1981

# Continuous plankton records : zooplankton and net phytoplankton in the southern regions of the Middle Atlantic Bight, 1978-80

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# CONTINUOUS PLANKTON RECORDS:

# ZOOPLANKTON AND NET PHYTOPLNAKTON IN THE SOUTHERN REGIONS OF THE MIDDLE ATLANTIC BIGHT

1978-80

By

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# CONTINUOUS PLANKTON RECORDS

# AND

# EXPENDABLE BATHYTHERMOGRAPH ANALYSIS

# CHESAPEAKE ROUTE

# AUGUST 1978 - AUGUST 1979

Part I

By

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## INTRODUCTION

The Virginia Institute of Marine Science (VIMS) is currently providing logistical and scientific support to the Atlantic Environmental Group's Ship of Opportunity program in accordance with a VIMS/NOAA service contract. This program includes a Continuous Plankton Recorder - Expendable Bathythermograph (CPR/XBT) survey along a standard transect off the Chesapeake Bay. Analysis of biological and physical data for this particular route is being processed by VIMS according to the standardized procedure set forth by NOAA and the Institute for Marine Environmental Research (IMER) of the United Kingdom.

The Physical data (XBT traces, surface temperature and salinity) are used to identify water masses through which the transect passes, locate frontal positions, and provide hydrographic data with which to correlate biological parameters. Criterion used by VIMS to identify these standard water masses is reviewed in Wright and Parker (1976) and Ruzecki (1979). The continuous record of biological composition sampled along the transect is subdivided into equal blocks corresponding to known volume filtered along a known length of the transect. The flora and fauna of these blocks are then associated with their respective water masses and spatial position along the transect.

Thus far the biological and physical data resulting from tows performed in August, November 1978 and January, March, April 1979 have been analyzed in the manner described above.

## AUGUST 1978

Thermal analysis reveals intense stratification of the upper 40 m of the sampled water column, characteristic of a strong seasonal thermocline (Fig. 1). Surface temperatures greater than 26° C are observed on the Continental Shelf and slope. The "cold pool" is located on the edge of the shelf break with a 7° C core, warming to 10° C along the outer edges. According to Cook (1979) minimum cold cell bottom temperatures are usually greater than 7° C by May. A 7° C cold cell cove in August indicates that the anomolous winter conditions of 1977-78 may have resulted in long-term consequences on the continental shelf in this area. The cold cell extends from 24-60 m depth with a horizontal range of 15-20 nautical miles. Surface thermal and salinity structure indicate no frontal boundary across the transect, however these data do demonstrate that the entire transect is representative of the shelf water mass.

The Continuous Plankton Recorder (CPR) was towed on an easterly course along the 37° N latitude line, sampling for 64 nautical miles (Fig. 2). Blocks #1, 3, 5 were analyzed and the data, tabulated for shelf water. Total copepods averaged $240/3M^3$, dominated by cyclopoid copepods (Oncaea, Oithona, and Coryceaus). Cladocerans were abundant near shore ($1600/3M^3$), while chaetognaths were noted throughout the transect.

## NOVEMBER 1978

According to XBT analysis, the Shelf-slope front is positioned near the shelf break between Station 3-4 (Fig. 3).

Fall overturn is well-established, as evidenced by nearly isothermal water on the shelf. Slope water surface temperatures are roughly 3°C greater (18°C) than adjacent shelf water surface observations (15°C). Surface salinity measurements reinforce positioning of shelf-slope front between station 2-3. No evidence of an isolated "cold pool" is present at this time.

The CPR was towed on an easterly course along the 37°N latitude line sampling for 120 nautical miles (Fig. 4). Blocks #1, 3, 5, 7, 9, 11 were analyzed with data from #1 designated as shelf water and #5, 7, 9, 11 as slope water. Para-pseudocalanus spp. were the dominant shelf copepods less than 2.0 mm, while dominant shelf copepods greater than 2.0 mm included Nannocalanus minor and Candacia armata. Slope copepods (<2.0 mm) averaged $240/3m^3$, dominated by Mecynocera clausi and unidentified copepod naupli. Pleuromamma borealis was the dominant copepod (>2.0 mm) in the sampled slope water mass. Metridia lucens was an important component of the fauna present in the mixed zone between shelf water and slope water. Euphausids were absent in the shelf water, but averaged $6/3m^3$ in slope water. The presence of tunicates and a phyllosome larva on Block #5 indicate warm slope water. Block #2 should be analyzed as shelf data to increase the number of samples for this water mass.

JANUARY 1979

The shelf-slope front is located roughly 30 nautical miles seaward of the shelf break between station 7-8, according to thermal structure of XBT analysis (Fig. 5). Vertically isothermal water ranging in temperature from 11-12°C is characteristic of the winter shelf water mass. A warm "slug" of slope water (13-14° C) is trapped by this overlying cooler shelf water which extends seaward of the shelf break. Surface salinity observations indicate slope water seaward of station 7.

The CPR was towed on an easterly course along the 37° N latitude line sampling for 125 nautical miles (Fig. 6). Blocks #1, 3, 5, 7, 9, 11 were analyzed; #1, 3, 5 were designated shelf, while #7, 9, 11 were tabulated as slope. Total copepods (<2.0 mm) in the shelf water declined from $240/3m^3$ nearshore to $40/3m^3$ near the shelf-slope front. Total copepods (<2.0 mm) within the slope water declined from $80/3m^3$ near the front to $0/3m^3$ seaward. Pleuromamma borealis was the dominant copepod (>2.0 MM) in both water masses averaging $6/3m^3$ and $26/3m^3$ in shelf and slope, respectively. Metridia lucens was an important component in the mixed area of the shelf-slope front ($6/3m^3$). Euphausids were absent nearshore (Block #1), but averaged $6/3m^3$ seaward in both water masses. In contrast chaetognaths were present near shore only ($3/3m^3$).

FEBRUARY 1979

No tow attempted, vessel unavailable.

MARCH 1979

Missing data (result of a shipboard power failure) precludes determination of the shelf-slope front using XBT analysis (Fig. 7); however, surface salinity and temperature data indicate the frontal position between Station 7-8, approximately 20 nautical miles seaward of the shelf break. Shelf water is encountered further offshore represented by the thermal and salinity structure between stations 21-23. This is an artifact of the transect; near station 12 a course change was established to the northeast into an area in which shelf water extended much further offshore, according to U. S. Navy Ocean Frontal Analysis 04-10 March, 1979. Near shore water temperatures are quite cold 3-4° C, while maximum offshore surface temperatures approach 16° C. Interpretation of the thermal structure between stations 19-21 is questionable; it may illustrate the tip of a submerged eddy. Possibly an eddy earlier in the year was destroyed superficially by extreme weather conditions and disappeared from satellite imagery analysis, in which case it might exist in a submerged condition. Other possibilities to explain this structure include an isolated parcel of warm water which migrated near the frontal position and remained there.

The CPR was towed on an easterly course along the 37°N latitude line until 73° N longitude at which point a course change to the northeast extended the transect to 38° 40' N, 71° 16' W (Fig. 8). Blocks #1, 3, 5, 7, 9, 11, 13, 15, 17, 19, 21 and 23 were analyzed for a sample transect total of 239 nautical miles. Blocks #1, 3, 5 were designated shelf; blocks #9,11,13, 15, 17, 19 21 designated as slope. In addition Block #23 tabulated as shelf, however it will be analyzed separately to eliminate latitudinal variability with southerly transect area.

A diatom bloom was evident in both water masses dominated by Thalassionema nitzchioides in slope water and Tha. nitzchioicles, Rhizosolenia alata genuina in shelf water. Total copepods (<2.0 mm), dominated by Centropages typicus in shelf water declined from $680/3m^3$ nearshore to $80/3m^3$ seaward to shelf-slope front. Total copepods (>2.0 mm) in slope water was variable, ranging from $240/3m^3$ to $0/3m^3$ demonstrating no isolated pattern or single species dominance. Calanus finmarchius and Pleuromamma borealis were present in shelf water while Rhincalanus nasutus was noted in slope water (copepods >2.0 mm). Metridia lucens again was an important component in waters near the front. Euphausids were absent near shore, but averaged $5/3m^3$ in both water masses seaward. Larval fish ($3/3m^3$) were observed on Block #1, nearshore. Further identification of these larval fish will be attempted at a later date.

APRIL, 1979

Thermal structure indicates a shelf-slope front positioned between station 10-11, 60 nautical miles seaward of the shelf break (Fig. 9). Nearshore water is still vertically isothermal (9-10° C), while the "slug" of shelf water off the shelf break is beginning to warm and stratify. Surface slope water temperatures do not appear significantly warmer than slope water of March 1979 along a similar transect. XBT drops ceased after station 13, however surface salinities were measured until station 23. This data indicates a shelf-slope front, as above, between station 10-11. In addition, according to salinity, only slope water was encountered seaward of station 11.

The CPR was towed on an easterly course along the 37°N latitude line for a sample of 194 nautical miles (Fig. 10). However the internal mechanism malfunctioned causing the silk to "bunch up" on one side. This condition increased so that the entire tunnel was not covered by the filtering silk. Also the mesh size was severely distorted. Blocks #1, 3, 5 were undamaged and thus analyzed quantitatively as shelf water. A dinoflagellate bloom was evident, dominated by _Ceratium tripos_. Total copepods (<2.0 mm), dominated by _Centropages typicus_ and _Paracalanus parvus_, averaged $680/3m^3$. _Limacina retroversa_ was noted in great abundance ($3000/3m^3$) on Block #3. Few copepods (>2.0 mm) were observed, however _Calanus finmarchius_ was present in the sampled shelf water. Euphausids (50% juveniles) were absent nearshore, but averaged $3/3m^3$ seaward.

MAY 1979

Tow performed by USCGC Taney. Proceeded immediately to the northeast from 37° 10' N, 75° 10' N to 39° 10' N, 73° 33' W. It is possible to analyze Blocks #1, 3, 5 for shelf water quantitative comparison. However it must be weighed that near shore components generally differ in abundance and composition from the extending shelf water mass.

JUNE 1979

Unsuccessful tow attempted by USCGC Cherokee. Diverted from transect area after 10-mile tow due to a higher priority interaction. XBT transect unsuccessful, instrument and personnel misunderstanding.

JULY 1979

Tow unsuccessfully attempted by USCGC Cherokee. Reason is the same as above for June. It may be possible to substitute August 5 results if that tow is successful.

AUGUST 1979

Currently attempting tow by USCGC Cherokee on August 5 and tow by USCGC Taney on August 23.

## RECOMMENDATIONS

1. Use High-endurance cutters whenever possible. These ships carry Marine Science Technicians familiar with oceanographic equipment.
2. Schedule tows for the first part of each month to allow for rescheduling in the event of an unsuccessful tow.
3. May be useful in future analysis to further subdivide water masses into coastal (nearshore), shelf, shelf-slope, slope, and gulfstream. This is based on physical and biological parameters.
4. Save euphausids for further identification. Numbers are generally high in shelf (excluding nearshore Blocks), low near frontal areas, and high in slope. This probably reflects changes in dominant species which may be useful for designating water mass indications since euphausids are large in size and common year-round in this transect area.

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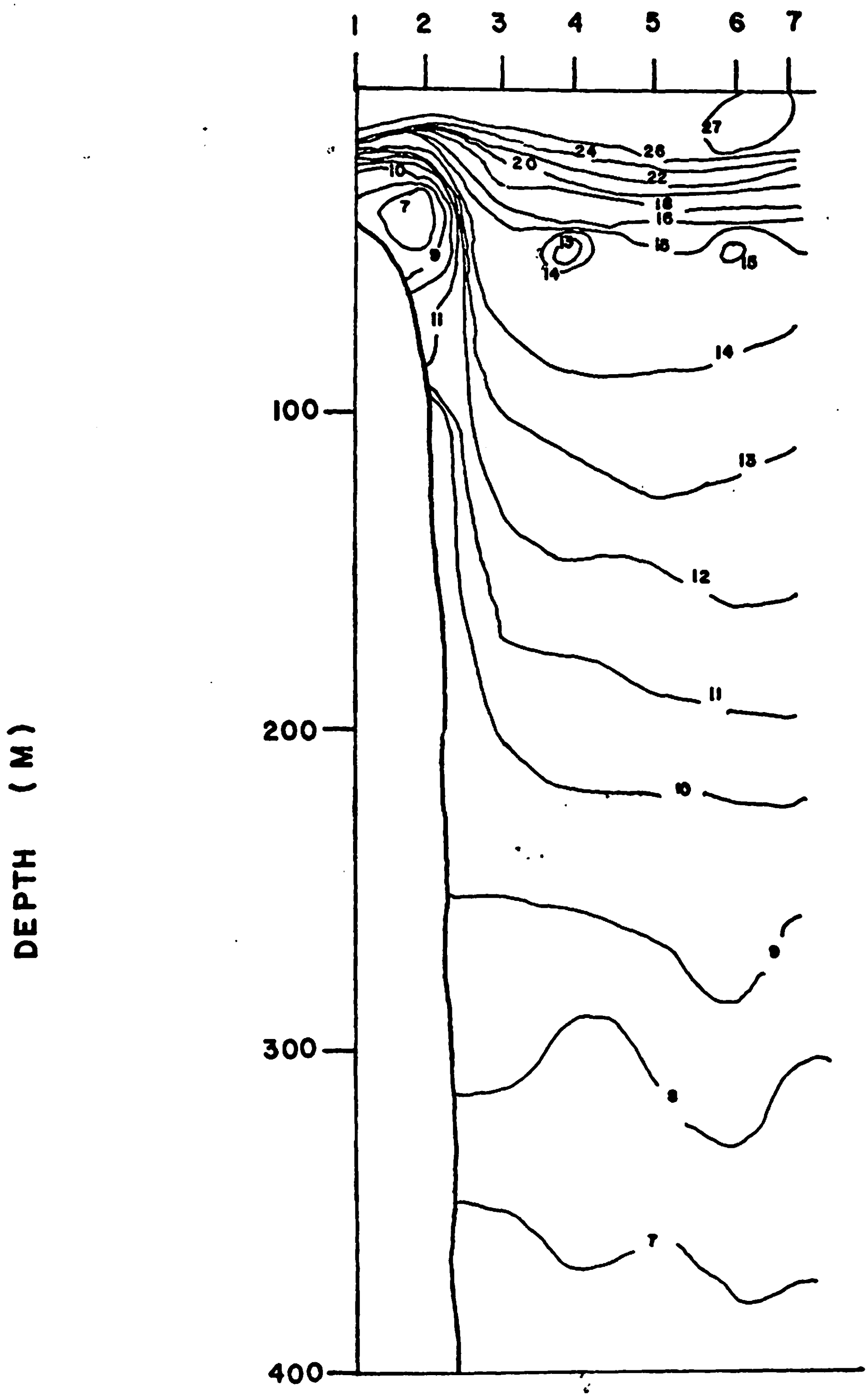
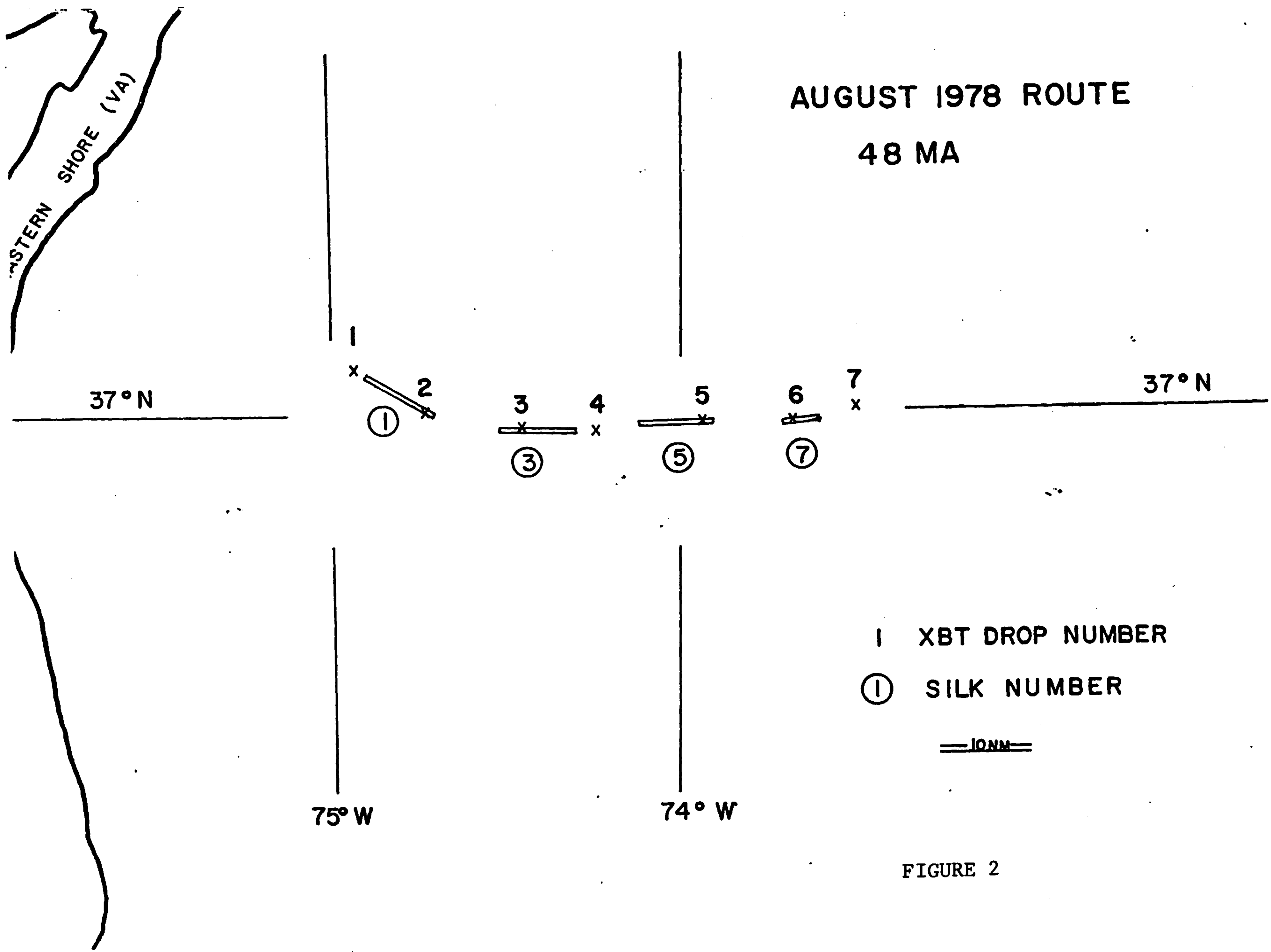
Wright, W. R. and C. E. Parker. 1976. A volumetric temperature/salinity census for the Middle Atlantic Bight. Limnol. and Oceanogr. 21(4):563-571.




AUGUST 08/31/78 - 09/01/78

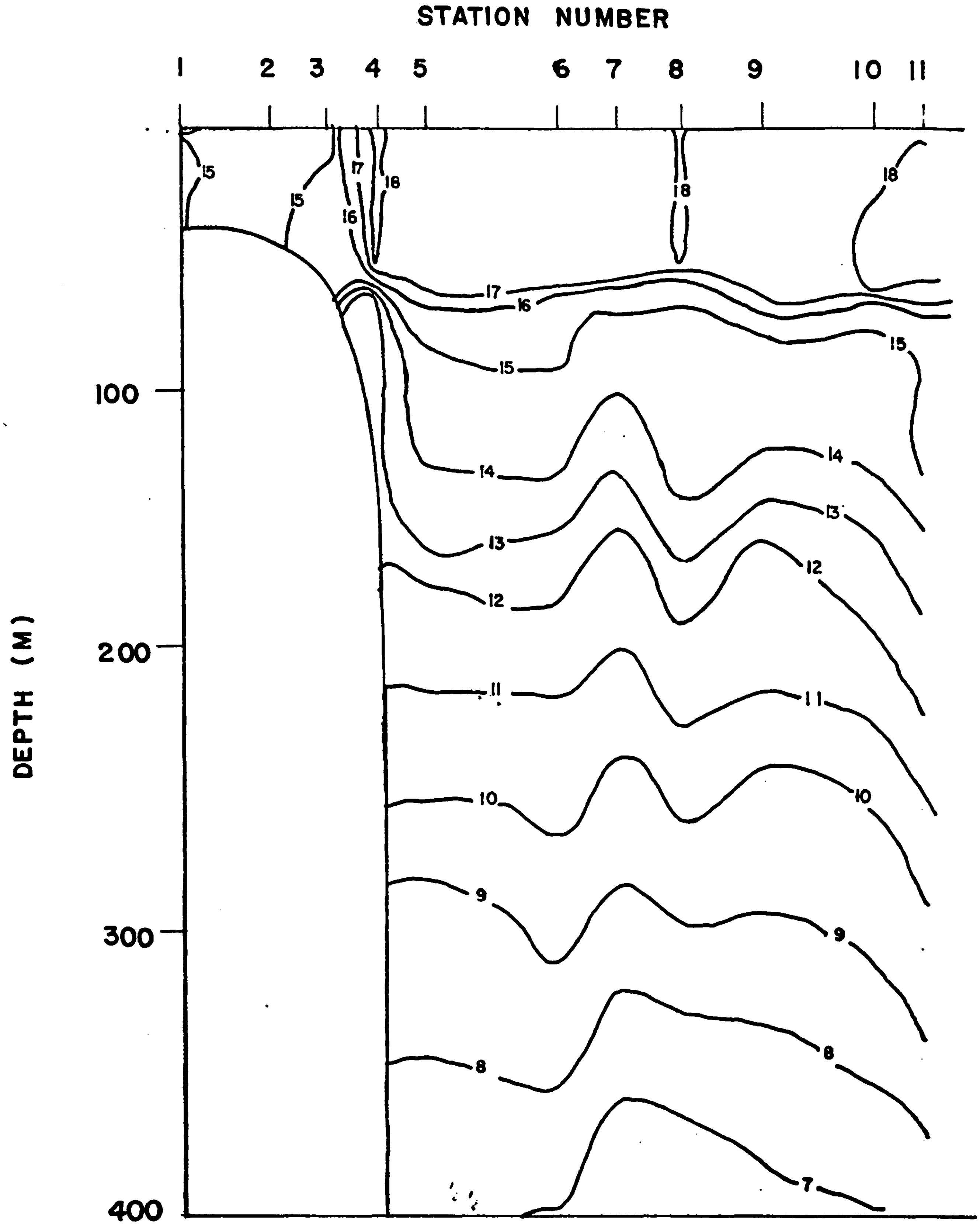
USCGC TANEY ⊢20 NM⊣

FIGURE 1



AUGUST 1978 ROUTE
48 MA
EASTERN SHORE (VA)
37° N
37° N
75° W
74° W
1
2
3
4
5
6
7
①
③
⑤
⑦
1 XBT DROP NUMBER
① SILK NUMBER
10NM


FIGURE 2




NOVEMBER 11/23/78

FIGURE 3

USCGC INGHAM

├—20 NM—┤

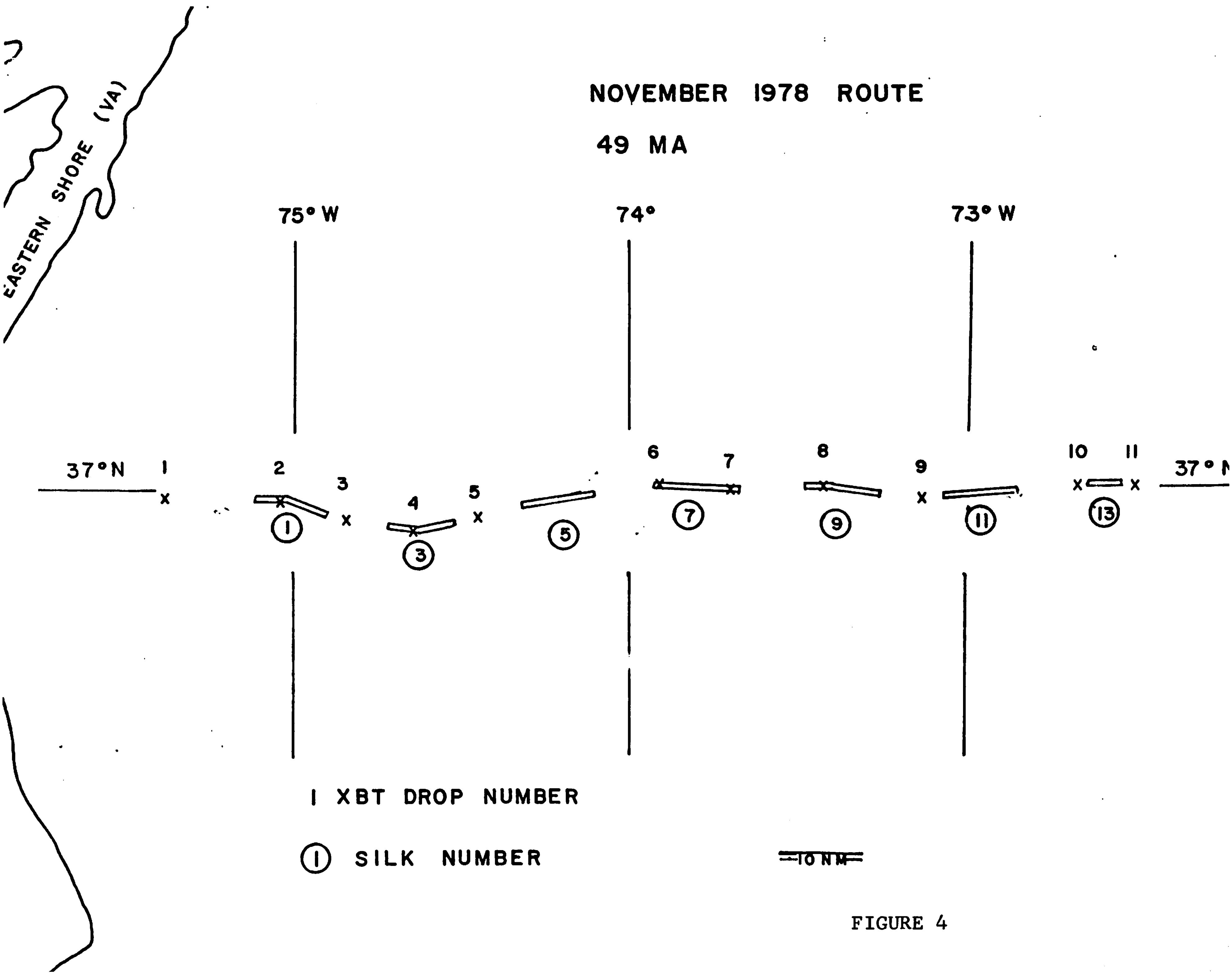

NOVEMBER 1978 ROUTE
49 MA
EASTERN SHORE (VA)
75° W
74°
73° W
37° N
37° N
1
2
3
4
5
6
7
8
9
10
11
1
3
5
7
9
11
13
1 XBT DROP NUMBER
1 SILK NUMBER
10 NM

FIGURE 4

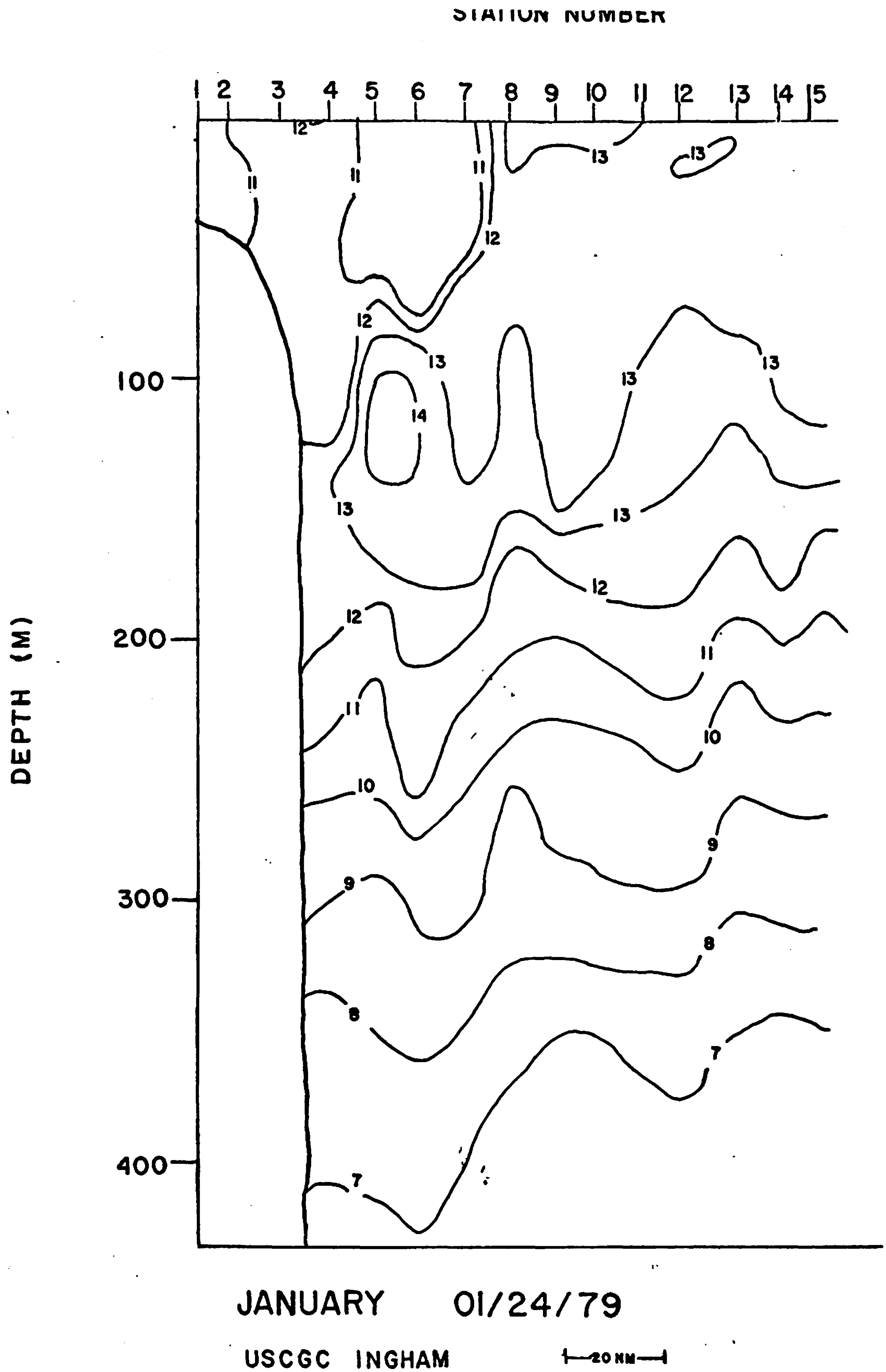
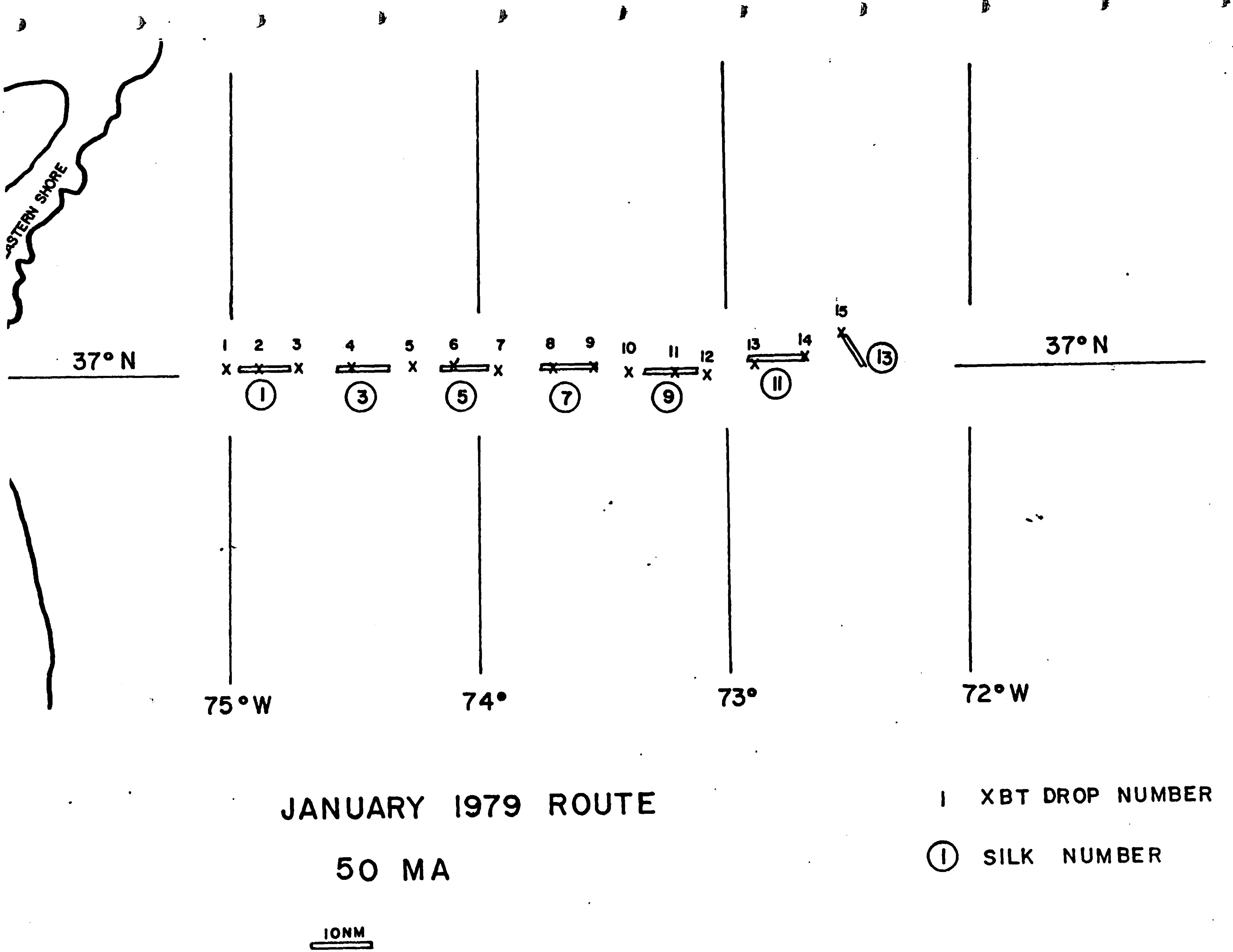
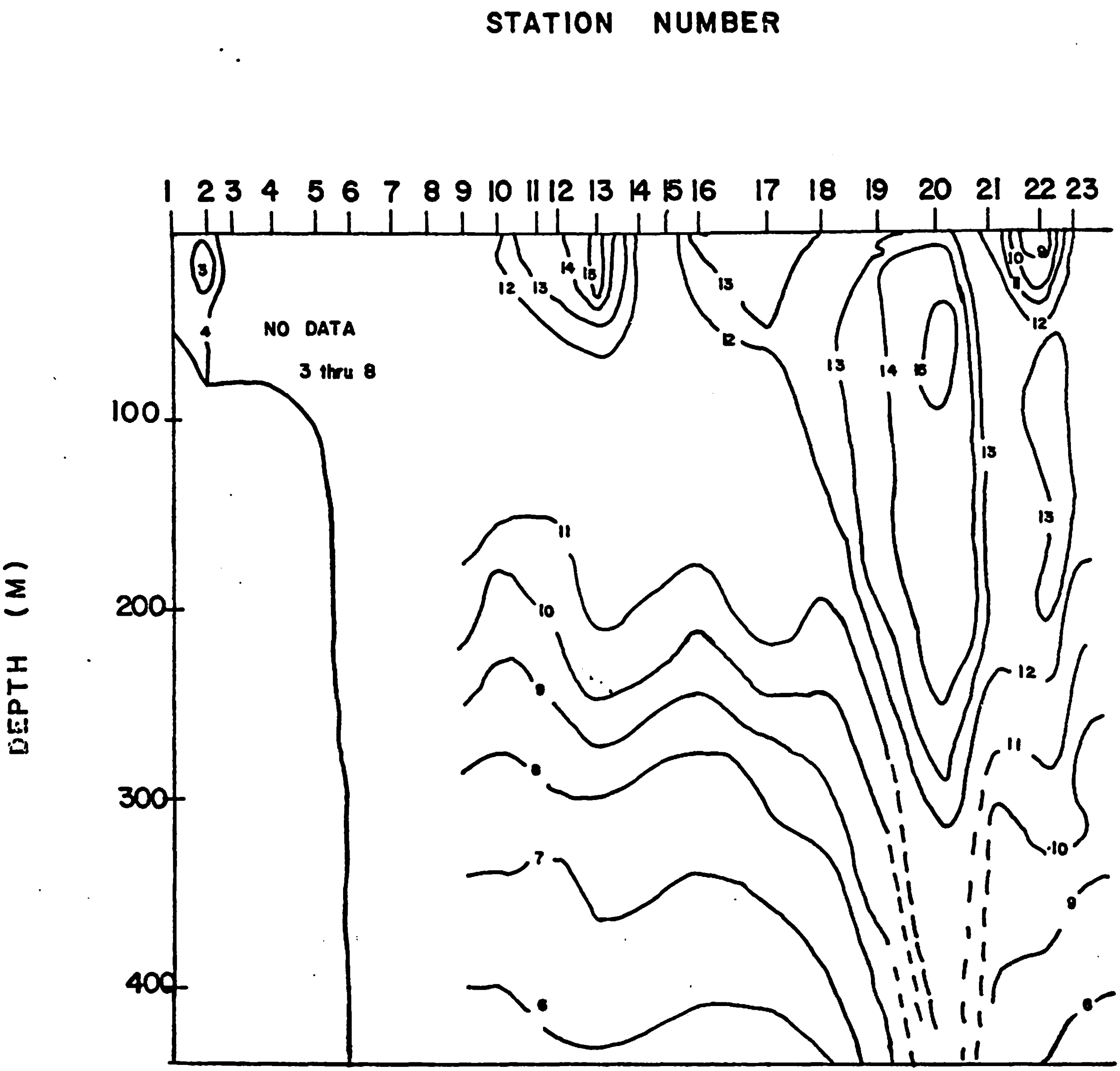

STATION NUMBER
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
DEPTH (M)
100
200
300
400
11
12
13
14
10
9
8
7
JANUARY 01/24/79
USCGC INGHAM
20 NM

FIGURE 5



EASTERN SHORE
37° N
37° N
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
1 3 5 7 9 11 13
75° W
74°
73°
72° W
JANUARY 1979 ROUTE
50 MA
1 XBT DROP NUMBER
1 SILK NUMBER
10NM


FIGURE 6




MARCH 03/02/79

USCGC INGHAM

NOTE/ COURSE CHANGE NEAR STATION 12,
L-SHAPED TO NORTHEAST

FIGURE 7

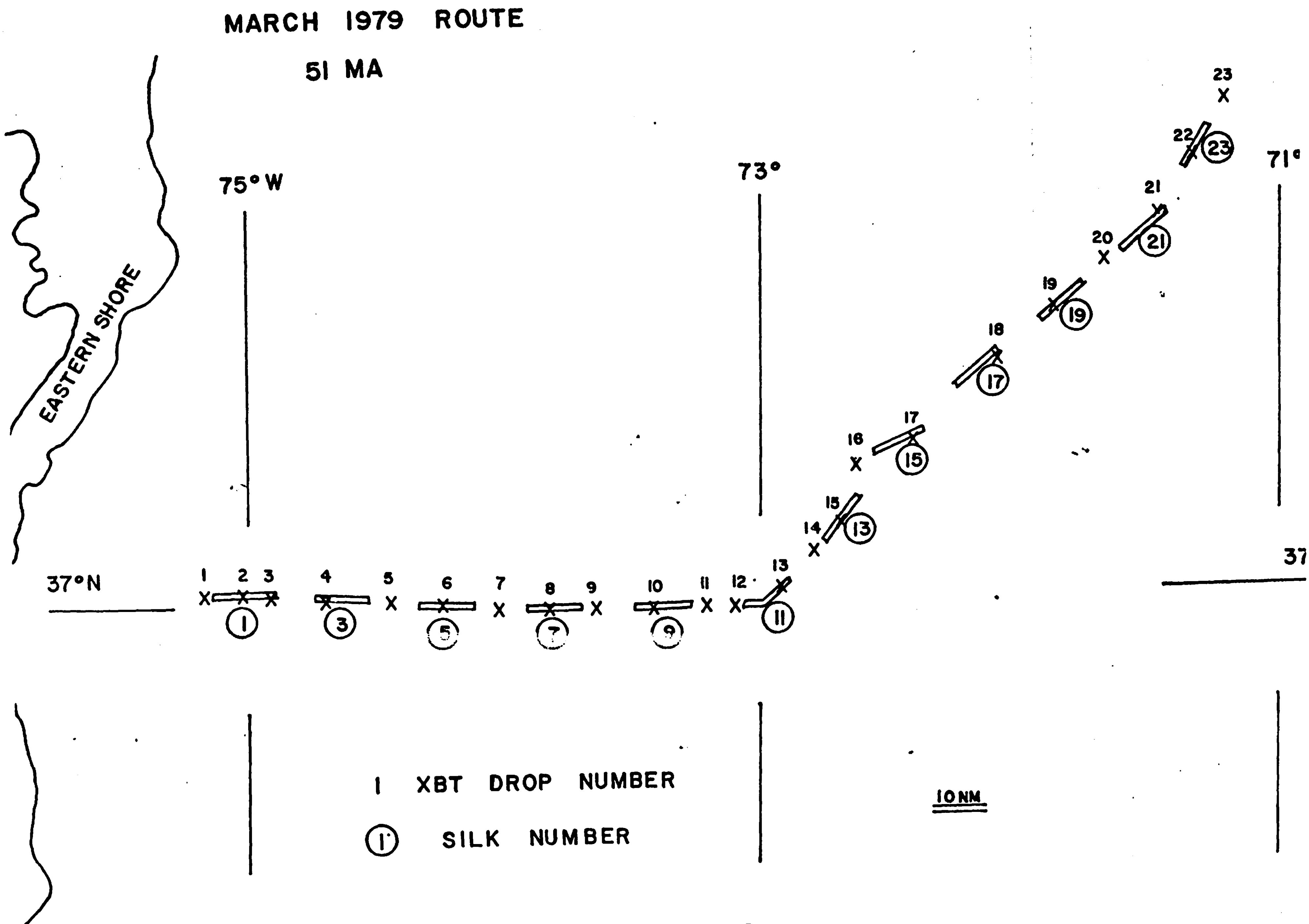

MARCH 1979 ROUTE
51 MA
EASTERN SHORE
75° W
73°
71°
37° N
37
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
1 3 5 7 9 11 13 15 17 19 21 23
1 XBT DROP NUMBER
1 SILK NUMBER
10 NM

FIGURE 8

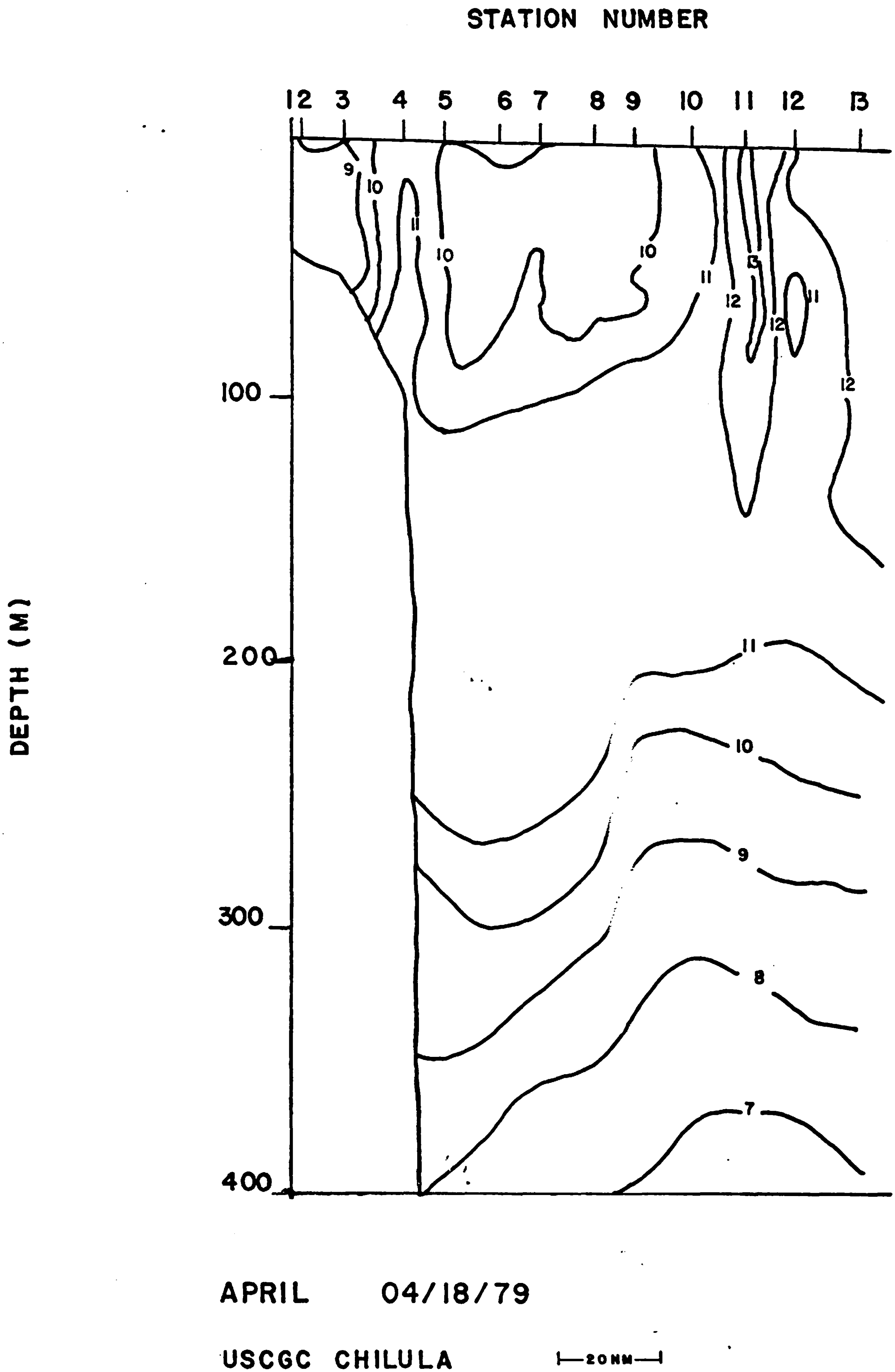

STATION NUMBER
1 2 3 4 5 6 7 8 9 10 11 12 13
DEPTH (M)
100
200
300
400
9
10
11
10
10
11
12
13
12
11
12
11
10
9
8
7
APRIL 04/18/79
USCGC CHILULA
20NM

FIGURE 9

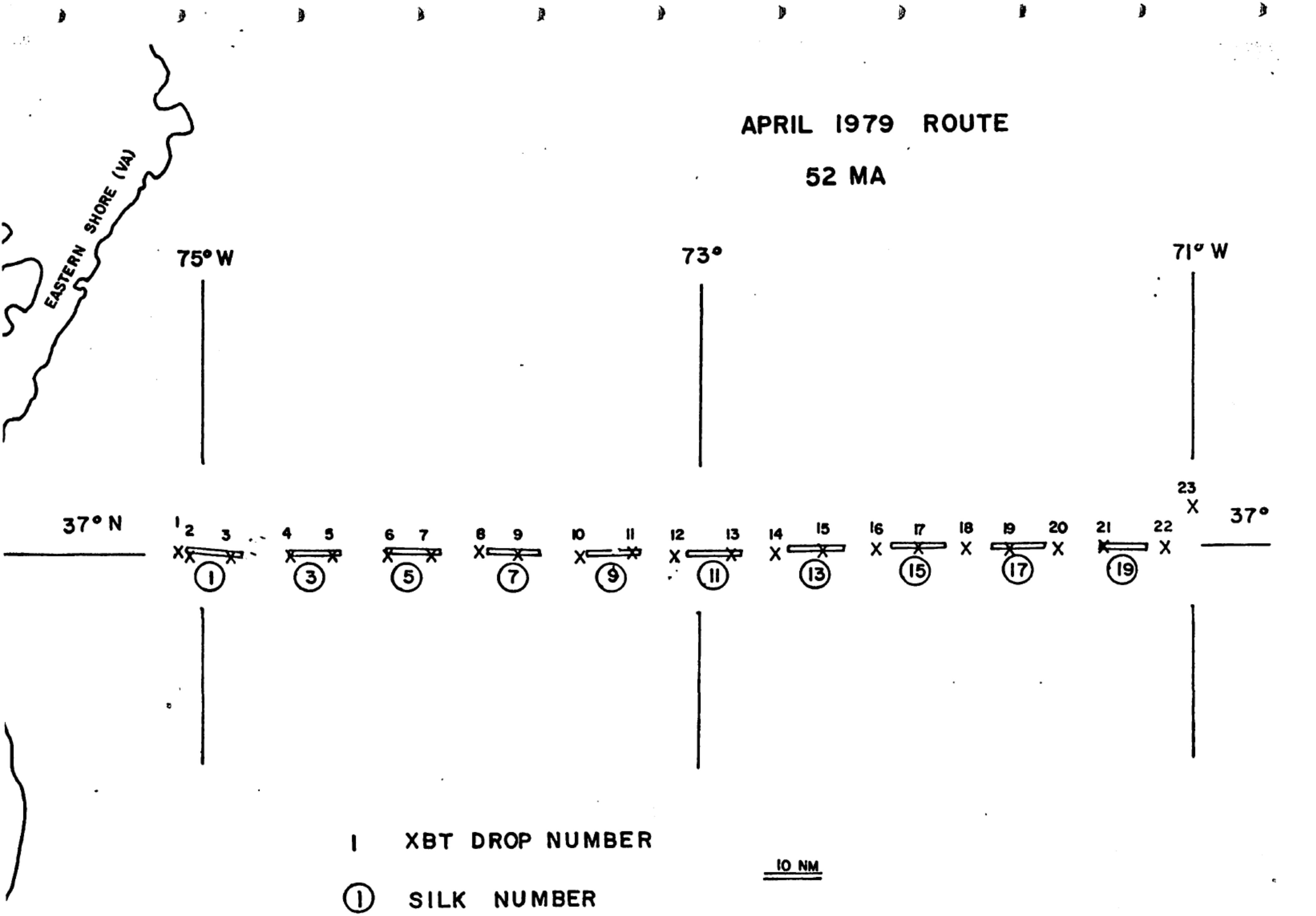

APRIL 1979 ROUTE
52 MA
EASTERN SHORE (VA)
75° W
73°
71° W
37° N
37°
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
1 3 5 7 9 11 13 15 17 19
1 XBT DROP NUMBER
1 SILK NUMBER
10 NM

FIGURE 10

# CONTINUOUS PLANKTON RECORDS:
# ZOOPLANKTON AND NET PHYTOPLANKTON IN THE SOUTHERN REGIONS OF THE MIDDLE ATLANTIC BIGHT
# 1978-80

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Part II

FINAL REPORT SUBMITTED TO THE
NATIONAL MARINE FISHERIES SERVICE

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Contract #NA-79-FAC-00009

# INTRODUCTION

The National Marine Fisheries Service (NMFS) Platform of Opportunity Program provides environmental and biological monitoring data for the Middle Atlantic Bight. Temperature (XBT), salinity (surface), and plankton (CPR) are monitored on a monthly basis along standard transects as defined by the Atlantic Environmental Group of NMFS. The standard transect for the southern Middle Atlantic Bight extends from the mouth of the Chesapeake Bay (20-fathom isobath) eastward to the Gulf-stream.

This study is part of a cooperative agreement between the MARMAP Program of the National Marine Fisheries Service, the U. S. Coast Guard, the Institute of Marine Environmental Research (IMER) of the United Kingdom and the Virginia Institute of Marine Science. The objectives of this survey include:

1) determine composition, abundance, and distribution of phytoplankton and zooplankton communities within two distinct water masses, shelf water and slope water;
2) identify seasonal and annual cycles in plankton dynamics, long term trends; and,
3) document spatial and temporal variations in the observed plankton dynamics in terms of timing and duration.

This report represents the conclusion of two year's analysis of the Chesapeake Route and is divided into three sections.

Part 1 provides a descriptive account of XBT, surface salinity and surface temperature analysis and a graphical presentation of XBT vertical sections along with the 1980 routes. Part 2 presents a monthly synopsis of the 1980 phytoplankton and zooplankton analysis. Part 3 is a comprehensive analysis of copepods using a composite five-year data base, 1974-1980 from the Chesapeake Route.

## METHODS

Plankton samples were collected at a depth of 10 m along the defined transect (e.g. Fig. 1) by U. S. Coast Guard vessels towing Hardy Continuous Plankton Recorders (CPR). Three cubic meters of water were filtered every 10 nm onto a continuously moving band of bolting silk (24 meshes per cm or 225 µ X 234 µ aperture) through an opening of 1.61 $cm^2$ in the nose of the CPR. The entire bolt of silk corresponding to a transect was cut into segments equivalent to 10 n.m of tow, numbered and treated as a single sample.

Hourly expendable bathythermograph (XBT), surface temperature and surface salinity measurements were taken bracketing the CPR tow. Vertical profiles were contoured using the XBT data to determine the water column thermal structure through which the CPR was towed. The contoured vertical profile, surface temperature, surface salinity, and satellite imagery (AEG-modified NESS oceanographic analysis) were used to determine the water mass from which each CPR sample originated.

A detailed account of CPR phytoplankton and zooplankton analyses has been described in Hardy (1939) and Colebrook (1960) and is summarized here. Species of phytoplankton were enumerated as the number of occurrences per twenty fields (.295 mm diameter) regardless of density within a specified field. This value was then converted to number per liter (Hardy, 1939).

Zooplankton enumeration was categorized according to the size range of individual taxa. Those groups less than 2.0 mm were subsampled; and each taxa counted as viewed within one complete staggered traverse of an individual silk. The area examined in this manner was equivalent to 1/49th of the entire 10 - nm silk. Number categories (Hardy, 1939) were used instead of actual counts. After the traverse examination, the number of organisms greater than 2.0 mm, present on the entire silk were enumerated by taxa. Number categories were used in this eyecount examination as well.

## RESULTS AND DISCUSSION

### Water Column Thermal Structure Across the Shelf and Slope East of Chesapeake Bay in 1980

During 1980, five expendable bathythermograph (XBT) transects were run over the continental shelf and slope east of the mouth of the Chesapeake Bay along 37°N. Contoured sections were drawn and analyzed for April, May, June, August and September. These data were correlated with the biological data obtained coincidentally using the Continuous Plankton Recorder (CPR) to identify and define water mass specific plankton assemblages. In addition special features of the water column thermal structure were monitored including: position of the shelf water-slope water front; eddies formed from the Gulf Stream, and variations in temperature and position of bottom water cold cell on the continental shelf. Position of the shelf water-slope water front was determined primarily through analysis of subsurface temperature gradients contoured as a vertical section. In addition surface temperature and surface salinity gradients along with AEG-modified National-Environmental Satellite Service (NESS) satellite imagery were used as supporting data.

FEBRUARY: Hourly surface temperature measurements were taken along an 89 n.m. CPR transect (Fig. 1), however XBT measurements were unsuccessful. Using only surface data the shelf water - slope water front was positioned seaward of Station 5 in the vicinity of 37°N 74° 35'W. Surface shelf water temperatures ranged from <3.0°C coastally to >9.0°C near the front. Slope water surface temperatures were more constantly fluctuating between 10-13°C.

APRIL: Thirteen XBT's were dropped along an 112 n.m. CPR transect (Fig. 2). Thermal subsurface analysis placed the shelf water - slope water front seaward of Station 5 near 36° 55'N 74° 20'W (Fig. 3) and was verified by the AEG-modified NESS analysis, 19-23 April. Subsurface water deeper than 20m was well mixed at 10°C over the continental shelf, while surface temperatures in the area had warmed to 11°C or greater. At this time the cold cell was not evident along the sampled shelf. Slope water surface temperatures ranged from greater than 12°C to less than 15°C. Upwelling of deep water between 150 - 400 m depth was noted along slope stations 7-9. Analysis of satellite imagery for this area revealed no eddy activity.

MAY: Seventeen XBT's were dropped along a 156 nm CPR transect (Fig. 4). The transect extended due northeast from the mouth of the Chesapeake Bay. According to XBT thermal analysis (Fig. 5), surface salinity determinations and the satellite analysis 4-7 May as modified by AEG, the transect ran parallel to the shelf water - slope water front but remained in shelf water. The first evidence of cold cell formation was noted by the presence of the characteristic "bubble-like structure" on the continental shelf at station 7-9. Temperatures ranged from less than 7°C to 9°C and the cell extended from a minimum bottom depth of 30 m to a maximum of 80 m. The horizontal extent exceeded 40 nm. The structure was approximately 35 m thick at the center. Spring warming resulted in stratification of surface waters with nearshore temperatures exceeding 15°C. Surface temperatures between Station 8-15 remained constant, 10.7 - 11.8°C. Subsurface structure in this area was less stable evidenced by various isolated parcels of warm and cool water. This was probably due to the close proximity of the shelf - slope water front. Stations 15-17 exhibited much warmer surface temperatures (greater than 14°C), however surface salinity remained below 34 o/oo, thus shelf water. Again this was the result of the transect running parallel to the front through a very dynamic area.

JUNE: The CPR was towed 220 nm, and twelve XBT's were successfully dropped along the shoreward half of the transect (Fig. 6). The shelf - slope water front was positioned just seaward of Station 5 near 37° 01' N 74° 40'W (Fig. 7). Intense stratification over the shelf was observed where temperatures ranged from 8°C to greater than 20°C between the cold cell and surface waters respectively. The thermocline was strongest nearshore between 10-20 m depth. The cold cell structure was evident close to the shelfbreak, where temperatures ranged from 8°C in the core to 10°C along the boundary. The shoreward extension of the entire cell was not determined. However the 8°C core extended horizontally approximately 10 nm with a 25 m thick core. Thermal stratification was not as intense in slope water. Surface temperatures varied between 20°C-25°C.

A pronounced upwelling feature of small horizontal extent (10 nm) was observed seaward of the shelfbreak and another of greater horizontal extent seaward of station 10. According to AEG modified satellite imagery Eddy 79-K was located in close proximity to the northeast of the transect. Subsurface eddy or thermal inversions may have been responsible for the observed water column thermal structure.

JULY: The CPR was towed for 192 nm, however no physical data or hourly log positions were taken. The transect started to the north of the original transect area travelling east. Silks 1,3,5, and 7 were analyzed as shelf water according to AEG modified satellite analysis, 9 July and supported by biological data. Eddy 79-K was present on satellite imagery to the south of the transect.

AUGUST: Eight XBT's were dropped along the transect, unfortunately the CPR malfunctioned. There was a 51 nm gap between Station 4-5 seaward of the shelfbreak (Fig. 8). Based on the downwarping of the isotherms, the shelf - slope water front was positioned just seaward of station 4 near 36° 59'N 74° 20'W (Fig. 9). The seasonal thermocline was strongest nearshore, 10-15 m deep. Surface temperatures across the shelf ranged from 26-27°C. The seaward edge of the cold cell was evident with bottom temperatures less than 10°C. Slope water surface temperatures exceeded 28°C. The transect re-entered shelf water as evidenced by the upwarping of isotherms near station 8 as the course changed northeast.

SEPTEMBER: Six XBT's were dropped along the transect, however the CPR malfunctioned (Fig. 10). The shelf water - slope water front was located between station 3-4, in the vicinity of 36° 59'N 74° 38'N (Fig. 11). The thermocline had intensified and deepened and was strongest nearshore between 22-30 m depth. The cold pool was still a prominent isolated structure with a 9°C core. The cell extended from a minimum bottom depth of 45 m to a maximum of 85 m. The horizontal extent was lessened to approximately 12 nm and the core was 30 m thick at the center. The slope water seasonal thermocline was deeper and less intensified than that of adjacent shelf water. Surface temperatures at the seaward edge of the transect were greater than 24°C, 3° cooler than the surface temperatures observed in August.

## 1980 Plankton Analysis

Due to the poor success of CPR transects August through December and the infrequent entry into slope water in 1980, only the winter-spring shelf communities will be discussed.

PHYTOPLANKTON: Phytoplankton standing stock was low in February 1980, typical of winter conditions. A large diatom Coscinodiscus spp. dominated the shelf community averaging 4.6/liter. Green algal mats were numerous in nearshore coastal areas only.

The major annual diatom spring bloom was not sampled in 1980 but was thought to have occurred during March. A dinoflagellate bloom was observed in May 1980 dominated by Ceratium tripos (16.7/lit), C. fusus (13.1/lit) and C. lineatum (4.8/lit). Dinoflagellate had begun to increase by April. Ceratium tripos dominated the shelf April phytoplankters but in much lower concentrations than May, approximately 3.1/ lit.

Dinoflagellate abundance declined in June while diatoms increased. Rhizosolenia alata alata dominated both water mass assemblages averaging 4.6/liter and 3.1/liter in shelf and slope water, respectively. By July Rhizosolenia alata alata had increased to 5.2/liter in shelf water. Dinoflagellates also increased in July with Ceratium tripos and C. fusus stocks reaching 16.8/lit and 10.5/lit in shelf water.

COPEPODS $\leq$ 2.0 mm: Diversity, in terms of the absolute numbers of species encountered was lowest in February, typical of the seasonal cycle. Species number increased to a maximum in May and was similar to the average long-term value for May. Standing crop values followed a similar trend to that of diversity increasing from a minimum of $48/m^3$ in February to a maximum of $415/m^3$ in May. In each case the 1980 standing stock value was much lower than that of the long term average standing crop for that particular month. Both diversity and standing crop values decreased in June followed by an increase in July. The observed standing stock in July ($748/m^3$) was much higher than the recorded long term average for that month. The phytoplankton standing stock, both diatom and dinoflagellates, in 1980 was much higher than the long-term average or the 1979 value which may explain the pulse in zooplankton standing crop in 1980.

The early winter copepod community was dominated by adult Centropages typicus and Para-pseudocalanus spp. By early spring Clausocalanus sp replaced Para-pseudocalanus in importance with C. typicus still dominant ($76/m^3$). In May at the peak of the winter-spring assemblage Oithona sp and Calanus copepodites had increased and were frequently observed in moderate numbers ($20/m^3$). Centropages typicus ($65/m^3$) dominated inshore being replaced by Clausocalanus ($83/m^3$) seaward. As the winter spring community declined in June, Oithona dominated in the shelf assemblage. Adult C. typicus were absent however copepodites of Centropages were present in moderate numbers. The summer-fall community usually becomes established during July with the appearance of subtropical forms such as Oncaea, Corycaeus and the disappearance of cool water forms such as C. typicus and Oithona. However, July 1980 was anomalous not only in terms of absolute abundances but also the dominant plankters. A substantial peak in C. typicus was observed in July ($300/m^3$). Oithona and Clausoclanus also appeared in relatively high numbers.

The winter-spring assemblage was dominated by C. typicus, which was the only copepod observed within shelf water every month sampled. It constituted from 10-75% of the total standing crop throughout the sampling period. Previous studies also

also indicated dominance of shelf zooplankton by C. *typicus* based on frequency of occurrence year-round (Grant, 1979, Grice and Hart, 1962).

COPEPODS >2.0mm: Trends in diversity and absolute standing stock paralleled those of copepods ≤ 2.0 mm. During winter the shelf copepod assemblage was comprised of *Calanus finmarchicus*, *Metridia lucens*, and *Pleuromamma borealis*. During peak abundances *C. finmarchicus* reached $2.5/m^3$. *Candacia armata* appeared in low abundances ($<1/m^3$) late in winter, early spring.

OTHER ZOOPLANKTERS: Chaetognaths were present every month sampled. They occurred sporadically in low abundances ($<1/m^3$) during February, April, and May. Chaethtognath abundances increased to $5/m^3$ for June and July.

Adult euphausids appeared in low numbers in April. By May, very high numbers were recorded ($>6/m^3$) mostly juveniles.

Zooplankton Analysis: Composite 5 Year Mean

Monthly sampling was initiated August 1974 and has been analyzed through August 1980. A total of 42 samples have been taken in shelf and 35 in slope water. The irregularity of the data is the result of conflicting Coast Guard operational priorities, ship breakdown, and equipment malfunction.

The actual months sampled and number of silks analyzed per water mass per month is shown in Table 1. An abundance value is the mean of all silks (three cubic meters filtered) sampled that month in a particular water mass. A composite one year mean was established by averaging all January samples to give a mean long term January and so on for all months. This long term composite year will be used as a comparison for future sampling in terms of timing, duration and magnitude of phytoplankton and zooplankton community dynamics. In addition all subsequent samples will be incorporated into the composite year.

COPEPODS $\leq$ 2.00 mm

The abundance of total copepods $\leq$ 2.0 mm for a composite mean year is illustrated in Fig. 12 a for both shelf and slope water. All standing stock values represent mean number of individuals per cubic meter of filtered sample. The mean number of species observed within a water mass will be used as an index of diversity. The diversity of copepods $\leq$2.0 mm for a composite year is presented in Fig. 12b for each water mass. Of all zooplankton categories analyzed, copepods $\leq$2.0 mm is the most abundant group numerically and is represented by the greatest number of species.

Two phases in diversity are exhibited in shelf water over an annual cycle (Fig. 12b). The number of species is characteristically low November through June, the winter-spring assemblage. Diversity increases abruptly in July and is maintained through the summer reaching a peak in October, characterizing the summer-fall assemblage. The number of species declines sharply in November decreasing to a minimum level in February. Peak species diversity for the late winter period is noted in April, however this pulse is much less in terms of absolute number of species compared to the summer-fall pulse.

Slope water is characterized by two seasonal peaks in diversity, April and September. In each case there is a progressive increase January to April and June to September followed by an abrupt decline. The absolute number of species is similar for the winter-spring and summer-fall peaks.

In general the trends in diversity during the period of winter-spring are similar between water masses in terms of timing and duration. The observed absolute number of species however differ by almost two-fold between shelf and slope. In contrast the absolute number of species appear similar between water masses during the summer-fall period, while duration and timing differ. Diversity increases more rapidly and is sustained for a greater length of time in shelf than that observed for slope water. The early decline in the number of species within slope water may reflect a diminished food supply available in these waters.

Shelf water standing crop values (Fig. 12a) for copepods $\leq$2.0 mm increase gradually through winter into March from the minimum abundance observed in January. Abundance increases abruptly three-fold from March (151/$m^3$) to April (435/$m^3$) and is maintained through May. The standing stock decreases in June and fluctuates irratically through the summer. Very low values are observed in August followed by a five-fold increase in abundance by October. This fall peak is short-lived decreasing rapidly to low winter values ($141/m^3$). The shelf water spring and fall peaks are similar in terms of absolute abundance however, the spring pulse is of longer duration than the abrupt fall increase.

Analysis of slope water standing crop reveals two annual peaks, April and November. Abundance values increase progressively from a minimum in January to a peak in April ($479/m^3$) with a similar decline into June. Low numbers ($<109/m^3$) are maintained through the summer into October. A pulse in standing crop of one month's duration is observed in November $226/m^3$ declining to a low value again by December. The slope water spring pulse is much greater in terms of absolute abundance and is of longer duration than that observed for fall.

In general, shelf and slope standing crop values during winter-spring are similar. The slope pulse occurs earlier and is of longer duration than in shelf water. Total copepod abundance remains much higher in shelf than slope throughout the annual cycle. Standing crop in slope water remains quite low $35\text{-}100/m^3$ year-round except for a 3-month spring and 1-month fall increase. In contrast shelf water exceeds $100/m^3$ year-round except January. The summer-fall peak is numerically much smaller and a month later in slope than adjacent shelf waters.

Peaks in diversity coincide with peaks in abundance during spring for both water masses. Shelf diversity is much less than slope during the spring peak even though standing crop values are similar. In contrast shelf diversity equals slope diversity during the fall peak; but shelf standing stocks is 2x greater than slope.

The winter-spring assemblage in shelf water is characterized by adult Centropages typicus, Para-pseudocalanus spp., Oithona spp. and Clausocalanus spp. All of these are cool-water or ubiquitous forms. In slope water the community is characterized by the above species plus a few warm-water genera such as Oncaea and Corycaeus both of which are absent in shelf $H_2O$. In addition copepodites of larger copepods (>2.0 mm) comprise a significant portion of the slope community.

Centropages typicus dominates the winter-spring community in both water masses comprising an average of 58% of the total in shelf samples and 47% of the total in slope samples. Para-pseudocalanus is second comprising 26% of the slope total and 20% shelf.

The summer-fall assemblage in shelf water is characterized by high diversity and evenness, i.e. no one particular species dominates the standing crop. Clausocalanus, Oncaea and Corycacus increase greatly in importance within shelf water. C. typicus occurs sporadically, however it can be found in great numbers upon occasion. In addition, tropical forms such as Farranula sp., Centropages furcatus and Mecynocera clausi are observed in the shelf water summer-fall community, but only in the lowest abundances.

Slope water is also characterized by high diversity and evenness; however, the absolute standing crop present at any one time is very low. Cool-water forms such as C. typicus and Para-pseudocalanus spp. are absent in most cases, however sporadic occurrence in low numbers may be observed. Oncaea, Clausocalanus and Corycaeus predominate, comprising an average $\leq$20% each of the total. Occurrence of tropical forms is not infrequent and individual species such as C. furcatus may comprise 10% of the standing crop in a particular month.

Centropages typicus is the most frequently occuring copepod within shelf water year-round. In this study it is present in 38 of 43 months sampled (90%). Abundances range from 5 to 758/$m^3$ in samples from November to May and 0 to 304/$m^3$ June throught October. Other studies using standard sampling gear indicate dominance of shelf zooplankton by C. typicus based on frequency of ocurrence for areas in the southern regions of the Mid-Atlantic Bight (Grant, 1979, Grice and Hart, 1962).

Oncaea, Oithona and Clausocalanas were each observed in 60% of the slope samples, thus are the most frequently occurring species within slope water. However standing crop values observed for any one of these taxa was always $<50/m^3$. C. typicus is present in slope water 19 of 35 sampled (54%), however it is absent only once from January-May. It reaches max abundance in slope water of $154/m^3$ by May. Summer-fall abundance of C. typicus range from 0 to $21/m^3$.

ZOOPLANKTON ANALYSIS

Copepods $>$2.0 mm will be treated as a separate category due to the method of enumeration. All standing crop values are based on the number observed upon the entire silk, in contrast to the subsample method used for copepods $\leq$ 2.0 mm. In addition copepods $>$ 2.0 mm are target prey of different predator species or different size of the same predator species feeding on copepods $\leq$ 2.0 mm. Thus categorial separation discussed above is supported by separation based on trophic function.

The mean number of species observed within a water mass in a particular month is used as an index of diversity for copepods $>$ 2.0 mm (Fig. 12c). As with copepods $\leq$ 2.0 mm, diversity appears two-phase in shelf water. Low diversity is observed January to June followed by an abrupt increase in July. This high diversity is maintained through the summer into October, at which time the number of species declines sharply by November.

In slope water diversity is bimodal, also a characteristic of copepods $\leq$ 2.0 mm. There is a progressive increase from January to a peak in April followed by a decline in June.

The absolute number of species is much higher in slope water during winter-spring compared to the shelf water mass.

Slope diversity increases in July and maintains a high level through November with moderate monthly fluctuations. Absolute numbers are similar between the two water masses during the summer. In contrast, slope diversity is sustained longer and does not decline to winter values until January compared to the shelf decline in November.

The shelf winter-spring community is comprised of Calanus finmarchicus, Metridia lucens and Pleuromamma borealis. C. finmarchicus occurs in 50% of all the samples taken January to June reaching a maximum abundance of $2/m^3$ in April. Metridia lucens occurs in fluctuating numbers depending on the proximity of the shelf/slope front. Pleuromamma abundances also fluctuate due to diel migratory habits.

In slope water the winter-spring community is also dominated by the cool-water forms listed above. Sporadic occurrences of warm-water fauna such as Euchaeta marina and Undinula vulgaris in low abundances is observed in slope water. C. finmarchicus occurs less frequently (35% of all samples, January-June) in slope water but may occur in abundances equal to those observed in shelf water. Pleuromamma borealis is present in similar abundances in both water masses, dominating the communitiies in January and February.

The dichotomy between shelf winter-spring and summer-fall communities is more defined and evident for copepods

>2.0 mm. The cool-water forms dominant through May, occur very seldom and then in numbers <1/$m^3$ July-November. The summer-fall shelf community is dominated by Nannocalanus minor. Peak abundances reach 4/$m^3$ in July and November. This is the greatest average abundance of any copepod > 2.0 mm observed in shelf water. Tropical forms such as Euchaeta marina and U. vulgaris also contribute significantly to the total shelf standing stock.

Nannocalanus minor is also an important component of slope summer-fall assemblage reaching a maximum abundance of 1/$m^3$ in July and November. The total abundance of all copepods >2.0 mm is distributed evenly among the species. No one particular species dominates the community. Undinula vulgaris and Euchaeta marina occur more frequently and in greater numbers than observed in slope water during winter-spring and more than observed in shelf water summer-fall. Occurrence of many tropical forms such as Scolecithrix danae, Pleuromamma abdominalis, and species of Copilia and Sapphirina are noted regularly in low abundances.

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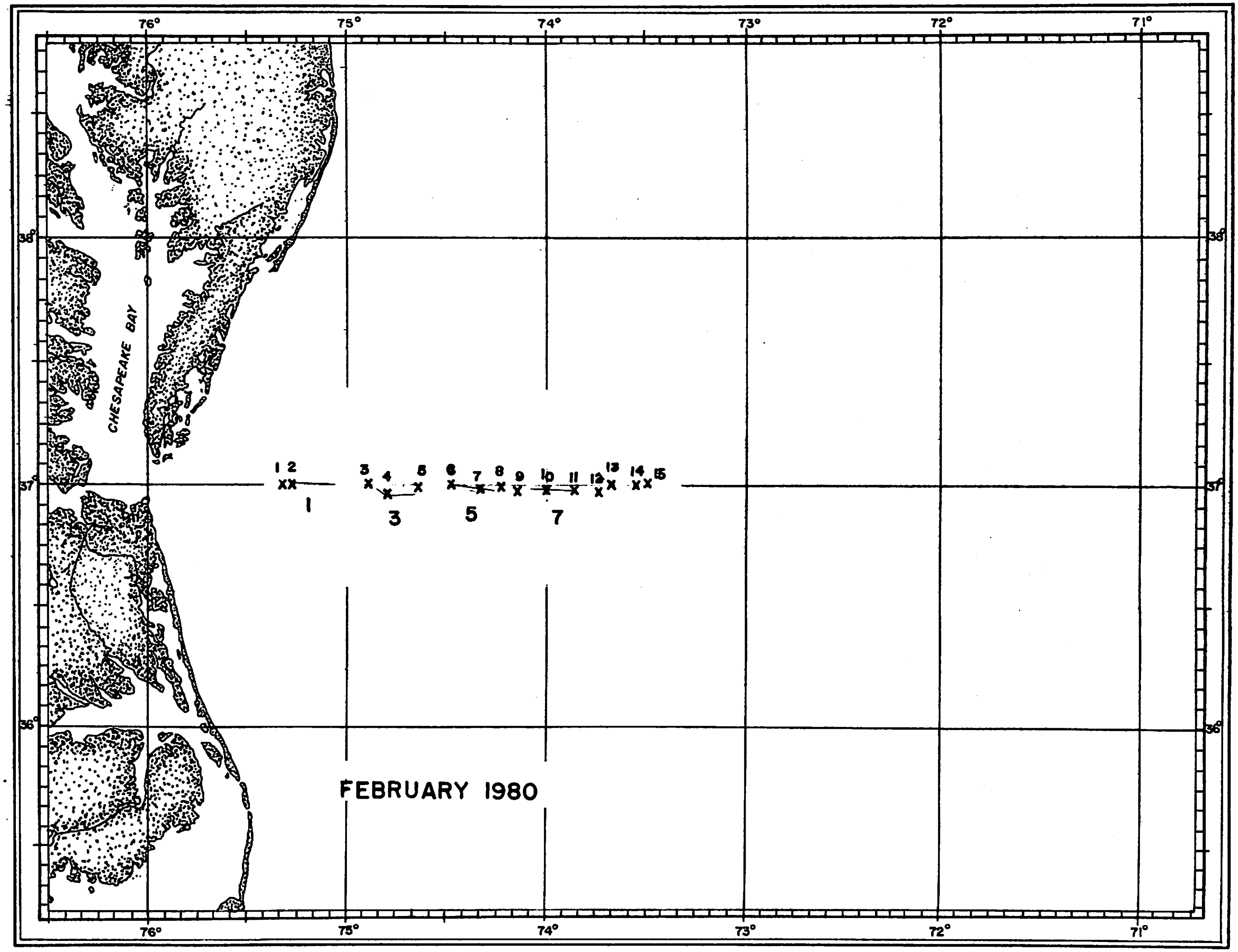


FIGURE 1. Transect positions of CPR samples and XBT/Surface Stations, February 1980. In this figure and the following: the X and small number above the transect correspond to XBT/Surface Stations and the horizontal (10-nm) bar and large number below the transect correspond to CPR blocks.

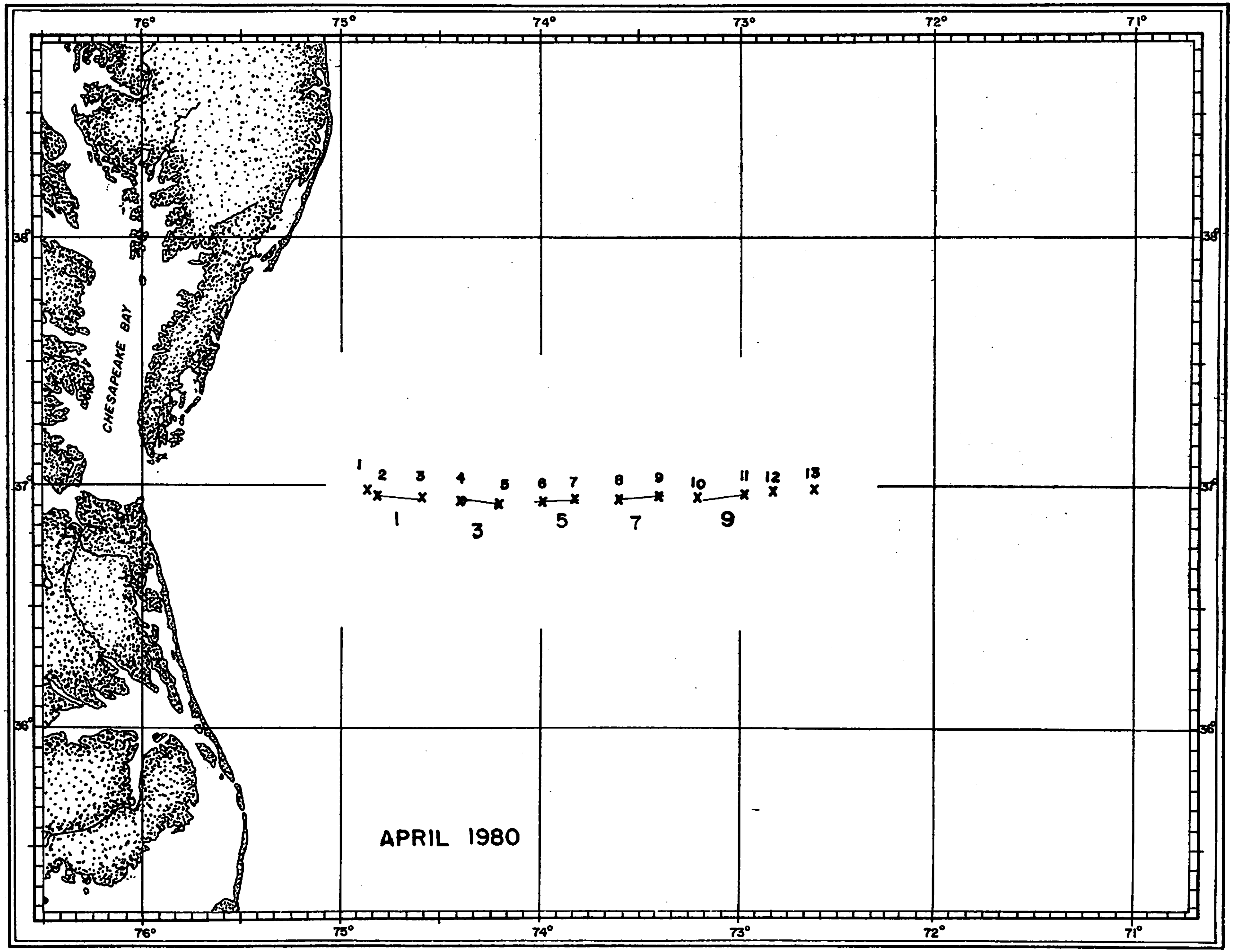


FIGURE 2. Transect positions of CPR samples and XBT/Surface Stations, April 1980.

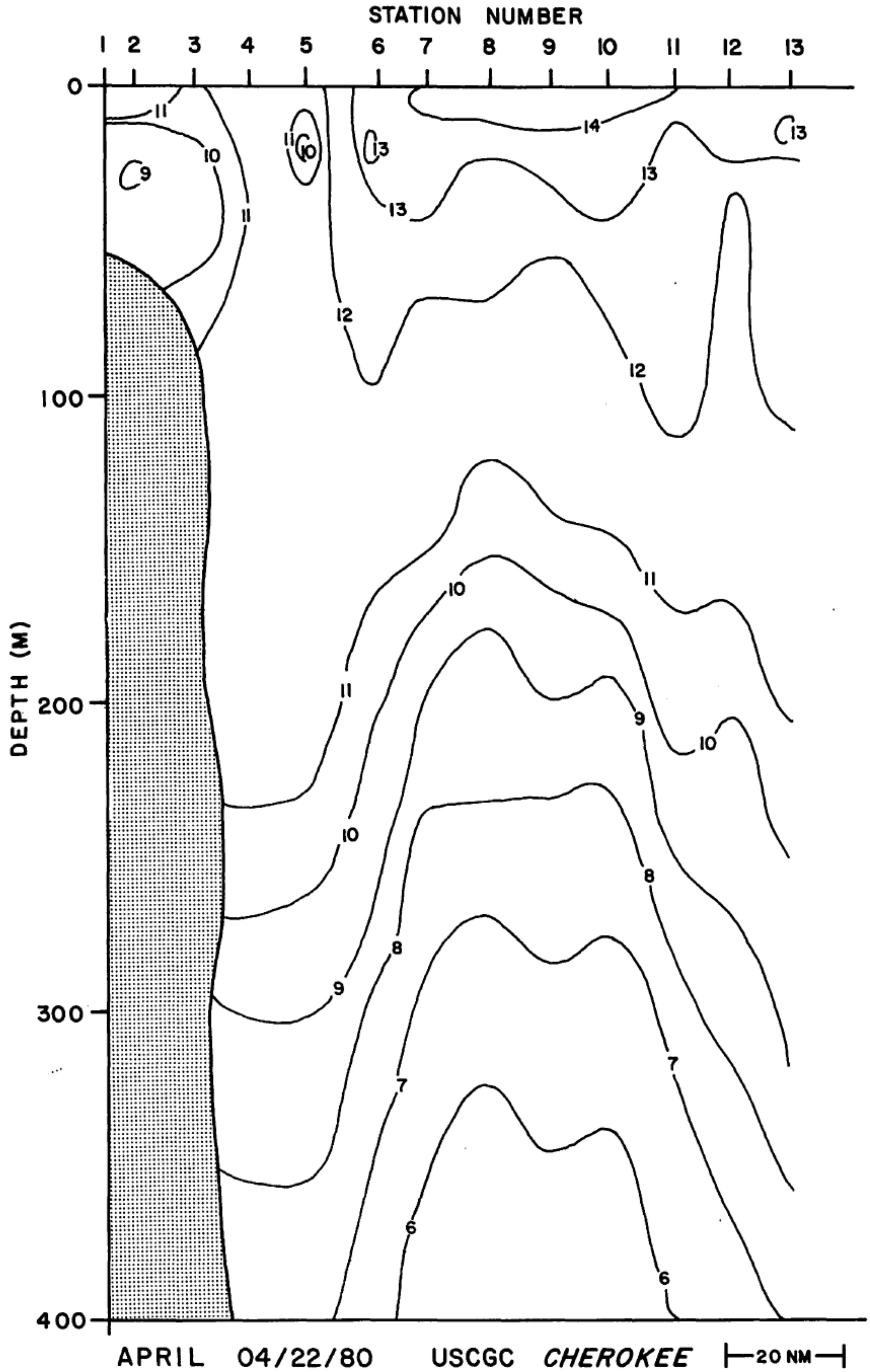


FIGURE 3. April vertical distribution of temperature (°C).

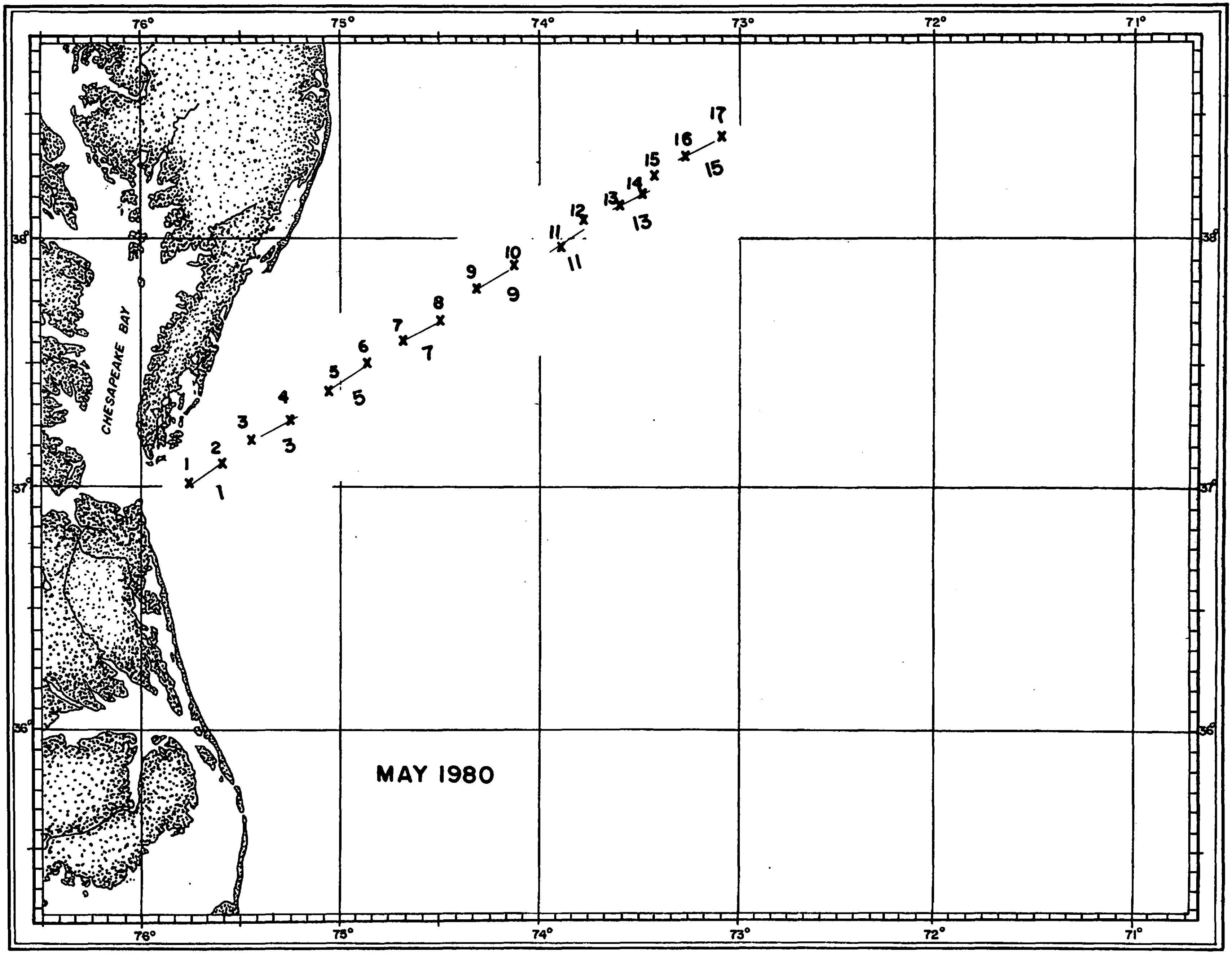


FIGURE 4. Transect positions of CPR samples and XBT/Surface Station, May 1980.

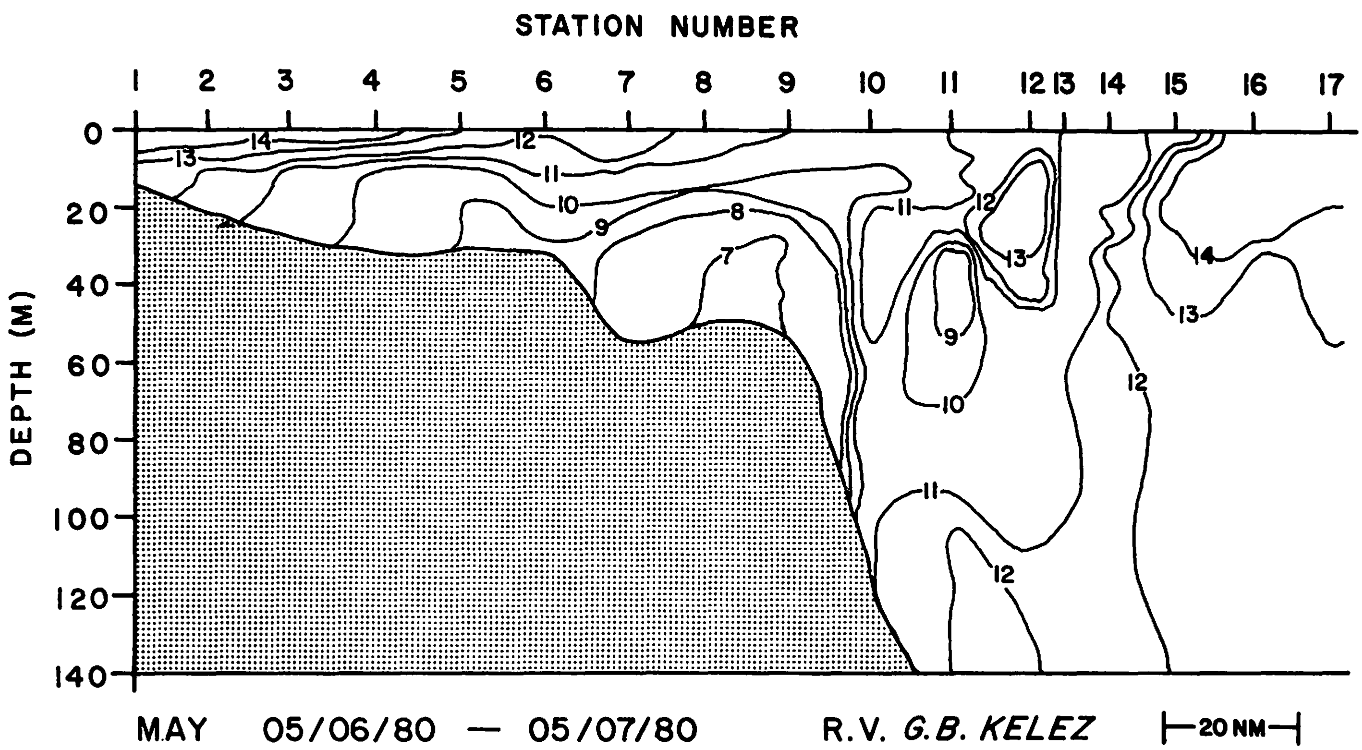


FIGURE 5. May vertical distribution of temperature (°C).

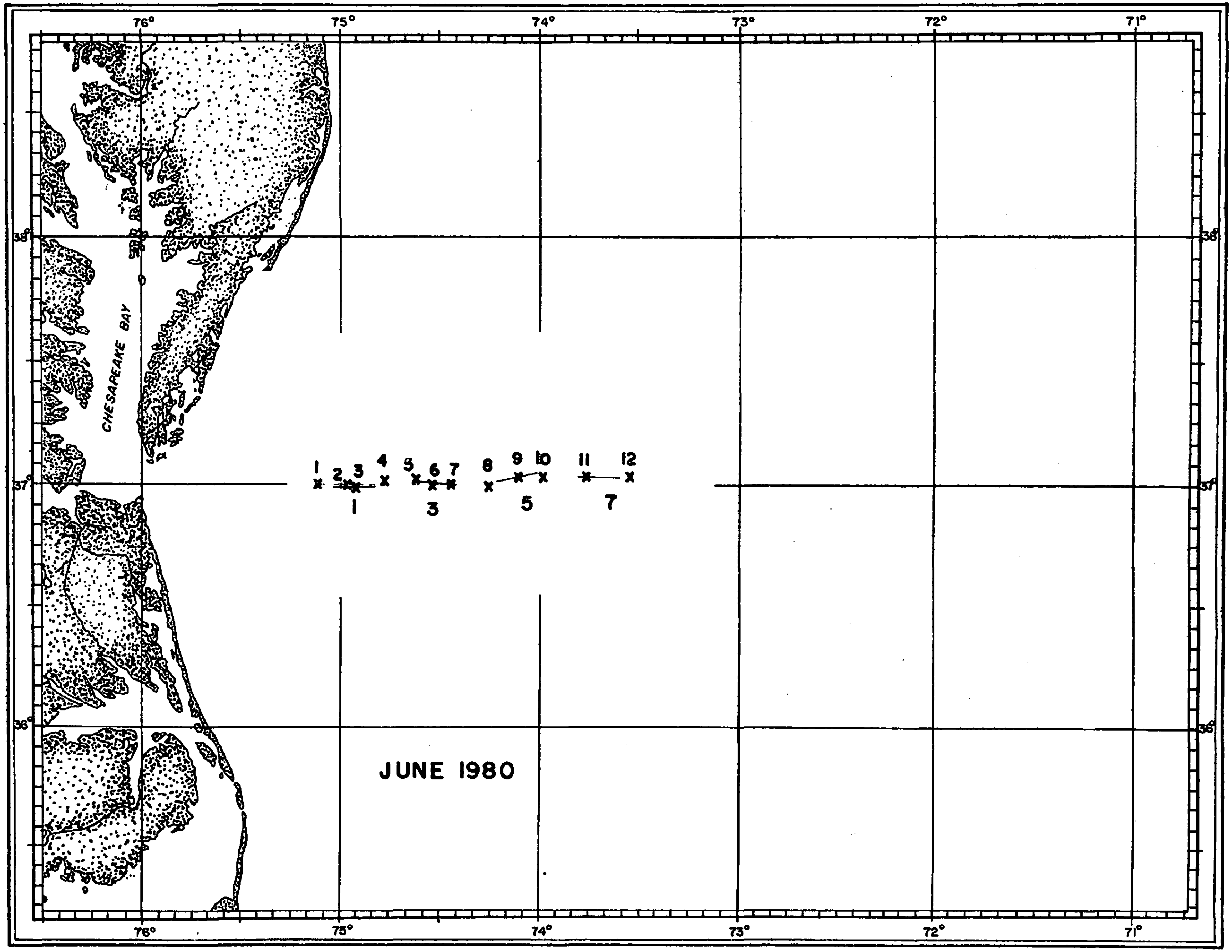


FIGURE 6. Transect positions of CPR samples and XBT/Surface Stations, June 1980.

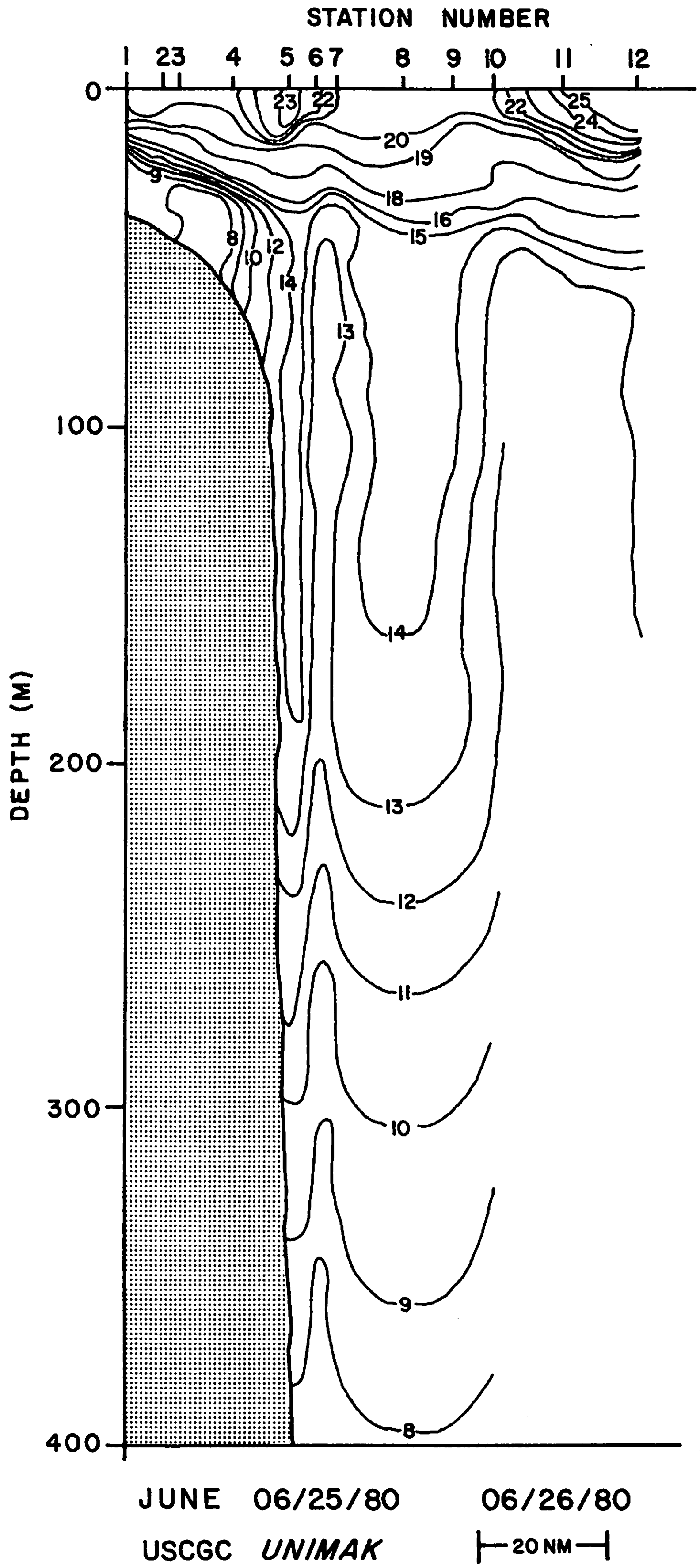


FIGURE 7. June vertical distribution of temperature (°C).

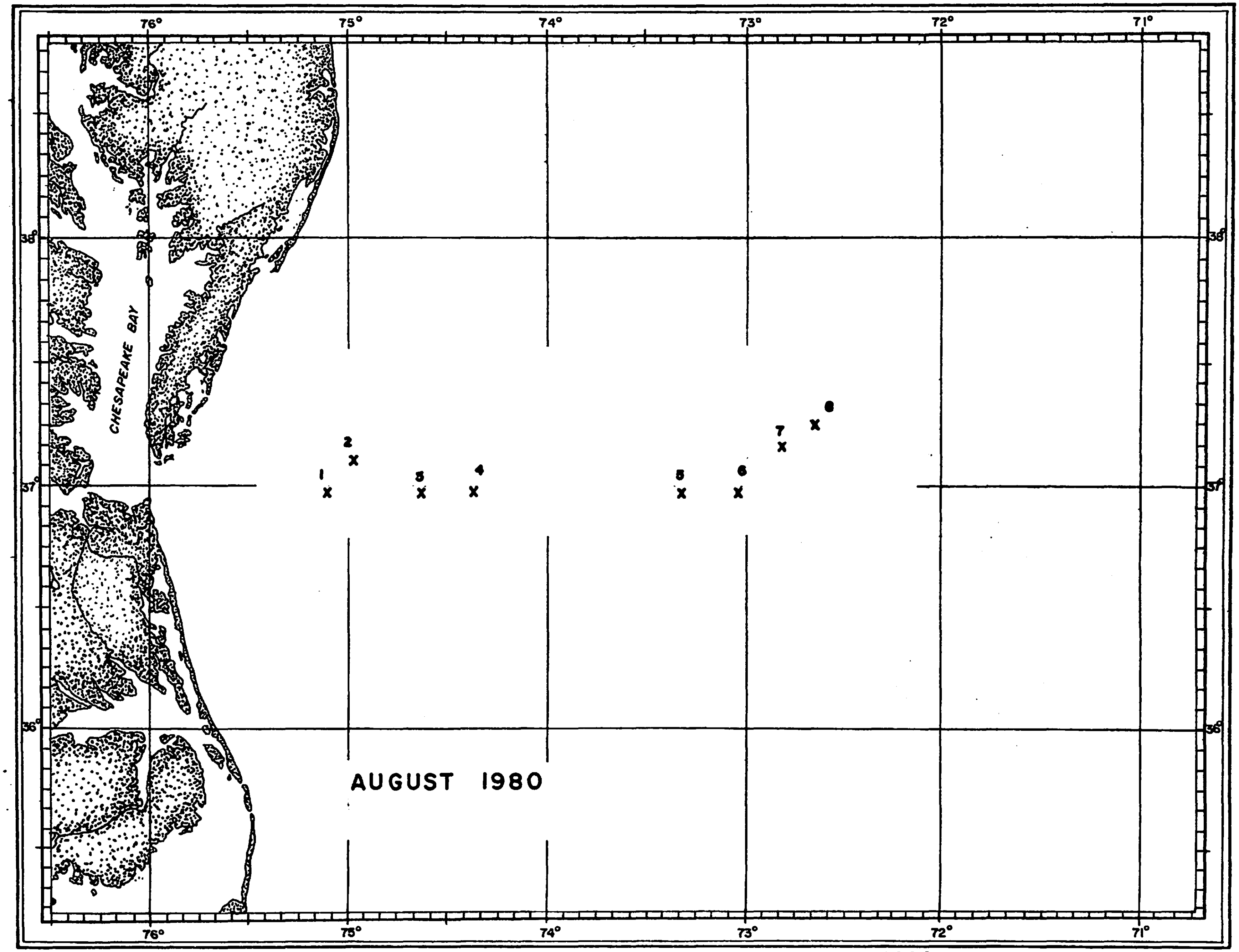

FIGURE 8. Transect positions of XBT/Surface Stations, August 1980.

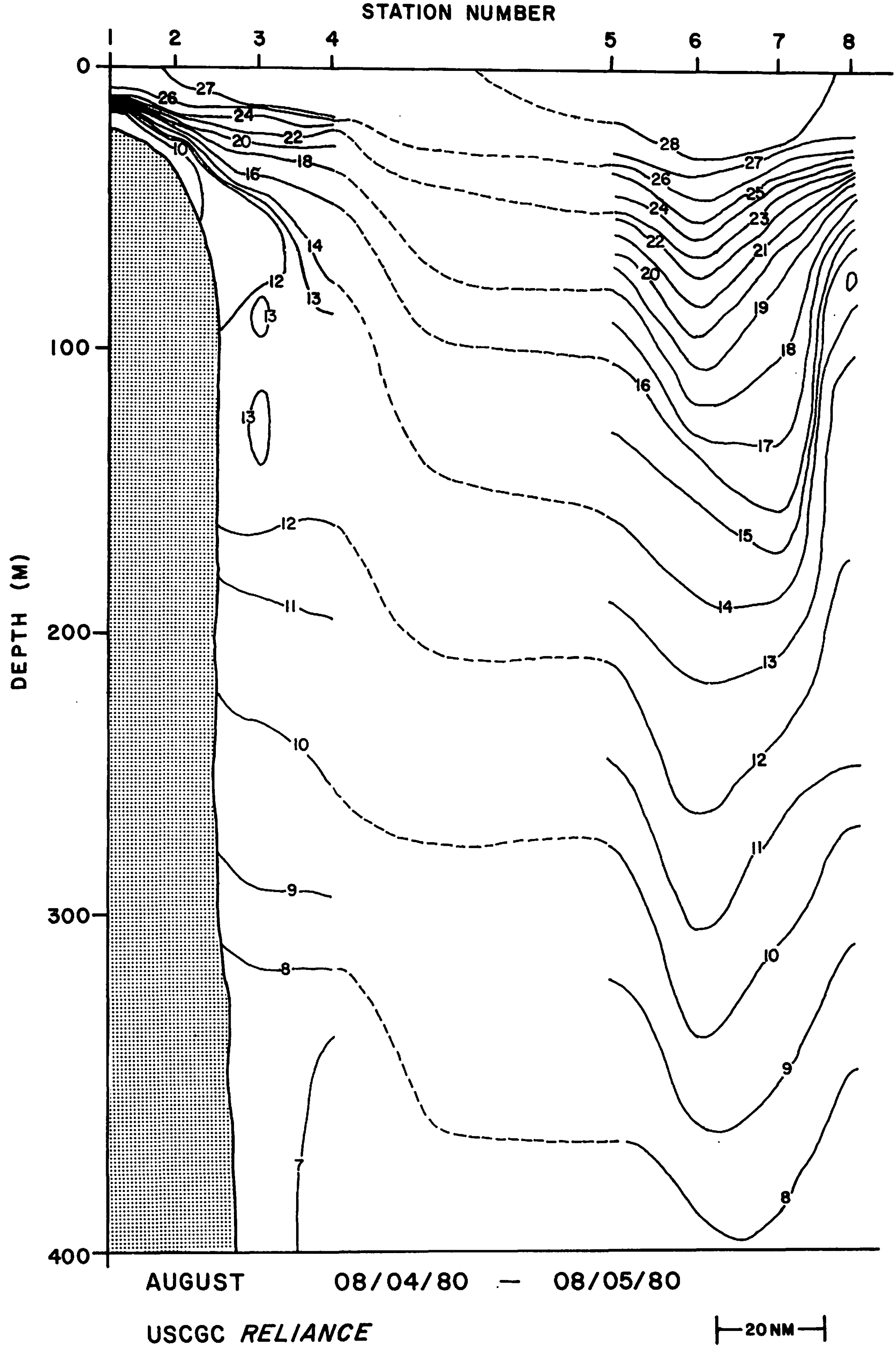


FIGURE 9. August vertical distribution of temperature (°C).

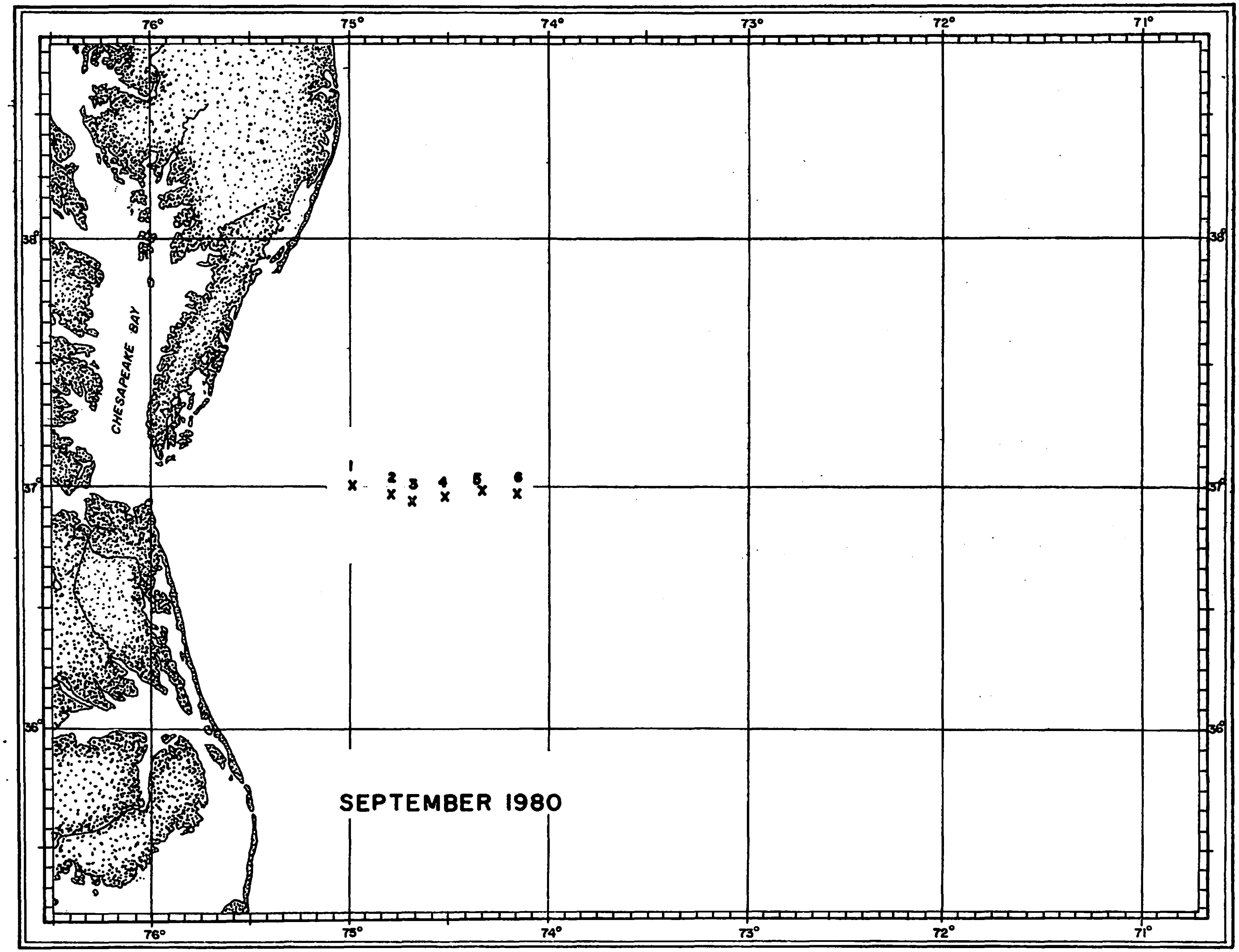


FIGURE 10. Transect positions of XBT/Surface Stations, September 1980.

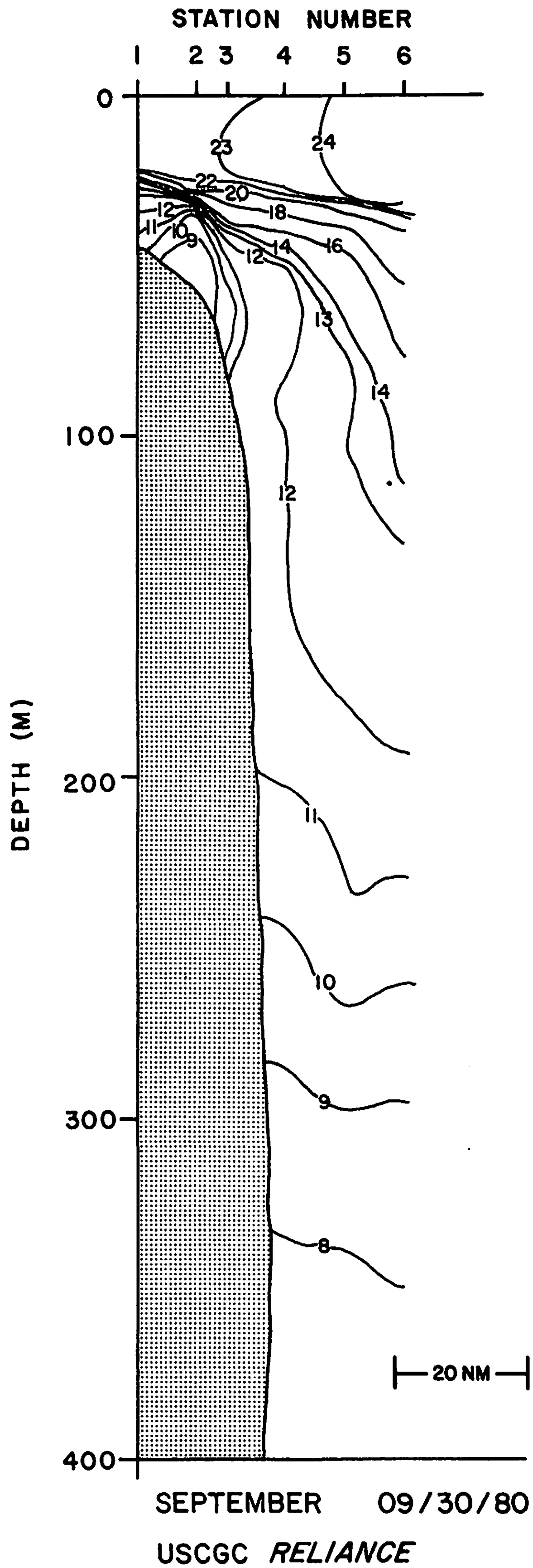


FIGURE 11. September vertical distirbution of temperature (°C).

TABLE 1. Months sampled from August 1974-August 1980, MA Route. Number of CPR silks analyzed per water mass.

| Month | Year | MA | Shelf | Slope |
|---|---|---|---|---|
| Aug | 74 | 1 | 0 | 7 |
| Oct | 74 | 3 | 3 | 8 |
| Nov | 74 | 4 | 1 | 9 |
| Jan | 75 | 6 | 2 | 3 |
| Feb | 75 | 7 | 2 | 4 |
| Mar | 75 | 8 | 2 | 4 |
| May | 75 | 10 | 4 | 2 |
| June | 75 | 11 | 2 | 0 |
| Aug | 75 | 13 | 3 | 2 |
| Sept | 75 | 14 | 4 | 8 |
| Nov | 75 | 16 | 4 | 5 |
| Dec | 75 | 17 | 5 | 8 |
| Jan | 76 | 18 | 4 | 5 |
| Feb | 76 | 19 | 1 | 9 |
| May | 76 | 23 | 3 | 3 |
| July | 76 | 25 | 3 | 8 |
| Oct | 76 | 28 | 3 | 3 |
| March | 77 | 33 | 3 | 5 |
| April | 77 | 34 | 4 | 4 |
| May | 77 | 35 | 3 | 0 |
| Aug | 77 | 37 | 3 | 2 |

| Month | Year | MA | Shelf | Slope |
|---|---|---|---|---|
| Oct | 77 | 39 | 3 | 3 |
| Nov | 77 | 40 | 4 | 3 |
| Dec | 77 | 41 | 2 | 4 |
| Jan | 78 | 42 | 2 | 3 |
| Apr | 78 | 43 | 5 | 0 |
| May | 78 | 44 | 3 | 0 |
| June | 78 | 45 | 5 | 0 |
| July | 78 | 46 | 7 | 0 |
| Aug | 78 | 47 | 1 | 4 |
| Sept | 78 | 48 | 5 | 0 |
| Nov | 78 | 49 | 1 | 4 |
| Jan | 79 | 50 | 3 | 3 |
| March | 79 | 51 | 3 | 7 |
| April | 79 | 52 | 3 | 0 |
| July | 79 | 56 | 3 | 3 |
| Aug | 79 | 57 | 0 | 7 |
| Sept | 79 | 58 | 0 | 5 |
| Oct | 79 | 59 | 2 | 3 |
| Nov | 79 | 60 | 1 | 1 |
| Feb | 80 | 61 | 3 | 3 |
| April | 80 | 62 | 3 | 3 |
| May | 80 | 63 | 9 | 0 |
| June | 80 | 64 | 1 | 3 |
| July | 80 | 65 | 4 | 0 |

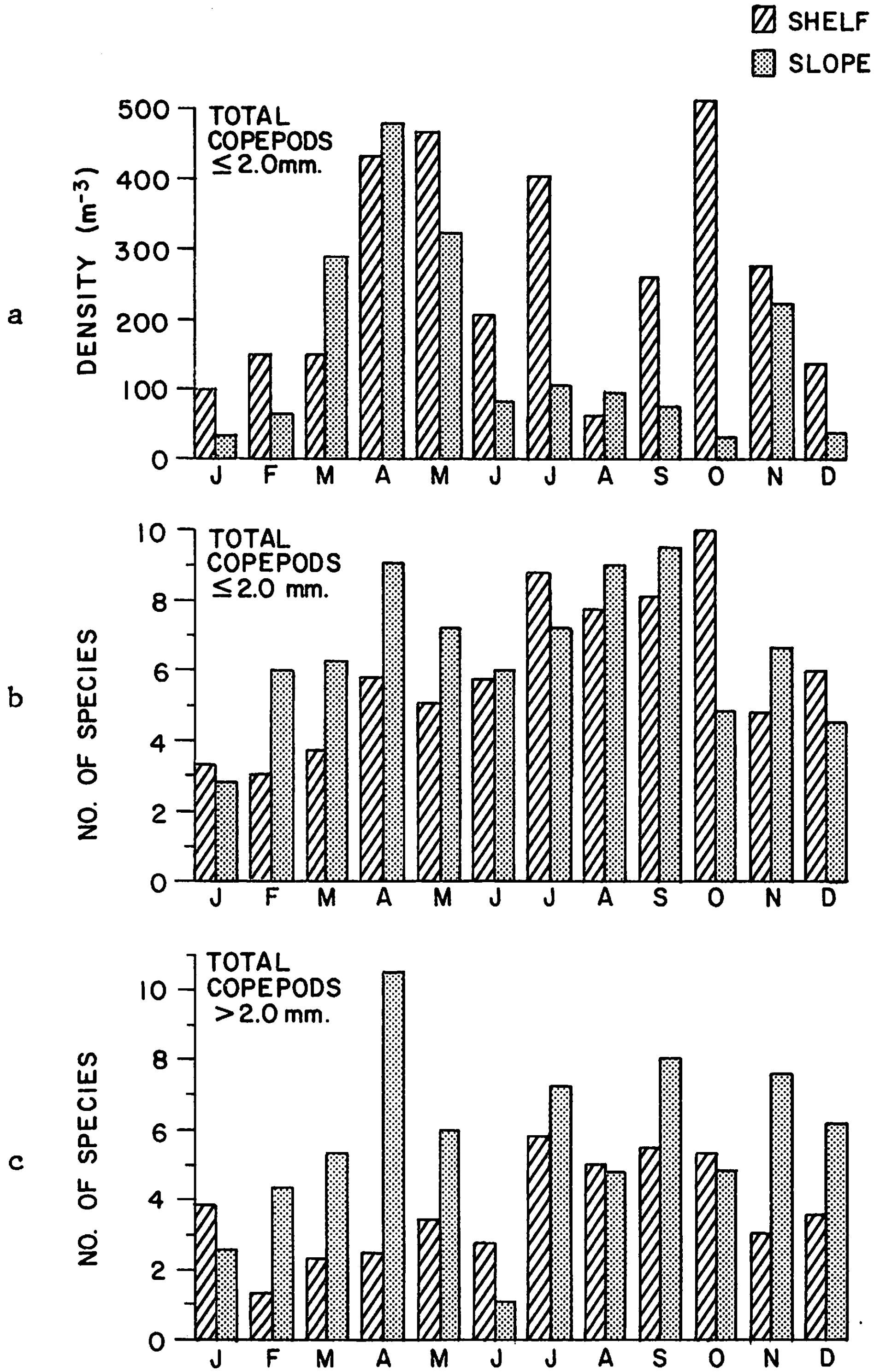


FIGURE 12. Five year composite mean annual cycle. Density of copepods ≤2.0mm (12a), number of species of copepods ≤ (12b), and number of species of copepods >2.0mm (12c) by month for shelf and slope water.

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