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# Zooplankton Faunal Zones and Their Relationship to Hydrography and Ichthyoplankton Production in the Georges Bank Region

by

G. R. Bolz and R. G. Lough

National Marine Fisheries Service, Northeast Fisheries Center
Woods Hole Lab., Woods Hole, Massachusetts 02543 USA

## Abstract

Zooplankton were identified and enumerated from 15 ICNAF Larval Herring Surveys covering the Georges Bank-Nantucket Shoals region during the autumn and winter seasons, 1974-1977. Distribution and abundance data were analyzed using numerical classification and statistical techniques to delimit discrete zooplankton communities. The resultant communities were examined to determine the extent, if any, of their correlation with current regimes and the production, survival and growth of larval fish.

## Introduction

During 1974-1979, the International Commission for the Northwest Atlantic Fisheries (ICNAF) coordinated the undertaking of larval herring surveys in the Georges Bank-Nantucket Shoals region (Fig. 1), in order to gain a better understanding of the early life history of Atlantic herring, *Clupea harengus*, and its relationship to recruitment and spawning stock size. More than 50 of these surveys, sampling a standard grid of stations, were conducted at 3-4 week intervals throughout the autumn and bimonthly during the winter. The United States participation in the program was conducted as part of the MARMAP (Marine Resources Monitoring, Assessment and Prediction) program of the Northeast Fisheries Center, which was designed to measure long-term changes in variability of fish stock abundance off the Northeast coast of the United States (Sherman, 1980). This paper summarizes the spatial distribution and abundance for all species of zooplankton for 15 larval herring surveys covering the autumn and winter period from December 1973 to February 1977.

Based on a study of the 1971-1977 survey seasons, Bolz and Lough (1984) found that ichthyoplankton in the Georges Bank-Nantucket Shoals region could be divided into two distinct faunal groupings: 1) a southern faunal zone composed of expatriated subtropical and mesopelagic taxa and located along the southern flank of Nantucket Shoals and Georges Bank; and 2) a northern zone dominated by endemic species and situated in the shallow water of Nantucket Shoals and Georges and extending into the Gulf of Maine. These faunal zones were found to be associated with distinct water mass characteristics of the region and, as such, proved good indicators of seasonal and annual fluctuations in the general circulation pattern. Disruption to the persistent clockwise gyre on Georges Bank, indicated by the poor development or absence of the southern faunal zone, was accompanied by low abundance of larval fish. It was hypothesized that the occassional breakdown of the gyre, possibly resulting from passage of warm-core eddies south of the shelf and from wind-driven currents, permits the transport of larvae southward across the 100-m isobath to a greater extent than usual with consequent effects on recruitment to the fish stocks of the region. The present study, still in its initial stages, was undertaken to assess whether zooplankton populations on Georges Bank also exhibited coherent species assemblages; and if so, how do fluctuations in their spatial distribution and abundance relate to the survival and recruitment of larval herring. Sherman et al. (1983) found

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evidence that zooplankton biomass and species composition have not altered significantly over the past 70 years and suggest that reduction in fish abundance cannot be attributed to a scarcity of available food. Whether or not this hypothesis is valid for short-term, aberrant fluctuations within the Georges Bank-Nantucket Shoals region is to be investigated. The possible importance of shifts in the relative abundance and distribution of dominant species and their life stages, as discussed by Cohen and Lough (1983), will be studied also.

## Sample and Processing Methods

Vessels, survey dates, and other pertinent information are listed chronologically in Table 1 for the 15 surveys during 1973-1977 included in this study. Cruise tracks and station positions for each of the surveys have been reported by Lough and Bolz (MS 1979). A double-oblique haul at a speed of 3.5 knots (108m/min) was made at each standard station (Fig. 1) with a paired 61-cm bongo sampler containing two nets (0.333 and 0.505 mm mesh). A V-fin depressor (122 cm) was used to achieve the desired wire angle of 45° for the relatively high towing speed, and a time-depth recorder was attached to the wire near the sampler to obtain a permanent trace of the haul profile. Flowmeters were located in the mouths of each sampler to monitor the amount of water strained. Gear configuration and other details have been described by Posgay and Marak (1980). The bongo gear was deployed at 50 m/min to a maximum depth of 100m, or to within 5m of the bottom in shallower areas, and retrieved at 10 m/min. A standard bongo haul filtered between 100 and 1,000 $m^3$ of water through each net depending on the depth of the tow.

Zooplankton contents of each sample from the 0.333-mm mesh net were sorted and identified at Morski Instytut Rybacki, Szczecin, Poland (Sherman and Ejsymont, MS 1976). Due to the large volume of plankton encountered in the samples, a subsample was taken to establish a representative distribution of the catch. The standard MARMAP sorting protocols were described by Sherman et al. (MS 1976a, 1976b), and sampling biases were discussed by Lough et al. (MS 1980). Where specific identity of zooplankters could not be ascertained, separation was made to the generic, familial or ordinal level.

The zooplankton data from each survey were standardized, and computer summaries and plots were produced. The computer routines include various internal audits to provide quality control of the data in addition to the initial control procedures prior to computer entry.

Biogeographical divisions of the study area were determined by using the numerical classification technique of Cluster Analysis. Prior to clustering all abundances were transformed to their square roots in order to reduce the effect of dominant species (Clifford and Stephenson, 1975). Stations were compared using Bray-Curtis similarity coefficients (Richardson and Stephencon, 1975) and were clustered using the Group Average Fusion Strategy of Sokal and Sneath, 1963. The resultant dendrograms (Fig. 2) were analyzed as to their station groupings. Each grouping was mapped and species composition and abundance were further studied to delimit faunal zones.

Data were compared by surveys and seasons for spatial and temporal fluctuations in biogeographical divisions, total zooplankton abundance, and spatial composition. Maps of each cruise were constructed showing the biogeographical divisions.

## Results

I. Faunal Groups - Boundaries, Diversity, Abundance, Species Composition Dominance

Cluster analysis of the 15 cruises clearly delineated three distinct faunal zones: 1) a southern faunal zone; 2) a shelf faunal zone; and 3) a northern faunal zone. These zones frequently were divisible into one or more subzones. Although the more dominate species, such as *Centropages typicus* and *Pseudocalanus* spp., were found throughout the region, each zone comprised a unique assemblage of species. A total of 392 taxa were identified in the study area. Many of the forms were identified only to the familial level resulting in possible redundancies, and the actual number of species is probably lower than the total reported.

A. Southern Faunal Zone

The southern faunal zone contained primarily oceanic and slope water zooplankton species. High diversity and low abundance were characteristic of the southern assemblage. Approximately 90% of the 392 taxa were represented in this zone which encompassed only 23% of the study area and accounted for less than 20% of the total abundance (Table 1). A mean of 24.3 species per station were recorded, and on several cruises the average was as high as, or higher, than 34. The more prevalent oceanic and slope water taxa observed in the southern faunal zone were Centropages bradyi, Rhincalanus nasutus, Pleuromamma borealis, Salpa maxima, Scolethrix danae, Temora stylifera and Sagitta serratodentata (Davis, 1986). Abundance fluctuated throughout throughout the 15 cruises reflecting the degree of slope water intrusion onto Georges Bank.

B. Shelf Faunal Zone

The shelf faunal zone was heavily dominated by species endemic to Georges Bank. Greater than 90% pf the total abundance was accounted for by Centropages typicus, Pseudocalanus spp., and Centropages hamatus. There was a mean of 15.2 species per station, and this average fluctuated very little from cruise to cruise. The zone encompassed 45% of the study area, and abundance was uniformly the highest of the three biogeographical divisions. Centropages typicus dominated early in the season while Pseudocalanus spp. was the most abundant species in the latter part of the study period. Overall abundance was highest in September and October and lowest in February.

C. Northern Faunal Zone

Many of the same taxa as were observed in the shelf faunal zone were found in the northern zone but in much lower abundances. The dominant species were Metridia lucens, Calanus finmarchicus, Paracalanus parvus, Euchaeta norvegica, Meganyctiphanes norvegica, Centropages typicus and Pseudocalanus spp.. The number of species per station ranged from 9.9 to 18.1 with a mean of 14.1. Abundance fluctuated from cruise to cruise but in general was about half that observed in the shelf faunal zone. With the exception of two cruises (Belogorsk 75-02 and 75-03) the northern assemblage encompassed approximately 34% of the total study area.

II. Seasonal and Annual Fluctuations

A. 1973

Only the December and February cruises were sorted for zooplankton in 1973. In December the southern faunal zone was delimited to the north by the 100-m isobath and covered 10% of the study area (Fig. 3). Finer scale clustering revealed that an additional 13% of the southernmost portion of the shelf zone was a mixed assemblage of oceanic and shelf taxa. The extreme dominance of Centropages typicus ,however, dictated that it be considered a subdivision of the shelf zone. An average of 21.2 species per station was found in the southern zone. Overall abundance for the cruise was similar to the following three years but was overwhelmingly concentrated in the shelf zone, especially between the 60 and 100-m isobaths. The mean number of species per tow was only 9.9 in the northern faunal zone which was the lowest in the entire time series. In February the southern faunal zone was found only in a small area east of the 100-m isobath (Fig. 4). A wedge of the northern faunal zone separated the southern zone from the shelf zone. Pseudocalanus spp. was the dominant species. Abundance on the shelf proper was the highest of the four years.

B. 1974

In early autumn, particularly in October, the soutnern faunal zone occupied as much as 43% of the study area (Figs. 5,6,7). Abundance at this time was the highest of the entire time series, especially in the shelf faunal zone which was again dominated by Centropages typicus and Pseudocalanus spp.. The southern faunal zone covered most of the Nantucket Shoals region and also extended through the Northeast Channel into the Gulf of Maine. A notable feature at this time was a large wedge of the northern faunal zone which intruded on eastern and southeastern Georges Bank. The shelf zone was almost entirely confined within the 60-m isobath. This was in striking contrast to the November period (Fig. 8) in which cluster analysis failed to clearly define a northern faunal zone. The southern faunal zone also was more constricted than in October and occupied only 15% of the sampling area. In December (Fig. 9) the study area again took on the spatial pattern noted in October, exhibiting a northern intrusion of the southern faunal zone onto Nantucket Shoals and a southern extension of the northern faunal zone onto eastern Georges Bank. Abundance was similar to that observed in 1973 in the shelf zone, but it was 11 times greater in the southern zone and 4 times as great in the northern zone. An extensive southern zone and the southeastward intrusion of the northern zone also characterized the February cruise (Fig. 10). Abundance was much lower in the shelf zone than in 1973 but much higher, although less diverse, in the southern faunal zone.

C. 1975

In October of 1975 (Fig. 11,12) abundance was much lower than in the preceding year; and although the southern faunal zone was still quite extensive, it was more constricted and was less diverse than in 1974. The southeastward intrusion of the northern faunal zone was also absent, and there were apparent extensions of the shelf zone beyond the 100-m isobath in the vicinity of the Great South Channel and northward off of central Georges Bank. In November (Fig. 13) the southern faunal zone was extremely constricted (7% of the study area), being confined to southwestern Nantucket Shoals and southeastern Georges Bank. An interesting feature was a pocket of the northern faunal zone to the south of Nantucket Shoals. The pattern observed in the winter (Fig. 14,15) closely resembled that found in 1974 in having a well-defined southern faunal zone to the south and east of Georges Bank and a small intrusion of the northern faunal zone onto the eastern portion of the shelf. Abundance was also similar to that observed the previous year.

D. 1976

As with the 1973 season zooplankton was sorted for the December and February time period only. The December cruise (Fig. 16) was similar in abundance, diversity and spatial pattern to those of the previous two years. The most notable feature was small isolated fragments of the northern faunal zone along southern Georges Bank and Nantucket Shoals and the extension of the southern faunal zone through the Northeast Channel into the Gulf of Maine. The February cruise (Fig. 17) was noteworthy for lacking any indication of a southern faunal zone and for the large intrusion onto Georges Bank of the northern faunal zone which occupied almost 50% of the study area. Diversity in the shelf faunal zone was very low (13 species/tow). Overall abundance was the lowest of the entire time series and was concentrated in the Nantucket Shoals area.

Discussion

Preliminary analysis indicates that the clustering of zooplankton species in the Georges Bank/Gulf of Maine region conforms to the circulation of the prevailing water masses and is able to delimit gross seasonal and annual fluctuations in those masses. As found in this and previous studies (Colton et al., 1962; Sherman and Shaner, 1968), oceanic species of copepods are particularly good delimiters of Slope Water intrusions onto Georges Bank and Nantucket Shoals. For the most part the results are in accord with and support the previous analysis (Bolz and Lough, 1984) of ichythyoplankton captured on the same cruises.

As first indicated by the larval fish study, it appears that a prolonged and extensive northward intrusion of Slope Water onto Georges Bank is conducive to high abundance of endemic zooplankton species. This was especially noticeable in October 1974 when the shelf faunal zone was confined to less than 20% of the study area but produced the highest numbers of zooplankters of the time series. A feature not noted in the previous study was the wedge of Gulf of Maine Water intruding onto eastern Georges Bank during the early autumn. This conforms to the known current patterns (Fig. 18) in which the eastward flowing jet along the northern flank of the shelf turns south-southeastward on eastern Georges Bank (Butman et al., 1982). The further intrusion of the northern assemblage along the southern edge between the 60 and 100-m isobaths also is in accordance with the general clockwise circulation found on Georges Bank. Both the southern and northern faunal intrusions followed the prevailing circulation pattern to which the reproductive strategy of endemic shelf zooplankters have become adapted (Davis, 1986). Deviations from the normal pattern, such as occur during periods of prolonged wind stress or the presence of warm-core Gulf Stream eddies along the southern flank of the shelf, would be expected to cause fluctuations in population abundances (Parrish et al., 1981).

Overall zooplankton abundances on the shelf for the four years, as with the spatial distribution patterns, were in agreement with the ichthyoplanton data. There were high abundances in 1973 and 1974, lesser numbers in 1975 and still less in 1976. The February 1977 cruise was the most aberrant and clearly suggests as severe a disruption to the zooplankton population on Georges Bank as was found for the ichthyoplankton. There were strong and persistent northerly winds during January and February of 1977 which would have contributed to the movement of the Shelf-Slope Front farther to the south (Ingham, 1979; Lough et al., MS 1979). This is further supported by the low temperatures ($4^\circ$ to $6^\circ$C) amd high salinities (33.5 to 34.0 ‰), characteristic of Gulf of Maine Water, found over Georges Bank during the winter of 1976/77 (Wright, 1979). Although there was a noticeable shift of high abundance from central Georges Bank to Nantucket Shoals, zooplankton levels on Georges Bank were still quite high and do not appear to have contributed significantly to the severe reduction of larval fish noted in February, 1977.

Further analysis of zooplankton species composition within each biogeographical division, shifts in the relative abundance and distribution of dominant species and their life stages, and a more detailed study of available hydrographic data is ongoing at present. It is hoped this will enhance out understanding of the population dynamics of zooplankters on Georges Bank and their relationship to current regimes and the recruitment of endemic larval fish populations.

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TABLE 1. *Survey data and estimates of mean zooplankton abundance, number of species and area for the southern, shelf and northern faunal zones in the Georges Bank-Nantucket Shoals region, 1973-76 survey seasons.*

| Year | | Vessel | Cruise number | Cruise dates | No. of stations used | No. of taxa observed | Abundance (Mean No./m³/Station) South | Abundance Shelf | Abundance North | Number of Species (Mean No./Station) South | Species Shelf | Species North | Area (% of Total) South | Area Shelf | Area North |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1973 | 1. | Albatross IV | 73-09 | Dec. 4-20 | 49 | 111 | 42.8 | 1058.8 | 274.6 | 21.2 | 17.8 | 9.9 | 12.0 | 49.0 | 39.0 |
| | 2. | Albatross IV | 74-02 | Feb. 11-22 | 28 | 80 | 20.0 | 533.2 | 95.8 | 25.8 | 12.3 | 10.0 | 11.0 | 58.0 | 31.0 |
| | | Total | | | 77 | 125 | 34.9 | 845.7 | 210.8 | 22.8 | 15.6 | 9.9 | 11.5 | 53.5 | 35.0 |
| 1974 | 3. | Cryos | 74-04 | Sep. 7-24 | 49 | 137 | 447.5 | 1572.9 | 651.0 | 29.7 | 20.7 | 11.4 | 16.0 | 49.0 | 35.0 |
| | 4. | Wieczno | 74-01 | Sep. 27-Oct. 18 | 65 | 155 | 337.6 | 1012.0 | 475.1 | 34.9 | 18.0 | 13.0 | 43.0 | 16.0 | 41.0 |
| | 5. | Prounoz | 74-01 | Oct. 18-30 | 45 | 135 | 199.2 | 1021.9 | 665.5 | 28.6 | 15.8 | 12.5 | 37.0 | 19.0 | 44.0 |
| | 6. | Anton Dohrn | 74-01 | Nov. 16-23 | 36 | 117 | 312.0 | 786.2 | ----- | 34.0 | 15.1 | ---- | 15.0 | 85.0 | ---- |
| | 7. | Albatross IV | 74-13 | Dec. 4-19 | 33 | 89 | 551.8 | 408.5 | 344.4 | 23.4 | 15.8 | 13.6 | 30.0 | 30.0 | 39.0 |
| | 8. | Albatross IV | 75-02 | Feb. 12-28 | 77 | 135 | 362.0 | 179.8 | 110.1 | 15.8 | 17.5 | 12.9 | 37.0 | 26.0 | 38.0 |
| | | Total | | | 305 | 253 | 350.5 | 865.1 | 422.5 | 26.5 | 17.3 | 12.7 | 29.7 | 37.5 | 32.8 |
| 1975 | 9. | Belogorsk | 75-02 | Sep. 25-Oct. 8 | 74 | 169 | 195.0 | 850.6 | 608.4 | 20.8 | 16.1 | 17.1 | 30.0 | 51.0 | 18.0 |
| | 10. | Belogorsk | 75-03 | Oct. 17-30 | 76 | 183 | 400.3 | 502.0 | 401.7 | 23.9 | 16.8 | 18.1 | 33.0 | 51.0 | 16.0 |
| | 11. | Anton Dohrn | 75-187 | Nov. 1-18 | 55 | 128 | 52.5 | 656.4 | 412.9 | 34.3 | 15.0 | 15.3 | 7.0 | 63.0 | 30.0 |
| | 12. | Albatross IV | 75-14 | Dec. 5-17 | 82 | 163 | 257.5 | 524.8 | 519.1 | 25.9 | 16.6 | 16.6 | 29.0 | 38.0 | 33.0 |
| | 13. | Albatross IV | 76-01 | Feb. 10-25 | 84 | 148 | 129.2 | 246.7 | 261.1 | 21.5 | 18.5 | 14.4 | 24.0 | 50.0 | 26.0 |
| | | Total | | | 371 | 286 | 245.3 | 526.7 | 435.2 | 23.6 | 15.9 | 16.1 | 24.6 | 50.6 | 24.6 |
| 1976 | 14. | Researcher | 76-01 | Nov. 27-Dec. 11 | 52 | 138 | 563.9 | 629.2 | 171.2 | 31.4 | 16.9 | 17.2 | 26.0 | 35.0 | 39.0 |
| | 15. | Mt. Mitchell | 77-01 | Feb. 13-24 | 50 | 96 | ----- | 223.5 | 43.9 | ---- | 13.0 | 14.9 | ---- | 54.0 | 46.0 |
| | | Total | | | 102 | 157 | 287.5 | 306.9 | 103.6 | 16.0 | 15.3 | 16.0 | 13.0 | 44.5 | 42.5 |
| | | Grand Total | | | 855 | 302 | 285.6 | 643.9 | [illegible] | 24.3 | 15.2 | 14.1 | 23.3 | 44.9 | 34.3 |

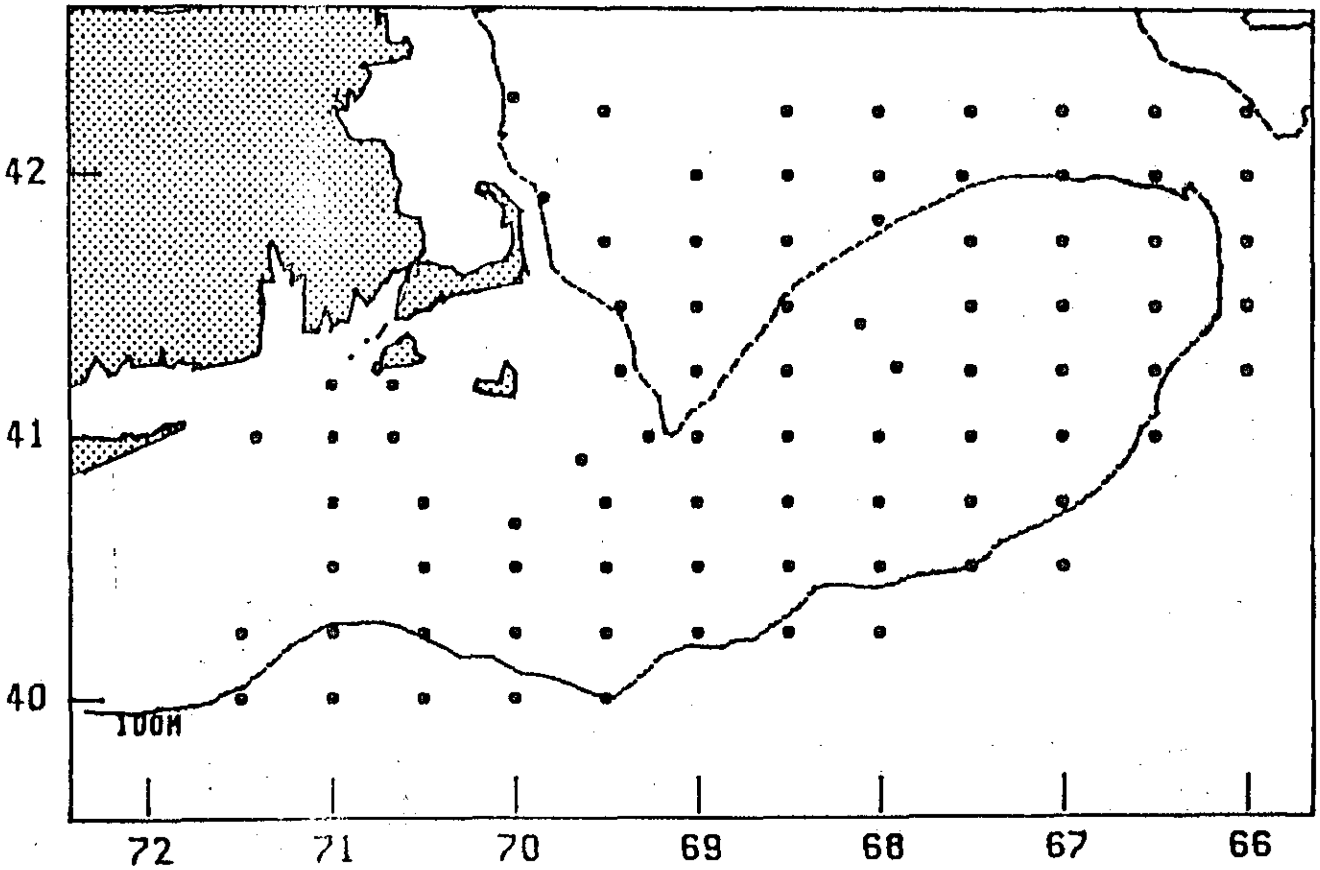


Figure 1. Map of Georges Bank-Nantucket Shoals regions showing the locations of stations from which zooplankton data were derived for analysis.

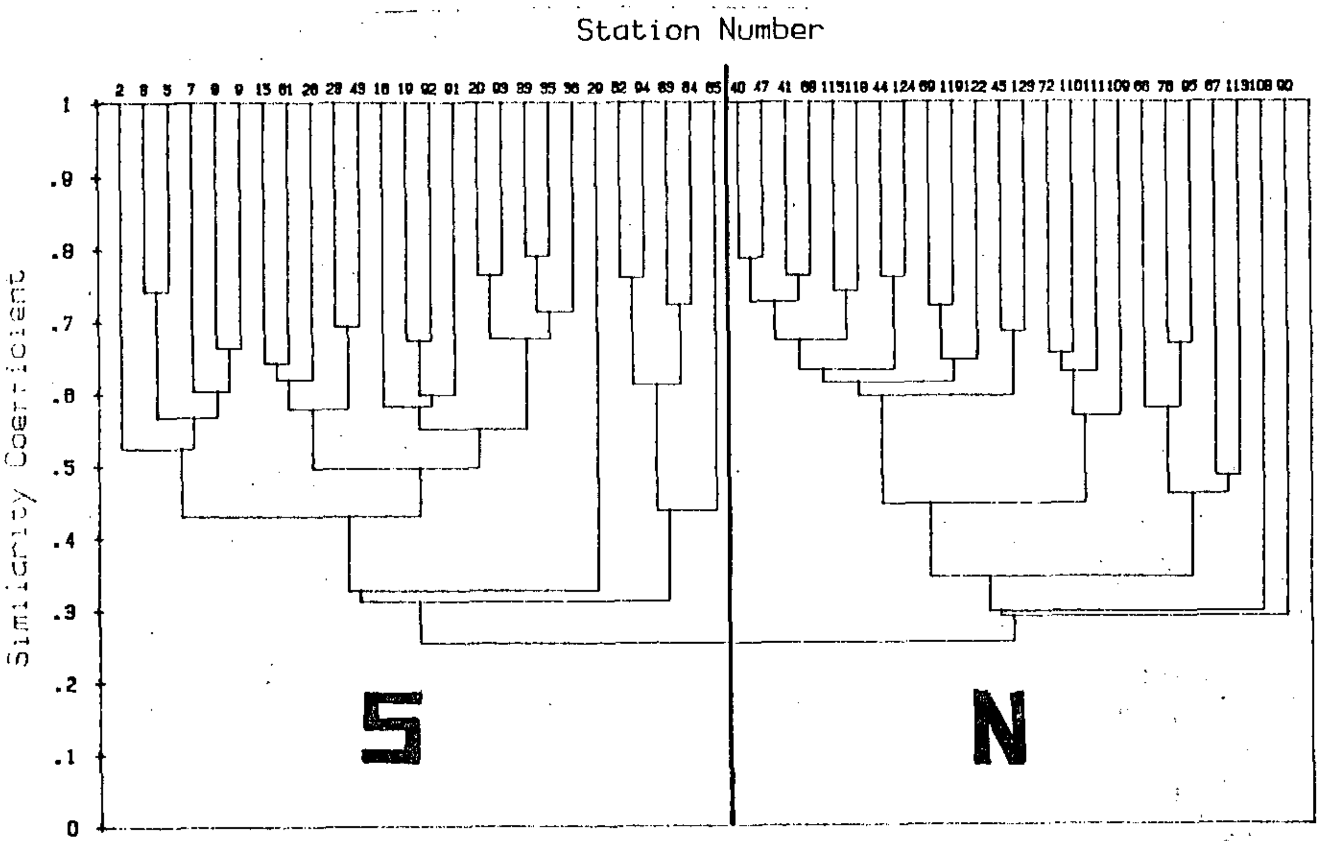


Figure 2. Dendrogram showing results of the cluster analysis of stations for the Mt. Mitchell 77-01 cruise. Biogeographical divisions indicated are: Shelf Faunal Zone (S) and Northern Faunal Zone (N).

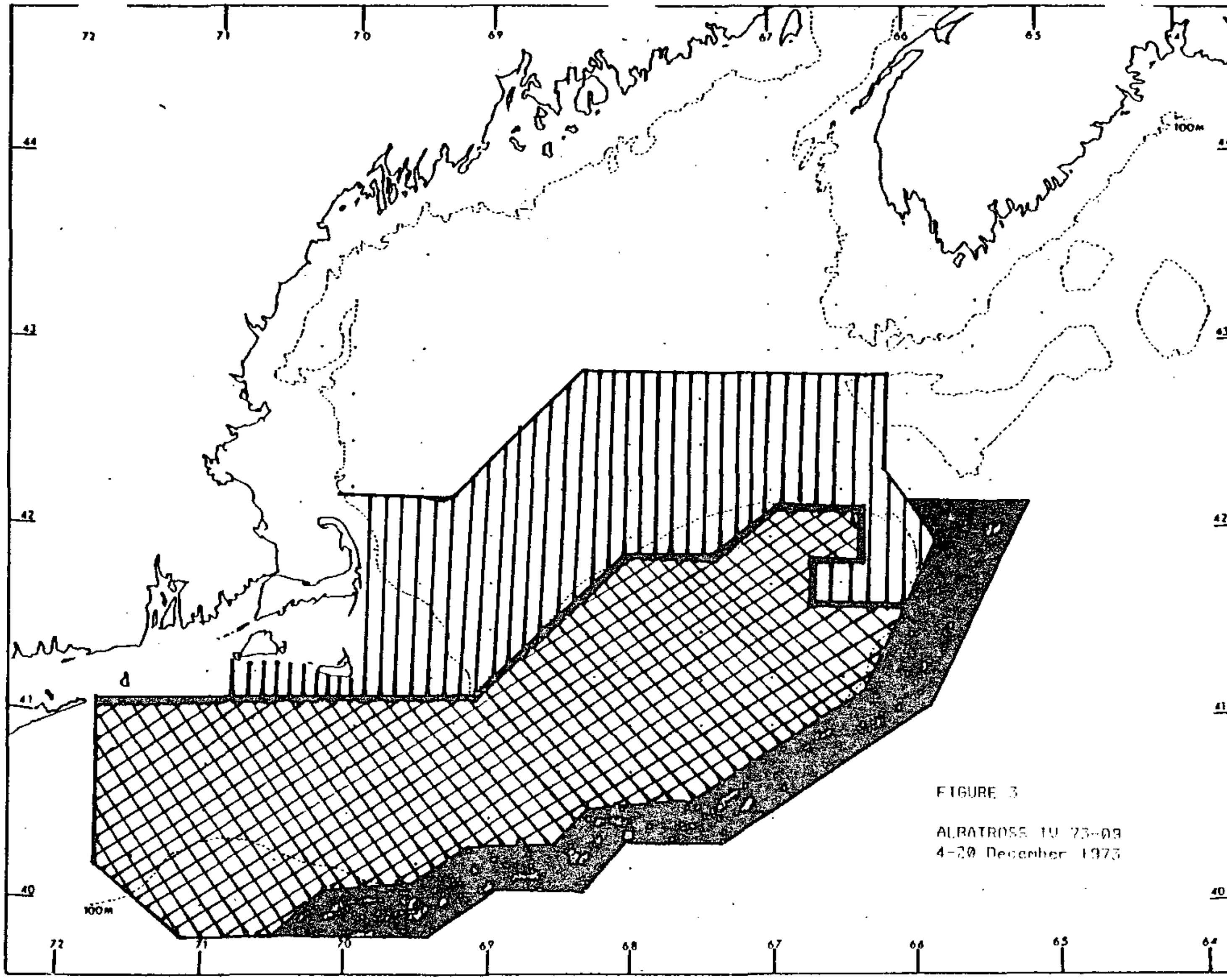


Figure 3. Faunal map for Albatross IV 73-09, 4-20 December 1973, showing the northern (vertical lines), shelf (hatched) and southern (shaded) faunal zones.

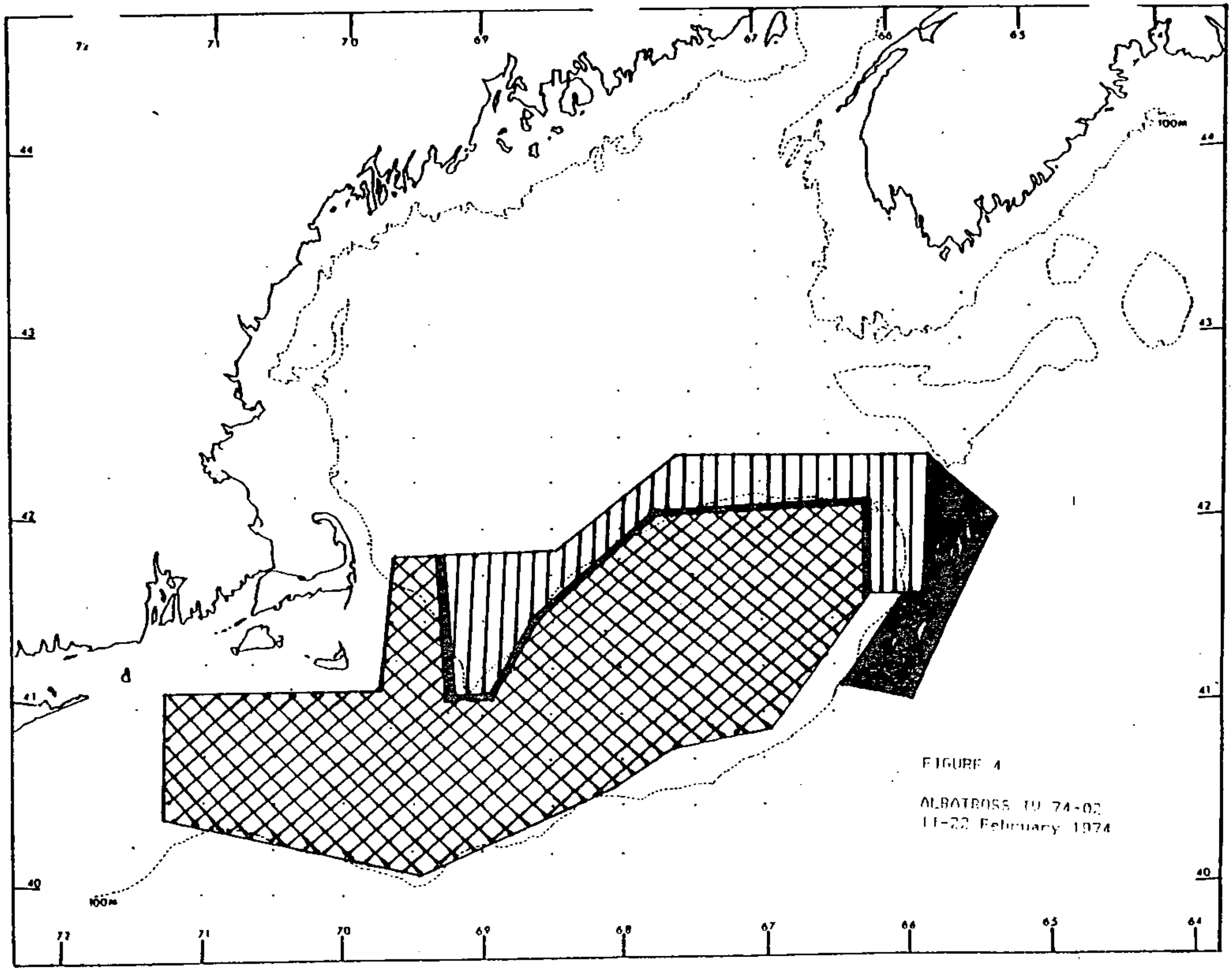


Figure 4. Faunal map for Albatross IV 74-02, 11-22 February 1974, showing the northern (vertical lines), shelf (hatched) and southern (shaded) faunal zones.

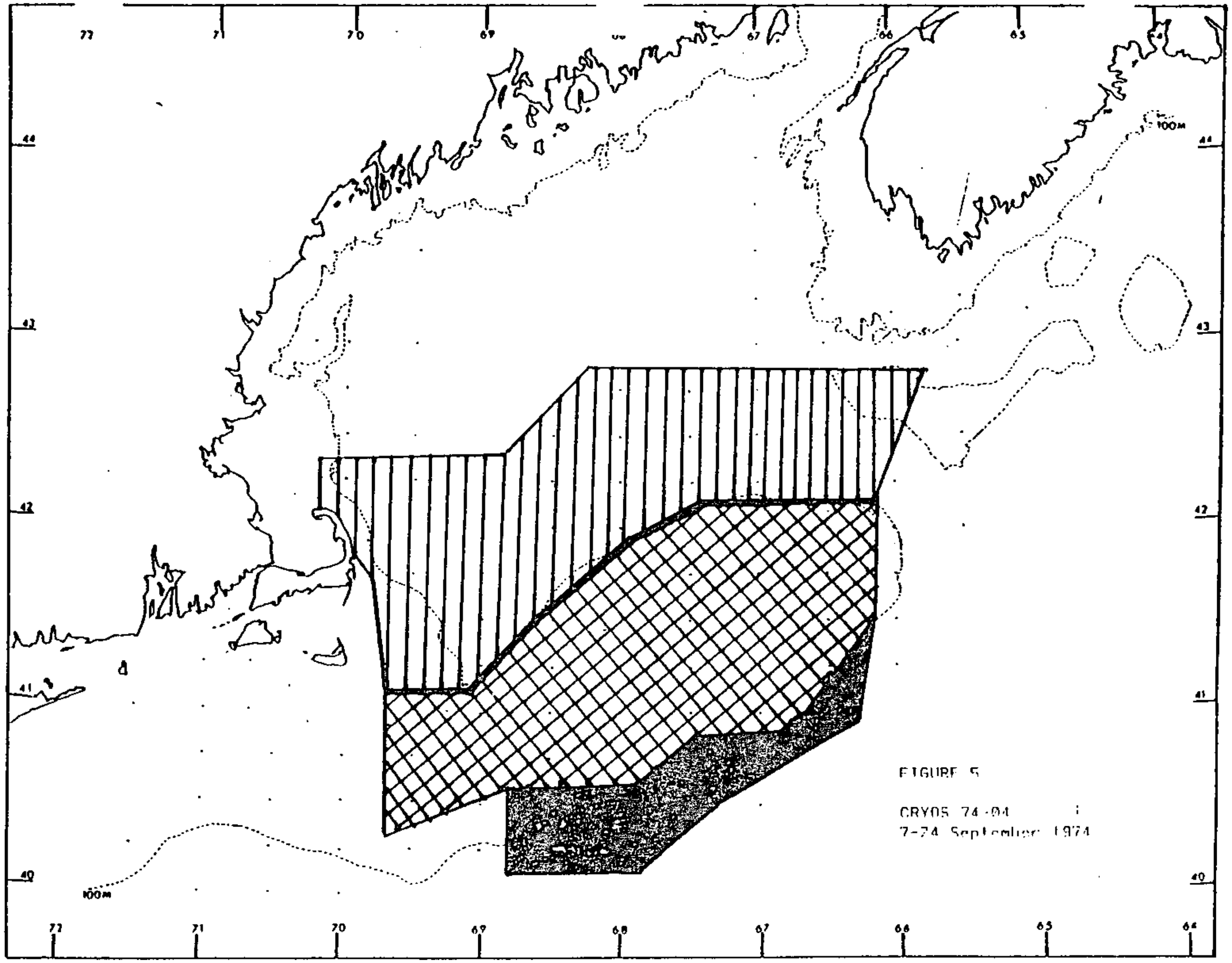


Figure 5. Faunal map for Crycs 74-04, 7-24 September 1974, showing the northern (vertical lines), shelf (hatched) and southern (shaded) faunal zones.

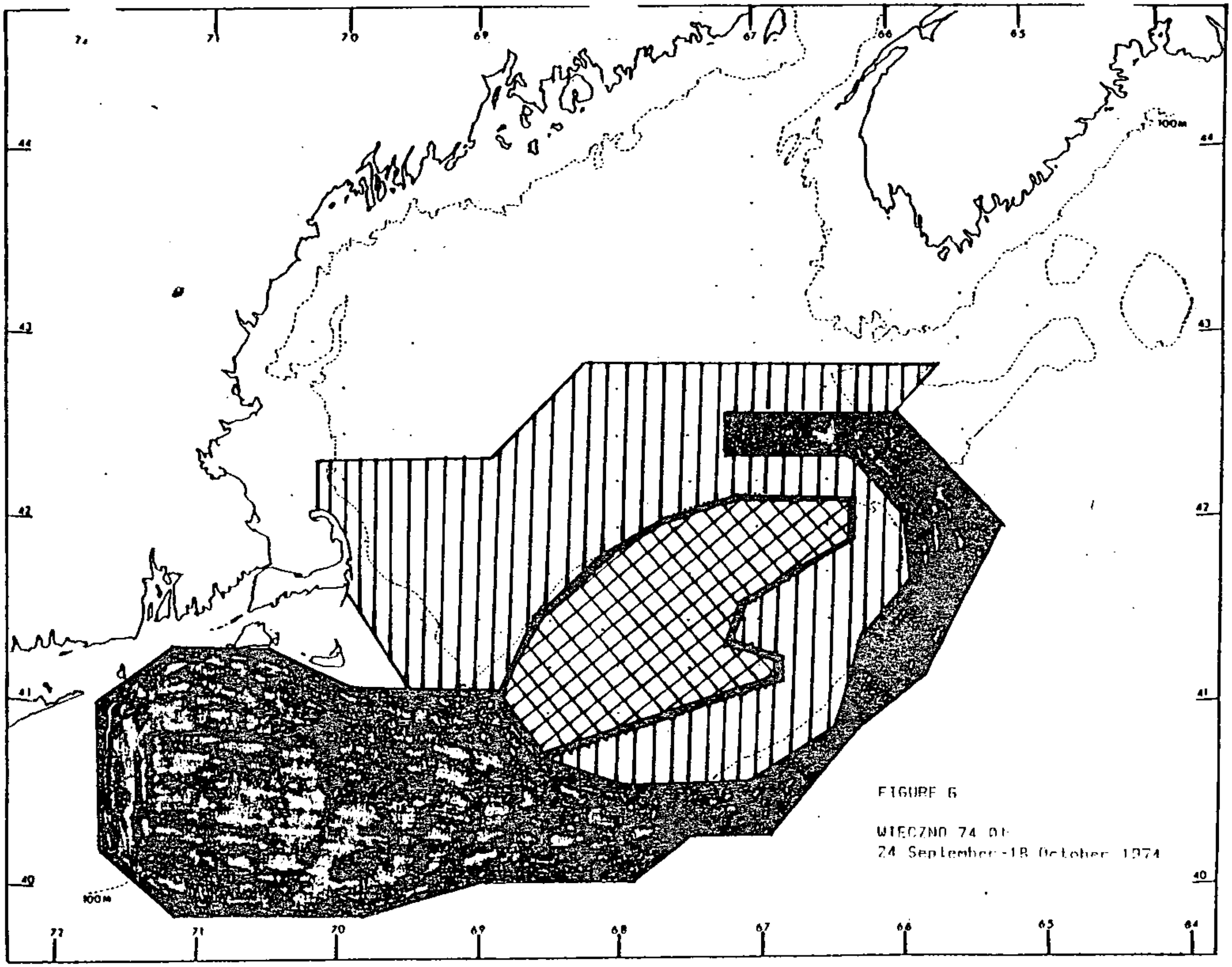


Figure 6. Faunal map for Wieczno 74-01, 27 September-18 October 1974, showing the northern (vertical lines), shelf (hatched) and southern (shaded) faunal zones.

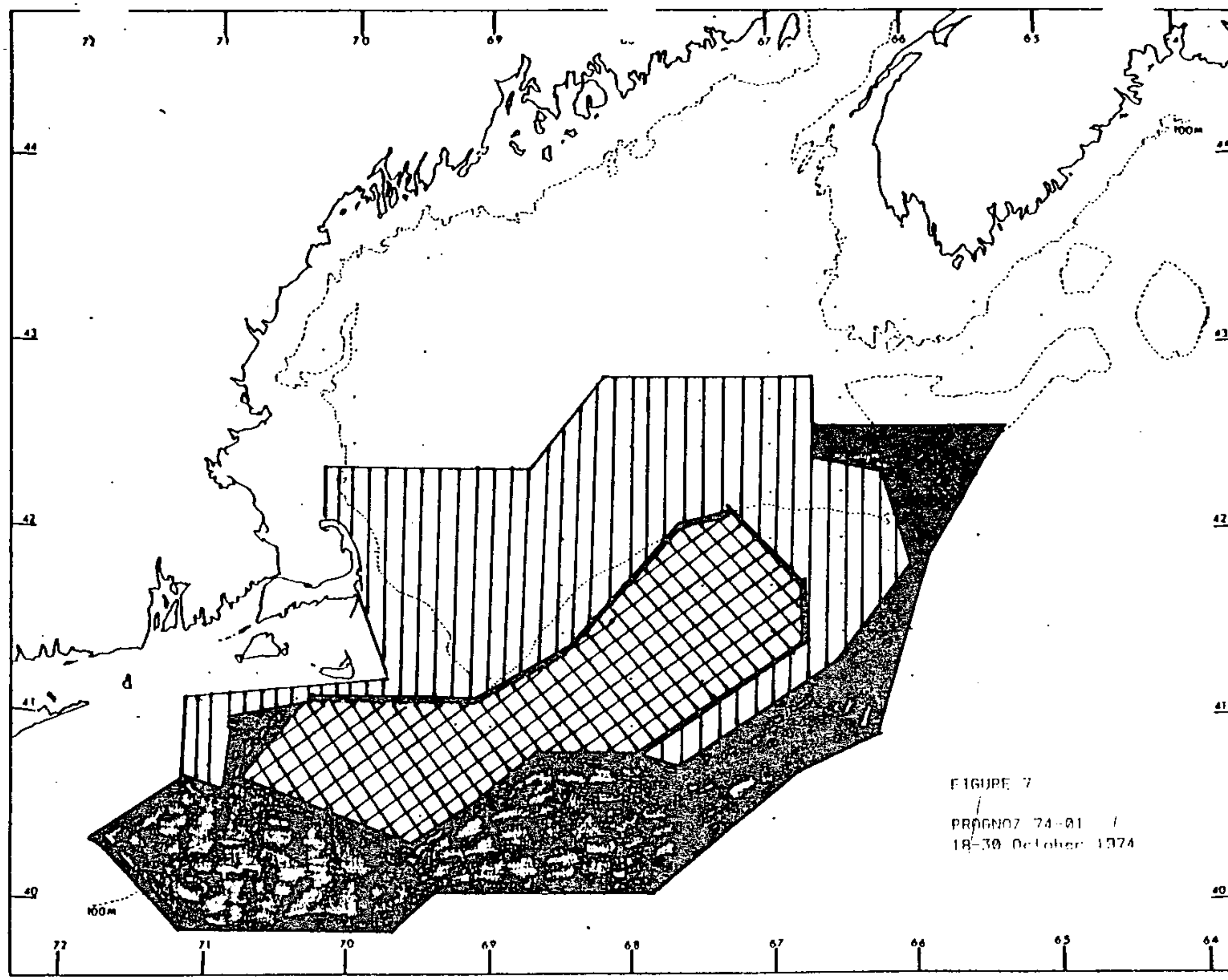


Figure 7. Faunal map for Prognoz 74-01, 18-30 October 1974, showing the northern (vertical lines), shelf (hatched) and southern (shaded) faunal zones.

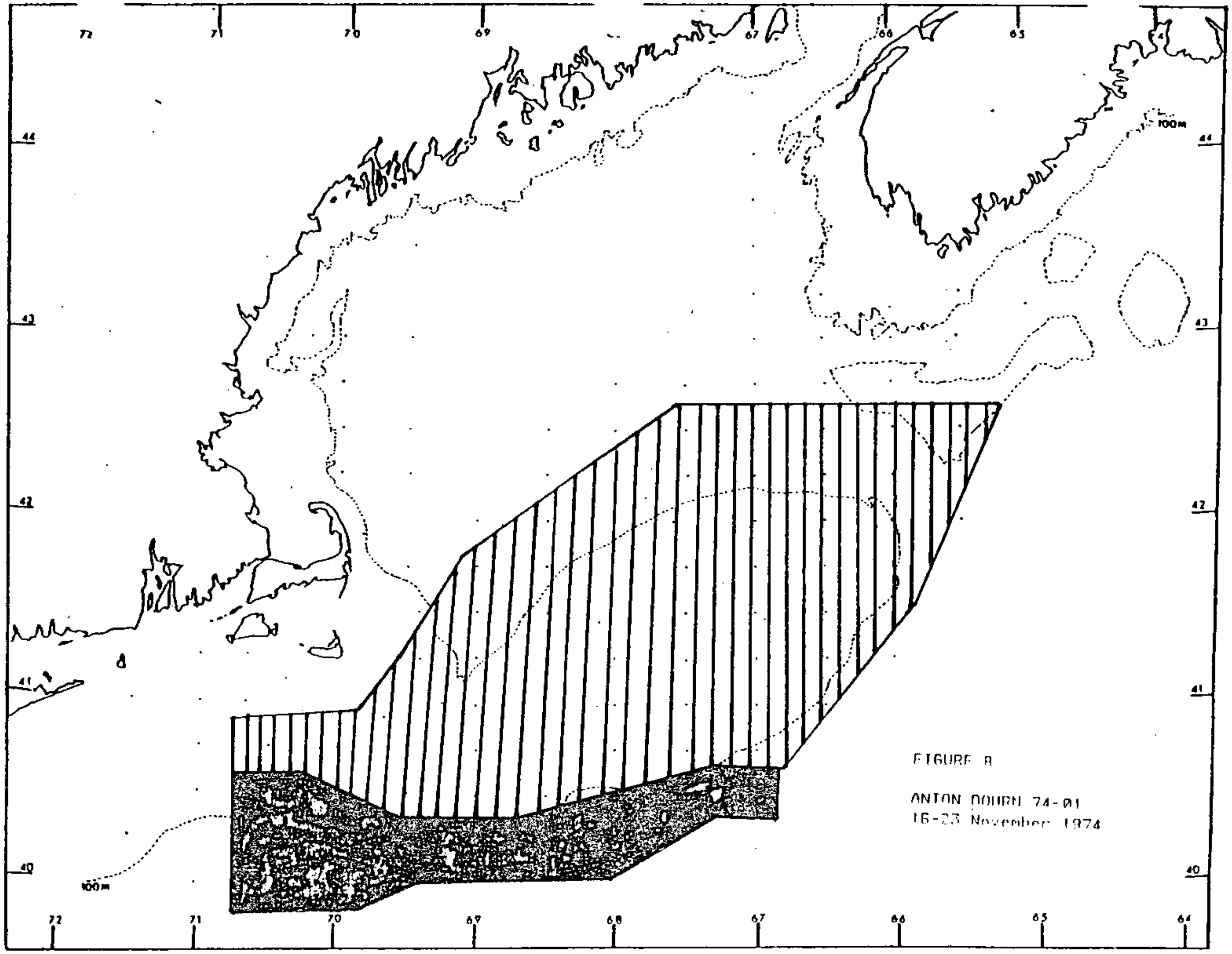


Figure 8. Faunal map for Anton Dohrn 74-01, 16-23 November 1974, showing the shelf (hatched) and southern (shaded) faunal zones.

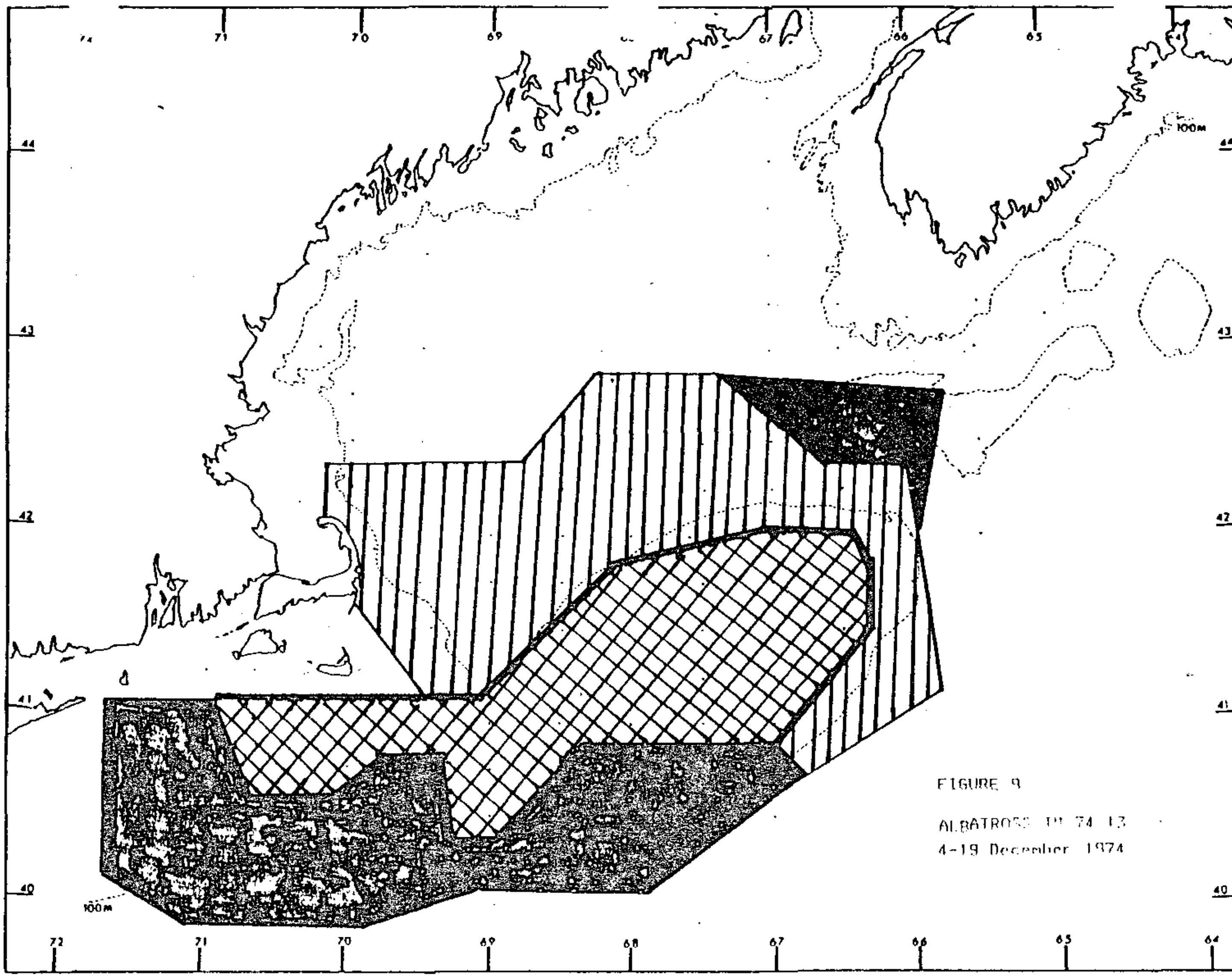


Figure 9. Faunal map for Albatross IV 74-13, 4-19 December 1974, showing the northern (vertical lines), shelf (hatched) and southern (shaded) faunal zones.

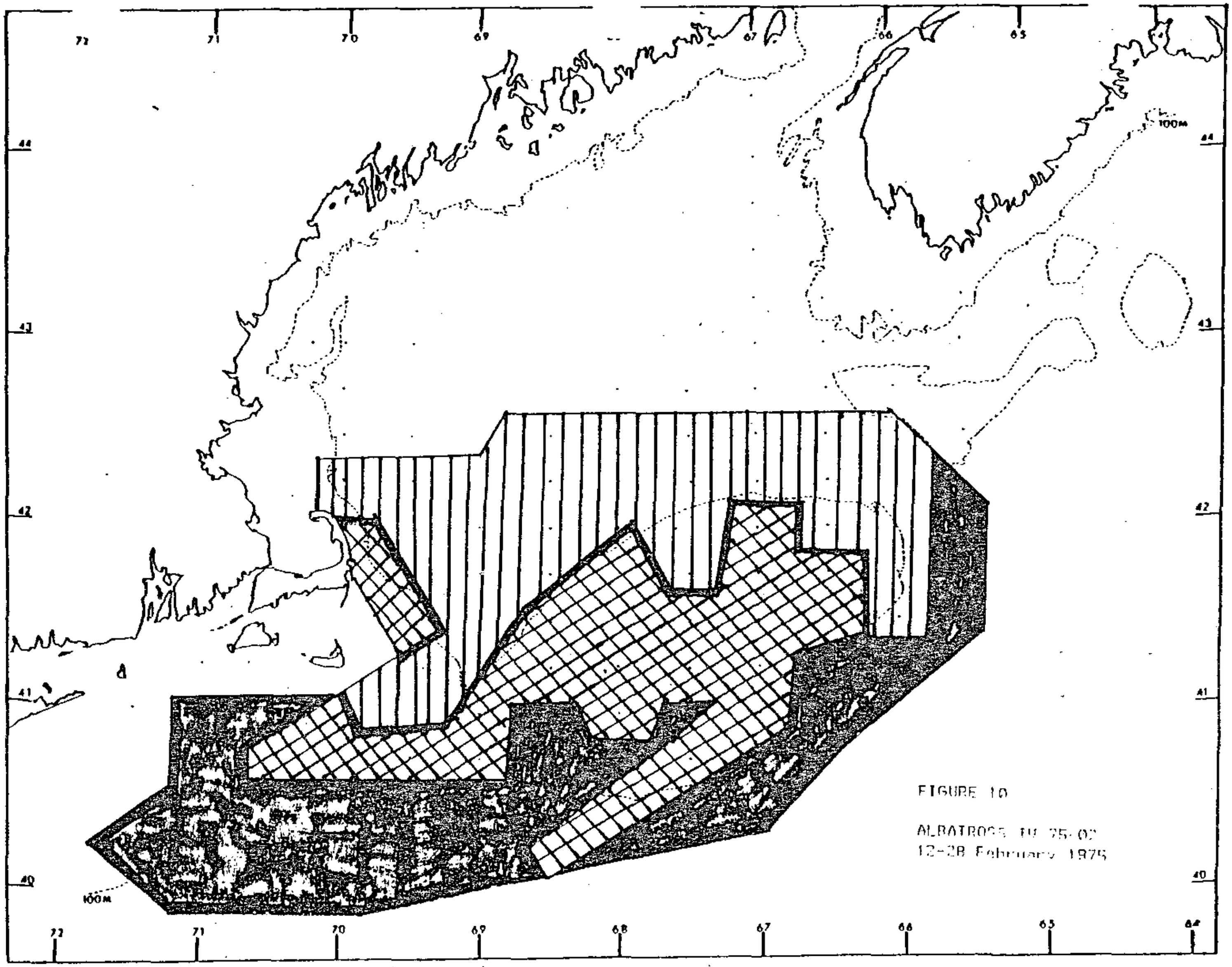


Figure 10. Faunal map for Albatross IV 75-02, 12-28 February 1975, showing the northern (vertical lines), shelf (hatched) and southern (shaded) faunal zones.

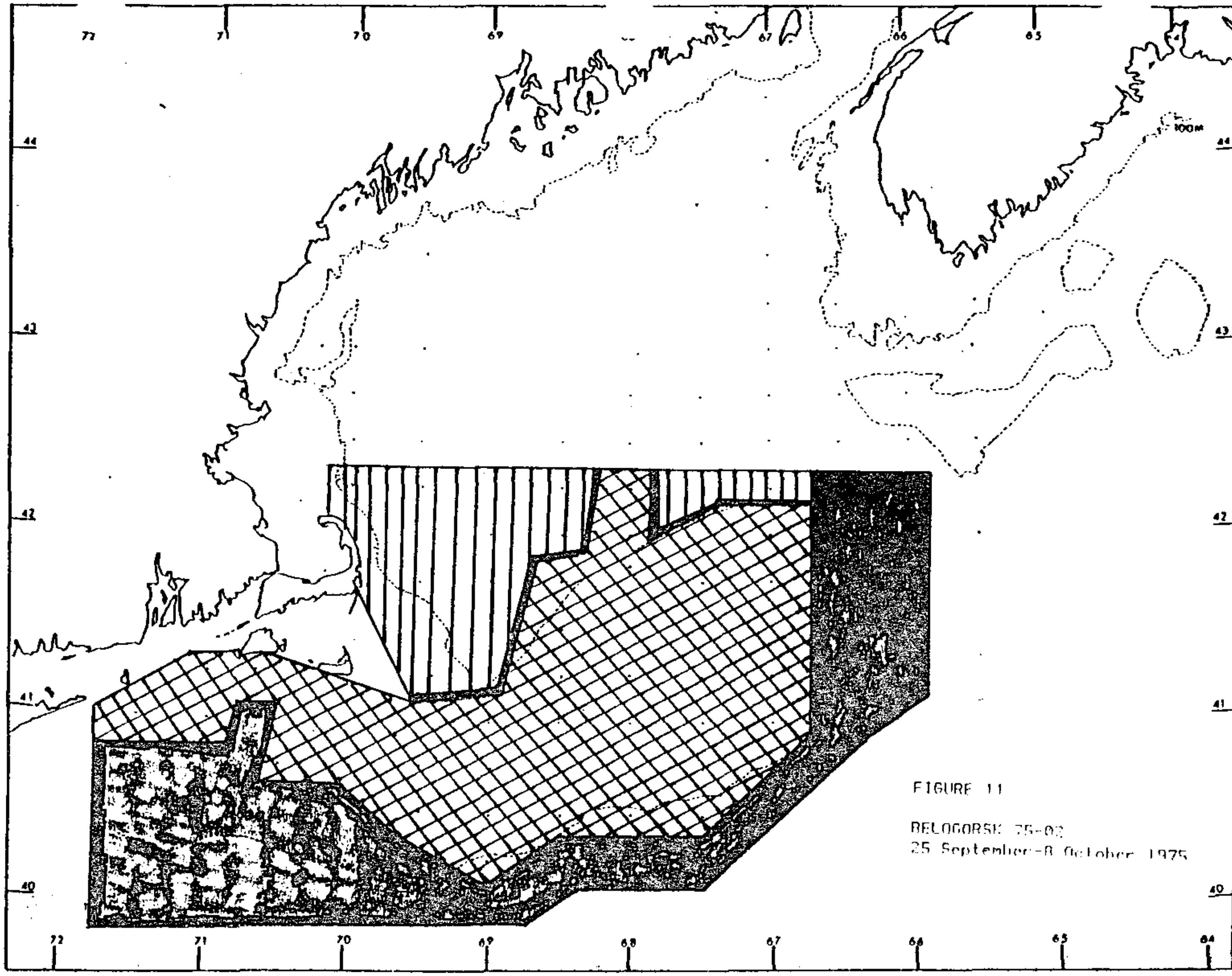


Figure 11. Faunal map for Belogorsk 75-02, 25 September-8 October 1975, showing the northern (vertical lines), shelf (hatched) and southern (shaded) faunal zones.

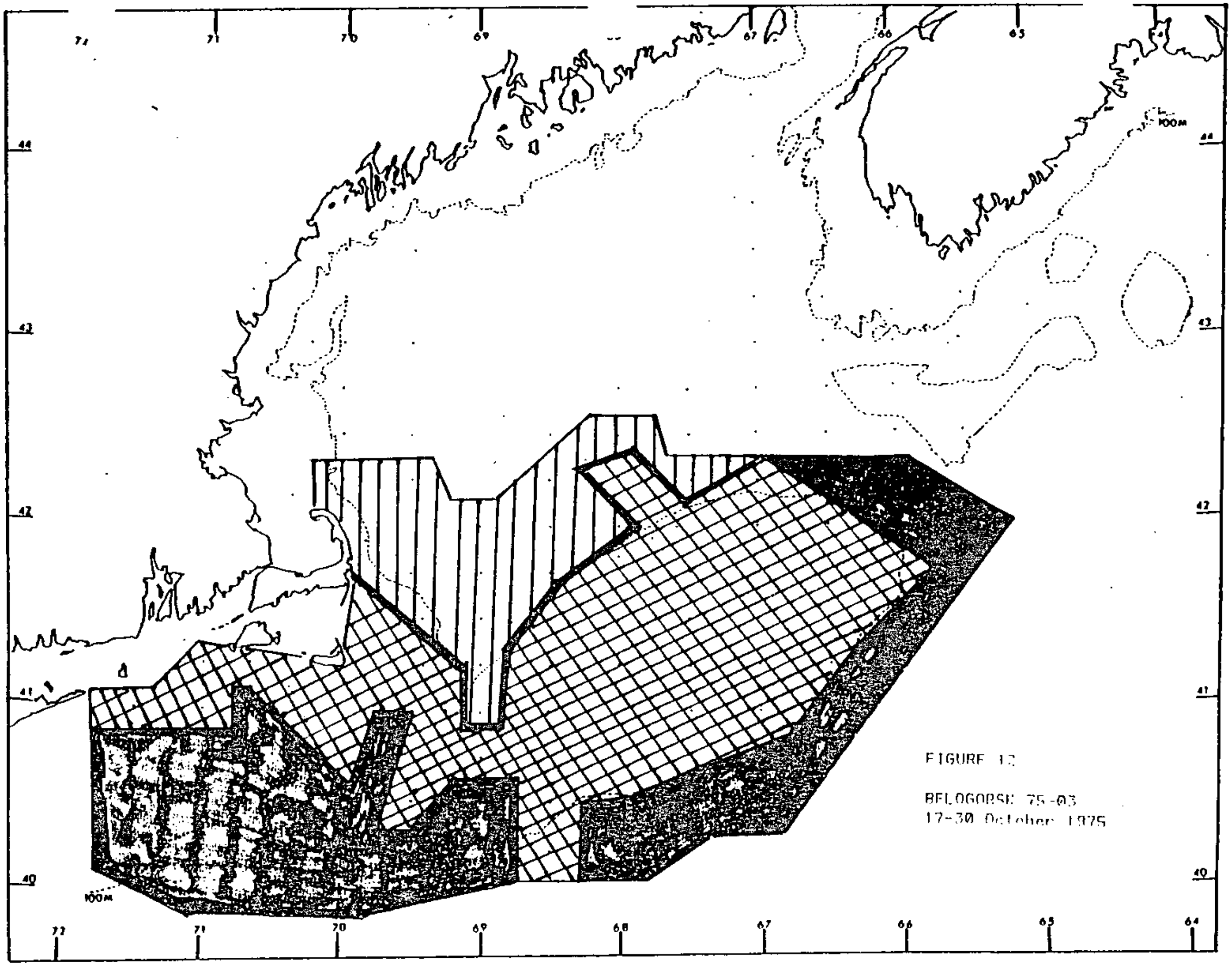


Figure 12. Faunal map for Belogorsk 75-03, 17-30 October 1975, showing the northern (vertical lines), shelf (hatched) and southern (shaded) faunal zones.

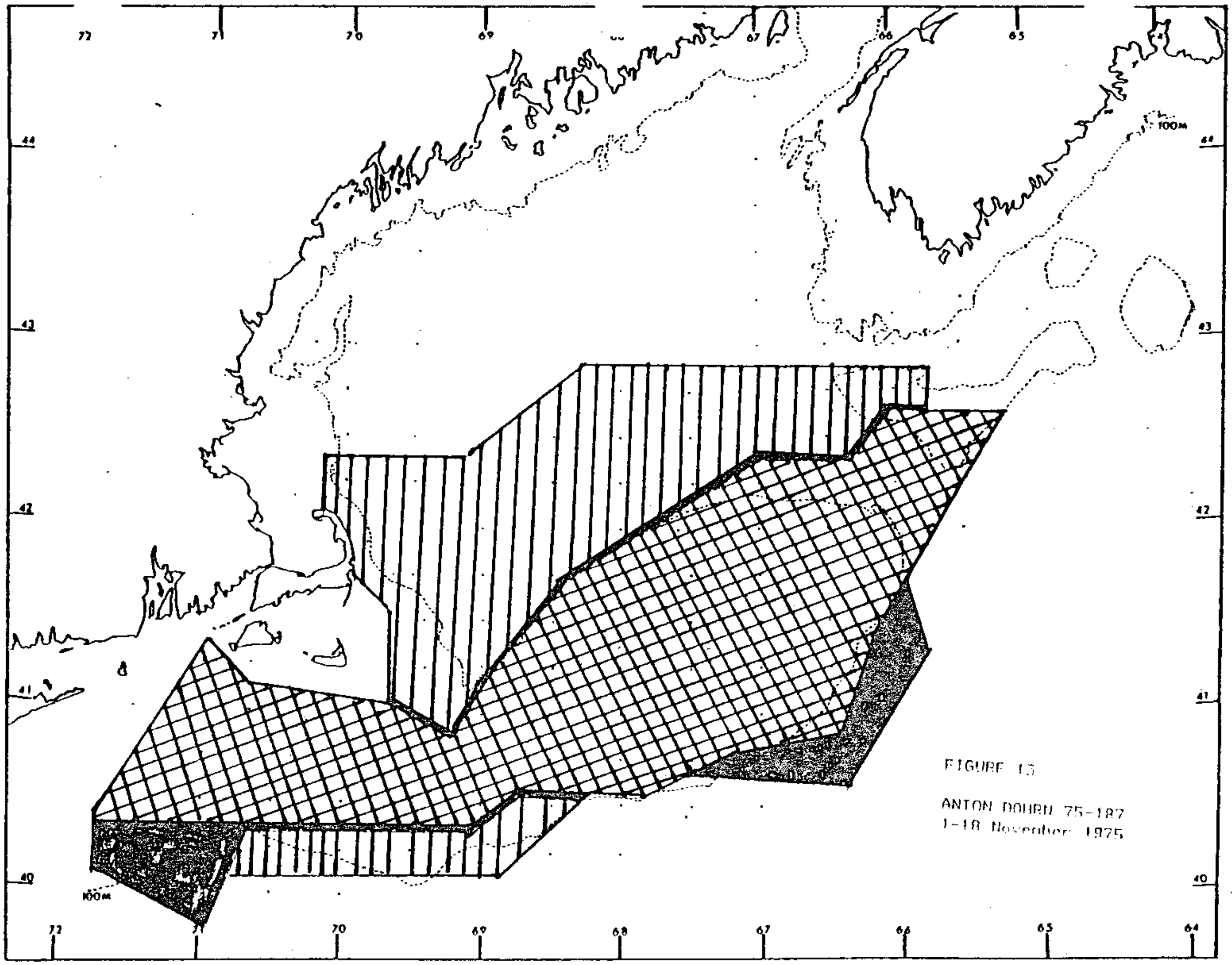


Figure 13. Faunal map for Anton Dohrn 75-187, 1-18 November 1975, showing the northern (vertical lines), shelf (hatched) and southern (shaded) faunal zones.

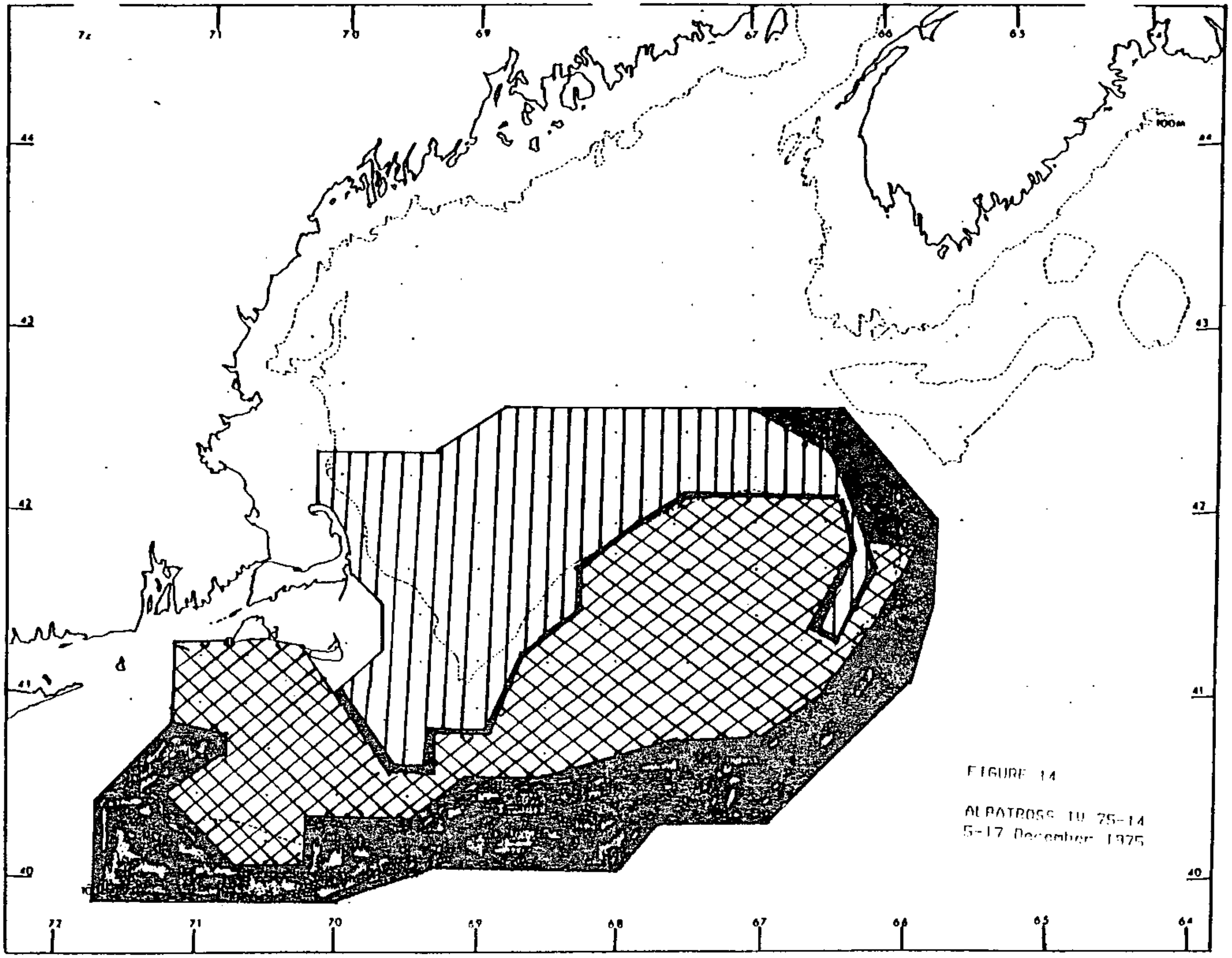


Figure 14. Faunal map for Albatross IV 75-14, 5-17 December 1975, showing the northern (vertical lines), shelf (hatched) and southern (shaded) faunal zones.

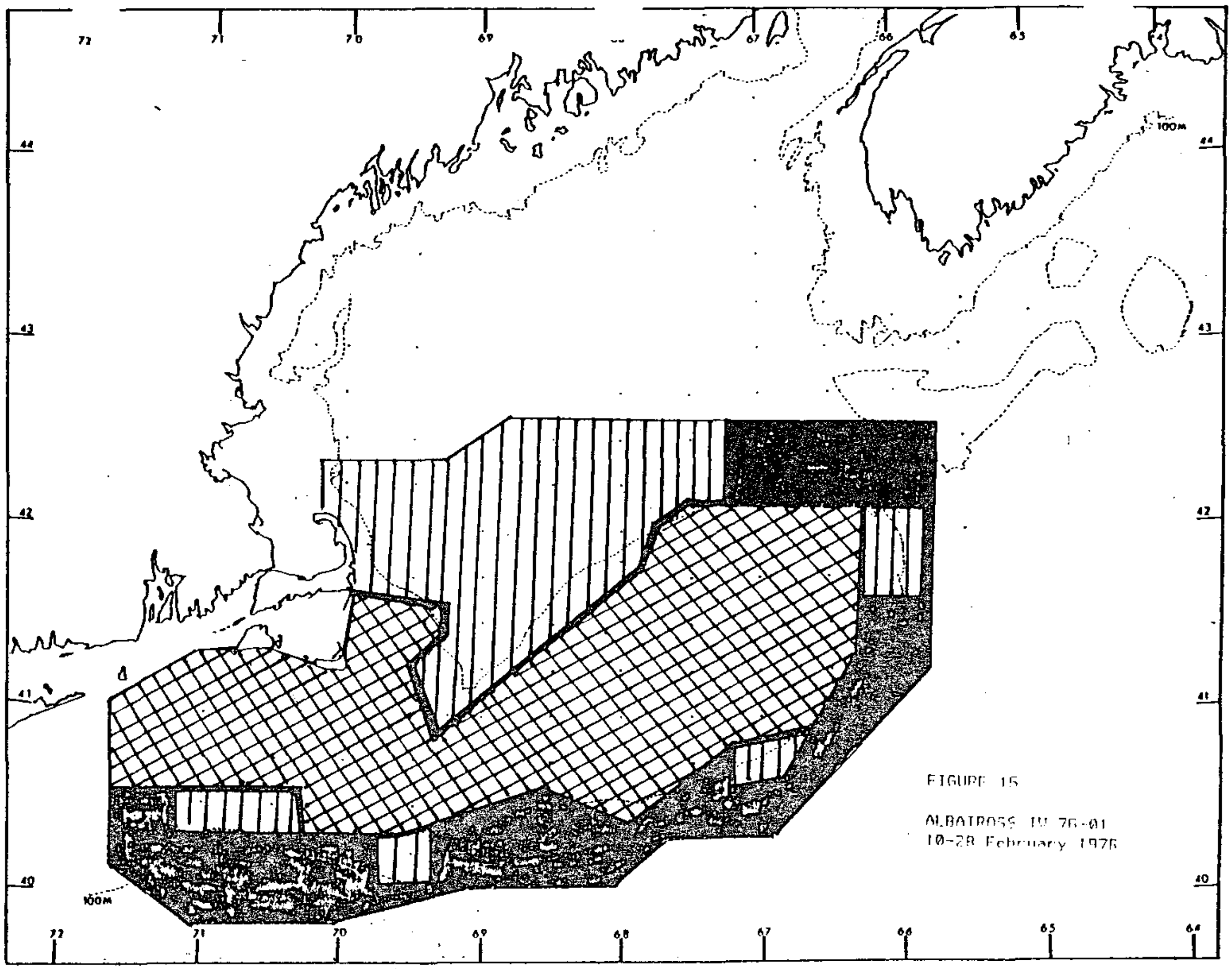


Figure 15. Faunal map for Albatross IV 76-01, 10-25 February 1976, showing the northern (vertical lines), shelf (hatched) and southern (shaded) faunal zones.

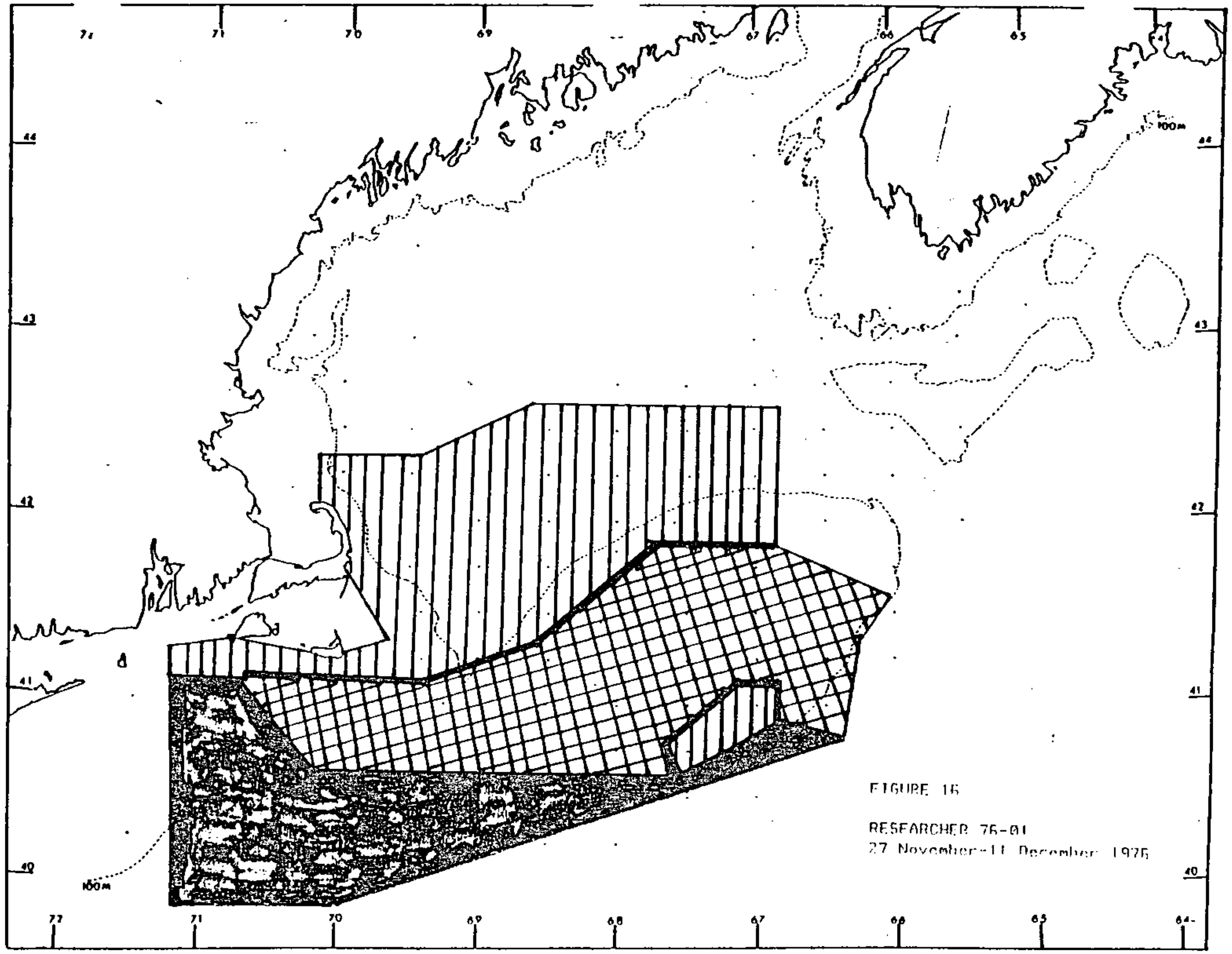


Figure 16. Faunal map for Researcher 76-01, 27 November-11 December 1976, showing the northern (vertical lines), shelf (hatched) and southern (shaded) faunal zones.

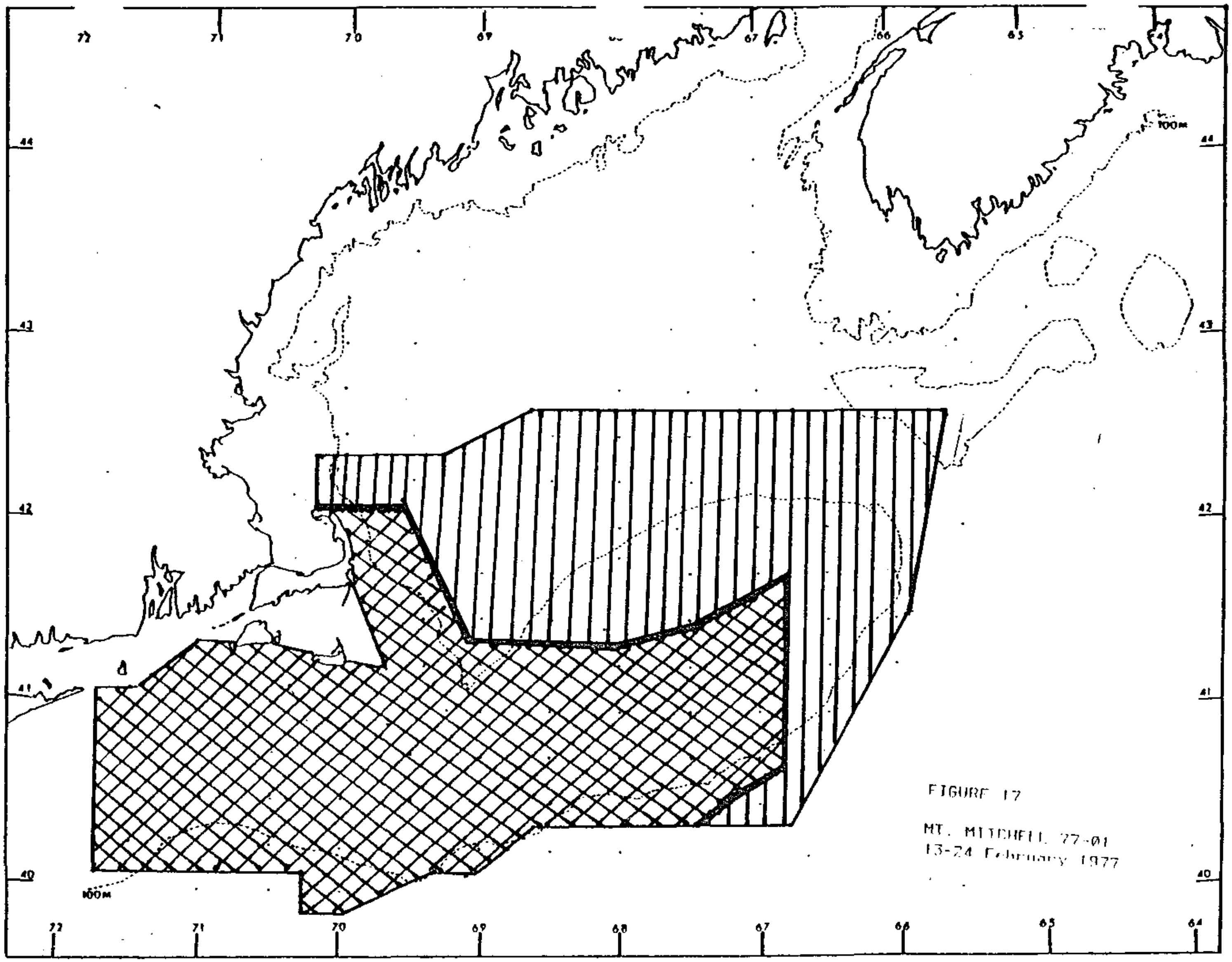


Figure 17. Faunal map for Mt. Mitchell 77-01, 13-24 February 1977, showing the northern (vertical lines) and shelf (hatched) faunal zones.

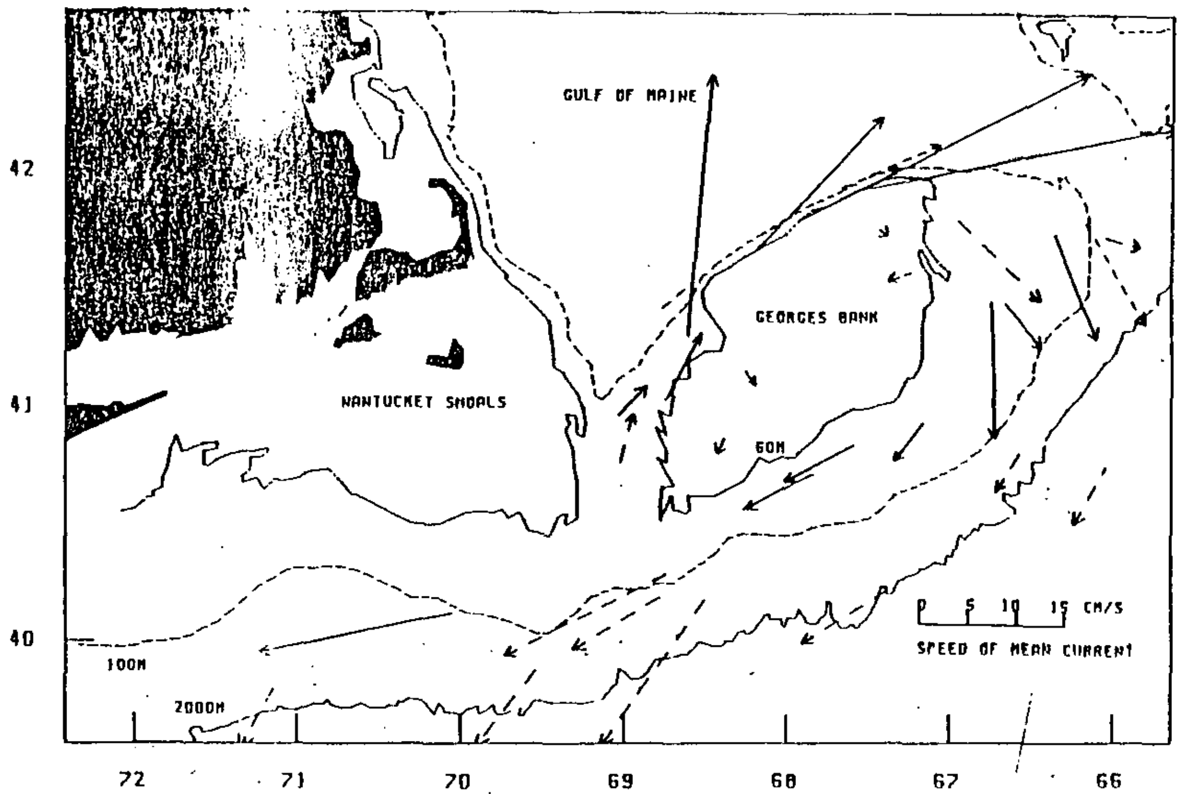


Figure 18. Mean circulation pattern of the Georges Bank region, based on satellite-tracked drifters with 10-m window-shade drogues centered at 10-m depth. Measurements were made during December 1978 (long dash), March 1979 (short dash) and August 1979 (solid line). (Adapted from Butman et al., 1982)