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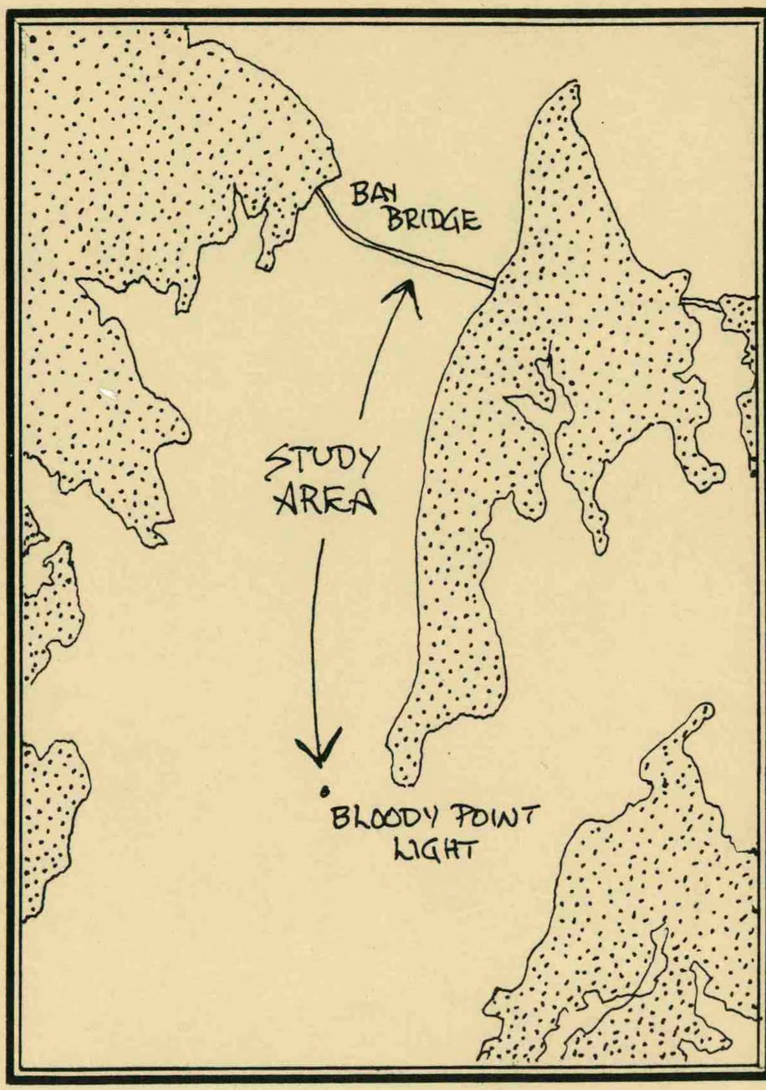
THE DEEP TROUGH STUDY OF THE CHESAPEAKE BAY



TIDEWATER ADMINISTRATION

MARYLAND DEPARTMENT of NATURAL RESOURCES

DEEP TROUGH STUDY

OF

THE CHESAPEAKE BAY

Prepared for

Coastal Resources Division
Tidewater Administration
Maryland Department of Natural Resources

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EXECUTIVE SUMMARY

The objective of the present study was to determine the ecological value of that portion of the Deep Trough which is the remnant of the old Susquehanna riverbed in the upper bay that has left an area of about 14 km (9 mi) in length having depths of 20-53 m (80-175 ft) adjacent to present ship channels. The site is attractive as a choice for overboard spoil disposal from an economic and engineering standpoint; approximately 19.9 million cubic meters of dredge spoil from the Baltimore Harbor approach channels will be generated for potential placement in the Deep Trough.

To address the question of environmental safeguards that would be necessary to minimize effects on the biota we have attempted to determine--by means of a nearly monthly sampling program--if the utilization of the trough by fishes shows preferences for the deepest bottom waters, by study of benthic life that might attract and serve fish populations, and by measurement of water quality variables that constrain or restrict the free use of Deep Trough waters.

Fishes caught by trawl in the Deep Trough and adjacent reference sites comprised 33 species. Marine-spawned populations were dominated by Atlantic croaker (36 percent), spot (10 percent), and Atlantic menhaden (4 percent), while estuarine fishes were dominated by bay anchovy. Diadromous species, including blueback herring, alewife, white perch (semi-anadromous) and striped bass, made up only 1.8 percent of the total catch, reflecting the decline observed in other studies over recent years.

Catches in Deep Trough bottom waters were significantly higher than those of the reference sites having depths of 6-12 m (20-40 feet), but no preference for the deepest areas, termed "holes" could be demonstrated from our findings. Catches within the trough were dominated by Atlantic croaker, while reference stations had bay anchovy as the most abundant species.

Fish populations were severely affected by the summer anoxic periods common in upper bay deep waters and in many tributaries. Anoxic waters show a slight trend of increasing seasonal duration and increasing volume so affected. May through October catches were insignificant and dominated by bay anchovy, a pelagic species probably taken in the upper water column during otter trawl retrieval. The absence of catches of spot during their late spring (April) migration suggests that this species, and some others, do not use the Deep Trough as a migration route--a phenomenon that may be effected by an avoidance response by the fishes to the low dissolved oxygen conditions found in summer. The design of our study did not permit detailed examination of this possible avoidance response, and while the autumn and winter movement of fish toward deep water took place after oxygen levels had recovered, this movement could have been driven by decreasing water temperature alone.

Failure to see aggregations of anadromous fish species during the 1982-83 sampling period may, in part, be due to the somewhat warmer average temperatures and a relatively mild winter. For example, gill netting success was reportedly better farther inshore near the mouths of tributaries during our sampling period.

The benthos of the Deep Trough is severely reduced during summer anoxia. Recovery begins by November, dominated by polychaetes, and is later supplemented by clams. The abundance patterns observed--greater abundance of polychaetes at references sites--do allow the possibility that consumption by demersal fishes makes the benthic animals a valuable resource in winter months.

Will the disposal of dredge spoil, with its assumed lessening of average trough depths by about 1.5 m (5 feet) have measurable impact on the biota?

The question is heavily dependent on the nature of the spoils to be deposited. If the spoils are essentially like trough sediments in physical and chemical properties, the observable impact relates primarily to the short-term smothering of the less-mobile benthic and demersal members of the community and the potential movement and resuspension of sediment.

The annual recovery of benthos following the summer anoxia suggests that short-term effects will be limited in duration and probably allow rapid repopulation. The resuspension potential due to bottom currents has been judged low in a separately conducted, parallel study carried out by the Horn Point Environmental Lab of the University of Maryland, although some uncertainties remain due to relative scarcity of data.

Trace metal concentration differences do exist in approach channel and Deep Trough sediments. Cadmium and lead occur at significantly higher levels in approach channels, while chromium and manganese levels are higher in the trough. All levels are within permissible levels set by the State of Maryland guidelines for overboard disposal of dredged materials. Experience with elutriate testing of spoils in Baltimore Harbor waters in other studies suggests the release potential to be small, although biological uptake and cycling by the benthic life forms during their winter activity could not be assessed within the framework of this study. The absence of sufficient data on the presence, significance, and potential for release of chlorinated hydrocarbons in approaches or the Deep Trough allows no effective comparisons. Again, experience with elutriate testing with sediments known to be contaminated showed no significant release, but such interpretations should clearly be based on direct measurements in the sediments to be dredged or covered.

Spoil disposal options can be grouped and summarized as follows:

1. The no disposal option would leave the present ecological value unchanged and the planned depth change would occur naturally, if present sedimentation rates continue, in about 100-150 years.

2. Disposal with restrictions calls for (a) summer disposal--here there is least impact on the benthos and nekton but may produce local, short-term stimulus to phytoplankton blooms. (b) Winter disposal would affect finfish and macroinvertebrates over the short term through covering, smothering and related stress. Recolonization would be expected the following winter, as it now follows after summer anoxic stress.

   In either case, the change in bathymetric contours is not believed to lead to significant change in the vertical extent of the summer anoxic zone, other variables remaining constant, but present models and existing data leave room for reasonable doubt.

3. Unrestricted disposal will have the effects mentioned above, provided the total quantity of spoil remains the same and depth changes remain as originally stated for purposes of this study. If the spoil release becomes protracted, chronic effects may occur that were not studied here, given the normal disposal operations now employed. Should depth changes exceed 2-meters, and spoil quantities exceed 19.9 million cubic meters, long-term impacts from the chemicals and physical effects, i.e., changes in salinity regimes and the extent of anoxic waters, and interaction with the biota will require extensive new analysis.

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Jerry Cox proved an excellent captain of the research vessel DISCOVERY. Hugo Gemignani was chief scientist during the cruises. On board staff included Nancy Matthews and Lynn Hirsch, lab technicians; Rick Younger, mate; David Bleil, Donald Lear, David Maney, Eli Reinharz, Melvin Selig, Frank Dawson, Ty Stinson, Anna Shaughnessy, and Richard Wagner. Eli Reinharz of the Maryland Geological Survey was responsible for lab analysis of benthos. We thank the support staff at Ecological Analysts for their efforts in data collation, computer entry, analysis, and typing. Graphical assistance was provided by Ed Sparks, Doris Kaufman, and Sally Barba.

1. INTRODUCTION

1.1 OBJECTIVE

The Chesapeake Bay has an average depth of about 8 meters (27 ft). Whereas this may contribute to high biological productivity in proportion to the Bay's volume, it has required considerable channel deepening to permit shipping activity to keep pace with economic development. Dredge spoils generated from planned deepening of the main ship channels from their present depth of 13 meters (42 ft) to 15 meters (50 ft) require disposal. Spoils containing significant amounts of toxic materials are slated for land deposit on the Hart-Miller Island complex designed for that purpose. Overboard disposal, however, remains a desirable alternative for comparatively "clean" spoils because of economic and engineering factors. The old Susquehanna river-bed forms a region over limited portions of the upper bay commonly referred to as the Deep Trough, where minimal sedimentation may have combined with possible erosive processes to form a narrow basin well in excess of the required 15-m channel depth. This makes the Deep Trough, including a few holes where the maximum depths of the entire bay are found, an attractive site for spoil disposal, more so by its close proximity to the Baltimore Harbor approaches scheduled for deepening.

The objective of this study was to determine the ecologic value of Deep Trough, particularly in terms of its fish resources. This will allow environmental managers of the State of Maryland to determine if there are significant ecological reasons that would demand either no spoil placement in the Deep Trough, or require a set of constraints under which spoil disposal should be conducted.

The factors that would contribute to the Deep Trough's ecological value include the possibility of fish utilization as migration routes, habitat during fall and early winter cooling of the surface waters, and potential as food resource to fishes. Additional factors that must be evaluated for contemplated spoil disposal are the impacts of the disposal operation itself, such as effects of the spoil plume during settling. The nature of the spoils in terms of their potential for releasing toxic constituents, and the risk of resuspension due to erosive processes, also require knowledge of the biota in order to estimate possible impacts.

We have addressed these objectives by selecting a survey plan that allows comparison of the Deep Trough biota, sampled at six sites in the approximately 14-km (9-mi) long deep area, with three reference sites that represent areas typical of Chesapeake Bay average depths. Survey cruises have been conducted at monthly intervals, excepting those summer months when anoxic conditions preclude the presence of significant fish populations.

Collections of nekton have been complemented by benthic and ichthyoplankton sampling, and measurement of relevant water quality variables. The Deep Trough stations have been further subdivided into two depth regimes to allow analyses seeking to establish if preferences in use of the deepest zones exist--zones that are likely to be most affected by dredge spoil placement.

Lastly, an attempt has been made to structure the study to allow interpretation of findings in terms of only recently available information concerning chemical contamination of the dredged materials and regarding the distribution of bottom currents that affect submarine spoil movement, or resuspension subsequent to placement.

1.2 BACKGROUND

1.2.1 Ecological Value of the Deep Trough

The value of the Deep Trough can be considered important if the abundance of fish or crabs (or selected species populations) is significantly greater there than in the more shallow Reference area. While anoxic conditions, typically beginning in late May and lasting nearly into October, limit the use of the Trough by finfish and crabs and kill the benthic community that may establish itself there during winter, the biota may be most abundant in the deeper waters in late autumn and winter. Prior research has supported the concept of overwintering in deep areas such as the Deep Trough. These studies and interpretation of our findings in this study will be discussed in subsequent sections.

Other functional aspects that may contribute to ecological value include its use as a migratory route and the opportunistic use by fish species when salinity or similar environmental variables make the area temporarily attractive. Lastly, utilization of the Trough in terms of its benthic communities will also contribute to ecologic value, despite the annual summer mortality due to anoxic conditions.

1.2.2 Depth Regimes

If one assumes that the long-term impact of spoil disposal is limited to the change in depth from the accumulated solids, the question still remains of whether this in itself produces an impact on the biota. It has been estimated that the proposed dredging of the approach channels to Baltimore Harbor will produce approximately 19.9 million cubic meters of spoil that are designated for overboard disposal. Should disposal occur in the Deep Trough, the change in depth, assuming uniform deposition, would only amount to about 1.5 meters (5 ft). Whereas such a change may be too insignificant to show measurable impacts, the question of impact still deserves to be asked, more so when one considers that effects on bottom water chemistry may be coupled with deposition in a manner that produces a wide range of changes.

An answer, if only tentative, may be provided if one sees preferences in habitat use that favor, or reject, the idea that the deepest zones are most used or most desirable. This requires a sampling program stratified as a function of depth. Accordingly, we have selected sampling sites that not only allow comparison to a "typical" bay depth reference area, but seek to observe if significant differences exist within the Trough itself. For this report we will refer to the sampling areas as Reference stations (the shallowest), Deep Trough stations (deeper areas that characterize the Deep Trough as an areal average), and the Deep Holes (the few locations where maximum depths for the entire Chesapeake Bay are found). One of the three Hole stations is located off Bloody Point Bar lighthouse, 53 meters (175 ft) deep; another is south of Matapeake, Queen Annes County, about 43 meters (140 ft) deep. Both locations are westward of the Kent Island shore (see Figure 2.1-1).

1.2.3 Effect of Water Quality Trends

The Chesapeake Bay, like most ecotones, is a dynamic system where modifications of the physical and chemical environment are reflected in the responses of the biota, e.g., changes in total biomass, population structure, or diversity. Human population pressure in the Bay watershed has had a significant impact on that system; impacts that range from chemical changes, such as increases in inorganic nutrients, total organic carbon, and toxic materials, to the significant decline in submerged aquatic vegetation, and the probable alteration of fish community structure. The impacts are long-term effects for which the methodology of assessing cumulative effects remain to be developed. Superimposed are climatological changes and individual events of various durations that add the complication of making any given short-term data set, e.g., a one-year survey such as this, depend on antecedent conditions and force the question of adequacy of representation.

One such trend is the observed slow increase in both the areal extent and duration of summer anoxic periods found in deep waters of Chesapeake Bay (Reinharz and O'Connell 1981, Boesch 1977). For example, in surveys conducted by Chesapeake Bay Institute between 1949 and 1961 (Hires et al. 1963), values indicative of oxygen stress, generally accepted as 5 ppm or less, were found at depths below 10 meters (30 ft) in summer months. These declined to values as low as 0.2 ppm at depths of 20 meters (60 ft) or more in the early 1950s. By the late 1950s, values less that 1 ppm were found in depths as little as 10 meters, showing a trend of reduced oxygen in shallower waters. Although totally anoxic conditions may have been found, they go unreported in the CBI document, implying that such conditions were not widespread in the Deep Trough area studied here. As will be discussed in the Results Section, by 1982-1983 we found not only reduced oxygen concentrations in Deep Trough waters, but an extensive occurrence of totally anoxic waters. The fisheries implications are obvious--fish will not move into such waters for more than short forays, which leads to the virtual exclusion of the deeper water as a productive habitat. The Chesapeake Bay Program of the U.S. EPA (Environmental Protection Agency) interprets the observed trends to be due largely to anthropogenic effects (EPA 1982). This implies that they may be at least partially reversible if that becomes a management goal.

Variables that affect data interpretation include those determined by long-term fluctuation of fresh water input to the Chesapeake Bay. Autumn and winter 1982 were marked by a fairly long dry spell, allowing salinity values to rise to levels consistent with those found in the lower bay, thus favoring the northward movement of fishes not normally seen in the upper bay brackish waters. The occurrence of black sea bass and hake during our surveys may serve as representative findings in this case.

The sampling year was also one of rather mild temperatures which in turn may have affected fish behavior differently than during "average" winter conditions. These unusual salinity and temperature phenomena are likely short-term episodes that may reverse themselves in the following year. A biological long-term effect is the changed fish distribution that is reflected in a decrease in fresh water spawners (anadromous species) with an attendant increase in the occurrence of ocean-spawners, many of which are plankton feeders of little or no commercial value and even less so to the sport fishermen. The increased abundance of plankton feeders may reflect increases in plankton as seen in the rise of chlorophyll levels in the last 20 years (EPA 1982).

It is wholly within the scope of this project to provide a measurable basis for judgment of ecological value of the Deep Trough. Such analysis rests on the findings amassed during the study period and on the interpretation of prior information. It is beyond the scope of this study, however, to provide interpretation of the impact of fluctuations having periods longer than the sampling interval. Findings based on extrapolations from limited information are clearly identified so that implications from existing data and those from estimates of trends and cycles can be appropriately weighed.

1.3 ASSESSMENT IN RELATION TO DREDGE SPOIL PLACEMENT

If the dredged spoils to be disposed of come from the Baltimore Harbor approaches, the sediment size distribution, organic carbon fraction, nutrient content, and bound or interstitial chlorinated hydrocarbons and heavy metals would not differ in a statistically significant manner from the sediments of Deep Trough (Schubel et al. 1980). An exception may be the generally decreasing petroleum hydrocarbon fraction found in a transect from the mouth of the Patapsco to the Northern and Central Bay areas (Krantz, personal communication). Synthesis of much prior work (Hirsch et al. 1978; Lee et al. 1975) suggests that three broad categories of impacts of dredged spoil disposal may be expected:

1. Direct Physical Effects: reduction of dissolved oxygen, increased water column turbidity, smothering of benthos, creation of a fluid-mud sediment-water interface, and possible effects on water circulation and upwelling.

2. Chemical Effects: release of nutrients, heavy metals, and toxic organic compounds into the water column, and production of ammonia.

3. Lethal and Sub-lethal Biological Impacts: these include smothering and suffocation of bottom organisms by clogging of gill surfaces, abrasion, and ingestion of excess solids (Ritchie 1970), the destruction of demersal fish eggs (Heelt 1965), and the possibility of epizootic diseases or other stresses leading to finrot, observed where organic

carbon fractions in spoils or other sludges were in excess of 3-5 percent (Bascom 1978; Murchelano and Zishowski 1976).

The effects must be separated into short-term, transient ones expected to follow the spoil emplacement operation for some brief period, and the long-term processes after spoil settlement, dispersion and attainment of equilibrium conditions. The physical effects are primarily associated with the former, short-term impacts. Dissolved oxygen conditions, already poor in summer, can experience short-term decreases, but recovery can take place over relatively few tidal cycles. Initial turbidity increases will decay to background levels as a function of lateral dispersion, from tidal exchange and net transport, and by settling rate.

2. METHODS

2.1 SURVEY DESIGN

The objective of the study requires a survey plan that can discern if definite preferences exist in fish use for deeper waters as opposed to waters of shallower depths. This requirement can best be met if observations are made that allow statistical tests of findings. Hence we chose three regimes: the Reference stations representative of the more typical depths seen in the upper Chesapeake Bay, and two zones within the Deep Trough--the Trough area in waters 20-30 meters deep (60-90 ft) and Hole stations in water from 30 meters (90 ft) to the deepest depths sampled, 43 meters (150 ft).

The nine stations selected for this survey have been grouped into three for each of the sampling zones. The existence of snags and underwater debris dictated slight shifts in the position of trawl sites. Because water quality and benthic sampling were not so affected, their positions were chosen for optimum depth placement. Thus station WQ1 (Water Quality) was placed as close to the Bay's deepest spot as possible, yet the numerically identical trawl station, T1, is more representative of the shallower of the Trough sites.

Station locations are depicted geographically in Figure 2.1-1, and are grouped by depth as follows:

Sample Type	Reference (20-40 ft)	Trough (60-90 ft)	Holes (90-150 ft)
Water Quality and Benthos	7,8,9	3,5,6	1,2,4
Trawl and Ichthyoplankton	7,8,9	1,3,6	2,4,5

Sampling frequency was dictated by the expected patterns of fish movement and behavior. Because the duration of anoxic conditions is extensive, only one survey was planned during that time, represented by the August 1982 cruise. The onset of anoxic conditions was observed during the May cruise, and the autumn recovery was seen in October. The remainder of the year was covered by monthly sampling cruises, allowing observations of fish movement during surface cooling in late autumn and early winter,

2.2 WATER QUALITY

Water quality variables were sampled before or after trawling at all nine sampling sites, at the surface, mid-depth, and near the bottom. The collection methods and instruments for each variable are as follows:

Variable	Collection Method	Instrument
Salinity	. in situ . Niskin bottle	. Hydrolab Surveyor . Beckman lab salinometer, S-5
Conductivity	. in situ	. Hydrolab
Temperature	. in situ . surface water/calibration	. Hydrolab . bucket thermometer
pH	. in situ . Niskin bottle	. Hydrolab . Digi-Sense pH meter
Dissolved oxygen	. in situ . Niskin bottle	. Hydrolab . on-board titration (macro-Winkler)
Turbidity	. Niskin bottle	. Turner Nephelometer
Light extinction	. in situ . surface water	. GM Instr. Corp. . Secchi disc
Suspended sediments	. Niskin bottle	. on-board filtration/ lab analysis
Hydrogen sulfide	. Niskin bottle	. on-board HACH kit

Whenever possible in situ water quality measurements were confirmed with on-board laboratory measurements to improve accuracy and reliability. Light extinction measurement was included to serve as an inexpensive supplement to turbidity data.

The hydrolab meter was lab calibrated prior to each cruise, but temperature, pH, and dissolved oxygen were also measured on board ship. Dissolved oxygen (DO) was measured using the macro-Winkler titrametric method. When the DO readings indicated anoxic conditions, the presence of hydrogen sulfide was determined.

Turbidity was measured using a Turner Nephelometer, precalibrated with a 5.00 FTU standard. Suspended sediment samples were filtered through a 0.45-micron Millipore filter, and dried at 75 C for one hour (Strickland and Parsons 1972). A minimum of 250 milliliters of water was filtered. The filters were redried for 1 hour at 75 C and reweighed to the nearest 0.1 milligrams. Suspended sediments are expressed as milligrams per liter.

Light extinction was measured, using a G.M. submarine photometer, at quarter-meter intervals until zero light levels were observed. In addition to the light extinction measurements, a Secchi disc reading was taken, and the depth at which the disc disappeared from eye sight was recorded.

2.3 BENTHOS

The benthos was sampled with a Petersen grab sampler, which samples an area of approximately 0.10 square meter to a maximum depth of 20 centimeters, depending on substrate type. Results of the Chesapeake Bay Program studies (Reinharz and O'Connell 1981; Diaz and Schaffner 1981) have shown that more than 80 percent of the benthic fauna is found in the top 10 centimeters of substrate. In addition, the deeper dwelling infaunal forms may be limited in abundance in the Deep Trough area due to the presence of fluid mud at the sediment-water interface. Therefore, this sampling gear probably provided representative samples of the benthic community.

Samples were washed on board ship through a 0.5-mm mesh screen to remove excess silt, and were preserved in 10 percent buffered formalin with Rose Bengal for later analysis. In the laboratory, macroinvertebrates were sorted from the replicate benthic grabs with the aid of a dissecting microscope and were stored in vials of 70 percent ethanol. Identification was made to the lowest practicable taxon (to species when possible) using appropriate keys and references (see Appendix Table A). Density data per taxon were summarized by station for evaluation and for calculation of the Shannon-Wiener diversity index.

2.4 ICHTHYOPLANKTON

Sampling was conducted at each of nine stations identified on Figure 2.1-1 as trawl sites. Samples were taken with two, side-mounted, 505-micron mesh plankton nets with circular openings 0.5 meter in diameter. The nets were laced to a double-hoop frame (sled) fitted with runners to keep the net just off firm substrates. Occasionally, the net filled with mud and the tow was redone. A tow consisted of lowering the sled rapidly to the bottom, towing for five minutes along the bottom, raising the net to just under the surface, and towing for an additional five minutes. The nets were then retrieved and rinsed with salt water. Samples were preserved in 10 percent buffered formalin. Flow meters attached to the sled outside the net and in the throat of each net provided flow data from which the volume filtered could be determined. Counts of organisms have been standardized to numbers per 100 cubic meters. Subsequent tables show densities of ichthyoplankters, not numbers collected.

Preserved samples were returned to the lab where they were examined in white enamel trays. All visible ichthyoplankton was placed on microscope slides and examined under a variable-power binocular dissecting scope for identification. The length of larvae was measured to the nearest 0.5 millimeters. After all visible ichthyoplankters were removed, the sample was then placed in a Fulsom plankton splitter and split twice. One of the quarter samples was then randomly selected and examined under the dissecting microscope for eggs and larvae too small to have been seen previously.

Identification of early life stages of fishes was made using <u>Development of Fishes of the Mid-Atlantic Bight: An Atlas of Egg, Larval and Juvenile Stages</u>, Volumes I through VI (Fish and Wildlife Service 1978). Keys from Lippson and Moran (1974) and Wang and Kernehan (1979) were also used. Common names of fishes used in the text follow the current edition of A List of Common and Scientific Names of Fishes from the United States and Canada (American Fisheries Society 1980).

2.5 NEKTON AND BLUE CRAB

Nektonic fishes of the Deep Trough Study area were sampled by two methods. Small, demersal fish were sampled by bottom trawl and larger specimens, which can avoid the trawl were sampled by gill net. Blue crab data also were taken from trawl catches.

The otter trawl design was a nominal 30-ft wide head rope and a 1/4-in bar mesh cod-end liner. The trawl was towed on the bottom for 10 minutes at an average speed of four knots (a 4000-ft tow).

The fishes collected were identified to species, designated live or dead, and counted. Occasionally, when specimens were too numerous to count individually, numbers were estimated by volumetric aliquots. The length of a representative number of each live species was measured (total length in millimeters). These data were recorded on a field sheet for each station with the addition of water quality data (as described in Section 2.2), station designation, sampling time, and other sample-specific information.

Blue crab data were recorded on a separate set of field sheets. Crabs were designated live or dead; male or female; mature or immature; and as hard, busting, or peeler stages. Specimens were counted and measured to the nearest millimeter across the carapace.

Two drift net areas roughly corresponding to trawl Stations 3 and 6 (Figure 2.1-1) were chosen as sampling sites for the collection of fishes which may avoid the trawl. Nets were fished near bottom in 80-100 feet of water. Sampling was scheduled for once at each area in May and August, October, November, March and April. Sampling frequency increased to five per month during December, January, and February with effort divided between the two drift sites.

Fishing was planned to permit the net to drift during the last hour before change of tide; where possible, the last of the flooding tide. However, the vagaries of weather and tide resulted in considerable variation in the tidal placement of nets and extent of drift.

On most days four or five mesh sizes were employed (3-1/4, 3-1/2, 3-3/4, 4-1/4, and 4-1/2 inches). Approximately 1,000 square yards of each mesh was fished, although actual areas varied between 500 and 3,000 square yards during the course of the year due to damage from hangs on shell bottom, lost crab traps, and drifting submerged trees. The net was replaced or bad sections cut out as needed.

Fish were identified to species and counted from each of the mesh sizes used during the sampling effort. The actual yardage of each mesh was also recorded.

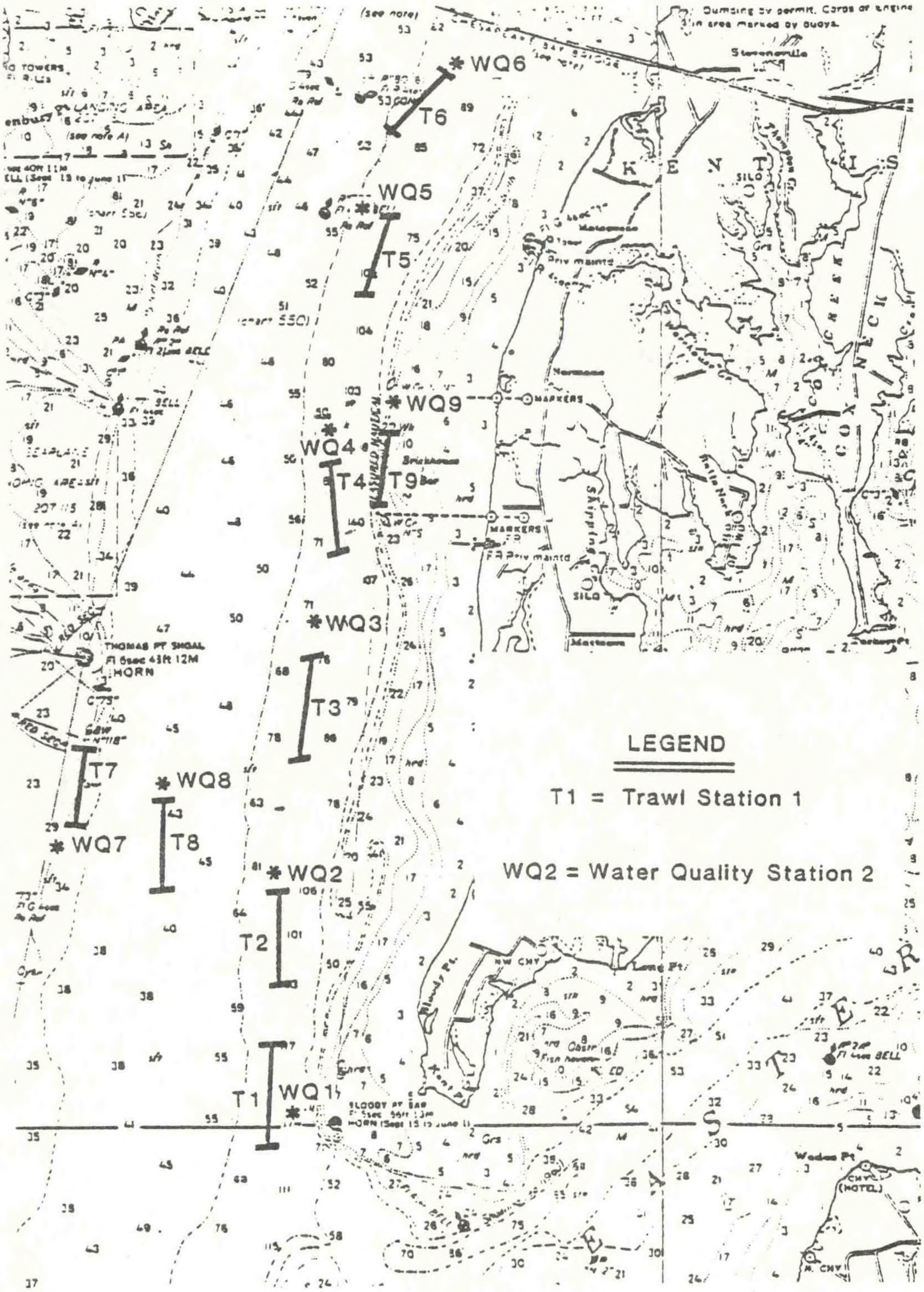


Figure 2.1-1
Sampling Stations

3. RESULTS AND DISCUSSION

3.1 INTRODUCTION

Because the fisheries findings depict populations whose structure is determined in part by the other variables investigated in this study, we have correspondingly structured this section of the report to reflect these aspects. We begin by presenting the water quality conditions found over the sampling period, followed by the findings of the benthic sampling task. This delineates the physico-chemical and biological constraints within which the extent of fish utilization of the Deep Trough takes place, both in terms of adults and juvenile or planktonic stages. As will be seen from the data that follow, the nonbiological environment affects the fishes directly, and in a drastic way, as well as indirectly through the regulation of benthic population that may serve as a food source.

3.2 WATER QUALITY

3.2.1 Hydrography

The water column of the portion of the upper Chesapeake Bay that includes the Deep Trough is affected by the mixing of waters of the Susquehanna River, already somewhat brackish by prior contact with estuarine water above the Chesapeake Bay bridge, and the slow northward movement of the saltier bottom water that originally entered the Bay as coastal ocean water. The saltwater intrusion, which in part accounts for the estuary's high productivity, is enhanced by the existence of the deep ancient riverbed, or in its absence, the man-made shipping channels. The somewhat laterally asymmetric bathymetry (the Deep Trough is closer to the eastern shore with respect to the Bay axis) may enhance this transport further, because less-salty surface waters have a slight tendency to remain nearer the western shore, and saltier deep waters tend to stay slightly to the east due to the coriolis effect.

The resulting density stratification tends to minimize or slow vertical exchange. This may be pronounced in regard to oxygen; once the existing demand in deep waters exhausts the supply, recovery is slow despite moderate to high surface concentrations. This example may serve to highlight the interrelation of physical conditions with the affected biota--the requirement for oxygen in fishes is absolute. In summer the increased temperatures reduce saturation levels, while contributing to stable density gradients that limit exchange.

The oxygen problem is made worse by the increasingly enriched concentration of inorganic nutrients, as found by studies of the Chesapeake Bay program (EPA 1982). The high nutrient levels serve to stimulate plankton blooms. The organisms then decrease water clarity while contributing to oxygen demand in waters darkened by their light blocking effect.

Currents may serve to increase the vertical mixing if they possess sufficient turbulence. They also serve as a transport mechanism, carrying with them nutrients, suspended sediments, and plankton. They transport dredge spoil material that remains suspended if particle sizes are small. If sufficiently rapid, currents may scour the bottom and cause sediment suspension. In the Deep Trough, currents are responses to astronomical (tidal) forces, fresh and saltwater input, and wind stress. Currents may attain appreciable velocities when the sum of all available forces happen to add rather than cancel, but such events are generally of short duration.

Details of water quality variables are viewed in several ways to discern their effect on the biota of interest. These include seasonal changes and extremes. Longitudinal profiles along the Deep Trough axis show patterns that arise from influences to the north or south of the area, as well as existing vertical differentiation. One may want to ask if the conditions found over a given time span reflect long-term averages or deviations therefrom. A continuous data set for the area of interest is not available, however, and inferences must be made from individual stations or indirect evidence. In the following sections the findings of the present survey are summarized in order of relative importance.

3.2.2 Dissolved Oxygen

The single most important variable to affect the Deep Trough biota is the dissolved oxygen content of the water. Five parts per million is generally taken as the level below which the oxygen consuming biota will experience stress. Figure 3.2-1a shows the distribution of oxygen concentration found in May 1982 during the first survey. The waters below 10 meters (30 ft) may be considered stressed, while below 20 meters (60 ft) the water is entirely anoxic for most of the Deep Trough. By August 1982, the 5 ppm contour is yet closer to the surface, beginning at only 3 meters (10 ft) (Figure 3.2-1b). One year later the anoxic zone is not quite as extensive by mid-May, but the 5 ppm contour is found at nearly the same depths (Figure 3.2-1c). By the end of May 1983, the anoxic zone has increased in extent both laterally and vertically (Figure 3.2-2a).

The summer anoxic period appears to last into September. By October 1982, no zero oxygen concentrations were found; however, bottom concentrations were 1 ppm or less (Figure 3.2-2b). In a transverse section taken along stations 7, 8, and 9 (reference stations), the anoxic and low oxygen values are found at somewhat shallower depths, suggesting that either sediment oxygen demand contributes to oxygen reduction or deep water occasionally spills into shallower portions having little vertical slope (Figure 3.2-2c). For example, the average gradient in water depths from the Bay's western shore to the edge of the Deep Trough is only 15 meters (45 ft) in 5 nautical miles (1 n.m. equals 1,852 m) or about 1 foot in depth when moving 600 feet along the bottom.

After October 1982, oxygen levels remain well above the 5 ppm lower limit throughout autumn, winter, and early spring. No clear trends of spatial variation emerge in longitudinal or transverse section, although portions of the study area still evince a drop in dissolved oxygen with increasing depth, particularly in the area of the Deep Holes. Figures 3.2-3 through 3.2-5 summarizes our findings and are included for the sake of completeness.

By May 1983 the steep decline in available oxygen is again evident, and Figure 3.2-5 shows the onset of this event, as found very early in the month. As stated, oxygen sags and anoxic conditions have been increasing since regular surveys were begun in 1949.

3.2.3 Temperature, Salinity, and Density

The seasonal temperature cycle for the Deep Trough can be summarized as follows. Spring warming leads to rapid temperature increase in upper layers, and sharp negative gradients below (Figure 3.2-6a). Continued warming allows nearly isothermal conditions to form by mid-summer, implying that density gradients must result primarily from salinity. Figures 3.2-6b,c show the corresponding May 1982 salinity and sigma-t values. Sigma-t is a shorthand notation for density, $\sigma_t = (\rho-1) \times 1000$. It should be noted that the increase from 4 to 10 units reflects only a 0.6 percent change in density. August temperature, salinity, and density are shown in Figure 3.2-7. Early autumn (October) shows modest surface cooling, while salinities are increasing slowly throughout the water column (Figure 3.2-8).

During autumn and winter of 1982, the low rainfall in the Chesapeake Bay watershed produced an increase in salinity that became marked by January 1983. Cool surface water mixes downward by the stronger autumnal winds, through wave action, surface stress, and sea level fluctuations in the Bay. Vertical temperature gradients are weak by November 1982, and become strongly established in January 1983 (Figures 3.2-9 and 3.2-10). These features persist into March, even though the temperature for the entire water column rises appreciably (Figure 3.2-11a). By April, spring warming is pronounced and the temperature structure seen in subsequent months is beginning to establish itself.

The unusually high salinities seen in winter and early spring of 1983, brought about by low precipitation averages beginning in autumn of 1982, persisted into April. The drought period was followed by a wet spring that produced more than 0.12 meters (5 inches) of rain above the seasonal average. Surface salinities dropped first, as seen for April (Figure 3.2-11b), and by May 1983 the entire water column had experienced a drop, though still maintaining a positive gradient of increasing salt content with increasing depth.

The wide range of environmental conditions the resident biota encounters requires that the organisms be quite tolerant to the rapid changes that may take place. Extremes of temperature found in this survey were a maximum of 26 C. Minimum temperatures occurred in February 1983, when surface values ranged from 1.0 to 1.7 C, increasing to 2.5 C at depth. A preliminary survey conducted in the Deep Trough prior to initiating this study, done in February 1982, showed that nearly isothermal conditions existed to the bottom, with temperature near 1 C. On that cruise no live fish were taken. The differences in findings may not wholly be attributed to temperature effects; the survey used somewhat coarser mesh otter trawls and was experimental in the sense that no snag-free trawl sites had been established and gear was handled very carefully. The unusually high salinities observed here, however, did appear to provide an environment tolerant to fishes normally found in coastal waters, or in the lower Bay.

Variation of temperature and salinity along the Deep Trough axis was small, with a slight increase in both values noted when transitting from north to south. This suggests that the fresher waters entering from the north tended to be slightly cooler, or conversely, that the longer residence time of the deeper saltier water allowed it to reach higher temperature equilibrium than waters from relatively recent run-off. No clear pattern emerges in transverse section; at times both salinity and temperature are higher on one side of the trough, but the conditions reverse at irregular intervals.

3.2.4 Suspended Sediments, pH, Light and Turbidity

The presence of suspended sediments, a primary cause of turbidity, rarely can be considered to have direct effects on the pelagic biota unless levels become quite high. It is, rather, the indicator role the suspended sediments may serve for ongoing processes that are of interest. If the suspended sediment is shown to be primarily inorganic, and high concentrations are reached, fishes may be subject to gill clogging or show an avoidance response to an area so affected. If the suspended sediments are primarily organic, i.e., consisting of microplankton and organic detritus, we may expect increased oxygen demand.

Three variables were measured that reflect turbidity level. Two of the methods used here, the gravitational and nephelometric techniques, involve analysis of small sample volumes. In the former case, about 250 milliliters are sampled; in the latter about 25 milliliters are involved. For such small volumes and small sample numbers, replicability is always a problem. It is well known, for example, that phytoplankton populations exhibit considerable patchiness. Changes of only a few feet in sampling location can show changes in population density that may differ by several orders of magnitude (Gucinski and Bird 1982). Little correlation would be expected between the methods, and the data collected in the Deep Trough appear to bear this out. The third technique, the measurement of light extinction coefficients is a depth-integrated technique. In the opaque waters of the Chesapeake Bay, this method is limited to shallow surface layers. A two-way correlation analysis for all three variables was performed and the correlation coefficient was found to be 0.54.

Similar problems using nearly identical techniques have been found in other studies (Gucinski 1980). Turbidity measurements by nephelometer showed somewhat greater consistency, allowing patterns to be profiled. These data are summarized in Figures 3.2-12 through 3.2-16.

In general, turbidity values tend to be slightly higher in the northern portion of the Deep Trough in all seasons, are higher in deep water from late autumn to late winter, and exhibit highest values in surface layers the remainder of the year. The high surface turbidities in summer most likely reflect the high plankton density during intense bloom periods as well as the spring freshet from the Susquehanna River. Reduced light levels in winter account for reduced primary productivity and somewhat clearer surface waters. This effect may overshadow the trend toward higher turbidity in deep waters (seen in other seasons), where bottom sediments will tend to remain suspended for long periods.

The extinction coefficients show trends only for surface waters, to depths of about 5 meters (15 feet). The agreement with turbidity trends is generally good. Extinction coefficients show better light penetration in the southern portion of the Deep Trough, and show a trend toward improved water clarity in the winter season. Light extinction is affected by plankton patchiness, as are the other indicators used here.

The extinction coefficient may be used to calculate the depth at which any given percentage of the light available just below the surface may be found:

$$L = -\frac{1}{k} \ln 0.01$$

Depths where one percent of surface light is available range from 7 to 11 meters (20-30 feet) in November 1982, the month having the best penetration. Such depths vary from 4 to 8 meters (12-24 feet) in October 1982, the worst conditions encountered. Figures 3.2-17 through 3.2-18 summarize these findings.

The measurement of pH can be a tool in water quality assessment. In fresh water systems, relatively small additions of acidic or basic substances will produce significant shifts in pH. In seawater systems, the ions of weakly dissociated acids serve as a buffer to minimize fluctuations in pH. Biological processes can locally alter the chemical equilibrium in pH by the uptake of CO_2 in plant oxygen production, or by CO_2 production in respiration. This process will occur in shallow surface layers during seasonal algal blooms, whereas the absence of available sunlight in deeper layers may shift the equilibria toward lower pH values because of respiration. For example, February 1983 pH values all are in the normal range for salty estuarine or oceanic waters (7.4 - 8.5 units). In the Deep Trough, values ranged from 7.7 to 7.8 units. By April 1983 values in upper layers exceed 8 units, and drop below 7.5 at depth. Highest values, in excess of 9 units, were found in May 1982 and May 1983 (Figure 3.2-19), which may be indicative of intense oxygen production and bicarbonate uptake. This is not uncommon and is reflected in historical records for these waters (Hires et al. 1963).

3.3 BENTHOS

3.3.1 Introduction

The composition and distribution of the benthic community within Chesapeake Bay has been well studied (Boesch 1977; Holland et al. 1977; Mountford et al. 1977; Loi and Wilson 1979; Reinharz and O'Connell 1981). The benthos of Chesapeake Bay has been generally characterized as being composed of opportunistic species that inhabit a wide range of salinity and substrate types (Reinharz and O'Connell 1981). A relatively high frequency of disturbance from storm events, and various inflows and tidal fluctuation are primary causes of a lack of equilibrium conditions for benthic communities. Sediment transport from rivers and shoreline erosion along the Bay result in changing patterns of deposition and erosion throughout the Bay (Reinharz and O'Connell 1981).

The purpose of this benthic study is to evaluate the macroinvertebrate communities of the deeper channel areas, especially the Deep Trough, and to compare these communities to those in shallower, nearby areas to elucidate any differences in community structure that would preclude filling in the Trough with dredge spoil. Seasonal collections were obtained to provide an analysis of normal seasonal fluctuation of the benthic community components and to determine biologically critical periods that both influence the composition and dominance of the community and provide the greatest impact on food availability for higher trophic levels.

3.3.2 Species Composition

The benthic community within the study area consisted of 42 taxa comprising seven phyla (Table 3.3-1). The taxonomic groups exhibiting the greatest variety of taxa were the polychaete annelids and the pelecypod molluscs (clams). Eleven polychaete species were present throughout the study period with five species occurring in each collection period. Nine species of pelecypods were found in the area with five species present in each collection period. Although some variability in seasonal community composition occurred, the least number of species was observed in May and August 1982, compared to the largest variety in February and May 1983.

Seventy-eight percent of the benthic abundance was composed of three polychaete and three mollusc species. *Mulinia lateralis* (a clam), was numerically dominant, averaging 466 individuals per square meter and constituting 36 percent of the benthos (Table 3.3-2). A polychaete, *Nereis succinea* (ranked second in abundance), averaged 162 individuals per square meter and 13 percent of the benthos. Seasonal dominance shifted from the polychaete *Polydora ligni* in May 1982 to *Gemma gemma* in August and November, and then to *Mulinea lateralis* in February and May 1983. However, total benthic densities ranged from a low of 310 organisms per square meter in August 1982 to a high of 2,610 organisms per square meter in May 1983.

3.3.3 Species Diversity

Spatial comparison among stations or depth regimes can be made at the community level by reviewing trends in species diversity (H'), total abundance, and number of species. Values for all three parameters fluctuated among stations within each depth regime during each collection date (Figures 3.3-1 through 3.3-4). However, diversity as well as abundance and number of species were generally higher in the shallow Reference area. Station 9 exhibited the greatest difference from all other stations in abundance and number of species and, occasionally, diversity. Community parameters were not graphed for August because of the depauperate fauna throughout the study area at that time. Recovery noted in November occurred to the greatest extent in the Reference area. Diversity remained higher at the shallow stations from November through May

1983 (Figures 3.3-2 to 3.3-4), but abundance became greater at stations in the Hole and Trough areas on May 1983 than in the Reference area with the exception of Station 9 (Figure 3.3-4).

3.3.4 Depth Distribution

An evaluation of spatial and seasonal trends of key taxa were limited to the numerically dominant benthic organisms, Mulinea lateralis and three abundant polychaetes, Nereis succinea, Paraprionospio pinnata, and Streblospio benedicti. M. lateralis was common to all depth zones, but it predominated in shallow areas from May through November 1982, primarily because of high abundances at Station 9 (Table 3.3-3). However, in February and May 1983, M. lateralis became more abundant in the Hole and Trough areas. N. succinea was found in all three depth zones but was most abundant in the shallow Reference area throughout the year (Table 3.3-4). S. benedicti (Table 3.3-5) and P. pinnata (Table 3.3-6) were abundant in the Hole and Trough areas during the spring and fall but were even more abundant in the shallow Reference area.

3.3.5 Evaluation of the Benthos Community

The species composition of the benthic community within the study area is typical for the mesohaline portion of the Bay and consists primarily of opportunistic species able to recover from intermittent disturbances. Seasonal differences in composition and abundance are attributed to one of these disturbance phenomena in the form of dissolved oxygen depletion in the bottom waters of the Holes and Trough in the warmer months of the year. During this study period, dissolved oxygen in the bottom waters did not rise above 0.0 in May and August 1982 except in the shallow water or Reference stations. This dissolved oxygen depletion caused a near elimination of the benthos in the affected areas. However, subsequent recovery was noted by November although the community appears to never reach equilibrium.

The polychaetes, Nereis succinea and Paraprionospio pinnata were numerically dominant in the pioneering community present in November, but were quickly replaced in abundance by the mollusc Mulinia lateralis in February 1983. The community within the three depth zones (Reference, Holes, Trough) do not differ greatly from each other except at Station 9 in the Reference zone which did not experience the summer low dissolved oxygen phenomenon. Similarities in composition and dominance among the depth-related communities and absence of unique species of the Trough community would suggest that modifying the depth of the Trough by spoil disposal would not significantly alter the benthos within the area.

3.4 ICHTHYOPLANKTON

3.4.1 Introduction

By some estimates, 70 percent of fishes now found in Atlantic coastal water depend upon estuaries during part of their life cycles (Schubel 1981). Deep Trough remains as a remnant of the old riverine migration route of anadromous fishes from the days of lower sea level. It is still a migration route for striped bass, sciaenids, menhaden, and other fish as well as a winter refuge (Hildebrand and Schroeder 1928; Wallace 1940; Haven 1957; Dovel 1967 and 1968; Lippson 1973).

In addition to movement in and out of the deeper areas in response to changing water temperatures, Miller and Dunn (1980) have found that juvenile estuarine fish will change their depth orientation in response to changes in salinity as small as 1 ppt or a change in dissolved oxygen of 0.01 mg/liter per day, in order to avoid suboptimal conditions.

Deoxygenation of the deeper water of the Deep Trough study area thus makes the region an unfavorable habitat through two mechanisms. The first is periodic disruption of the population of benthic food organisms which form the bulk of the diet of the juvenile sciaenids (Chao and Musick 1977) and anchovies (Odum and Heald 1972). Second, although adult yellow perch have been reported entering anoxic water to feed (Hammer 1943) where food is available, most fish avoid these conditions.

Movement of the early life stages of fishes through the Trough region is strongly influenced by bottom water circulation (Harrison et al. 1967; Nelson et al. 1977; Bleil 1978). In turn, the bottom water currents are variable and strongly related to changes in river discharge and seasonal prevailing winds (Beauchamp 1974). Boicourt (1973 and 1981) has shown that the inflow of shelf water at depth is confined primarily to the deep Chesapeake Channel. The strongest inflow occurs during periods of prevailing northwesterly winds (winter) and the weakest inflow during prevailing southwesterly winds (summer).

The winter period is also the period of the inbay migration of menhaden and sciaenids such as Atlantic croaker and spot. During this time measured dissolved oxygen values are higher (see Section 3.2.2) and the benthic fauna are repopulating with high densities of opportunistic colonizer species (see Section 3.3).

3.4.2 Species Composition

Eighteen species of ichthyoplankton were collected, counting a few small adults. Table 3.4-1 lists the species collected by life stage during the year, in order of abundance.

Only pelagic estuarine fish eggs are susceptible to capture by the method used in this study. Ocean-spawned eggs, such as those of the Atlantic croaker, and attached eggs, such as yellow perch and goby, do not appear in the collections because the eggs are not present in the area sampled.

The bulk of the eggs taken were bay anchovy which spawns in open waters over much of the Bay. Olney (1983), after comparing his collection densities with data from other East Coast estuaries suggests that Chespeake Bay is a major center for spawning activity for the bay anchovy. He found that mean monthly abundances of eggs never fell below 30 eggs per cubic meter during the spawning season and reached 140 eggs per cubic meter in August of 1973. He found no difference between surface and subsurface densities of the eggs. Dovel (1971) has also recorded the bay anchovy egg as the dominant ichthyoplankter in the upper Chesapeake Bay.

The second most abundant species in the collections was the Atlantic menhaden which is considered a marine spawner. The greatest concentrations of eggs are normally found midway offshore over the continental shelf; however, Pearson (1941) found menhaden eggs in the lower Chesapeake Bay and Dovel (1971) collected manhaden eggs in waters of up to 10 ppt salinity in Chesapeake Bay and the lower Patuxent River. The egg hatch within 48 hours (Wang and Karnehan 1979) and the presence of eggs in the study area is probably indicative of rapid up-bay transport of water through the Deep Trough.

Postlarval menhaden move into shallow areas at the fresh water interface. The transition from larvae to juvenile is marked by gross morphological changes in the alimentary tract (June and Carlson 1971) and changes in diet from zooplankton and particulate carbon to phytoplankton (Jeffries 1975; Peters and Kjelson 1975). Thus it is likely that the postlarvae and juvenile stages were migrating through the Deep Trough area in opposite directions--the former up-bay and the latter down-bay.

The Atlantic croaker has a migration pattern similar to that of menhaden (Wallace 1940; Lippson 1973; Bleil 1978) with the smallest juveniles closest to the fresh water interface (Haven 1957). The range of sizes taken indicates that the Deep Trough may serve as an up and down-Bay migration route for the young croaker in the same season.

3.4.3 Seasonal and Spatial Distribution

In May the bay anchovies were spawning in the deepest water stations with very little spawning activity at the Reference stations (Table 3.4-2). By August the center of spawning activity had shifted to the Reference stations. Dovel (1971) reported that bay anchovies are abundant in deeper waters from October to March and move to shallower waters from June through September. Spawning apparently occurs throughout this period of movement. The peak month for spawning occurs during July between our sampling schedule dates. Preferred spawning environment is between 13 and 15 ppt salinity and 20-25 C water temperature (Dovel 1971). Fish eggs were present in the Deep Trough and the Reference stations throughout the summer and into the fall. Eggs were no longer present in November and none were collected until the following Spring.

The largest concentrations of juvenile fishes occurred during the winter months of January and February. Densities of juvenile fish were highest in the Trough stations throughout the winter. In January and March, the highest density of juveniles occurred at Trough Stations 1, 3, and 6. In February, the coldest month, the fish were in the deepest water at Hole Stations 2, 4, and 5. The first juvenile croaker appeared in November and the first juvenile menhaden appeared in January. These species are ocean spawners with estuarine dependent early life stages. As mentioned earlier, they use the Deep Trough as a migration route to their low salinity nursery areas. The croaker and menhaden comprise the bulk of the juvenile fish taken in the winter months. Juvenile weakfish were taken in January; juvenile eel were taken in February.

By March yellow perch larvae were reaching the Trough area as well as the Reference stations from a spawning region in fresh water upstream of the study site. Yellow perch eggs are adhesive and attached to submerged debris. The larvae are carried downstream in the spring runoff after hatching. Yellow perch larvae and juveniles have been found in salinities from 0 to 11 ppt and water temperatures from 4 to 22 C (Dovel 1971). Yellow perch larvae made up the bulk of the spring larvae collected. They were collected at Reference and Trough stations without apparent preference. The larvae were probably all in the surface layer.

The habitat of benthic fishes is influenced by the amount of cover available. Station 9 is located adjacent to Brickhouse Bar, an oyster rock, while Reference Stations 7 and 8 are located in a relatively flat open stretch of Chesapeake Bay with a soft bottom. Gobies and skilletfish possess sucking disks on their ventral surface to anchor themselves to hard substrates. These fish should be more common in the vicinity of the oyster rock than the soft bottom. Table 3.4-3 shows species by station, averaged across replicates and dates. Fish eggs are omitted from the table. The gobies and skilletfish were not found to occur at Station 9 exclusively but were also collected at the Trough stations. Only two species were present at every station, the bay anchovy and the Atlantic croaker. Atlantic menhaden and Atlantic silverside were collected at all stations except Station 1. Station 1 had the lowest average density of ichthyoplankton on an annual basis whereas Station 5 had the highest average annual density. The total average annual ichthyoplankton density at Station 5 was nearly 4 times greater than at Station 1.

3.5 NEKTON

3.5.1 Introduction

The location of the Deep Trough study area, in the central, narrow reach of the Chesapeake Bay in Maryland, suggests that various species of fish may occur there during at least a portion of their life cycle. Based on a salinity range of 5-19 ppt (combined seasonal averages of surface and bottom water [Stroup and Lynn 1963]), it is likely that estuarine residents would comprise a major component of the fish fauna, although occurrence of some species such as bay anchovy and atherinids would be mediated by seasonal inshore-offshore movements (Dovel 1971; Swingle and Bland 1974, in Martin and Drewry 1978). Diadromous species, which migrate between upper Bay natal streams (or nursery areas in the case of eels) and more saline waters, might briefly utilize the deeper waters of the Trough or overwinter, in the case of preadults (Mansueti and Murphy 1961; Moore and Burton 1975). Finally, Musicks´ (1972) records of the salinity range in which marine-spawned species have been collected suggest that the Deep Trough nekton would be supplemented seasonally by a large variety of euryhaline young-of-the-year and low-salinity-tolerant adults of this life history category.

In view of the potential ecological importance of the Deep Trough area as a migration route and overwintering refuge for fisheries resources, surprisingly few nekton surveys have been conducted in the area. Radcliffe and Cowles sampled the deep holes of Chesapeake Bay by trawl, including two areas off Kent Island, to document the fishes of the Bay (Hildebrand and Schroeder 1928) but provided no site-specific data. However, general reference to young specimens overwintering in deep water is made in several species accounts, including that of spot, Atlantic croaker, and white perch. They also note the occurrence of a winter gill net fishery for striped bass in the Deep Trough area and farther north at the mouth of the Chester River.

Massmann and Mansueti (1963) trawled in deep water off Kent Island on a quarterly basis in 1957 and 1958. Unfortunately, the catch data was summarized across four stations covering a larger area, from south of Kent Island to near the mouth of the Patapsco River, and thus cannot be attributed solely to the Deep Trough study site. White perch dominated the annual catch due to the large number collected during an ice-over in January (along with striped bass), a pattern supporting the notion of overwintering. The annual catch consisted of 20 species representing the three life history groups described previously. Among these, only hogchoker was collected in relatively consistent numbers during each survey.

The trawl and gill net study described herein was designed to provide a more detailed and accurate description of the nekton fauna of Deep Trough. Particular attention is given to trends in catch size with depth and to detection of aggregations of overwintering species. As will be shown, the occurrence of fish in this portion of the Bay is related to a seasonal increase in dissolved oxygen level following summer anoxic conditions and that fish are more abundant in deeper water during the fall through spring period.

3.5.2 Species Composition

The nekton collected by trawl consisted of live and dead specimens. The live catch consisted of 33 species and 16,779 specimens, which may be classified as diadromous, estuarine, and marine life history types (Table 3.5-1). The economically important marine-spawned fish constituted approximately half the total number of species (17) and number of specimens (8,605 individuals, 51.4 percent) collected during the year. This group was dominated by Atlantic croaker (36.0 percent of annual catch), spot (9.5 percent), and Atlantic menhaden (4.0 percent). As shown in Table 3.5-1, the marine-spawned species were dominated by the relatively euryhaline forms, with fewer representatives of less tolerant species, as would be expected. The estuarine resident fish, which are a critical component of the food-web but lack direct commercial importance, were dominated by catches of bay anchovy (45.6 percent of total catch). Finally, the diadromous species of major importance to Maryland fisheries, including the blueback herring, alewife, American shad, white perch (semi-anadromous), striped bass, and American eel, comprised only 1.8 percent of the total catch.

The annual fish catch by depth regime (Table 3.5-1) varied notably only in terms of the relative abundance of the three dominant species. The total catch was higher at Hole (6431 specimens) and Trough (6513 specimens) stations than at Reference stations (3833 specimens), largely because of the higher abundance of Atlantic croaker and spot. In contrast, bay anchovy, though slightly decreasing in abundance with sampling depth, was collected in comparable numbers in each area. As a proportion of the catch at each depth, therefore, Hole stations were dominated by Atlantic croaker (37.6 percent) and bay anchovy (36.8 percent), Trough Stations were dominated by Atlantic croaker (48 percent), and Reference Stations were dominated by bay anchovy (74.7 percent).

The dead fish catch consisted of 155 specimens among nine species; 0.9 percent of the total catch. Species which exhibited a high proportion of dead specimens included hogchoker (10 of 41 specimens, 24 percent), blueback herring (36 of 162, 22 percent), and Atlantic menhaden (84 of 760, 11 percent).

3.5.3 Seasonal Abundance and Diversity

The monthly total catch per trawl was very low (less than 20 fish) in May, August, and October 1982, indicating a virtual absence of small bottom fish during the warmer months of the year (Table 3.5-2, Figure 3.5-1). Catches increased sharply in November 1982 (293 per tow), peaked in February 1983 (460 per tow), and then declined rapidly to previous low levels by May. The higher catch rates in fall, winter, and spring were due primarily to cyclical abundances of bay anchovy (November), spot (December), Atlantic croaker (December-February), and a return of bay anchovy (March and April). Table 3.5-2 shows the relative abundance of other species. Though they constituted only a small percentage of the total monthly catch, their occurrence largely defined the seasonal species richness of the fish fauna.

To examine the species composition of catches by depth zone, the monthly mean diversity (H), number of species, and number of specimens per station (trawl) were calculated for each depth regime (Figure 3.5-2). The diversity value provides a combined measure of the species richness of catches and the evenness of the distribution of specimens among those species. As shown in the figure, the seasonal diversity trend was similar to the trend in number of species and the (logarithmic) number of fish. During the warm-water months of May, August, and October, few fish were caught (Figure 3.5-2) and, as is often the case, catches were predominately of one species (in this case, bay anchovy, Table 3.5-2). This resulted in low diversity values. During fall, winter, and spring, all values were substantially higher thoughout the study area and exhibited trends with depth. Fewer species and numbers of fish were collected at the Reference stations compared to the Trough and Hole stations, indicating a faunal preference for deep water. Diversity values, however, tended to remain slightly higher at the Reference stations. Apparently, the catch at the shallow Reference stations exhibited a more even distribution of specimens among available species relative to catches at greater depths.

3.5.4 Depth Distribution

It is apparent from the presentation thus far that the number and variety of bottom fishes susceptible to collection by trawl varies by season and depth. Catches were low throughout the study area from May through October 1982 and were substantially higher during the colder months from November 1982 through April 1983. During the latter period of higher catches, it was also evident that in general more fish were collected in the Hole and Trough areas than in the shallower Reference area (Figure 3.5-2). The mean catches, however, do not reveal the range of values obtained within each area, and it is of interest to learn whether differences in catch rates by depth are statistically significant and support a hypothesis of depth preferences by total catch and dominant species.

For this determination, a two-way analysis of variance (ANOVA) model was run, with month (sampling date) and location (Hole, Trough, Reference areas) as main effects. Samples within areas on a given date were treated as replicates (N=3). For ANOVA purposes, the data analyzed were limited to those obtained in months in which at least half the trawling efforts obtained fish. Further, the data for May were not analyzed because one Trough station was not sampled. The catch data were normalized, ln (X+1), prior to analysis. As a follow-up to ANOVA, analysis of covariance (ANCOVA) was run on the catch date (using the bottom water quality variables temperature, salinity, and dissolved oxygen as covariates) to determine their relationship to catches and whether these habitat characteristics could account for differences in the depth preferences (catches) of bottom fish.

The distribution of the total catch of all fish is shown in Table 3.5-3. The ANOVA results for the period from November 1982 through April 1983, revealed that catches did not differ significantly by month (P=0.18) or location (P=0.15). However, there was a highly significant (P=0.0039) month x location interaction term, indicating that trends in the size of catches with depth were not consistent over the selected survey dates. The nature of this interaction is shown in Table 3.5-3. The highest mean catch shifted during the November to April period from the Hole to the Trough to the Reference area.

The catch of bay anchovy is shown in Table 3.5-4. ANOVA over the period from November through April revealed no effect due to location (P=0.56), but a highly significant effect due to month (P=0.0001) and interaction (P=0.007). Table 3.5-4 shows the nature of this interaction. As in the case of the total catch, the inability to detect differences between sampling areas appears to be due to a shift in the area in which the species concentrates as well as to considerable variation in catch size within areas.

The catch of Atlantic croaker is shown in Table 3.5-5. Most specimens were collected from the Trough and Hole areas and ANOVA of the November through April data support this impression. The hypotheses of no difference in catches over month or depth was rejected in both cases (P=0.0001 and P=0.019, respectively), and the interaction term was not significant (P=0.30). Duncan's Test results indicate that Trough catches were highest, followed by Hole and Reference area catches. The Reference area catches were significantly lower (α=0.05) than catches in the two deeper areas, which in turn were not significantly different from each other.

Spot were collected only from November 1982 through February 1983 (Table 3.5-6) and the data for all months except January were examined by ANOVA. Although the largest catches were taken from the Holes (67 percent of total), followed by the Trough (18 percent) and Reference areas (15 percent), the difference between areas and the interaction term were not significant (P=0.29 and P=0.86). This apparently results from the high variability of catches of spot within areas.

The temporal-spatial pattern of Atlantic menhaden catches (Table 3.5-7) suggests that too few fish may have been collected to adequately define their distribution. From December through February, there appears to be a shift from the deeper Hole areas toward the shallower Reference areas and a return to the Holes. Differences in mean area catches from December through April were marginally significant (ANOVA, P=0.08), suggesting that more intensive sampling might show a clearer trend of higher catches toward deeper waters.

The distribution of less-abundant fishes, that is, the total catch less the numerically dominant bay anchovy, Atlantic croaker, spot and Atlantic menhaden, is shown in Table 3.5-8. Although these catches constitute only about 5 percent of the total annual catch, they represent the composite distribution of almost 90 percent of the species collected (29 of 33 species). During November and December, when these fish first appeared in the study area in abundance, higher catches were made in the Hole and Trough area; during later months fish appear more evenly distributed. ANOVA of data collected from November through April indicates that both sampling month (P=0.001) and depth (P=0.04) were significant sources of variation in catches (with non-significant interaction). Duncan's Test revealed that mean catches in the Trough and Hole areas were not statistically different at the α=0.05 level but were significantly higher than in the shallower Reference area. This trend in depth distribution is similar to that of Atlantic croaker.

The results of ANCOVA usually indicated that water temperature was a significant covariant ($P<0.05$) with catches (all cases except Atlantic menhaden and the less-abundant species) whereas salinity and dissolved oxygen were not significant during the period of high catches. It is interesting to note that Atlantic croaker and less-abundant species catches, which were shown to be significantly different by depth in ANOVA, were not significant in ANCOVA. Thus, the depth distributions of these two taxa would appear to be related to, but not necessarily caused by, these three water quality variables. Although is was not possible to further examine the nature of these water quality/abundance correlations in detail, preliminary inspections suggest that generally the total catch and that of Atlantic croaker were negatively correlated with water temperature and that bay anchovy and spot catches were positively correlated with temperature. The direction of the correlation for each species catch may vary by depth regime, thus accounting for the change in ANOVA results of Atlantic croaker and the less-abundant species.

3.5.5 Gill Net Catches

Drift gill nets deployed in the Deep Trough area during 21 days from October 1982 through April 1983 collected ten species of fish (Table 3.5-9). Catches were dominated by Atlantic menhaden (N = 3155, 97 percent of total) and butterfish (N = 72, 2 percent), and included incidental catches of six other marine species, one anadromous species (white perch) and one estuarine species (bay anchovy).

The very low catch of anadromous and marine food fish in this survey, was unexpected based on the assumption that the Deep Trough area provides an overwintering haven or staging grounds for fish. Mansueti and Murphy (1961) first reached this conclusion, largely based on the winter gill net fishery for striped bass, and observed that specimens tagged near Cove Point later migrated to Upper Bay and Potomac River spawning grounds. Species commonly captured by commercial fisherman in deep water include white perch and striped bass from late fall through early spring, weakfish and bluefish early and late in the season, and winter flounder at mid-season (Brody 1983).

Reported winter commercial landings of striped bass from the Deep Trough area in 1975, 1980, and 1981 averaged about 250 pounds per day (NOAA data, compiled by Maryland Tidewater Administration), but do not provide a sufficient historical perspective with which to judge the 1983 catch. During three days in January 1982, the Maryland Department of Natural Resources collected 330 striped bass and 177 white perch from the Deep Trough study area (during a more intensive sampling effort than in 1983). It is apparent from these data and the results of the present study, that striped bass and white perch and other large nektonic species occur in the Deep Trough area during winter but not consistently from year to year. The virtual absence of striped bass and white perch in catches obtained during the 1982-1983 winter, despite considerable sampling effort, suggests that these populations may migrate offshore into deeper waters only as far as is necessary to avoid adverse conditions, such as a specific low temperature. Evidence of substantial gill net catches at the mouths of rivers during the 1982-83 winter (R. Wagner, personal communication), lends support to this notion.

3.6 BLUE CRABS

3.6.1 Results and Discussion

A total of 144 live blue crabs were caught by trawl net during this study. Of these 144 crabs, 23 (16 percent) were caught in the Deep Trough (Hole and Trough areas). The remaining 121 crabs (84 percent) were caught at the Reference sites. Table 3.6-1 shows the distribution of the catch by month, site, and crab size.

During the first sampling date (May 1982), a total of only eight crabs from all sample sites was caught. All of the crabs were dead with the exception of one taken at Reference Station 7. Trough and Hole Stations 1 through 6 had bottom dissolved oxygen (DO) readings of zero. A total of five crabs were taken at these sites. All were dead. The only live crab caught on this sample date was the immature female taken at Station 7. The bottom DO there was 4.47 ppm. Reference Station 9 had a bottom DO reading of 11.07 ppm, but no crabs were caught.

During May 1983 sampling, 16 crabs were caught, all of which were alive. Eight were taken at the Trough and Hole stations and eight were taken at the Reference sites. Bottom DO readings in the Deep Trough ranged from 1.06 ppm at Hole Station 2 to 5.49 ppm at Trough Station 3. Dissolved oxygen readings at the Reference sites ranged from 9.03 ppm to 9.38 ppm.

The largest number of mature crabs caught at any one site was 37 taken at Reference Station 9 during the August sampling period. Of these 37 crabs, 21 were mature females, recently mated and just beginning their migration southward toward more saline waters for egg laying. This migration occurs annually following the peak of the mating season. The peak of the mating season in Maryland is generally from the end of July to mid-August.

A total of 46 recruit crabs were caught during the November sampling period. Fourty-four of these crabs were caught at Reference Station 7. They ranged in size from 4 to 33 mm. These are crabs that were hatched in August or September of this same year and were migrating to the upper Bay areas. Generally, these small crabs do not get much farther up Chesapeake Bay than the mouth of the Potomac River before cold weather sets in and forces them to stop to over winter. Crabs 15-25 millimeters in width usually are not seen in great numbers in the upper Bay until May of the year following the hatch.

By December, these recruit crabs were more generally scattered over the sample area. Recruit crabs were caught at all stations except 1 and 4. All crabs were recruits with the exception of one mature male taken at Hole Station 2. Sixty-three percent of all the crabs taken during the December samples were from the Reference sites (Stations 7, 8, and 9).

During the January, February, and March samples only four recruit crabs and one mature crab were caught at the Deep Trough sites. Only four recruit crabs were taken at the Reference sites.

3.6.2 Conclusions

Results of trawl net samples taken during the sample year suggest that the Deep Trough is not a significant habitat for blue crabs during any season of the year. The commercial harvest of blue crabs in Maryland for the 1982 calendar year was 52.7 million pounds. This could be considered a normal harvest year. Crabs present in the Deep Trough (Trough and Hole areas) and the Reference Stations during the study period should represent "normal" numbers of crabs found in these areas, or, at least reflect the relative depth distribution of crabs despite possible higher or lower catches in subsequent surveys.

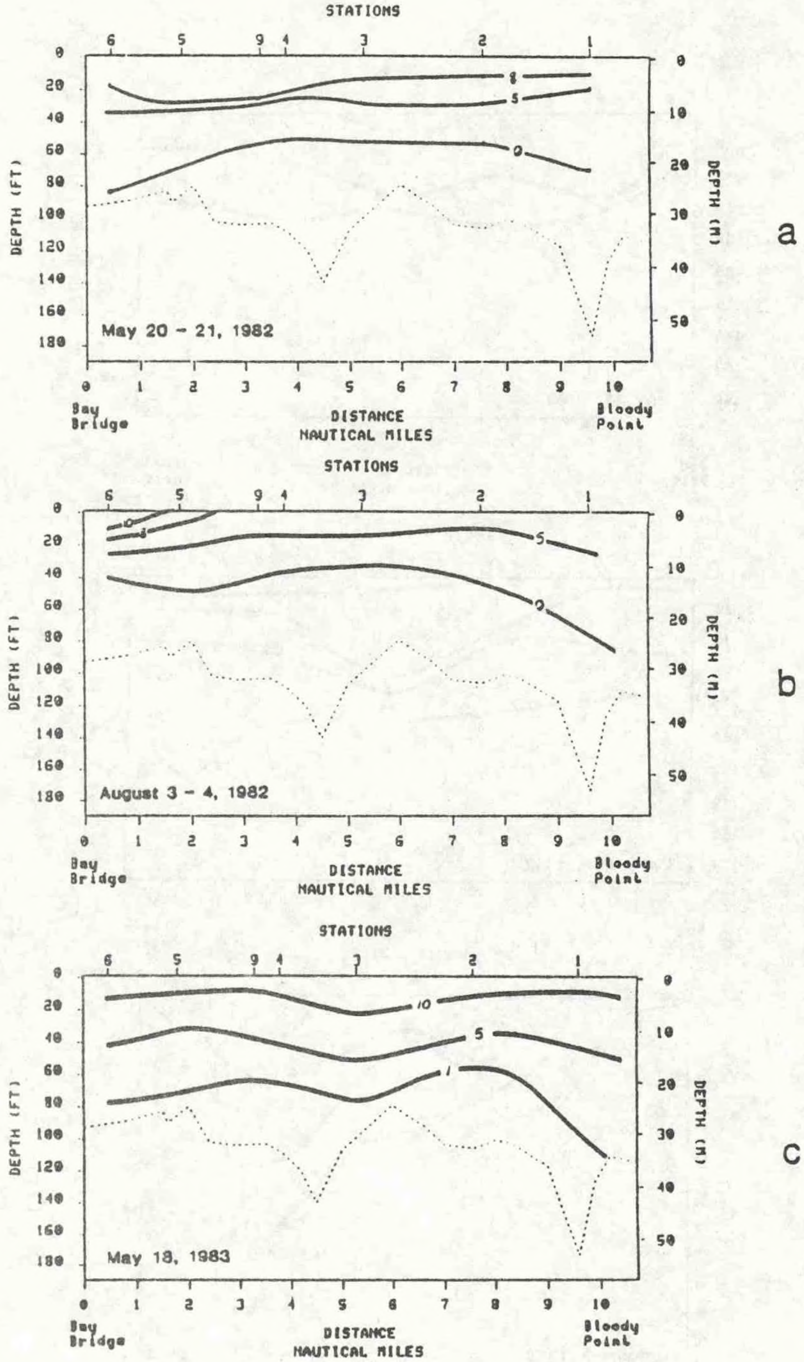


Figure 3.2-1 Dissolved Oxygen (ppm)

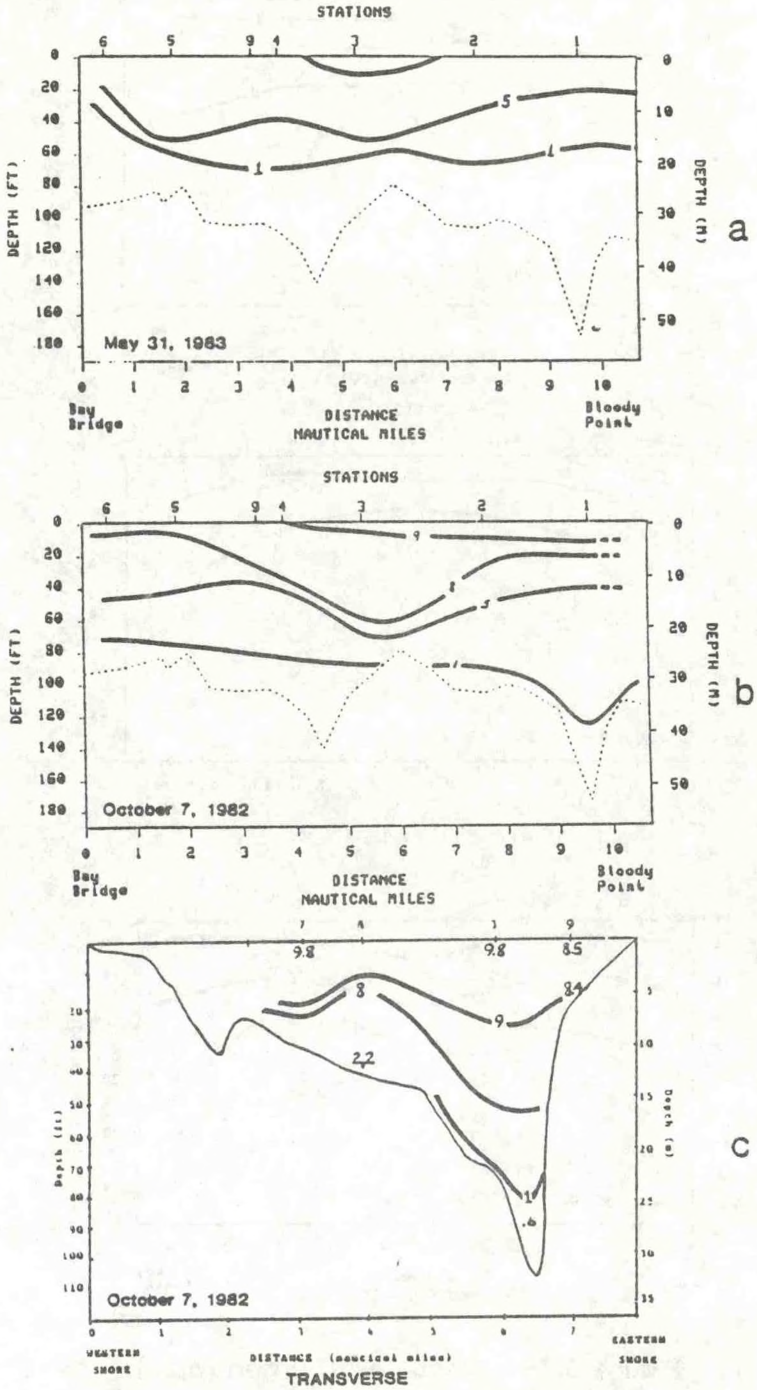


Figure 3.2-2 Dissolved Oxygen (ppm)

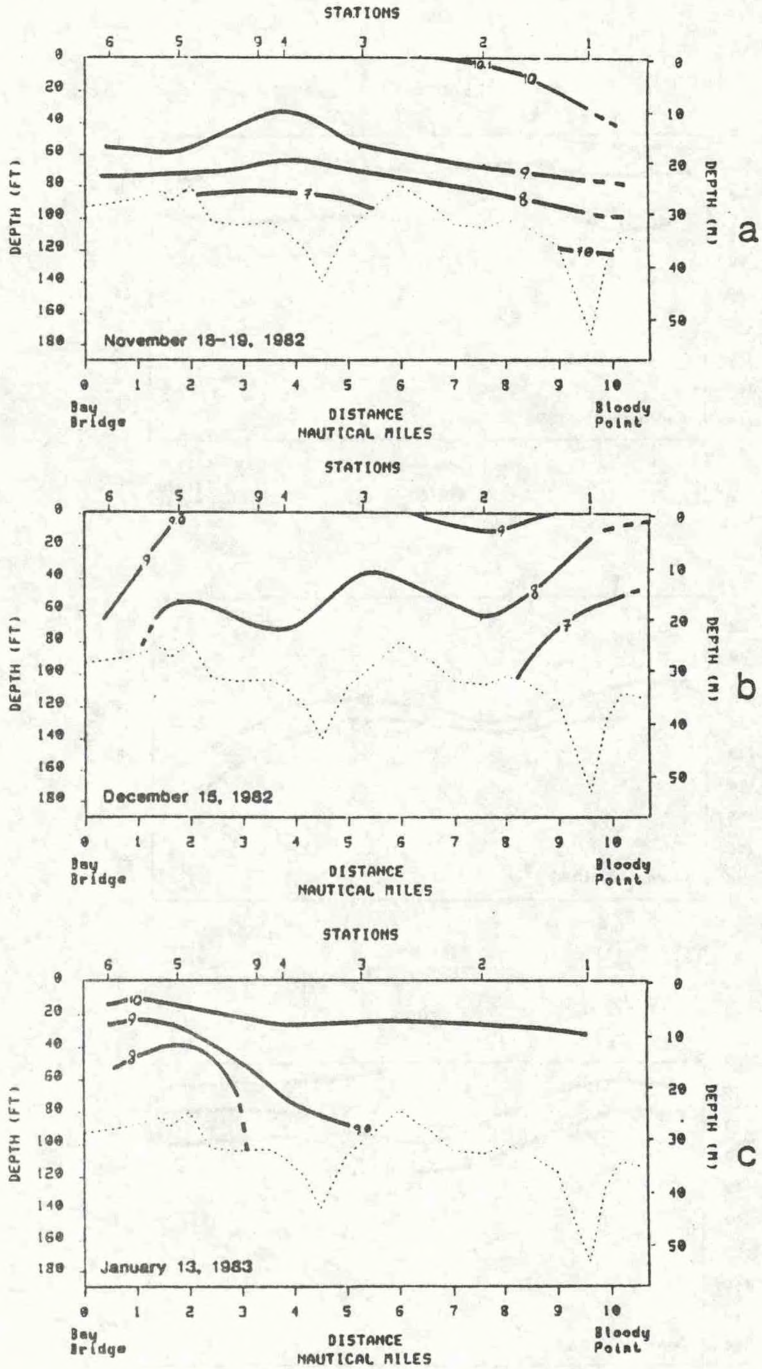


Figure 3.2-3 Dissolved Oxygen (ppm)

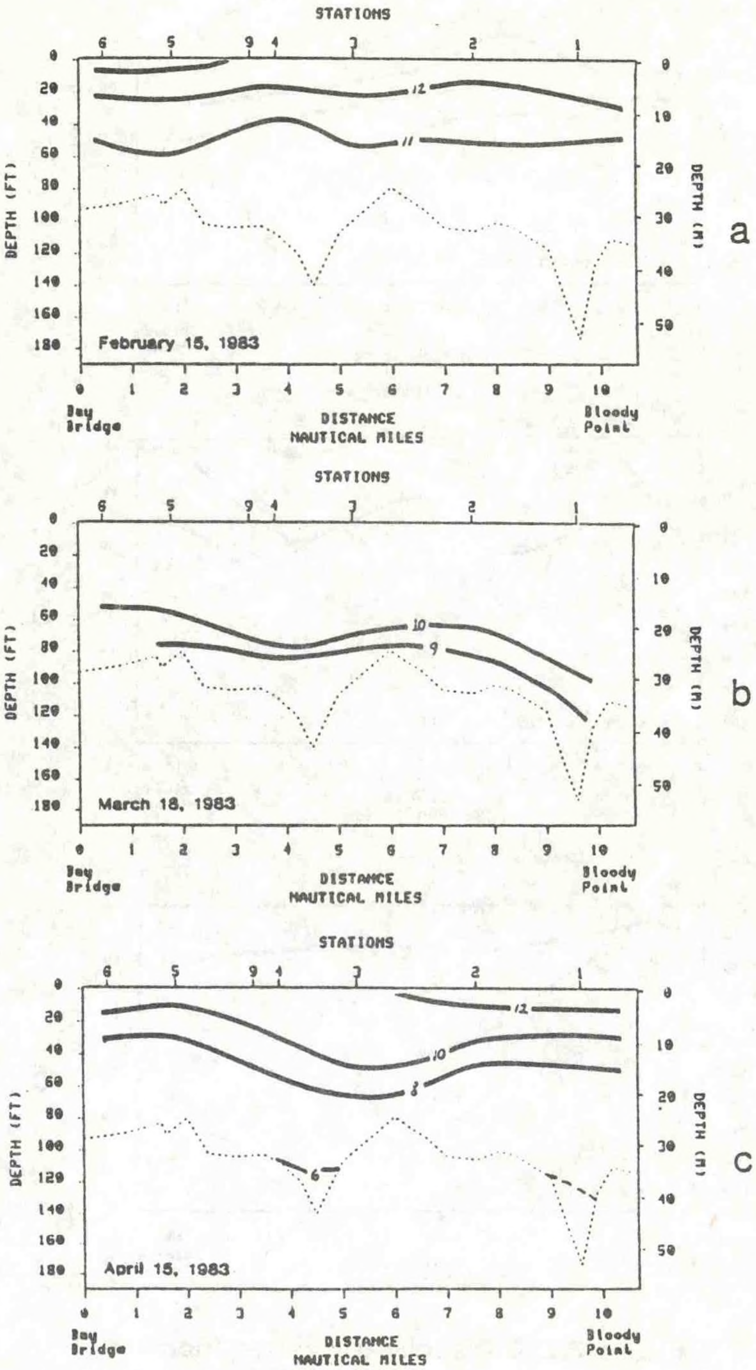


Figure 3.2-4 Dissolved Oxygen (ppm)

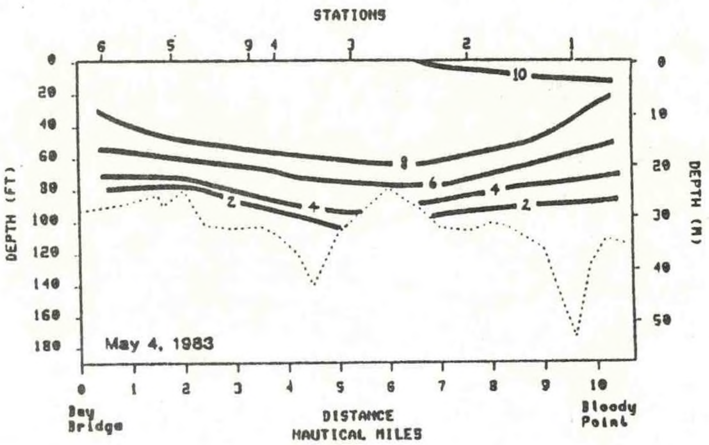


Figure 3.2-5 Dissolved Oxygen (ppm)

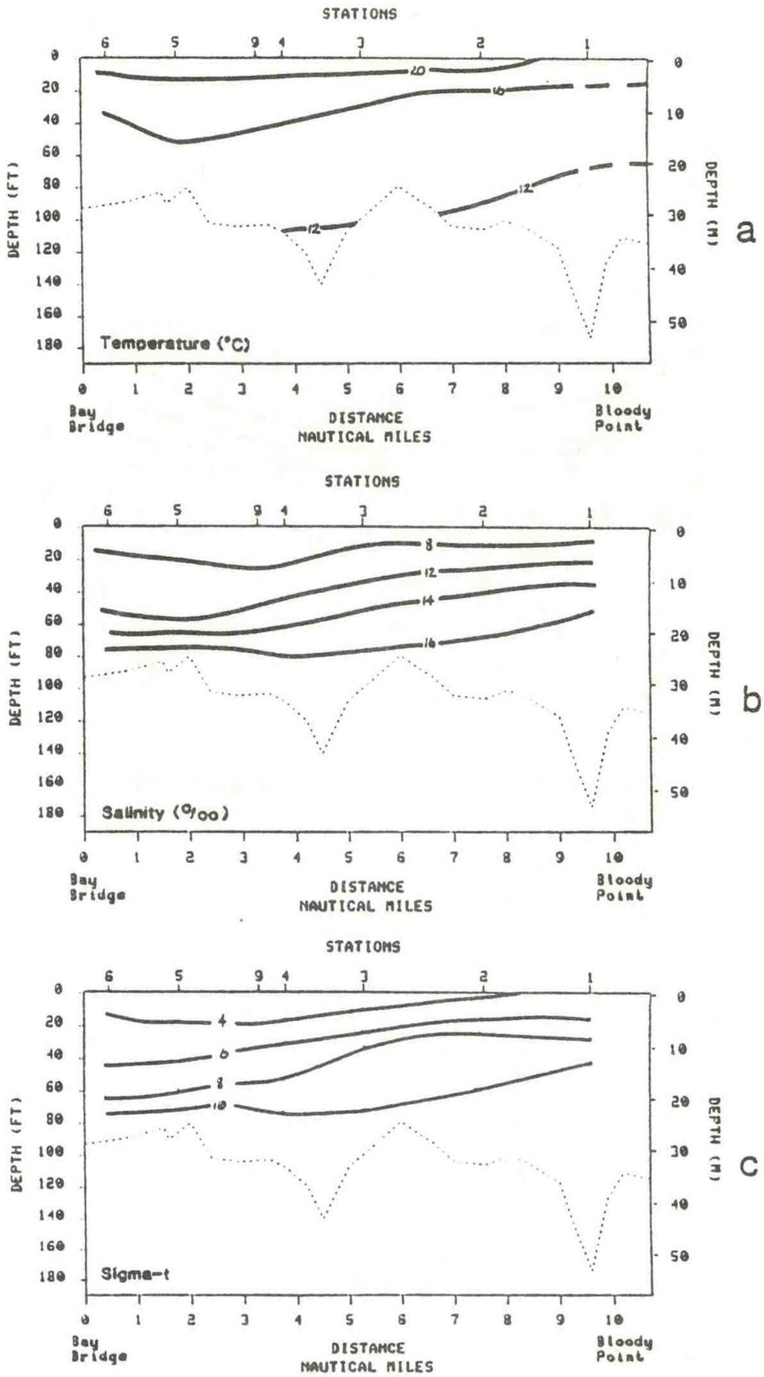


Figure 3.2-6 May 20 - 21, 1982 Profiles

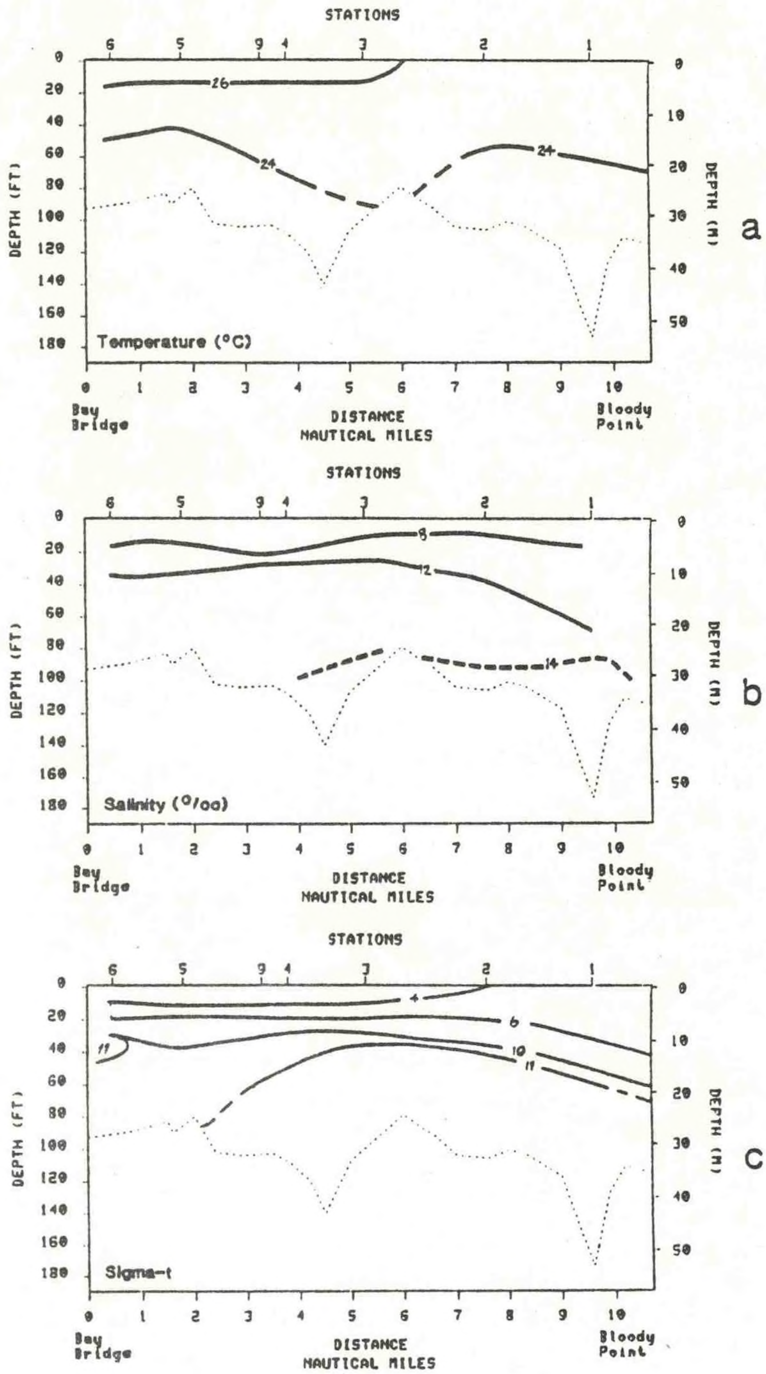


Figure 3.2-7 August 3, 1982 Profiles

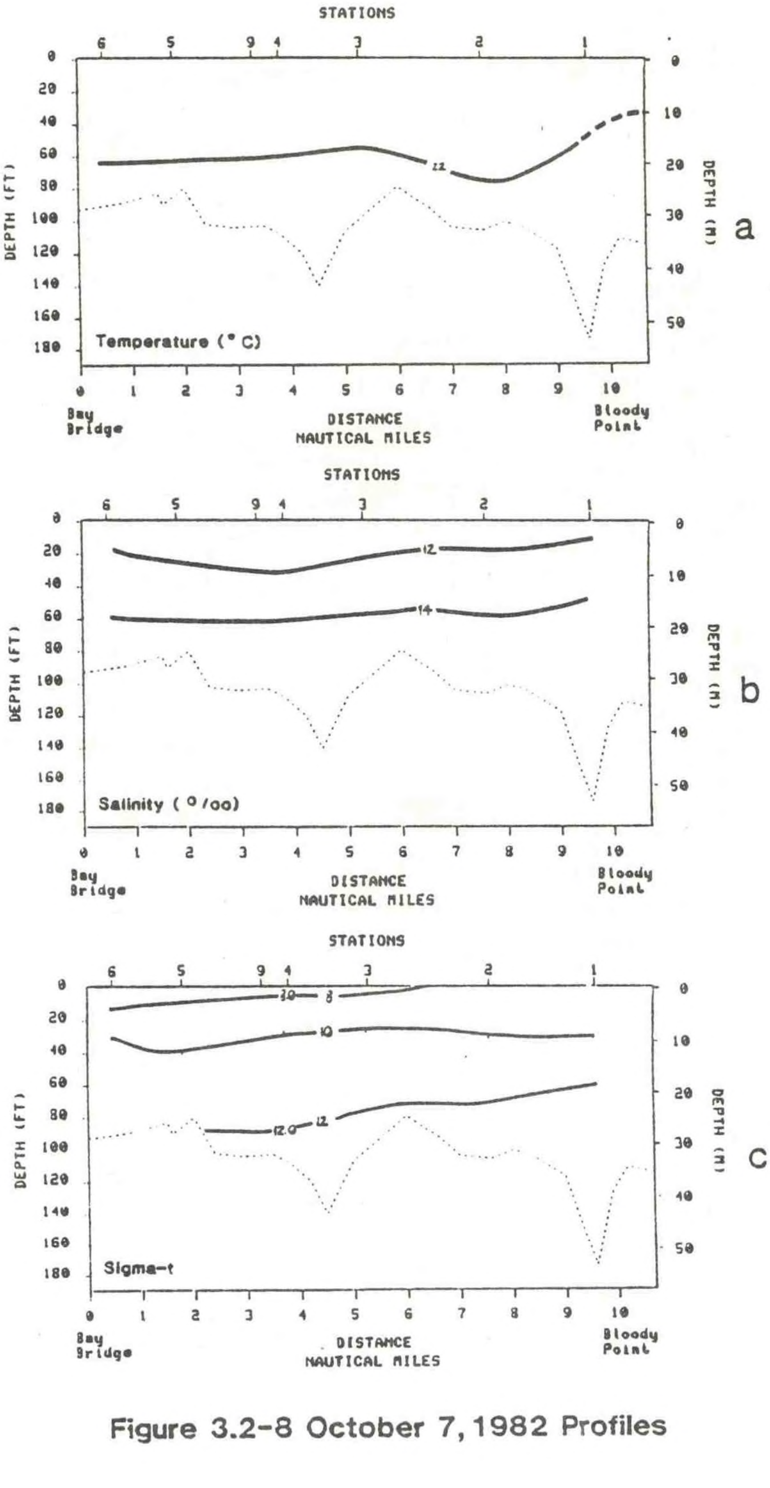


Figure 3.2-8 October 7, 1982 Profiles

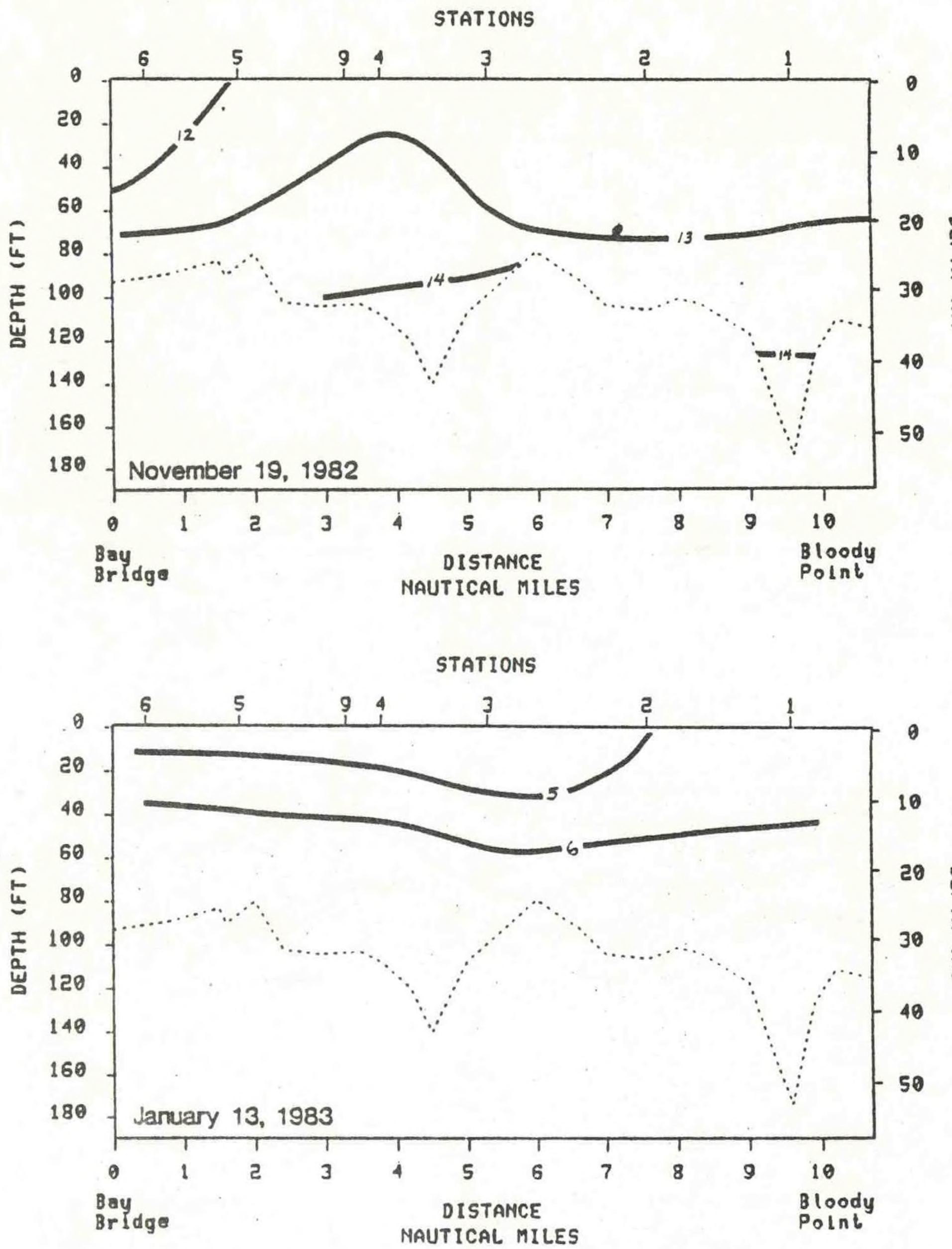
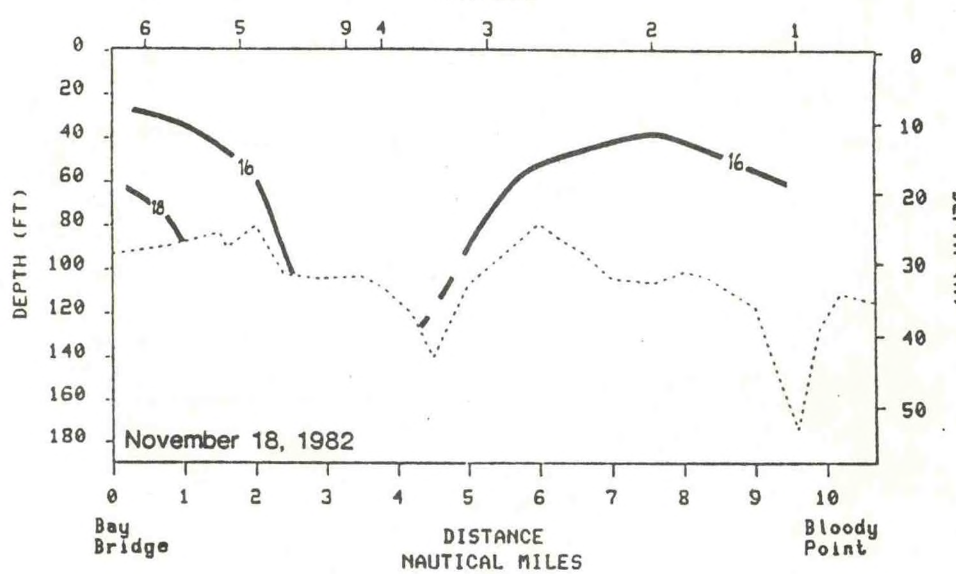


Figure 3.2-9 Temperature (°C)



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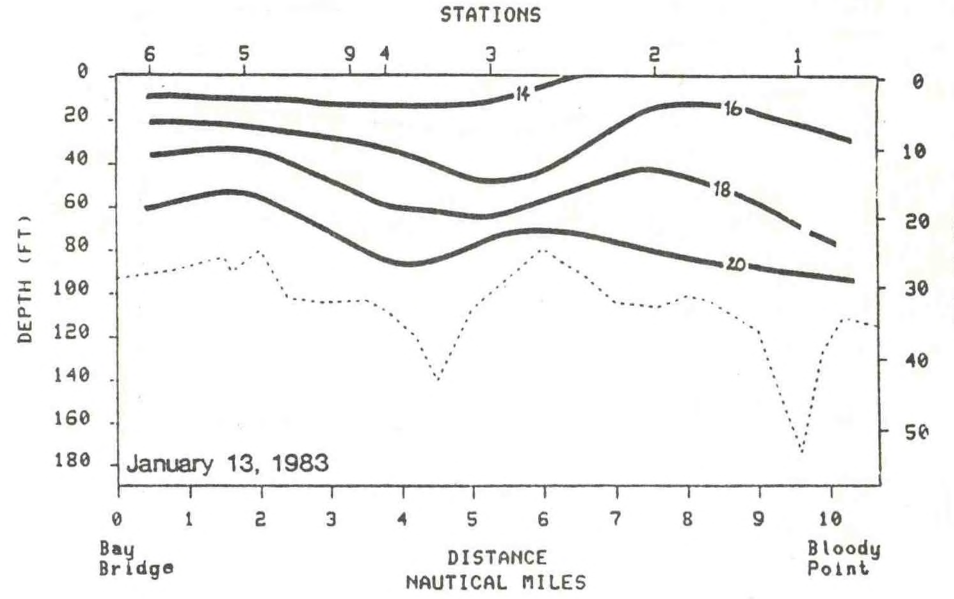
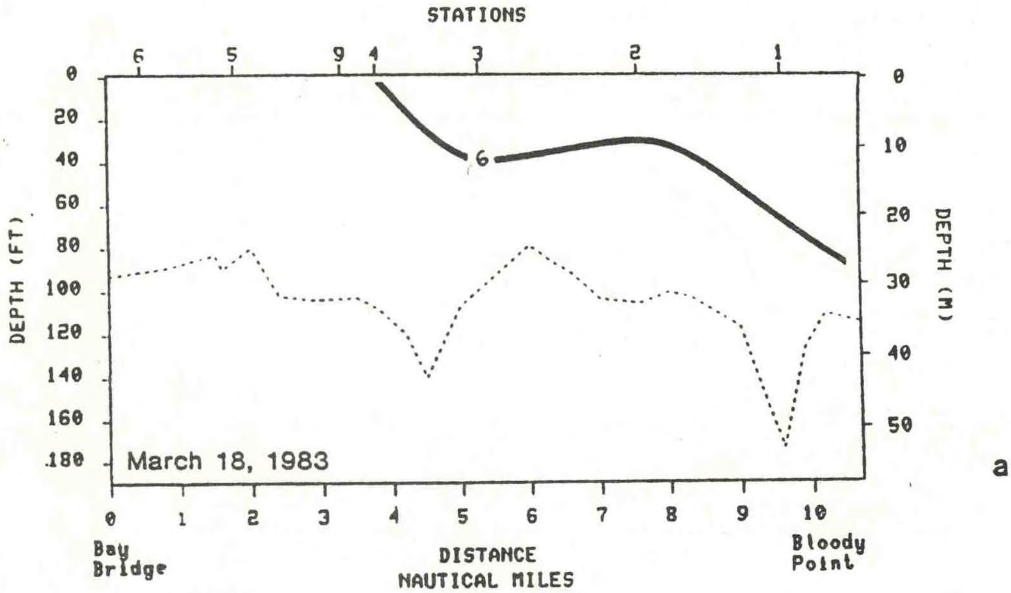


b

Figure 3.2-10 Salinity($^{o}/_{oo}$)



Temperature (°C)

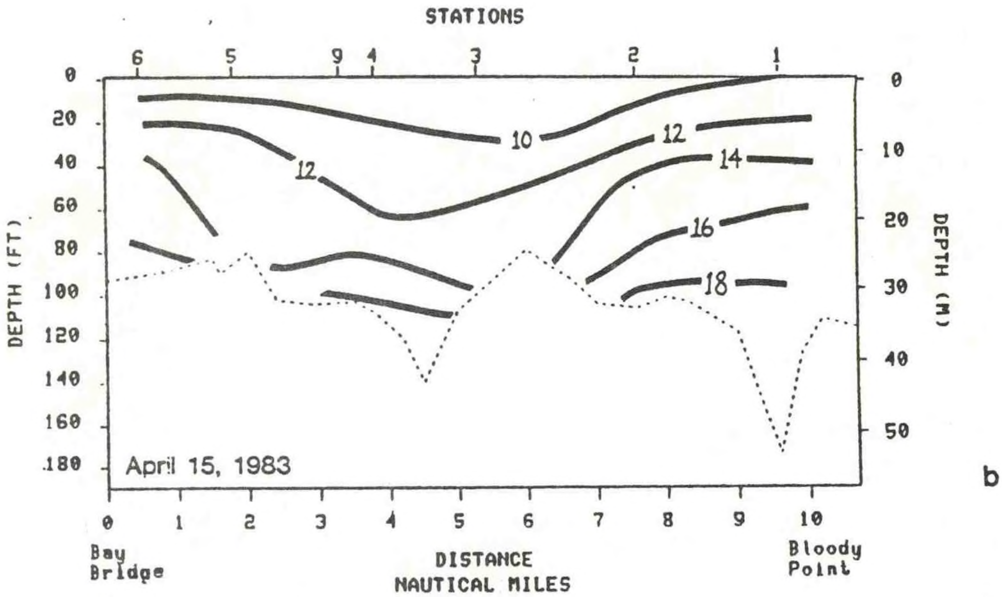


Figure 3.2-11 Salinity (‰)

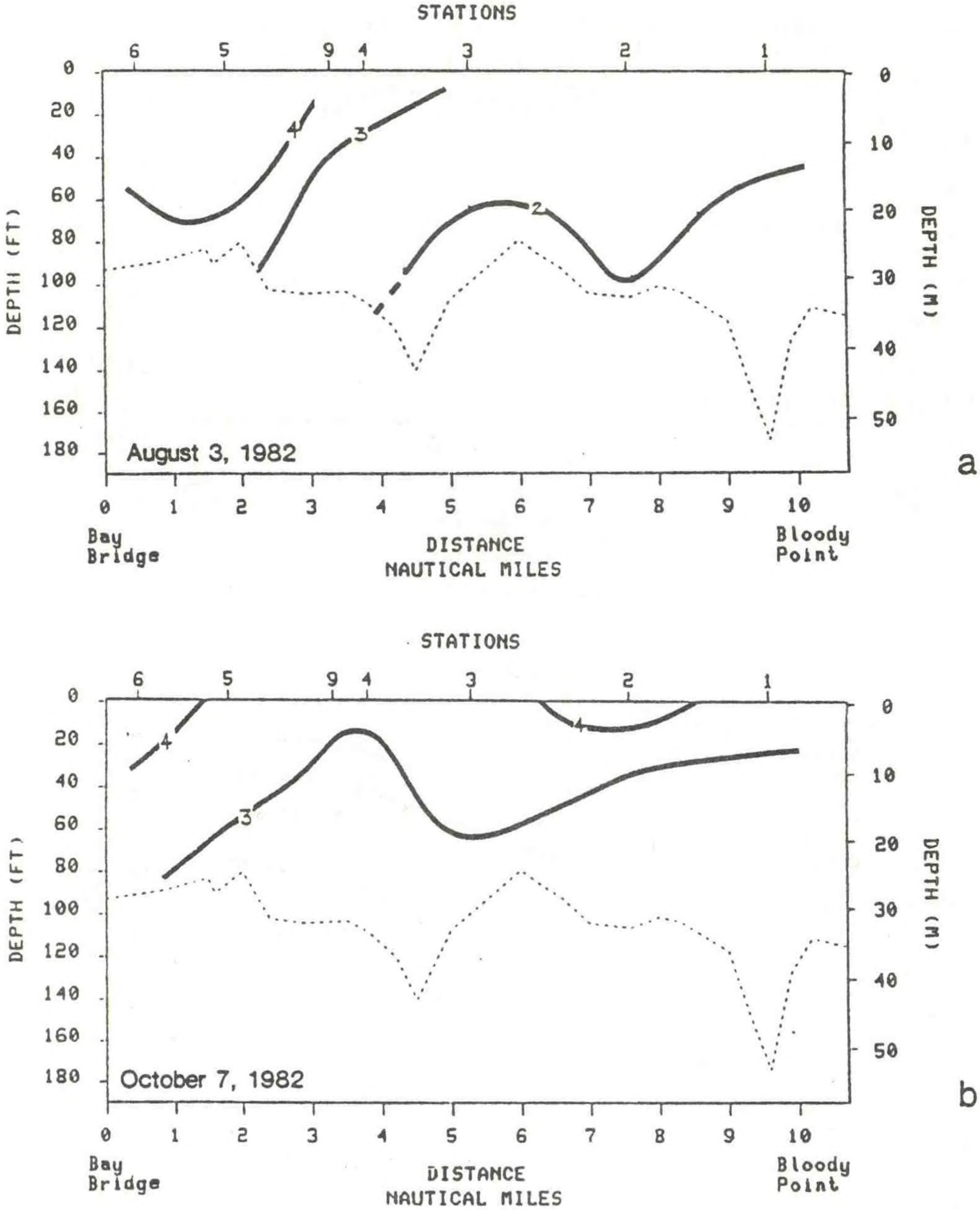


Figure 3.2-12 Turbidity (FTU)

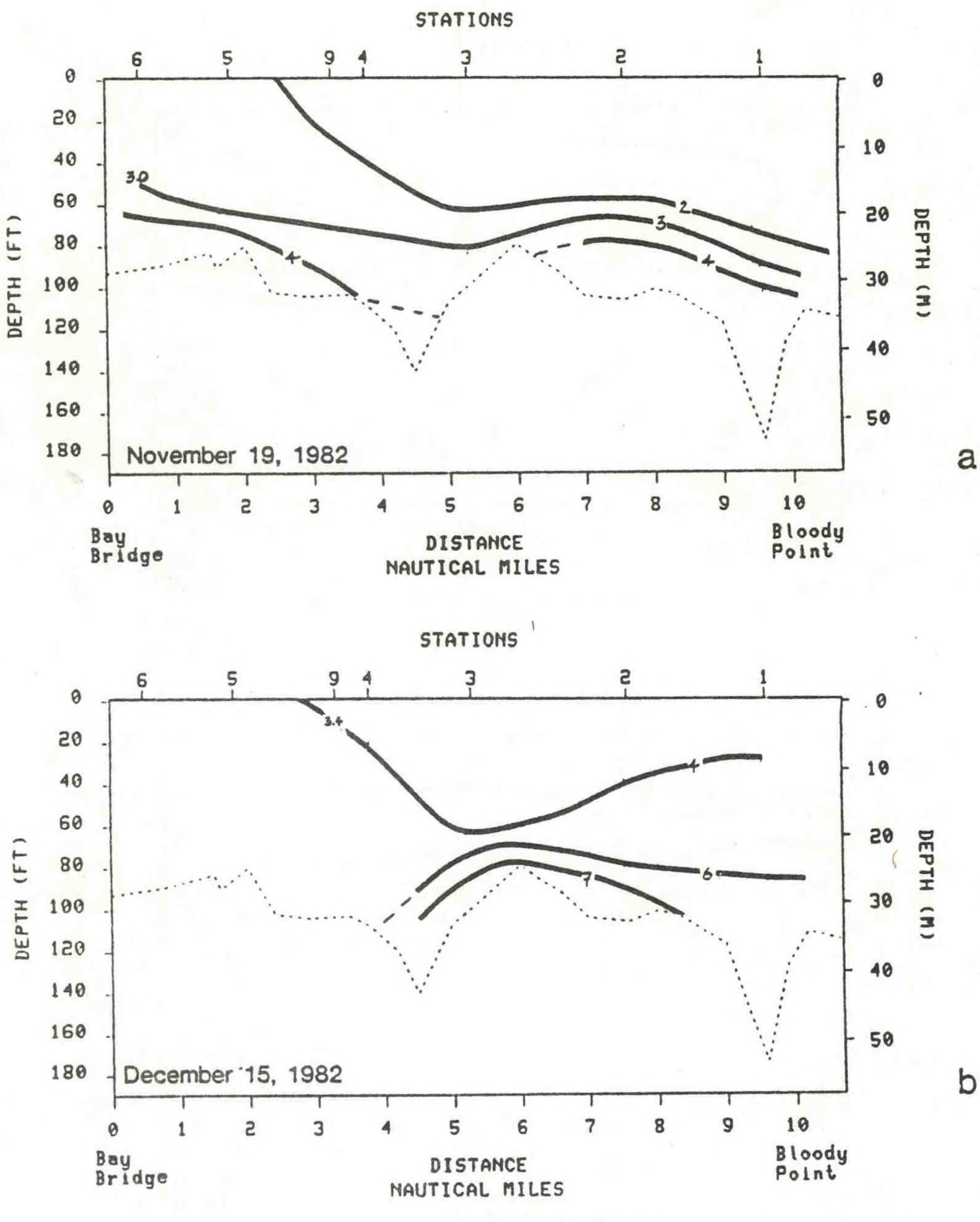


Figure 3.2-13 Turbidity (FTU)

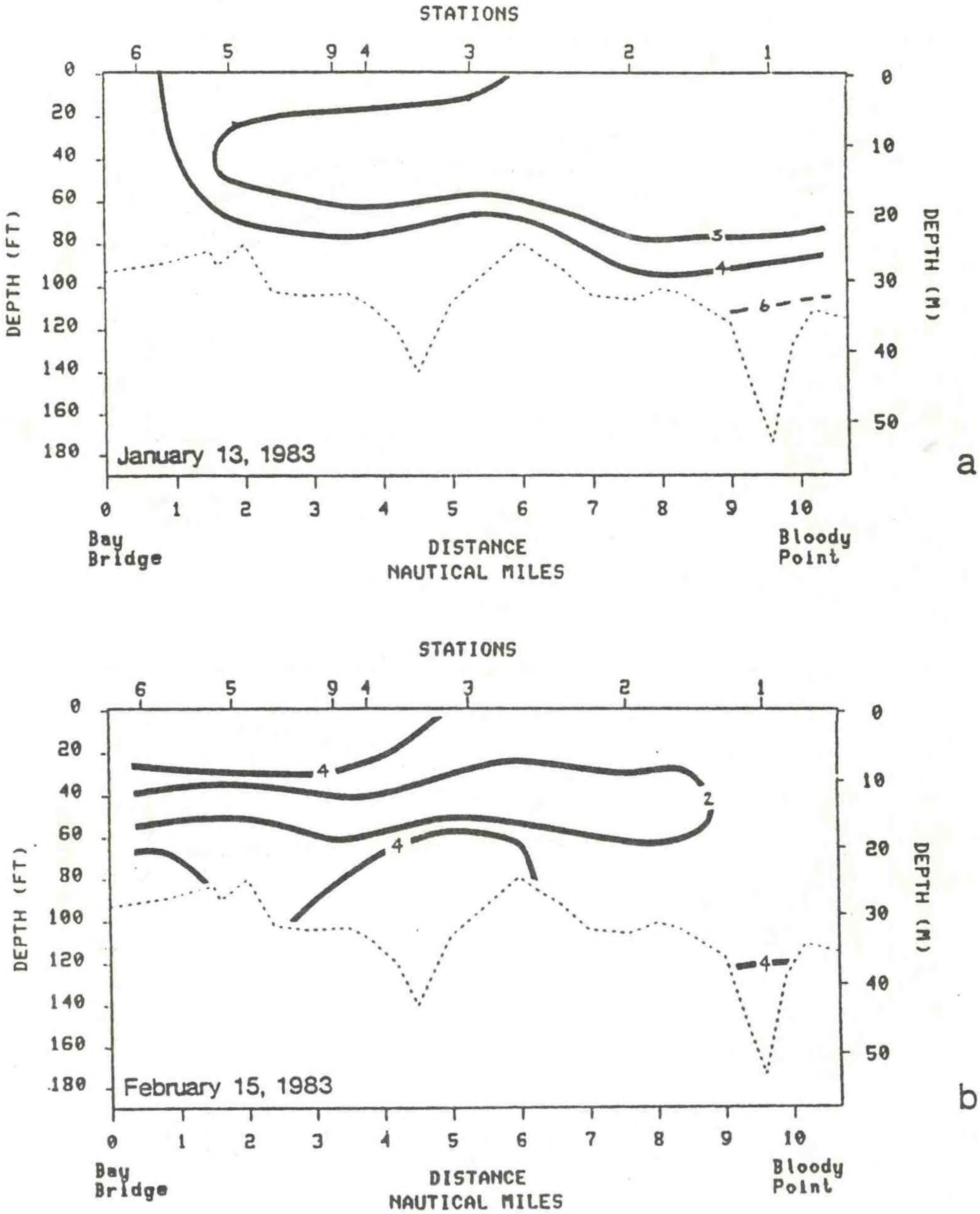
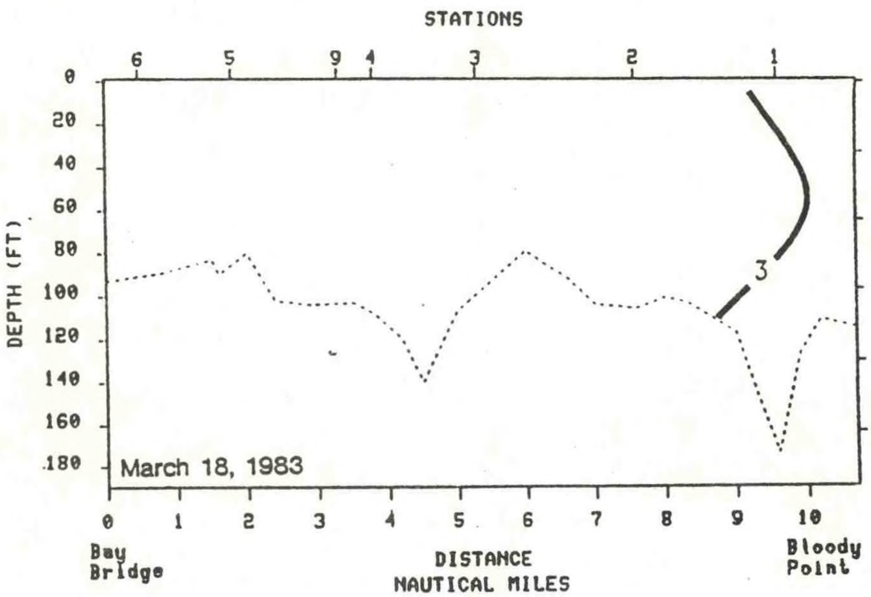
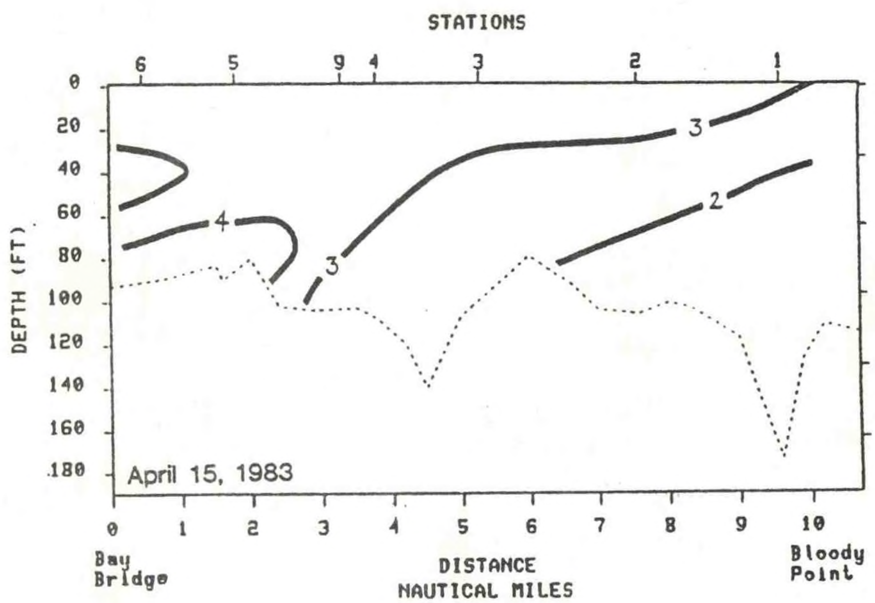


Figure 3.2-14 **Turbidity (FTU)**



a



b

Figure 3.2-15 Turbidity (FTU)

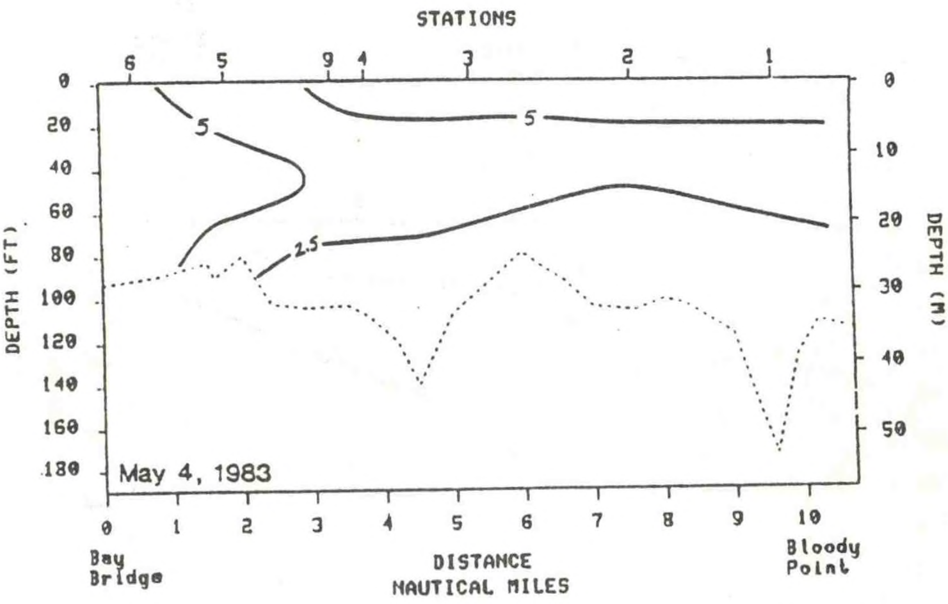


Figure 3.2-16 Turbidity (FTU)

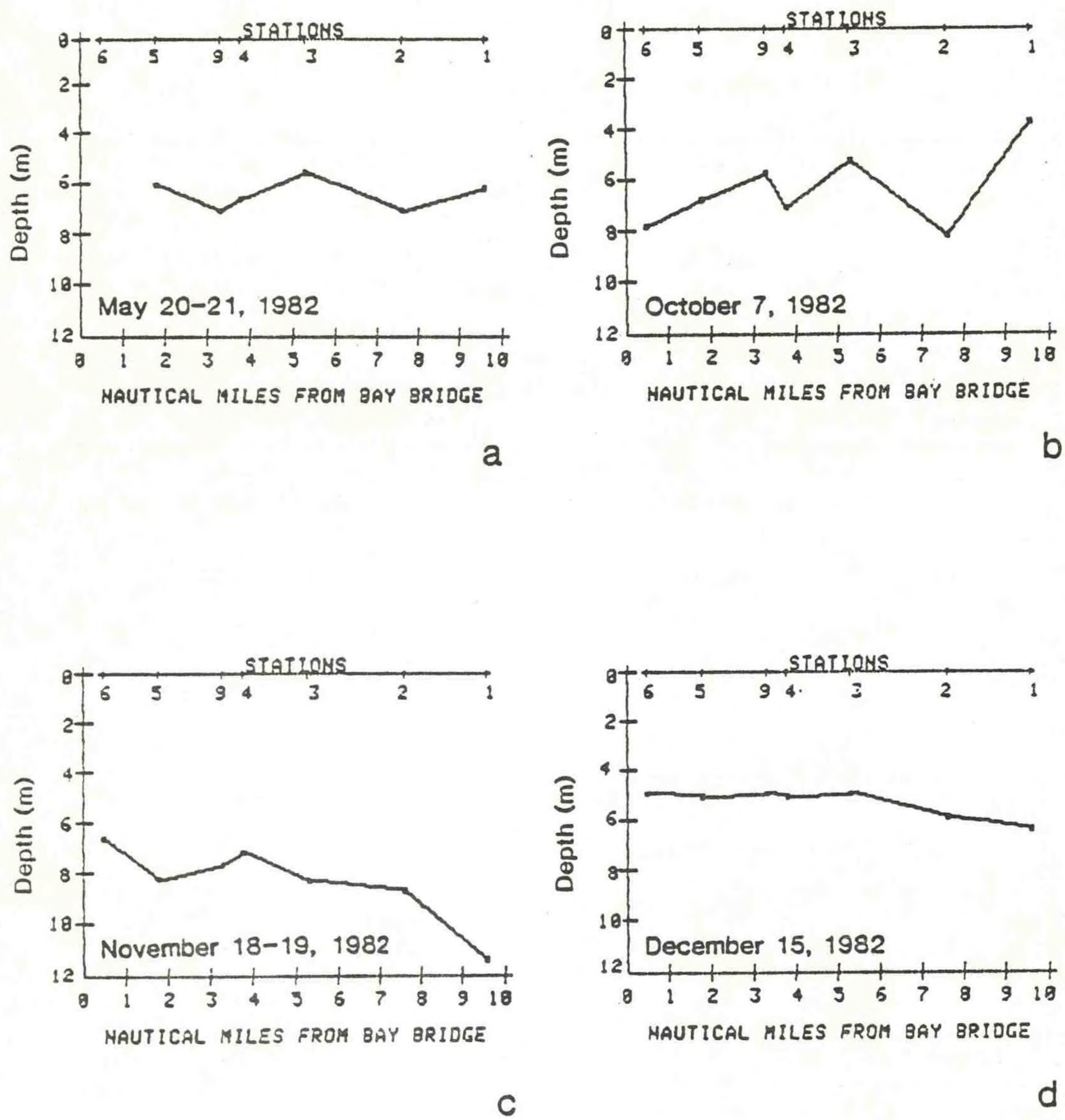


Figure 3.2-17 Depth of 1 percent light level

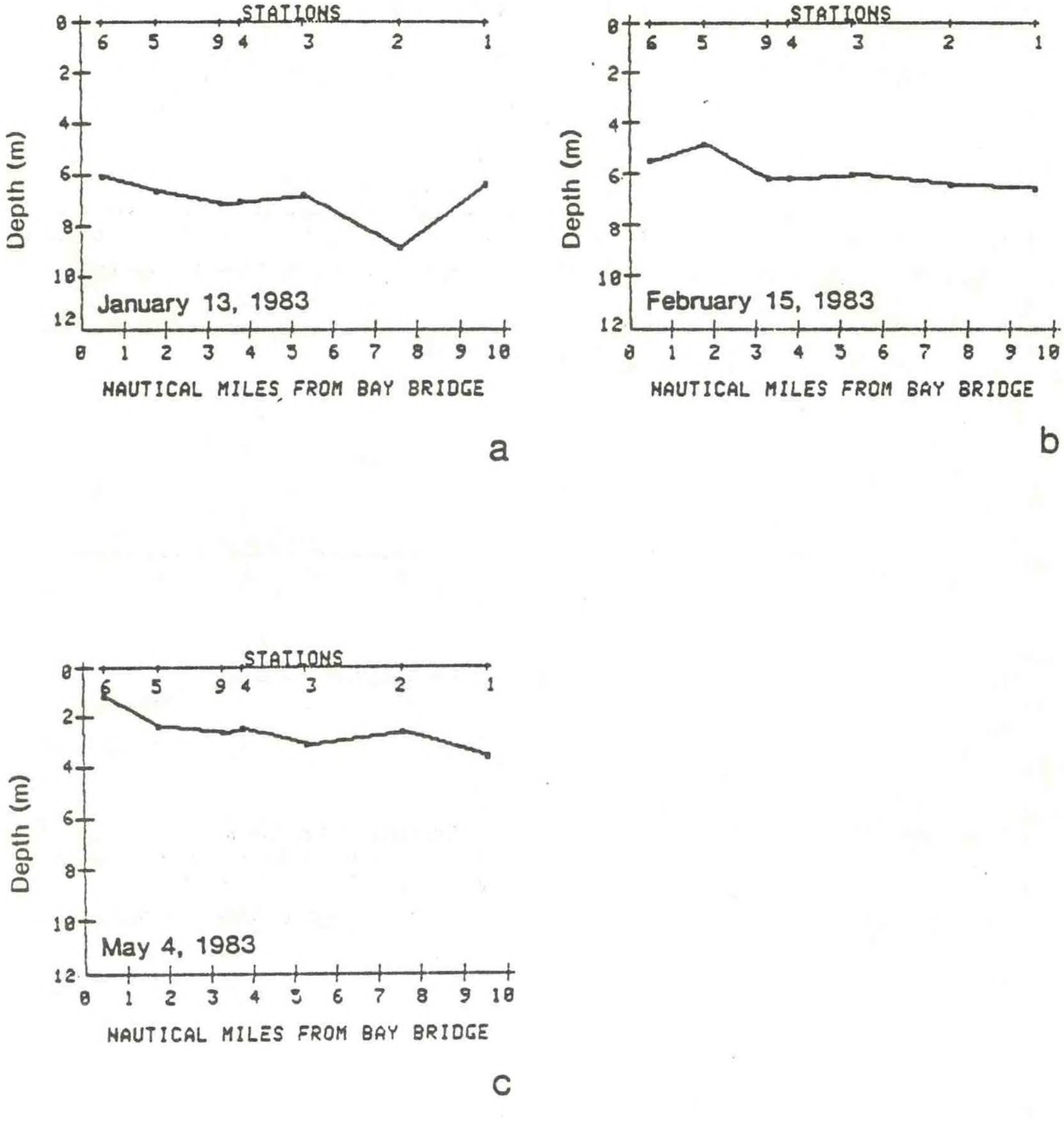


Figure 3.2-18 Depth of 1 percent light level

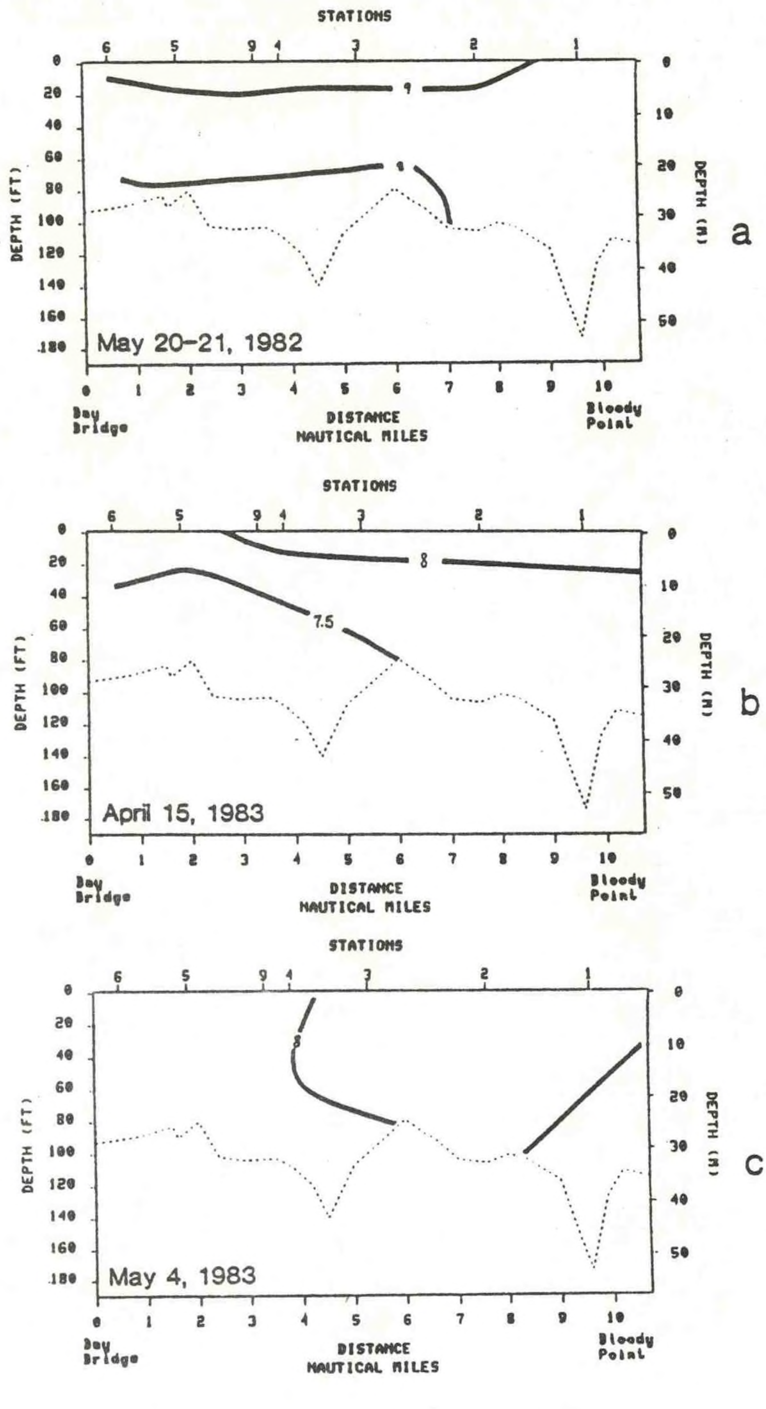


Figure 3.2-19 pH Profiles

TABLE 3.3-1 TAXONOMIC LIST OF THE BENTHIC COMMUNITY AND SEASONAL REPRESENTATION OF TAXA COLLECTED FROM THE DEEP TROUGH STUDY AREA, 1982-1983

	MAY	AUG	NOV	FEB	MAY
Cnidaria					
Anthozoa					
Diadumene leucolena			X	X	X
Platyhelminthes					
Turbellaria					
Stylochus ellipticus			X	X	X
Nemertea					
Anopla					
Tubulanus pellucidus					X
Micrura sp.					X
Micrura leidyi	X	X	X	X	
Annelida					
Polychaeta					
Heteromastus filiformis	X	X	X	X	X
Loimia medusa					X
Nereis succinea	X	X	X	X	X
Glycinde solitaria	X		X	X	X
Eteone heteropoda	X	X	X	X	X
Polydora ligni	X	X	X	X	X
Paraprionospio pinnata	X		X	X	X
Scolecolepides viridis	X				X
Streblospio benedicti	X	X	X	X	X
Haploscolopos fragilis					X
Pectinaria gouldii			X	X	X
Oligochaeta					
Immature Tubificidae w/o capilliform chaetae		X			
Tubificoides brownae	X	X		X	X
Tubificoides heterochaetus				X	
Mollusca					
Pelecypoda					
Ischadium recurvum		X	X	X	X
Crassostrea virginica			X	X	
Gemma gemma	X	X	X	X	X
Mulinia lateralis	X	X	X	X	X
Macoma mitchelli	X	X	X	X	X
Macoma balthica	X	X	X	X	X
Mya arenaria	X	X	X	X	X
Tagelus plebius		X			
Lyonsia hyalina	X				
Gastropoda					
Hydrobia sp.					X
Epitonium rupicolum			X	X	X
Retusa canaliculata	X		X	X	X
Doridella obscura			X	X	X

TABLE 3.3-1 (CONT.)

	MAY	AUG	NOV	FEB	MAY
Arthropoda					
Crustacea					
Cirripedia					
Balanus improvisus	X	X	X	X	X
Mysidacea					
Neomysis americana				X	X
Isopoda					
Chiridotea coeca		X	X	X	X
Amphipoda					
Leptocheirus plumulosus	X	X	X	X	X
Corophium sp.			X		
Corophium lacustre				X	X
Gammarus palustris					X
Melita nitida				X	X
Decapoda					
Rhithropanopeus harrisii			X	X	
Phoronida					
Phoronis architecta	X	X			
Number of species	20	19	26	30	33

TABLE 3.3-2 THE ANNUAL MEAN DENSITY (number/m^2) OF EACH BENTHIC SPECIES COLLECTED IN THE DEEP TROUGH STUDY AREA, 1982-1983

SPP. NAME	NUMBER	%	CUMU. %
MULINIA LATERALIS	465.542	36.414	36.414
NEREIS SUCCINEA	162.471	12.708	49.122
GEMMA GEMMA	120.209	9.403	58.525
POLYDORA LIGNI	111.740	8.740	67.265
STREBLOSPIO BENEDICTI	87.156	6.817	74.082
MYA ARENARIA	53.116	4.155	78.237
MELITA NITIDA	47.360	3.704	81.941
PARAPRIONOSPIO PINNATA	42.262	3.306	85.247
COROPHIUM LACUSTRE	35.684	2.791	88.038
DIADUMENE LEUCOLENA	34.616	2.708	90.745
HETEROMASTUS FILIFORMIS	30.011	2.347	93.093
LEPTOCHEIRUS PLUMULOSUS	10.689	0.836	93.929
CHIRIDOTEA COECA	10.607	0.830	94.759
ETEONE HETEROPODA	8.962	0.701	95.460
MACOMA MITCHELLI	8.469	0.662	96.122
MACOMA BALTHICA	6.660	0.521	96.643
ISCHADIUM RECURVUM	6.002	0.469	97.112
SCOLECOLEPIDES VIRIDIS	5.920	0.463	97.575
MICRURA LEIDYI	5.920	0.463	98.038
BALANUS IMPROVISUS	3.124	0.244	98.283
EPITONIUM RUPICOLUM	2.631	0.206	98.489
STYLOCHUS ELLIPTICUS	2.302	0.180	98.669
PHORONIS ARCHITECTA	2.220	0.174	98.842
DORIDELLA OBSCURA	2.056	0.161	99.003
COROPHIUM	1.562	0.122	99.125
MICRURA SP	1.480	0.116	99.241
GLYCINDE SOLITARIA	1.480	0.116	99.357
TUBIFICOIDES BROWNAE	1.480	0.116	99.473
RETUSA CANALICULATA	1.398	0.109	99.582
PECTINARIA GOULDII	1.151	0.090	99.672
LYONSIA HYALINA	1.151	0.090	99.762
OLIGOCHAETA	0.576	0.045	99.807
CRASSOSTREA VIRGINICA	0.493	0.039	99.846
TUBULANUS PELLUCIDUS	0.411	0.032	99.878
NEOMYSIS AMERICANA	0.411	0.032	99.910
R HARRISII Z	0.329	0.026	99.936
LOIMIA MEDUSA	0.247	0.019	99.955
HYDROBIA	0.164	0.013	99.968
HAPLOSCOLOPLOS FRAGILIS	0.082	0.006	99.974

TABLE 3.3-3 THE TEMPORAL-SPATIAL DISTRIBUTION (number/m^2) OF Mulinia lateralis IN THE DEEP TROUGH STUDY AREA, 1982-1983

DATE	STATION ST1X	ST2X	ST4X	ST3X	ST5X
20 MAY 82	0.0	11.1	3.7	22.2	14.8
3 AUG 82	0.0	0.0	0.0	0.0	0.0
18 NOV 82	0.0	0.0	0.0	0.0	0.0
16 FEB 83	266.4	865.8	769.6	366.3	688.2
4 MAY 83	1132.2	1824.1	4184.7	2519.7	758.5
MEAN	279.7	540.2	991.6	581.6	292.3

DATE	STATION ST6X	ST7X	ST8X	ST9X	MEAN
20 MAY 82	3.7	7.4	3.7	355.2	46.9
3 AUG 82	0.0	0.0	0.0	355.2	39.5
18 NOV 82	0.0	40.7	29.6	162.8	25.9
16 FEB 83	1883.3	103.6	81.4	99.9	569.4
4 MAY 83	3581.6	11.1	29.6	773.3	1646.1
MEAN	1093.7	32.6	28.9	349.3	465.5

TABLE 3.3-4 THE TEMPORAL-SPATIAL DISTRIBUTION (number/m^2) OF <u>Nereis succinea</u> IN THE DEEP TROUGH STUDY AREA, 1982-1983

STATION

DATE	ST1X	ST2X	ST4X	ST3X	ST5X
20 MAY 82	0.0	14.8	0.0	0.0	7.4
3 AUG 82	0.0	0.0	0.0	0.0	0.0
18 NOV 82	0.0	7.4	0.0	51.8	0.0
16 FEB 83	0.0	7.4	0.0	18.5	7.4
4 MAY 83	0.0	3.7	22.2	59.2	0.0
MEAN	0.0	6.7	4.4	25.9	3.0

STATION

DATE	ST6X	ST7X	ST8X	ST9X	MEAN
20 MAY 82	0.0	62.9	0.0	11.1	10.7
3 AUG 82	0.0	0.0	0.0	307.1	34.1
18 NOV 82	0.0	125.8	70.3	928.7	131.6
16 FEB 83	3.7	155.4	51.8	3737.0	442.4
4 MAY 83	3.7	170.2	66.6	1417.1	193.6
MEAN	1.5	102.9	37.7	1280.2	162.5

TABLE 3.3-5 THE TEMPORAL-SPATIAL DISTRIBUTION (number/m^2) OF Streblospio benedicti IN THE DEEP TROUGH STUDY AREA, 1982-1983

DATE	ST1X	ST2X	ST4X	ST3X	ST5X
20 MAY 82	0.0	111.0	33.3	70.3	407.0
3 AUG 82	0.0	0.0	0.0	0.0	0.0
18 NOV 82	0.0	0.0	0.0	0.0	0.0
16 FEB 83	0.0	11.1	0.0	0.0	0.0
4 MAY 83	66.6	103.6	162.8	817.7	0.0
MEAN	13.3	45.1	39.2	177.6	81.4

DATE	ST6X	ST7X	ST8X	ST9X	MEAN
20 MAY 82	59.2	1028.6	11.1	22.2	193.6
3 AUG 82	0.0	0.0	0.0	114.7	12.7
18 NOV 82	0.0	74.0	14.8	3.7	10.3
16 FEB 83	0.0	11.1	22.2	59.2	11.5
4 MAY 83	7.4	691.9	14.8	3.7	207.6
MEAN	13.3	361.1	12.6	40.7	87.2

TABLE 3.3-6 THE TEMPORAL-SPATIAL DISTRIBUTION (number/m^2) OF *Paraprionospio pinnata* IN THE DEEP TROUGH STUDY AREA, 1982-1983

	STATION				
DATE	ST1X	ST2X	ST4X	ST3X	ST5X
20 MAY 82	0.0	0.0	0.0	0.0	40.7
3 AUG 82	0.0	0.0	0.0	0.0	0.0
18 NOV 82	0.0	37.0	3.7	344.1	85.1
16 FEB 83	0.0	55.5	0.0	18.5	33.3
4 MAY 83	3.7	0.0	62.9	173.9	3.7
MEAN	0.7	18.5	13.3	107.3	32.6

	STATION				
DATE	ST6X	ST7X	ST8X	ST9X	MEAN
20 MAY 82	0.0	3.7	0.0	0.0	4.9
3 AUG 82	0.0	0.0	0.0	0.0	0.0
18 NOV 82	14.8	170.2	199.8	18.5	97.0
16 FEB 83	3.7	273.8	177.6	22.2	65.0
4 MAY 83	0.0	85.1	70.3	0.0	44.4
MEAN	3.7	106.6	89.5	8.1	42.3

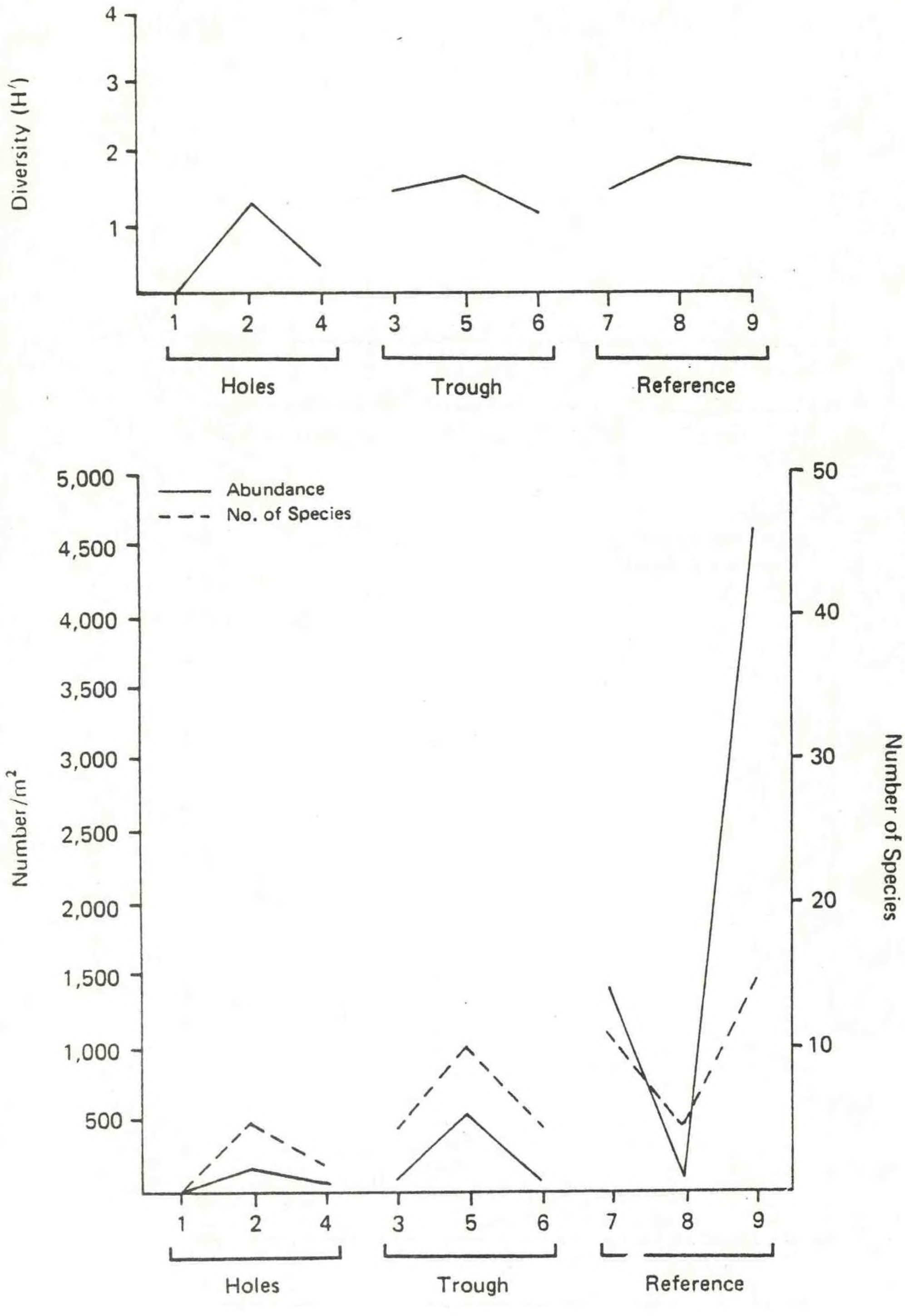


Figure 3.3-1. Benthic Species Diversity (H′) and components of diversity, 20 May 1982, Deep Trough.

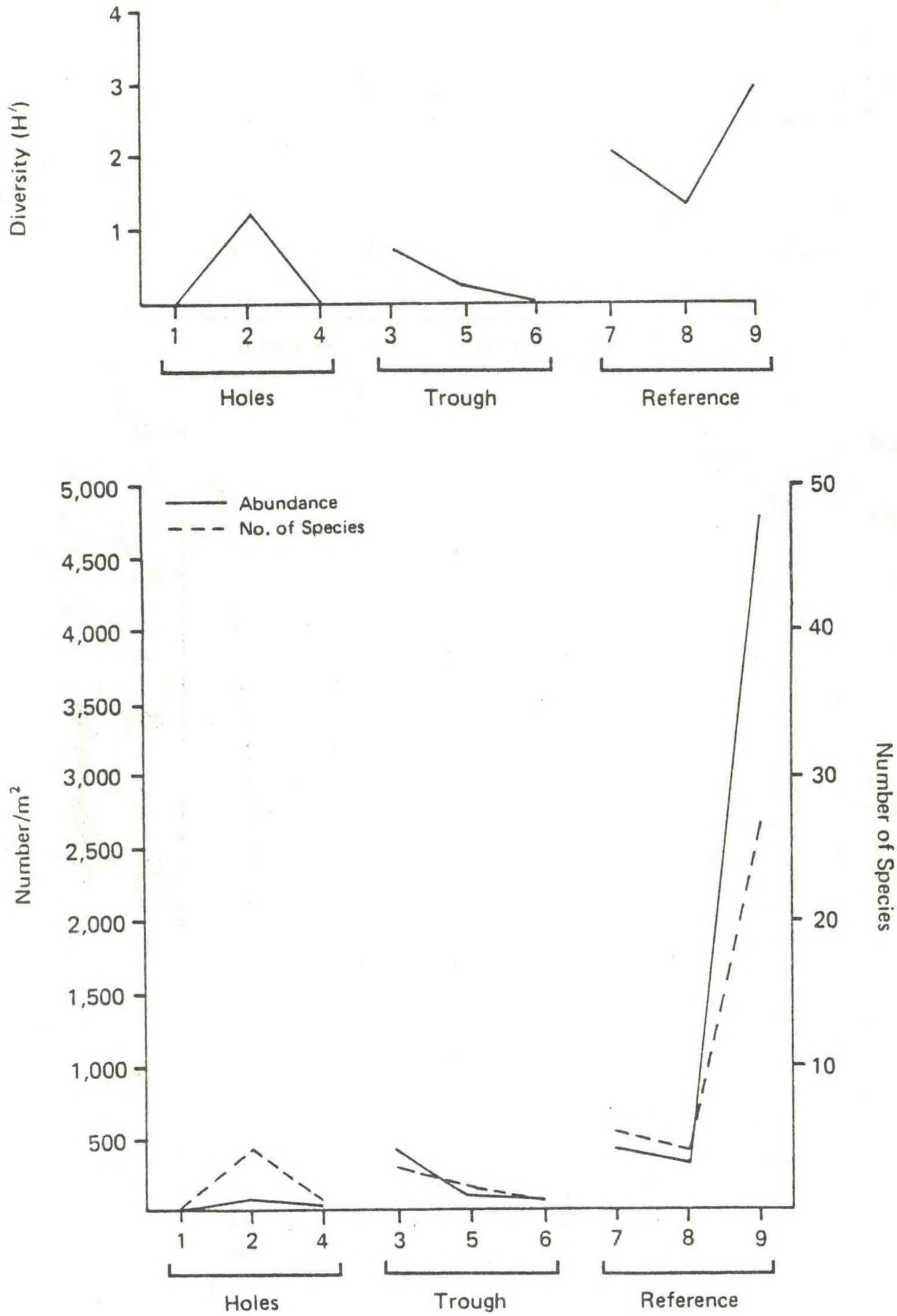
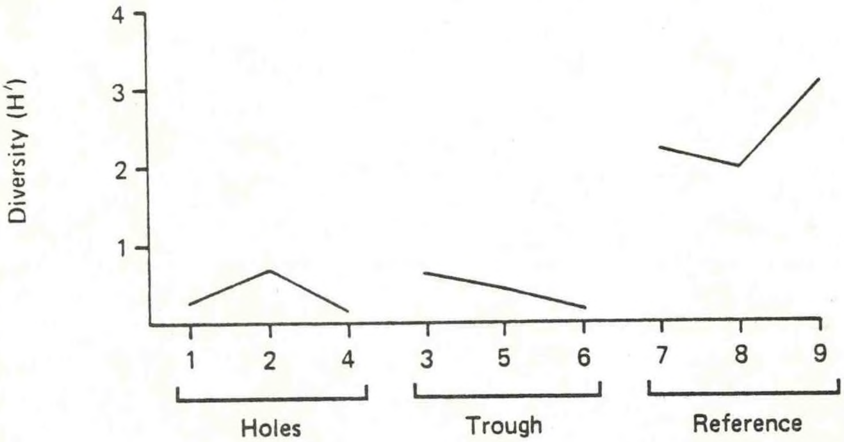


Figure 3.3-2. Benthic Species Diversity (H′) and components of diversity, 18 November 1982, Deep Trough.



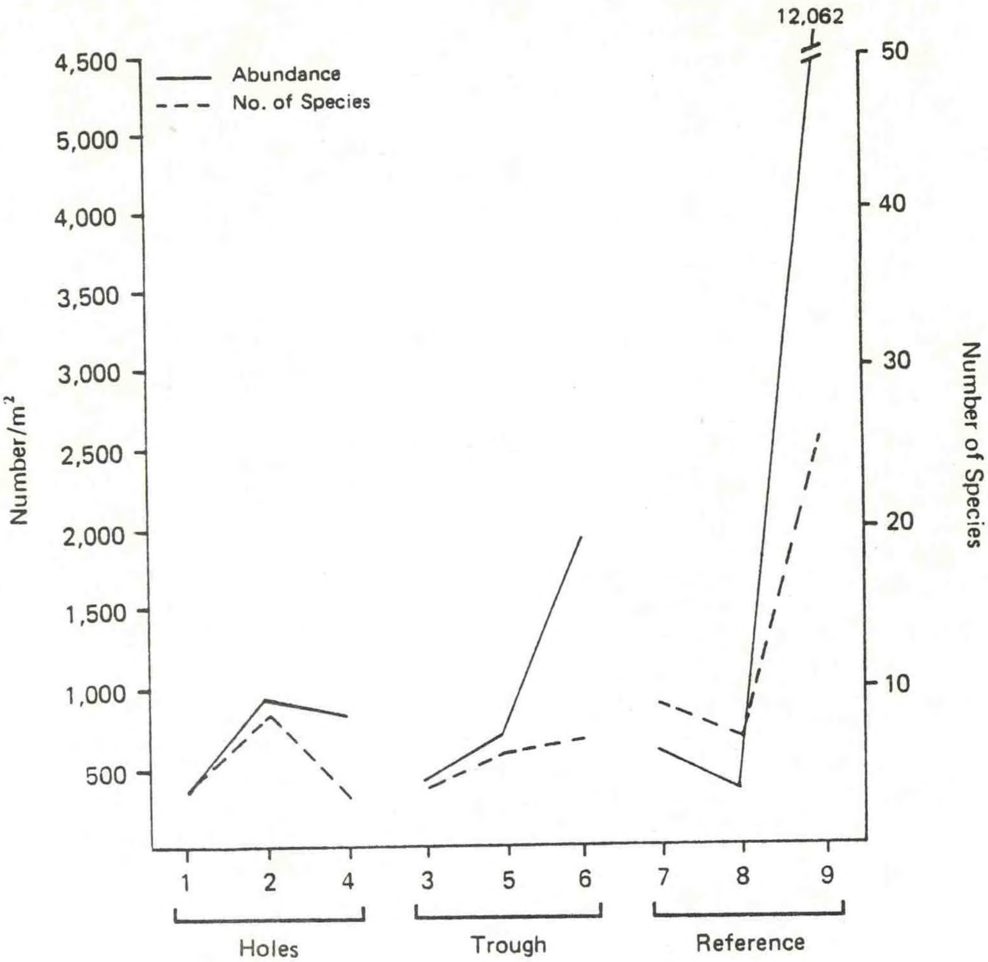
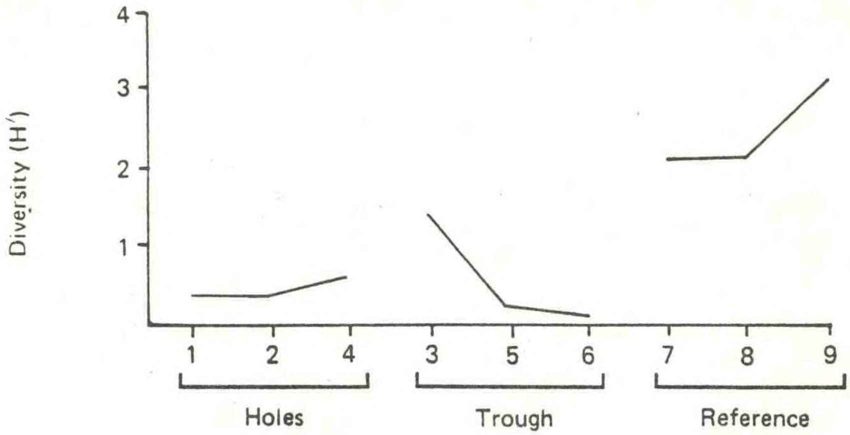


Figure 3.3-3. Benthic Species Diversity (H′) and components of diversity, 16 February 1983.



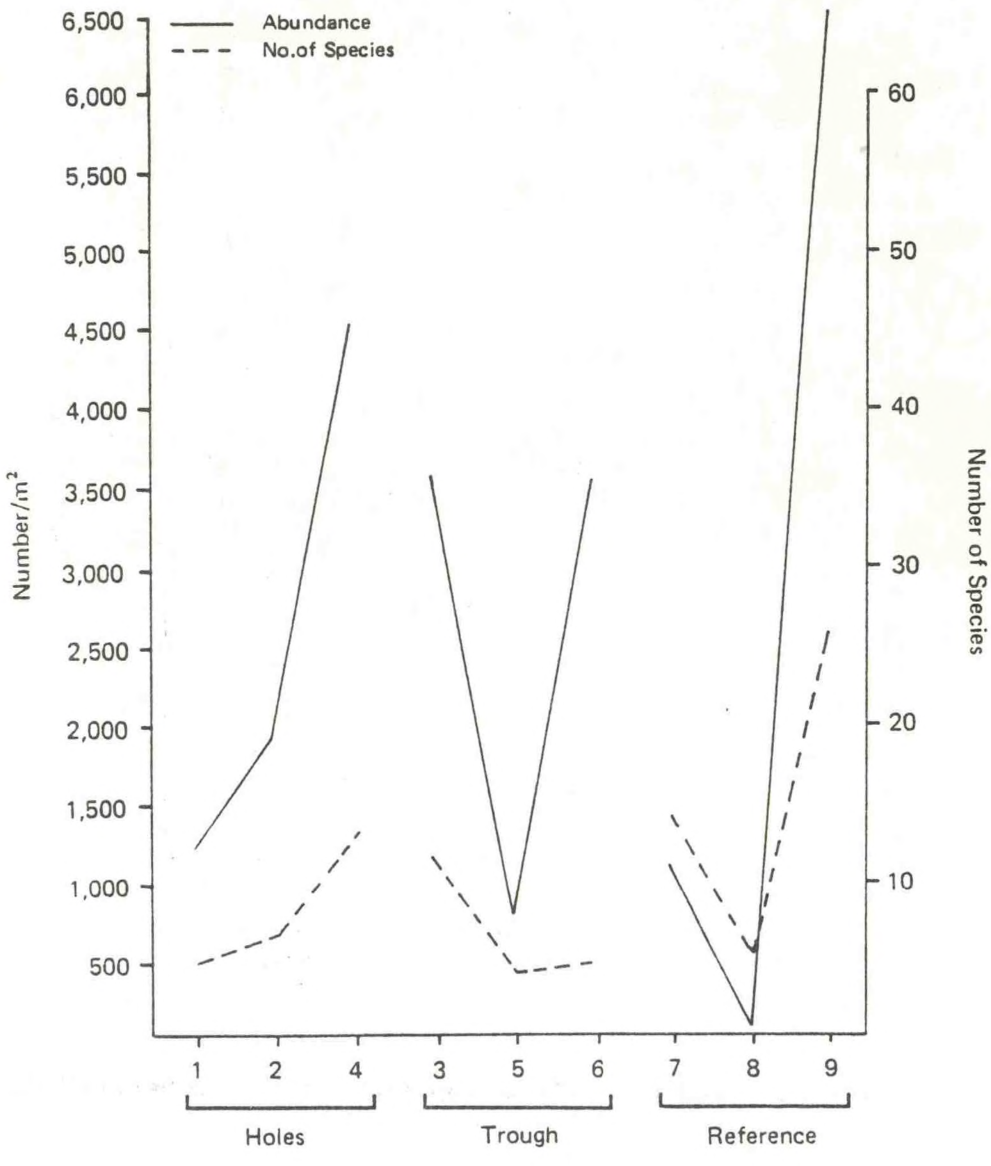


Figure 3.3-4. Benthic Species Diversity (H′) and components of diversity, 4 May 1983.

TABLE 3.4-1. TOTAL ANNUAL ICHTHYOPLANKTON SPECIES DENSITIES (number/100m^3) BY LIFE STAGE, DEEP TROUGH, 1982–1983

Species	Eggs	Prolarvae	Postlarvae	Juvenile	Adult
Bay anchovy	71.596		0.087	0.265	0.218
Atlantic menhaden	1.194		0.046	0.161	
Atlantic silverside			0.354		
Atlantic croaker				0.262	0.006
Rough silverside	0.208		0.011		
Striped anchovy			0.076	0.005	0.002
Yellow perch		0.079			
Three spine stickleback					0.064
Skilletfish	0.035		0.031		
Hogchoker			0.021		
Darter goby			0.006		
American eel				0.005	0.005
Winter flounder				0.004	
Alosa spp			0.003		
Inland silverside					0.003
Northern pipefish				0.003	0.002
Weakfish				0.003	
Green goby			0.002		
TOTAL	73.033	0.079	0.637	0.708	*

*Adult classification is determined arbitrarily by a cut off size and not, as is normal usage, by determination of the state of the gonads.

TABLE 3.4-2 MONTHLY RELATIVE DENSITY (number/600m^3)[a] OF ICHTHYOPLANKTON BY LIFE STAGE AND DEPTH REGIME, DEEP TROUGH, 1982-1983

Control stations											
Average Bay depths.	Eggs	0.0	4,734.2	27.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Larvae	30.2	13.7	3.0	0.0	0.0	2.2	0.0	6.2	2.0	0.0
# 7, 8, 9	Juveniles	0.0	0.6	0.0	0.0	0.6	12.1	7.0	2.7	1.3	4.1
	Adults[b]	6.4	0.0	0.0	0.6	0.0	1.6	0.0	2.0	0.0	3.1
Trough stations											
# 1, 3, 6	Eggs	156.1	516.4	130.2	0.0	0.0	0.0	0.0	0.6	0.0	0.0
	Larvae	7.8	1.1	3.5	0.4	0.0	2.3	0.0	7.4	0.0	0.0
	Juveniles	0.0	0.0	0.0	0.0	1.6	22.1	13.5	18.4	4.5	0.0
	Adults[b]	1.9	0.0	0.0	2.0	0.0	0.0	1.1	14.6	1.1	1.2
Deep Hole Stations											
# 2, 4, 5	Eggs	7,059.7	313.0	60.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Larvae	25.1	15.8	0.0	0.4	0.0	1.6	0.0	0.5	3.4	1.5
	Juveniles	0.7	0.0	0.0	0.4	1.0	2.2	18.5	10.4	0.6	3.4
	Adults[b]	4.0	0.0	0.0	0.0	0.0	0.0	1.2	0.6	9.2	2.9
Month of collection		May	Aug	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May

(a) Sum of six replicates.

(b) Arbitrarily size determined.

TABLE 3.4-3 ANNUAL STATION DENSITY (number/200m^3)[a] OF LARVAL ICHTHYOPLANKTON SPECIES, DEEP TROUGH, 1982-1983

Station #	1	2	3	4	5	6	7	8	9
Atlantic croaker	0.19	0.11	0.20	0.39	0.65	0.96	0.15	0.12	0.16
Atlantic menhaden	-	0.16	0.16	0.08	0.13	0.20	0.42	0.10	0.22
Atlantic silverside	-	0.19	0.14	0.20	1.05	0.33	0.59	0.33	0.90
rough silverside	-	-	-	-	-	0.03	-	0.05	0.03
Inland silverside	-	-	-	--	-	0.03	-	-	-
bay anchovy	0.46	0.61	1.06	0.32	1.68	0.71	0.43	0.10	0.23
striped anchovy	-	0.02	0.02	0.02	0.03	-	0.09	0.31	0.26
darter goby	-	-	-	0.05	-	--	-	-	-
green goby	0.02	-	-	-	-	-	-	-	-
skillet fish	0.13	-	0.06	-	-	-	0.07	-	0.06
three spine stickle-back	-	0.04	0.10	0.09	0.08	-	-	0.08	0.20
yellow perch	0.18	-	0.11	0.02	-	0.10	0.20	0.12	-
hogchoker	-	-	-	0.09	0.03	-	0.04	0.04	-
winter flounder	-	0.04	-	-	-	-	-	-	-
American eel	-	-	-	0.03	0.02	-	0.05	-	-
weakfish	0.03	-	-	-	-	-	-	-	-
northern pipefish	-	-	-	-	-	0.02	0.03	-	-
Alosa spp.	-	-	0.03	-	--	-	-	-	-
Total densities (eggs excluded)	1.01	1.17	1.88	1.29	3.67	2.38	2.07	1.25	2.06

(a) Sum of two replicates.

TABLE 3.5-1 THE ANNUAL CATCH AND SPECIES COMPOSITION OF FISH COLLECTED BY TRAWL IN HOLE, TROUGH, AND REFERENCE DEPTH REGIMES OF THE DEEP TROUGH STUDY AREA, 1982-1983

	Total Catch				Percent Composition			
	Holes	Trough	Reference	Total	Holes	Trough	Reference	Total
DIADROMOUS								
Blueback herring	32	80	14	126	0.5	1.2	0.4	0.8
Alewife	41	33	4	78	0.6	0.5	0.1	0.5
American shad	1			1	(a)			(a)
White perch	3	1	58	62	(a)	(a)	1.5	0.4
Striped bass	2	3	5	10	(a)	(a)	0.1	0.1
American eel	17	5		22	0.3	0.1		0.1
ESTUARINE								
Bay anchovy	2,374	2,420	2,862	7,656	36.9	37.2	74.7	45.6
Inland silverside	23	38	30	91	0.4	0.6	0.8	0.5
Rough silverside	1		3	4	(a)		0.1	(a)
Atlantic silverside	1		1	2	(a)		(a)	(a)
Northern pipefish	17	27	4	48	0.3	0.4	0.1	0.3
Hogchoker	14	6	11	31	0.2	0.1	0.3	0.2
Skilletfish	5	6	3	14	0.1	0.1	0.1	0.1
Oyster toadfish	5	3	1	9	0.1	(a)	(a)	0.1
Naked goby	4		1	5	0.1		(a)	(a)
Feather blenny			1	1			(a)	(a)

(a) Less than 0.1 percent.
(b) The terms applied here refer to the extent to which these species may migrate into low salinity water: ubiquitous = 0-10 ppt, invaders = 10-15 ppt, intruders = 15-25 ppt, coastals = 25-30 ppt. (salinities from Musick 1972).

TABLE 3.5-1 (CONT.)

	Total Catch				Percent Composition			
	Holes	Trough	Reference	Total	Holes	Trough	Reference	Total
MARINE (UBIQUITOUS)(b)								
Atlantic croaker	2,424	3,127	485	6,036	37.7	48.0	12.7	36.0
Spot	1,071	286	237	1,594	16.7	4.4	6.2	9.5
Weakfish	18	120		138	0.3	1.8		0.8
Spotted seatrout	61	11	3	75	0.9	0.2	0.1	0.4
Atlantic menhaden	257	325	92	676	4.0	5.0	2.4	4.0
Butterfish	39	1		40	0.6	(a)		0.2
Winter flounder	8	12	9	29	0.1	0.2	0.2	0.2
Summer flounder	1	4	3	8	(a)	0.1	0.1	(a)
Red hake	3	2		5	(a)	(a)		(a)
Spotted hake	1		3	4	(a)		0.1	(a)
MARINE (INVADERS)(b)								
Inshore lizard fish	4		1	5	0.1		(a)	(a)
Atlantic spadefish	3			3	(a)			(a)
Silver hake		1		1		(a)		(a)
Black sea bass		1		1		(a)		(a)
MARINE (INTRUDERS)(b)								
Bluntnose stingray	1	1		2	(a)	(a)		(a)
MARINE (COASTALS)(b)								
Ladyfish			1	1			(a)	(a)
Seaweed blenny			1	1			(a)	(a)
TOTAL	6,431	6,513	3,833	16,779				

TABLE 3.5-2 THE MONTHLY CATCH OF FISH SPECIES BY TRAWL IN THE DEEP TROUGH STUDY AREA, 1982-1983

	MAY	AUG	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY
DIADROMOUS										
Blueback herring				5		10	106	4	1	
Alewife					2	3	62	11		
American shad					1					
White perch					4	1	55			2
Striped bass				1	1		2			6
American eel				7	10	3	1	1		
ESTUARINE										
Bay anchovy	81	3	129	2,065	208	605	124	2,456	1,795	190
Inland silverside						17	74			
Rough silverside					3					1
Atlantic silverside					1	1				
Northern pipefish				5	29	3	4	4	3	
Hogchoker		1		8	8		3	1	1	9
Skilletfish				1	7	1	3	2		
Oyster toadfish	1	1			2	2	3			
Naked goby				4			1			
Feather blenny					1					
MARINE (UBIQUITOUS)										
Atlantic croaker				130	1,049	1,313	3,204	305	28	7
Spot				373	1,181	7	33			
Weakfish				30	107	1				
Spotted seatrout					71	4				
Atlantic menhaden				5	34	149	465	6	7	10
Butterfish					38	2				
Winter flounder				5	17	2	1	2	2	
Summer flounder		1	1		3		1	2		
Red hake							3	1	1	
Spotted hake										4

TABLE 3.5-2 (CONT.)

	MAY	AUG	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY
MARINE (INVADERS)										
Inshore lizard fish	1				4					
Atlantic spadefish				1	2					
Silver hake					1					
Black sea bass					1					
MARINE (INTRUDERS)										
Bluntnose stingray				1	1					
MARINE (COASTALS)										
Ladyfish										1
Seaweed blenny							1			

TABLE 3.5-3 THE MONTHLY TRAWL CATCH OF ALL FISH BY STATION IN THE DEEP TROUGH STUDY AREA, 1982-1983

Month		Total	Hole			Trough			Reference		
			2	4	5	1	3	6	7	8	9
MAY	N[a]	83	6	3	2	6	5	10	33	14	4
	P			13.3			25.3			61.4	
AUG	N	6	0	0	0	0	0	0	3	0	3
	P			0.0			0.0			100.0	
OCT	N	130	0	0	0	0	0	0	9	106	15
	P			0.0			0.0			100.0	
NOV	N	2,641	576	341	584	253	299	182	144	96	166
	P			56.8			27.8			15.4	
DEC	N	2,786	959	454	53	806	207	52	194	55	6
	P			52.6			38.2			9.2	
JAN	N	2,124	248	77	230	385	218	385	50	507	24
	P			26.1			46.5			27.4	
FEB	N	4,146	849	805	158	685	1,250	91	106	170	32
	P			43.7			48.9			7.4	
MAR	N	2,795	125	338	509	280	221	1,015	106	179	22
	P			34.8			54.2			11.0	
APR	N	1,838	15	28	5	31	59	38	503	157	1,002
	P			2.6			7.0			90.4	

(a) N = number per trawl, P = percent distribution by area.
(b) Because of missing data, calculated on a mean catch per unit effort per area basis.
(c) -- = no data.

TABLE 3.5-3 (CONT.)

Month		Total	Hole			Trough			Reference		
			2	4	5	1	3	6	7	8	9
MAY	N	230	17	9	40	--(c)	16	21	13	6	108
	P(b)			13.1			11.0			75.8	
ANNUAL	N	16,779	2,795	2,055	1,581	2,446	2,275	1,794	1,161	1,290	1,382
	P(b)			37.7			39.8			22.5	

TABLE 3.5-4 THE MONTHLY TRAWL CATCH OF BAY ANCHOVY BY STATION IN THE DEEP TROUGH STUDY AREA, 1982-1983

			Hole			Trough			Reference		
Month		Total	2	4	5	1	3	6	7	8	9
MAY	N(a)	81	6	2	2	6	5	10	32	14	4
	P			12.3			25.9			61.7	
AUG	N	3	0	0	0	0	0	0	3	0	0
	P			0.0			0.0			100.0	
OCT	N	129	0	0	0	0	0	0	9	106	14
	P			0.0			0.0			100.0	
NOV	N	2,065	492	334	303	205	253	174	83	59	162
	P			54.7			30.6			14.7	
DEC	N	208	77	57	16	30	11	2	11	4	0
	P			72.1			20.7			7.2	
JAN	N	605	41	0	29	77	23	20	14	400	1
	P			11.6			19.8			68.6	
FEB	N	124	14	11	2	17	40	4	0	35	1
	P			21.8			49.2			29.0	
MAR	N	2,456	100	300	500	250	150	1,000	36	100	20
	P			36.7			57.0			6.4	
APR	N	1,795	3	22	5	30	50	35	500	150	1,000
	P			1.7			6.4			92.0	

(a) N = number per trawl, P = percent distribution by area.
(b) Because of missing data, calculated on a mean catch per unit effort per area basis.
(c) --- = no data.

TABLE 3.5-4 (CONT.)

Month		Total	Hole 2	Hole 4	Hole 5	Trough 1	Trough 3	Trough 6	Reference 7	Reference 8	Reference 9
MAY	N	190	16	6	36	--(c)	14	14	2	2	100
	p(b)			28.4			20.6			51.0	
ANNUAL	N	7,656	749	732	893	615	546	1,259	690	870	1,302
	p(b)			30.7			32.2			37.1	

TABLE 3.5-5 THE MONTHLY TRAWL CATCH OF ATLANTIC CROAKER BY STATION IN THE DEEP TROUGH STUDY AREA, 1982-1983

			Hole			Trough			Reference		
Month		Total	2	4	5	1	3	6	7	8	9
NOV	N(a)	130	18	3	42	17	0	0	23	27	0
	P			48.4			13.0			38.5	
DEC	N	1,049	302	39	22	500	150	5	1	30	0
	P			34.6			62.5			3.0	
JAN	N	1,313	185	72	193	300	161	321	2	57	22
	P			34.3			59.5			6.2	
FEB	N	3,204	700	700	75	500	1,000	60	50	100	19
	P			45.9			48.7			5.3	
MAR	N	305	19	34	9	27	65	10	63	76	2
	P			20.3			33.5			46.3	
APR	N	28	6	4	0	0	8	2	3	5	0
	P			35.7			35.7			28.6	
MAY	N	7	0	0	1	--(c)	0	1	0	0	5
	P(b)			13.3			20.0			66.7	
ANNUAL	N	6,036	1,230	852	342	1,344	1,384	399	142	295	48
	P(b)			39.2			53.0			7.8	

(a) N = number per trawl, P = percent distribution by area.
(b) Because of missing data, calculated on a mean catch per unit effort per area basis.
(c) -- = no data.

TABLE 3.5-6 THE MONTHLY TRAWL CATCH OF SPOT BY STATION IN THE DEEP TROUGH STUDY AREA, 1982-1983

Month		Total	Hole			Trough			Reference		
			2	4	5	1	3	6	7	8	9
NOV	N[a]	373	41	1	227	17	40	0	37	10	0
	P			72.1			15.3			12.6	
DEC	N	1,181	504	285	0	135	37	30	175	15	0
	P			66.8			17.1			16.1	
JAN	N	7	5	0	1	0	1	0	0	0	0
	P			85.7			14.3			0.0	
FEB	N	33	3	1	3	6	9	11	0	0	0
	P			21.2			78.8			0.0	
ANNUAL	N	1,594	553	287	231	158	87	41	212	25	0
	P			67.2			17.9			14.9	

(a) N = number per trawl, P = percent distribution by area.

TABLE 3.5-7 THE MONTHLY TRAWL CATCH OF ATLANTIC MENHADEN BY STATION IN THE DEEP TROUGH STUDY AREA, 1982-1983

Month		Total	Hole			Trough			Reference		
			2	4	5	1	3	6	7	8	9
NOV	N(a)	5	0	1	0	0	0	4	0	0	0
	P			20.0			80.0			0.0	
DEC	N	34	7	12	3	7	2	1	1	1	0
	P			64.7			29.4			5.9	
JAN	N	149	8	4	4	3	21	43	17	48	1
	P			10.7			45.0			44.3	
FEB	N	465	91	64	56	94	137	7	1	14	1
	P			45.4			51.1			3.4	
MAR	N	6	0	0	0	0	0	1	5	0	0
	P			0.0			16.7			83.3	
APR	N	7	3	2	0	1	0	0	0	0	1
	P			71.4			14.3			14.3	
MAY	N	10	1	0	1	--(c)	0	6	2	0	0
	P(b)			8.3			75.0			16.7	
ANNUAL	N	676	110	83	64	105	160	62	26	63	3
	P(b)			37.4			49.2			13.4	

(a) N = number per trawl, P = percent distribution by area.
(b) Because of missing data, calculated on a mean catch per unit effort per area basis.
(c) -- = no data.

TABLE 3.5-8 THE MONTHLY TRAWL CATCH OF ALL LESS-ABUNDANT FISH (ALL FISH EXCEPT BAY ANCHOVY, ATLANTIC CROAKER, SPOT, AND ATLANTIC MENHADEN) BY STATION IN THE DEEP TROUGH STUDY AREA, 1982-1983

Month		Total	Hole			Trough			Reference		
			2	4	5	1	3	6	7	8	9
MAY	N(a)	2	0	1	0	0	0	0	1	0	0
	P			50.0			0.0			50.0	
AUG	N	3	0	0	0	0	0	0	0	0	3
	P			0.0			0.0			100.0	
OCT	N	1	0	0	0	0	0	0	0	0	1
	P			0.0			0.0			100.0	
NOV	N	68	25	2	12	14	6	4	1	0	4
	P			57.4			35.3			7.4	
DEC	N	314	69	61	12	134	7	14	6	5	6
	P			45.2			49.4			5.4	
JAN	N	50	9	1	3	5	12	1	17	2	0
	P			26.0			36.0			38.0	
FEB	N	320	41	29	22	68	64	9	55	21	11
	P			28.8			44.1			27.2	
MAR	N	28	6	4	0	3	6	4	2	3	0
	P			35.7			46.4			17.9	
APR	N	8	3	0	0	0	1	1	0	2	1
	P			37.5			25.0			37.5	

(a) N = number per trawl, P = percent distribution by area.
(b) Because of missing data, calculated on a mean catch per unit effort per area basis.
(c) -- = no data.

TABLE 3.5-8 (CONT.)

Month		Total	Hole			Trough			Reference		
			2	4	5	1	3	6	7	8	9
MAY	N	23	0	3	2	--(c)	2	0	9	4	3
	P(b)			20.0			12.0			68.0	
ANNUAL	N	817	153	101	51	224	98	33	91	37	29
	P(b)			36.2			45.1			18.6	

TABLE 3.5-9 THE NUMBER OF FISH OF EACH SPECIES COLLECTED BY DRIFT GILL NET IN THE DEEP TROUGH AREA, 1982-1983

Month	October		November		December					January				February				March		April	
Day	7	8	18	19	3	15	16	22	28	5	13	20	26	2	9	16	24	16	18	7	8
Station	L	U	L	U	U	L	U	L	U	L	L	U	U	U	L	U	U	L	U		
Species																					
Brevoortia	0	0	728	72	28	1033	100	151	80	147	136	649	14	3	4	9	1	0	0	39	32
Peprilus				1	29	17	1	17	1	5	1										
Pseudopleuronectes					1		1									1					
Centropristes					1			1		1											
Cynoscion					1																
Leiostomus					1	1															
Urophycis						2															
Morone								1													
Anchoa														2							
Pomatomus			2																		

U = Upper Drift: general area of T6
L = Lower Drift: general area of T3

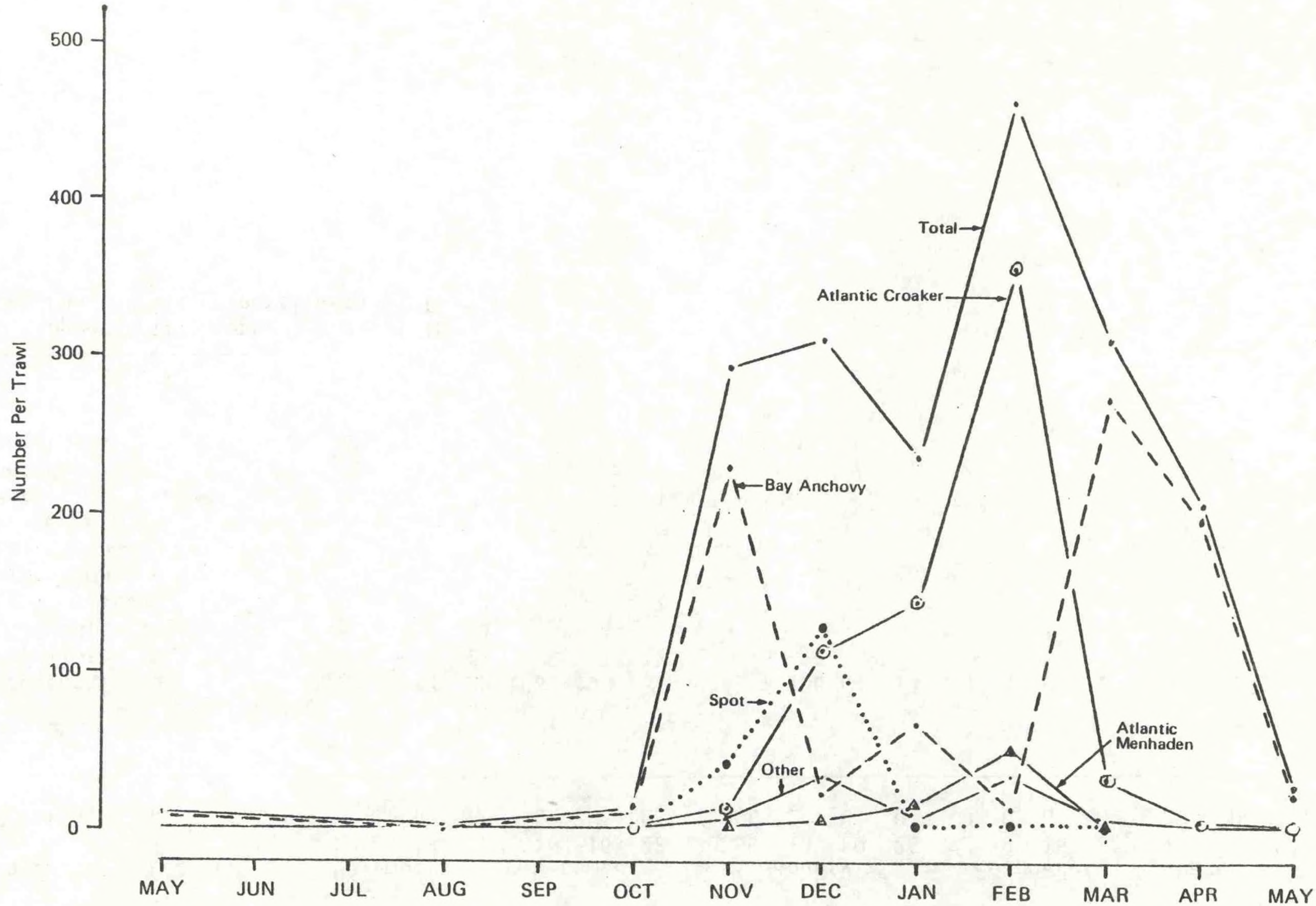


Figure 3.5-1. Monthly trend in the total fish catch and four numerically dominant species collected by trawl in the Deep Trough Study Area, 1982 – 1983.

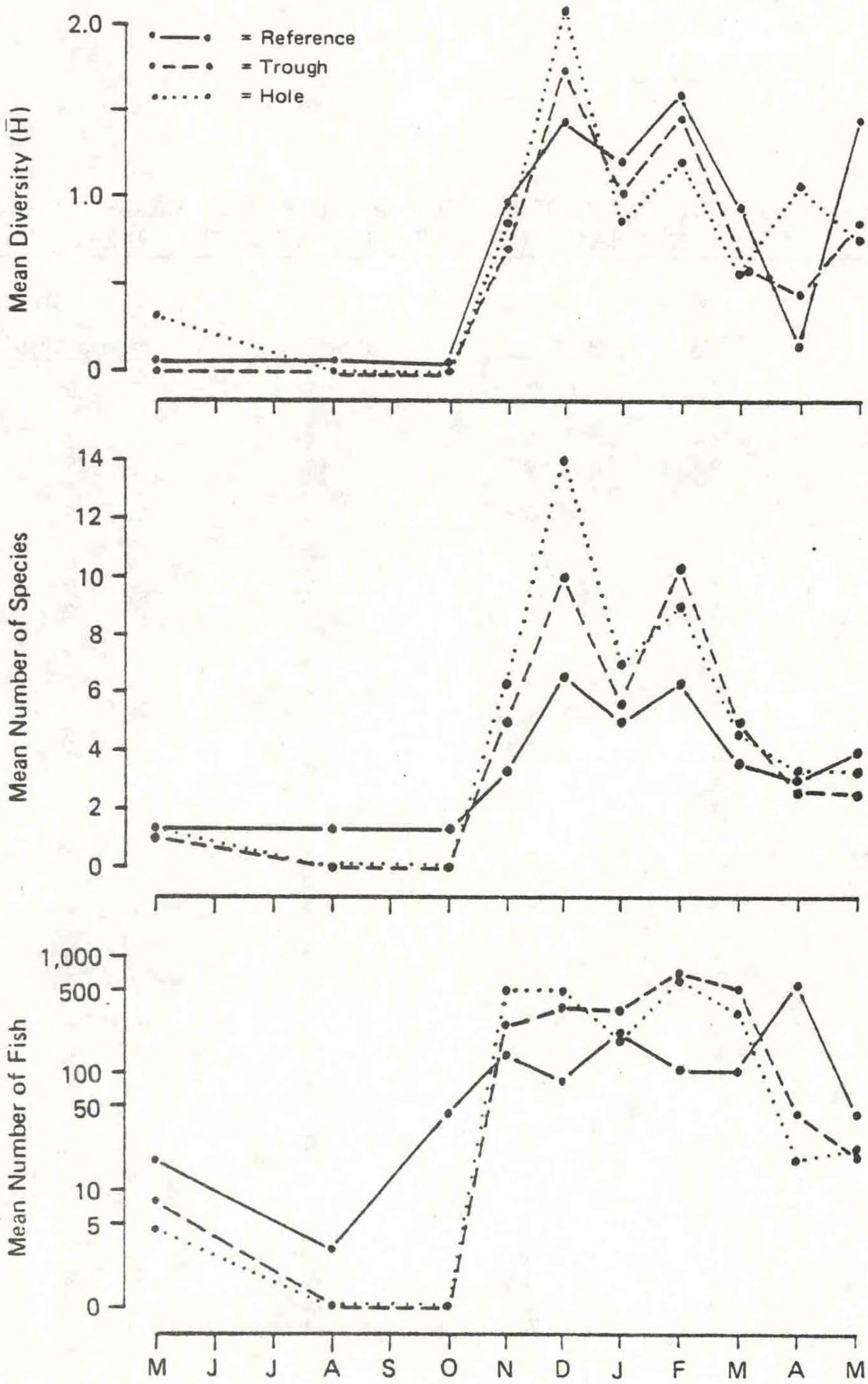


Figure 3.5-2. Monthly trend by depth regime in number of fish, number of species, and diversity index of trawl catches in the Deep Trough Study Area, 1982 – 1983.

TABLE 3.6-1 MONTHLY CATCH PER TRAWL OF LIVE BLUE CRABS BY LIFE STAGE AND SAMPLING SITE, DEEP TROUGH, 1982-1983

Sample Date	Site	Recruit Crabs[a]	Growth Crabs[b]	Mature Crabs[c]
May 1982	7	0	1	0
August	8	0	0	1
	9	0	11	26
October	9	0	0	2
November	5	1	0	0
	7	44	0	0
	9	1	0	0
December	2	1	0	1
	3	3	0	0
	5	1	0	0
	6	3	0	0
	7	8	0	0
	8	6	0	0
	9	1	0	0
January 1983	2	1	0	0
	4	1	0	0
	8	1	0	0
February	8	1	0	0
	9	0	0	1
March	2	2	0	0
	7	1	0	0
	8	1	0	0
April	6	0	0	1
	7	3	0	0
	8	1	0	0
	9	1	1	1
May	3	0	0	2
	5	6	0	0
	8	0	0	2
	9	0	1	5

(a) Recruit - Carapace width - 0-60 mm

(b) Growth - Carapace width - 61-120 mm

(c) Mature - Carapace width - 121+ mm

4. ASSESSMENT OF FISHERIES VALUE OF THE DEEP TROUGH

In the previous sections of this report, the results of an annual survey of the Deep Trough, initiated in May 1982, were described. The presentations emphasized the seasonal distribution of water quality variables and the biota, i.e., comparisons between samples derived from deep-water areas in the Deep Trough with samples from reference areas at a shallower depth representative of the Bay average. Providing for a comparison within this study was important because few previous studies were available for this purpose. In the same light, and with regard to the assessment which follows, it should be remembered that a one-year study can only provide an initial look at conditions and the biota of the area; annual differences may be expected, although perhaps not of a magnitude that would contradict the basic patterns described here.

To provide an assessment of the fisheries value of the Deep Trough, the apparent depth preference of the biota is summarized here and integrated with life history information. Section 4.1 considers the evidence for use of the Deep Trough as a migratory route and overwintering area. The importance of the area for spawning is discussed in Section 4.2. Finally, in Section 4.3, water quality variables and the availability of food for fish are examined in relation to fish distributions to assess the quality of Deep Trough as fish habitat.

4.1 THE DISTRIBUTION OF FISH AND BLUE CRABS

Collections of demersal fish and blue crabs and of larger nekton are the focal points of the present study, which was designed to allow an assessment of whether special fisheries value is associated with the Deep Trough area based on the depth distribution of catches. The trawl catches provide an initial characterization of the species composition and diversity of the fish fauna in this previously unstudied area.

The variety of fish species collected by trawl was not unusual. Thirty-three species were collected, including 17 that may be categorized as marine-spawned, 10 estuarine species, and 6 diadromous species. The addition of the blue crab and bluefish, the latter collected only by gill net, brings the total list of nekton species to 35. By comparison, Musick (1972) lists 65 marine-spawned, 22 estuarine, 12 diadromous, and 10 freshwater species that have been collected in water of a salinity comparable to that of the Deep Trough. A portion of the disparity in the number of species in Musick's "ideal" list and that of this study is, of course, due to the fact that his is a compilation of records in various types of habitats involving substantially greater sampling effort. The longer list of marine-spawned species and the inclusion of freshwater species may, for example, be due to sampling in areas relatively near to freshwater and marine habitats, as might occur in the river estuaries near the mouth of Chesapeake Bay. The longer list of estuarine species includes many inshore fishes not expected to be found offshore in deep waters. In general, the make-up of the fish fauna of the Deep Trough study area is based on consideration of the salinity tolerances of species and habitat preference. Further sampling, moreover, will reveal the presence of additional rare species not found in the first year.

Numerically dominant species in trawl catches included Atlantic croaker, spot, bay anchovy, and Atlantic menhaden. Menhaden also dominated gill net catches (97 percent of total). The high rank abundance of these four species is not unusual; for example, they often dominate trawl catches made south of the study area near Calvert Cliffs (BG&E 1976; BGE and ANSP 1982). The commercially important diadromous species, such as the herrings, shad, white perch, and striped bass, constituted only a small portion (1.8 percent) of the total trawl catch and were represented by a single white perch in the gill net catch. Because winter gill netters often obtain substantial catches of white perch and striped bass in deep water, it is possible that the 1982-1983 catch of these species is related to the mild winter of the survey year, and might constitute a larger proportion of the total catch during severe winters characterized by ice cover.

With regard to the annual composition of demersal fish by depth regime, the only notable differences were due to the distributions of numerically important Atlantic croaker and spot, which were more abundant in the Deep Trough area (Hole and Trough stations) compared to the shallower Reference area. However, as will be shown later, the combined catch of less prominant species also exhibited a pattern of higher abundance in deep water and, in some cases, in the shallows. The degree to which these less abundant species exhibited a preference for deeper water in colder months was reflected in the monthly plot of the mean number of species collected per trawl by depth regime. From November through March, the average was always lower in the shallower reference area and higher in Deep Trough (Hole or Trough areas).

One of the most striking features of fish utilization of the Deep Trough area was the seasonality of their occurrence. During May, August, and October 1982, very few specimens were collected by trawl (213 bay anchovy, 1 hogchoker, 2 oyster toadfish, 2 summer flounder, and 1 inshore lizardfish in 27 tows). Most specimens of fish and all crabs were collected from Reference stations at this time. Similar results were obtained from private and charter boat sportfish surveys conducted by the Marine Police and DNR (Cpl. Jones and R. Wagner; memorandum from Wagner). Catches were considered poor from the end of May through August 1982. In September, catches improved but were largely limited to landings of weakfish in the shoal area near Reference Station 9. Bluefish also were caught that month, although catches were much higher a month later in October. Initial deployment of gill nets in offshore bottom waters in October, however, failed to collect any fish and reinforces the impression derived from trawl catches that few fish inhabit the lower water column in the Deep Trough area from late spring through early fall. This phenomenon was associated with dissolved oxygen depletion, a subject that will be discussed further in Section 4.3.

From November 1982 through April 1983, when the bulk of the trawl catch was made, several fish species were cyclically abundant, with peak catches occurring in separate months. These patterns are summarized in

Table 4-1 in terms of the catch of each species, percent of the total catch, and depth distribution. The distribution of the total catch showed a pattern of being higher in the Deep Trough (Hole and/or Trough areas) in all months except April, when the bulk of the catch, consisting of bay anchovies, was collected in the Reference area. However, statistical testing of the catch rates between areas for the total catch and each major component (bay anchovy, Atlantic croaker, spot, Atlantic menhaden, and all other species combined) failed to demonstrate a significant difference ($\alpha=0.05$) except for Atlantic croaker and the lesser species. Catches of these latter two taxa were statistically higher in Deep Trough than in the Reference area. The failure to detect significant differences by area for bay anchovy and Atlantic menhaden may be largely due to monthly shifts between areas of population concentrations. However, the failure to detect significant differences in the total catch and that of spot would appear to be caused primarily by substantial variation between catches within areas. This, in turn, suggests that sampling design improvements might be made generally, in terms of increasing sampling size (replicate sampling and sampling in successive days), to increase the ability to detect differences between areas that may actually exist.

The seasonal occurrence in the study area of Atlantic croaker, spot, and most other marine-spawning species is indicative of the timing of their migrations through the area and possible overwintering. Relatively abundant, euryhaline young-of-the-year, such as spot and Atlantic menhaden, would be expected to migrate upestuary in late spring and downestuary in late fall, based on their presence in the upper Bay (Ecological Analysts 1981). The occurrence of large numbers of Atlantic croaker in Deep Trough during mid-winter could represent a sudden offshore movement of specimens from adjacent shallows and subsequent movement to an area downbay. Croakers were relatively abundant near shore at Calvert Cliffs until November (BG&E 1976), and young are known to overwinter in the York River (Chao and Musick 1977). In terms of the statistical results, then, the movements of Atlantic croaker, but not those of spot or Atlantic menhaden, appear to show a preference for the deeper waters of the Trough. Other migratory species, which collectively were demonstrated to show a preference for Trough waters over the shallows but could not be tested individually, include weakfish, spotted seatrout, and butterfish (see Table 3.5-1).

As noted previously, the winter gill netting efforts did not detect aggregations of anadromous species during the sampling year. Sampling during a colder winter is necessary to determine whether the deepest holes in the study area are unique refuges for these fish or whether they might move farther downbay in response to lower than average winter temperatures. Data that suggest the Deep Trough area in general may be important to blueback herring, alewife, and American eel are shown in Table 3.5-1. White perch, in contrast, were most abundant in the Reference area. Again, it should be realized that these data were obtained sporadically and were not individually tested for significant differences between sampling areas, but contributed to the depth distribution pattern of all lesser abundant species.

4.2 FISH SPAWNING AND TRANSPORT OF ICHTHYOPLANKTON

Ichthyoplankton sampling revealed little evidence to suggest that the Deep Trough area (Trough and Holes) is of unique value for fish spawning or larval transport. This conclusion is based on the number of species collected and their distribution. A variety of estuarine and marine-spawned fishes were collected. Compared to Dovel's (1971) list of species catches by salinity, 2 of 6 species of eggs and 13 of 25 species of larvae/juveniles expected in the area were collected, with two types of eggs and three larvae not in Dovel's inventory. Most species, however, occurred in very low densities or sporadically, such that three species (bay anchovy, Atlantic menhaden, and Atlantic croaker) largely defined the temporal-spatial distribution of the plankton.

Bay anchovy eggs dominated annual catches of this life stage. Eggs were most abundant in the water column during the summer months of 1982; in the Hole area in May, and in the Reference area in August. Silversides (*Menidia beryllina* and *Menidia menidia*) and bay anchovy dominated the collections of larvae at this time. The other prominent characteristic of the ichthyoplankton was the midwinter (January and February 1983) occurrence of larvae/juvenile Atlantic croaker and Atlantic menhaden. Two phenomena, the collection of menhaden eggs in October 1982 and of yellow perch prolarvae in March 1983, would appear to be due, respectively, to the unusually high salinities and the high freshwater runoff experienced during those periods, and may not recur annually.

The bay anchovy is widely recognized as the most abundant fish of Chesapeake Bay (McHugh 1967) and spawns over most of its range, from the upper (Dovel 1971) to lower portions (Olney 1983). These species' characteristics strongly mitigate against concern that the Deep Trough area may be spawning grounds of critical importance. With regard to the spatial distributions of larval anchovy, Atlantic croaker, and Atlantic menhaden, statistical tests on densities during months of highest catches generally revealed no significant differences in abundance as a function of water depth.

4.3 THE DISTRIBUTION OF FISHES IN RELATION TO ENVIRONMENTAL FACTORS

The ecological value of the Deep Trough, as described in the previous sections, is largely restricted to the fall through spring period when Atlantic croaker and the combined catch of less abundant species exhibited significantly greater abundance in the Trough than in the shallower reference area. In contrast, the distribution of three other numerically dominant fishes and blue crab did not suggest that the Deep Trough was an important migration area for these species, and a similar conclusion was reached in terms of its use as a spawning habitat. In this section, the distinctive seasonal and depth-related distributional patterns of fish are examined further to better define the ecological value of the Deep Trough.

The most striking feature of the variation in catches was the low number of fish observed in May, August, and October 1982, when bottom dissolved oxygen values averaged less than about 2 mg/liter. During these months, higher oxygen concentrations were found at the shallower Reference stations (monthly means of 5.7, 2.6, and 5.1 mg/liter, respectively) relative to the Trough and Hole areas (0.0, 0.0, and 0.7 mg/liter), but catches were only slightly higher in the former area. The few individuals that were collected were mostly bay anchovy, and those may have been collected from the water column as the trawl was deployed and then retrieved from the bottom.

Clearly, the nearly anoxic waters of the Deep Trough preclude the presence of demersal fish in summer. However, because most estuarine fish, and particularly demersal forms vulnerable to a trawl, would be expected to tolerate oxygen values as low as 3-5 mg/liter, their absence in Reference areas raises questions about the extent to which this factor is effecting avoidance. The distribution of spot illustrates this point. Spot are abundant in the shallows of upper Chesapeake Bay in June and July (Ecological Analysts 1981) and may be expected to initially migrate through the Deep Trough area in April or May (Pacheco 1962). The fact that none were collected by trawl until November suggests two possibilities. Spot may migrate upestuary in shoal water much shallower and farther inshore than was sampled here (a trend noted by Chao and Musick [1977] in the York River) and largely do not encounter anoxic water. Alternatively, the spatial extent of anoxic waters may be more widespread in shoal waters at night due to increased algal respiration, leading to an avoidance response that lingers through daylight hours when sampling occurred.

Data lending support to the first possibility, that is, that the Deep Trough area may not be utilized extensively, at least in spring, regardless of anoxic conditions, are provided by trawl catches in March and April 1983. At this time, many species were declining in abundance from winter levels, although oxygen concentrations were above 6 mg/liter at all stations. On the other hand, when oxygen levels increased markedly in the Deep Trough in November (about 7 mg/liter) over October levels (less than 1 mg/liter), the number of species and the number of fish collected (particularly bay anchovy and spot) also increased. This trend is consistent with what would be expected if the fauna were avoiding a condition (low DO) that was suddenly alleviated.

Fall is also the period in which water temperature would exert a major influence on fish distributions. Movements of populations toward warmer bottom waters from inshore habitats and toward the lower Bay from farther upestuary can be viewed as a response to declining temperatures and other climatic changes such as photoperiod. During five months (sampling dates) from October through February, the temperature of Deep Trough bottom water was warmer than Reference area water by an average of 1.0 C (range 0.5-2.2 C). This period largely corresponds to the interval over which Atlantic croaker increased in seasonal abundance, and was found to be significantly more abundant in the Deep Trough relative to the Reference area. However, the depth distribution of this species and others was not consistent, suggesting a possible shift in population concentration from deep water to the shallows during some winter months. Such movements may be a response to short-term warming trends, as noted by Mansueti and Murphy (1961) in the case of striped bass. They contrasted this situation with the occurrence of prolonged and abnormally cold conditions that were associated with concentrations of stripers in deep waters. The coldest average temperatures measured in the present study during trawling was 2.4 C, and overall, the winter was not severe. This could be the major reason for the failure to detect aggregations of anadromous species in Deep Trough during 1982-1983. Major catches by winter gill netters were reportedly made farther inshore near the mouths of major rivers.

The finding that some groups of fish were significantly more abundant in the Deep Trough area during fall through spring may be related to food resources as well as water temperature. Two categories of food can be considered here: the macrozooplankton as represented by Neomysis americana, and the benthos.

The benthos community was eliminated in the Deep Trough area during summer and was recolonized largely by polychaetes in November (Nereis and Paraprionospio) and by a clam in February (Mulinea lateralis) (Section 3.3). The polychaetes generally were more abundant at Reference Stations with the exception of Trough Station 3. M. lateralis, however, was more abundant in Deep Trough. Although the preference of these organisms as food for spot and croaker is not known, Chao and Musick (1977) note a high frequency of occcurrence of polychaetes in both species but only spot frequently consumed clams. Because polychaetes were generally more abundant outside of the Deep Trough area, it is possible that this food resource is being heavily exploited by demersal fish in deep water.

The chance that benthic food resources in the Deep Trough become over exploited, however, is diminished by the distribution pattern of N. americana in the study area. This species was collected in the ichthyoplankton surveys and is summarized for use here. During the period from November 1982 through April 1983, the monthly mean density of this species ranged between 0.2 and 11.5 organisms/100 m^3 (mean 5.5). In each month, except January, 88-100 percent of the catch (mean 91 percent) was made in the Deep Trough, compared to 66 percent that might be expected with a uniform distribution across the three sampling depth regimes.

TABLE 4-1 THE DEPTH DISTRIBUTION OF DOMINANT SPECIES OF FINFISH IN MONTHLY TRAWL CATCHES, DEEP TROUGH, 1982-1983

	NOV	DEC	JAN	FEB	MAR	APR
Total	2,641	2,786	2,124	4,146	2,795	1,838
% distribution						
Hole	56	52	26	43	34	2
Trough	27	38	46	48	54	7
Reference	15	9	27	7	11	90
Bay anchovy	2,065	208	605	124	2,456	1,795
% of total	78	7	28	3	88	98
% distribution						
Hole	54	72	11	21	36	1
Trough	30	20	19	49	57	6
Reference	14	7	68	29	6	92
Atlantic croaker	130	1,049	1,313	3,204	305	28
% of total	5	38	62	77	11	2
% distribution						
Hole	48	34	34	45	20	35
Trough	13	62	59	48	33	35
Reference	38	3	6	5	46	28
Spot	373	1,181	7	33	0	0
% of total	14	42	0.3	0.8	0	0
% distribution						
Hole	72	66	85	21	--	--
Trough	15	17	14	78	--	--
Reference	12	16	0	0	--	--
Atlantic menhaden	5	34	149	465	6	7
% of total	0.2	1	7	11	0.2	0.4
% distribution						
Hole	20	64	10	45	0	71
Trough	80	29	45	51	16	14
Reference	0	5	44	3	83	14
All other species	68	314	50	320	28	8
% of total	3	11	2	8	1	0.4
% distribution						
Hole	57	45	26	28	35	37
Trough	35	49	36	44	46	25
Reference	7	5	38	27	17	37

5. POTENTIAL IMPACT OF DREDGE SPOIL PLACEMENT

The purpose of this section is to review the short-term and long-term environmental impacts which can be expected from the disposal of dredged material into Deep Trough waters. The factors that would contribute to the ecological value of the Trough in its present condition are discussed in the light of the information reviewed and in light of the results of recent studies conducted. The surveys discussed in this section were designed to adequately examine the relationship of the Trough to shallower reference areas adjacent to the Trough. The two most important general considerations are (1) the present value of the Trough and the losses to it should filling occur, and (2) the role of the Trough as part of the overall Bay ecosystem and the indirect effects to that ecosystem which might result should filling occur. Only when the ecological value of the Deep Trough has been established can the short- and long-term impacts of spoil disposal be defined.

An obvious factor which relates to the potential impact of the proposed action is the condition of the specific material to be dredged. We have assumed for purposes of this study that the material to be placed in the Trough would only derive from areas outside of Baltimore Harbor, namely channels approaching and to the south of the Patapsco estuary (Craighill and Brewerton Extension). The materials in place here have characteristics similar to those sediments already at the bottom of the Trough (Maryland Geological Survey data, in Boicourt and Ward 1983). Should a future decision be made to utilize other materials, particularly from within the Patapsco estuary, then some of the following discussions regarding environmental impacts would not apply. It should also be noted that some of the short-term impacts are related to the method of spoil disposal used. For purposes of the discussion here, it is assumed that disposal will be by bottom dump hopper dredge, bottom dump barge, or scow. Hydraulic dredging with pipeline discharge within the Trough is not considered in the following discussion. Should that method be chosen in the future, the following discussion of short-term impacts would also no longer apply. It should be noted that the following interpretations are based on observations of physical, chemical, and biological aspects for one year (1982-1983). Whereas many deductions are clearly reasonable and in accord with longer term conditions, we must caution that for certain other interpretations, a single sampling year represents an unreasonably narrow window.

5.1 SEDIMENT TYPE AND CONTAMINANTS FROM DREDGE AND DISPOSAL AREAS

It has generally been determined that the type of material to be disposed of in open water should be as similar as possible to that already in place (Maryland 1975). The materials proposed for placement in the Trough are those from the approach channels to Baltimore Harbor, generally in the area between the mouth of the Patapsco River estuary and the Bay Bridge. Because it is likely that the material will originate from both channel maintenance activities and deepening to 50 feet, a total of approximately 30 million cubic meters of dredge material will require disposal (Boicourt and Ward 1983). Schubel et al. (1980) estimates the maximum volume to be 25 million cubic yards. This material has a mean grain size ranging from 1.2 to 2.6 microns, are poorly sorted, and have a water content varying from 67 to 75 percent (Boicourt and Ward 1983). This is virtually identical to the sediment already found in place in the Deep Trough. Sediments collected and analyzed in water depths greater than 10 meters from south of Annapolis Bay Bridge to Bloody Point range between 1.0 and 2.5 microns are poorly sorted, have water contents of between 65 and 73 percent. The materials to be disposed of are, therefore, similar to the sediments in the bottom of the Trough.

The degree of trace metals contamination of the sediments proposed for dredging, was reviewed using data from the EPA Chesapeake Bay Program. A comparison is presented in Table 5-1 between the approach channels and the Deep Trough. A 98 percent confidence interval and T-tests for significant differences between areas were calculated so that a more effective comparison could be made. Concentrations of cadmium and lead were statistically significantly higher in the sediments from the approach channels than in samples taken from the Deep Trough. Chromium and manganese concentrations were statistically significantly higher in the Deep Trough than in the approach channels. Copper and zinc concentrations were not significantly different between the two areas. In general, the variation of the concentrations is high. Of these metals, however, only zinc showed average concentrations which were higher than the State of Maryland guidelines for bulk sediment constituent concentrations when such sediments are designated for overboard disposal (Maryland 1975). These guidelines are presented in Table 5-2. Because much of the zinc in Chesapeake Bay is of natural origin, and the concentrations in the Deep Trough are already somewhat higher than the concentrations from the approach channels, the metal concentrations do not appear to present a significant impediment to overboard disposal. Comparison of chlorinated hydrocarbon concentrations could not be made because of the near total absence of data.

In general, both metals and other constitutents such as chlorinated hydrocarbons would be very strongly bound to the fine clay particles in the sediments. A series of monitoring surveys undertaken during the construction of the Baltimore I-95 tunnel, as well as studies in the Outer Harbor area, indicate that there is, at minimum, a two order of magnitude difference between bound and dissolved constituents (U.S. DOT/MDOT 1979; Ecological Analysts 1980). Analyses of polychlorinated biphenyls (PCBs) and hydrocarbon pesticides indicated their concentrations in the elutriate water following standard Corps of Engineer elutriate testing were generally undetectable or in the nanogram per liter range (less than 1 ppb). Studies conducted for the Baltimore Gas and Electric Company in the Outer Harbor area showed no detectable concentrations of chlorinated hydrocarbons (CHCs) or PCBs in elutriate water (Ecological Analysts 1980). The sediments analyzed in this last study would be expected to be similar to those proposed for disposal in the Trough. It would appear reasonable that the materials proposed for disposal are similar to those already in the Trough and that they may meet the intent of the guidelines set by the State of Maryland for overboard disposal of dredge materials. However, data are not adequate to allow comparison of CHCs in sediment of the Trough, and the Harbor approaches to be dredged cannot be made because of inadequate data. Further information would be required to adequately make these comparisons, expecially in regard to biological impacts of a sublethal nature.

5.2 THE FATE OF SPOILS RELEASED OVER THE DEEP TROUGH

In order to adequately define the fate of materials released after dumping in the Trough, W.C. Boicourt and L.G. Ward (1983) undertook a study of the physical and hydrological conditions in that area. In their study of circulation patterns, they have defined those forces that drive circulation within the Trough area and have suggested which of those would be most likely to affect disposal operations or the fate of materials once they had been placed in the Trough. For sediments similar to those in Baltimore Harbor approaches, the short-term effects of any given spoil dump would be the dispersion of 1-5 percent of the dumped volume into the water column (Bokuniewicz et al. 1978, in Boicourt and Ward 1983). This material would consist of the fine particles (<1μ) which would spread laterally in the water column creating a short-term high turbidity zone. This zone would dissipate by dispersion, rather than settling, and would not be detectable above background within three to four hours following the dump (Pritchard 1983). The remaining material would spread radially as it fell through the water column and would form a flattened, though centrally domed area at the floor of the Trough. At the pycnocline (the point of maximum density change between the surface fresher water outflows and the deeper more saline ocean water which moves into the Bay along the bottom from the ocean) some of the fine material would tend to be retarded from penetrating into the deeper portions of the water column. Whereas this may create a larger area of influence with respect to chemical interactions between these fine silts and dissolved constituents at the pycnocline, the relative area of the Deep Trough which would be involved at any given time is extremely small. It has been suggested that the silt plume would not remain detectable much beyond one tidal cycle.

Spoils settled to the bottom will begin to consolidate except for a surface layer of finer material. The surface layer is subjected to shear from diurnal tidal influence and may be resuspended in the water column when tidal currents reach the critical velocity for particle resuspension. Studies undertaken by Pritchard and by Boicourt and Ward (1983) indicate that typical flood tide peak flows can achieve 40 cm/sec. This velocity occurs at between 1 and 2 meters above the sediment-water interface and would entrain unconsolidated bottom sediment particles. These particles may rise into the water column as much as 2 meters. It is unlikely, however, that a significant portion of these particles would be entrained in the water column at great distances from the bottom.

Boicourt and Ward (1983) also conducted studies in August 1983 to determine the probability for existing bottom sediments in the Trough to be re-entrained in the water column at peak flood tides. The studies were conducted in an area 25 meters deep. They found current velocities to be approximately 37 cm/sec at mid-flood tide. The suspended sediment concentrations 50 centimeters off the bed were less than 5 mg/liter at slack water. They reached a maximum concentration of 20 mg/liter at mid-flood tide during highest current velocities. Between 1 and 2 meters from the bottom a similar pattern of increased turbidity occurred, although concentrations were found to be lower. Above this point, concentrations remained relatively constant regardless of the tidal stage. The authors conclude that should re-entrainment occur following minimal consolidation of the disposed dredged material, any resuspended sediment would not rise far enough above the sediment-water interface to either leave the Trough, or to create serious turbidity problems within the Trough. In general, it is believed that sediments will consolidate relatively rapidly and that either electrostatic forces or lack of repelling charges will result in a cohesive material that is far less susceptible to surface erosion.

Boicourt and Ward indicate that the evidence shows a stable and non-eroding condition for deposited sediments as evidenced by surveys of the Kent Island dump area (Schubel et al. 1978). It is generally agreed that the processes for consolidation of freshly disposed dredge spoil is short--on the order of a few days to weeks.

Although the evidence appears to support the model that the sediments will consolidate relatively rapidly, and that the initial plume will not last more than several hours, there is sufficient uncertainty involving these two factors to warrant further testing. At this time, however, the consensus is that disposal of these materials in the Deep Trough will not have the significant effect of increasing turbidity in the long-term and will not result in increased removal of materials from the Trough (Pritchard 1983; Boicourt and Ward 1983; Schubel et al. 1978).

5.3 POTENTIAL FOR WATER QUALITY CHANGES

As discussed in Section 5.3, the primary short-term effect upon water quality will be increased turbidities in the upper layers of the water column in the vicinity of the disposal point. Should hopper dredge disposal be utilized, it is important to note that most large hopper dredges have a draft of 30 feet or greater when fully loaded. Therefore, the disposal of dredged material by bottom dump method will occur with the initial depth of the dump being at the greatest draft of the dredge. This is usually considered to be well below the pycnocline (which in the area of the Trough is generally located at about 5 m from the surface), though this varies through the year), and the amount of material to be entrained in the upper layers of the water is therefore minimized. Experience from similar overboard disposal efforts undertaken in the Kent Island area, north of the Bay Bridge, indicates that a residual plume of fine silts cannot be detected after several hours following the disposal (Schubel 1979).

Another factor to consider is the dissolved constituents in the interstitial water. Because the sediments are cleaner than those in Baltimore Harbor proper, a comparison to Baltimore Harbor surveys and studies would indicate a conservative estimate of the potential effect dissolved materials upon water quality. Additions of contaminants would probably be minimal because more than 99 percent of most contaminants are tightly bound to clay particles (Ecological Analysts 1980; U.S. DOT/MDOT 1979). This is particularly true with nonwater-soluble components of low solubility such as chlorinated hydrocarbon pesticides and PCBs. Elutriate testing of Outer Baltimore Harbor sediment did not indicate the presence of these compounds in the elutriate (Ecological Analysts 1980). It should further be noted that the metal concentrations in the sediments to be dredged are quite similar to those already in place in the Trough with few exceptions such as lead, etc. (Helz et al. 1981; Nichols et al. 1981; Schubel 1981). Long-term leaching of these constituents would be expected to be on the same order of magnitude as that presently occurring in the Trough. Further, natural sedimentary processes will result in a covering over of the dredge spoil material, but over a long period of time because natural sedimentation rates are on the order of less than 1 cm/year.

Dissolved nutrient additions may be expected to occur to some extent, and Bay waters in the vicinity of the proposed dredge site and the Trough would be expected to be relatively clean. Finfish bioassays conducted using Baltimore Harbor sediments (Tsai et al. 1979) indicated that the bottom materials in the areas bayward of North Point and Rock Point were only slightly polluted when compared to upharbor sediments. Although the bioassays were conducted using finfish, their relative toxicity may be used as an indication of the potential of sediment toxic effects on benthic infauna (Tsai et al. 1979). Because these outer Harbor sediments have relatively low toxicity, the sediments to be dredged from the approach channels (farther east) would be expected to be of equal or lesser toxicity.

If disposal was to take place in summer, additional phytoplankton growth may occur in the short term above the pycnocline within the euphotic zone as a result of possible short-term increases in dissolved nitrogen and phosphorus concentrations. These effects would be expected to be limited to the period immediately following disposal and are not expected to result in long-term changes in phytoplankton populations. The chemical oxygen demand (COD) of the dredged material is likely to be high. This may result in some reduction of available dissolved oxygen (DO) during the disposal period. Disposal during the summer months should not significantly affect the area below 20 meters since at these depths dissolved oxygen is less than 1 ppm in any case. During the winter, the lower temperatures and reduced biological oxygen demand of the Trough waters allow higher DO concentrations at the bottom. The effects of low temperature on the chemical oxygen demand of the disposed materials will reduce that demand for DO at the bottom of the Trough. Once the materials have settled in place then the COD would be expected to return to levels presently found in the Trough.

5.4 POTENTIAL BIOLOGICAL EFFECTS OF CONTAMINANT RELEASE FROM DREDGE MATERIAL

The direct effects of the anticipated contaminant releases during dredge disposal operations are expected to be minimal. Direct toxic effects are not expected to occur. The most disturbing short-term impact of dredge spoil disposal of this type is the smothering effect and the potential for increased clogging of gills in macroinvertebrates and finfish that might be entrained in the sediment plume. The highly motile organisms are likely to escape at the time of the dump; hence, only relatively few of these would be affected by the short-term high turbidities.

Most fish species are highly motile and would be expected to readily escape and avoid both the initial dump and the areas of elevated turbidity following the dump. Those individuals which might be caught in high turbidity areas might be expected to experience some nominal distress at contaminated sediment concentrations of approximately 1000 mg/liter (Tsai et al. 1979). Such concentrations would be expected to occur within the immediate vicinity of the dump and could be expected to persist for less than two hours (Pritchard 1983). Fish would be expected to avoid such areas following the dump and the actual number affected would be expected to be ecologically insignificant.

There is a probability of some stimulation of phytoplankton growth due to increased nutrient concentration if the dredged material is released above the pycnocline (Schubel et al. 1980; Schubel 1981). When hopper dredges are used, however, the point were the dredge material is discharged is generally far enough below the surface to prevent large amounts of material from entering the euphotic zone. As stated above in Section 5.4, the leaching of materials in the long-term is not expected to be significantly greater than that already occurring because the constituent concentrations appear to be relatively similar when the material proposed for dredging is compared with that already in place at the bottom of the trough. However, the paucity of adequate data suggests the need for comparative measuring of the concentrations of toxic materials in sediments, especially for CHCs.

There remains the possibility of uptake of contaminants by the benthic infaunal community which will recolonize the disposed dredged material. This would be considered a potential problem if concentrations of contaminants were substantially higher in sediments to be disposed of. Because the available evidence indicates that there are few differences between the approach channel sediments and those already in the Trough, there is little likelihood of an increase in the rate of contaminant uptake by the biological community. There is a possibility that some of the chlorinated hydrocarbons might be taken up by plankton and nekton in addition to uptake by benthic infauna (Schubel et al. 1980; Schubel 1981). This would be related to possible releases into the water column during disposal. The uptake of CHCs from dredged materials once they have consolidated at the bottom of the Trough is expected to be very slow, but further information on the actual concentrations of CHCs is required before any accurate comparison between Trough sediments and channel sediments can be made.

Another consideration is the possibility that disposal operations increase the areal extent of low DO waters adjacent to the Trough. During the summer months the waters of the Trough below 20 meters are consistently at or near zero DO levels. This occurs because the rate of oxygen demand exceeds the rate at which oxygen from the surface can mix downwardly across the pycnocline and into the lower waters of the Trough. Most of the oxygen in the upper waters of the Chesapeake Bay is derived from two sources: (1) the production by phytoplankton in the euphotic zone during daylight hours and (2) the transport of oxygen across the air-water interface. Production of oxygen by photosynthetic processes is the more important of these. Because depths below 20 meters do not support photosynthetic oxygen production by periphyton, epipelic algae, or macrophytes, the only source of oxygen to these deeper waters is the downward mixing of well oxygenated water from the euphotic zone.

The primary factor controlling surface water oxygen production through photosynthesis is the availability of light below the surface. The compensation point for photosynthetic activity is generally considered to be 1 percent of full sunlight at the surface. Oxygen production can occur, therefore, to a depth corresponding to the 1 percent light level. Throughout most of the Chesapeake Bay, that depth corresponds reasonably well with the depth of the pycnocline and averages approximately 10 meters (Seliger et al. 1975). Whereas high algal production will further reduce this depth, it is not likely that any significant increase in the maximum average depth (10 meters) will change because of the naturally high turbidities of the surface waters and the self-shading effects of phytoplankton blooms. Turbulent downward mixing of oxygen is dependent on wind effects and currents, but generally occurs at a fairly consistent rate throughout the middle and lower bay. The deeper the area, the longer the time required for oxygen to penetrate these depths. It is this downward mixing which counters the oxygen demand in deeper waters. The biochemical oxygen demand of sediments (SOD) would be similar at the bottom of the Trough to that elsewhere, and this would not significantly change following the disposal of approach channel sediments. The demand depends upon the size of the benthic community, the number of mobile organisms utilizing a given area, and microbial densities. The proposed disposal operation would reduce the average cross-sectional area of the Bay in the vicinity of the Trough by about two percent (1.44 percent of the volume, as calculated from data in Cronin 1971), and change bottom depths by 1.5-2 meters. No measurable change in the physical dynamics is expected however, by which an increase in oxygenated waters might occur in the Trough.

During summer disposal operations small volumes of deoxygenated water might be displaced upward. As a long-term phenonmena, however, a permanent increase in the areas affected by reduced DO is not expected to occur as a result of the limited depth change. The summer oxygen deficit at the deeper depths is in part caused by the difference between the saturation value--which is temperature-dependent--and the observed oxygen content. Whereas super saturation can occur at the surface, at various production rates and temperature regimes, saturation can occur at the bottom of the Trough (depths greater than 10 m) only during the winter when temperatures are sufficiently low and biological oxygen demand virtually zero. One of the reasons that oxygen concentrations rarely drop below 1 ppm outside of the Trough is that light penetration of the upper layers during productive summer months usually results in oxygen production and downward mixing into those areas that are less than 10 meters in depth at a rate sufficient to maintain higher DO concentrations. Below that depth, the rate of downward mixing is limited by the pycnocline, which tends to act as a barrier. According to physical model study results, reduction of the depth of the Trough is not expected to have an effect on the depth of the 1 percent compensation point or on the rate at which dissolved oxygen at the surface is mixed downward (Boicourt and Ward 1983). The total oxygen demand within the Trough is not expected to increase appreciably since (1) the biological community would not be expected to be significantly different following recovery, (2) the depths will not change more than two meters, and (3) the exposed surface area of sediment is not expected to increase significantly. Because the rate of mixing downward (counterbalancing the rate of oxygen utilization) is the primary factor controlling the dissolved oxygen concentrations below 10 meters, the Trough will continue to experience DO concentrations of less than 1 ppm because of the inability of the oxygen to mix rapidly enough into those greater depths. Because no change in the rate of mixing is expected outside the Trough, increases in areas affected by low DO would not be expected to result from the use of the Trough as a disposal site.

The possible short-term decreases in the depth of the low DO contours would occur only should disposal occur during the summer months. Disposal during the colder months would result in some increased oxygen demand, but low winter temperatures would limit that demand and prevent serious reductions in ambient (greater than or equal to 7 ppm) DO concentrations.

5.5 SELECTION OF SEASON TO MINIMIZE IMPACTS

Evidence from the biological surveys undertaken in 1982 and 1983 indicates that there are significant seasonal differences in the chemical and biological characteristics of the Deep Trough. Between mid-May and early October, the depths greater than 20 meters experienced dissolved oxygen levels of between one and zero parts per million. Therefore, the entire biological community at the bottom of the Trough becomes virtually eliminated by the seasonal DO minimum. This was confirmed by field surveys in May, August, and October 1982. During the winter months, however, oxygen levels were found to be sufficiently high to support populations of finfish and a recolonization by benthic infauna. Within the Trough area some localized spawning of the bay anchovy apparently occurred during the spring and early summer, but this had shifted to reference stations by August. The bottom waters may be considered to be of very limited value with respect to supporting both spawning and also larval feeding (Schubel et al. 1980). The area may function, particularly in years of heavy icing at the river mouths, as a refuge for finfish species. The disposal operations planned and the depth of anticipated filling (1.5-2 m) would not be expected to substantially alter the available habitat now utilized by fish during the winter months. Winter disposal would disturb the immediate area surrounding the dumping operations but would not be expected to influence more than a very small percentage of the available finfish habitat at any specific point in time. Winter dumping operations would however, be expected to smother the benthic community. The total area covered by dumping operations during one full winter season would be essentially lost as a food source for that one winter season although some short-term recruitment and survival might occur. Past studies have indicated, however, that recruitment would be rapid and that the benthic community would be reestablished by the following winter season (Hirsch et al. 1978; Pfitzenmeyer 1975; Sweeney and

Millner 1981). This is, in fact, a normal pattern in the areas of the Trough below 20 meters because nearly all infaunal organisms die during the summer months as a result of anoxic conditions, and the entire community at those depths must be reestablished each winter. The only changes in species composition or dominance which might occur would result from whatever differences in substrate might follow from disposal of materials with different grain sizes.

From a benthic community standpoint, short-term impacts for a dredge disposal would probably be fewer during the summer months. On the other hand, the potential for entrained nutrients to cause short term increases in phytoplankton production would more likely occur during these summer months than during winter disposal, when temperatures would present a limiting effect. If the disposal were done between October and March, interference with what little spawning does occur and with spring utilization would be minimized. In general, the short-term effects on the biological community from the disposal operation itself are considered sufficiently limited in impact that they are unlikely to be a significant consideration for disposal design or season.

TABLE 5-1 BULK METAL CONCENTRATIONS IN SEDIMENTS FROM THE APPROACH CHANNELS AND THE BOTTOM OF THE DEEP TROUGH

Constituent	Concentration (mg/Kg) (mean ± 98% confidence interval)		T-test Result
	Approach Channels	Deep Trough	
Cadmium	1.2 ± 0.3	0.5 ± 0.2	Approach > Trough - p> .95
Chromium, Total	46.9 ± 6.8	65.8 ± 22.8	Trough > Approach - p> .90
Copper	45.0 ± 6.4	37.5 ± 12.2	
Lead	64.9 ± 8.3	48.6 ± 18.9	Approach > Trough - p> .95
Nickel	49.1 ± 13.0	41.0 ± 12.0	
Manganese	504.3 ± 1,390	1,400 ± 630	Trough > Approach - p> .90
Zinc	303.2 ± 48.5	319 ± 99	

Sources: Helz et al. 1981; Nichols et al. 1981

TABLE 5-2 STATE OF MARYLAND BULK SEDIMENT GUIDELINES FOR OVERBOARD DISPOSAL OF DREDGE SPOIL MATERIAL

Parameter	Guidelines[(a)] (maximum contaminant concentrations) Percent Dry Weight	Milligrams/ Kilogram
Volatile solids	11.0	110,000
Chemical oxygen demand	10.0	100,000
Hexane extractables	0.5	5,000
Total organic carbon	2.0	20,000
Zinc	0.03	300
Mercury	0.0001	1
Cadmium	0.0002	2
Copper	0.008	80
Chromium (as total)	0.008	80
Lead	0.01	100
Total kjeldahl nitrogen	0.25	2,500
Total phosphorus	0.25	2,500

(a) From Spoil Disposal Criteria for Maryland Waters; Progress Report of the Spoil Disposal Criteria Committee--EPA/MdDNR. 1975.

6. CONCLUSIONS AND SPOIL DISPOSAL OPTIONS

6.1 THE NO-DISPOSAL OPTION

The option to leave the Deep Trough undisturbed would result in no net change in the ecology of the area. At present the area is utilized by a limited number of watermen for drift gill-net fishing during the winter and spring. The area would remain undisturbed and existing utilization would continue. No short- or long-term impacts would result and the Trough would fill naturally at the rate of less than 1 centimeter per year. Under natural conditions it would take between 100 and 150 years for the bottom to decrease in depth by 1.0-1.5 meters due to such deposition. The deep hole areas, particularly the Bloody Point hole, would most likely remain open because the mechanism for maintaining these holes would be unchanged. This mechanism is the inflow of fresh water from the aquifer underlying the mid-Chesapeake Bay. This aquifer has been exposed since the last glaciation before the Susequehanna River Valley had been flooded (Pritchard 1983).

6.2 DISPOSAL WITH RESTRICTIONS

Disposal may occur with restrictions on the season and on the maximum volumes of material. It is difficult to define which of the two seasons, either summer or winter, would be the most appropriate in order to minimize impacts. If disposal were undertaken during the summer months, there would be no interference with the existing biological communities on the bottom because the dissolved oxygen concentrations would be too low to support life below 30 meters. Finfish populations were not found during the summer months in the deeper portions of the Trough and the benthic community was nonviable. Summer disposal might result in localized short-term increases in phytoplankton production due to nutrient enrichment in the upper 10 meters of the water column. Dissolved nutrients in the dredge spoil material would dissipate above the pycnocline and might result in increases in some algal populations. On the other hand, short- term increases in turbidity due to lateral dispersion of fines during the dump might result in a balancing effect by reducing the depth of the 1 percent compensation point during the period immediately after the spoil dump. Also during the summer months, very localized short-term upwelling of small amounts of deoxygenated water might occur as the dredge spoil material displaced waters at the bottom of the Trough. This would be a very short-term phenomena and the effects would not be expected to be biologically significant.

Disposal during the winter months would have short-term impacts upon local finfish and macroinvertebrate populations. Those organisms within the immediate area of the spoil dump would be scattered with the possibility of a small percentage being either smothered or stressed from momentary high total suspended solids concentrations. Because the benthic community at the bottom of the Trough re-establishes itself following the late fall increases in dissolved oxygen, that community would be smothered and temporarily eliminated during the spoil dumping period. Some recruitment and recolonization would be expected following disposal during the winter season of that year. Complete recolonization would be expected to occur the following year as is normally the case within the Trough. Some spawning activity by the Bay anchovy had been noted during studies conducted in 1982 and 1983. Limited interference with this spawning would not occur during the winter disposal period. Stimulation of phytoplankton blooms would be unlikely because low temperatures inhibit the growth of these organisms during the winter months. The short-term increases in both nutrients and fine sediments above the pycnocline would not be expected to significantly change the pelagic community in the upper 10 meters of the water column. Because the bottom of the Trough experiences average dissolved oxygen concentrations of 7 parts per million (ppm) during the winter, there would not be any displacement of anoxic waters during winter dumping episodes.

It has been generally agreed that no significant biological impact would result in the filling of the bottom of the Trough to a depth of 1-1.5 meters. Physically, this would change the cross-sectional area of the Chesapeake Bay in the vicinity of the Trough by 2.2 percent (1.44 percent by volume). The potential for permanently raising the minimum depth of anoxic waters, however, needs to be more thoroughly investigated in order to determine the potential effect upon adjacent shallower areas. While some researchers, such as Pritchard, Boicourt and Ward, believe that no increase in the lateral extent of anoxic waters would result from the disposal operations proposed, there are data which need to be reviewed regarding the areal extent of anoxic waters in the Chesapeake Bay and their origin.

6.3 UNRESTRICTED DISPOSAL

Should disposal be unrestricted with respect to season, the short-term impacts as defined above would occur during each respective season. If the depth to which the Trough is planned to be filled becomes unrestricted, then it is difficult to predict the long-term impacts should more than 19.9 million cubic meters of material be disposed of on the bottom of the Trough. The ecological value of the Trough has been determined to be quite limited and the depths below 30 meters are utilized only during the winter months. The area is not fished heavily but the drift gillnetters will experience some difficulty in utilizing their nets because the bottom will become rougher following disposal. The proposed restriction on the volume to be disposed of is anticipated to result in no net long-term impacts. Should this restriction be lifted, shallower depths would be involved and it is not possible to predict at this time the relative long-term impacts upon the physical and chemical nature of the mid-Bay area.

6.4 CAVEATS

The major concerns regarding disposal operations relate to disposal method and the need for further information regarding organic contaminants. As long as the method of disposal is restricted to bottom dumps by hopper dredge or scow, there should be only short-term biological impacts within the Trough resulting from the operation. Whereas the sediments to be disposed of have been found to be similar to those already in the Trough with respect to grain size and metal contamination, there is insufficient information regarding organic contaminants such as pesticides. It is likely that there are few significant differences between the sediments to be disposed of and those already in place with regard to organics but information is lacking on this issue. The final issue which is of importance relates to the displacement of anoxic waters on a long-term basis. At this time it would appear that the dynamics which define the minimum depths of anoxic waters within the Trough are related to surface phenomena and that filling of the Trough should have little or no effect on changing this minimum depth. It may be necessary to review recent data collections and on-going studies to further refine this judgement and to determine the potential long-term effects on the aerial extent of anoxic waters in the mid-Bay area.

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TABLE B SPECIES LIST OF FISHES FOUND IN DEEP TROUGH SURVEYS

COMMON NAME	SCIENTIFIC NAME
Alewife	Alosa pseudoharengus
American eel	Anguilla rostrata
American shad	Alosa sapidissima
Atlantic croaker	Micropogonias undulatus
Atlantic menhaden	Brevoortia tyrannus
Atlantic silverside	Menidia menidia
Atlantic Spadefish	Chaetodipterus faber
Bay anchovy	Anchoa mitchilli
Black sea bass	Centropristis striata
Blueback herring	Alosa aestivalis
Bluntnose stingray	Dasyatis sayi
Butterfish	Peprilus triacanthus
Darter goby	Gobionellus boleosoma
Feather blenny	Hypsoblennius hentz
Green Goby	Microgobius thalassinus
Hogchoker	Trinectes maculatus
Inshore lizardfish	Synodus foetens
Ladyfish	Elops saurus
Naked goby	Gobiosoma bosci
Northern pipefish	Syngnathus fuscus
Oyster toadfish	Opsanus tau
Red hake	Urophycis chuss
Rough silverside	Membras martinica
Seaweed blenny	Blennius marmoreus
Silver hake	Merluccius bilinearis
Skilletfish	Gobiesox strumosus
Spot	Leiostomus xanthurus
Spotted hake	Urophycis regia
Spotted seatrout	Cynoscion nebulosus
Striped anchovy	Anchoa hepsetus
Striped bass	Morone saxatilis
Summer flounder	Paralichthys dentatus
Tidewater silverside	Menidia beryllina
Threespine stickleback	Gasterosteus aculeatus

TABLE B (CONT.)

COMMON NAME	SCIENTIFIC NAME
Weakfish	Cynoscion regalis
White perch	Morone americana
Winter flounder	Pseudopleuronectes americanus
Yellow perch	Perca flavesens

TABLE C SCIENTIFIC NAME BY FAMILY

Dasyatidae
- Dasyatis sayi - Bluntnose stingray

Elopidae
- Elops saurus - Ladyfish

Clupeidae - herrings
- Alosa aestivalis - Blueback herring
- Alosa pseudoharengus - Alewife
- Brevoortia tyrannus - Atlantic menhaden
- Alosa sapidissima - American shad

Engraulidae - anchovies
- Anchoa hepsetus - Striped anchovy
- Anchoa mitchilli - Bay anchovy

Synodontidae - Lizardfish
- Synodus foetens - Inshore lizardfish

Anguillidae - Freshwater eels
- Anguilla rostrata - American eel

Gadidae - Codfishes
- Urophycis chuss - Red hake
- Urophycis regius - Spotted hake

Merlucciidae - Merlucciid hakes
- Merluccius bilinearis - Silver hake

Gasterosteidae - Sticklebacks
- Gasterosteus aculeatus - Threespine stickleback

Syngnathidae - Pipefish and seahorses
- Syngnathus fuscus - Northern pipefish

Serranidae - Sea basses
- Centropristis striata - Black sea bass

Percichthyidae - Temperate basses
- Morone americana - White perch
- Morone saxatilis - Striped bass

Percidae - Perches
- Perca flavesens - Yellow perch

Sciaenidae - Drums
Cynoscion nebulosus - Spotted seatrout
Cynoscion regalis - Weakfish
Leiostomus xanthurus - Spot
Micropogonias undulatus - Atlantic croaker

Ephippidae - Spadefishes
Chaetodipterus faber - Atlantic spadefish

Gobiidae
Gobionellus boleosoma - Darter goby
Gobiosoma bosci - Naked goby
Microgobius thalassinnus - Green goby

Stromateidae - Butterfish
Peprilus traicanthus - Butterfish

Atherinidae - Silversides
Membras martinica - Rough silverside
Menidia beryllina - Tidewater silverside
Menidia menidia - Atlantic silverside

Bothidae - Lefteye flounder
Paralichthys dentatus - Summer flounder

Pleuronectidae - Righteye flounder
Pseudopleuronectes americanus - Winter flounder

Soleidae - Soles
Trinectes maculatus - Hogchoker

Gobiesoidae - Clingfishes
Gobiesox strumosus - Skilletfish

Blenniidae - Combtooth blennies
Blennius marmoreus - Seaweed blenny
Hypsoblennius hentz - Feather blenny

Batrachoididae
Opsanus tau - Oyster toadfish

ADDENDUM

Report of fisheries and water quality sampling for winter period of 1983-1984. By Richard H. Wagner, Coastal Resources Division, Maryland Department of Natural Resources.

The Deep Trough Study conducted from May 1982 through May 1983 was recommended to be extended for an additional year of sampling due to the unusually warm winter and dry conditions that existed in the 82-83 winter. This study was repeated for the 83-84 winter months for water quality and fisheries (trawl) samples. The benthic and ichthyoplankton portion of the study was not repeated in 83-84 due to budgetary limitations. The water quality and trawl sampling was performed in the second year in the identical manner at the same number and locations of sampling sites with the same equipment, sampling gear and boat so that this data could be used for a comparative analysis.

The 1983-84 winter was colder than the 82-83 period and salinities were generally lower due to more precipitation recorded for the 83-84 sampling period. In 1983-84, sampling was conducted for the months of May, October, November and December, 1983; February, March, April and May, 1984. January 1984 sampling was not conducted due to ice cover over the sample sites. No sampling was conducted for the months of June, July, August and September of 1983 as the trough's deep water becomes anoxic around the middle part of May and stays anoxic until the first part of October. This continuing summer anoxic condition was monitored and documented for the summer months of 1982, 83 and 84 from other EPA and DNR studies.

Figures D-4 through D-11 isopleths of Temperature, Salinity and Dissolved Oxygen (DO) for the two years sampling period reflect that the 82-83 winter was generally warmer (no ice in the sample area) and salinities were higher than were found in the 83-84 winter period. The one exception to this comparative analysis is for temperature differences in the month of February. The February 1984 sampling was conducted following three days of heavy rain, of spring-like temperatures that warmed the surface layer of water. See Figure D-8.

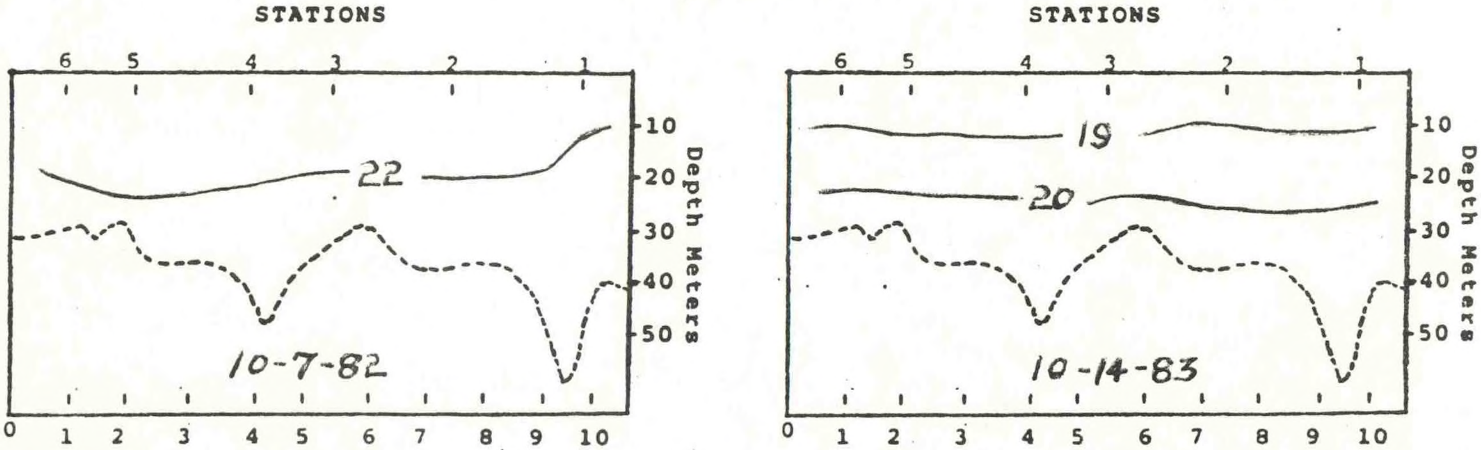
The species diversity and relative abundance of the trawl samples reflect the temperature and salinity changes from one winter to the other as shown in Figure D-12. The 82-83 high salinity winter brought in many more marine species than are normally found this far north in the Bay. Conversely, striped bass which are normally found within the deeper, warmer, waters during the winter were lower in numbers during the 82-83 winter months than the 83-84 period. Distribution of this species may have been influenced by other factors such as food abundance, year class strength, etc. However, an examination of the commercial harvest records found that striped bass evidently remained in the river mouths throughout the 82-83 winter months. Practically no landings were made in the trough deep waters where they are normally found once the rivers become iced. Atlantic croaker also appear to have been affected by temperature differences of the two winter periods. There was good survival of Atlantic croaker throughout the 82-83 winter due to warm water conditions. Diminishing numbers in March and April 1983 were not from mortality, but due to out-migration of the species. Atlantic croakers were not found in the sample area in 1984 following the ice cover and freezing temperatures in January of that year. Also of interest if that all Bay anchovy and Atlantic menhaden caught in February 1984 were dead. It appeared that the fish had died from the freezing temperatures in January. Bay anchovy which are the most abundant of all species caught, remained low in relative abundance until May of 1984. The freezing temperatures of January 1984 seem to have killed most of the standing stock of this species within the sample area.

As previously stated, the 83-84 sampling period was performed as an addition to the previous 82-83 study for water quality and trawl sampling only. The trawl sampling was performed by Maryland State, Tidal Fisheries personnel, Messrs Don Cosden, Ray Dintaman, Ben Florence, Roy Scott and James Uphoff. Water quality sampling was performed by Maryland State, Coastal Resources Division personnel, Messrs. Frank Dawson and Richard Wagner. Titration for DO aboard boat was performed by Nancy Matthews of Anne Arundel Community College assisted by Debby Luquette, Towson State University.

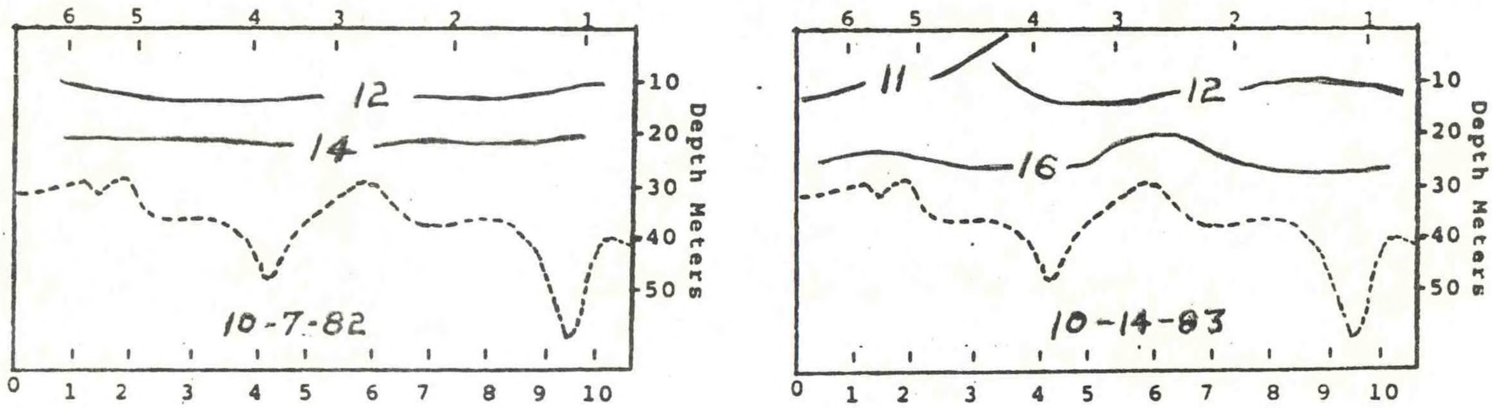
Data from the two years sampling effort will be stored in the "Resources Monitoring Data Storage System" at the Maryland State Data Center.

October 82-83

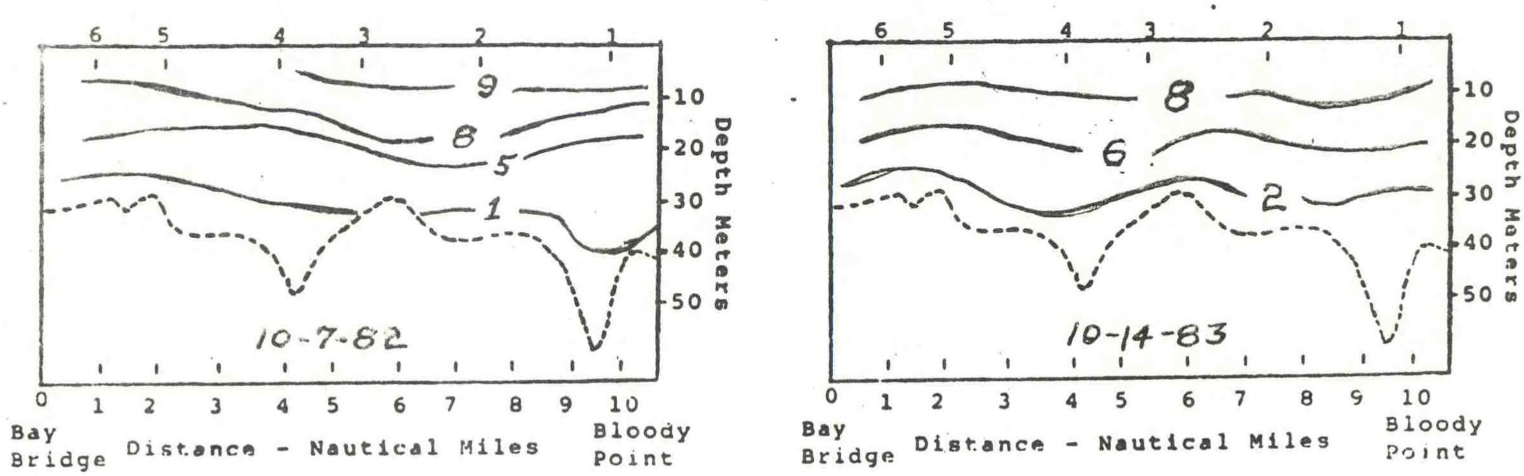
TEMPERATURE (°C)



SALINITY (°/oo)



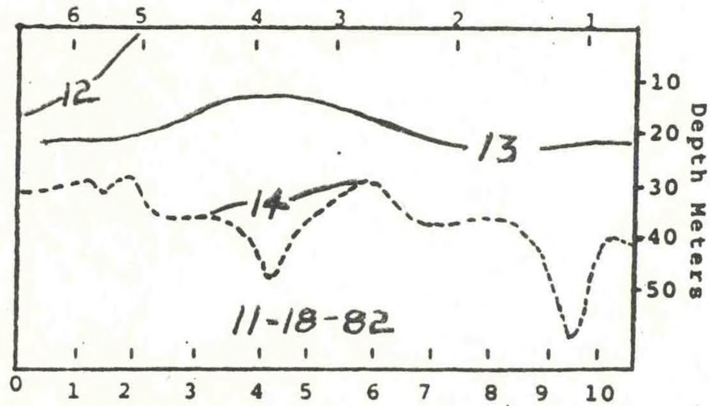
DISSOLVED OXYGEN (PPM)



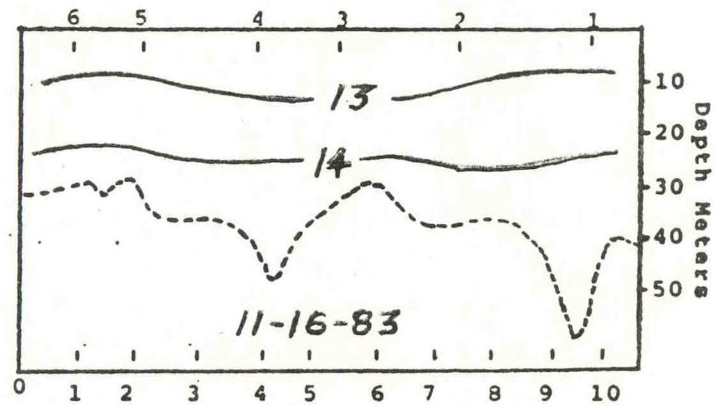
November 82-83

TEMPERATURE (°C)

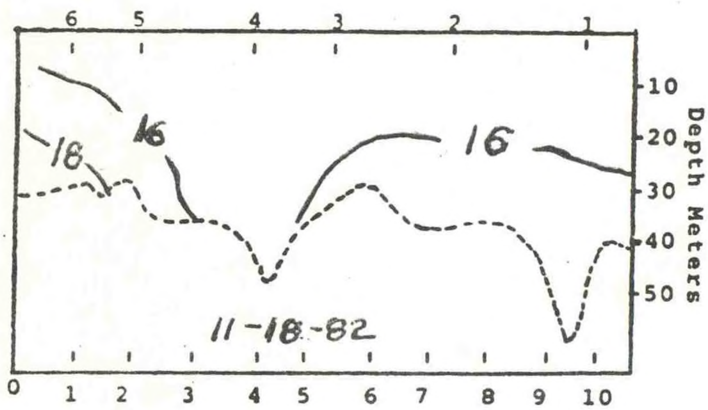
STATIONS

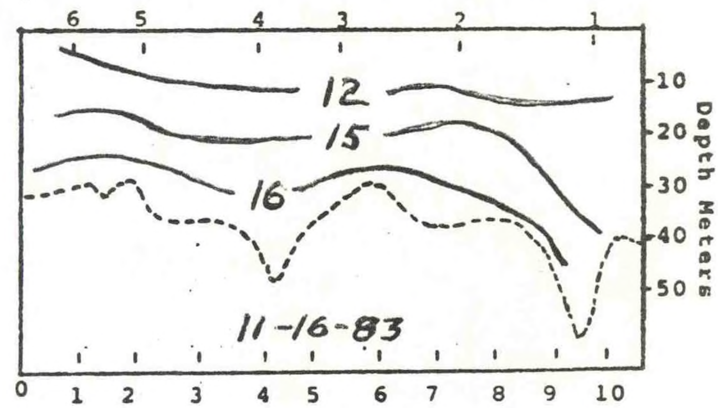


STATIONS



SALINITY (°/oo)





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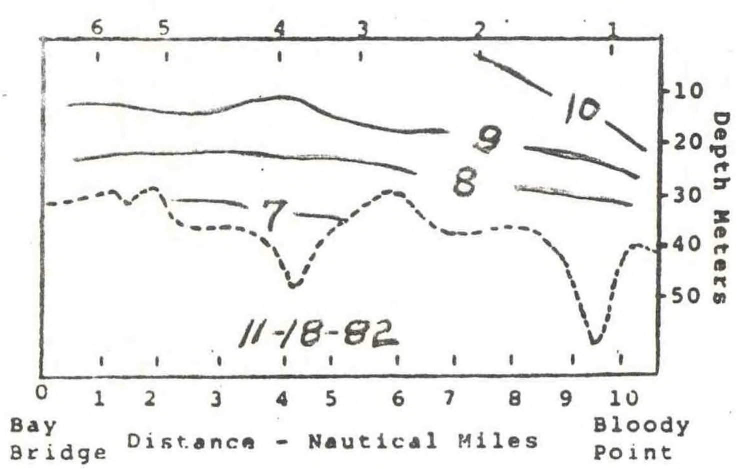
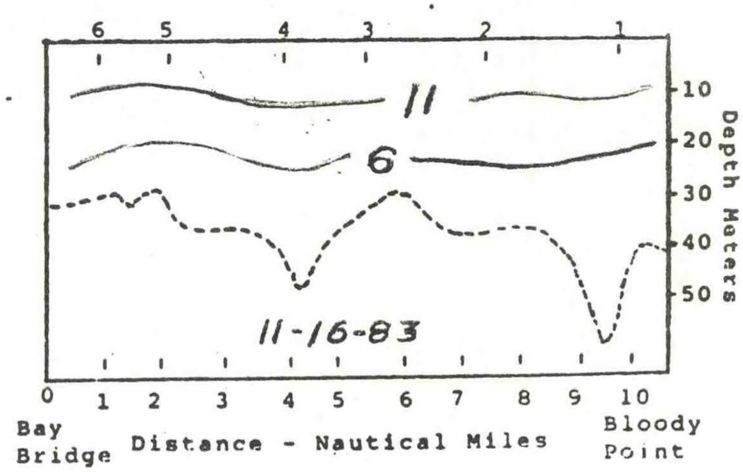
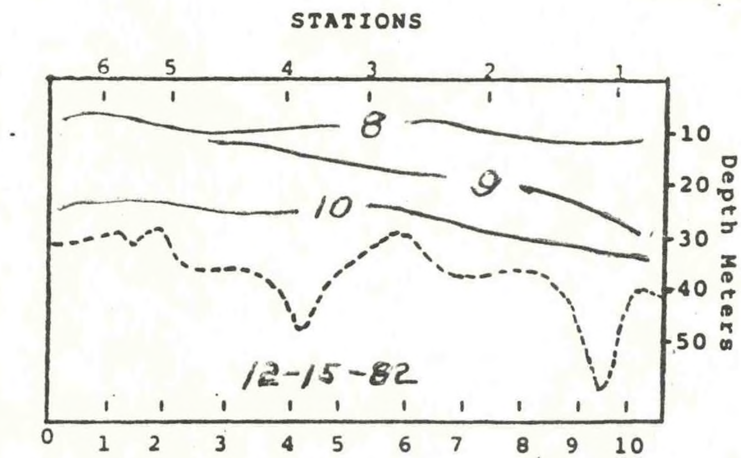
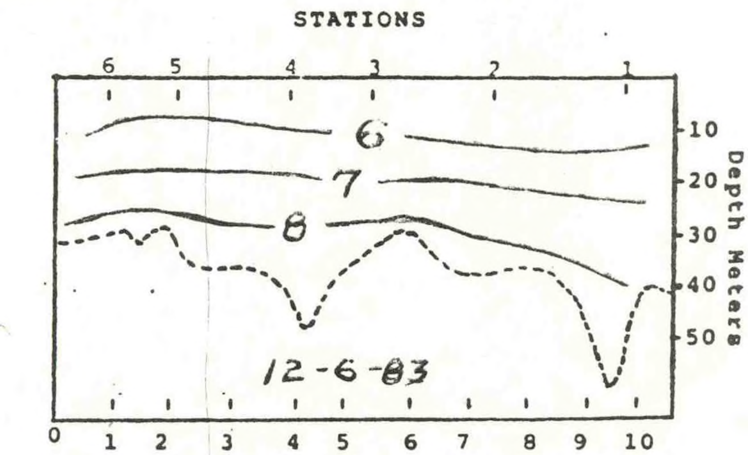




December 82-83

TEMPERATURE (°C)





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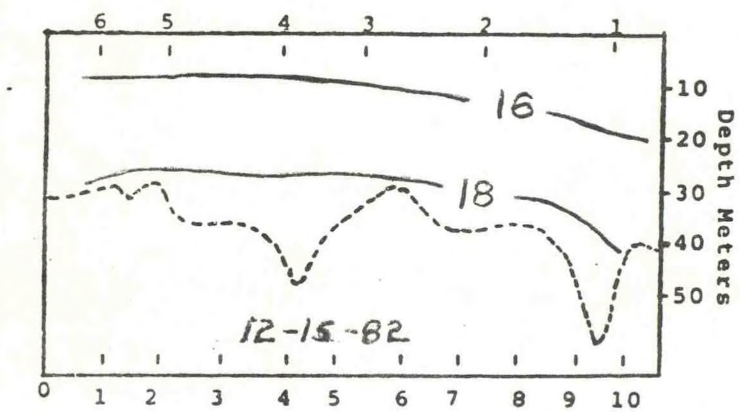

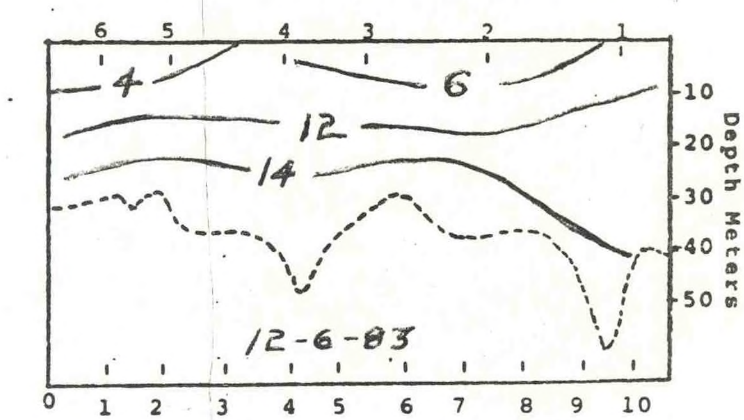

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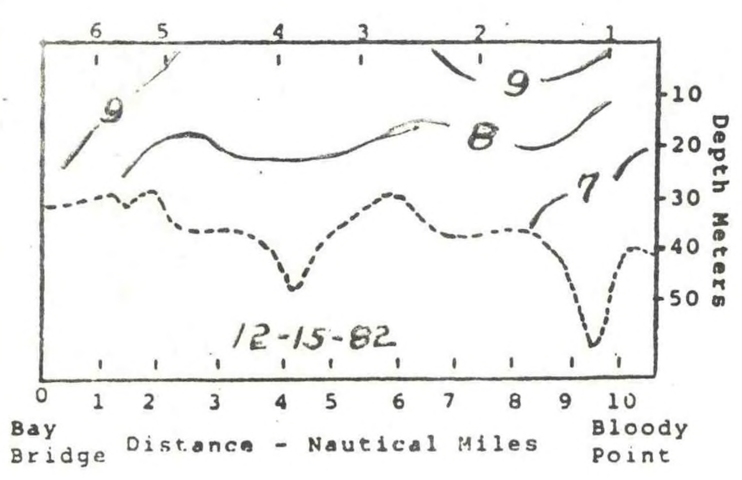
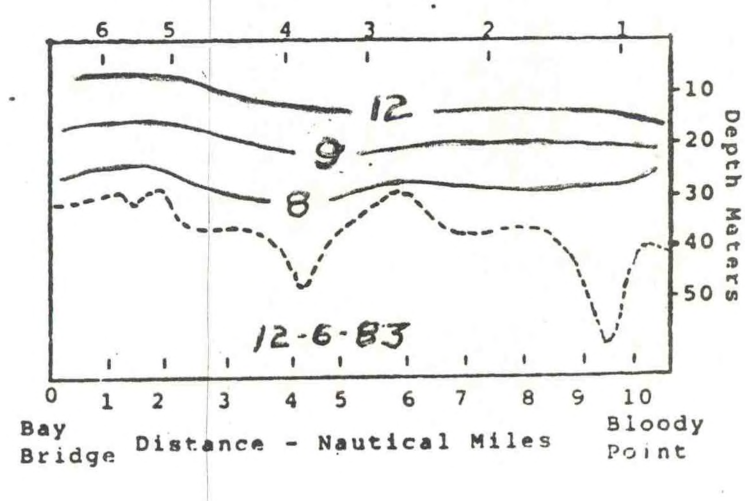
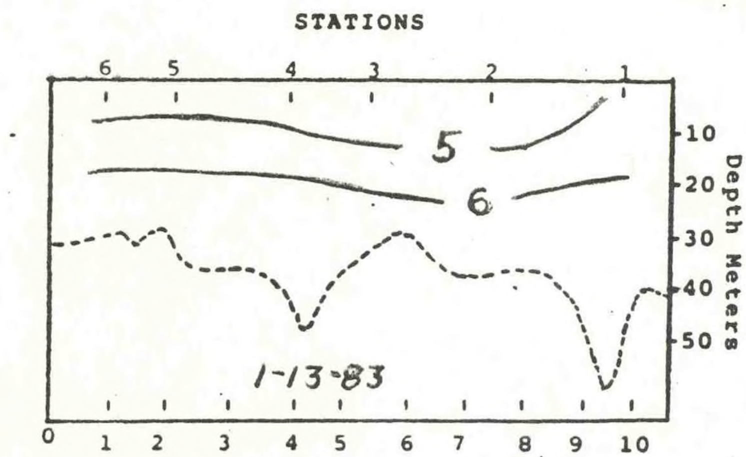
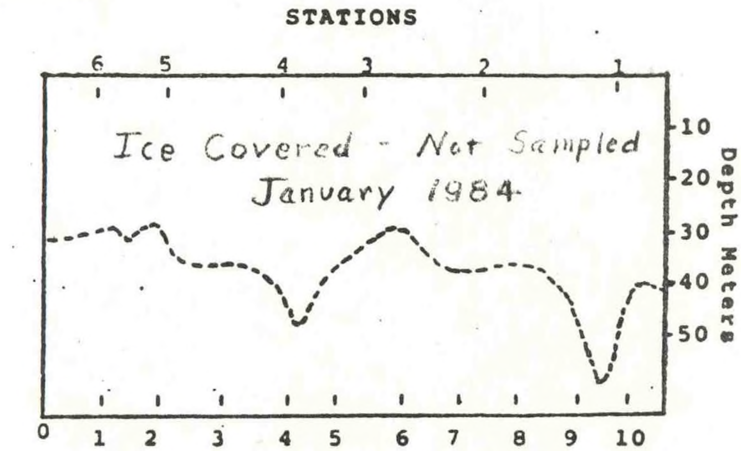




January 83-84

TEMPERATURE (°C)





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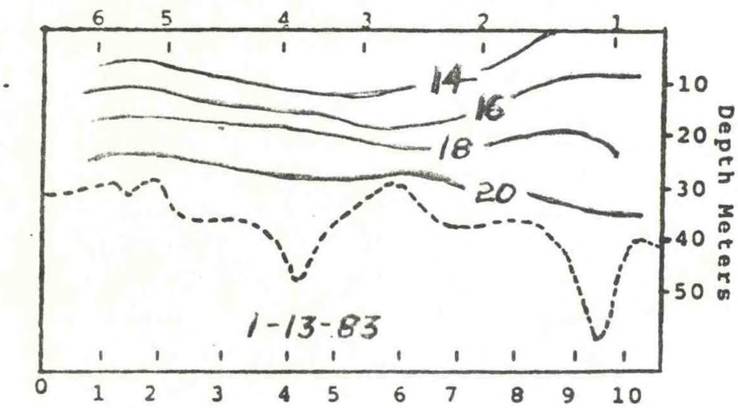

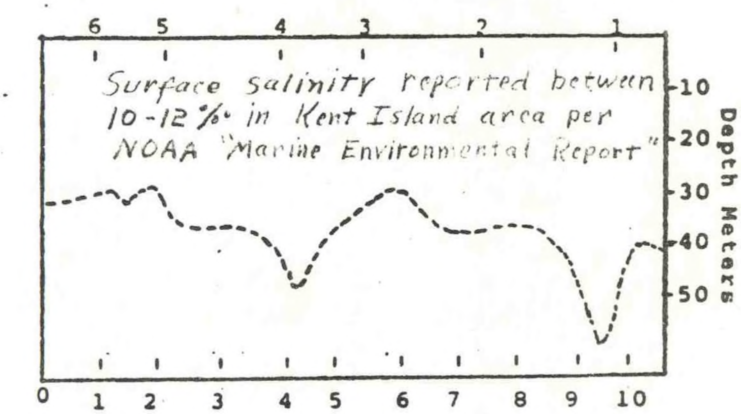

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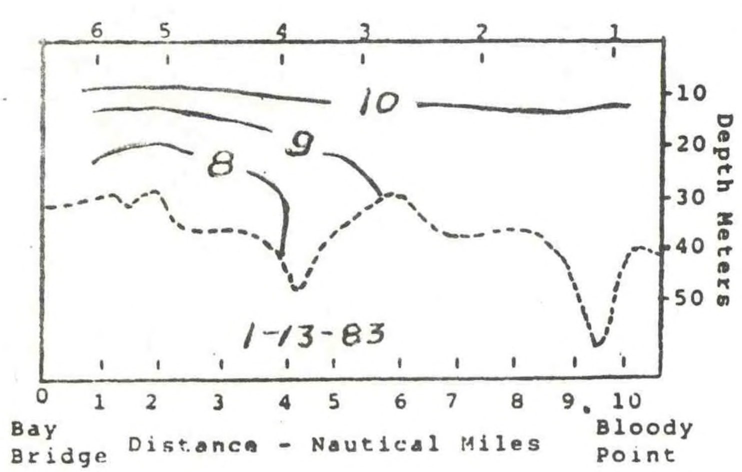
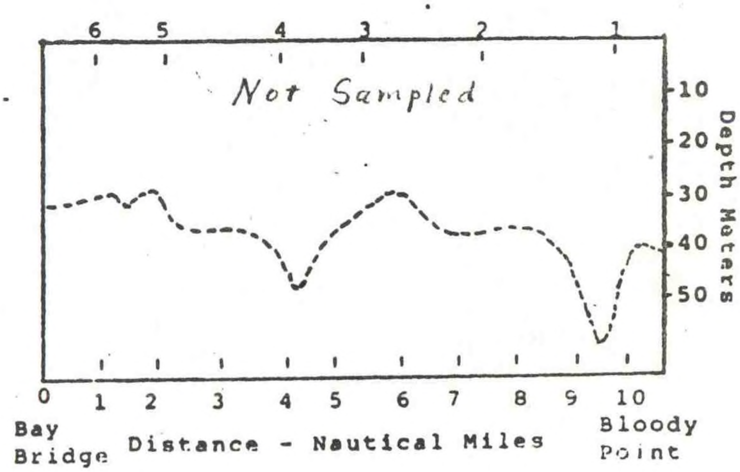
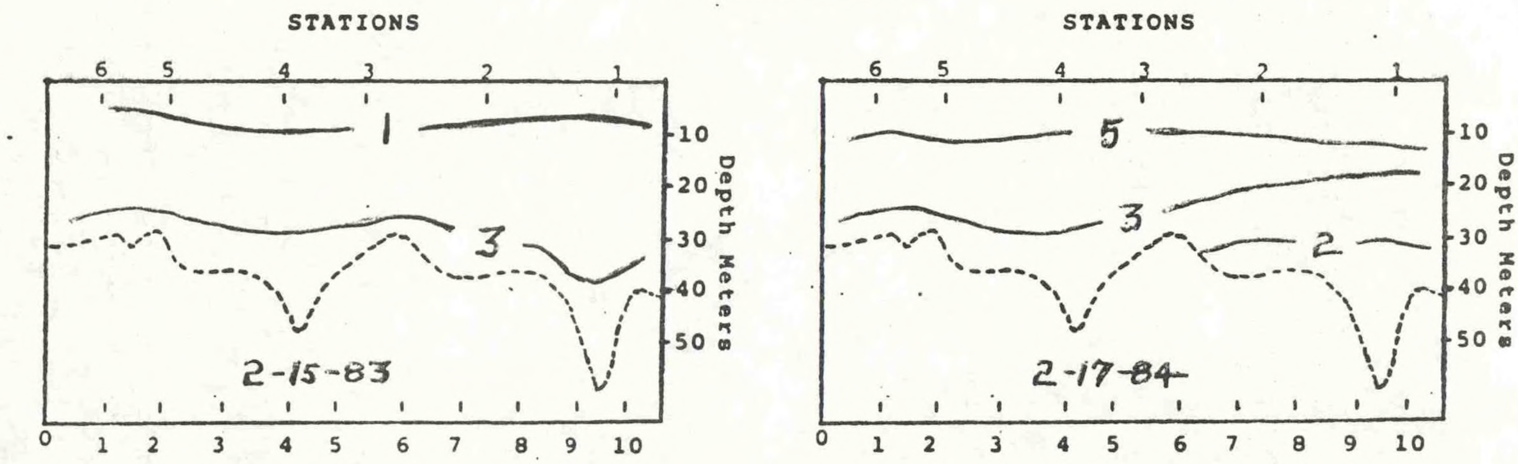




February 83-84

TEMPERATURE (°C)



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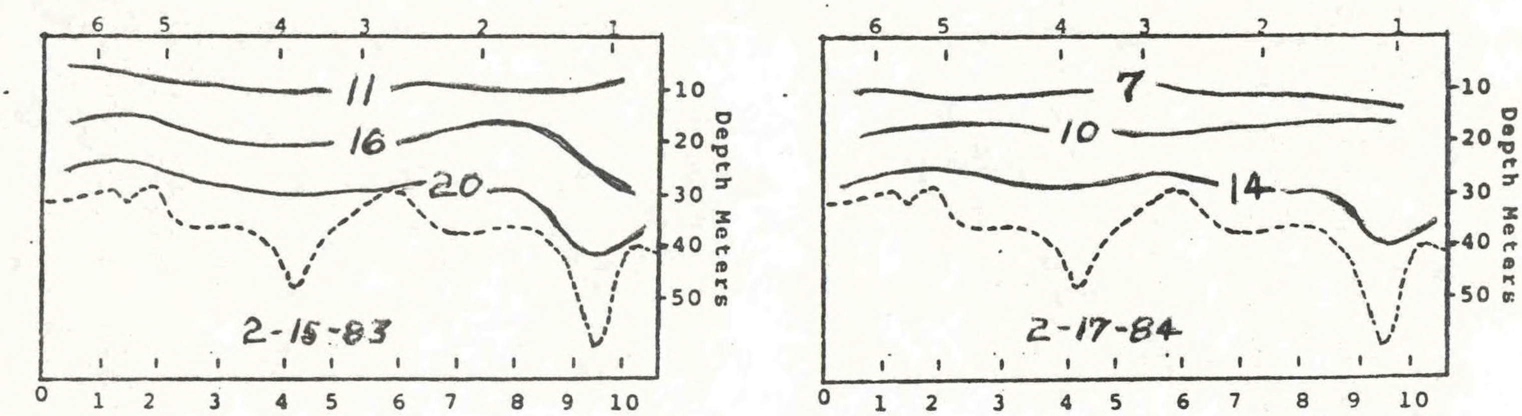

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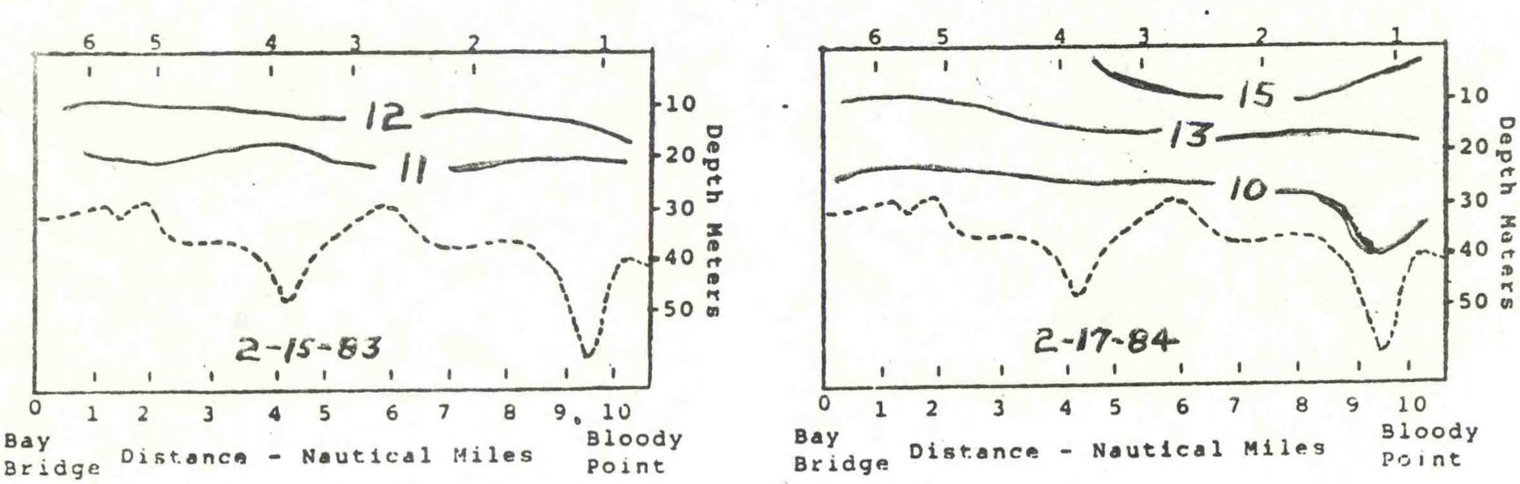
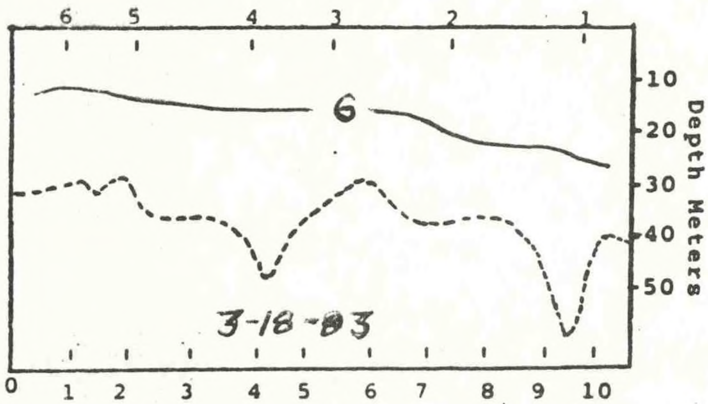


March 83-84

TEMPERATURE (°C)

STATIONS



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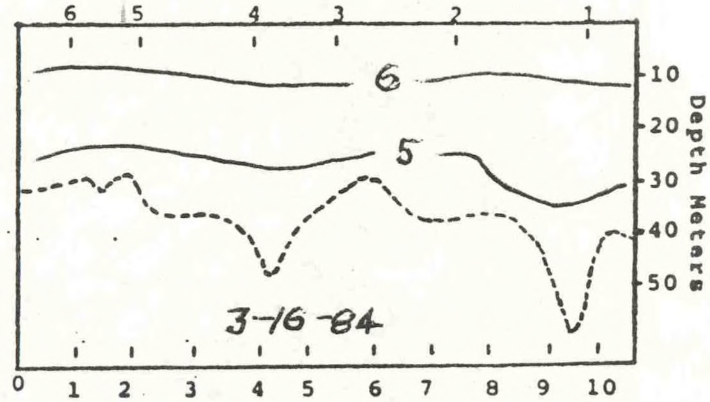
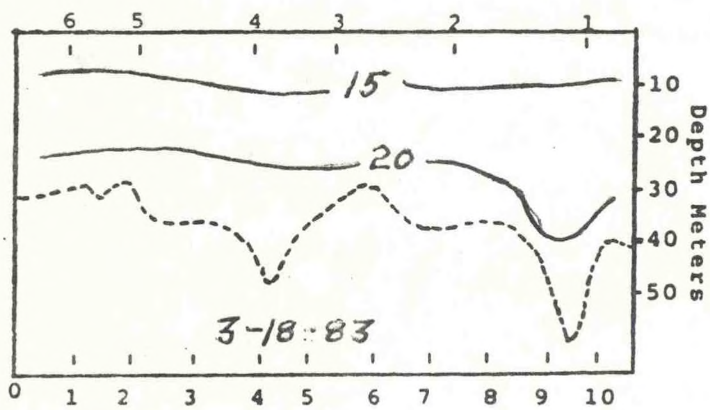
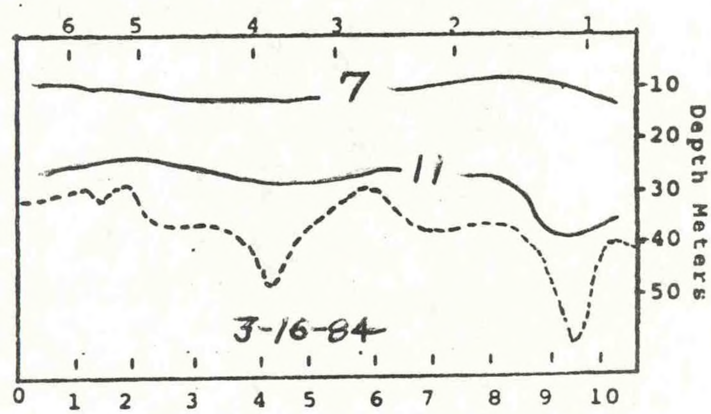


SALINITY (°/oo)





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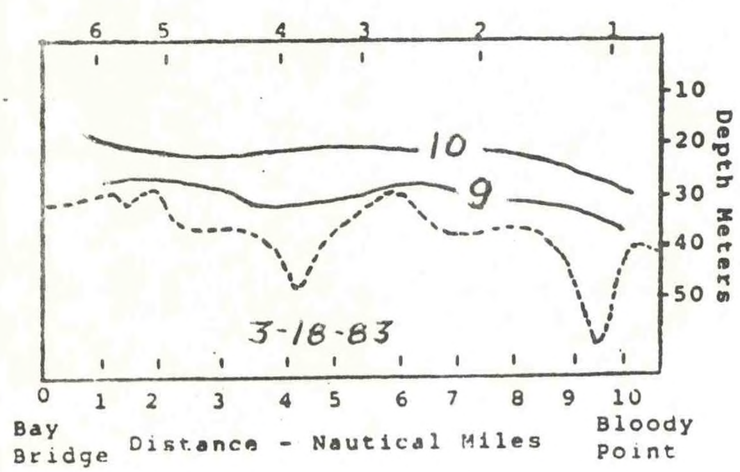
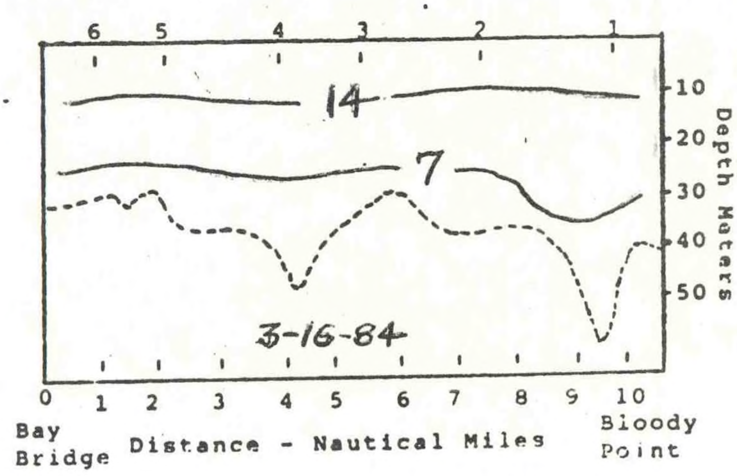
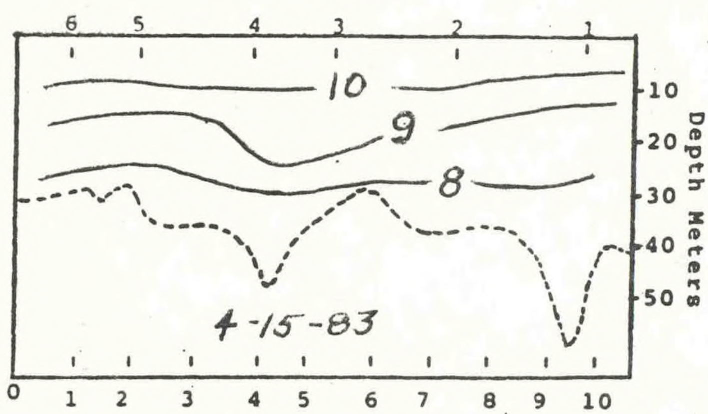
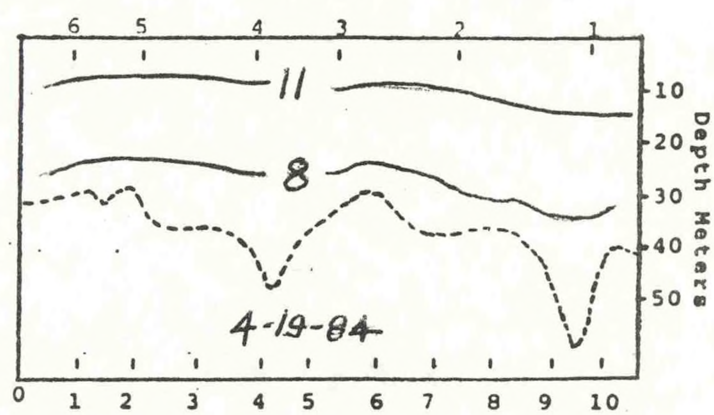




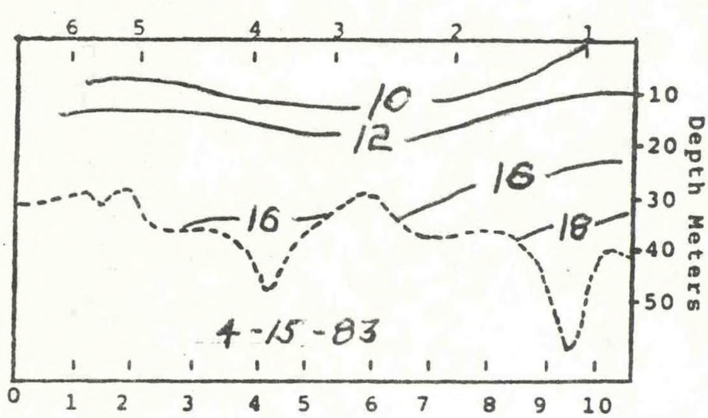
April 83-84

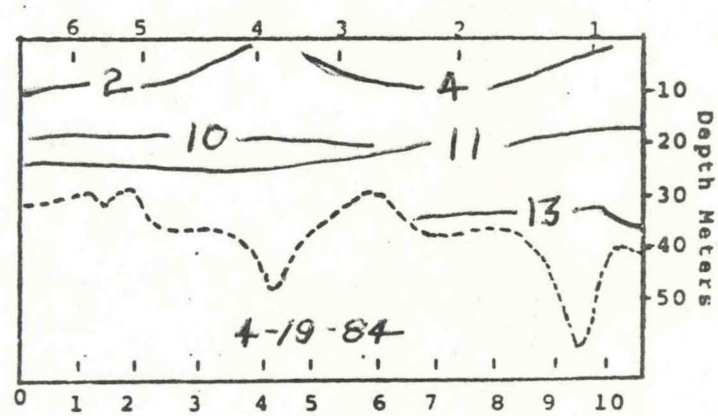
TEMPERATURE (°C)



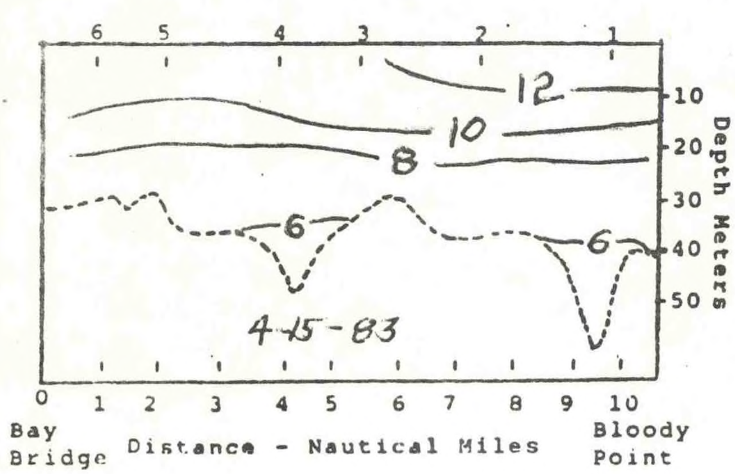


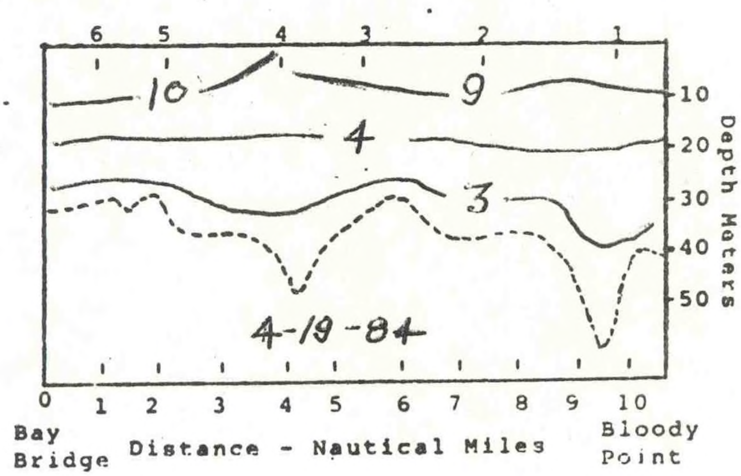
SALINITY (°/oo)





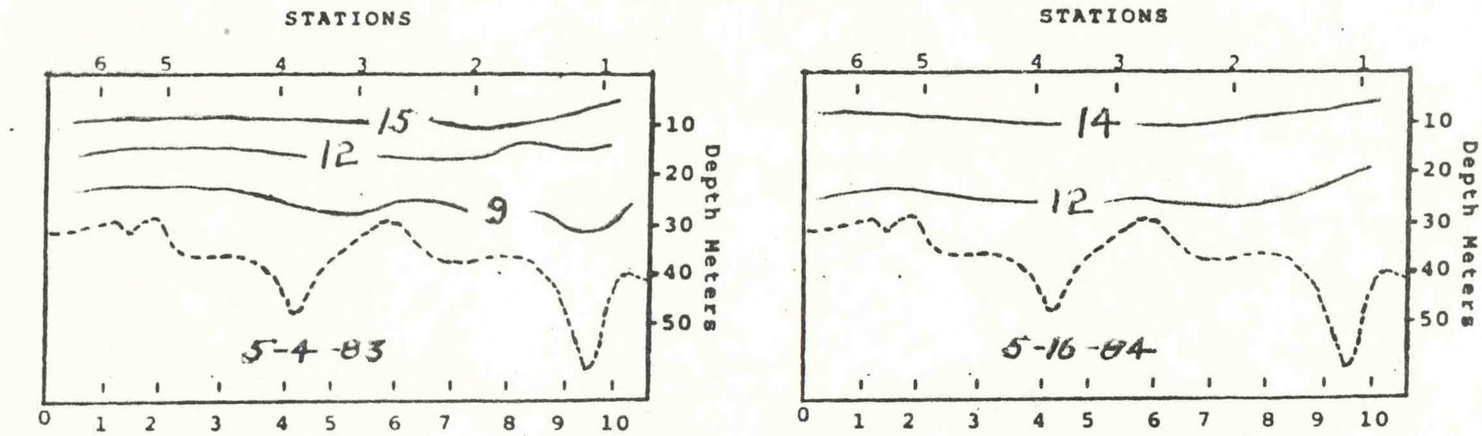
DISSOLVED OXYGEN (PPM)



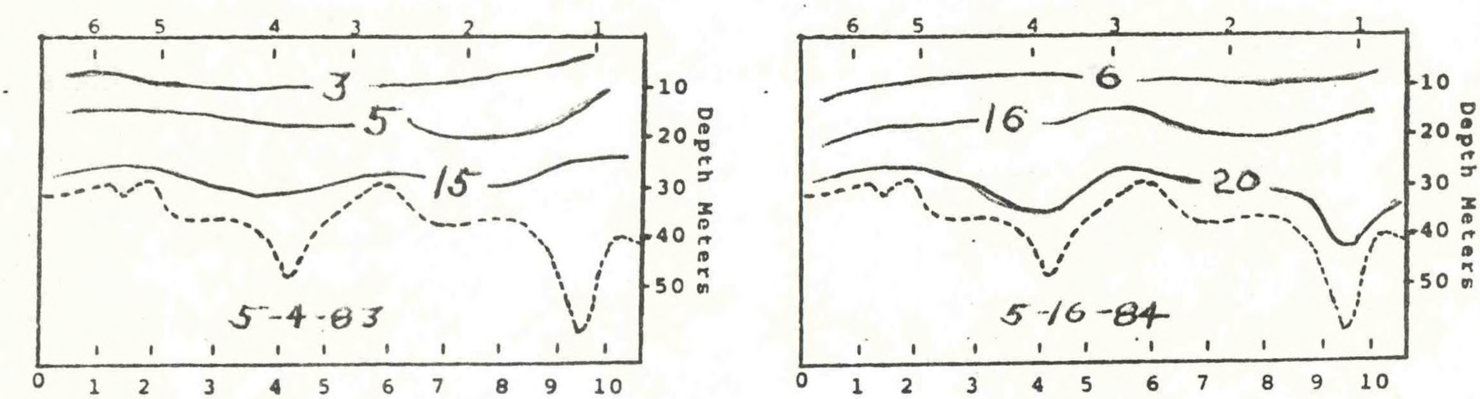


May 83-84

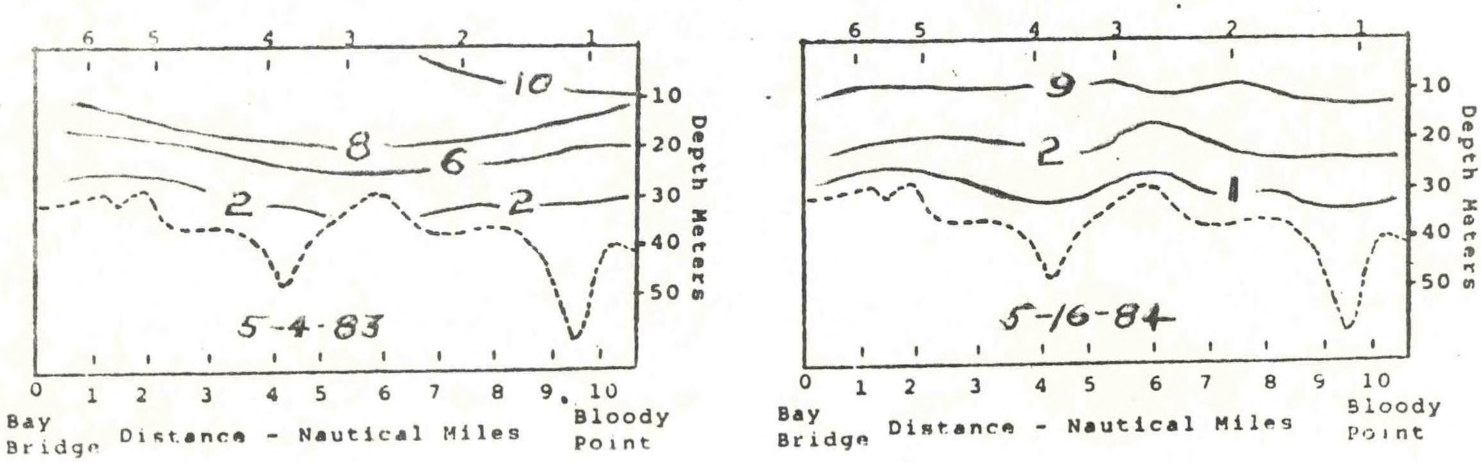
TEMPERATURE (°C)



SALINITY (°/oo)



DISSOLVED OXYGEN (PPM)



THE MONTHLY CATCH OF FISH SPECIES BY TRAWL IN THE DEEP TROUGH STUDY AREA - 1982-1984

D-12

	OCTOBER		NOVEMBER		DECEMBER		JANUARY		FEBRUARY		MARCH		APRIL		MAY	
	82	83	82	83	82	83	83	84	83	84	83	84	83	84	83	84
DIADROMOUS								NOT SAMPLED DUE TO ICE COVER								
Blueback herring			5			6	10		106	1	4	5	1			
Alewife					2		3		62	2	11					
American Shad					1											
White perch					4	1	1		55	8		4			2	
Striped bass			1		1	21			2	8		24		2	6	
American eel			7	206	10	10	3		1	1*	1	1		1		
Gizzard shad										1		2				
ESTUARINE																
Bay anchovy	129	951	2,065	1,775	208	10	605		124	200*	2,456	1	1,795	36	190	269
Inland silverside							17		74							
Rough silverside					3										1	
Atlantic silverside					1		1									
Northern pipefish		1	5	11	29	91	3		4	93	4	11	3	3		
Hogchoker		41	8	63	8	8			3	2	1	4	1	6	9	4
Skilletfish			1	6	7	15	1		3	37	2	21		5		
Oyster toadfish		5		10	2	6	2		3			2		2		5
Naked goby			4						1	9						
Feather blenny					1					2						
MARINE (UBIQUITOUS)																
Atlantic croaker		40	130	618	1,049	1,107	1,313		3,204		305		28		7	
Spot		435	373	255	1,181	11	7		33							
Weakfish		308	30	843	107	4	1									
Spotted seatrout					71		4									
Atlantic menhaden			5	270	34	94	149		465	164*	6		7	82	10	12

THE MONTHLY CATCH OF FISH SPECIES BY TRAWL IN THE DEEP TROUGH STUDY AREA - 1982-1984 - page 2

	OCTOBER		NOVEMBER		DECEMBER		JANUARY		FEBRUARY		MARCH		APRIL		MAY	
	82	83	82	83	82	83	83	84	83	84	83	84	83	84	83	84
MARINE (UBIQUITOUS) Continued								NOT SAMPLED DUE TO ICE COVER								
Butterfish		1			38		2									
Winter flounder			5		17		2		1	1	2	1	2	1		
Summer flounder	1	20		16	3	2			1		2	1				
Red hake									3		1	1	1			
Spotted hake															4	3
Bluefish		6														
Harvestfish		4														
MARINE (INVADERS)																
Inshore lizard fish					4											
Atlantic spadefish			1		2											
Silver hake					1											
Black sea bass					1											
MARINE (INTRUDERS)																
Bluntnose stingray			1		1											
MARINE (COASTALS)																
Ladyfish															1	
Seaweed blenny									1							
Blue Crabs	2	247	46	138	26	55	3		2	21	4	46	8	61	16	147

* Dead Fish