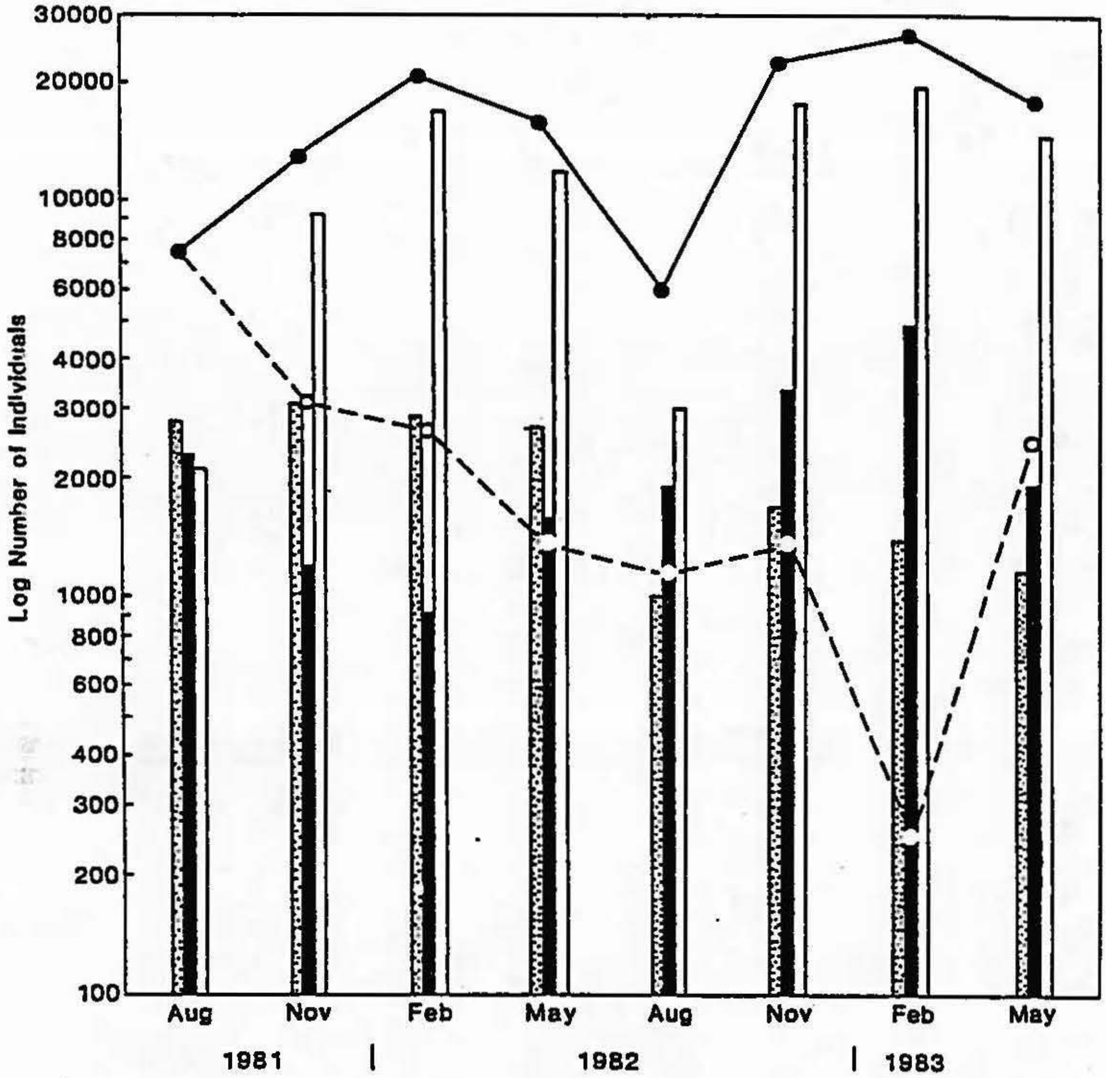

Figure 2. Total number of individuals collected during each sampling period (solid line). Bar graphs show number of individuals of the three major phyla; stippled, annelids; solid, mollusks; open, crustaceans. Broken line represents number of benthic feeding fish collected by trawl for each sampling period.

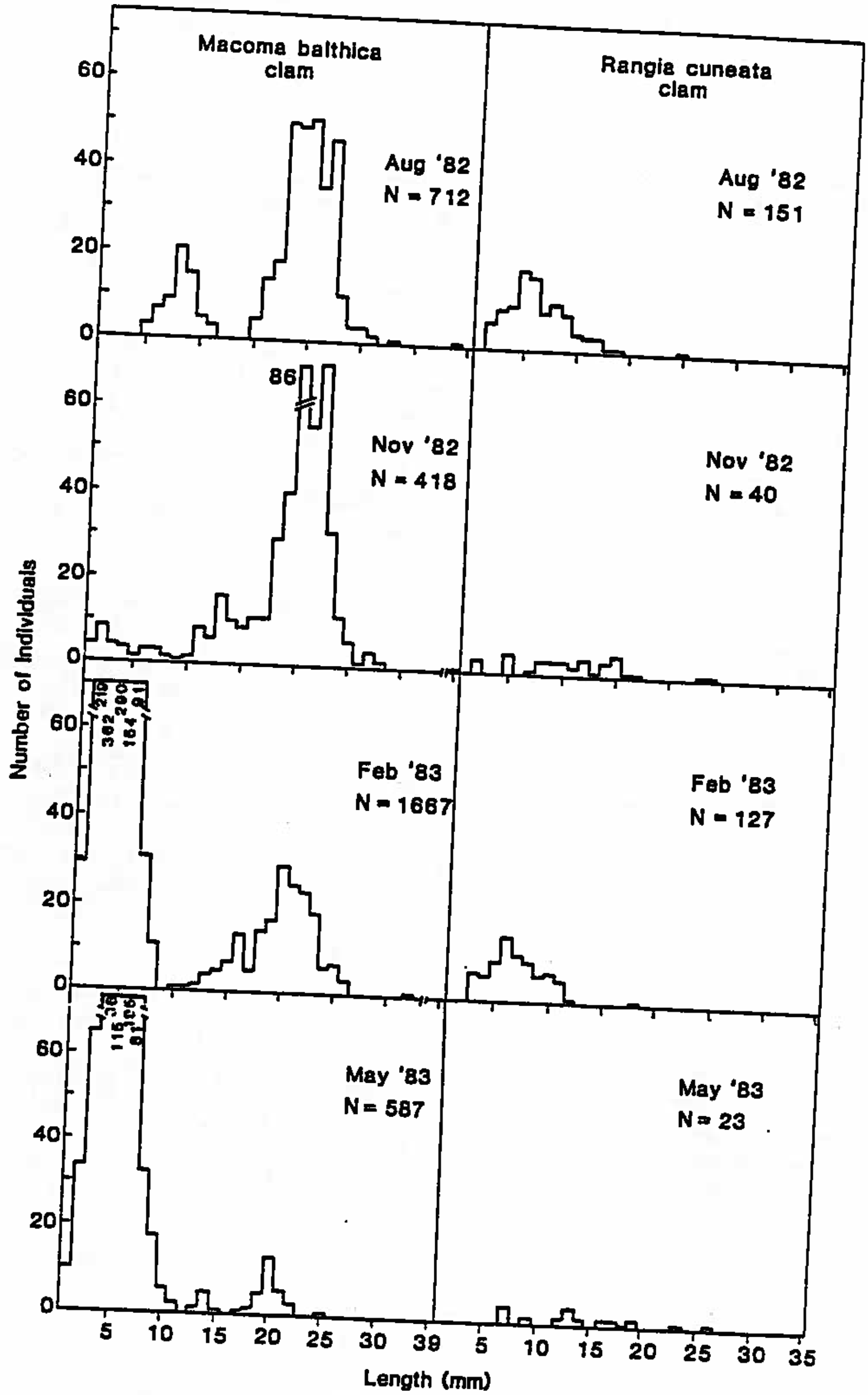

Figure 3. Length frequency diagram for the clam species Macoma balthica and Rangia cuneata collected at all stations during the four sampling periods.

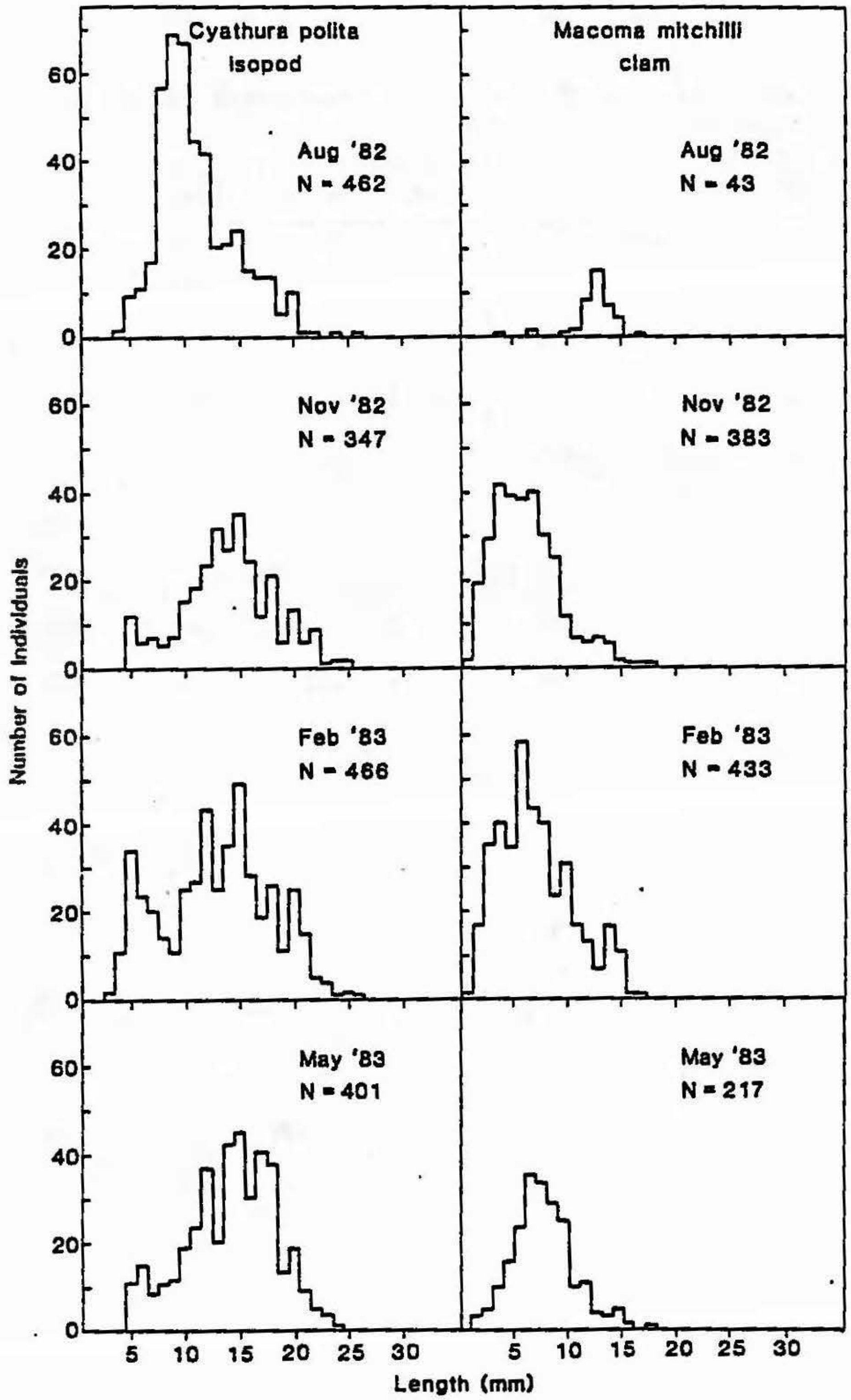

Figure 4. Length frequency diagrams for the isopod Cyathura polita and the clam Macoma mitchelli.

Table 5. Species dominance for the two sampling years for each of the two major sediment types and screen sizes.

> 1.0 mm Screen

	Aug 81	Aug 82	Nov 81	Nov 82	Feb 82	Feb 83	May 82	May 83
SAND								
Scolecolepides	1	2	1	3	1	3	2	2
Leptocheirus	2	1	2	1	2	1	1	1
Heteromastus			3		3			
Corophium	3							3
Neohaustorius		3						
Macoma mitchelli				2		2		
Cyathura							3	
SILT/CLAY								
Leptocheirus	2	1	1	1	1	1	1	1
Macoma balthica	1	3	2	3	3	2	3	3
Scolecolepides	3				2		2	
Heteromastus			3					
Cyathura		2		2		3		2

< 1.0 mm Screen

	Aug 81	Aug 82	Nov 81	Nov 82	Feb 82	Feb 83	May 82	May 83
SAND								
Leptocheirus	2	1	1	1	1	1	1	1
Heteromastus			3		2		2	
Scolecolepides	1	3			3	2	3	2
Peloscolex			2			3		
Cyathura	3							
Strebolospio		2						
Corophium				2				3
Macoma Balthica				3				
SILT/CLAY								
Leptocheirus	2	1	1	1	1	1	1	1
Peloscolex		2	2	2	2	2	2	2
Heteromastus	1		3		3		3	
Scolecolepides	3					3		
Strebolospio				3				
Cyathura		3						
Melita								3

Stations 6, 7, 15 and 19 are ones which had large numbers of Leptocheirus compared with number of other benthic species. Conveniently, during the warm season of the year, amphipods are capable of high reproductive rates and the young do not undergo a larval stage but upon hatching from the adult are merely miniature forms of the parent (Bousfield 1973, Reish and Barnard 1979). As a result, repopulation following the summer reduction is very rapid and only a specially designed project would show the immediate effects of predators.

Mathematical averages of species diversity indices for each sampling period and for the year showed decreasing values with water depth (Table 6). High numbers of Leptocheirus and other dominants are more common at deeper water stations. An exception to this gradient was the August period when values were high and fairly uniform at all depths. The probable reasons for this pertaining to the presence of predators was discussed earlier.

An analysis of the samples taken at Station No. 14, which was 230 yards from the dike, revealed an almost total absence (1 specimen) of benthic animals. This was reflected obviously as 0 diversity for that sampling period. However, if one were to examine only species diversity values, four months later the index was 1.574 which appears normal in comparison with other stations. A detailed examination of the species and numbers involved would indicate otherwise and will be discussed later in this report under the section Deposition of Fluid Mud.

Cluster analysis or grouping of elements based on their similarity or dissimilarity to each other is one objective way of arranging order to large amounts of data (Boesch, 1977). In our first interpretive report we were able to show a general grouping of sampling stations whose fauna was responsive to sediments. Here we again used the same program (BMDP 1981, Computer Program P2M) as a comparison to our initial analyses and to see if our initial observations remained the same.

The August sampling period produced results which have been described by Boesch (1977) as "chaining" which may occur in single link clustering where elements are added one at a time rather than forming groups (Fig. 5). In our analyses it was not considered undesirable because the same program did not produce similar results for the November, February, and May sampling periods. To us, it indicates an inherent characteristic of the benthic fauna during the period of the year when predation was most influential and severe. Overall the benthic populations within and between stations were most homogenous because of this reduction in the dominant or most abundant species. Thereby less differences may be found between stations when trying to relate organisms to bottom type. One station which stood out from all others as characteristically different was Station 9 or the oyster shell station. Two species found in high abundance here but not at the other stations were barnacles and the false mussel Congeria, which require hard surfaces for attachment. The results of the August sediment analysis performed on each stations' substrate is given in Table 7.

Beginning with the November period a grouping of stations relative to

Table 7. August 1982 results of sediment analysis (%), depth (ft), bottom salinity (°/₀₀), bottom temperature (°C) for corresponding sampling stations.

STA	COARSE 500	MEDIUM 250	FINE 125	V. FINE 63	TOTAL SAND	SILT	CLAY	DEPTH	BOT SAL	BOT TEMP
1	12.5	57.2	24.7	4.4	98.8	.7	.5	2		
3	9.9	45.4	22.0	3.7	81.0	14.9	4.1	2		
6	10.0	1.1	1.4	1.6	14.1	67.5	18.5	10	4.5	24.0
7	.6	.5	.2	.3	1.6	64.5	33.9	10		
8	4.0	29.0	55.7	7.4	96.0	1.8	2.2	10		
9*	77.1	2.3	4.4	.7	84.5	13.0	2.5	15		
10	37.0	1.7	26.8	5.1	70.6	25.2	4.1	20	6.3	24.3
14	.6	.0	.1	.0	.7	60.8	38.5	10		
15	27.4	5.1	4.5	2.1	39.0	45.9	15.1	15		
16	5.9	1.2	1.2	.8	9.0	60.4	30.6	15		
17	4.5	14.0	17.0	46.3	81.9	14.0	4.1	10	7.4	24.6
19	8.8	4.1	4.1	11.2	28.2	41.4	30.5	15	5.9	24.3
20	-	-	-	-	-	-	-			
21	7.2	38.2	25.8	4.0	75.2	15.2	9.6	10		
22	2.5	1.4	2.0	2.1	8.1	65.6	26.3	15	6.0	24.2
23	-	-	-	-	-	-	-			
24	.1	2.7	83.8	12.6	99.2	.4	.4	10		
25	22.2	20.9	23.0	3.7	69.9	21.7	8.4	15	8.7	24.7
26	4.2	4.3	9.4	27.8	45.7	42.2	12.1	15		
*	Oyster shell									
Av	14.0	13.5	18.0	7.9	53.2	36.7	14.2			

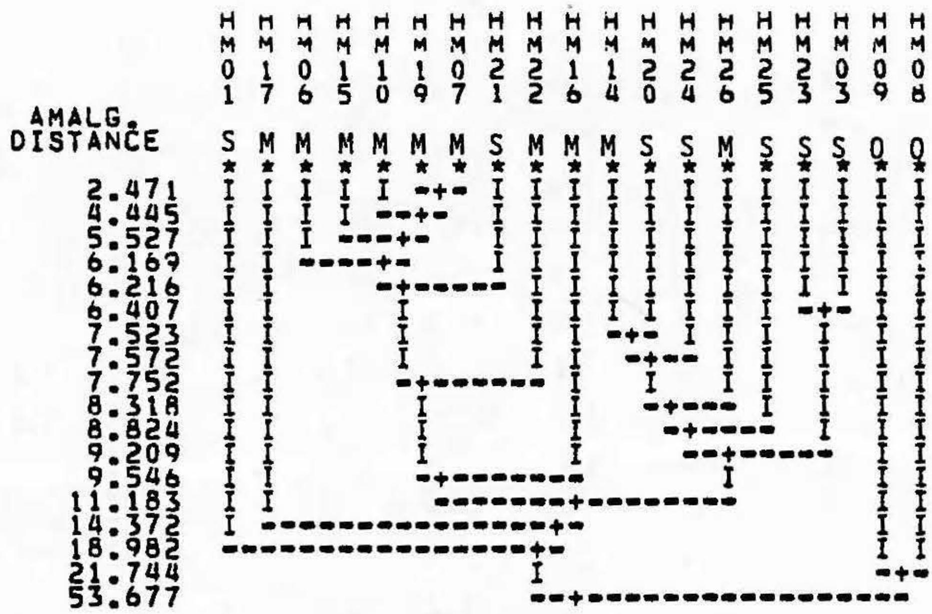

Figure 6. Cluster analysis of November 1982 benthic data giving station numbers and general bottom type (S=sand, M= silt/clay, O=oyster shell).

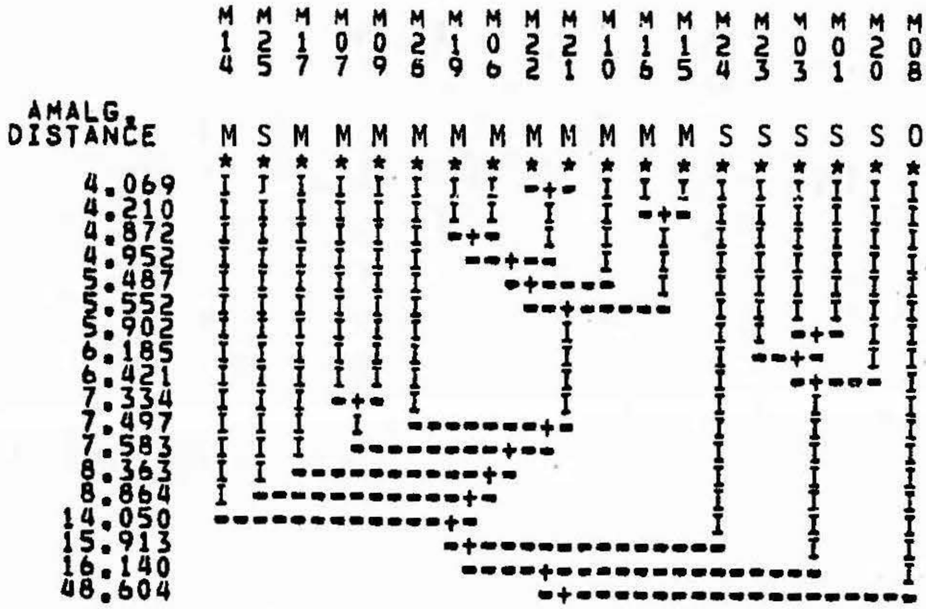

Figure 8. Cluster analysis of May 1983 benthic data giving station numbers and general bottom type. (S=sand, M=silt/clay, O=oyster shell).

Table 11. The Student-Neuman-Keuls test of significance among means of individuals per station for the two sampling periods. Subsets show grouping of stations not significantly different (P<0.05). Stations in a vertical column and row by themselves are significantly different from others.

August 82

SUBSET	STATION NUMBERS																		
1	14																		
2		23	6	24	10	1	21	20	19	7	8	3	15	22	25	26			
3			6	24	10	1	21	20	19	7	8	3	15	22	25	26	16	17	
4																			9

ANALYSIS OF VARIANCE

SOURCE	D.F.	SUM OF SQUARE	MEAN SQ	F	F PROB.
Between Gps.	18	146.897	8.161	14.8	.00
Within Gps.	38	20.984	.552		
TOTAL	56	167.881			

November 82

SUBSET	STATION NUMBERS																		
1	3	4	23																
2				20	25	1	6	24	17	10									
3					25	1	6	24	17	10	16	22	7	26	15	19	21		
4								24	17	10	16	22	7	26	15	19	21	8	
5																		8	9

ANALYSIS OF VARIANCE

SOURCE	D.F.	SUM OF SQ	MEAN SQ	F	F PROB.
Between Gps.	18	170.508	9.473	17.2	.00
Within Gps.	38	20.969	.552		
TOTAL	56	191.477			

should say 14 see p. 170

Table 12. Results of Friedman's non-parametric test for differences in mean levels between different depths testing number of organisms.

Source	d.f.	X^2	.05%	Sig. Diff.
All depths	18	43.8	28.9	Yes
2 x 10	10	21.4	18.3	Yes
2 x 15	10	21.8	18.3	Yes
10 x 15	13	26.7	22.4	Yes
2	3	3.8	7.8	No
10	6	15.0	12.6	Yes
15	6	9.14	12.6	No

Table 13. Results of Friedman's non-parametric test for differences in mean levels of species diversity indices at various depths.

Source	d.f.	X^2	.05%	Sig. Diff.
All depths	2	10.5	5.9	Yes
2	2	0	0	No
10	2	2.6	5.9	No
15	2	10.3	5.9	Yes
2 x 10	2	1.6	5.9	No
2 x 15	2	6.5	5.9	Yes
10 x 15	2	11.6	5.9	Yes

three depths over the three sampling periods (Table 13). There was a significant difference when all stations were included in the analysis. By performing the analysis on the three depths separately it was found that the difference in species diversity indices was located only at the 15 feet depth stations. This influence held true when two depths (2 and 10, 2 and 15, 10 and 15) were tested with each other. The reason for the difference associated with the 15 feet stations may lie in the fact that during August they had a higher average value compared with 2 and 10 feet stations. However in succeeding sampling periods they were the lowest because of the large number of the dominant amphipod Leptocheirus found at these deeper stations.

DEPOSITION OF FLUID MUD

A report from Maryland Geological Survey indicated there were two periods when material from dike construction was misplaced. The first spill occurred June 7, 1982 and the second took place September 15, 1982, both along the bay side of the dike but both shortly reclaimed (Kerhin 1982). A later report stated that in July 1982 another recently deposited volume of material was detected along the same eastern and southeastern side of the dike. Subsequent sampling indicated that about 450,000 to 550,000 cubic meters of material between 10 and 38 cm in thickness had been deposited (Wells and Kerhin 1983). A chart of the areal extent of the material indicated that it surrounded the dike about 400 yds distance at the northern end to a maximum at the southeast corner of about 1100 yds. We have estimated an area of about 460 to 560 acres were covered at an average 24 cm thickness.

One benthic station (14) was located within this area of deposition off the southeast corner of the dike. This station was usually one of diverse and abundant fauna but in August 1982 (about one month after deposition) the fauna was reduced to a total of 3 individuals on both screens, two annelids, Scolecolepides, Peloscolex, and one ribbon worm, Micrura. This represented less than 1% of the number of individuals collected during the last August or the previous sampling period in May 1982. Four months later in November 1982 the fauna showed some recovery but still much reduced at 11% of the number of individuals collected in November 1981. By February 83 or 9 months after the deposition the fauna had 55% recovered based on the previous years figures for number of individuals collected at station 14. By May 83 it had 85% numerically recovered.

The material found at Hart and Miller Islands was very similar in physical appearance to pipeline spoil dredged from channel areas. The benthic repopulation in recently deposited sediments surrounding the newly constructed dike paralleled the progression found in shoal-water spoil disposal studies at nearby Pooles Island (Pfitzenmeyer 1981, 1982). An area completely covered with spoil in November required about 6 months for benthic recovery with the dominant species Scolecolepides, Leptocheirus and Macoma. These same species were the dominant ones at Hart and Miller Islands 8 months after this recent deposition. Repopulation by the more mobile species Leptocheirus was by adult individuals, whereas all

CONCLUSIONS

1. Thirty nine benthic macroinvertebrates have been identified from samples taken over a two year period at Hart and Miller Islands. Four new species were added during the second year and these represent only minor numerical contributions to the fauna.

2. A 22% increase in total number of organisms sampled during the second year was believed due to the increasing trend in salinity which favored the mesohaline fauna.

3. The amphipod Leptocheirus plumulosus remained the numerically dominant species in sand or silt/clay sediments. The barnacles, Balanus improvisus and B. subalbidus, and the false mussel, Congeria leucophaeta showed greatest increases in abundance but only on shell substrate.

4. Highest average index of species diversity continued to be found during August or the season of the year when predaceous fish and crabs are present in the area. Throughout the year, the average diversity at stations in 15 feet of water were significantly different than those at 2 or 10 foot depths.

5. Through use of a cluster analysis, stations grouped according to bottom type. The most pronounced station separation by sediments was observed during February when the largest population of benthos was found.

6. The Student-Neuman-Keuls multiple range test separated stations whose populations were significantly different from others and grouped stations of similar populations means (P=>0.05). The August sampling period had the most uniform faunal distribution while May was most heterogeneous.

7. Non-parametric tests showed that there was a significant difference between sampling periods. Stations at the 10 foot water depth were significantly different than those at 2 and 15 foot depths. Stations located at the 10 foot depth included oyster shell populations which had a greater number of organisms than other stations and probably accounted for this difference.

8. Samples taken during August indicated a deposit of fluid mud at Station 14, about 230 yards from the dike. A total of three specimens were found at this time which represented less than 1% of organisms previously found there. Numerically, the fauna indicated a 11% recovery in four months and a 85% recovery about ten months after deposition of the spoil. Because repopulating of this barren area is mostly by juvenile specimens, it is estimated that biomass will lag behind other unaffected areas for about a 2 year period.

CHAPTER 6

FISH NEAR HART AND MILLER ISLANDS

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SUMMARY

During August 1981 - May 1983, quarterly collections of fish and macro-epibenthos were made at six inshore stations and ten offshore stations. During the two years of the study a total of 8,695 fish representing 25 species were collected at the inshore stations and 22,172 fish representing 20 species were taken at the offshore stations. At the inshore stations total numbers of fish and species diversity peaked in May. Annual lows in abundance and diversity occurred in February. The inshore fish community was dominated by Atlantic silversides and bay anchovies. At the offshore stations total numbers of fish were highest in August (first year) and May (second year). Species diversity peaked in May of both years. Annual lows for both parameters occurred in February. The offshore fish community was dominated by spot (August) and white perch (November - February). Crabs were most abundant during August of both years. Fish and crabs were much less abundant during August 1982 - May 1983 than during the corresponding period of 1981-1982. Our study did not indicate that these decreases were due to the construction of the Hart and Miller Islands Containment Facility.

representing 16 species was collected. A peak in abundance and biomass occurred in late summer when spot was the dominant species. In fall and winter white perch replaced spot as dominant. Species diversity peaked in May.

METHODS

In the second year of the study fish sampling stations, sampling methods, and sampling periods followed those in the first year of the study. Quarterly collections of fish and macro-epibenthic samples were made on August 24-25 and November 16, 1982, and February 22 and May 17, 1983. Locations of the six inshore and ten offshore stations are shown in Figure 1. For the inshore stations, a 15.2 x 1.8 m beach seine (0.6 cm mesh) was used to collect fish. At each station, three semicircular hauls were made along the beach. The total area sampled was estimated to be approximately 616 m^2. For the offshore stations, a 7.6 m otter trawl (0.6 cm mesh at the cod end) was used. The trawling period was five minutes over a distance of approximately 615 m.

Crabs collected at each station were counted, measured (carapace width), and the total catch weighed in the field. Large fish were measured (fork length) and weighed. The small fish were preserved in 15 percent formalin. Species that were very numerous were subsampled and their abundance was estimated by calculating the numbers in a subsample compared to the volume in the total catch. Preserved samples were brought back to the laboratory where the fish were sorted, identified, weighed, and measured. Coefficients of condition (K), which express the relative robustness of fish, were calculated as $K = W/L^3 \times 100$, where W is weight in grams and L is fork length in cm (Lagler, 1956). For crabs, carapace width was substituted for length in the calculation of the coefficient of condition.

Estimates were made of the total number of individuals (community size), total weight (total biomass), species composition, and species diversity. The species diversity index used in this study is based on information theory and defined as

$$\bar{H} = -\sum_{i=1}^{s} \left(\frac{n_i}{N}\right) \log_e\left(\frac{n_i}{N}\right)$$

where s is the number of species, n_i is the number of individuals in the ith species, and N is the total number of individuals (MacArthur, 1965; Wilhm, 1967).

A method described by Bray and Curtis (1957) and Wilhm (1967) was used to calculate coefficients of similarity between stations for each sampling period. Stations which have similar species composition and similar densities yield high coefficients of similarity. If changes occur in the fish fauna as a result of dike construction, these changes should be reflected in the similarity coefficients. Stations nearest the construction site would be expected to have low similarity coefficients with Stations HMS 6 and HMT 10, the stations most distant from the dike.

Single classification analysis of variance (Sokal and Rohlf, 1969) was used to test the significance of differences among seasons in number of individuals, number of species, and species diversity ($\bar{H}$), and to test for differences among stations in coefficient of condition of fish. A t-test for paired comparisons (Sokal and Rohlf, 1969) was used to test for differences in abundances between years at each station. For analysis, numerical fish data were transformed by l_n (n+1).

RESULTS

INSHORE FISH

Fish Community

A total of 957 individuals representing 21 species was collected at the inshore stations during August 1982 to May 1983 (Table 1). The structure of the inshore fish community changed with season. Analysis of variance revealed that there were significant ($P<0.01$) seasonal changes in number of individuals, number of species, and species diversity ($\bar{H}$). The number of species was higher in May (17) and August (13) than in November (6) or February (2). Among the individual stations, the total number of species collected during the year ranged from 8 at Station HMS 3 to 13 at Station HMS 6. The species diversity Index ($\bar{H}$) was highest in May (1.413) and August (1.115) and lowest in February (0.083). There was considerable variation among the individual stations. The annual mean $\bar{H}$ was highest at Stations HMS 6 (1.190) and HMS 2 (1.049) and lowest at Station HMS 3 (0.429). The spring peak in both number of species and species diversity index occurred when salinities were very low (1 ppt.). Five species of freshwater fish were captured in May in addition to the resident species.

The number of individuals and the fish biomass were higher in August and May than in November or February (Table 1). The total number of fish did not change greatly from November to February. However, while fish were found at every station in November, most of the February catch occurred at Station HMS 6. Total numbers of fish were highest at Station HMS 5 where bay anchovies, Atlantic silversides, and tidewater silversides were abundant. Stations HMS 1 and HMS 2 ranked highest in biomass due to the relative abundance of white perch at those stations. Station HMS 6, which ranked highest among the inshore stations in number of species and species diversity ($\bar{H}$), ranked low in biomass. Large fish such as white perch and yellow perch were uncommon at Station HMS 6.

Fish Populations

Atlantic silverside (*Menidia menidia*) - The Atlantic silverside was the most abundant species at the inshore stations and accounted for 33%, in number, of the total beach seine catch (Table 2). This species was most abundant in August when it occurred at every inshore station. It was found only at Stations HMS 4 and HMS 5 in November and HMS 1 and HMS 6 in February, but its numbers were relatively high. The Atlantic silverside was not collected in February 1982 and its presence at the inshore stations in February 1983 probably reflects the milder winter of 1982-1983. In May

Table 2. Number and weight of fish collected at the inshore stations, August 1982 - May 1983.

	August		November		February		May		Total	
SPECIES	No.	Wt. g	No.	Wt. g	No.	Wt. g	No.	Wt. g	No.	Wt. g
Menidia menidia	219	397.2	17	49.4	41	129.3	38	162.5	315	738.4
Anchoa mitchilli	5	3.6	-	-	-	-	143	143.9	148	147.5
Menidia beryllina	-	-	33	47.6	11	14.6	61	74.3	105	136.5
Morone americana	62	4629.0	11	1208.9	-	-	31	2786.7	104	8624.5
Brevoortia tyrannus	4	17.9	1	9.2	-	-	94	81.0	99	108.1
Fundulus heteroclitus	1	9.6	-	-	-	-	50	165.0	51	174.6
Membras martinica	19	62.6	-	-	-	-	13	55.6	32	118.2
Fundulus majalis	1	2.1	2	4.9	-	-	25	193.8	28	200.8
Leiostomus xanthurus	18	476.9	-	-	-	-	-	-	18	476.9
Morone saxatilis	17	203.8	-	-	-	-	-	-	17	203.8
Pomatomus saltatrix	14	921.7	-	-	-	-	-	-	14	921.7
Dorosoma cepedianum	4	1925.0	-	-	-	-	4	25.9	8	1950.9
Perca flavescens	1	79.6	4	466.7	-	-	2	231.9	7	778.2
Cyprinus carpio	-	-	-	-	-	-	-	-	4	-*
Anchoa hepsetus	1	8.1	-	-	-	-	-	-	1	8.1
Notropis hudsonius	-	-	-	-	-	-	1	6.6	1	6.6
Alosa aestivalis	-	-	-	-	-	-	1	2.7	1	2.7
Notropis analostanus	-	-	-	-	-	-	1	2.7	1	2.7
Cyprinodon variegatus	-	-	-	-	-	-	1	1.8	1	1.8
Fundulus diaphanus	-	-	-	-	-	-	1	1.4	1	1.4
Umbra pygmaea	-	-	-	-	-	-	1	0.9	1	0.9
TOTAL	366	8737.1	68	1786.7	52	143.9	471	3936.7	957	14604.4

* Too large to weigh.

Table 3. Coefficients of similarity between inshore stations during August and November 1982, and May 1983.

AUGUST	HMS 1	HMS 2	HMS 3	HMS 4	HMS 5	HMS 6
HMS 1	—					
HMS 2	.233	—				
HMS 3	.057	.398	—			
HMS 4	.275	.814	.325	—		
HMS 5	.144	.511	.785	.447	—	
HMS 6	.274	.356	.160	.309	.247	—
NOVEMBER	HMS 1	HMS 2	HMS 3	HMS 4	HMS 5	HMS 6
HMS 1	—					
HMS 2	.491	—				
HMS 3	.309	.579	—			
HMS 4	.326	.443	.536	—		
HMS 5	.153	.285	.629	.722	—	
HMS 6	.307	.752	.484	.435	.297	—
MAY	HMS 1	HMS 2	HMS 3	HMS 4	HMS 5	HMS6
HMS 1	—					
HMS 2	.300	—				
HMS 3	.147	.297	—			
HMS 4	.226	.136	.145	—		
HMS 5	.246	.083	.075	.022	—	
HMS 6	.502	.087	.150	.500	.158	—

Table 4. Mean fork length (mm), weight (g), and coefficient of condition (K) of Atlantic silversides collected at inshore stations during August and November 1982, and February and May 1983. (Number of fish in parentheses.)

		HMS 1	HMS 2	HMS 3	HMS 4	HMS 5	HMS 6	Total
Aug	L	65	63±5.9	58±6.3	60±6.6	64±7.5	58±3.3	61.1±6.5
	W	2.5	2.1±0.6	1.7±0.5	1.9±0.6	2.2±0.8	1.8±0.4	1.97±0.6
	K	0.910	0.835±0.1	0.854±0.1	0.864±0.1	0.805±0.1	0.894±0.1	0.841±0.09
		(1)	(24)	(30)	(22)	(30)	(5)	(112)
Nov	L	-	-	-	70±11.1	75±10.9	-	72.6±11.0
	W	-	-	-	2.7±1.8	3.1±1.2	-	2.9±1.5
	K	-	-	-	0.764±0.1	0.705±0.1	-	0.733±0.1
					(8)	(9)		(17)
Feb	L	71	-	-	-	-	75±10.4	75±10.4
	W	-	-	-	-	-	3.2±1.4	3.2±1.4
	K	-	-	-	-	-	0.736±0.1	0.736±0.1
							(40)	(40)
May	L	83±10.5	89±0.6	85±9.1	92	81±8.2	96±2.8	84±8.6
	W	4.2±2.1	5.0±0.4	4.8±1.4	5.5	3.8±1.3	5.9±0.7	4.3±1.5
	K	0.701±0.1	0.706±0.1	0.774±0	0.706	0. 694±0.1	0.665±0	0.711±0.1
		(4)	(3)	(8)	(1)	(20)	(2)	(38)

Table 5. Total number, number of species, species diversity ($\bar{H}$), total weight, and biomass of fish collected at the offshore stations, Augus to May 1983.

PARAMETER	MONTH	HMT 1	HMT 2	HMT 3	HMT 4	HMT 5	HMT 6	HMT 7	HMT 8	HMT 9	HMT 10	TOTAL
Total Number	Aug	261	35	148	102	11	111	6	18	118	118	928
	Nov	81	67	60	244	360	188	76	221	160	214	1671
	Feb	4	6	1	4	3	5	3	0	177	65	262
	May	160	322	215	90	202	257	339	216	591	141	2533
	TOTAL	506	430	422	440	576	561	424	455	1046	538	5400
Number of Species	Aug	7	3	5	7	2	5	1	3	4	6	10
	Nov	5	5	8	6	7	8	3	4	6	4	10
	Feb	2	2	1	3	2	2	2	0	1	1	4
	May	8	7	6	9	8	8	8	6	8	7	14
	TOTAL	13	10	11	14	11	11	10	10	11	8	17
Species Diversity $\bar{H}$	Aug	0.906	0.250	0.741	0.863	0.474	0.993	0	0.426	0.564	0.965	0.619 ($\bar{X}$)
	Nov	0.314	0.704	1.193	1.363	0.917	0.941	0.504	0.242	0.446	0.451	0.708 ($\bar{X}$)
	Feb	0.562	0.450	0	1.0404	0.637	0.500	0.637	0	0	0	0.383 ($\bar{X}$)
	May	1.556	1.347	1.643	1.550	1.334	1.374	1.310	1.644	1.451	1.660	1.487 ($\bar{X}$)
	MEAN	0.835	0.690	0.894	1.204	0.841	0.952	0.613	0.578	0.615	0.769	0.799
Total Weight (Kg)	Aug	14.423	1.512	3.554	3.677	0.439	7.598	0.325	0.753	5.555	7.540	45.378
	Nov	0.230	4.037	2.214	8.873	19.431	10.293	4.670	14.474	9.767	13.572	87.561
	Feb	0.163	0.870	0.003	0.029	0.327	0.382	0.212	0	15.800	6.400	24.186
	May	6.789	7.938	13.282	3.643	14.731	17.050	14.998	15.415	10.600	5.368	109.814
	TOTAL	21.605	14.357	19.053	16.222	34.928	35.323	20.205	30.642	41.722	32.880	266.936
Biomass (g/m^2)	Aug	3.076	0.289	0.758	0.784	0.094	1.620	0.069	0.161	1.185	1.608	0.964 ($\bar{X}$)
	Nov	0.049	0.861	0.472	1.892	4.144	2.195	0.996	3.087	2.083	2.894	1.867 ($\bar{X}$)
	Feb	0.035	0.186	0.001	0.006	0.070	0.082	0.045	0	3.369	1.365	0.516 ($\bar{X}$)
	May	1.448	1.693	2.832	0.777	3.128	3.632	3.198	3.287	2.260	1.145	2.340 ($\bar{X}$)
	MEAN	1.152	0.757	1.016	0.865	1.859	1.882	1.077	1.634	2.224	1.753	1.422

catch during those sampling periods. They were rare in November and were not taken in February.

Atlantic croaker (Micropogon undulatus) - Croakers were very abundant in the trawl catch in May. A total of 603 croakers were taken in February and May of 1983 compared to 0 during the same months of 1982. All specimens were young-of-the-year.

Miscellaneous Species - Large catches of the Atlantic menhaden (Brevoortia tyrannus) were made at Stations HMT 4 and HMT 5 in November. It was uncommon at other stations in November and was rare during other sampling periods. The hogchoker (Trinectes maculatus) was taken at most stations in August and November, but numbers were low. In May hogchokers were abundant at all offshore stations. A total of 25 striped bass (Morone saxatilis) were captured in August and November. They were most abundant in November and were taken at 7 of 10 stations. Gizzard shad (Dorosoma cepedianum) were collected only during February. They occurred at most stations during February, but in low numbers. The white catfish (Ictalurus catus), brown bullhead (Ictalurus nebulosus) and pumpkinseed (Lepomis gibbosus) were taken only in May. They are freshwater species and were not taken during the first year of the study.

Faunal Similarity

Similarity coefficients for the offshore stations during each sampling period are presented in Table 7. In August the similarity coefficient was high among Stations HMT 3, HMT 4, HMT 6, HMT 9, and HMT 10. These stations had similar species composition and were dominated by spot. The similarity coefficient was also high in August between Stations HMT 5 and HMT 7, which had very few fish. In November large numbers of white perch at Stations HMT 5, HMT 6, HMT 8, HMT 9 and HMT 10 were responsible for high similarity coefficients among these stations. In February the number of species was low and white perch were concentrated at Stations HMT 9 and HMT 10. Similarity among stations was highly variable and depended primarily on abundance of white perch. In May species diversity was high and the dominant species were distributed fairly evenly among the offshore stations. Similarity coefficients averaged higher than during other sampling periods. Similarity values in May depended largely on the relative abundance of white perch, croakers, eels, hogchokers, and channel catfish at the various stations.

Comparing stations with HMT 10, the reference station, did not reveal spatial patterns of faunal similarity which could be attributed to the dike construction. Stations which had low similarity coefficients with Station HMT 10 in August (e.g. HMT 5, HMT 7, HMT 9) had fairly high similarity coefficients with this station in November.

Size and coefficient of condition of the white perch.

Average size and coefficient of condition (K) for white perch during each sampling period are shown in Table 8. The average size was smallest in May. Both average size and coefficent of condition were greatest in

Table 8. Mean fork length (mm), weight (g), and coefficient of condition (K) of white perch collected at the offshore stations during August and November 1982 and February and May 1983. (Number of fish in parentheses).

		HMT 1	HMT 2	HMT 3	HMT 4	HMT 5	HMT 6	HMT 7	HMT 8	HMT 9	HMT 10	T[illegible]
Aug	L	168±14.8	–	154	–	153±1.4	160±13.1	–	–	168±8.1	163±20.7	16[illegible]
	W	87.5±24.8	–	56.2	–	71.2±1.7	77.7±19.3	–	–	87.6±13.5	86.5±1.9	83.3
	K	1.797±0.2	–	1.539	–	1.988±0.01	1.868±0.1	–	–	1.828±0.2	1.974±0.3	1.923
		(19)		(1)		(2)	(14)			(5)	(9)	(50[illegible]
Nov	L	111±14.9	155±5.6	144±21.4	143±11.7	141±20.9	148±24.3	149±23.2	125±38.9	150±28.5	–	143.9
	W	30.6±28.9	69.5±8.5	57.2±21.7	55.8±15.3	55.0±21.5	68.2±21.3	65.2±13.1	39.6±26.5	70.5±19.4	–	59.5
	K	1.821±0.1	1.843±0.2	1.781±0.2	1.858±0.2	1.868±0.2	1.942±0.2	1.803±0.2	1.779±0.3	1.795±0.2	–	1.835
		(2)	(27)	(30)	(30)	(30)	(28)	(25)	(26)	(22)		(22[illegible]
Feb	L	191	187±60.4	–	–	178±36.7	164±25.3	188	–	–	165±16.7	170.2[illegible]
	W	148.3	173±185.5	–	–	160.3±126.8	92.6±48.5	200	–	–	101±35.8	117.9[illegible]
	K	2.128	2.051±0.2	–	–	2.478±0.7	1.967±0.2	3.010	–	–	2.168±0.2	2.169[illegible]
		(1)	(5)			(2)	(4)	(1)			(22)	(35[illegible]
May	L	109±37.9	148±38.6	149±26.1	97±40.7	132±33.1	96±39.0	137±37.3	122±37.4	108±39.1	97±38.6	119.5[illegible]
	W	39.3±33.2	85.5±44.9	75.3±28.9	28.9±33.8	56.2±29.6	26.9±30.3	70.3±34.9	50.7±236.7	38.8±36.8	24.2±33.1	49.4[illegible]
	K	2.015±0.3	2.196±0.3	2.086±0.2	1.807±0.3	2.044±0.3	1.835±0.4	2.140±0.3	2.088±0.4	2.056±0.1	1.875±0.2	[illegible]
		(30)	(32)	(30)	(17)	(30)	(30)	(28)	(30)	(30)	(30)	[illegible]

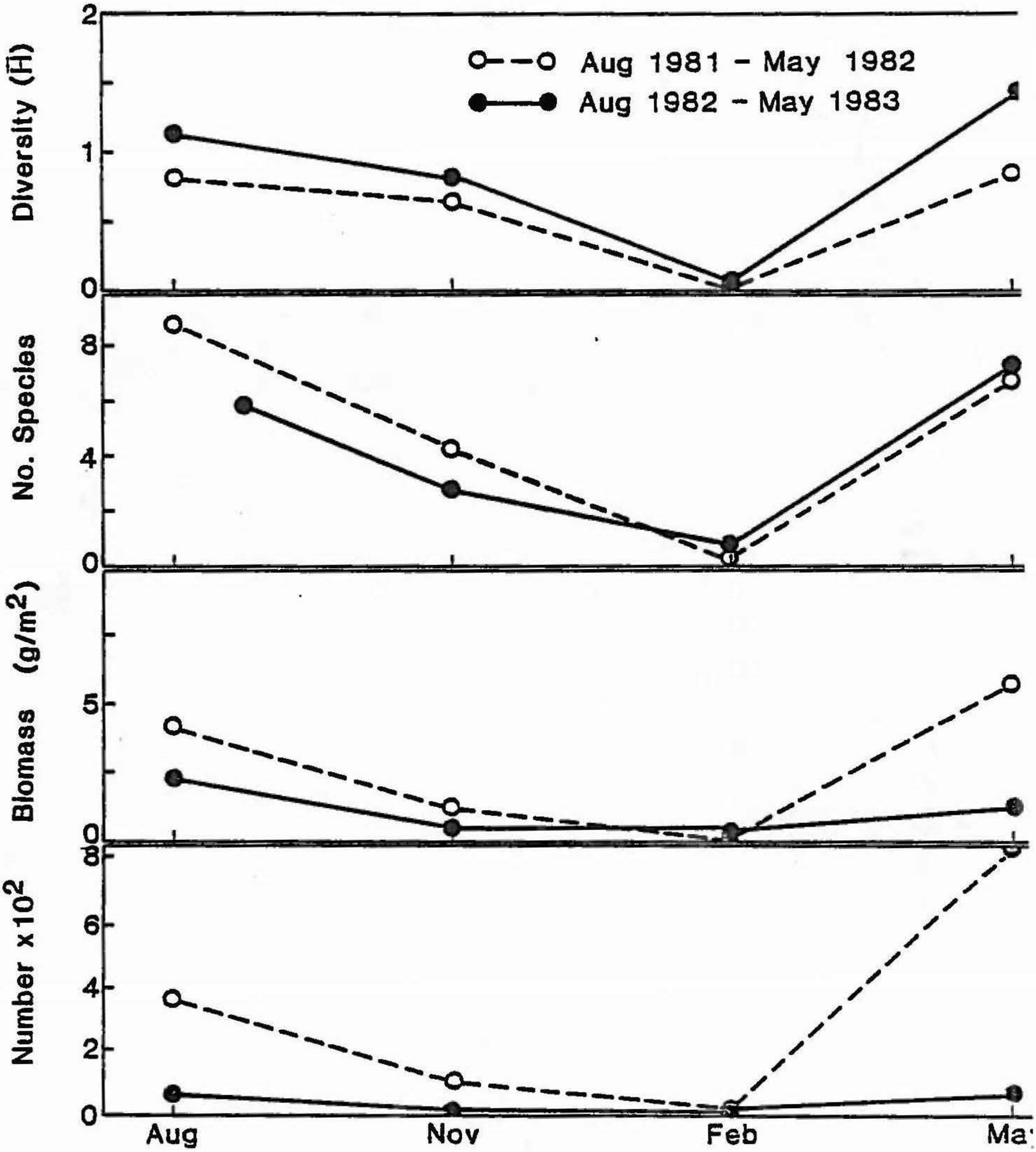

Figure 2. Mean number of individuals, biomass, number of species, and species diversity ($\bar{H}$) at the six inshore stations during August 1981-May 1982 (dotted line) and August 1982-May 1983 (solid line).

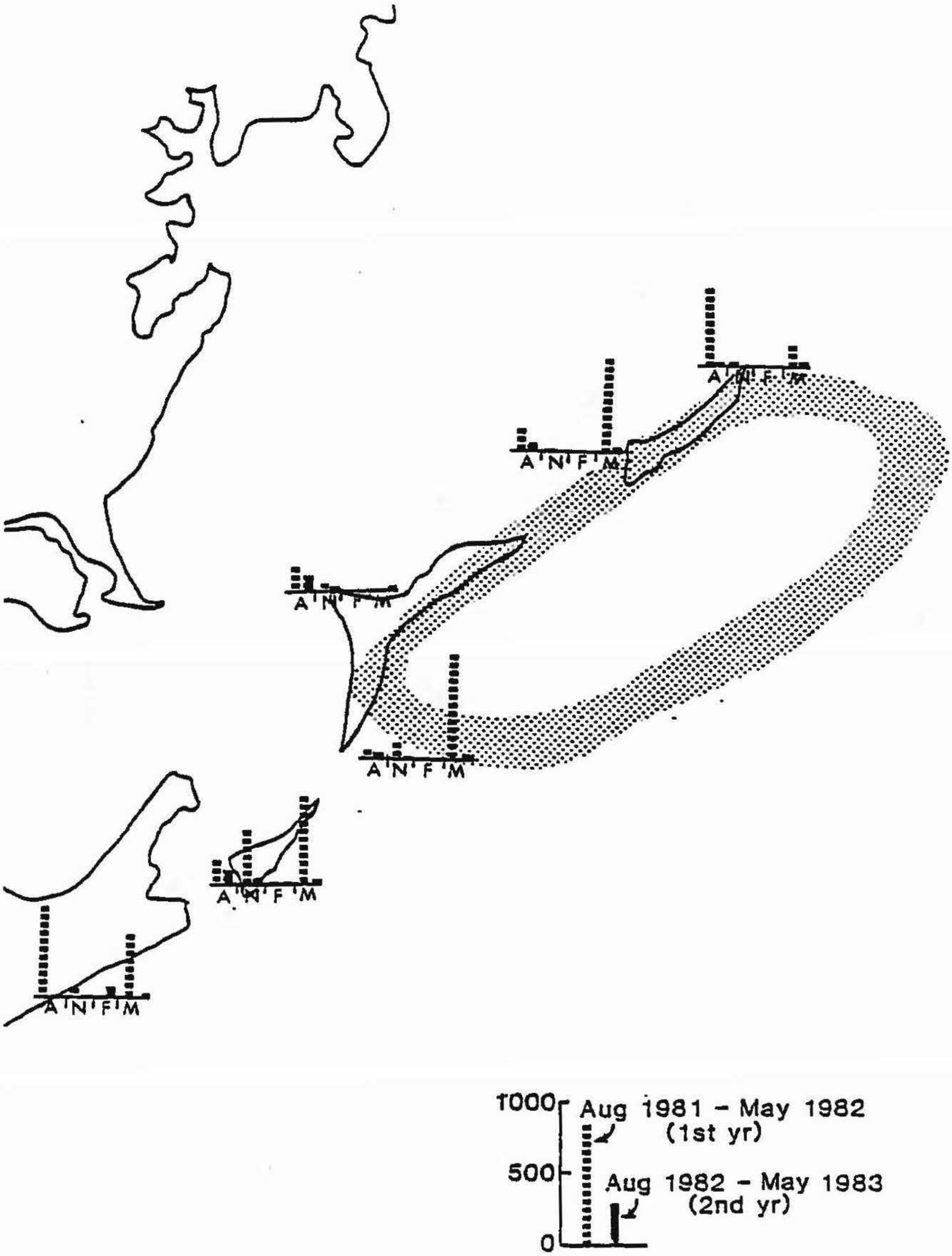

Figure 4. Distribution and abundance of Atlantic silverside, (*Menidia menidia*), at the inshore stations during August 1981-May 1982 and August 1982-May 1983.

catch during the two years of the study. Of these six species, all decreased in abundance in 1982-1983.

There was a similar reduction in the abundance of fish at the offshore Stations (Figs. 5-8). The total trawl catch for August through May fell from 16,772 fish in 1981-1982 to 5,400 fish in 1982-1983. A paired comparison t-test revealed that differences in abundance between the two years were significant for August ($P<0.01$) and February ($P<0.05$) data. The diversity index (H) increased during November, February, and May of the second year. This increase in the diversity index resulted from both a decrease in abundance of the dominant species and an increase in the total number of species. The six species listed in Table 10 accounted for 98% of the total catch at the offshore stations. Of these six species, only Atlantic menhaden remained fairly stable in abundance over the two years. The most important changes in the trawl catch during the two years were the decreases in numbers of spot in August 1982 and of white perch in February 1983.

The total catch (for all stations) of blue crabs dropped from 1,485 in August 1981-May 1982 to 274 during August 1982-May 1983 (Figure 9). The reduction in numbers of crabs, like that observed for fish, occurred over the entire study area.

Salinity and water temperature play a crucial role in determining the distribution of fish in the upper bay. Salinities and water temperatures were fairly similar in November and February during the two years of the study, but differed in August and May (Table 11). Lower salinity in August of 1982 may have been responsible for the lower abundance of spot and blue crabs in that month. Low salinity during May 1983 was responsible for the presence of several freshwater species and the resulting increase in number of species and species diversity.

It is clear that during August 1982-Feburary 1983 numbers of fish and crabs in the vicinity of Hart and Miller Islands were very low compared with those observed in the previous year. The important question is whether this decline in abundance is related to the construction of the containment facility, or is a result of natural fluctuations. Conover and Ross (1982) observed a large change in summer and fall densities of Atlantic silversides in Essex Bay, Massachusetts from one year to the next. Hoff and Ibara (1977) found great annual variation in the abundance of Atlantic silversides, Atlantic menhaden, and white perch in the Slocum River estuary, Massachusetts.

There are several indications that the observed decreases in abundance of fish and crabs in the vicinity of Hart and Miller Islands were not due to the dike construction. First, decreases in abundance of fish and crabs at the control stations (HMS 6 and HMT 10) were similar in magnitude to those observed at those stations which are located close to the facility (Figs. 3, 4, 6-9). Second, coefficients of similarity at both inshore and offshore stations showed no clear spatial patterns which could be attributed to dredging and dike construction. Stations nearest the dike did not consistently rank lower in similarity with control stations than

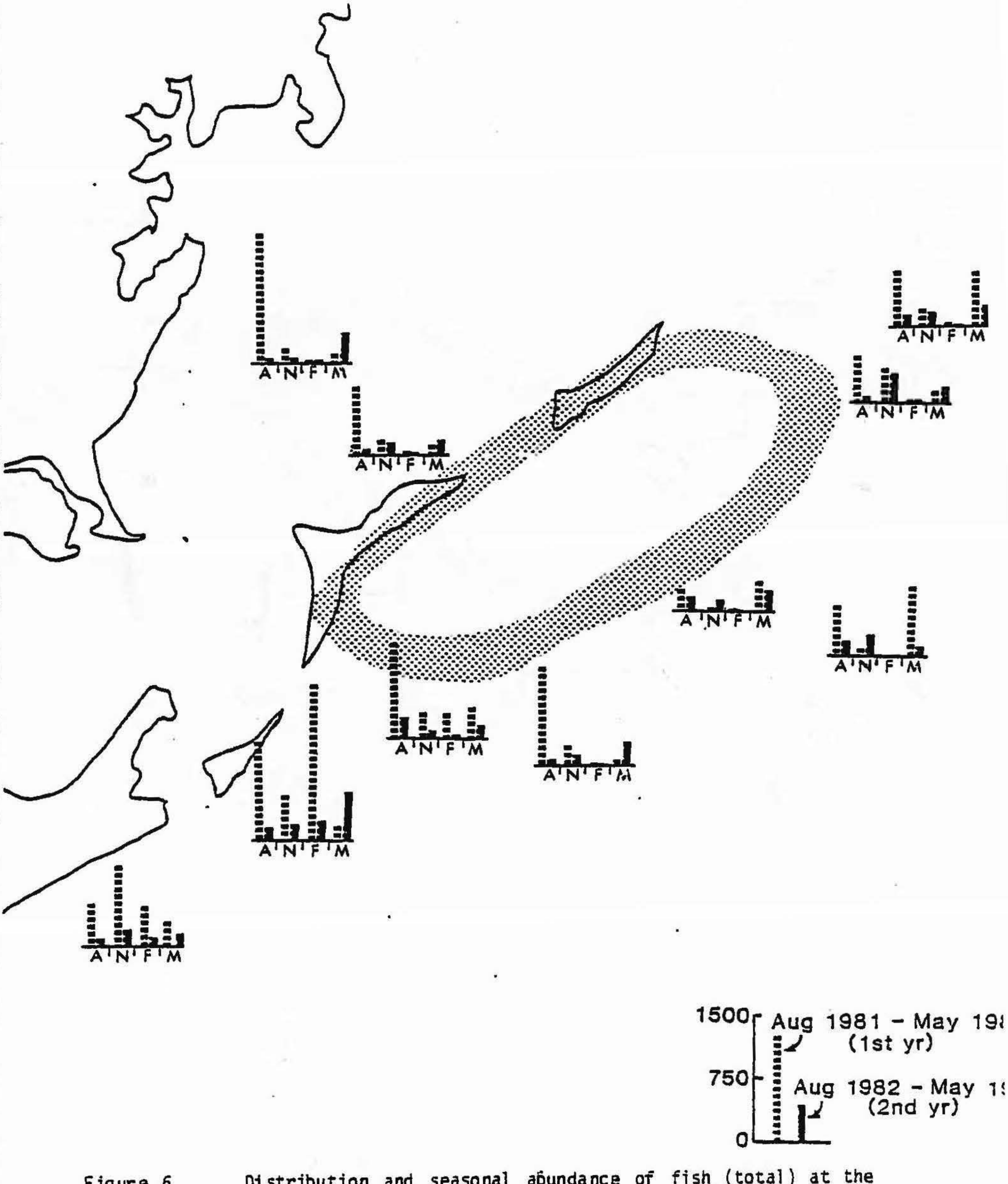

Figure 6. Distribution and seasonal abundance of fish (total) at the offshore stations during August 1981-May 1983 and August 1982- May 1983.

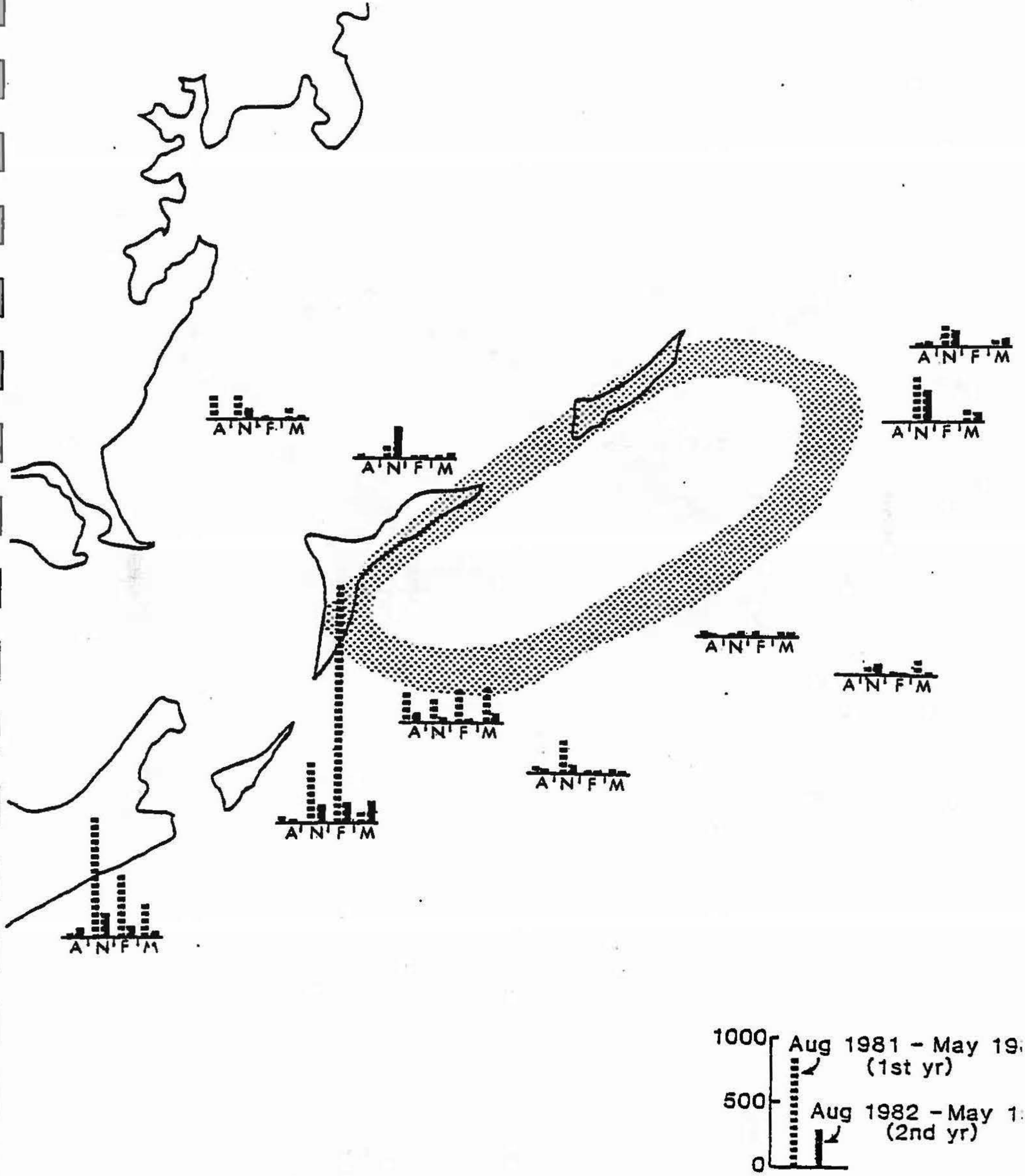

Figure 8. Distribution and seasonal abundance of white perch, (*Morone americana*), at the offshore stations during August 1981-May 1982 and August 1982-May 1983.

Table 10. Numbers of the six most abundant species at the offshore stations during August 1981 - May 1982 and August 1982 - May 1983.

Species	August		November		February		May		Total	
	1981	1982	1981	1982	1982	1983	1982	1983	First Year	Second Year
Morone americana	468	81	2794	1186	2667	255	949	700	6878	2222
Leiostomus xanthurus	6480	697	339	107	0	0	1	1	6820	805
Anchoa mitchilli	366	72	5	215	0	1	1824	232	2195	520
Trinectes maculatus	311	25	7	8	1	0	183	250	502	283
Anguilla rostrata	118	0	1	32	0	0	2	583	121	615
Micropogon undulatus	0	0	1	0	0	1	0	602	1	603

Table 11. Mean bottom salinities and temperatures during August 1981 - May 1982 and August 1982 - May 1983.

	August		November		February		May	
	1981	1982	1981	1982	1982	1983	1982	1983
Mean bottom salinity	9.7	5.8	10.0	10.1	8.2	9.6	3.7	1.1
Mean bottom temperature	23.1	24.6	9.8	8.6	2.6	3.0	20.4	16.9

CHAPTER 7

SUBMERGED AQUATIC MACROPHYTES

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INTRODUCTION

Recent scientific literature emphasizes the importance of submerged macrophyte communities in estuarine systems and research conducted in Chesapeake Bay over the last 5 years has confirmed this general belief. Specifically, healthy submerged macrophyte communities were found to: (1) provide an important refuge and habitat for many estuarine species; (2) provide a considerable capacity for trapping and stabilizing estuarine sediments thus reducing turbidity; (3) act as natural nutrient buffers wherein nutrients associated with diffuse-source runoff are rapidly removed from solution and incorporated into plant tissue and; (4) produce a substantial amount of organic matter which is of direct use to water fowl as well as detrital-based food webs (Kemp et al., 1984). In view of the general importance of this ecosystem component a program was designed and implemented to monitor for the presence or absence of submerged vascular plants as part of the Hart and Miller Islands Program. The results of this effort have largely been reported previously (Kaumeyer and Boynton, 1982; Kaumeyer, 1982) and here we provide a summary which includes a review of historical records and an overview of observations made between August 1981 and June 1983.

HISTORICAL RECORDS

Between 1960 and 1980 there were 5 surveys of submerged vascular plant communities conducted in the vicinity of Hart and Miller Islands (Stotts, 1961; Monro, pers. comm.; Anderson and Macomber, 1978; Nichols and Anderson, 1980; Nichols et al., 1980). While submerged vascular plant communities were generally quite healthy in the early 1960's (Bayley et al., 1978) the Stotts survey at that time found only one location on the western shore of Hart Island supporting macrophyte growth. However, this survey was conducted in October, a time of the year when some plant species have lost above-ground structures. The long-term monitoring study conducted by the U.S. Fish and Wildlife Service (Monro, pers. comm.) also have not detected any significant macrophyte growth around Hart and Miller Islands since their study began in 1971.

In contrast to the findings of the Stotts (1961) and Monro (pers. comm.) Anderson and Macomber (1980) found several sites having submerged vascular plant communities along the northwestern and southwestern shore of Miller Island during an aerial survey in 1978. Similarly, Nichols

CHAPTER 8

TRACE METALS

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SUMMARY

Chemical monitoring of biota, sediments and water from the Hart and Miller Island area was carried out during 1981-83 in order to provide extensive background data prior to the construction and operation of the containment facility. The work was undertaken to provide baseline levels for chemicals in the environment which could be used as reference data in the event of future suspected contamination.

Analysis of biota is a common form of monitoring the environment and is prompted by concern for the health of the organisms themselves and of possible consumers including man. Several species act as natural indicators of trace metals and other pollutants in the environment. However, care must be taken in interpreting such chemical data in view of the natural variability of contaminant levels in many organisms. Furthermore it has been shown that there may be significant seasonal effects on the chemical content of several species. Contributory causes may be run-off, salinity and differential growth rates, and such factors may also partially explain differences between pollutant concentrations in organisms from different sites. Several factors must, therefore be considered before attributing different levels of contaminants in organisms to a pollution situation.

Several different species occupying differing habitats were studied. Some were selected for their potential as bioindicators, others because of their food value. These species were white perch (*Morone americanus*), silverside (*Menidia menidia*), spot (*Liostomus xanthurus*), blue crab (*Callinectes sapidus*), Baltic clam (*Macoma balthica*), benthic shrimps (*Leptocheirus plumulosus*), benthic worms (*Scolecolipedes viridis*), the curved mussel (*Brachiodontes recurvus*) and the American eastern oyster (*Crassostrea virginica*). All except the last two species were indigenous

and worms (Scolecolipedes) was recommended together with the analysis of a single seasonally-matched sample.

It was stressed that the effect of extrinsic factors (e.g. salinity) and intrinsic factors (e.g. body size) on trace metal concentration should be taken into account and that continuity of the program will be critical to its effectiveness. The information and experience is now available to create an effective annual monitoring program on the basis of approximately 380 biota samples. Some reduction in the number of metals analyzed may be possible in the future.

MATERIALS AND METHODS

TRACE METAL ANALYSES

All analyses contained herein are on a dry weight basis following digestion with concentrated nitric acid. All dry weights are whole body weights with the exception of the fish which have been evicerated before digestion. Atomic absorbtion spectroscopy was usually performed on a Perkin Elmer 503 AAS fitted with a graphite furnace, although samples with higher metal concentrations were analyzed by flame AAS.

Mercury, arsenic and selenium were analyzed using the Perkin-Elmer MHS-10 hydride analyzer. A slight problem arose when samples were highly acidic. Foaming occurred, and for all analysis except those done on sediments we were unable to use more than 0.50 mls of sample for each analysis. Antifoaming agents were used but did little or nothing to reduce this problem.

The highest volume allowable for each of these analys s is 10 mls. Since we used 0.50 mls or less for each analyses, when a sample was run and the value was less than our lowest standard we found it necessary to report Not Detectable (N.D.). For further explanation of individual metal methodologies consult table 1.

Standard curves were obtained by regression of at least three standard solutions of each metal. Most analyses were the result of duplicate samples. Additional quality assurance was done on EPA water samples and NBS tissue and sediment samples in conjunction with an independent laboratory. Our results coincide extremely well with the EPA standards, NBS standards, and the independent laboratory. These results are reported in Tables 2 and 3.

RESULTS AND DISCUSSION

Sediments

Figure 1 shows the positions of the stations sampled for surface sediment during September 1982. For sampling methodology see Kerhin et al. (Section IV, this report).

Trace metal concentrations in surficial sediments collected in September 1982 are listed in Table 4 and mapped in Figures 2-10. Box core samples were collected in June 1983 and the results listed in Table 5. Maps showing the relative positions of these samples are given in Figures 11-20. In terms of overall metal concentration (dry weight basis) the picture is very similar to that noted in 1981, that is, a general trend towards lower concentrations at the eastern end of the study area. To the north, the Spry Island reference site, added in 1982, (Station 22) showed higher metal concentrations than sites 10, 11 and 13 due east of the dyke although these levels were only moderate. The station (23) added in the Back River estuary generally had the highest metal concentrations and tended to reinforce the impression that this river represents a significant source of metals in the Hart and Miller Islands area. Trace metal iron ratios from Box Core number 7 (BC 7) close to the mouth of the Back River

Table 1 (con't.)

Lead (Pb) in tissue/sediment (b) Digestion with nitric acid followed by direct aspiration AAS (EPA 239.2)

Lead (Pb) in water: EPA special extraction procedure (EPA note METALS 9.2) followed by graphite furnace AAS (EPA 239.2)

Iron (Fe) in tissue/sediment - nitric acid digestion followed by direct aspiration AAS (EPA 236.1)

Tin (Sn) in tissue/sediment (a) nitric acid digestion then addition of 10% ascorbic acid followed by graphite furnace AAS (EPA 282.2)

Tin (Sn) in tissue/sediment (b) nitric acid digestion followed by direct aspiration AAS (EPA 282.1)

Tin (Sn) in water: Perkin Elmer AAS method using hydride generation

Manganese (Mn) in tissue/sediment (a) nitric acid digestion followed by graphite furnace AAS (EPA 243.2)

Manganese (Mn) in tissue/sediment (b) nitric acid digestion followed by direct aspiration AAS (EPA 243.1)

Manganese (Mn) in water - EPA special extraction procedure (EPA note METALS 9.2) followed by graphite furnace AAS (EPA 243.2)

Zinc (Zn) in tissue/sediment (a) nitric acid digestion followed by graphite furnace AAS (EPA 289.2)

Zinc (Zn) in tissue/sediment (b) nitric acid digestion followed by direct aspiration AAS (EPA 289.1)

Zinc (Zn) in water - EPA special extraction ethod (EPA note METALS 9.2) followed by graphite furnace AAS (EPA 289.2)

Copper (Cu) in tissue/sediment (a) nitric acid digestion followed by graphite furnace AAS (EPA 220.2)

Copper (Cu) in tissue/sediment (b) nitric acid digestion followed by direct aspiration AAS (EPA 220.1)

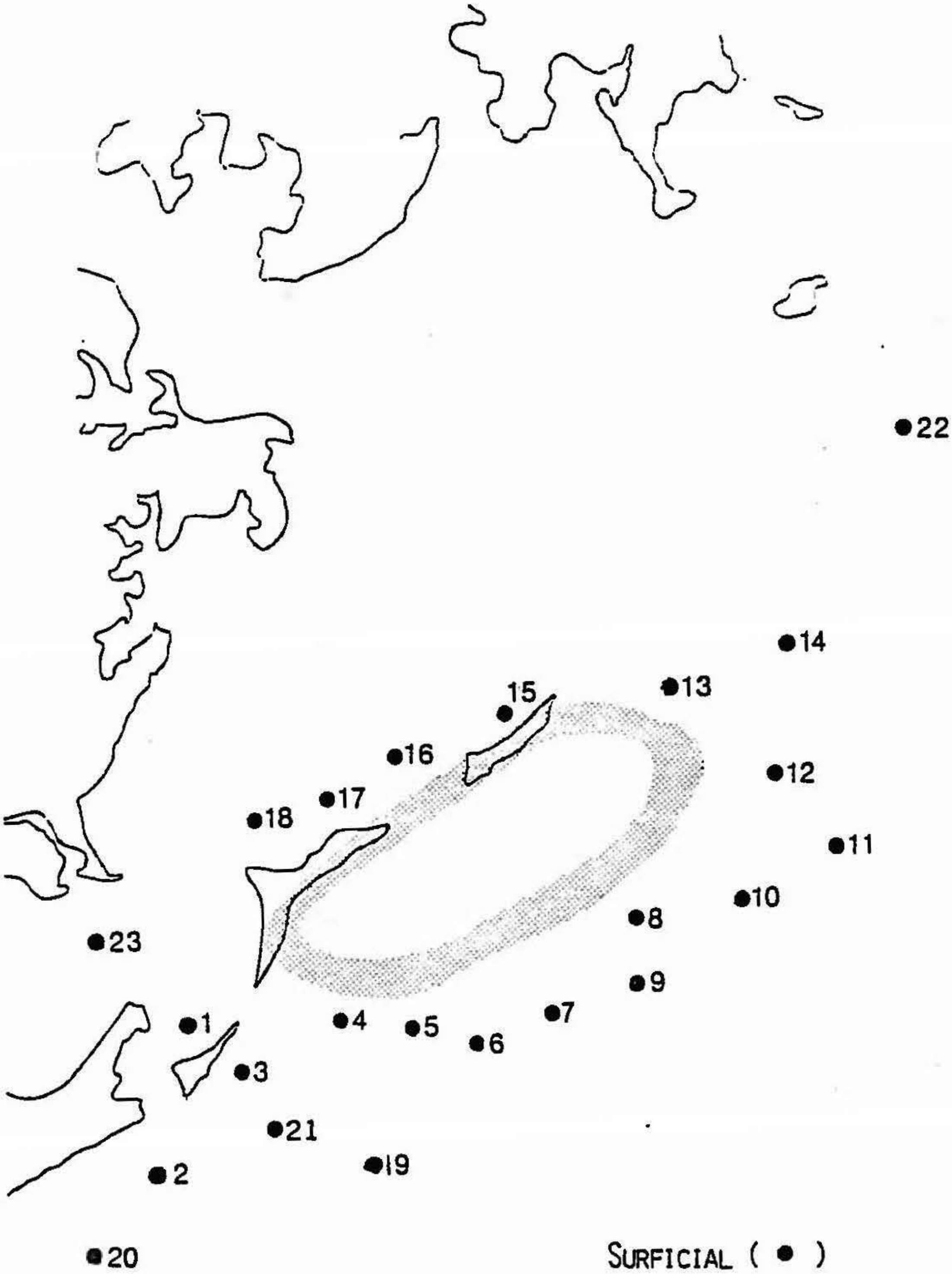
Copper (Cu) in water - EPA special extraction method (EPA note METALS 9.2) followed by graphite furnace AAS (EPA 220.2)

Pesticides in tissue/sediment - methyl chloride extraction - sodium sulphate drying column - fluorocil column clean-up - injection into GC/MS

Phthalate esters and petroleum hydrocarbons - methyl chloride extraction - sodium sulphate drying - GC/MS analysis

Organics in water - preconcentration by SEP-PAK elution with methanol followed by methodology in 053 or 054

Figure 1



SURFICIAL (●)
SEDIMENT COLLECTION STATIONS
SEPTEMBER, 1982.

collected

83.417

Sept 1982

see page 223

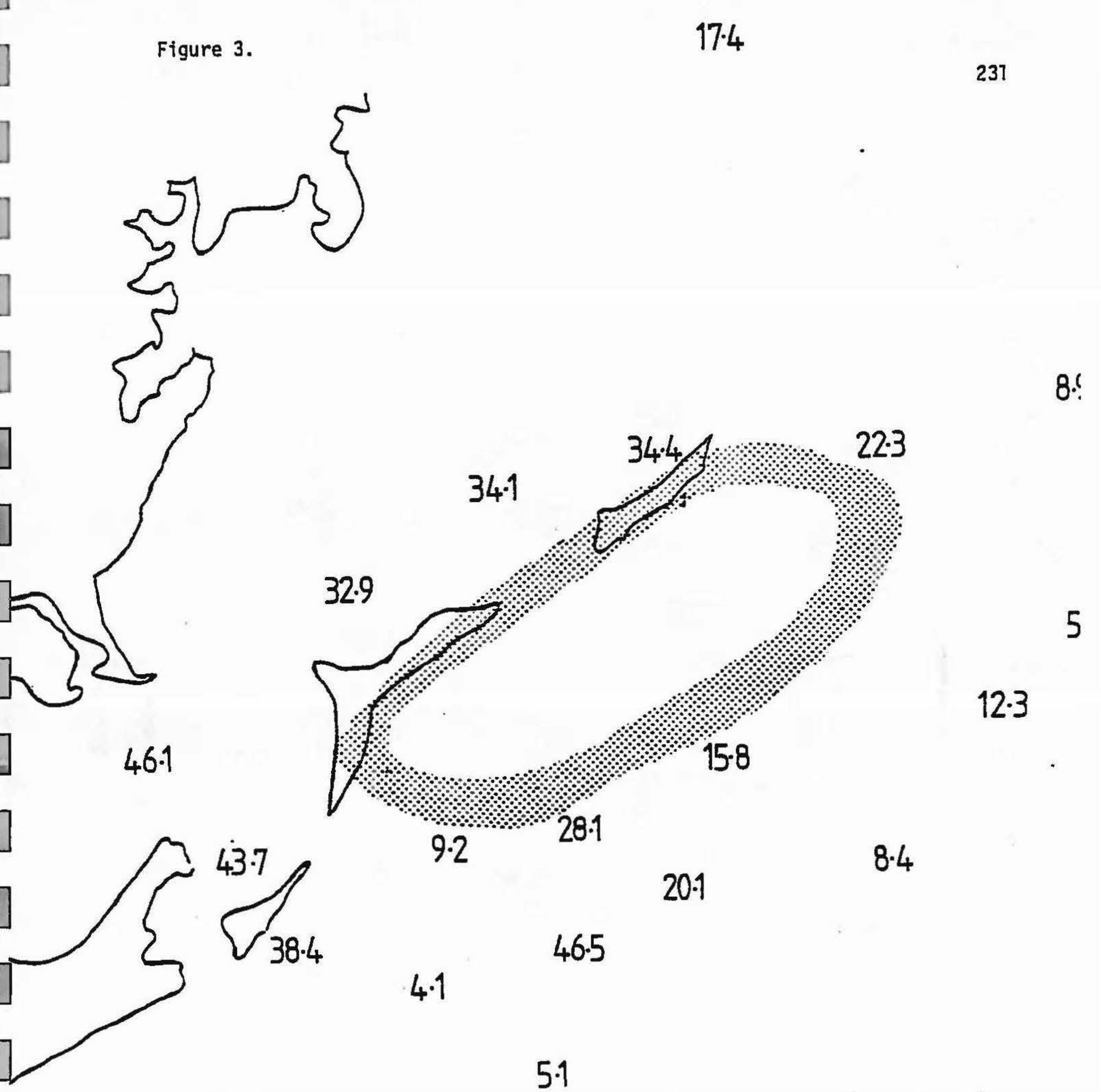
Table 4.
Trace Metal Analysis - Sediments-surficial

10/6/82

Sample I.D.	Ni	47 Zn	26 Cd	28 Cr	50 Cu	37 Pb	44 Mn	31 Hg	23 As	Se	40 Fe
1	46.11	160.1	0.77	30.56	43.7	8.86	851.6	0.05	2.6	N.D.	20,708.
2	25.98	125.7	0.22	13.68	25.1	5.12	771.5	0.04	1.99	N.D.	20,165.
3	78.79	240.9	0.60	24.89	30.4	8.97	1,740.9	0.06	3.42	N.D.	37.522.
4	20.18	65.16	0.14	4.00	9.25	7.52	576.9	0.07	1.28	N.D	# 8,713.
5	43.73	207.4	1.04	9.09	28.1	10.32	1,449.4	0.07	0.88	N.D.	28,396.
6	84.70	261.1	0.52	21.63	46.5	25.96	2,585.0	0.05	1.85	N.D.	38,811.
7	46.60	118.1	0.38	12.98	20.9	12.95	1,029.0	0.05	0.82	N.D.	21,121.
8	21.30	83.14	0.75	7.94	15.8	4.62	664.8	0.03	0.81	N.D.	27,071.
9	15.60	49.76	0.15	3.28	8.36	5.49	447.5	0.035	0.16	N.D.	9,522.
10	24.30	95.84	0.23	11.25	12.3	10.25	824.9	<0.01	0.2	N.D.	15,360.
11	17.80	65.56	0.26	# 6.64	5.90	5.14	549.2	# 0.049	<0.10	N.D.	9,909.
13	42.80	123.7	0.42	26.54	22.3	7.81	999.6	0.02	1.78	N.D.	41,750.
14	19.10	61.94	0.15	7.14	8.97	1.57	161.1	<0.01	0.28	N.D.	17,377.
15	74.00	265.3	0.68	36.66	34.4	26.12	1,376.0	0.085	0.98	N.D.	39,923.
16	90.30	357.0	0.79	44.94	34.1	34.70	2,361.5	0.10	0.90	N.D.	47,555.
18	110.20	294.7	0.69	46.30	32.9	35.85	2,709.3	0.086	1.25	N.D.	55,873.
19	23.10	102.4	0.18	3.78	5.14	4.56	779.2	0.041	0.25	N.D.	10,167.
20	26.00	168.3	0.34	19.84	17.8	4.39	447.9	0.45	0.8	N.D.	16,993.
21	11.70	98.87	0.13	3.98	4.08	5.95	784.0	0.06	0.69	N.D.	5,298.
22	47.20	204.3	0.47	13.38	17.4	16.89	1,575.0	0.06	0.59	N.D.	32,057.
23	88.00	373.2	0.94	59.03	46.1	4.17	4,126.5	0.099	2.48	N.D.	42,959.
Mean	45.59	167.7	0.47	19.41	22.74	11.77	1,277.	0.079	1.20	N.D.	26,060
Std. Dev.	29.92	98.6	0.47	16.07	14.02	10.19	967	0.092	0.89	N.D.	14,646

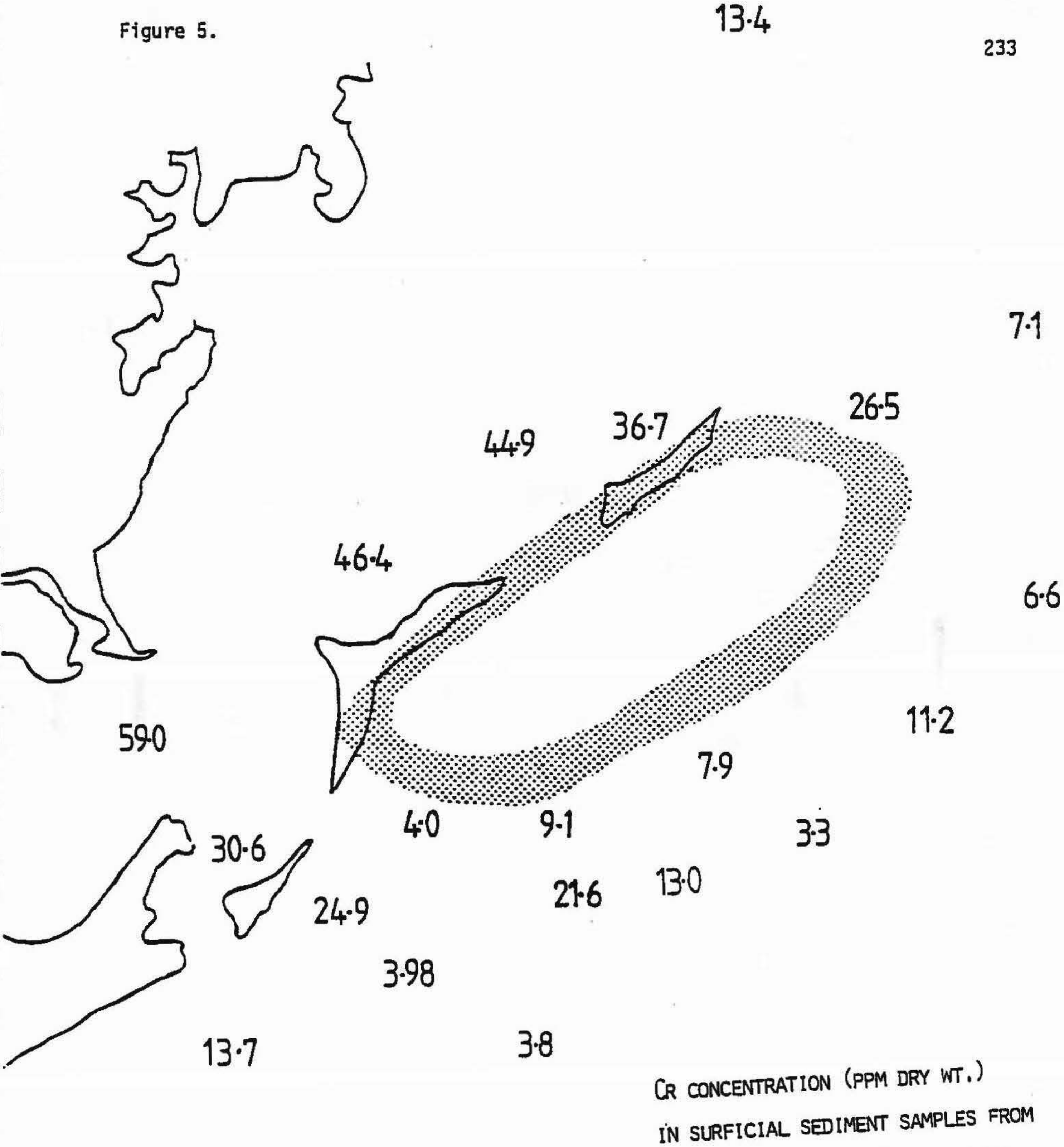
- error found

Figure 3.



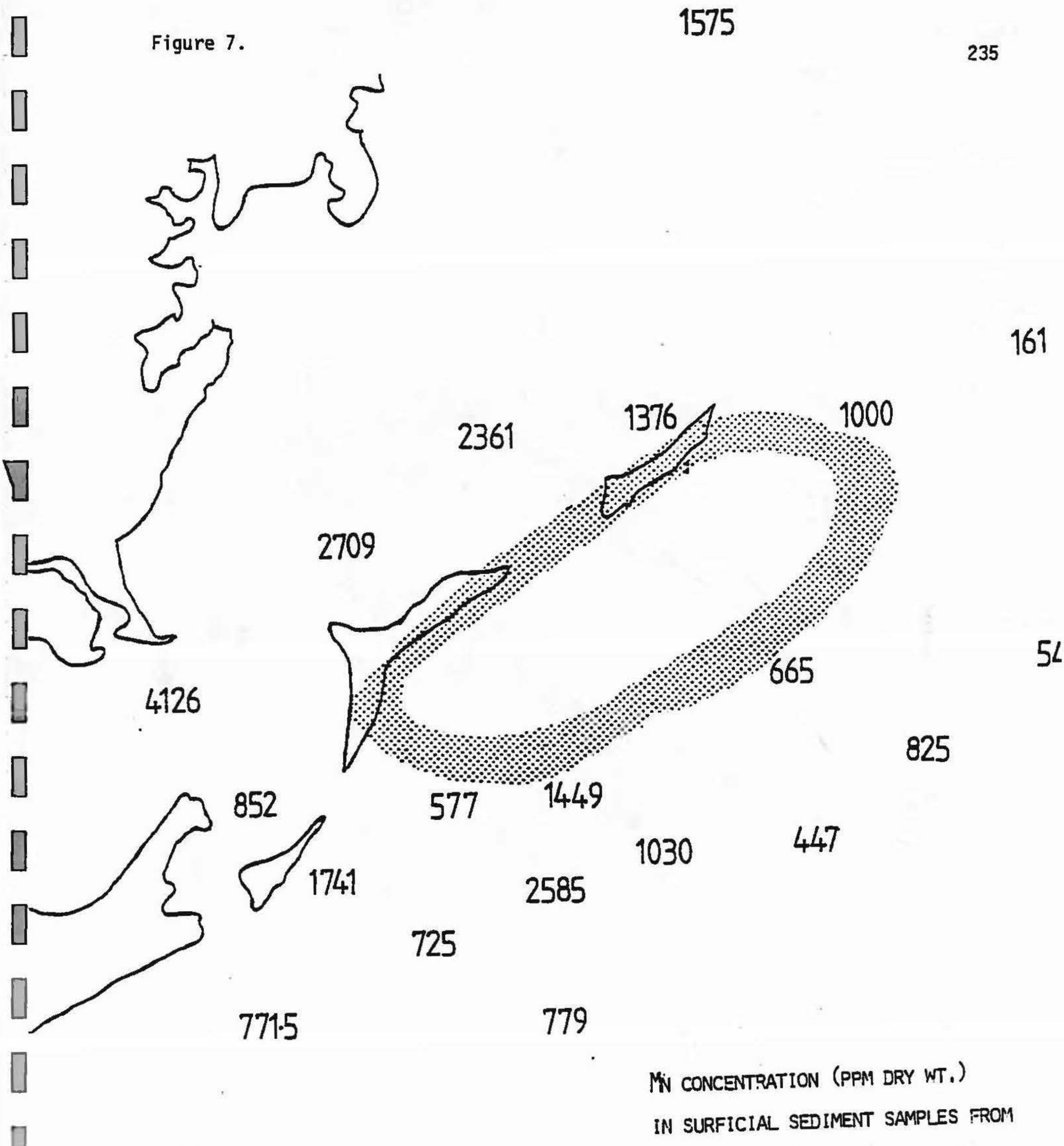
CU CONCENTRATION (PPM DRY WT.) IN SURFICIAL SEDIMENT SAMPLES FROM THE HART AND MILLER ISLANDS AREA COLLECTED IN SEPTEMBER 1982

Figure 5.



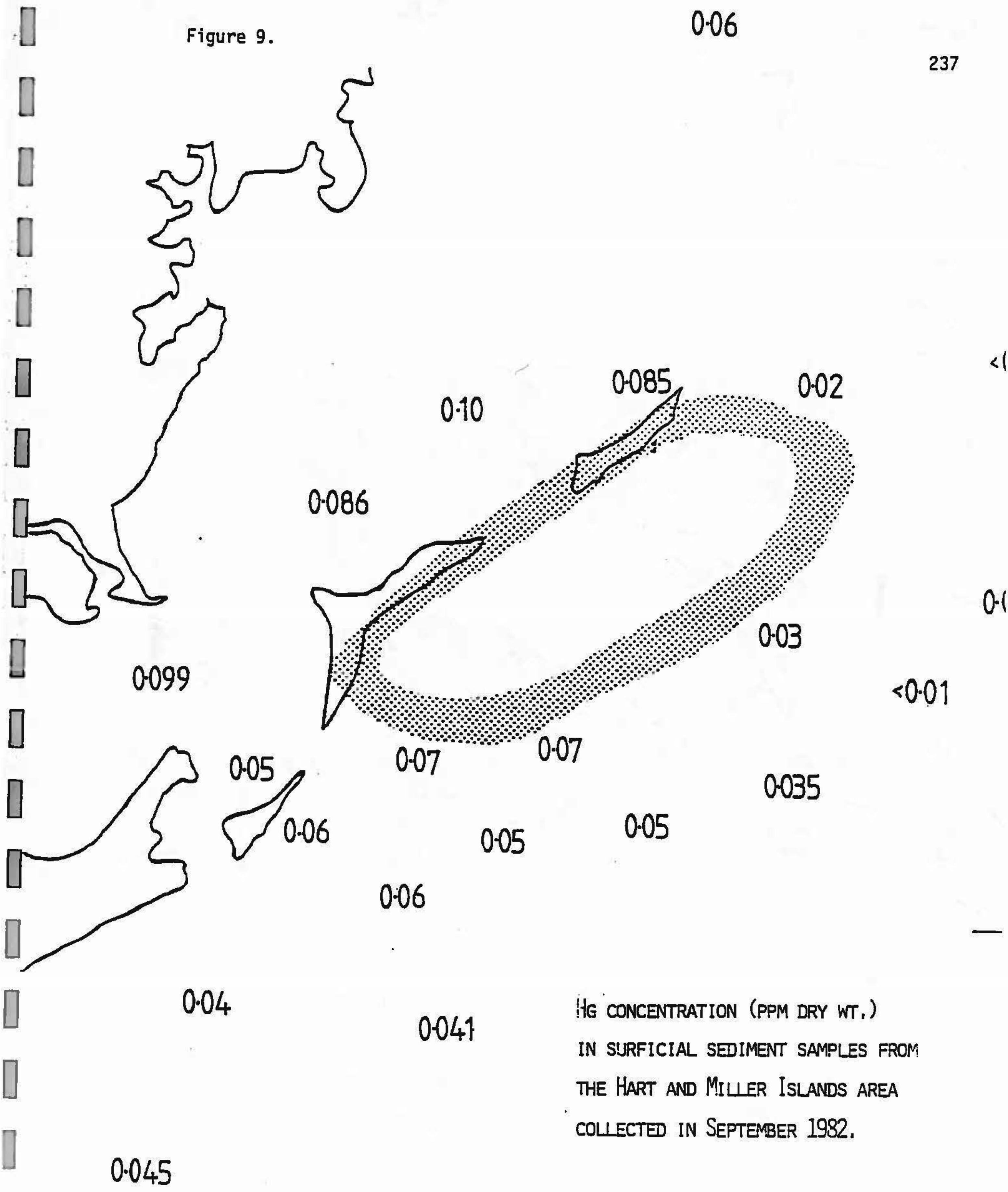
Cr CONCENTRATION (PPM DRY WT.) IN SURFICIAL SEDIMENT SAMPLES FROM THE HART AND MILLER ISLANDS AREA COLLECTED IN SEPTEMBER 1982

Figure 7.



MN CONCENTRATION (PPM DRY WT.)
IN SURFICIAL SEDIMENT SAMPLES FROM
THE HART AND MILLER ISLANDS AREA
COLLECTED IN SEPTEMBER 1982

Figure 9.



Hg concentration (ppm dry wt.) in surficial sediment samples from the Hart and Miller Islands area collected in September 1982.

Table 5.

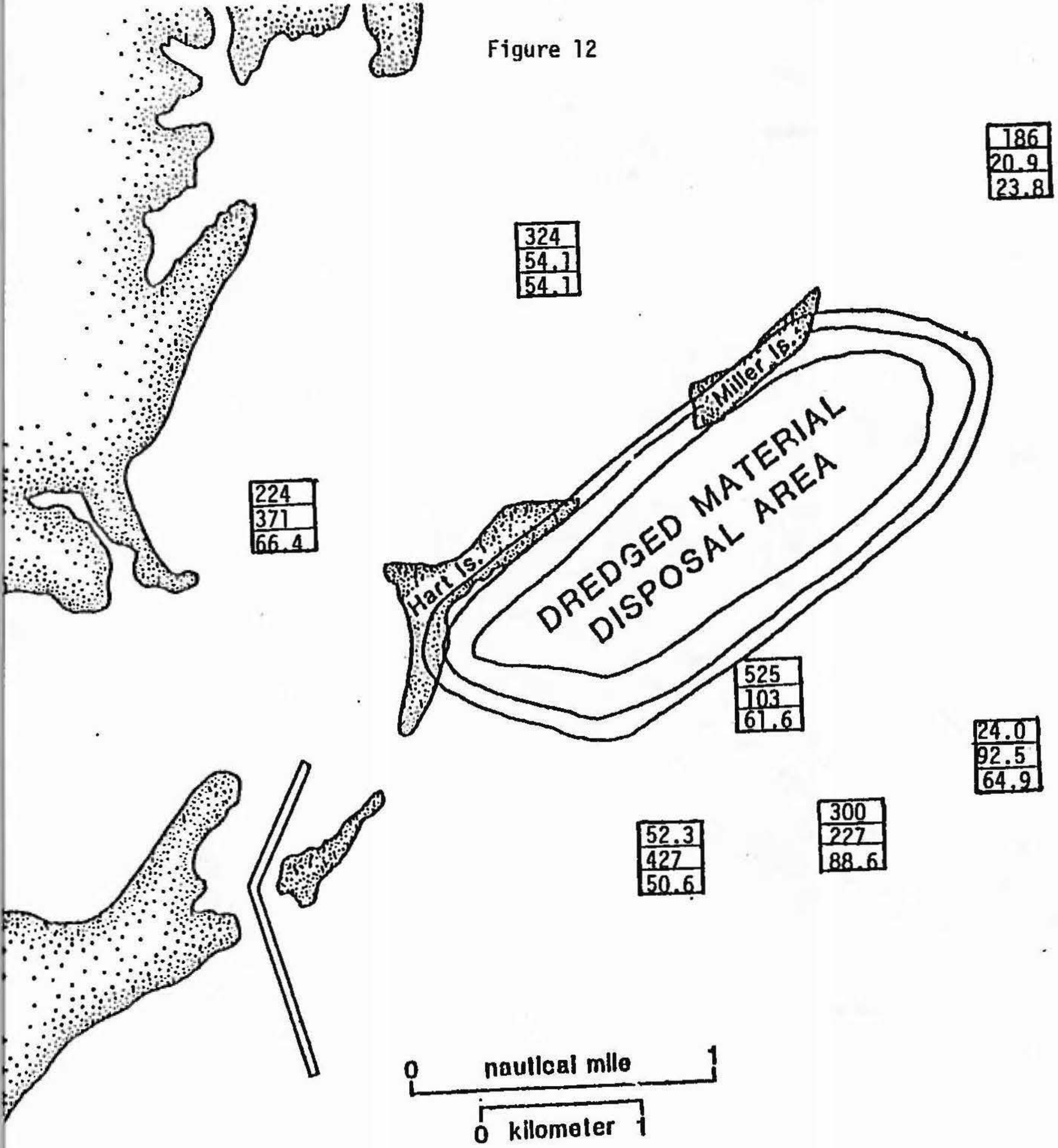
Trace Metal Analysis - Sediments-box core

collected June 83

Sample I.D.	Ni	Zn	Cd	Cr	Cu	Pb	Mn	Hg	As	Se	Fe
BC1-T	33.3	52.3	0.31	27.0	14.2	11.3	410.3	0.011	0.49	0.012	14,447.
M	142.5	427	2.00	64.8	38.0	121	1,267	0.021	1.07	0.022	28,944.
B	49.8	50.6	0.42	31.2	10.5	9.35	699.8	0.010	0.67	0.016	20,131
BC2-T	120.56	300	0.89	61.8	36.0	107	1,578	0.012	0.96	0.021	31,498
M	65.25	227	0.56	35.1	44.8	89.4	1,222	0.065	1.13	0.028	25,854
B	51.57	88.6	0.26	33.3	22.2	51.2	1,162	0.011	0.71	0.017	27,254
BC3 T	16.23	24.0	0.08	11.4	6.38	4.42	72.2	0.006	0.26	0.004	7,451
M	29.79	92.5	0.33	38.7	17.4	46.9	672.0	0.010	0.50	0.007	17,142
B	53.71	64.9	0.22	26.7	15.9	35.3	706.9	0.008	0.67	0.009	19,867
BC4-T	204.98	525	2.57	57.1	99.8	124	2,217	0.026	1.05	0.020	36,438
M	65.43	103	0.36	27.6	19.4	42.2	928.4	0.007	0.63	0.007	22,379
B	44.0	61.6	0.37	46.5	11.1	15.8	1,013	0.013	0.73	0.021	33,176
BC5-T	18.3	186	0.65	73.1	25.6	42.9	1,750	0.025	0.080	0.025	26,913
M	5.89	20.9	0.09	12.8	3.15	7.63	225.6	0.003	0.18	0.001	8,920
B	6.46	23.8	0.13	13.0	3.89	10.8	238.3	0.004	0.29	0.002	9,973
BC6-T	55.1	324	1.29	78.1	35.2	138	1,268	0.021	0.74	0.008	31,296
M	15.2	54.1	0.33	33.4	22.4	41.1	711.6	0.022	0.71	0.009	29,100
B	20.7	54.1	0.18	36.3	9.28	20.2	786.4	0.016	0.42	0.004	23,328
BC7-T	10.65	224	1.28	91.0	41.3	80.7	771.6	0.019	0.57	0.007	21,673
M	21.3	371	2.48	149.6	52.9	276	634.1	0.044	0.57	0.008	23,392
B	136.12	66.4	6.67	255.6	80.0	343	547.2	0.010	0.83	0.083	32.780

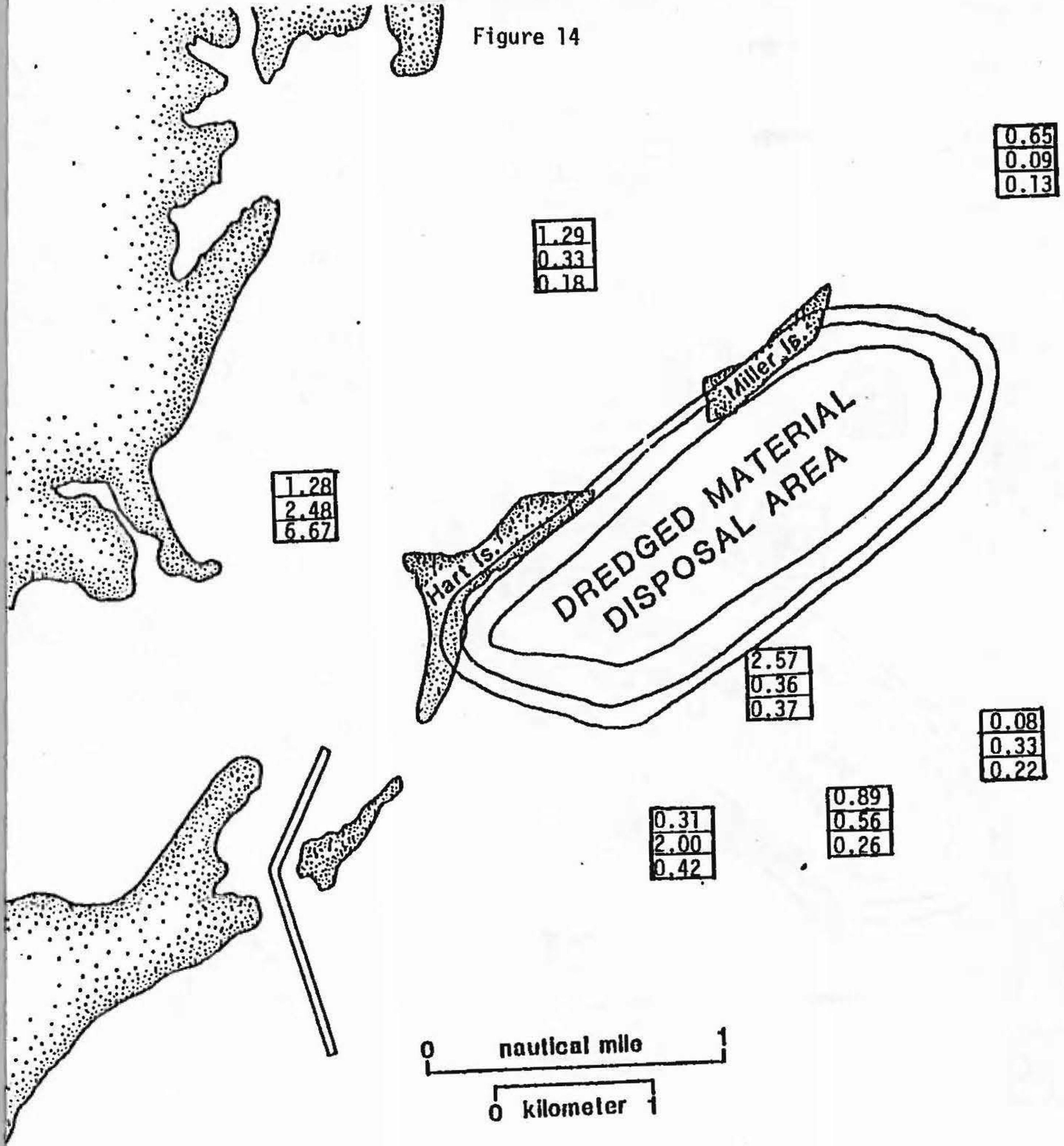
T=Top
M=Middle

Figure 12



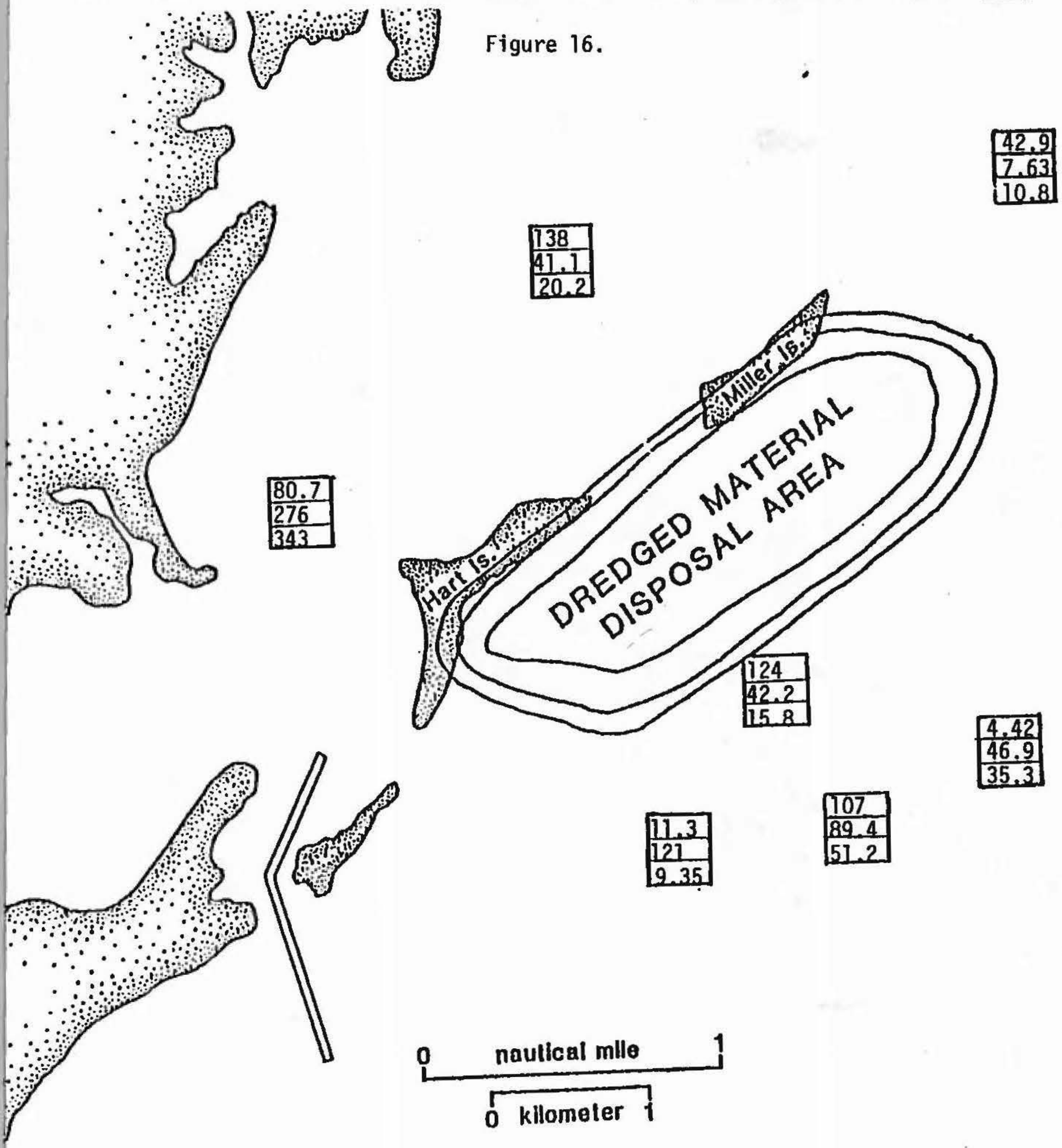
Zn concentration (PPM dry wt.) in box core sediment samples from the Hart and Miller Islands area collected in June 1983.

Figure 14



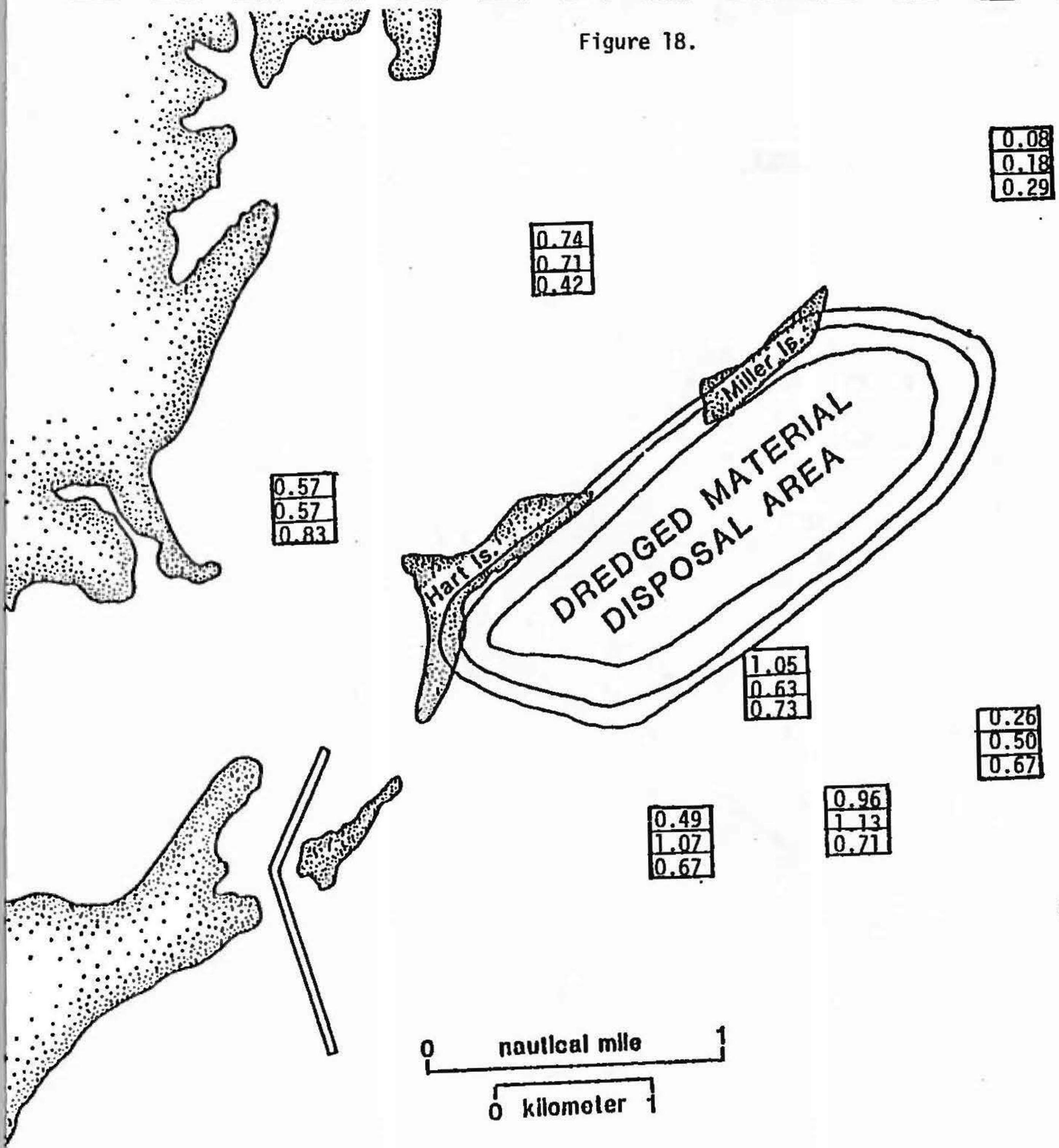
Cd concentration (PPM dry wt.) in box core sediment samples from the Hart and Miller Islands area collected in June 1983.

Figure 16.



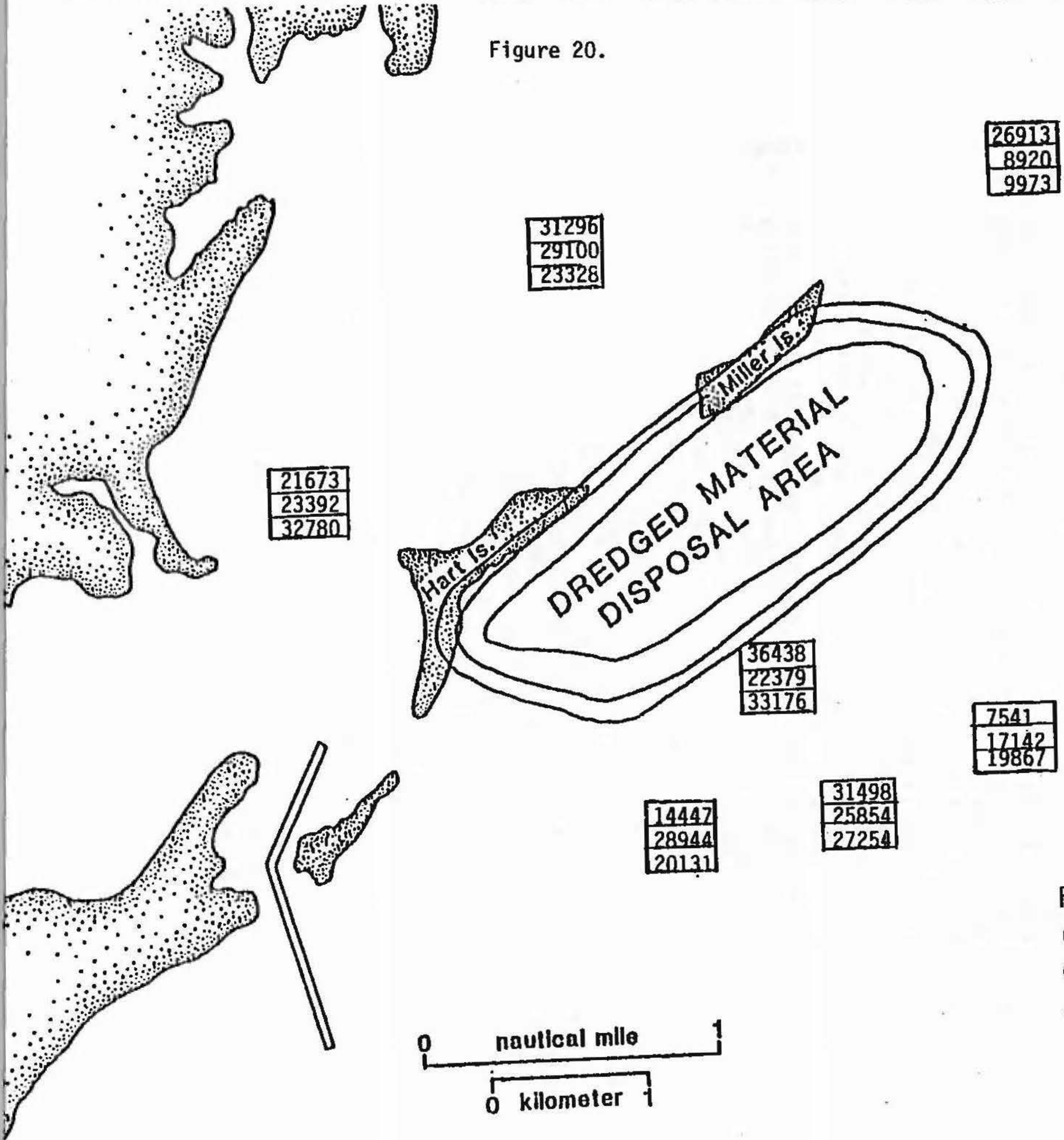
Pd concentration (PPM dry wt.) in box core sediment samples from the Hart and Miller Islands area collected in June 1983.

Figure 18.



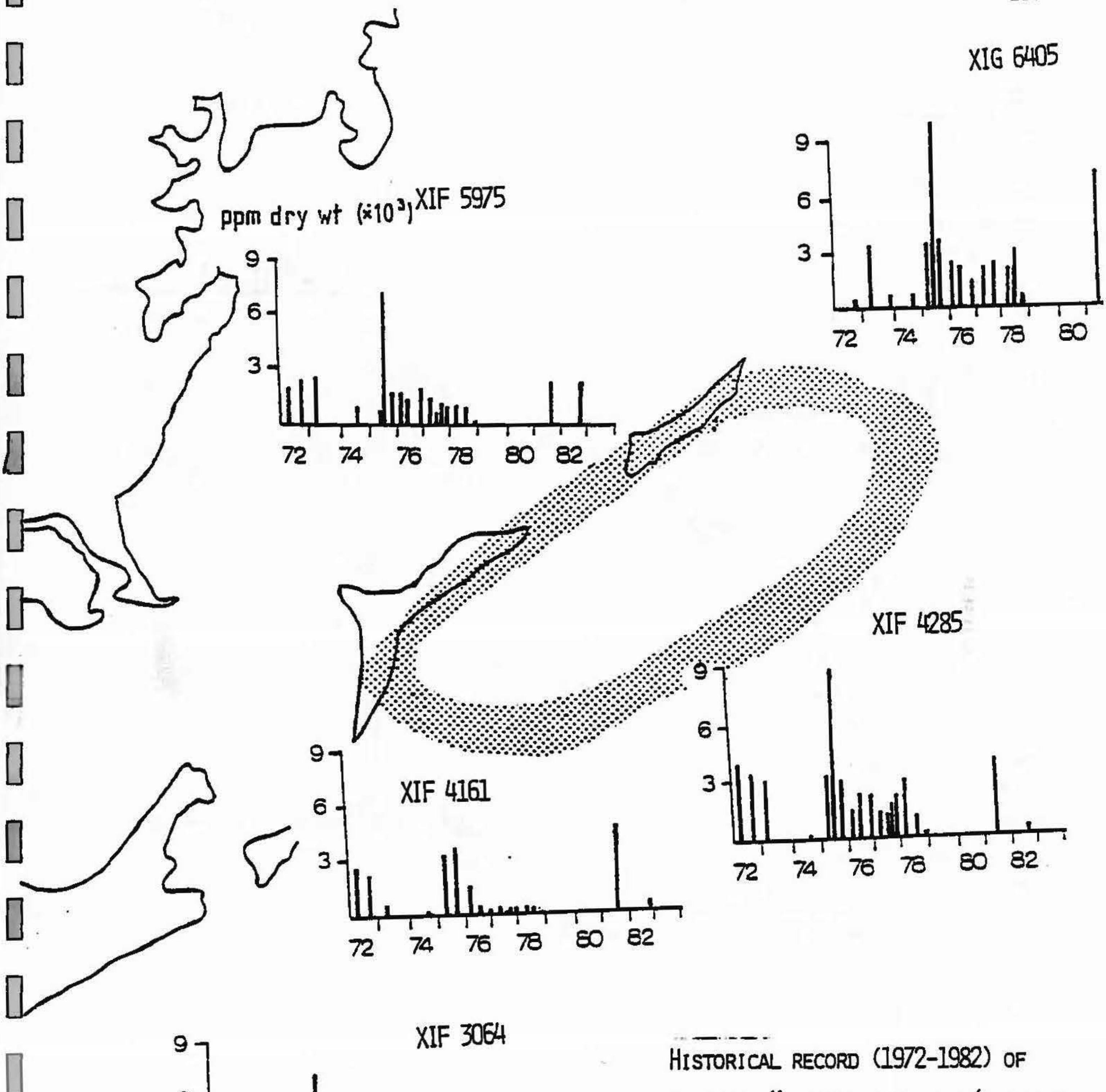
As concentration (PPM dry wt.) in box core sediment samples from the Hart and Miller Islands area collected in June 1983.

Figure 20.



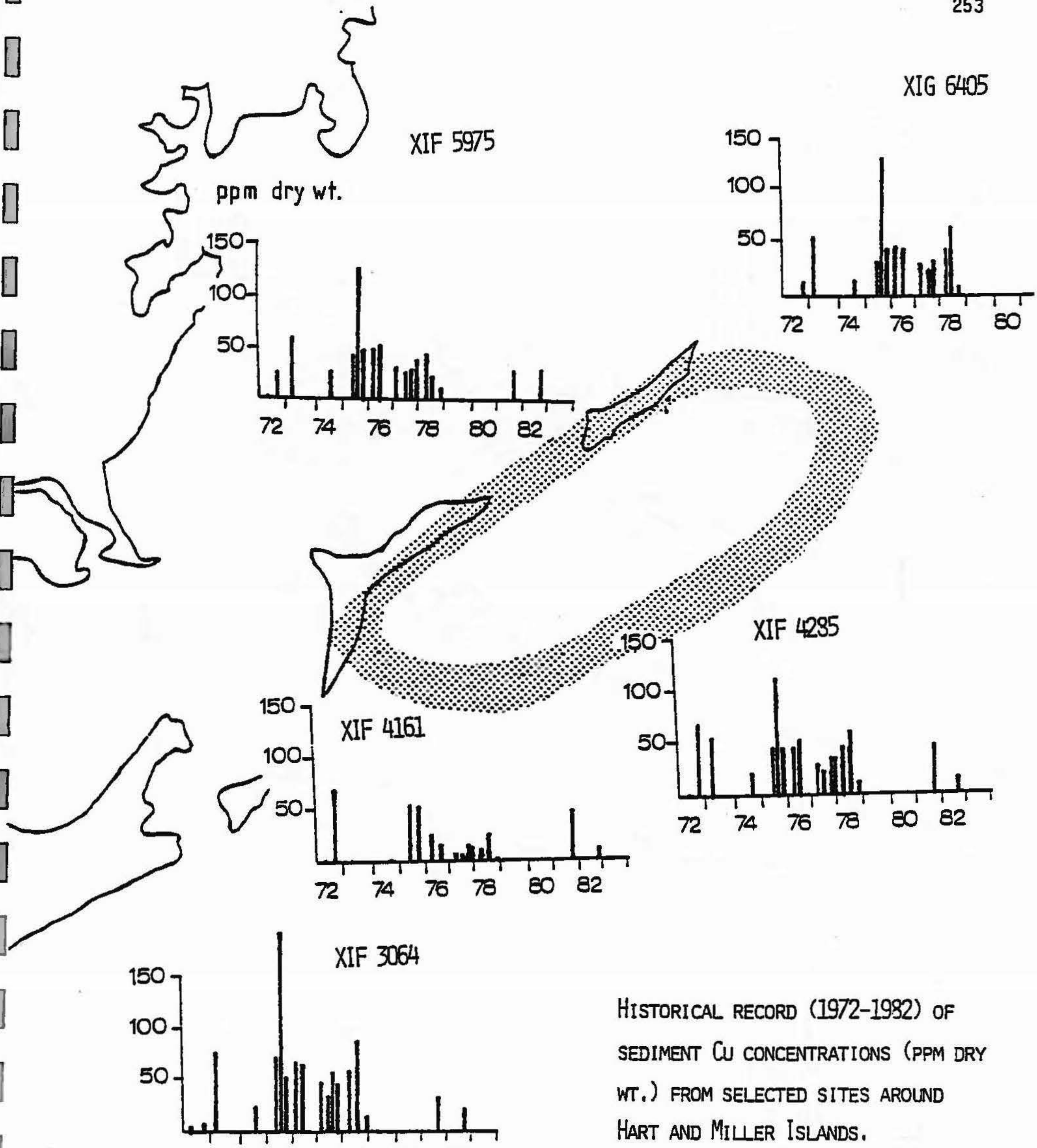
Fe concentration (PPM dry wt.) in box core sediment samples from the Hart and Miller Islands area collected in June 1983.

Figure 21.



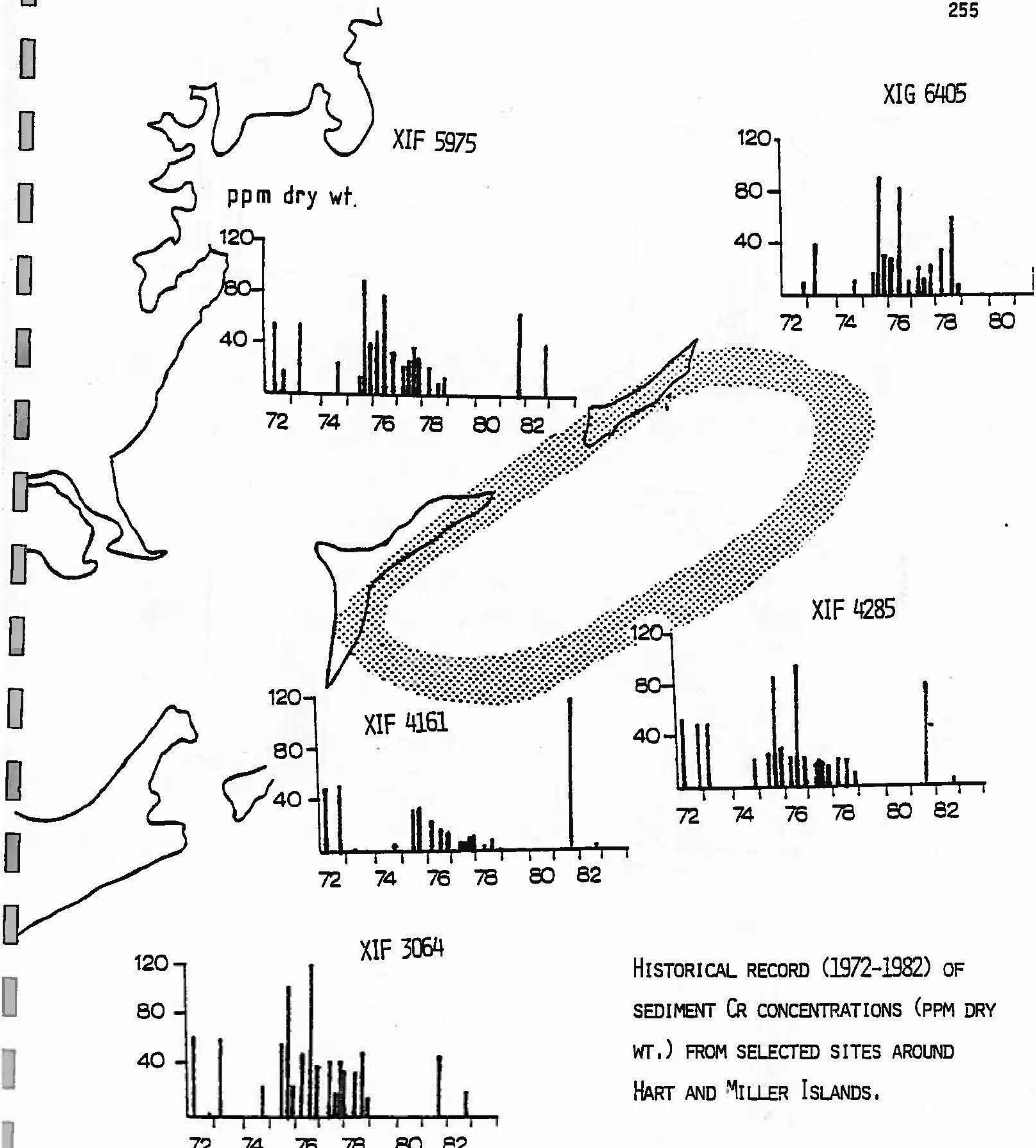
HISTORICAL RECORD (1972-1982) OF SEDIMENT MN CONCENTRATIONS (PPM DRY WT.) FROM SELECTED SITES AROUND HART AND MILLER ISLANDS.

Figure 23.



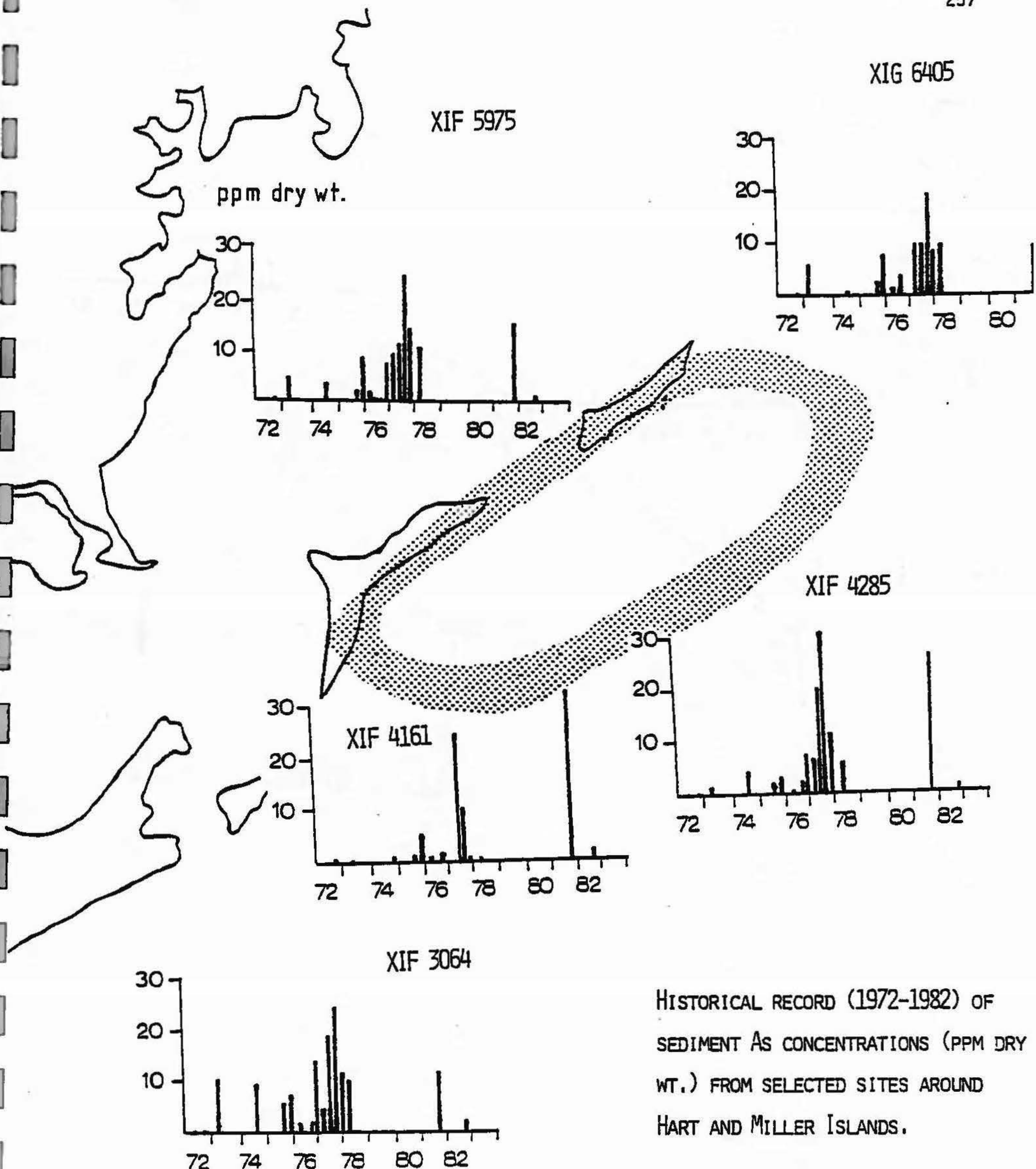
HISTORICAL RECORD (1972-1982) OF SEDIMENT CU CONCENTRATIONS (PPM DRY WT.) FROM SELECTED SITES AROUND HART AND MILLER ISLANDS.

Figure 25.



HISTORICAL RECORD (1972-1982) OF SEDIMENT CR CONCENTRATIONS (PPM DRY WT.) FROM SELECTED SITES AROUND HART AND MILLER ISLANDS.

Figure 27.



HISTORICAL RECORD (1972-1982) OF SEDIMENT As CONCENTRATIONS (PPM DRY WT.) FROM SELECTED SITES AROUND HART AND MILLER ISLANDS.

Table 6.

Trace metal/iron ratios for surficial sediment samples collected in September 1981 (Boxes enclose 3 highest values)

Station No.	Trace metal/Fe ratio ($x 10^{-5}$)										
	Ni	Zn	Cd	Cr	Cu	Pb	Mn	Hg	As	Se	Sn
1	313	592	0.83	109	71	214	4,750	**0.53**	15	0.01	**25**
2	298	705	0.73	123	62	368	13,176	0.49	11	0.06	**13**
3	233	846	**0.86**	**170**	**111**	234	22,456	**0.53**	**23**	0.22	8
5	402	594	0.60	117	73	309	10,083	0.23	**22**	0.42	0.8
6	**660**	680	0.57	129	78	301	14,441	0.19	10	0.53	8
7	340	808	0.66	124	78	148	17,003	0.20	10	**0.77**	3
8	216	**1,473**	0.62	124	88	65	16,293	0.18	8	0.69	4
9	**526**	**1,187**	**1.07**	**187**	**175**	107	20,990	0.26	14	**0.91**	8
10	125	649	0.67	117	83	**411**	**36,891**	**0.51**	12	0.02	9
11	152	315	0.25	68	46	170	9,037	0.29	10	0.008	12
12	381	647	0.52	108	70	362	**39,974**	0.33	13	0.008	1
13	386	806	0.50	139	107	304	10,666	0.48	**24**	**0.91**	7
14	**412**	868	0.80	123	57	266	**41,564**	0,10	7	0,02	1
15	241	570	0.36	103	70	249	7,845	0,19	7	0.05	2
16	267	672	0,58	147	106	282	12,124	0.26	9	0,22	**18**
17	258	723	0.42	117	76	291	11,472	0.16	9	0.51	4
18	159	649	0.37	110	65	64	5,767	0.13	6	0.28	3
19	288	797	0.62	157	**121**	**459**	6,411	0.22	8	0.45	5
20	335	**969**	**0.84**	**161**	101	**381**	14,591	0.16	11	0,21	7

For an analysis of metal/metal ratios in sediment samples, the reader is referred to the 1981/1982 interpretive report (C.R.C. 1982).

BIOTA ANALYSES

A map showing sampling stations for biota referred to in this report is given in Figure 29.

Individual Variability

Sample size is often given insufficient consideration in monitoring studies, and it was found during the first year of study that this problem was compounded by the presence of outliers ie. individuals with unnaturally high metal levels, which were capable of disproportionately affecting the mean of a collection (see 1981-1982 Interpretive Report, Section VI). Clearly the sample size (ie. number of individuals comprising a sample) must be sufficiently large to minimize the effect of these outliers, without making the collecting effort impractical. This was investigated empirically in the 1981-1982 interpretive report (Cronin et al. 1982) by taking the analyses of individuals, randomizing them and then computing a cumulative mean. As more individuals were added, this running mean converged with the mean metal concentration of the whole collection. The rate at which this occurred depended on the variability of the material. For example, in some collections it was found that the cumulative mean metal concentration from ten individuals was still more than 40% away from a mean derived from the whole collection of 30 animals. High (and low) outliers caused the running (cumulative) mean to jump considerably as they were added in. In Figures 30-34 this treatment has been refined insofar as, for 5 species, a cumulative mean has been derived ten times from the same data set after re-randomizing the data every time. The mean deviation of the running mean from the collection mean has been plotted as a function of the number of individuals used to compute the mean.

The approach is similar to that used by Gordon et al. (1980) except that those authors initially eliminated high outliers using the formulae of Dixon (1951). Considering the putative use of composite samples (now adopted for all mollusks and benthic invertebrates in the study) it was considered that it would be inappropriate to ignore outliers in the current data as they would in any case be hidden in a pooled sample. The results indicate that, in several cases, a large proportion of the total collection must be added before the running mean falls within 10% of the collection mean. In oysters, for example (Figure 30), this is achieved for zinc and chromium with respectively 23 and 27 of the 30 animals making up the collection. In such cases it is clear that, given the inherent variability associated with these metals, even the use of 30 animals may not be adequate to achieve a true population mean. Clearly in such cases the use of pooled samples is desirable and for oysters, mussels, clams (Macoma), and the benthic invertebrates Leptocheirus and Scolecolipedes the use of pooled samples was adopted in 1982-1983. In the case of the latter species the numbers available for analysis often fell well short of the optimum (usually >15) required for a low % deviation of the mean. Often only 4-6 animals were available for analysis (after considerable collection

Figure 30. (Crassostrea virginica)

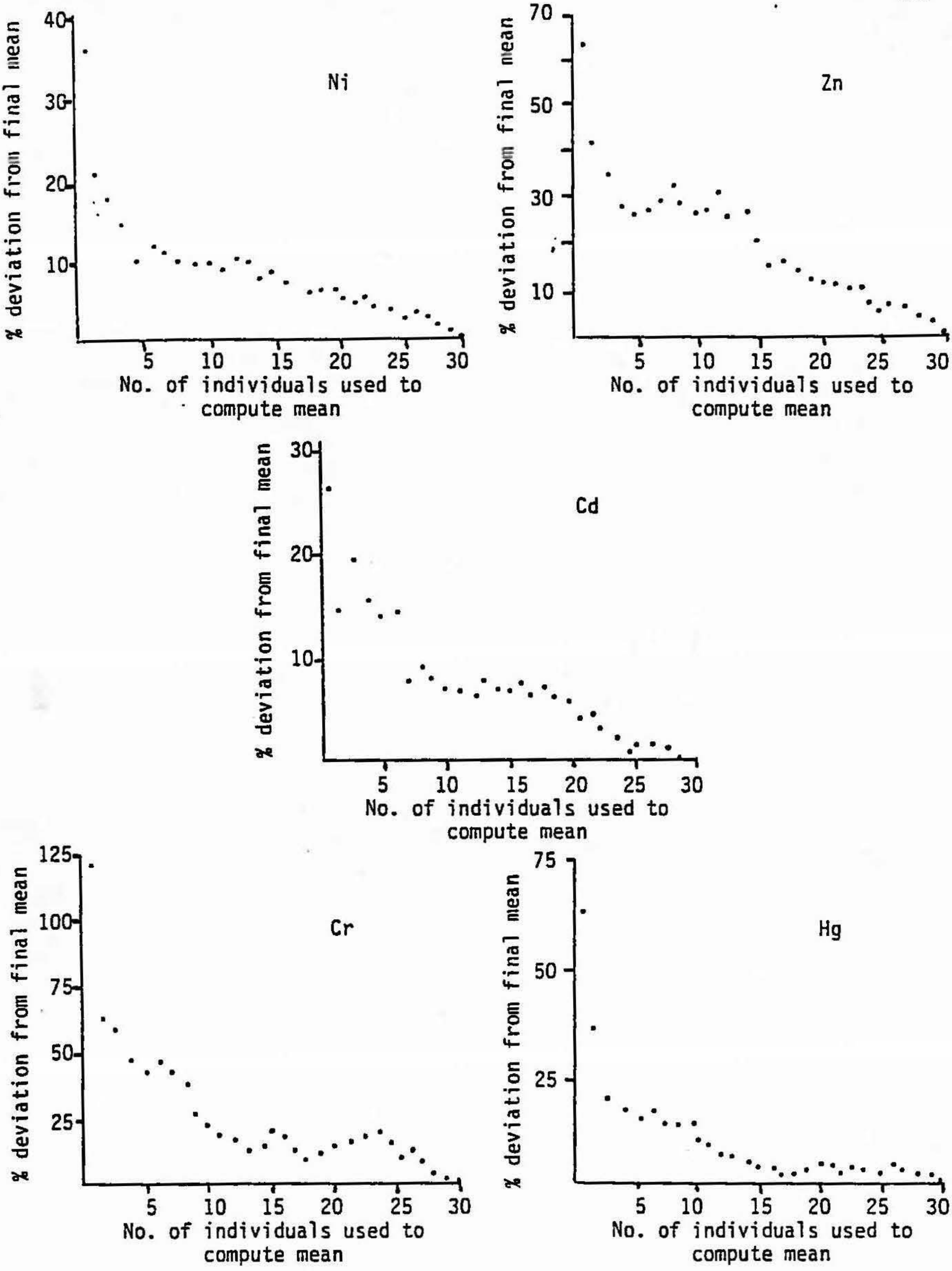


Figure 32. (Macoma balthica)

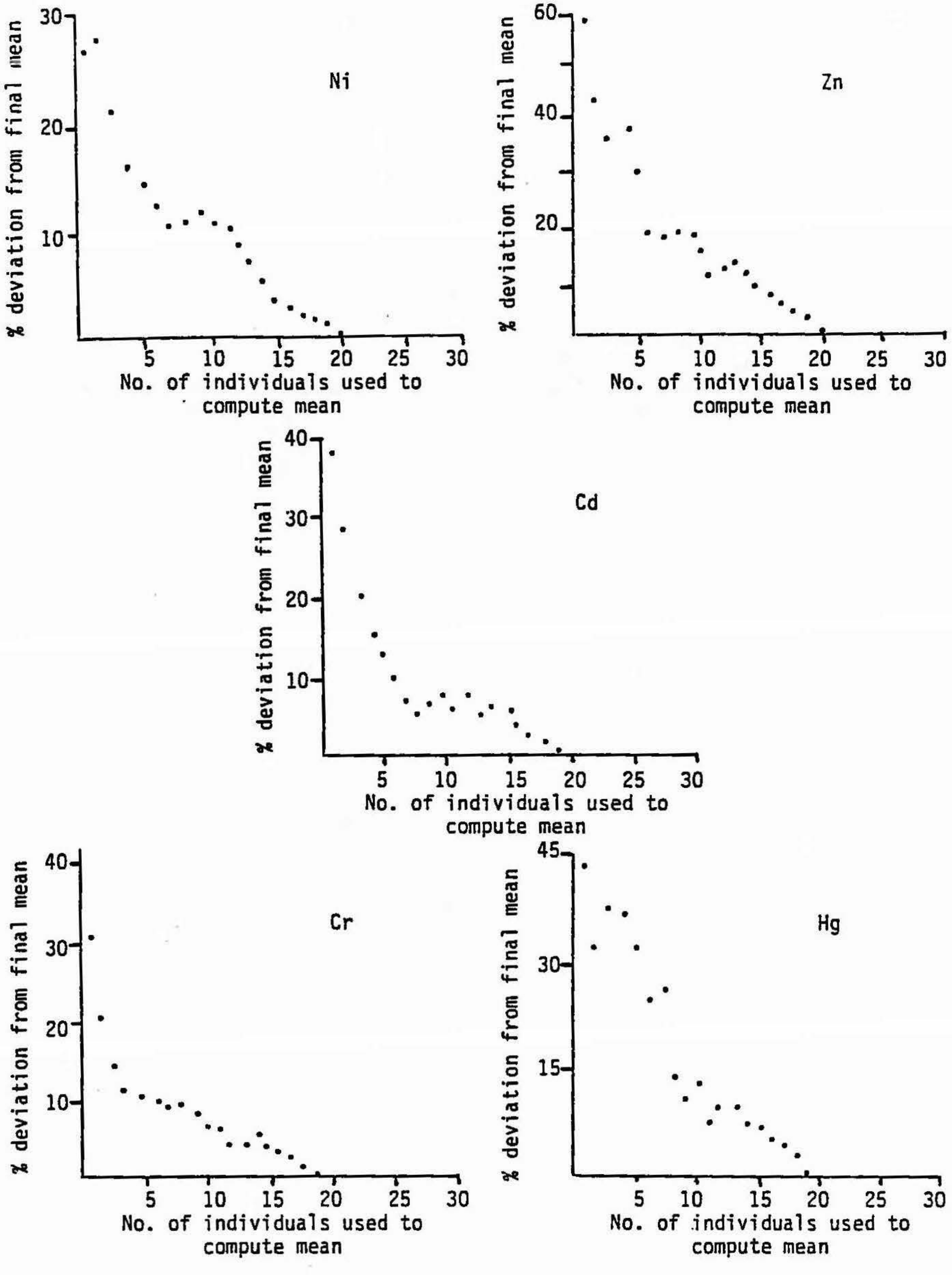


Figure 34. (Scolecolepides viridis)

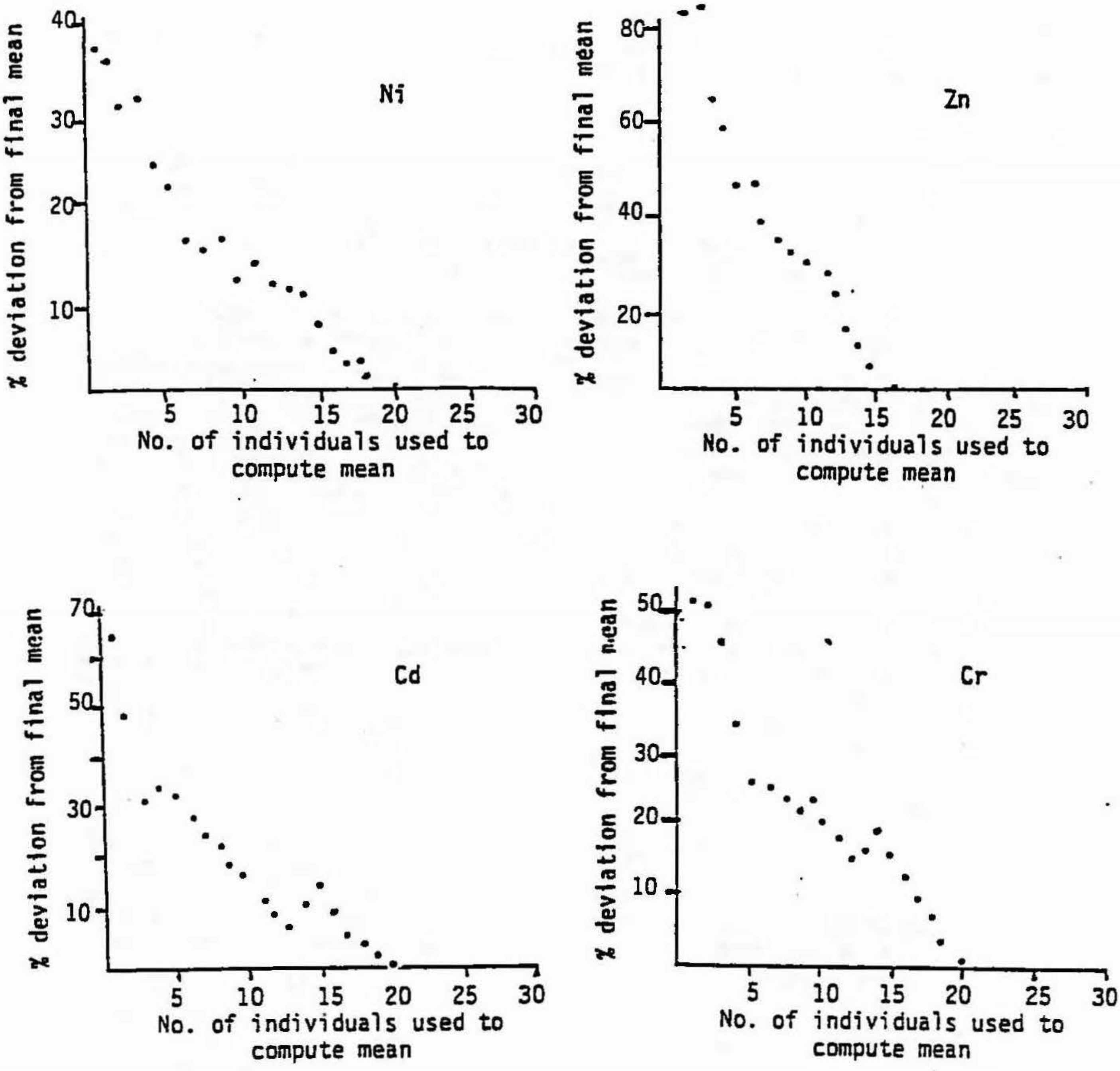


Figure 35.

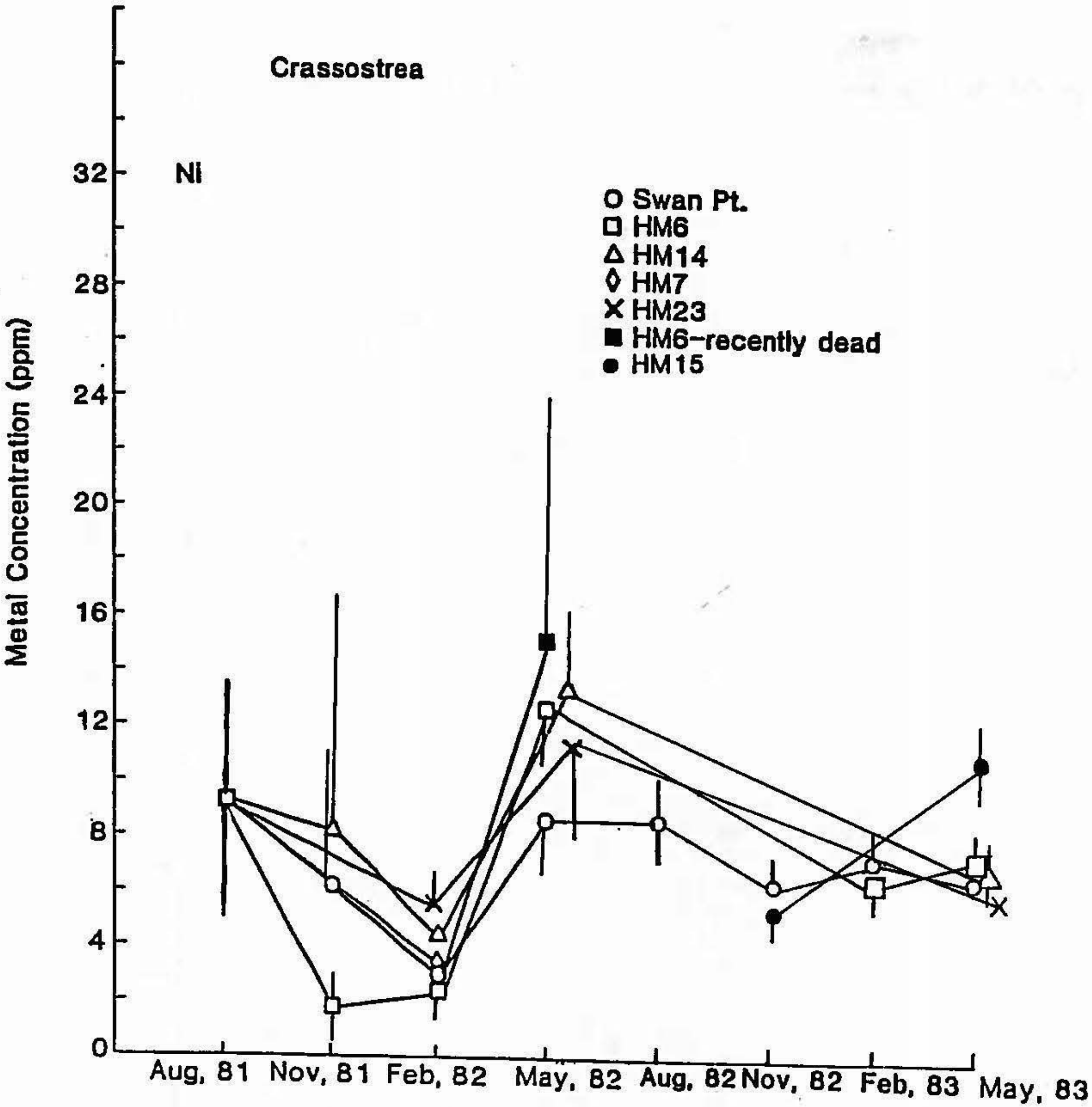

Crassostrea
Ni
Swan Pt.
HM6
HM14
HM7
HM23
HM6-recently dead
HM15
Metal Concentration (ppm)
0
4
8
12
16
20
24
28
32
Aug, 81
Nov, 81
Feb, 82
May, 82
Aug, 82
Nov, 82
Feb, 83
May, 83

Figure 37.

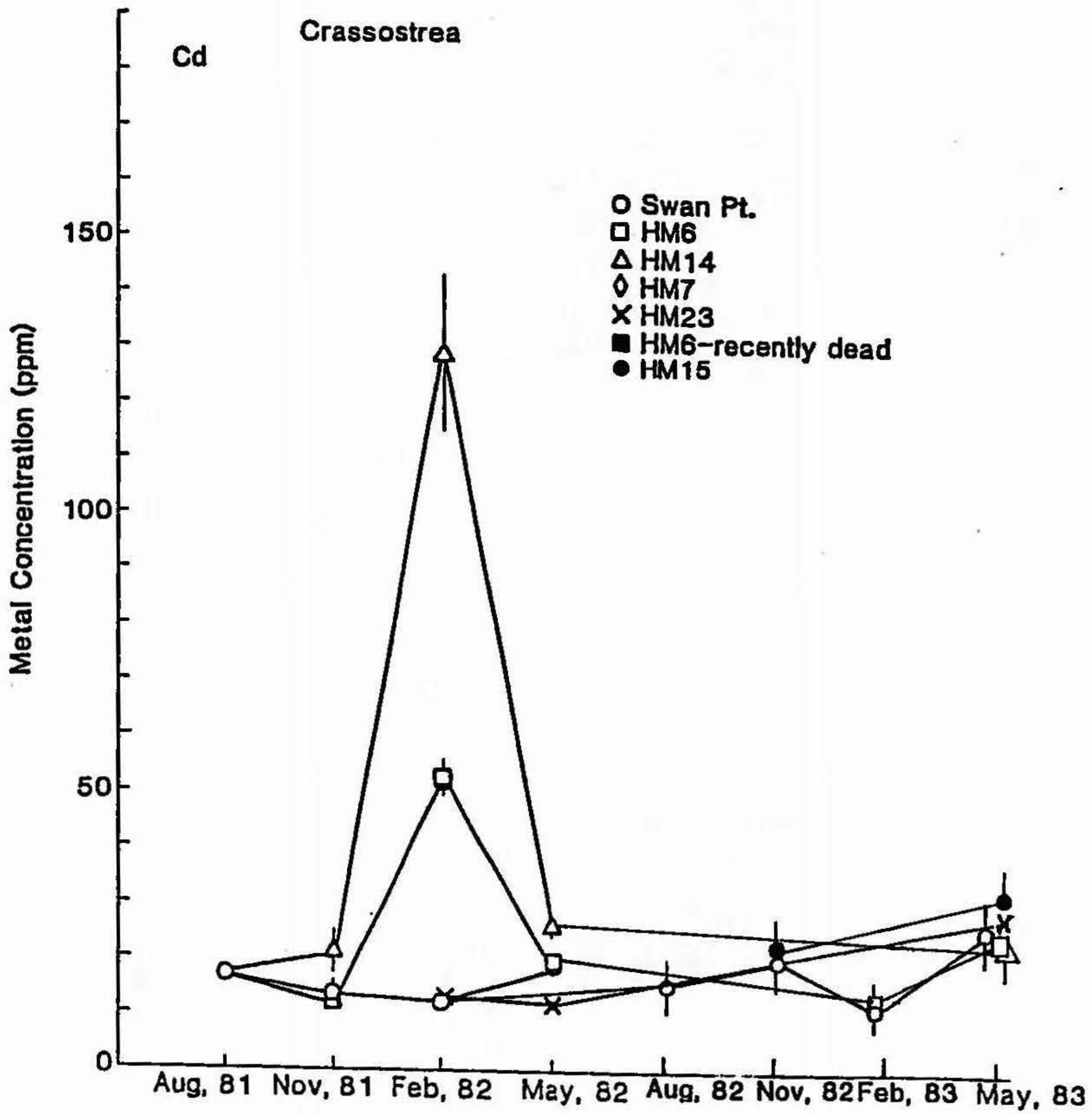
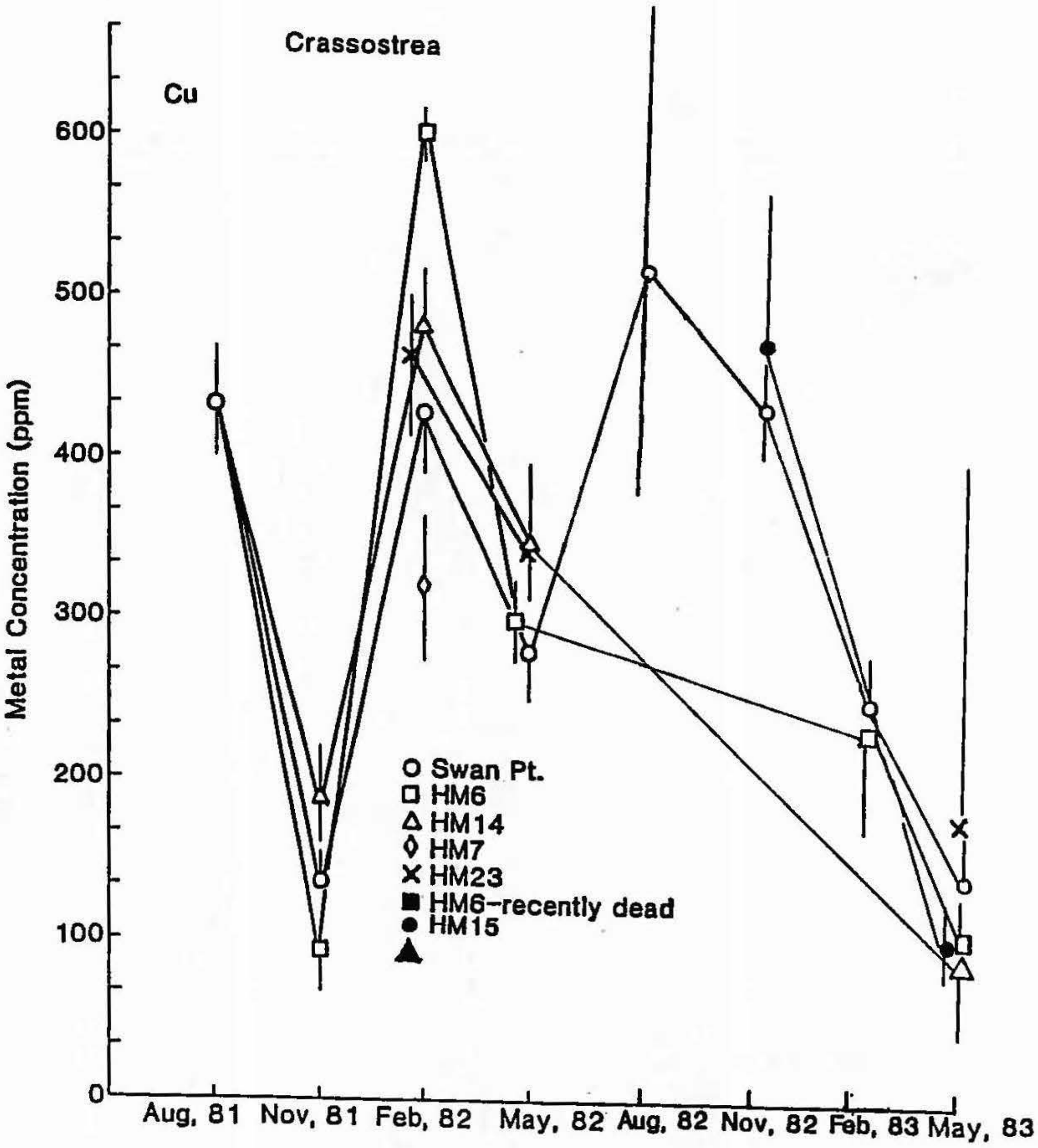
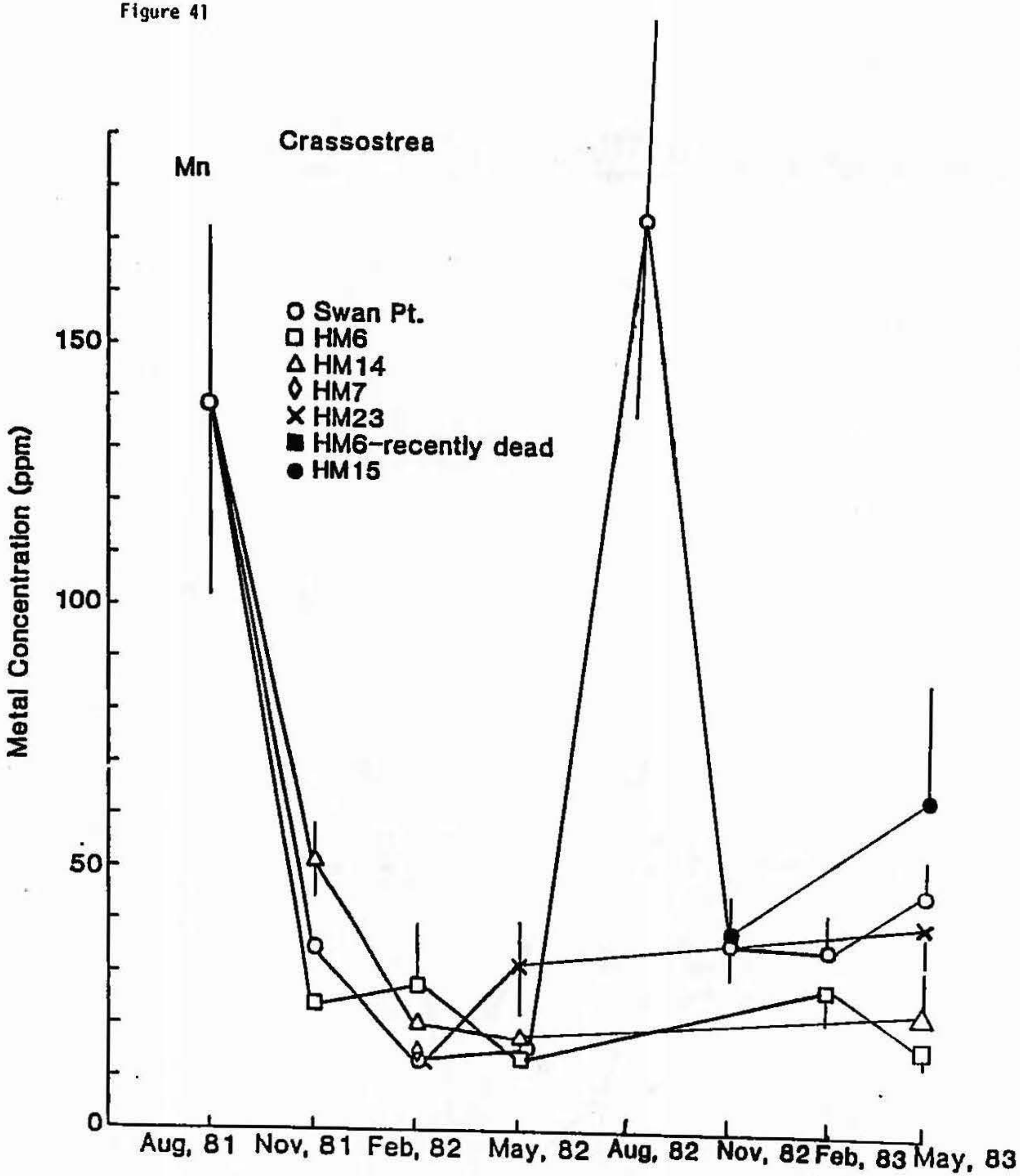

Crassostrea
Cd
Metal Concentration (ppm)
150
100
50
0
O Swan Pt.
□ HM6
Δ HM14
◊ HM7
× HM23
■ HM6-recently dead
● HM15
Aug, 81
Nov, 81
Feb, 82
May, 82
Aug, 82
Nov, 82
Feb, 83
May, 83

Figure 39.



Crassostrea
Cu
Metal Concentration (ppm)
600
500
400
300
200
100
0
Aug, 81
Nov, 81
Feb, 82
May, 82
Aug, 82
Nov, 82
Feb, 83
May, 83
Swan Pt.
HM6
HM14
HM7
HM23
HM6-recently dead
HM15

Figure 41



Crassostrea
Mn
Swan Pt.
HM6
HM14
HM7
HM23
HM6-recently dead
HM15
Metal Concentration (ppm)
150
100
50
0
Aug, 81
Nov, 81
Feb, 82
May, 82
Aug, 82
Nov, 82
Feb, 83
May, 83

Figure 43

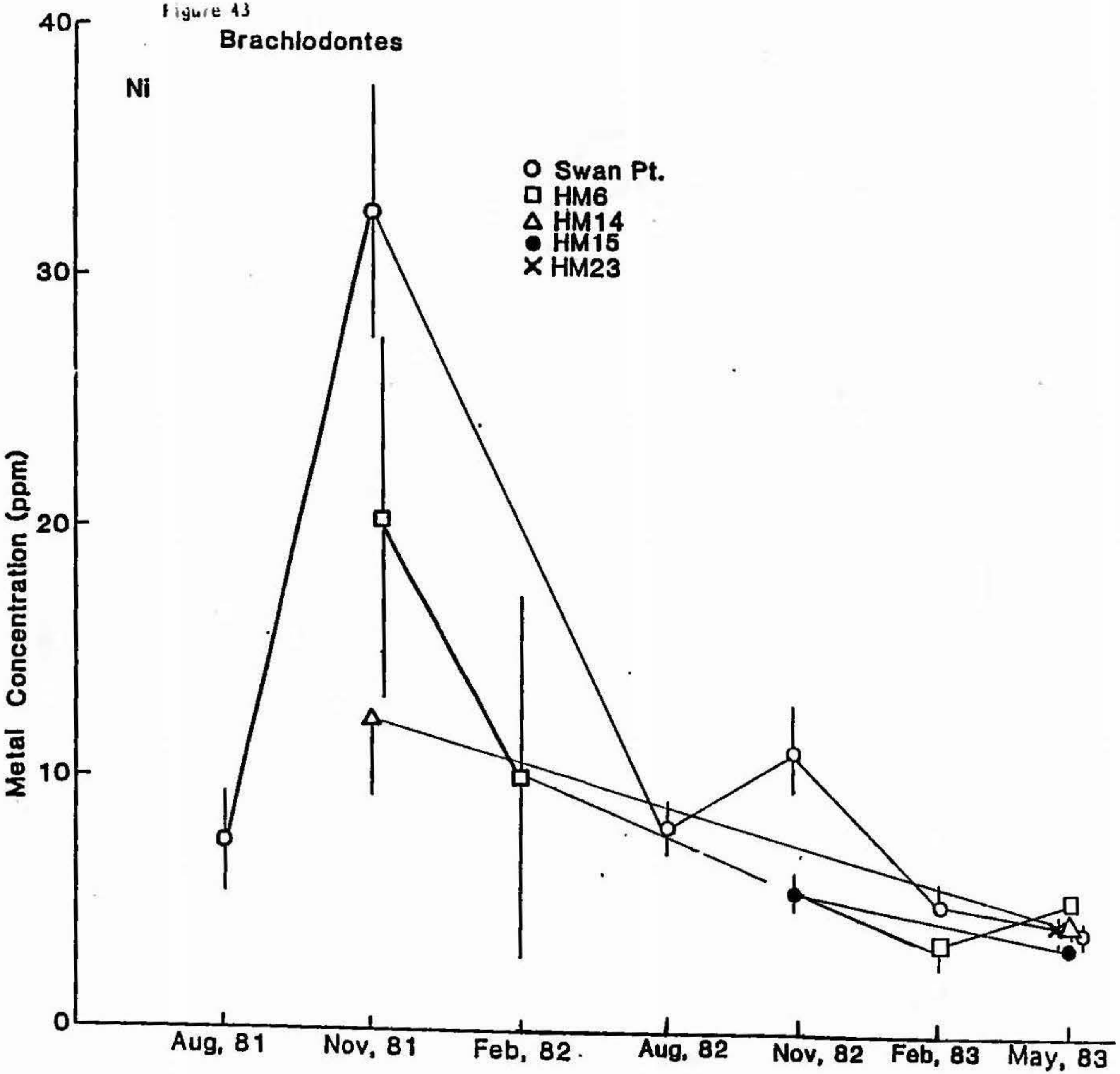
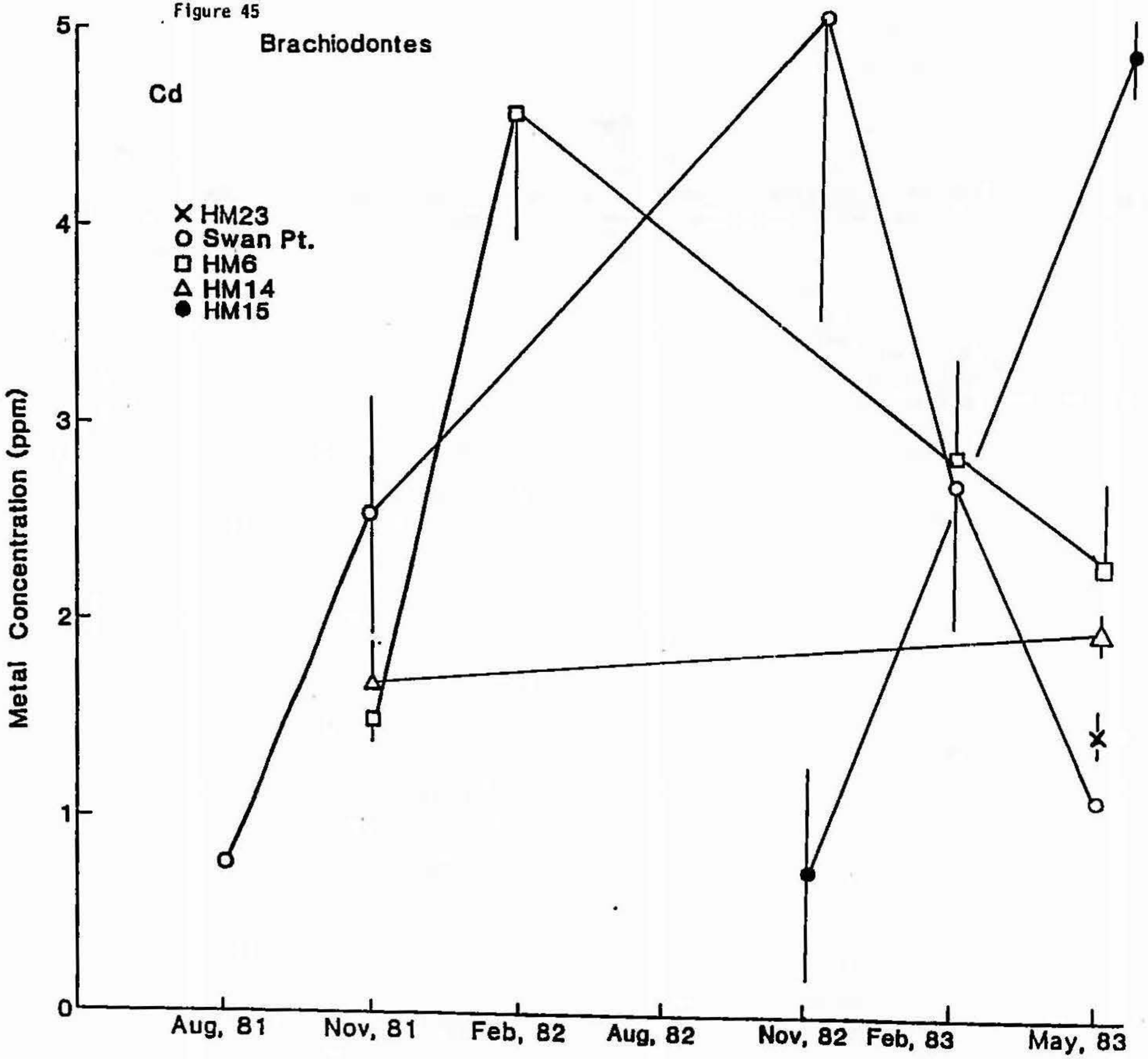
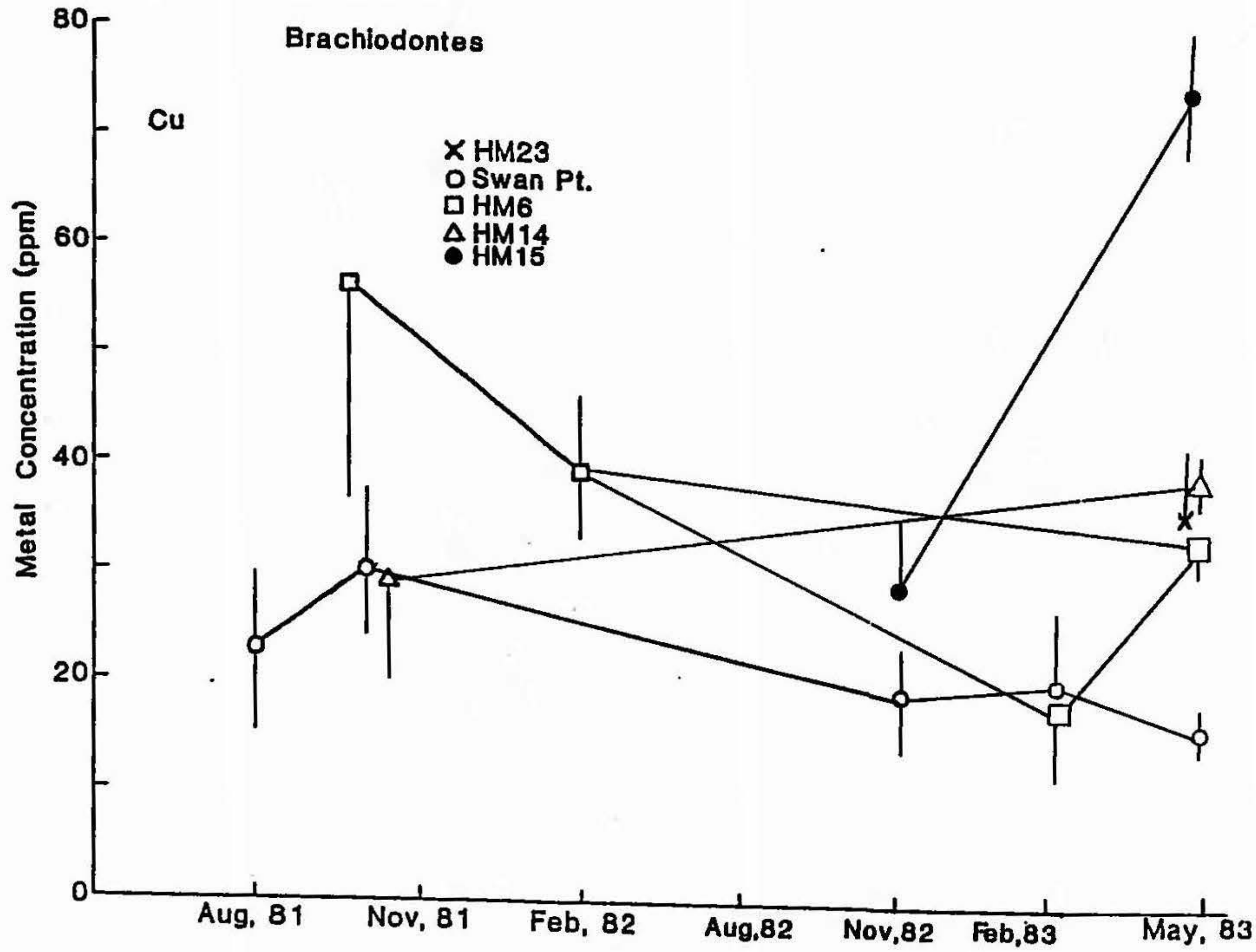

Brachiodontes
Ni
Swan Pt.
HM6
HM14
HM15
HM23
Metal Concentration (ppm)
40
30
20
10
0
Aug, 81
Nov, 81
Feb, 82
Aug, 82
Nov, 82
Feb, 83
May, 83

Figure 45



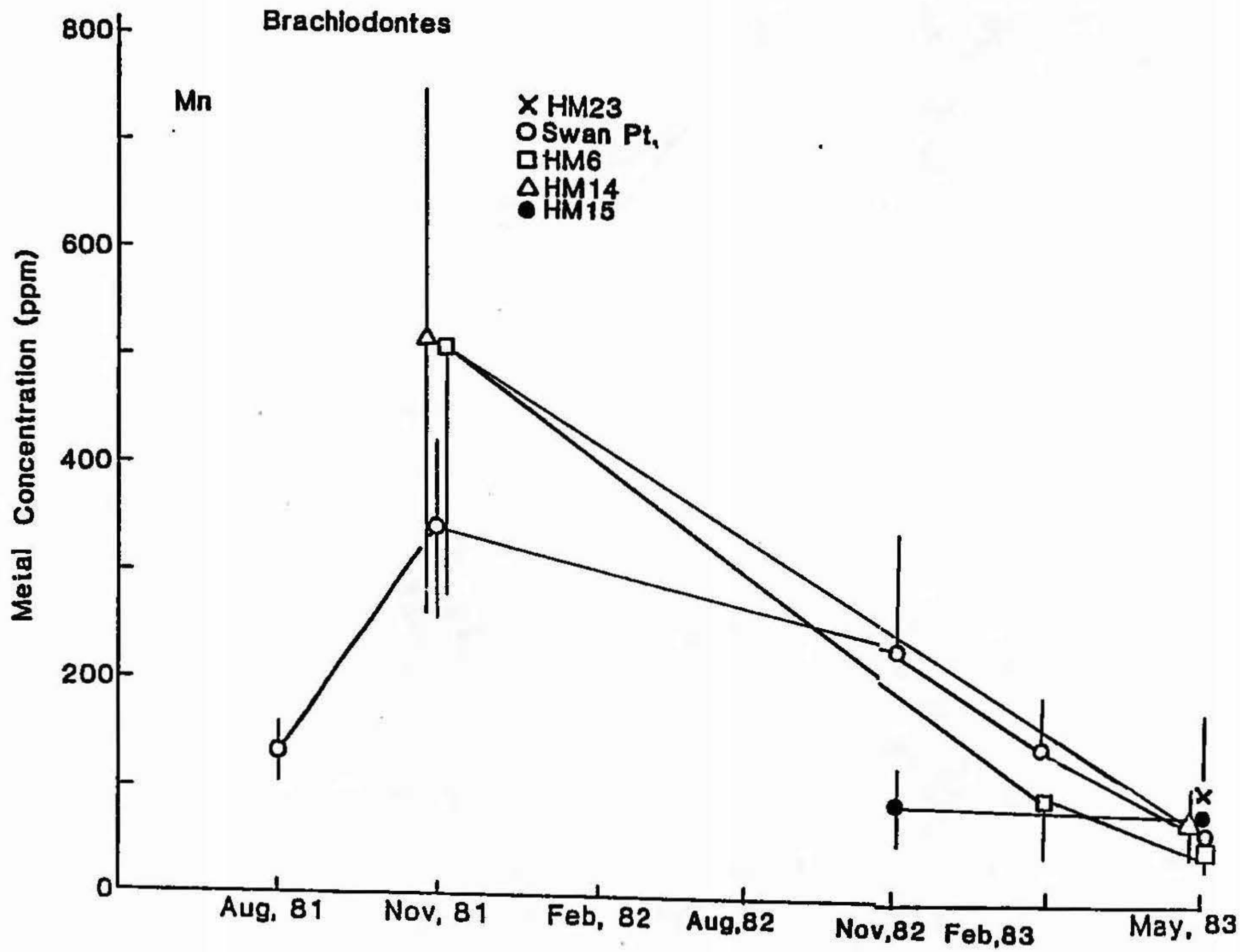
Brachiodontes
Cd
X HM23
O Swan Pt.
□ HM6
Δ HM14
● HM15
Metal Concentration (ppm)
0
1
2
3
4
5
Aug, 81
Nov, 81
Feb, 82
Aug, 82
Nov, 82
Feb, 83
May, 83

Figure 47



Brachiodontes
Cu
✕ HM23
○ Swan Pt.
□ HM6
△ HM14
● HM15
Metal Concentration (ppm)
80
60
40
20
0
Aug, 81
Nov, 81
Feb, 82
Aug,82
Nov,82
Feb,83
May, 83

Figure 49



Brachiodontes
Mn
X HM23
O Swan Pt.
□ HM6
△ HM14
● HM15
Metal Concentration (ppm)
800
600
400
200
0
Aug. 81
Nov. 81
Feb. 82
Aug.82
Nov,82
Feb,83
May. 83

Figure 51

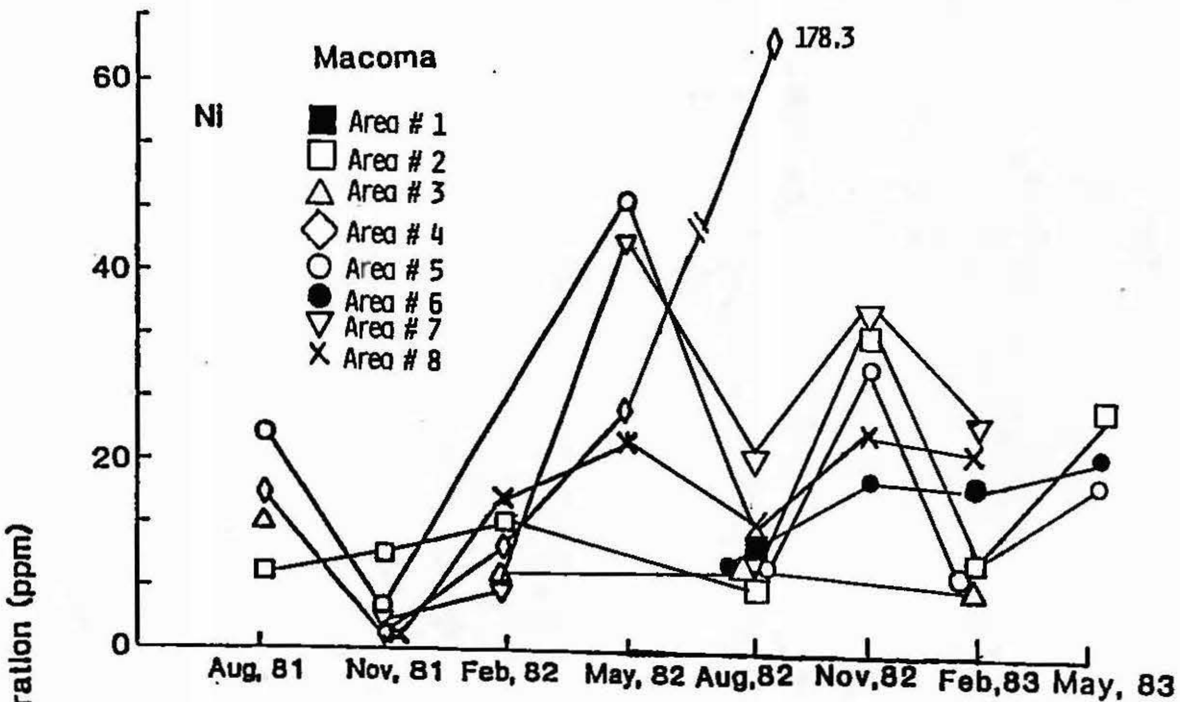


Figure 52

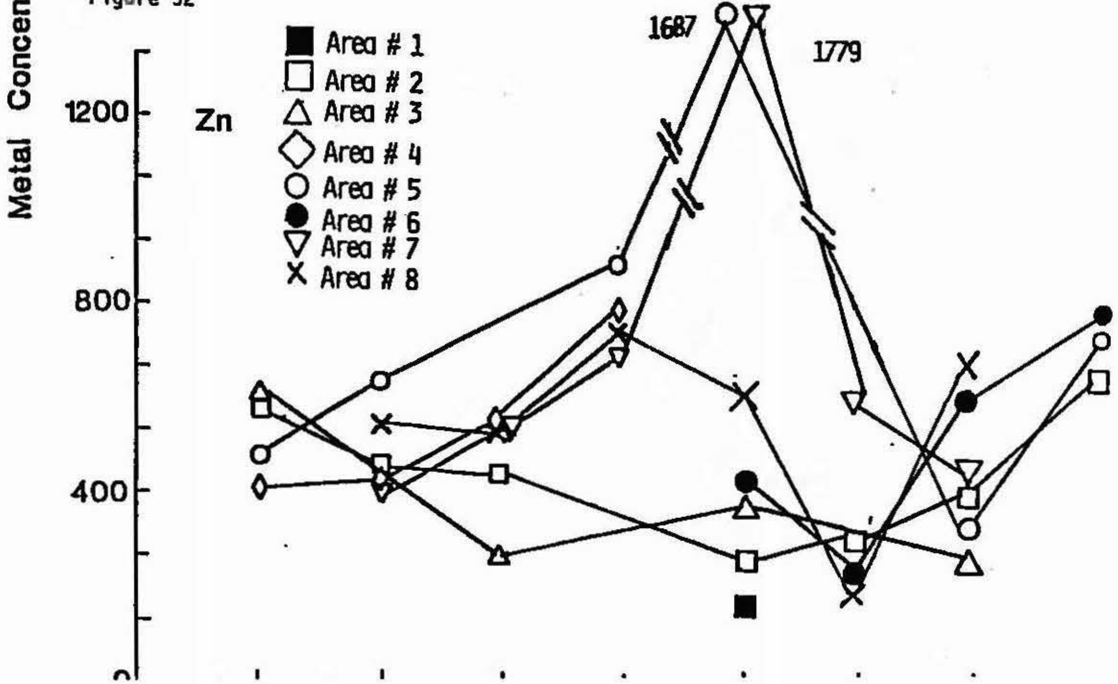
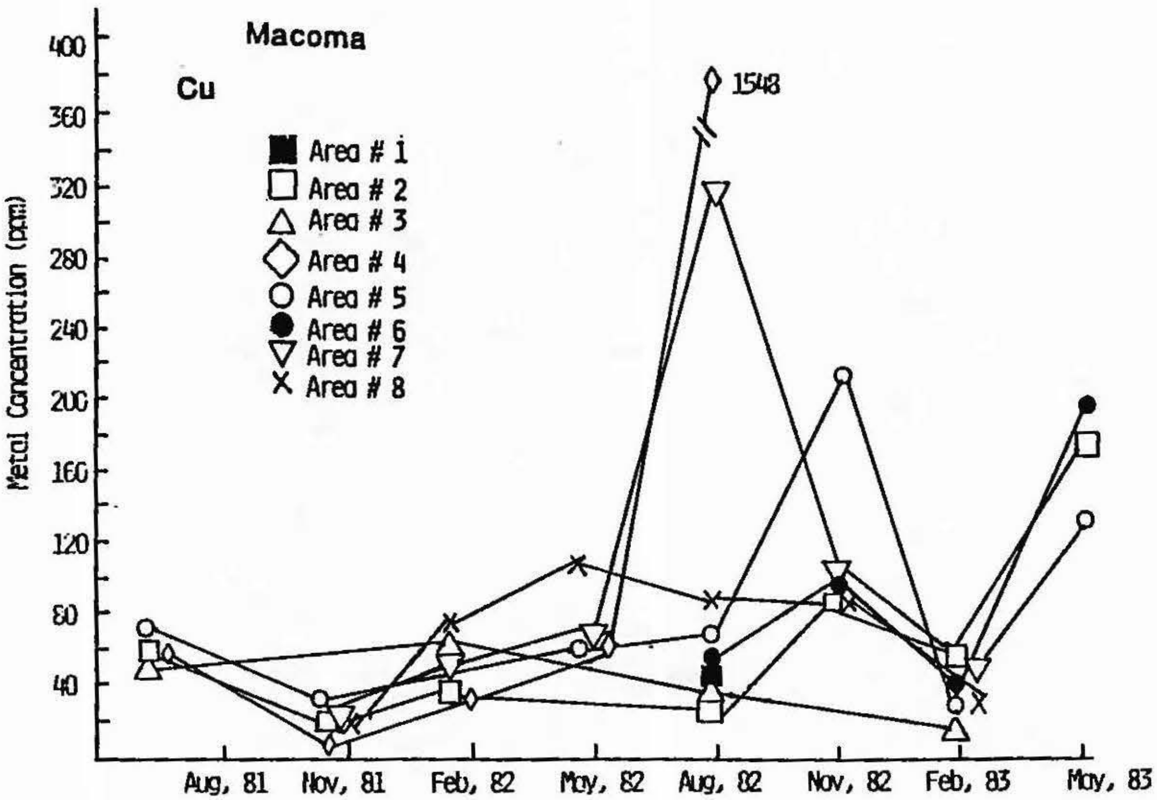
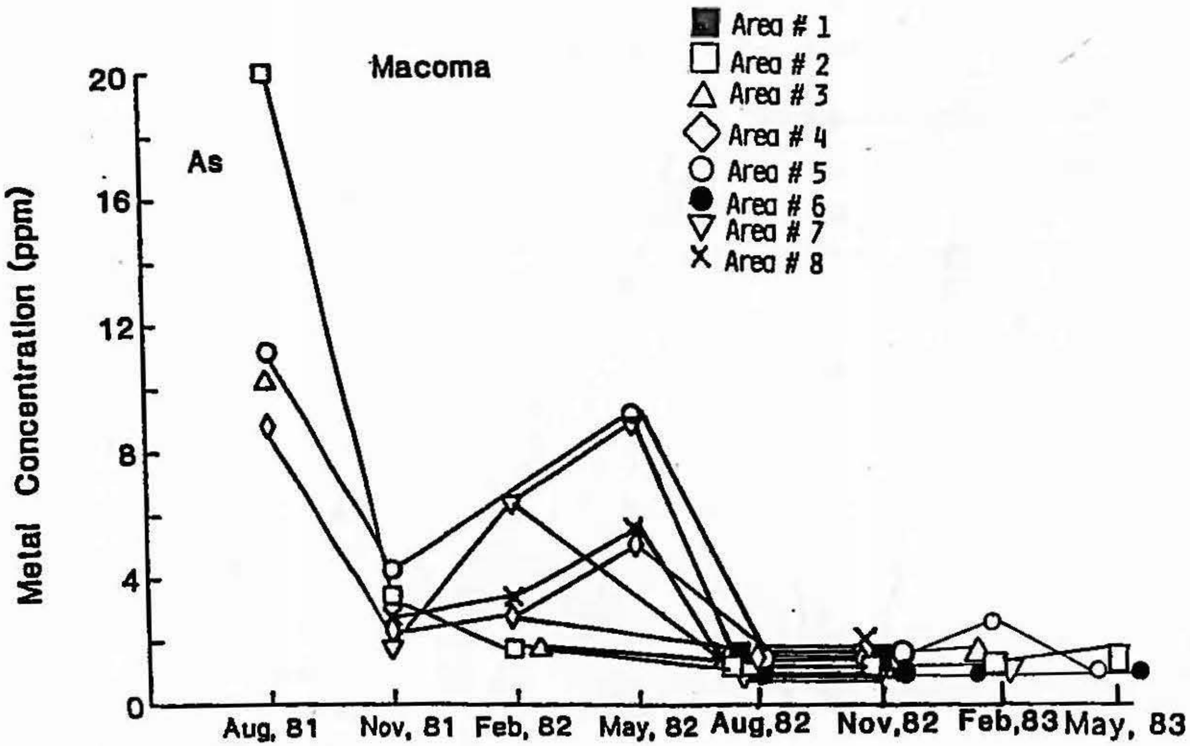


Figure 55.



Macoma
Cu
Area # 1
Area # 2
Area # 3
Area # 4
Area # 5
Area # 6
Area # 7
Area # 8
1548
Metal Concentration (ppm)
400
360
320
280
240
200
160
120
80
40
Aug, 81
Nov, 81
Feb, 82
May, 82
Aug, 82
Nov, 82
Feb, 83
May, 83

Figure 57.



Macoma
As
Area # 1
Area # 2
Area # 3
Area # 4
Area # 5
Area # 6
Area # 7
Area # 8
Metal Concentration (ppm)
20
16
12
8
4
0
Aug, 81
Nov, 81
Feb, 82
May, 82
Aug,82
Nov,82
Feb,83
May, 83

Figure 59

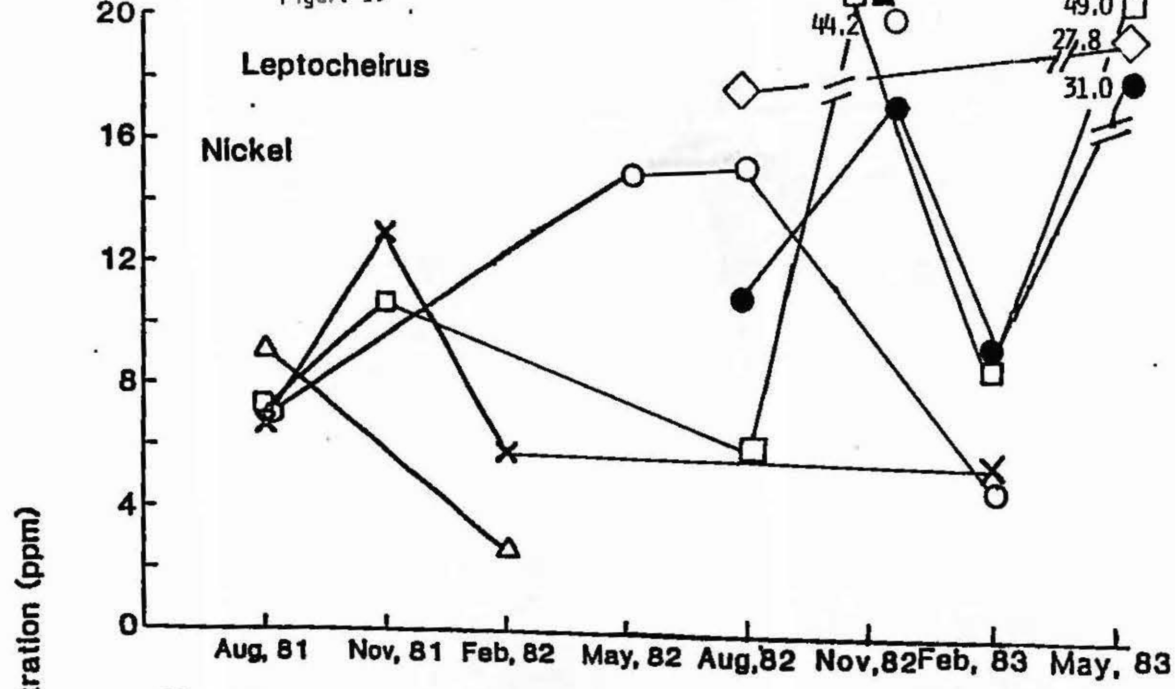


Figure 60

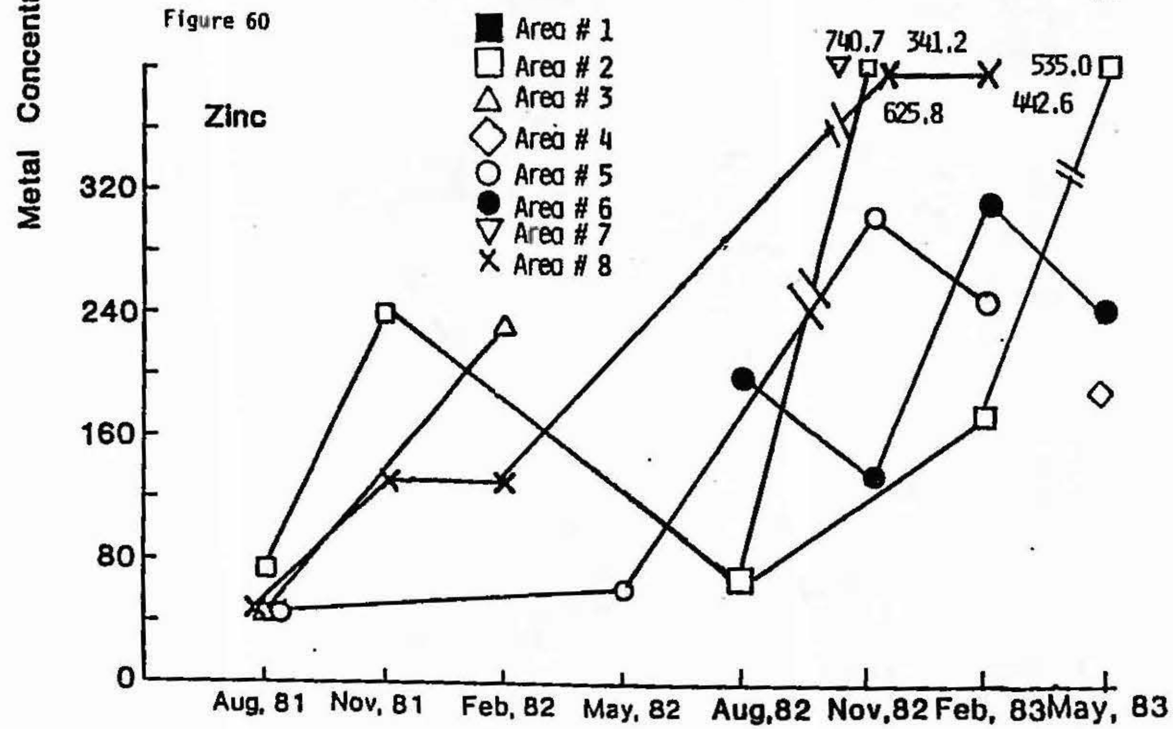


Figure 63

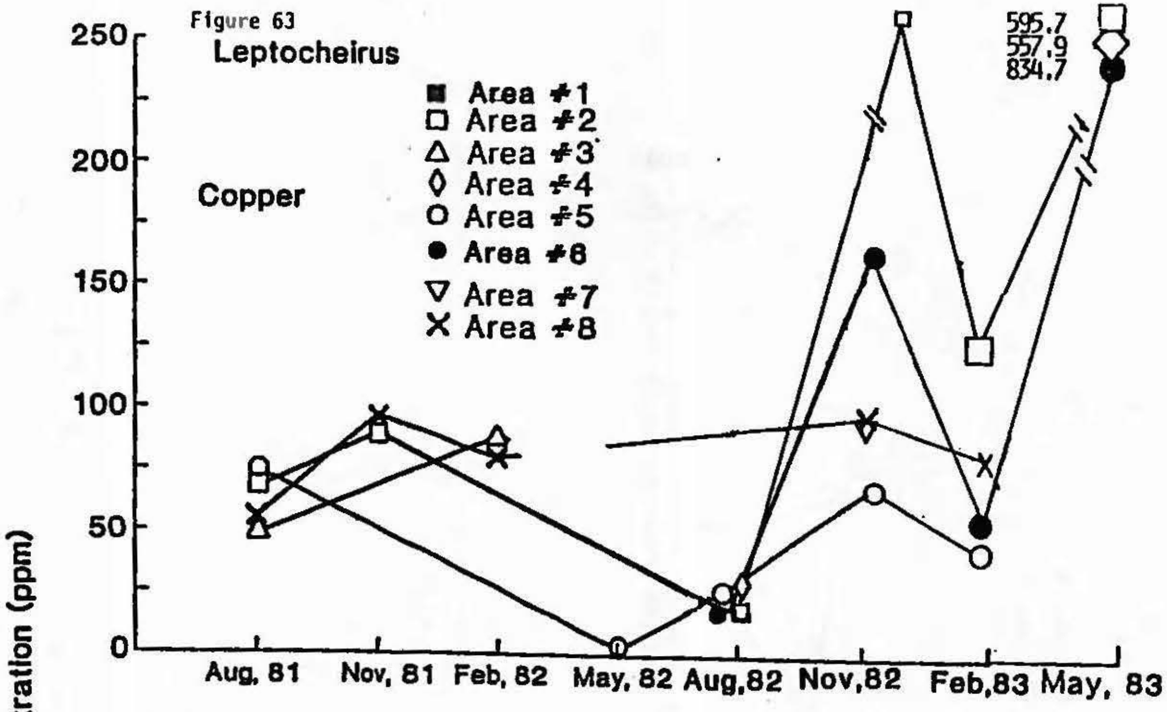


Figure 64

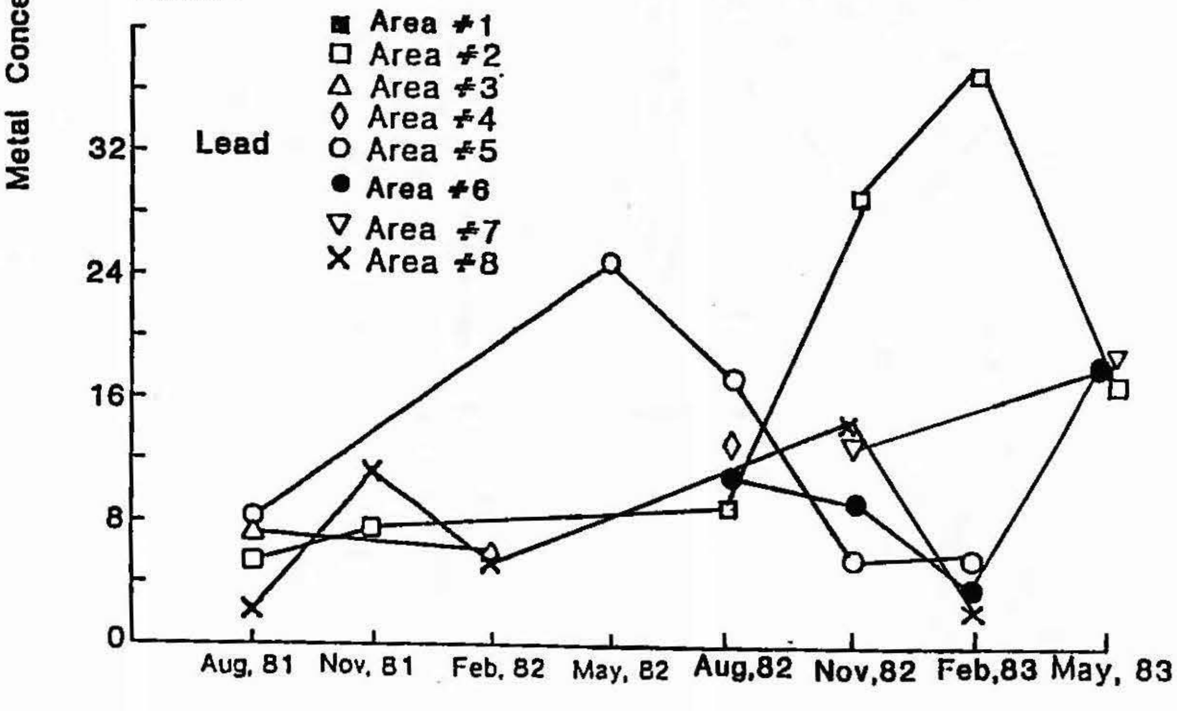


Figure 67

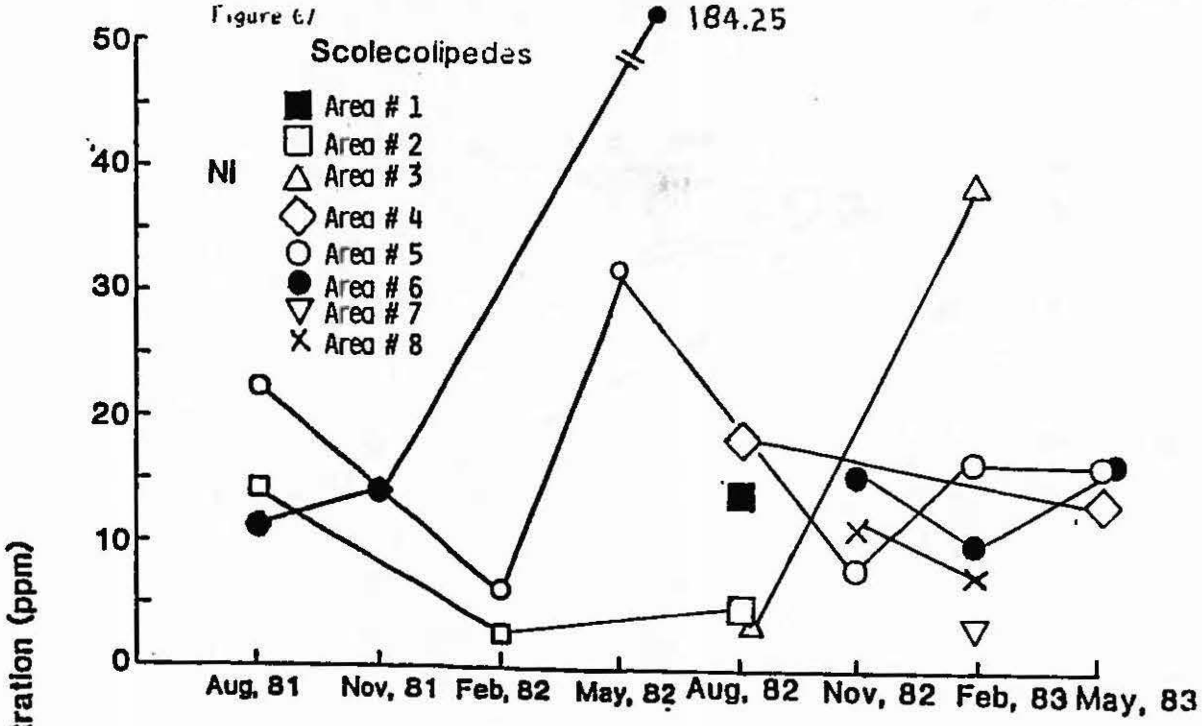


Figure 68

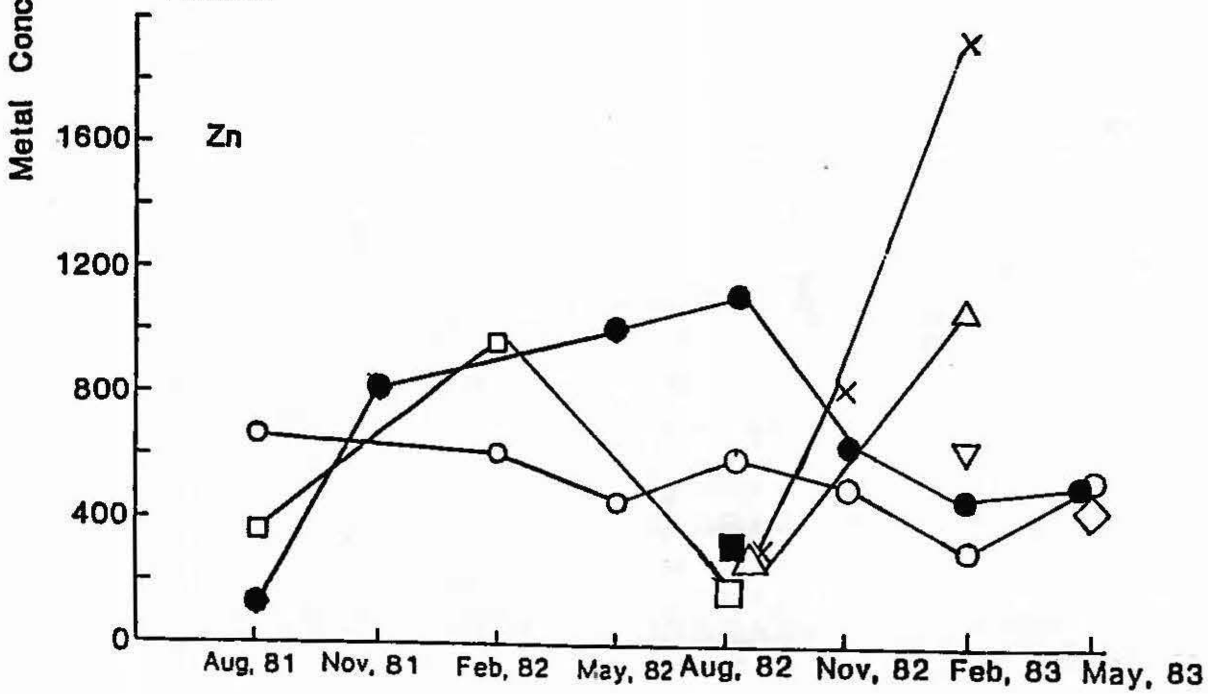


Figure 71

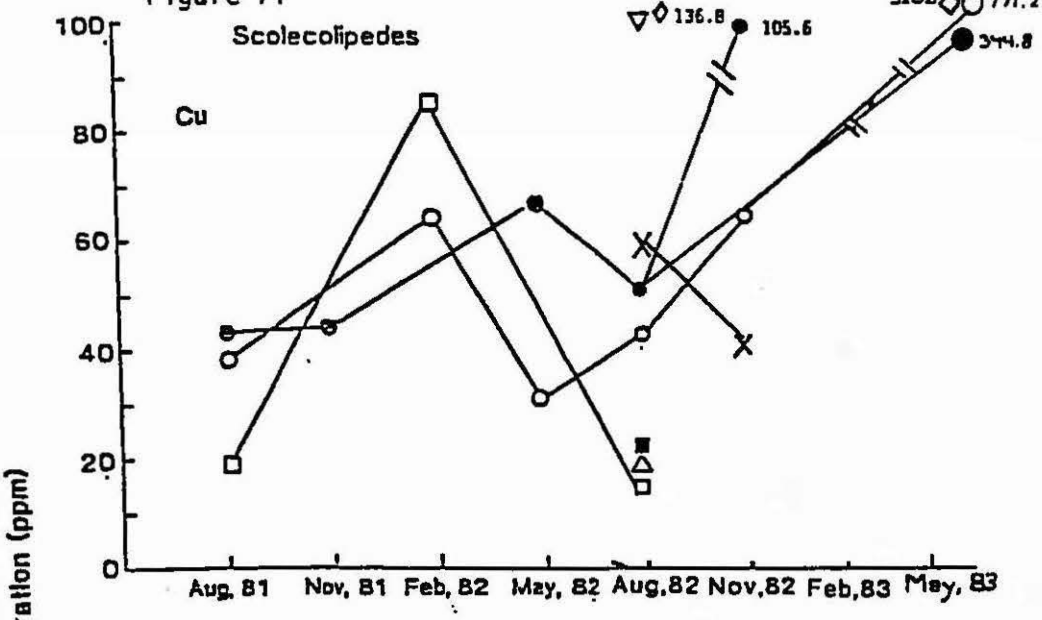
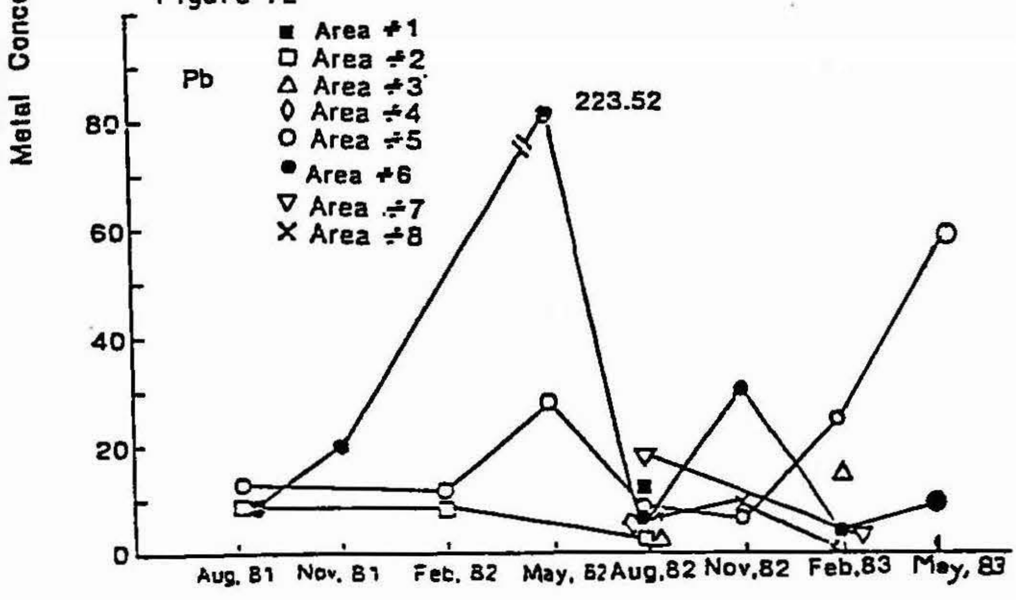


Figure 72



Fish and Crabs

An attempt was made to match sample collections in 1982 with those made in 1981. However, this was only partly successful. With spot (Leiostomus xanthurus) it was possible to match three out of four stations (Table 8). The remaining stations in each case (Trawl 2, 1982 and Trawl 1, 1982) represented an approximate pair in view of the close proximity of these trawls. Comparing Trawl 2, 1981 data with Trawl 1, 1982 data it may be seen that copper, zinc, manganese, selenium and especially cadmium are significantly higher in the 1982 collection (as judged by a t-test, $P<0.01$). On the other hand, chromium is higher in the 1981 collection and this was also found in two out of the other three stations (Trawl 6 and Trawl 10). The overriding impression, however, is one of higher metal levels in the 1982 collections compared with equivalent collections made in 1981. Of particular interest is the high copper level in spot from Trawl 10 in 1982 which not only greatly exceeded that of the corresponding 1981 collection but all other 1982 collections.

The same disparity in copper concentrations is seen in white perch (Morone americana) collected from Trawl 1, 1981 and 1982 (Table 9) and it is interesting that the 1981 copper data from this species were split between two high-copper stations (Trawl 2 and Trawl 5) and two low-copper stations (Trawl 1 and Trawl 7). It was only possible to sample two stations for white perch in August 1982 (Trawl 1 and shore station 2) and two further samples (Trawl 4 and Trawl 10) were sampled in November 1982. Unlike spot, there was not a strong tendency for 1982 samples to be higher than 1981 specimens. Exceptions to this were Cd (on average 16.4x higher in 1982 specimens and Se (5.7x higher in 1982 specimens).

In 1983 metals were determined in single collections of eels (Anguilla rostrata) and channel catfish (Ictalurus punctatus). The results are shown in Tables 10 and 11. Although most metals are comparable in range with other species arsenic and selenium levels are lower than in other species analysed. Of particular note is the large variability seen in copper (and to a lesser extent chromium) levels in these species. For example copper concentrations in eels range from below detection limit to 266 $\mu g\ g^{-1}$ dry weight. The source of this variability is unknown. Although livers have been shown to concentrate copper to a high degree, all eel and catfish analyses were made on eviscerated fish.

Of the four blue crab (Callinectes sapidus) collections made in August 1982 only two (Trawl 6 and Trawl 9) could be matched with 1981 samples. Of the 16 sets of matched analyses made of Callinectes (Table 12) only one (Se) was higher in 1981.

DISCUSSION

The Chesapeake Bay is the largest and most productive estuarine system in the United States, yet in recent years there have been disturbing declines in several important biota, notably submerged aquatic vegetation, fish such as striped bass and shad, and oysters.

Table 9.

Comparison of metal concentrations in White Perch (*Morone americana*) collected in 1981 and 1982. (values as μg/g dry wt. ± standard deviation).

	Ni	Zn	Cd	Cr	Cu	Pb	Mn	Se
Trawl 1								
Aug. 1981	0.94±0.24	55.81±18.3	0.05±0.031	5.24±1.57	4.07±1.0	0.48±0.18	25.2±20.4	0.40±0.22
Aug. 1982	1.88±0.93	103.12±38.6	0.72±0.17	0.73±0.36	73.7±24.3	1.06±0.58	94.2±27.7	1.87±1.09
Aug. 1981								
Trawl 7	1.05±0.214	65.76±15.26	0.036±0.017	4.94±3.97	3.8±3.44	0.45±0.38	41.34±42.24	0.80±0.45
Trawl 2	1.48±0.59	51.24±17.63	0.058±0.03	5.55±1.72	71.92±48.7	12.00±10.6	25.6±14.84	0.697±0.23
Shor Stn.5	1.49±0.88	52.54±13.7	0.11±0.03	6.21±3.7	68.55±42.6	0.19±0.11	49.6±12.5	0.52±0.30
Aug. 1982								
Shore Stn.2	0.40±0.13	86.86±18.03	0.62±0.13	0.36±0.11	91.3±44.1	0.64±0.07	52.8±19.3	4.47±0.53
Nov. 1982								
Trawl 10	N.A.	100.8±22.89	1.66±1.31	0.58±0.27	11.8±4.18	1.22±0.44	67.7±47.7	3.68±0.96
Trawl 4	N.A.	87.29±16.29	0.93±0.20	0.44±0.23	29.84±26.87	0.81±0.2	50.46±33.18	3.73±1.05

Table 11.

Trace Metal Analysis of Catfish (Ictalierus punctatus)

Sample I.D.	Ni	Zn	Cd	Cr	Cu	Pb	Mn	Hg	As	Se
1	1.80	60	0.18	0.98	7.96	0.34	18.7	N.D.	0.017	N.D.
2	5.59	64	0.16	4.89	5.71	1.66	3.71	0.005	0.03	0.018
3	12.9	103	0.20	8.46	90.9	2.90	53.5	N.D.	0.05	0.017
4	3.84	65	0.11	1.24	5.4	0.45	35.8	N.D.	0.04	0.027
5	1.72	47	0.12	1.12	10.7	0.26	18.0	0.007	0.03	0.034
6	1.97	89	0.36	2.81	14.1	0.52	20.9	N.D.	0.06	0.060
7	2.32	167	0.40	2.67	16.7	0.36	24.2	N.D.	0.06	0.016
8	8.29	439	0.51	5.05	28.3	1.43	167.4	N.D.	0.08	0.047
Mean	4.82	129	0.26	3.40	28.90	0.99	47.2	-	0.04	0.031
Std. Dev.	4.01	131	0.15	2.60	30.07	0.94	50.0	-	0.02	0.017

Toxic substances such as trace metals have been implicated in this regard although hard evidence is difficult to find and recent scrutiny of the bay system through the Chesapeake Bay Program has highlighted our ignorance of the pollution status of many of the Bay components. Even now there is very little knowledge of trace metal concentrations in many species and a broad scale monitoring program such as this one serves to provide a great deal of original data in a particularly sensitive area. One group of animals which has received more attention than most is the bivalve mollusks. The use of filter-feeding mollusks as indicators of trace metal pollution is now world-wide (Bayne 1978; Goldberg et al. 1978). Many species are excellent bioaccumulators of trace metals and act as natural integrators of these and other pollutants over time (e.g. Davies and Pirie 1978; deWolf 1975; Harris et al. 1979; Murray 1982; Phillips 1976a,b; 1977a,b; 1980). Although many of these programs have been successful in identifying point sources of contaminants, a number of investigations have identified several different parameters affecting trace metal concentration by biological material quite apart from metal input to the aquatic environment. Following the work of Boyden (1974, 1977) and several others (e.g. Davies and Pirie 1978; Harris et al. 1979; Thomson 1982; Cooper et al. 1982) it is apparent that animal size (not always equated with age) is an important factor influencing trace metal concentration in several species, although size/metal relationships are not always consistent from one investigation to another. Figure 75 shows that cadmium concentrations in Crassostrea virginica collected from the Hart and Miller Island area have an inverse relationship with body size as determined by soft parts dry weight. A similar relationship is seen in Calllinectes between copper concentrtion and soft parts dry weight (Figure 76). In the latter case the relationship is heavily influenced by a batch of small, high-copper animals emanating from one site (Shore Station 2). An analysis of variance together with a multiple range test (Student-Neuman-Kuels procedure, Table 13) shows that, for several metals (based on August 1981 data) this station (SS2) separates from the rest either singly or together with Trawl Station 6 which also yielded some small animals having relatively high metal concentration. Salinity, too, seems to have an important bearing on trace metal concentration. Figure 77 gives data from three different studies within the Chesapeake Bay which had sampling stations sufficiently geographically separated to enable salinity to be considered as a dependent variable. Further evidence of this salinity effect comes from two pieces of work on oysters from the Chesapeake system, Huggett et al. (1973) and Frazier (1979). Together with the investigations referred to in Figure 77, these studies collectively comprise the great majority of information concerning trace metals in Bay organisms. Explanations for such a salinity effect may be physiochemical or physiological (or both) in origin and have been discussed in an unpublished ms. by Wright and Phelps. Whatever the reasons for this salinity effect, the implications are that comparison of metal loads in animals from differing salinities must be made with care, taking into account such a phenomenon.

Cronin et al. (1974) developed formulae which described zinc, copper and cadmium concentrations in oysters as a function of salinity and growth rate. The equations generated by Cronin et al. (1974) were complex and

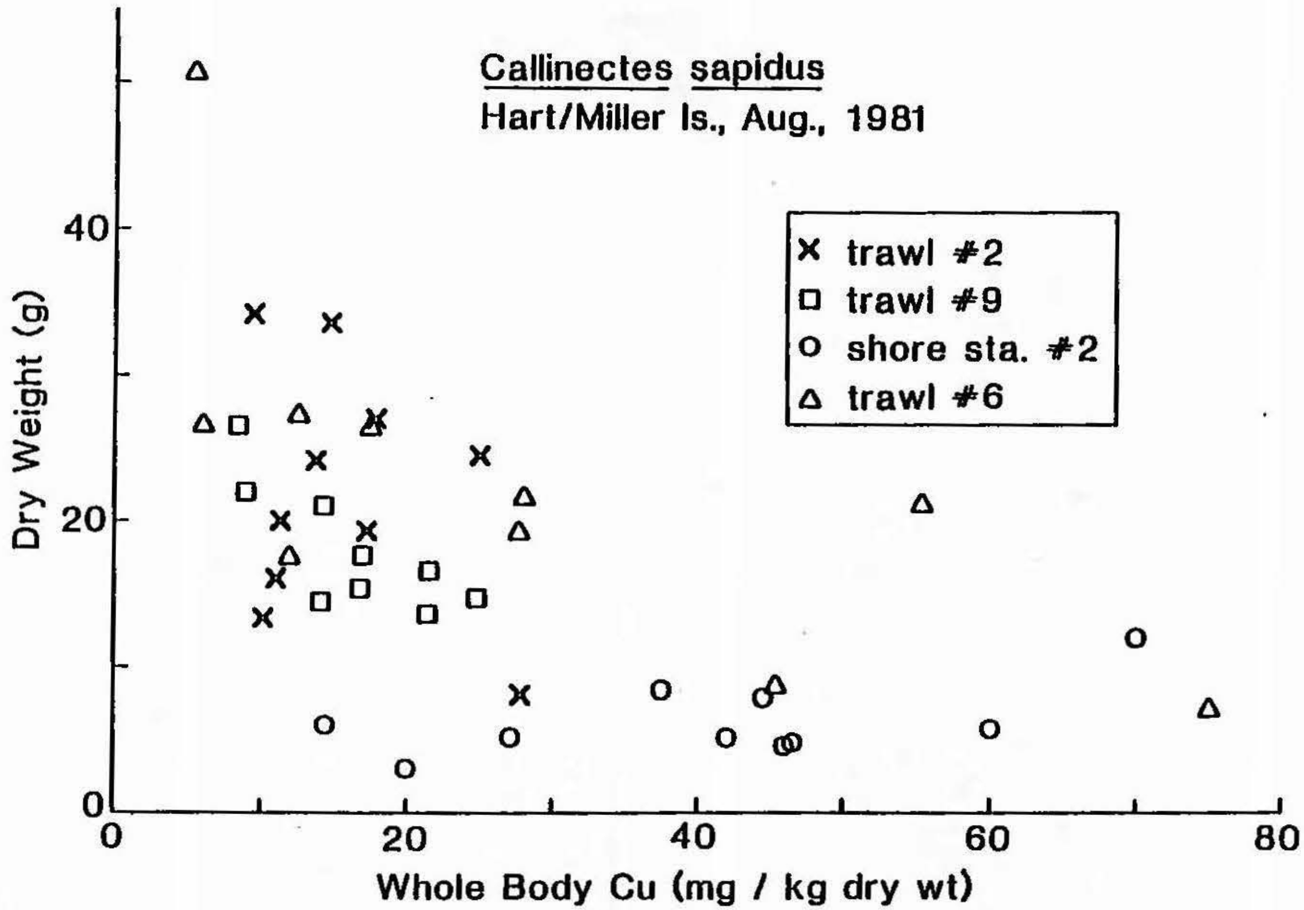


Figure 76. Copper concentrations in blue crabs (Callinectes sapidus) as a function of dry weight.

Table 15.

Comparison of zinc and copper levels predicted for Hart and Miller Islands (tray-set) oysters from empirical salinity (size model from mid-Bay oysters, Wright & Phelps unpublished) with metal levels actually determined from Hart and Miller Islands oysters.

Date	Site	Cu conc. (ppm dry wt.) predicted from equation	Cu conc. (ppm dry wt.) determined	Zn conc. (ppm dry wt.) predicted from equation	Zn conc. (ppm dry wt.) determined
Aug. 1981	Swan Pt.	314	432	8,023	16,474
Nov. 1981	Swan Pt.	197	138	5,852	4,069
	HM 6	188	94	5,488	9,926
	HM 14	377	187	6,022	7,956
Feb. 1982	Swan Pt.	167	429	5,082	10,215
	HM 6	434	602	9,384	13,105
	HM 14	199	483	6,038	11,923
	HM 7	194	321	5,815	7,912
	HM 23	199	460	5,796	13,068
May 1982	Swan Pt.	318	280	7,489	9,361
	HM 6	392	296	8,417	16,127
	HM 14	382	346	8,487	20,353
	HM 23	344	341	7,876	11,084
Aug 1982	Swan Pt.	376	650	8,764	10,529
Nov. 1982	HM 15	211.1	462	6,114	4,263
	Swan Pt.	88	419	5,490	4,235

beyond the scope of most monitoring programs insofar as the necessary growth rate information could only be derived with the use of carefully selected brood stock of uniform size. Wright and Phelps (unpublished) have generated multiple regression equations relating metal concentrations in oysters to salinity and wet weight. The equations were derived from large collections of oysters made from the central Chesapeake Bay region over the years 1978, 1979 and 1981, and are shown in Table 14. The animals covered a wide size range and a salinity range from 3-17^{o}/oo and the equations provide the basis for normalizing data to take into account size and salinity effects. Applicability to current data remains limited, however, as biota collections around the Hart and Miller Island area were all from areas of similar salinity and any possible salinity effects on Hart and Miller Island animals are only likely to be seen over time ie. metals may be higher in a low salinity season than a high salinity season.

One problem with this approach is that the equation may alter from season to season, or at least from year to year. Reference to Table 10 shows that in a low-saline year (1978), salinity has a proportionately greater influence on metal concentrations than a comparatively high-saline year (1981). Strictly speaking, in order to normalize data for salinity/size from season to season it would be necessary to invoke a new, updated, regression equation each time. Using data from Hart and Miller Island alone it would not be possible to construct a meaningful model describing the effect of salinity on metal levels in animals (bivalves), and ideally such a model would have to be constructed using material from throughout the bay and over the whole salinity range. As a compromise, salinity and size data from the 1981-83 oysters were substituted in the 1981 regression equation derived from mid-bay animals (Table 14) in an attempt to define the amount of variation in zinc and copper levels which might be expected to arise from these two parameters alone. Zinc and copper values derived from substitution in this equation are compared in Table 15 with the actual zinc and copper concentrations determined for oysters throughout this study. For the most part zinc levels predicted by the equation are often as much as 50% lower than those actually found. This means that either a/ the salinity model is not yet sufficiently refined to include data from the northern part of the Chesapeake system, or b/ there is genuine zinc enrichment of the Hart and Miller (and Swan Point) area relative to the central bay area. Reference to Table 15 shows that, while the salinity model explains some of the seasonal variability in both zinc and copper, there are several inconsistencies which make interpretation difficult. Sinex et al. (1979) found that salinity dominated the regional metal distribution pattern within a single estuary, although comparison of zinc, copper and cadmium levels in oysters from different estuaries but of similar salinity revealed other regional effects which these authors attributed to differential metal availability from both natural and anthropogenic sources. Sinex et al. (1979) found poor correlation between trace metal concentrations in oysters and in related sediments and water. Therefore, while oysters and mussels give important information on the bioavailable fraction of metals in the environment, it is clearly of a different nature to that obtained from sediment and water column analyses.

It seems likely that trace metals in Macoma may better reflect levels in the physical environment. However any future monitoring effort must be better focussed in this regard. For example, it would be more meaningful if Macoma collections and analyses (together with other benthic animals) were made concomitantly with sediment collection and analysis.

As a result of a second year of monitoring many of the conclusions reached at the end of the first year remain largely unchanged (Wright and Striegel 1982). Problems arising from the effect of extraneous variables such as salinity will be resolved with a greater monitoring effort on the Chesapeake system in general. Meaningful results from a focussed monitoring program such as this can only really be gained from a long-term program. Regarding tray-set bivalves, the idea of a single annual (or better 2 biannual) sample(s) from 6 trays (Wright and Striegel 1982) remains tenable, although some stations will have to be altered. Now that the outer perimeter of the dyke has been completed, trays moored to the dyke wall by lines will eliminate costly buoy setting and will lessen interference through better camouflage and diminished accessibility (trays can be serviced from a small inshore boat). Figures 30 and 31 reinforce the proposed minimum of 25 animals per sample (Wright and Striegel 1982) although it is clear that smaller animals are required for, say, mercury than for zinc.

From the monitoring point of view, doubts remain concerning the use of small benthic invertebrates such as Leptocheirus and Scolecolipedes. Figures 33 and 34 suggest that, due to the high degree of individual variability with these species, the use of small numbers of individuals may, for some metals, involve a large discrepancy between the mean metal concentration determined and that obtained from a larger, more representative population sample. The large numbers of animals used for the initial studies of sample variability involved an unusually large collection effort which could not be matched in a routine monitoring operation. Accordingly, most Scolecolipedes samples routinely taken contained 5-8 individuals and occasionally less. In the case of zinc such numbers might involve inherent errors of more than 30%. Although there is some evidence that, like Macoma, the monitoring strategy for Scolecolipedes might be improved by matching biota and sediment samples, it is recommended that Leptocheirus and Scolecolipedes be relegated to a secondary role (see Wright and Striegel 1982).

Analyses of fish and crabs have more public health than monitoring implications, as the source of metals found in comparatively mobile species must always remain in doubt. Analysis of the most indigenous species, Menidia, is confined at present to the May 1982 collection (Table 16). May 1983 samples are still in the process of preparation and analysis at the time of writing this report. The most notable aspect of fish analysis has been the significant differences found in certain metals (e.g. copper) from one trawl to another taken throughout the same cruise. Copper analyses of individual tissues taken from spot and white perch in 1981 (Figure 78) show that the liver may be strongly implicated in this regard as a site of exceptional metal accumulation. Such values of >1000 ppm copper are unique when compared with levels from other monitoring studies involving

Figure 78.

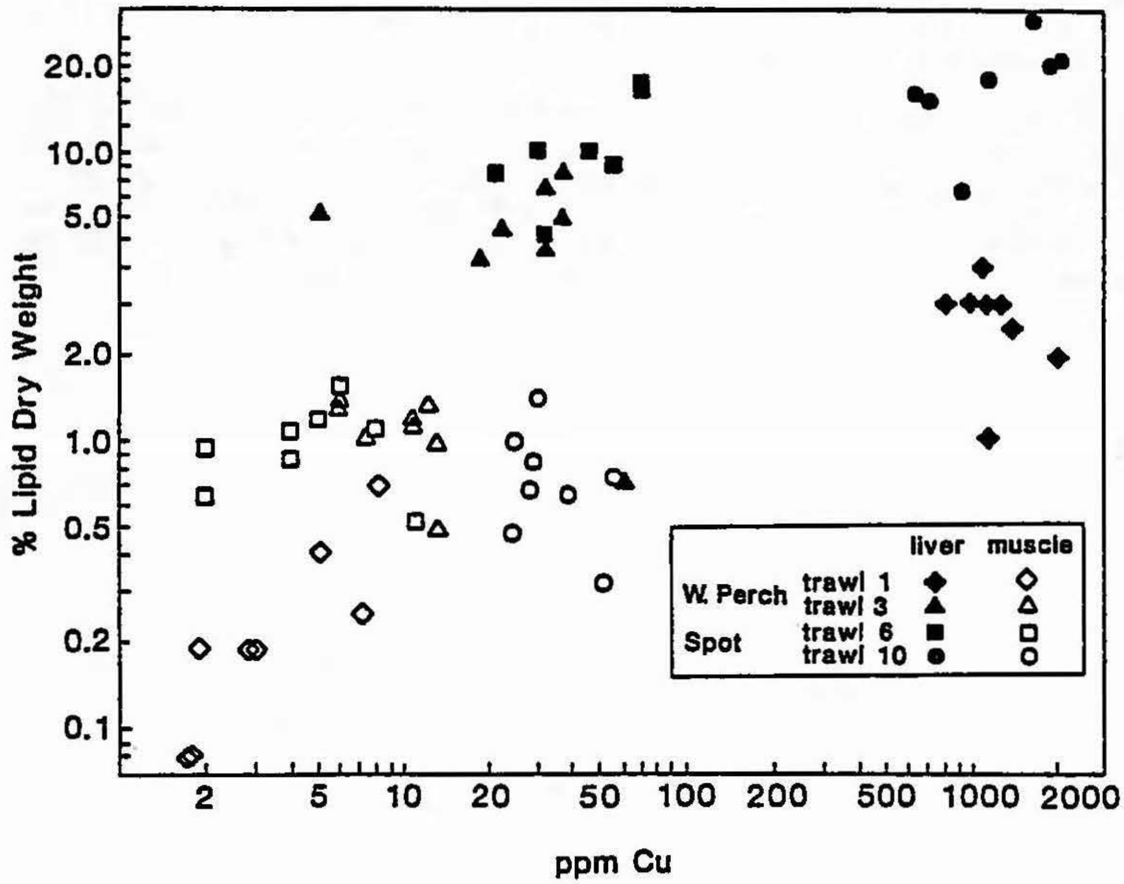


Figure 78. Tissue copper analysis in white perch (Morone americana) and spot (Leiostomus xanthurus) collected August 1981.

LITERATURE CITED

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CHAPTER 9

ORGANIC CONTAMINANTS

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SUMMARY

The levels of 44 individual trace organic contaminant compounds were determined in samples of water, sediment and several species of biota in the region of Hart and Miller Islands. In general, the levels of these toxic organics were extremely low in water but several orders of magnitude higher in sediments in the region. Elevated levels of many compounds were observed when compared to the baseline 1981/1982 period, particularly in the water column during the active construction phase. Most of the organic toxic chemicals found in the sediments in the region were also found in the various species of benthic invertebrates collected. The measured levels ranged from about the same as in the sediments to as high as 10000 times the levels in the sediments. This bioconcentration of organics is typical of many benthic invertebrates which live in the bottom and provides a way to detect low levels of pollutants entering the region. However, the high degree of variability observed in the levels of compounds in these species complicates the interpretation of the data. However, it was clear that the levels of many compounds in these organisms had also increased well above those observed in the baseline year. Moderate levels of most of the pollutants tested were also found in one species of fish collected in the region. The magnitude of bioconcentration observed in these organisms was less when compared to the levels of compounds in the sediments than for the benthic invertebrates. Contaminant levels in fish were similar to the baseline year data. It should be emphasized that <u>none</u> of the pollutants detected were found at levels where a hazard to humans is indicated if ingested. For those species for which standards limiting concentrations of PCB and chlorinated pesticides exist, the data obtained in this study indicate that these compounds do not exceed such

INTRODUCTION

The sampling of water, sediment and biota in the Hart-Miller Island area was performed on seven dates: August 23-25, 1982, Sept. 8-9, 1982, Nov. 15-17, 1982, Feb. 21-23, 1983, May 16-18, 1983, June 21-22, 1983 and July 14-15, 1983. The sampling design was established to obtain information on several critical questions which need to be assessed in order to accurately identify changes occurring as the result of construction and operation of the Hart-Miller dredge disposal containment facility. These questions were:

1. What are the levels of organic contaminants, likely to be found in the dredge spoils, currently found in the water, sediments and biota in the Hart-Miller Island area during the construction phase?

2. What is the variability of observed levels of these contaminants in the various media sampled?

3. What are the best indicator organisms to monitor changes in contaminant levels in the region?

4. What changes above the baseline levels observed in 1981/1982 are detected?

For this reason, sampling of the region in the second year was weighted more evenly throughout the year. Table 1 show the samples collected in the 1982-1983 cruises. A total of 80 samples were collected for analysis during the second year. The raw data were presented on pages 210 to 249 in the earlier Data Report (Means 1983b, Data Tables 1-80).

METHODS OF ANALYSIS

Analyses of 44 organic compounds (Table 2) were performed on each sample using selected ion mass spectrometry coupled with high resolution capillary gas chromatography. Quantitation was performed using the internal standard method. Detailed procedures are presented here.

Water - Two liter samples of water were collected at each station at a depth of 0.5 m in pre-cleaned glass bottles. Pre-cleaning was achieved using successive solvent washes of pesticide grade acetone, methylene chloride, methanol and followed by a wash with glass distilled water and finally a wash with sample water. These samples were stored for not longer than 7 days prior to extraction in the dark at 4°C.

One liter of water was filtered through pre-combusted Whatman GF/C glass fiber filters (1.2 um) and successively extracted with 100 ml, 50 ml, and 50 ml of methylene chloride. The extract was dried over anhydrous

Table 2. List of 44 compounds analyzed.

Compound
alpha-BHC
lindane
beta-BHC
aldrin
heptachlor
heptachlor epoxide
dieldrin
naphthalene
fluorene
phenanthrene
anthracene
fluoranthene
pyrene
benzo(a)pyrene
benzo(a)anthracene
benzo(k)fluoranthrene
3,4 benzofluoranthene
chrysene
acenaphthylene
benzo(ghi)perylene
dibenz(a,h)anthracene
indeno(1,2,3-cd)pyrene
acenaphthene
PCBs, total
kepone
dimethyl phthalate
diethyl phthalate
dibutyl phthalate
di-2-ethyl hexyl phthalate
di octyl phthalate
atrazine
simazine
trifluraline
chlordane
diazinon
DDE
DDD
DDT
linuron
butyl benzyl phthalate
endrin
malathion
methyl parathion
ethyl parathion

200°C and a source pressure of 4-6 x 10^{-6} torr. Each compound was detected using three diagnostic selected ions characteristic of the compound. Calibration curves of the response per ug of each compound relative to the response observed for the internal standard were prepared and used to convert the responses observed for samples to concentrations in the extracts.

The identity of each compound was confirmed by: 1) its retention time relative to the internal standard; 2) the presence of all three characteristic ions; and 3) the correct intensity ratios of the three characteristic ions.

Quality Assurance

Calibrations were prepared on each day when samples were analyzed. The mass spectrometer was also tuned and optimized on each analysis day. Solvent and reagent blanks were analyzed along with each batch of samples analyzed. Known samples were analyzed to assure that the sample evaporation and saponification steps did not result in sample losses. Standard methods of extraction and analysis were used and check samples were analyzed periodically. Results of method blank studies indicated that no significant concentrations (<0.025 ng/ul) of the 44 compounds were present in the solvents or reagents used. Based on this information, and upon day-to-day variations in instrument background, a detection limit of 0.1ng/ul of analyzed extract was set for the compounds reported. Tests of extraction efficiencies for the compounds tested indicated that the recoveries of all compounds were in the range of 89-102%, thus no recovery factors were applied to the calibrations for the compounds.

STATISTICAL APPROACH

The data for the 44 organic contaminants is difficult to analyze using conventional statistical measures. The data set contains many values which are reported "less than a detection limit." These detection limits are dependent upon sample size and the presence of interferences as well as instrument parameters and, therefore, are variable not only between media/species analyzed but also within a given media/species. Because "less than" data cannot be used to calculate means and standard deviations, we have used ranges and medians as the primary method of data analysis and comparison. This approach gives equal weight to low (undetectable) levels and extremely high values which occur in the data set, thus yielding a median value which is more typical of the data set than a mean calculated by excluding all "less than detection limit" data.

RESULTS AND DISCUSSION

TRACE ORGANICS IN WATER

Water samples were collected at eight stations designated (B-1, N-1-4, SF-1-2, WQ-8) (see Figure 1). In addition, in September, two additional water samples were collected in the plume of material coming from the construction area. (Plume #1 and #2). As would be expected for these 44 compounds, all of which are fairly water insoluble, the levels of most compounds were at or below the detection limit. The data represented in Data Tables 1-18 (pages 210-218) in the Data Report (Means 1983b) and the ranges and median values obtained for each compound are presented here in Table 3.

Table 3. Ranges of concentrations and median values for 44 compounds in water.

COMPOUND	September 1982[1]		June 1983[2]	
	Range (ppb)	Median (ppb)	Range (ppb)	Median (ppb)
alpha-BHC	0.18-1.4	0.58	<0.1 -0.31	0.18
lindane	0.13-2.0	0.47	0.10-0.52	0.20
beta-BHC	<0.1 -2.3	0.63	<0.10-0.52	0.30
aldrin	0.1 -1.1	0.43	<0.1 -0.18	0.11
heptachlor	<0.1 -1.4	0.44	<0.1 -0.18	<0.1
heptachlor epoxide	<0.1 -0.41	0.06	<0.1 -0.36	0.12
dieldrin	<0.1 -1.2	0.37	<0.1 -0.30	<0.1
napthalene	ND		<0.1 -55	<0.1
fluorene	ND		ND	
phenanthrene	<0.1 -31	<0.1	<0.1 -55	<0.1
anthracene	<0.1 -27	<0.1	<0.1 -35	<0.1
fluoranthene	<0.1 -1400	<0.1	<0.1 -122	<0.1
pyrene	<0.1 -6400	<0.1	<0.1 -570	<0.1
benzo(a)pyrene	ND		ND	
benzo(a)anthracene	ND		ND	
benzo(k)fluoranthrene	ND		ND	
3,4 benzofluoranthene	ND		ND	
chrysene	ND		ND	
acenaphthylene	<0.1 -160	<0.1	ND	
benzo(ghi)perylene	ND		ND	
dibenz(a,h)anthracene	ND		ND	
indeno(1,2,3-cd)pyrene	ND		ND	
acenaphthene	<0.1 -43	<0.1	ND	
PCBs, total	0.31-4.7	1.8	<0.1 -0.76	0.29
kepone	ND		ND	
dimethyl phthalate	ND		ND	
diethyl phthalate	<0.1 -3300	170	1400-4100	2700
dibutyl phthalate	1.3 -4200	600	<0.1 -4200	445
di-2-ethyl hexyl phthalate	<0.1 -8600	26	ND	
di octyl phthalate	<0.1 -1400	<0.1	ND	
atrazine	ND		<0.1 -0.55	0.15
simazine	ND		<0.1 -0.35	0.10
trifluralin	ND		ND	
chlordane	0.15-3.1	0.62	<0.1 -0.34	0.11
diazinon	ND		ND	
DDE	<0.10-2.6	0.23	<0.1 -0.10	<0.1
DDD	<0.1 -9.1	0.22	<0.1 -0.17	<0.1
DDT	<0.1 -6.3	0.32	ND	
linuron	<0.1 -0.53	0.21	ND	
butyl benzyl phthalate	<0.1 -1100	<0.1	ND	
endrin	<0.1 -2.6	<0.1	ND	
malathion	ND		ND	
methyl parathion	ND		ND	
ethyl parathion	ND		ND	

ND = not detected
[1]N = 10 for median
[2]N = 8 for median

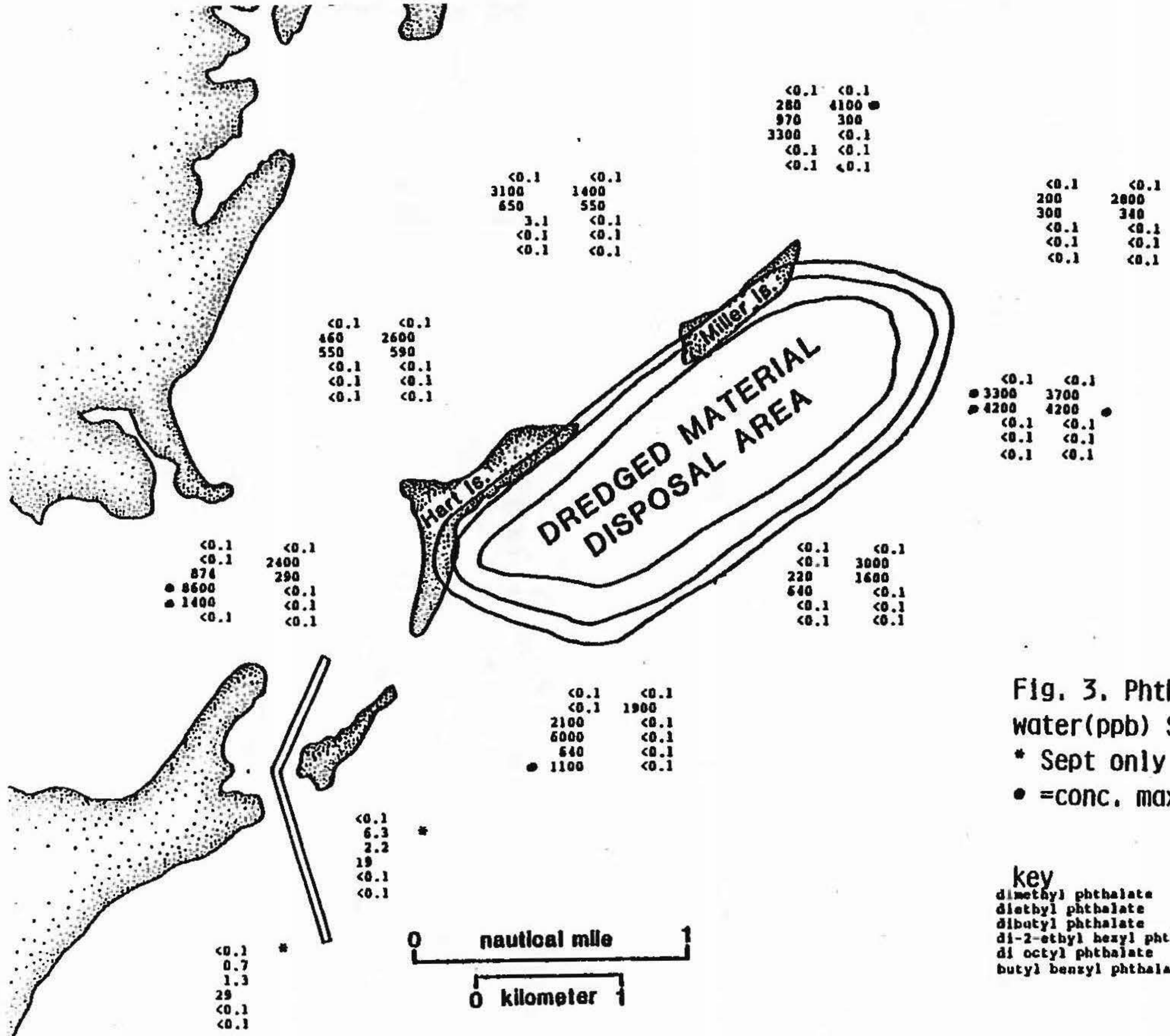

Fig. 3. Phthalate esters in water(ppb) Sept/June
* Sept only
• =conc. maxima

key
dimethyl phthalate
diethyl phthalate
dibutyl phthalate
di-2-ethyl hexyl phthalate
di octyl phthalate
butyl benzyl phthalate

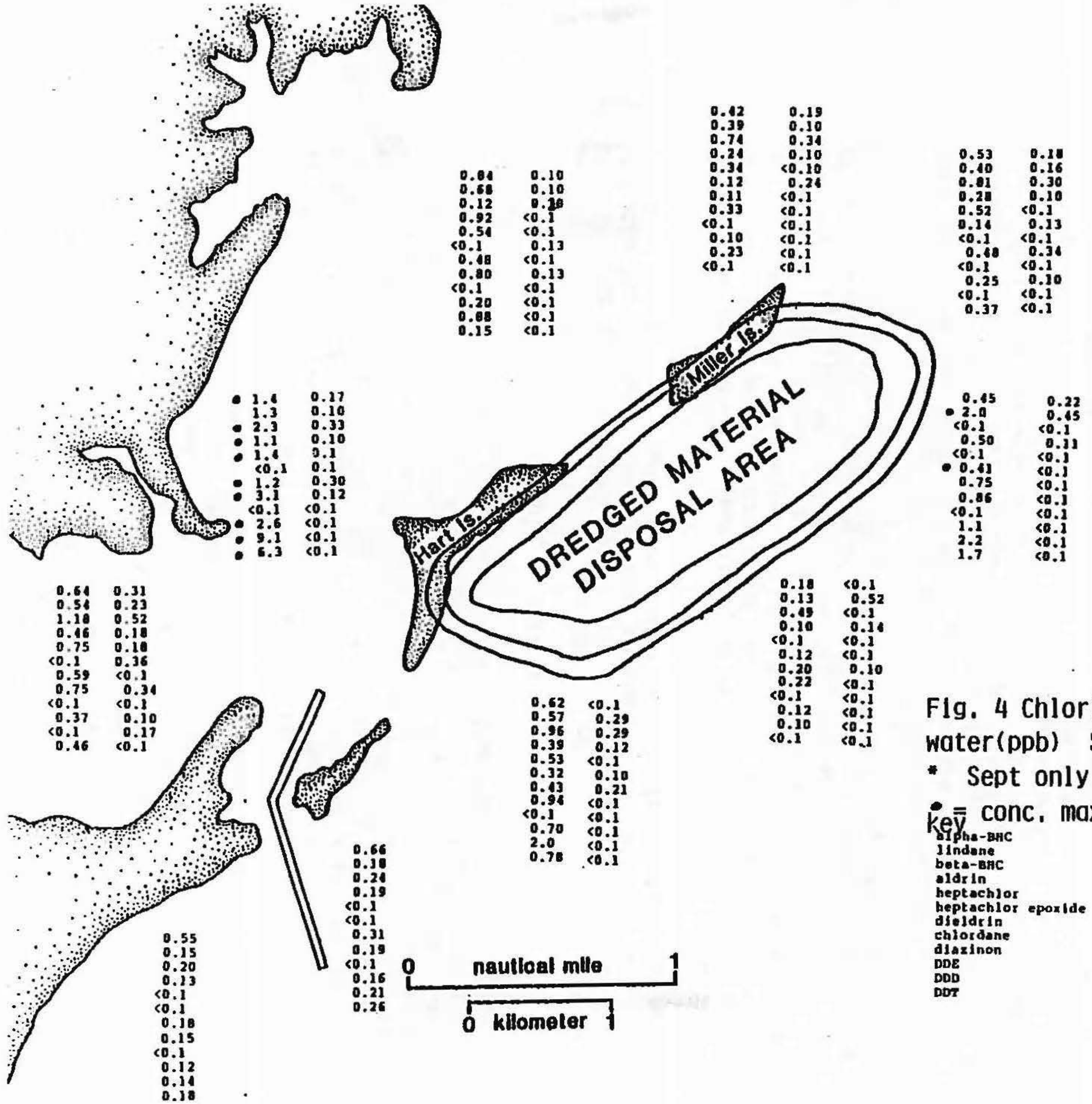

Fig. 4 Chlorinated pesticides in water(ppb) Sept/June

* Sept only

• = conc. maxima

key
alpha-BHC
lindane
beta-BHC
aldrin
heptachlor
heptachlor epoxide
dieldrin
chlordane
diazinon
DDE
DDD
DDT

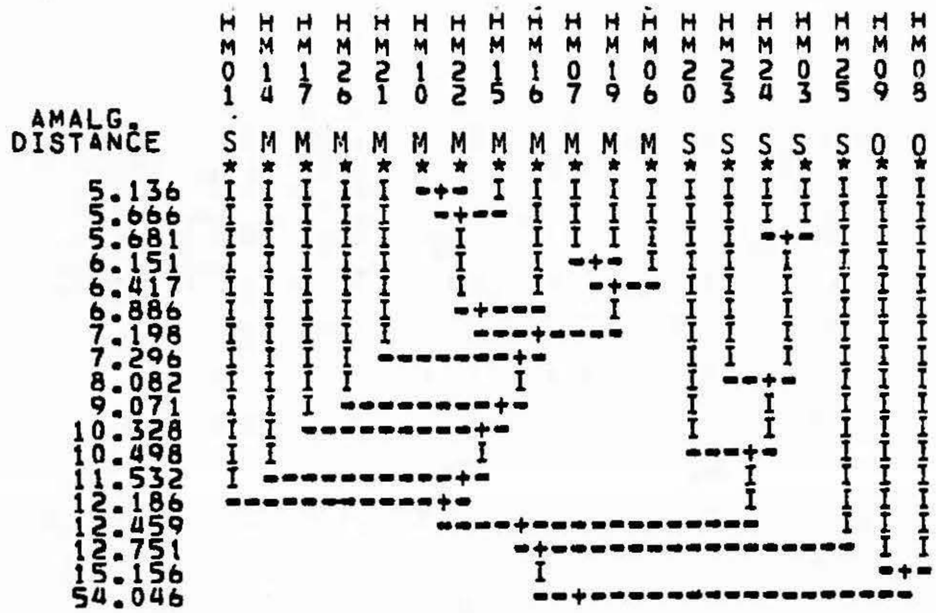

Figure 7. Cluster analysis of February 1983 benthic data giving station numbers and general bottom type (S=sand, M=silt/clay, O=oyster shell).

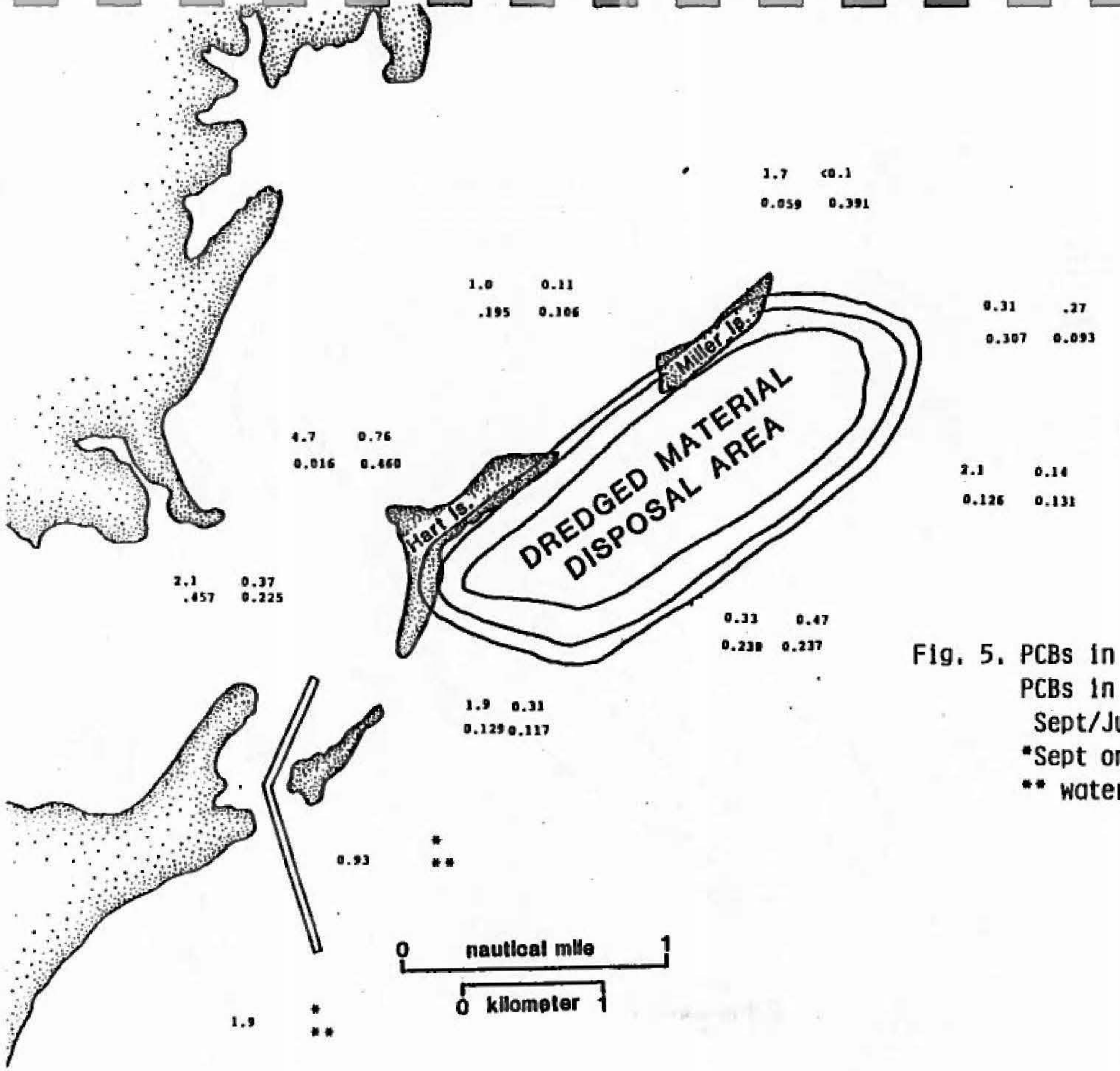

Fig. 5. PCBs in water(ppb) &
PCBs in sediments(ppm)
Sept/June
*Sept only
** water only

Table 4. Ranges of concentrations and median values for 44 compounds in sediments.

COMPOUND	September 1982[1] Range (ppm)	Median (ppm)	June 1983[1] Range (ppm)	Median (ppm)
alpha-BHC	0.002-0.031	0.011	0.002-0.014	0.010
lindane	0.002-0.042	0.010	0.003-0.048	0.008
beta-BHC	<0.001-0.019	0.009	0.004-0.017	0.013
aldrin	0.002-0.038	0.009	<0.001-0.083	0.027
heptachlor	0.001-0.037	0.005	<0.001-0.010	<0.001
heptachlor epoxide	<0.001-0.021	0.002	<0.001-0.023	0.004
dieldrin	0.005-0.062	0.018	0.011-0.061	0.028
napthalene	<0.001-0.036	0.001	<0.001-0.110	0.004
fluorene	<0.001-0.054	0.008	<0.001-0.046	0.009
phenanthrene	0.002-0.039	0.013	0.007-0.050	0.012
anthracene	0.002-0.028	0.012	0.007-0.040	0.011
fluoranthene	0.010-0.078	0.039	0.007-0.120	0.028
pyrene	0.009-0.140	0.068	0.009-0.160	0.037
benzo(a)pyrene	<0.001-0.011	0.005	<0.001-0.030	0.002
benzo(a)anthracene	ND		ND	
benzo(k)fluoranthrene	<0.001-0.005	0.002	<0.001-0.014	0.004
3,4 benzofluoranthene	ND		ND	
chrysene	<0.001-0.022	0.007	<0.001-0.045	0.006
acenaphthylene	<0.001-0.040	0.002	<0.001-0.034	0.002
benzo(ghi)perylene	<0.001-0.002	<0.001	<0.001-0.004	<0.001
dibenz(a,h)anthracene	<0.001-0.005	<0.001	<0.001-0.009	0.001
indeno(1,2,3-cd)pyrene	<0.001-0.001	<0.001	<0.001-0.004	0.001
acenaphthene	<0.001-0.063	<0.001	<0.001-0.011	<0.001
PCBs, total	0.016-0.457	0.162	0.093-0.460	0.179
kepone	ND		ND	
dimethyl phthalate	<0.001-0.088	0.017	<0.001-0.072	0.007
diethyl phthalate	ND		<0.001-0.006	<0.001
dibutyl phthalate	0.090-4.5	0.685	<0.001-16.0	0.840
di-2-ethyl hexyl phthalate	0.290-14.0	7.0	<0.001-50.0	4.3
di octyl phthalate	<0.001-11.0	0.555	<0.001-0.270	<0.001
atrazine	ND		ND	
simazine	ND		ND	
trifluralin	ND		ND	
chlordane	0.004-0.109	0.027	0.008-0.055	0.029
diazinon	ND		ND	
DDE	0.004-0.117	0.045	0.006-0.053	0.025
DDD	0.006-0.117	0.027	0.007-0.112	0.053
DDT	<0.001-0.150	<0.001	<0.001-0.114	0.032
linuron	ND		ND	
butyl benzyl phthalate	<0.001-6.0	0.001	ND	
endrin	ND		ND	
malathion	ND		ND	
methyl parathion	ND		ND	
ethyl parathion	ND		ND	

ND = not detected
[1]N = 8 for median

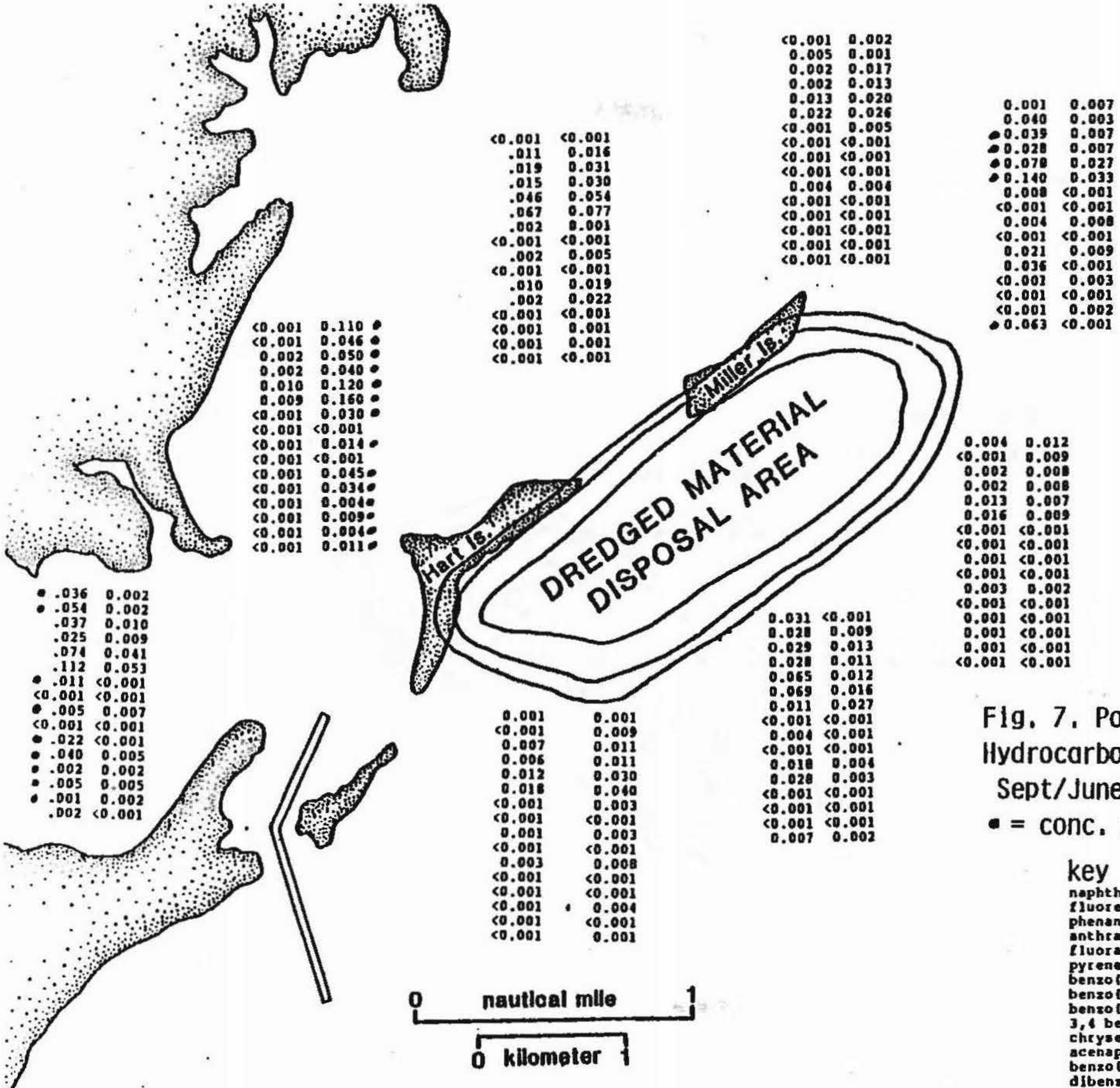

Fig. 7. Polynuclear Aromatic Hydrocarbons in sediment(ppm) Sept/June

• = conc. maxima

key

naphthalene
fluorenr
phenanthrene
anthracene
fluoranthene
pyrene
benzo(a)pyrene
benzo(a)anthracene
benzo(k)fluoranthrene
3,4 benzofluoranthene
chrysene
acenaphthylene
benzo(ghi)perylene
dibenz(a,h)anthracene
indeno(1,2,3-cd)pyrene
acenaphthene

Table 5. Ranges (ppb) of concentrations for 44 compounds in Leptocheirus.

COMPOUND	February 1983[1]	May 1983[1]
alpha-BHC	1000-<1900	870- 1740
lindane	498-24600	411- 4700
beta-BHC	<170-<1900	255-<2600
aldrin	1110-17900	170- 4250
heptachlor	<777-11200	217-<2600
heptachlor epoxide	<170-<1900	129- 3770
dieldrin	<170-34700	442- 4350
napthalene	ND	ND
fluorene	<777-20300	ND
phenanthrene	170-<1900	<166-<2600
anthracene	170-<1900	<166-<2600
fluoranthene	ND	<166- 6800
pyrene	ND	<166- 4500
benzo(a)pyrene	ND	ND
benzo(a)anthracene	ND	ND
benzo(k)fluoranthrene	ND	ND
3,4 benzofluoranthene	ND	ND
chrysene	ND	ND
acenaphthylene	ND	ND
benzo(ghi)perylene	ND	ND
dibenz(a,h)anthracene	ND	ND
indeno(1,2,3-cd)pyrene	ND	ND
acenaphthene	ND	ND
PCBs, total	1290- 2910	1270- 6910
kepone	ND	ND
dimethyl phthalate	170-<1900	ND
diethyl phthalate	<1500-553000	<110-19200
dibutyl phthalate	<170-350000	2100-217000
di-2-ethyl hexyl phthalate	25100-590000	25500-490000
di octyl phthalate	1300-180000	<110-65000
atrazine	ND	ND
simazine	ND	ND
trifluralin	ND	ND
chlordane	1030-18400	477- 8000
diazinon	ND	ND
DDE	647-27200	250-<2600
DDD	<170-76900	1621-51000
DDT	ND	<110-<2600
linuron	ND	ND
butyl benzyl phthalate	1300-7000000	<110-740000
endrin	ND	ND
malathion	ND	ND
methyl parathion	ND	ND
ethyl parathion	ND	ND

ND = not detected
[1]N = 5

Table 8 . Concentrations of Selected Organic Contaminants in Cyathura at Stations , May 1983.

Compound	HM6	HM10
	Concentration, ug/kg	
alpha-BHC	3510	4240
lindane	4210	4860
beta-BHC	3930	3650
aldrin	3700	2630
heptachlor	2650	6000
heptachlor epoxide	<2800	<1660
dieldrin	2915	3070
naphthalene	<2800	<1660
fluorene	<2800	<1660
phenanthrene	<2800	<1660
anthracene	<2800	<1660
fluoranthene	<2800	<1660
pyrene	<2800	<1660
benzo(a)pyrene	<2800	<1660
benzo(a)anthracene	<2800	<1660
benzo(k)fluoranthrene	<2800	<1660
3,4 benzofluoranthene	<2800	<1660
chrysene	<2800	<1660
acenaphthylene	<2800	<1660
benzo(ghi)perylene	<2800	<1660
dibenz(a,h)anthracene	<2800	<1660
indeno(1,2,3-cd)pyrene	<2800	<1660
acenaphthene	<2800	<1660
PCBs, total	2830	2630
kepone	<2800	<1660
dimethyl phthalate	<2800	<1660
diethyl phthalate	<2800	<1660
dibutyl phthalate	<2800	<1660
di-2-ethyl hexyl phthalate	27000	24000
di octyl phthalate	<2800	<1660
atrazine	<2800	<1660
simazine	<2800	<1660
trifluraline	<2800	<1660
chlordane	5980	5460
diazinon	<2800	<1660
DDE	<2800	5540
DDD	45000	1660
DDT	<2800	<1660
linuron	<2800	<1660
butyl benzyl phthalate	7400000	<1660
endrin	<2800	<1660
malathion	<2800	<1660
methyl parathion	<2800	<1660
ethyl parathion	<2800	<1660

anthene, acenaphthene, acenaphthylene, indeno[1,2,3cd]pyrene, benzo[ghi]-perylene and dibenz(a,h)anthracene were not detected in any samples. The compounds naphthalene, fluorene, phenanthrene, anthracene, and chrysene were only detected in the February, 1983 sample. The most frequently found PAHs were fluoranthene and pyrene. The relatively low levels and occurrence of this class of compounds is probably related in part to the ability of these and other fish to degrade aromatic hydrocarbons in their livers and excrete them as polar metabolites.

No herbicides were detected in any of the samples of either species of fish.

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