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Some Features of Water Masses and Spatial Distribution of Nektonic Groups in the Area Between the Scotian Shelf and Gulf Stream

by

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Introduction

According to the NAFO program on young and larval short-finned squid (*Illex illecebrosus*), ecological research was conducted during the joint Soviet-Canadian study aboard the R/V *Atlant* in the area between the Scotian Shelf and Sargasso Sea in March-May 1981. During these cruises, data were collected on spatial distribution of some mezo and micronektonic animals and oceanographic conditions characterizing these organisms. This report presents *preliminary* results from the study. It should be recognized that estimates calculated and presented in this report are broad approximations, and they will be re-assessed after the material collected is fully processed in the laboratory ashore.

Spatial distribution of the dominant groups of the nektonic organisms is important for developing a model of a marine pelagic ecosystem, which could be used for resource conservation and exploitation. From this standpoint studies of the pelagic ecosystem biological structure in the zones adjacent to the Gulf Stream in particular, are of great interest. Ecological study within this area was initiated in 1979 (the RTM *Belogorsk* cruise) but there are no published data on the subject discussed in the present report, except for the analysis of the effect of abiotic factors on the distribution of squid *Illex illecebrosus* (Fedulov and Froerman, 1980). Descriptions of the water mass structure, origin and dynamics of the area under investigation have been subjects of discussion in papers by McLellan *et. al.*,(1953), Gatien (1976) as well as the paper by Fedulov and Froerman (1980).

Materials and Methods

Materials were collected during the R/V Atlant cruise conducted within the framework of the NAFO program with the main objective of determining spatial distribution and migration patterns of the young and larval short-finned squid Illex illecebrosus. Data were obtained from the area between the Scotian Shelf and Gulf Stream (Fig. 1) between 27 March and 3 May 1981. A total of 99 trawling ecological stations were occupied which included 272 tows at the following depths: 50 m (43 hauls), 100 m (98 hauls), 200 m (44 hauls), 300 m (53 hauls), and 500 m (34 hauls). A total of 33 stations sampled all five depth levels (28 stations during the hours of darkness and 6 during the daylight). These stations were spaced along 8 transects running almost at right angles to the shelf edge. The distance between the transects was 50 miles. Before towing water temperature was measured either by XBT or by hydrocasts. An area of 306 thousand square km was covered. Sampling was conducted around the clock, using the Canadian research trawl of EMT type. The horizontal spread, vertical opening and the opening of the trawl were 8.6 m, 6.5 m, and 55.5 sq. m., respectively. The average towing speed was 2.4 knots and a tow duration - 15 minutes. Mesh size in the EMT cod end was 6 mm.

Since the majority of data were collected during hours of darkness, calculations of biomass distribution within the survey area and along the transect II (Fig. 4) were made for night time only. The analyses of the diurnal dynamics of the vertical biomass distribution however, used all data.

All catches were sorted by groups of mezo and micronektonic organisms. Weight and proportion of each group in the total catch were then determined. Catchability of the EMT trawl (which is a subject for a special study) was taken as 1.00. All the calculations assumed that nekton biomass had a relatively uniform distribution and station to station variation had a linear function. Applying these assumptions the calculated biomass estimates for water volumes filtered by EMT were recalculated for the water volume in the survey area at each depth stratum and total biomass (in tons/sq. km) was calculated for the entire region under investigation.

In the present paper all the nektonic organisms are defined as mezo and micronektonic animals, while large fish species and marine mammals are classified as macronekton.

The hydrological data collected at 50 mile stations were as follows: temperature measurements with reversing thermometers at 0, 10, 20, 30, 50, 75, 100, 150, 200, 300, 400, 500, 600, 800, and 1000 m depths; water sampling for salinity, dissolved oxygen and nutrients with Nanssen bottles. Water samples for salinity and dissolved oxygen content were treated aboard the ship while those for nutrients were frozen to be treated later.

Between 50 mile stations, water temperature profiles were taken by XBT casts down to 750 or 1800 m. Within zones where high temperature gradients were observed, the XBT stations were placed 10-12 miles apart (Fig. 1).

All the stations were placed along 8 transects running at right angles to the shelf edge (Fig.1). Almost all the transects (except transect IV) traversed through the Gulf Stream at their southern ends. For each transect vertical temperature, salinity and dissolved oxygen sections were constructed. Since these characteristics along all transects were similar to one another in their general distribution patterns, only transect II is chosen for discussion. This was the longest transect with the largest number of biological stations with hauls made at all 5 depths. This transect also had a fine resolution with stations placed close to each other (Fig. 1).

Results and Discussion

Spatial Distribution of the Water Masses. The oceanographic data are in close agreement with spatial features of the water mass distribution in the region observed and described in 1979 (Fedulov and Froerman, 1980), with the exception that Warm Core Eddies (WCE) separated and moved away from the Gulf Stream in 1981. A well defined WCE with a diameter of about 120 miles existed during the whole period from 27 March to 4 May in the western region of the operational field.

During the period from 30 March to 4 May, the eddy which was almost circular moved 90 miles southwestwards while its shape transformed into an elliptical one with a long axis oriented in the west-east direction (according to the sattelite maps). Transect II went through the eddy close to its centre (Fig. 2).

Spatial temperature distribution. A wide temperature range was observed in the investigated area. The temperatures ranged between 3°-4°C close to the shelf and 20°-21°C in the Gulf Stream region.

The upper layer, down to 100 m in the northern portion of the operational field adjacent to the shelf, was occupied with cold shelf waters with the temperatures <5-6°C. This layer penetrated into the deep ocean as far as 100 miles off the shelf edge. Beneath the cold shelf waters at depths from 100-200 m, there was an intermediate layer of warm water with temperatures >10°C. These warm waters were directly adjacent to the continental slope. While stretching offshore the thickness of the layer increased and it rose to the surface outside the boundary of the shelf waters.

Water temperatures beneath the intermediate warm layer gradually decreased from 8°C at 400-500 m to 4-4.5°C at 1000 m depth over the whole area between the shelf and the Gulf Stream.

The Gulf Stream waters along the southern parts of all the transects are defined by steep deepening of the isotherms as well as by sharp horizontal temperature gradient at all depths (from 14° to 18°C). The depth of the Gulf Stream water layer defined by isotherm inclination was 800-1000 m. Directly outside the Gulf Stream, temperatures ranging from 19° to 22°C were observed in the 0-100 m layer. This area was adjacent to the eastern boundary of the Gulf Stream.

The above spatial distribution of the temperatures along the transects was, however, broken by the presence of the WCE (Fig. 2) which encroached into the intermediate warm water layer. The temperatures wtihin the whole eddy water mass were >17°C, and maximum depth of the eddy was 450 m. The highest temperature along the vertical axis of the eddy was 17.60°C. A zone of sharp horizontal gradients amounting 1.2° per mile was formed between shelf waters and the northern boundary of the eddy.

The eddy rotating clockwise absorbed cold shelf waters which upon mixing with warm open ocean waters form a zone of lowered temperatures at the eddy's periphery. This zone is distinctly defined along the transect II (Fig. 2) outside the southern boundary of the eddy.

Salinity distribution pattern. The salinity distribution, in general, were similar to the temperature distribution pattern though it was less variable over the whole area of the operational field (Fig. 2). Shelf waters are characterized by salinity <34°/₀₀ while the intermediate warm waters had salinity of about 35°/₀₀ -36°/₀₀. Salinity of these waters gradually increased from the shelf towards the Gulf Stream (which is patricularly well defined along the transects not running through the eddy). Salinity within the narrow Gulf Stream zone ranged between 36.20°/₀₀ and 36.50°/₀₀. Some increase in salinity (≥ 36.5°/₀₀) outside the Gulf Stream corresponded to the Sargasso Sea water properties. Salinity in the ring was almost stable: 36.45 ± 0.05°/₀₀.

At depths greater than 400-500 m the salinity is practically unchanged at 35°/₀₀. Under the eddy, water with the same property was deeper than 800 m.

Distribution of dissolved oxygen. The highest values of dissolved oxygen were characteristic for the shelf waters (>6 ml/l) with maximums being observed in the pre-surface layers (>7 ml/l).

A peculiar feature of the dissolved oxygen distribution - the presence of a layer of minimum oxygen content - was described by Fedulov and Froerman (1980) for the first time. This layer was clearly seen at all the transects with oxygen content <4 ml/l. This layer coincided with the position of a boundary between warm and intermediate waters (Fig. 2). The layer gradually deepened and thickened from the shelf towards the Gulf Stream. Under this layer the dissolved oxygen content increased with depth. The oxygen content close to the shelf at 600-1000 m depths was, however, higher than that in the offshore area at the same depths.

Beneath the eddy, there was a layer of minimum oxygen content at depths which had temperatures corresponding to the intermediate warm water (10°-12°C). At transect II this layer deepened under the eddy, down to 600-700 m (Fig. 2).

Types of water masses in the operational field area. The above features of temperature, salinity and dissolved oxygen distributions may relate to the peculiarities of water mass formation and spatial distribution in the investigated area. McLellan et al. (1953), McLellan (1957) and Gatien (1976) showed that the water masses in this area are formed by North Atlantic Central water, Labrador Current water, and Coastal water. Labrador Current water mixing with North Atlantic Central water forms slope water, where Gatien (1976) distinguishes between Labrador Slope water occupying the area close to the continental slope and Warm Slope water in the area between Coastal water and the Gulf Stream at depths down to 200-300 m.

Fresh Coastal water is likely to mix with North Atlantic Central water on a small scale only. McLellan (1957) holds a view that North Atlantic Central water mixes with Coastal and Labrador water masses in a ratio 4:1. When moving westward along the Scotian shelf, however, this ratio increases which is the reason for a less pronounced difference between Slope water and North Atlantic Central water over the western portions of the continental slope when compared with its eastern parts.

The data obtained during the R/V Atlant cruise suggest that in the operational field area Warm Slope water is characterized by temperatures and salinity ranging between 10°-15°C and 35.50°/₀₀-36.10°/₀₀, respectively, and occupies depths down to 200-300 m.

Labrador Slope water in the area under investigation is poorly defined and(by its T-S characteristics) with temperatures 6-8°C and salinity 34.90°/₀₀ -35.10°/₀₀ at depth of about 500 m cannot be distinguished from North Atlantic Central water.

The spacial distribution features of some groups of the mezo- and micronekton

In the area under investigation the mezonektonic and micronektonic species were dominated by bathypelagic fish species (37-38% of the total biomass). The main families of fish can be arranged in sequence of their proportion in the biomass as follows: Myctophidae (15-16% of the total mezo- and micronecton or 42% of the total fish species biomass); Malacosteidae, Gonostomatidae, Nemichthyidae, Sternoptychidae, Chauliodontidae, Serrivomeridae, Anoplogasteridae and other bathypelagic families as well as the eel larvae of the *Anguilla* genus and some epipelagic fish larvae and fries.

The invertebrate fauna of the mezo- and micronektonic species comprises some major groups: cephalopods (squid and octopus species), crustaceans, jellyfish, and salps.

In this paper we shall only discuss the following three components of spacial distribution of the nectonic species: the biomass of all mezo- and micronectonic organisms (including fish and invertebrate species), fish species biomass (Pisces), and the fish species biomass of the *Myctophidae* family.

Vertical distribution of the mezo- and micronectonic organisms during the light and dark hours of the day.

Analysis of averaged vertical distribution data of the three major groups of mezo- and micronekton (Fig. 3) suggests that biomass has a highly uneven distribution in the water layer from 0 down to 500 m, exhibiting some variations during the light and dark hours. Vertical distribution was characterized by three maxima: the major one was recorded at 500 m depth, the second dominant maximum - at 200 m depth, and the third one, occurring in the pre-surface layer (50 m), showed diurnal importance with decreases during the daylight period and increases during the hours of darkness.

Presence of two minima was a feature in the vertical distribution of the mezo- and micronecton biomass; they occurred at 100 m (this minimum deepened in the daylight period and rose upward to the above-mentioned level at night) and 300 m depths.

The vertical distribution of the fish species biomass had basically, the same features as those of the total mezo- and micronecton biomass. During daylight fish species of *Myctophidae* family, had their biomass minimum within the layer from the surface to 200 m (with a gradual increase in biomass with depth - down to 500 m), while during the dark hours biomass in the pre-surface layer increases due to diurnal vertical migrations which are highly characteristic for this family.

The mezo- and micronecton biomass distribution along the transect from the Nova Scotia shelf to the Gulf Stream. Data collected along transect II (Fig. 4) generally showed two distinguishable maxima (for Myctophidae spp. and Pisces spp. as a whole): a northern one, located in the continental slope area, and a southern one, observed 180-200 nautical miles off the shelf edge or 250-300 nautical miles off the shelf edge (for the total biomass of mezo- and micronectonic organisms). It is interesting to note, that in the continental slope area the biomass maximum is formed mainly by the crustaceans, while that in the oceanic zone - by jellyfish (northern edge of the Gulf Stream) and crustaceans (southern periphery of a ring). The oceanic maximum was not so apparent along the other transects. In the zones of maximum biomass the latter often increases with depth (in the layer from surface down to 500 m). The oceanographic events which may determine this pattern of the nekton biomass distribution will be discussed in the passages following.

To conduct the analysis 28 stations were chosen where tows were made at all standard depths during the dark hours of the day. While analyzing these data, the peculiarities of diurnal dynamics in the vertical nekton biomass distribution were taken into account. Maps of distribution of the total mezo- and micro-nekton biomass, total fish species biomass as well as biomass from Myctophidae family (Fig. 4, in tons/sq. km in the layer 0-650 m) were analysed, and the analysis resulted in higher estimate of the biological productivity of the waters adjacent to the shelf and shelf break as compared to the areas more distant from the shelf.

This was revealed in all the three groups of marine organisms under investigation. Only in the vicinity of the Gulf Stream northern edge (transect II) the estimtes for the total biomass increase, while in the stream and near the Gulf Stream southern edge they decrease again.

Preliminary estimate of the total biomass of some nektonic species groups within the survey area in the layer 0-650 m. Mean estimates of the total biomass of some nektonic species groups per 1 sq. km. (layer 0-650 m) were calculated for the whole operational area equal to 306 thous. sq. km. The mean estimates are 5.51, 13.17, and 32.38 tons/sq. km for the fish species of the Myctophidae family, all bathypelagic fish species, and all mezo- and micronektonic organisms caught by EMT trawl, respectively.

Thus, from preliminary and highly approximate estimates, the total biomass of the fish species of the Myctophidae family within the area under investigation - between the Nova Scotia shelf and the Gulf Stream in the layer 0-650 m - amounts to approximately 1.7 million tons, that of all bathypelagic fish species - to 4 million tons, and the total biomass of all the mezo- and micronektonic organisms caught by the trawl of EMT type - to approximately 11 million tons. It should be noted here, that the calculated estimates of the nekton biomass (in tons/sq. km) are rather high.

Relationships between distribution of nekton biomass and the peculiar features of water mass distribution in the investigated area. The distribution of biomass of the investigated nektonic organisms by group is closely related to the water mass structure. A significant increase in biomass of all three groups of nektonic animals is observed in the area adjacent to the shelf with maximum estimates for the total fish species biomass and all nektonic organisms being recorded at the stations occupied directly over the shelf beak (for example, the northernmost station at the transect IV, Fig. 5). This area is occupied by Labrador slope water, which judging by its origin, is likely to be more rich in nutrients as compared with Warm Slope Water.

The data from transect II suggest that the biomass estimates at the southern and northern peripheries of the eddy are high as well (Fig. 4). Minimum biomass estimates are recorded in the centre of the eddy which can be related to the fact that the eddy's body is formed almost exclusively by the Gulf Stream waters which are characterized by low estimates of nekton biomass (the fish species biomass, particularly). The anti-clockwise rotation of water in the eddy must lead to the deepening of warm water in the eddy's central portion and to the upwelling of cold water at its periphery which phenomenon may effect the distribution of nektonic biomass within the eddy's zone.

Just outside the eddy's edge there exists a narrow zone (10-12 miles wide) which is formed by shelf waters entrained by the eddy (previously described). This zone has high estimates of nekton biomass. This zone is clearly seen at the southern periphery of the eddy at the transect II (Fig. 4) and is well defined in the chart of the nekton biomass distribution over the operational field area (Fig. 5, transect IV).

Low biomass estimates, though somewhat higher as compared to those in the inner portion of the eddy, correspond to Slope Water mass (occupying the area between the Gulf Stream and the eddy at the transect II).

Just in front of the northern edge of the Gulf Stream a significant increase in nekton biomass, which mainly accounts for jellyfish, is observed (Fig. 4 (III)). As for the fish species biomass in this region, such an increase is less pronounced (Fig. 4 (II)).

No distinct relationship is revealed between the averaged vertical distribution of nekton biomass (Fig. 3) and the vertical water structure in the area under investigation. It is probable, however, that a detailed analysis of vertical biomass distribution of particular marine organisms, as well as the use of data on nutrient contents, are necessary to establish this type of relations. The data on nutrient have been collected and will be treated later.

Conclusion

Preliminary analysis data obtained during the R/V ATLANT cruise during the March-May period, 1981, in the area between the Scotian Shelf and the Gulf Stream revealed a high biological productivity of the waters in this region. General features of the spatial biomass distribution of micro- and mezonektonic organisms are closely related to the water mass structure and dynamics. The data obtained can be used to plan further research in structure and functioning of the ecosystem in this part of the ocean.

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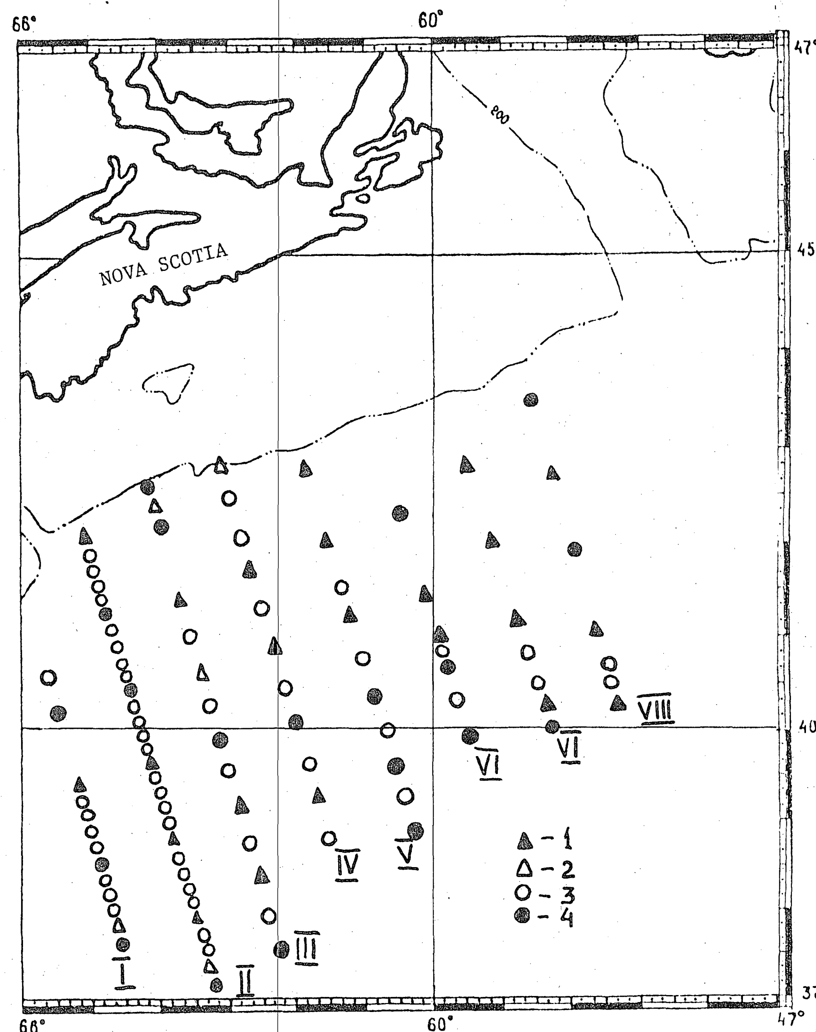

Fig. 1. Scheme of station and transect positions over the operational field:

1 - hydro and biological stations (with EMT tows at 50, 100, 200, 300 and 500 m)
2 - biological station with 5 EMT tows and XBT station
3 - biological station (less than 5 EMT tows) and XBT station
4 - biological station (less than 5 EMT tows) and hydro station.

Roman numerals designate transect numbers.

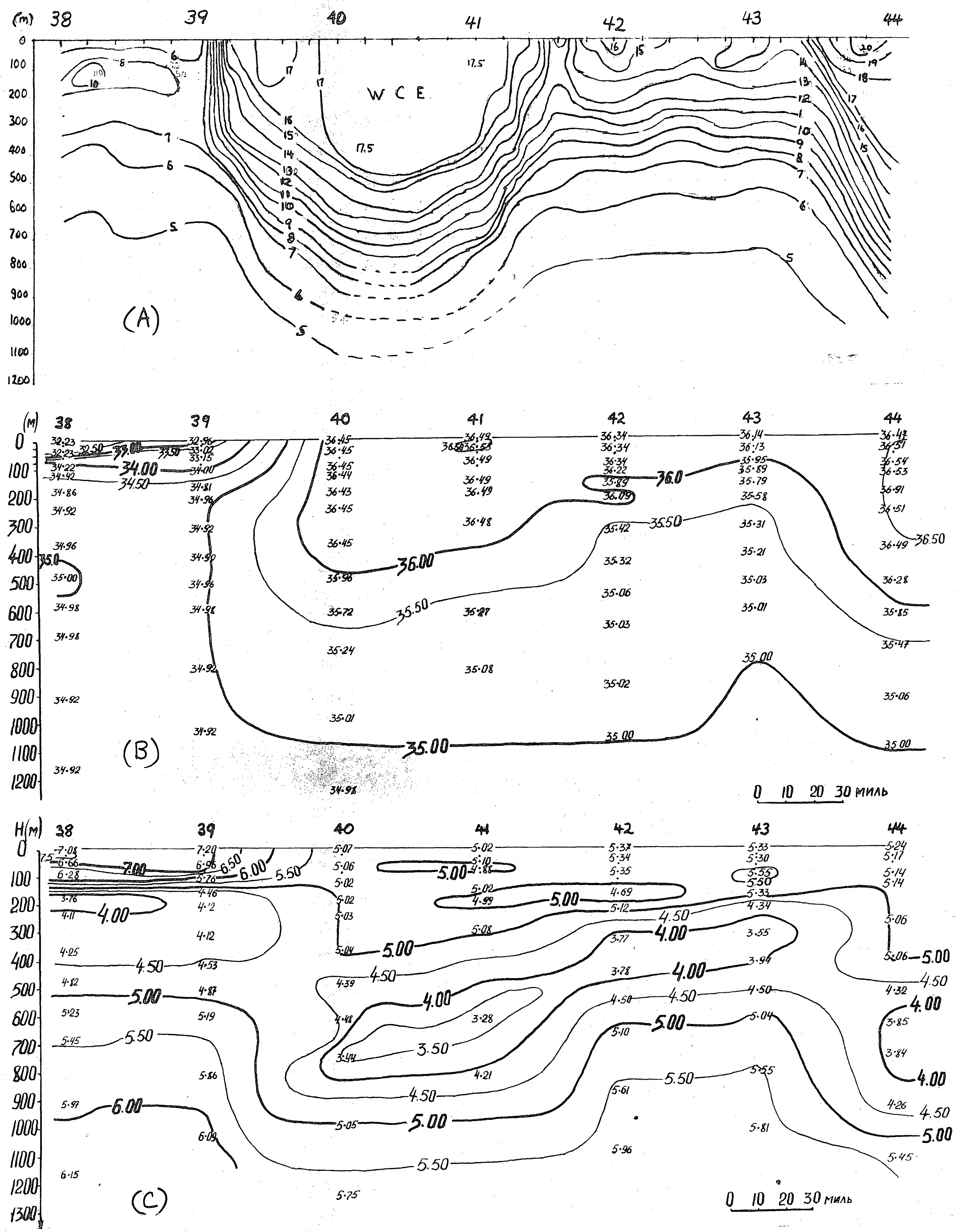

Fig. 2. Vertical distribution of temperature (A), salinity (B), and dissolved oxygen content (C), along Transect II.

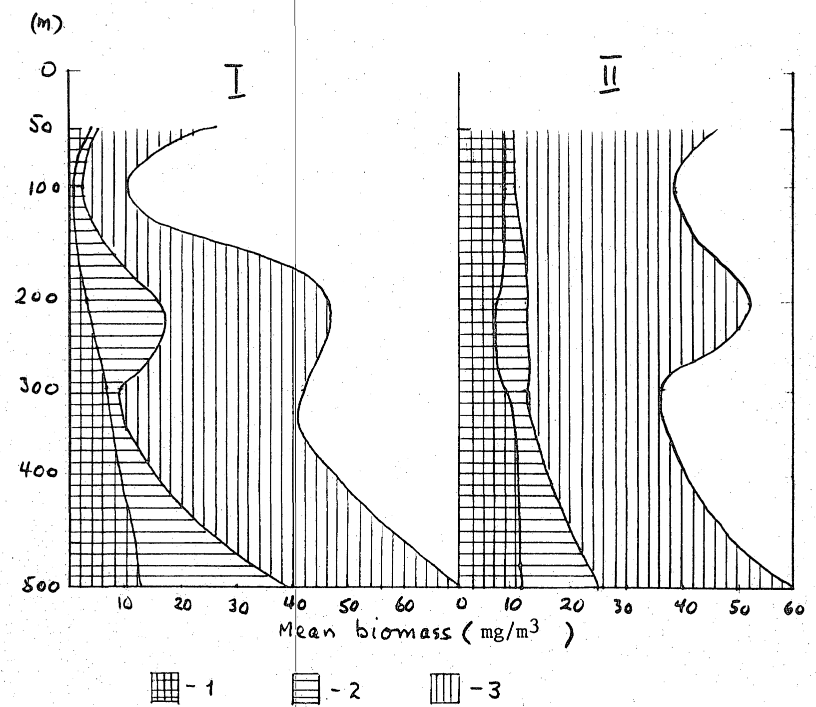

Fig. 3. Vertical distribution of mean biomass estimates for fish species of the _Myctophidae_ family (1), all fish species (2), and other mezo and micronektonic organisms (3), in the area between the Scotian Shelf and the Gulf Stream within the layer 0-500 m (mg/m^3), by data from R/V _Atlant_ cruise, March-May 1981: I - light hours of the day (105 tows); II - dark hours of the day (136 tows).

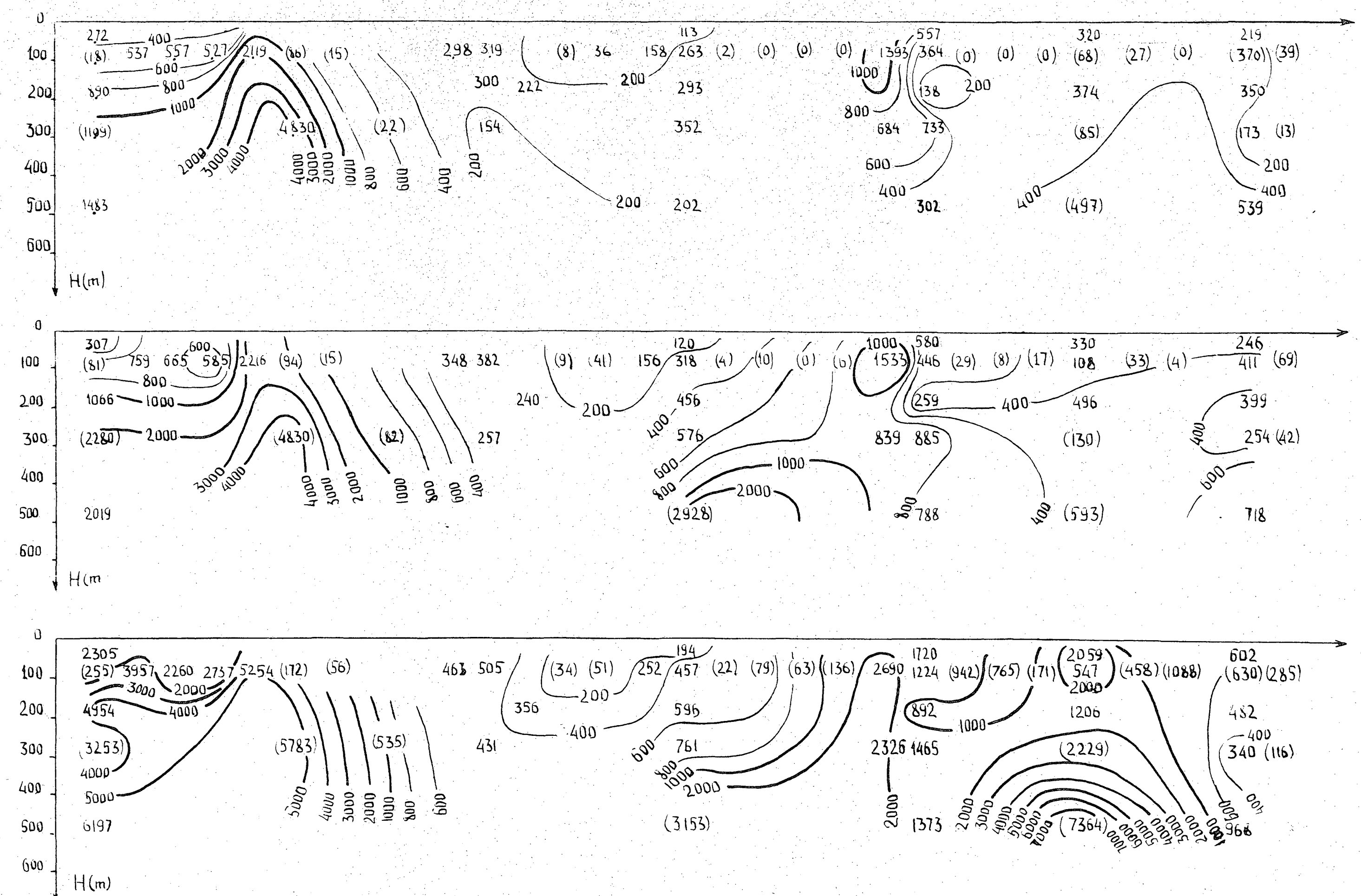

Fig. 4. The biomass distribuiton of the fish species from the Myctophidae family (1), all fish species (2), and mezo and micronekton (3), along the transect II from the Scotian shelf towards the Gulf Stream during the time period from March 31 to April 5,1981 (in grams per 15-minute tow by EMT; R/V Atlant cruise 81-05).

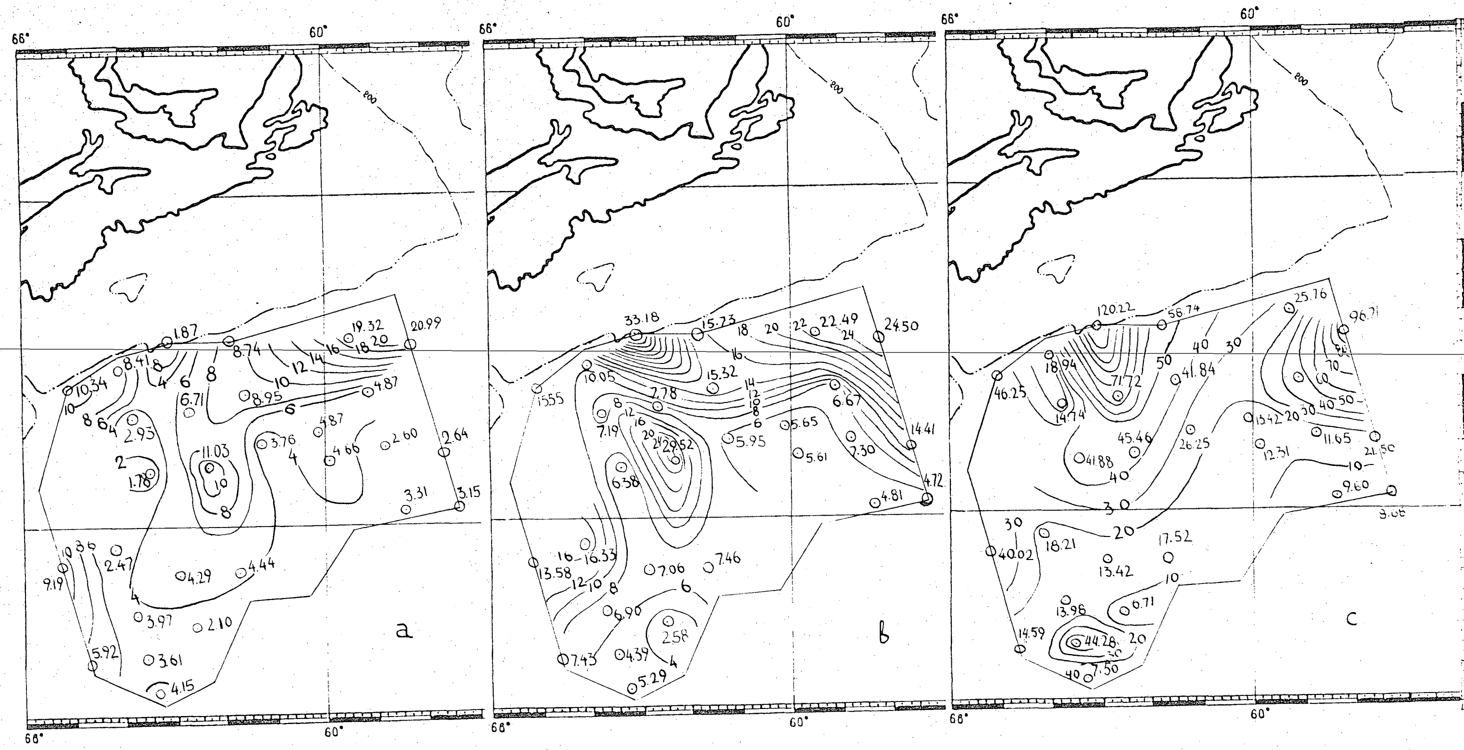

Fig. 5. Spatial distribution of biomass estimates for the fish species of the <u>Myctophidae</u> family (A), all fish species (B), and all nektonik organisms (C), over the area between the Scotian shelf and the Gulf Stream (tons/sq. km in the layer 0-650 m) during the period from 31 March to 5 May 1981.