Northwest Atlantic Fisheries Organization

Serial No. N722

NAFO SCR Doc. 83/VI/62

SCIENTIFIC COUNCIL MEETING - JUNE 1983

Diurnal Movember of Young *Illex illecebrosus* and Some Other Cephalopods in Relation to Vertical Water Structure off the Nova Scotia Shelf

by

A. I. Arkhipkin, P. P. Fedulov and V. V. Perov

Atlantic Research Institute of Marine Fisheries and Oceanography (AtlantNIRO)
5 Dmitry Donskoy Street, Kaliningrad, 236000, USSR

Abstract

In this paper,data on observations over vertical distribution of some cephalopod species made off the Scotian Shelf are presented. A relationship between diurnal vertical migrations of the cephalopods and the vertical water structure is established. Patterns of diurnal movement of the young short-finned squid *(Illex illecebrosus*) of various length groups are described. Other cephalopods are classified by group relative to their patterns of vertical movements.

Introduction

In recent years much interest has grown to the biology of short-finned squid, *Illex illecebrosus* (Le Sueur, 1821). In spite of this almost nothing is still known on the diurnal vertical movements of this animal. Study of this type of migrations is essential for biomass estimation of squid coming onto the Scotian Shelf and Grand Banks using a pre-season estimate of juvenile and young *Illex* abundance in the Gulf Stream and Slope waters (Froerman, 1980).

Short-finned squid larvae are mainly caught in the Gulf Stream waters. At night they are evenly dispersed through the layer 0-100 m above the thermocline while in the daytime they move down and are located in a layer of 50-100 m (Hatanaka *et al.*, 1982). Juvenile *Illex illecebrosus* with a mantle length of 12-29 mm are caught by the trawl in great numbers at 100 m at night. In the daytime they are caught in smaller numbers and at greater depths (Fedulov and Froerman, 1980; Dawe *et al.*, 1981).

In spring, young squid larger than 30 mm are usually caught in the Slope waters. These *Illex* are more abundant above the thermocline layer where the latter is well pronounced (Hatanaka *et al.*, 1982). Fedulov and Froerman (1980) have determined that the young of *Illex* are observed above the oxygen minimum layer lying in the Slope water as deep as 150-300m. In the area of deeper penetration of oxygen minimum (down to 300-500 m) *Illex* is caught in significant numbers even at depths of 200-300 m.

During the Soviet R/V *Beloyorsk* cruise in 1979, one diurnal and one semi-diurnal station was made. Based on the data obtained, Froerman (1980) has calculated time coefficients to correct the catches taken in the daytime and to get the real biomass values for *Illex* in the locations of trawl sets. The catchability of the EMT gear was assumed to vary to different depths depending on the time period of the day. This parameter was taken as 1 for the night but it significantly decreased during the daytime. The background of that phenomenon was not revealed then.

The purpose of the present paper is to determine the features of the vertical distribution and diurnal movements of *Illex illecebrosus* as well as other cephalopods inhabiting the waters off the Nova Scotia Shelf.

Materials and Methods

Present paper is based on the data collected at two diurnal stations made on the round-the-clock basis during the cruise by R/V *Gizhiga* in March-June 1983 according to NAFO program focused on short-finned squid research in the Northwest Atlantic.

The first station was started at 11:00 p.m. on April 27 and ended at 10:00 p.m. on April 30 at position 42°07'N, 63°36'W (cruise 83-02) and the second one lasted from 01:00 a.m. until 10:00 p.m.on May 24 at 42°07'N, 57°59'W (cruise 83-04; Fig. 1). At the start and the end of each station, temperature was measured and samples for salinity and oxygen determinations were taken with Nansen bottles at standard depths. During the operations at both stations, temperature and oxygen content variations were monitored by TO_2 D-zond casts each 6 hours.

Data from Nansen bottles and TO_2 D-zond casts were used to obtain temperature, salinity and oxygen vertical profiles. Based on these profiles, one profile for each parameter average for the whole period of operations at the stations was drawn. Those averaged "temperature" and "salinity" profiles were used to plot T-S curves for vertical water mass distributions at each of two stations.

To specify the spatial distribution of water masses, when the 1st station was completed, a micro-scale survey was conducted around the site consisting of a hydrographic cast and trawl sets at predetermined depths; those stations were spaced 30 miles apart and a TO_2 D-zond was casted between them (Fig. 2). Temperature distributions at towing depths were chartered using data from a micro-scale survey.

Depth of towing at the first station ranged between 35 and 500 m and from 25 to 300 m at the second one. Twenty-four hours of the day were divided into three time intervals (7:00 p.m.-5:00 a.m., dark period; 5:00 a.m.-12:00 a.m., 1st half of the light period; and 12:00 a.m.-7:00 p.m., 2nd half of the light period) and each trawl set was assigned to one of those time intervals (Table 1).

Towings were made using large mid-water trawl with a small meshed liner (# 10 mm). Their duration was 15 min. and towing speed - 3.5 knots. During the trawl operations it was determined that the trawl caught almost no animals when being retrieved since it went up vertically. It was assumed that the squid were caught only by a small-meshed liner having a vertical opening of 15 m and a square of a mouth - 176 m^2.

Catches were sorted into fish, euphausiids and cephalopods. Each group of animals was weighted. All cephalopods were identified to the genus (when possible, to the species) using a key by K. N.Nesis (1982), after which they were counted and weighted.

From each trawl catch, 30 specimens of fresh squid *Illex illecebrosus* were sampled aboard for biological analysis as described by Amaratunga and Durward (1978). When the catch of *Illex* consisted of not more than 100 specimens, the dorsal mantle length was measured for all other animals from the catch. When the number of *Illex* caught exceeded 100 all the animals, except those 100 mentioned above, were counted but not measured.

To study periodic diurnal feeding behaviour of squid, three grades of gut fullness were used: (a) gut is empty, (b) food remnants present, and (c) incorporates grades 1-3 of gut fullness described by Amaratunga and Durward (1978).

Using the data on fish, euphausiids, *Illex illecebrosus* and *Gonatus fabricii* separately, an attempt was made to study the dynamics of their abundance and biomass by depth in relation to the time of the day. For this purpose, the data obtained during the dark period of the day (7:00 p.m.-5:00 a.m.), first (5:00 a.m.-12:00 a.m.) and second (12:00 a.m.-7:00 p.m.) halves of the light period were analysed separately.

Based on averaged T-S curves (Fig. 5 and 6), the water column at each of two stations was stratified into layers having some peculiar hydrographic features.

To characterize vertical distribution of animals within the water column two parameters were used: biomass (tons per layer) for fish and euphausiids, and quantity (specimens per layer) for cephalopods. It was assumed that each group of animals has a constant value for those parameters for each layer and each time interval. To estimate those parameters either quantity or biomass of a particular group of animals were averaged for catches at depths lying within a particular water column layer, after which those averaged values were extrapolated for the whole layer.

Results

1st diurnal station

Hydrographic conditions. The first diurnal station was made at the outer boundary of a well-defined intrusion of warm slope water (Fig. 1a). Judging by the micro-scale survey data, the gradient zone went through the southwestern part of the survey area, a little southerner off the station location. The temperature of the upper 50 m layer within this zone ranged from 6.5°C to 11°C (Fig. 3a). In the deeper layers the gradient zone was but less prominent (Fig. 3b, d).

Vertical thermal structure of waters at the station was characterized by a minimum at 30 m (6.0°C) and maximum temperatures (10-11°C) in the layer of 110-180 m (Fig. 5).

Salinity of water increased with depth reaching its maximum (35.10-35.50°/₀₀) in a layer of Slope water (approximately at 150-200 m). At greater depths salinity kept almost constant and ranged from 34.75 to 35.00°/₀₀ (Fig. 5).

Thus, during the period of diurnal station, the vertical thermo-haline structure at depths greater than 30 m did not change, while a noticeable decrease in salinity and temperature took place in the upper 30 m layer (Fig. 5a, c). For example, the salinity and temperature at the surface dropped from 33.35 to 32.65°/₀₀ and from 7.5 to 6.6°C, respectively. Judging by the temperature, this change had taken place somewhere between 3:00 p.m. and 6:00 p.m. on April 28.

A main peculiar feature of the vertical oxygen distribution was a location of oxygen minimum (4.0 ÷ 4.3 ml/l) in the layer of 200-300 m (Fig. 5).

All stations occupied during the micro-scale survey can be sub-divided into two groups as to their similarity in the vertical distribution of the hydrographic characteristics. Stations 51, 53, 55, 114, 116 and 117 (Fig. 2) had the hydrological structure similar to that described above. Stations 54 and 115 were occupied immediately within the gradient zone and differed from the previously mentioned ones in that they had higher temperature and salinity estimates for the upper layer and lower vertical temperature gradients under the layer of maximum temperatures (Fig. 4).

Based on the T-S curve for the diurnal station as well as on the vertical oxygen distribution, all of the water column was stratified into the layers each being characterized by definite values or by definite changes in hydrographic parameters (Fig. 5d).

Layer A (0-30 m) was occupied by Shelf water with low salinity (32.75 ÷ 33.20°/₀₀) and temperature (6.0-7.0°C) values.

Layer B (30-110 m) occupied an intermediate position between Shelf and Slope waters and was characterized by maximum vertical gradients of temperature and salinity. The salinity in this layer increased from 33.20 up to 34.90°/₀₀ and the temperature from 6.0 up to 10.5°C.

Layer C (110-180 m) was made up of Slope water with maximum temperatures (T°C = 10.5 and 11.0) and high salinity (S°/₀₀ = 34.95 ÷ 35.10).

Layer D (180-300 m) was located between the lower boundary of warm Slope water and down to the depth of the oxygen minimum. This layer was characterized by a gradual decrease in temperature from 10.5 down to 7.0°C. Salinity dropped from maximum values (35.10°/₀₀) in the upper portion of the layer down to 34.90°/₀₀ at a depth of oxygen minimum.

Layer E (300-600 m) stretched from a depth of oxygen minimum down to the North Atlantic Central water masses. The layer was characterized by almost uniform, less steep as compared to the Layer D, change in temperature with depth (from 7.0 to 5.0°C). The salinity changed insignificantly.

Layers A, B and C are referred to epipelagic layers; Layer D is the boundary between the epipelagic and mesopelagic layers while Layer E lies at depths of mesopelagic layers.

Vertical distribution of the animals

1. *Illex illecebrosus*. From a total of 33 trawl sets made at the diurnal station, 24 tows brought young *Illex illecebrosus* (Table 2). A total of 908 specimens of this squid was caught through the 24-hour period. All animals were at the maturity stage 1; sex ratio was 1:1.

Mantle length of *Illex* ranged from 3 to 11 cm; two modes were observed falling on 5 and 8 cm. Vertical distribution of *Illex* from those length-groups are described separately below.

5 cm length-group. Animals of this length were mainly found in the upper epipelagic layers (Fig. 7a, b). The largest catches in terms of numbers (up to 144 specimens per tow; Table 2) were recorded at night for Layer B, while there were not many *Illex* in Layers C and D during that time interval (Fig. 10e). In the daytime, *Illex* from this length-group were caught in much smaller numbers (approximately 10 times as less as compared to the night) being taken mainly from Layer D.

During the twilight on the second day of a diurnal station an unusual phenomenon was observed: 234 *Illex* of 5 cm length-group were caught at 35 m (Fig. 7b) which was accompanied by a sharp simultaneous change in water temperature and salinity. Earlier, all catches taken during the daytime at the same or 50 m depths, contained but a few *Illex* specimens (2-3 per set; Table 2) and this catch, therefore, was excluded from the calculations of mean number of specimens per set.

The patterns of the diurnal feeding behaviour were observed as follows (Fig. 9a): a portion of animals having empty guts gradually decreased towards night starting from noon; maximum numbers of squid with full guts (b and c grades) were caught in the morning before noon.

8 cm length-group. *Illex* from this length-group concentrated mainly in the lower epipelagic layers (Layer D; Fig. 7c, d). 161 and 108 specimens were caught in the daytime and at night, respectively, which is approximately equal. During the daytime almost all squid aggregated within the Layer D - above the oxygen minimum (Fig. 10d). At night a small portion of squid aggregation moved upwards into the upper epipelagic layers (Layer B; Fig. 10d).

Maximum numbers of squid with empty guts were caught at night. In the morning and during the first half of the day, they were actively feeding; the portion of animals having guts of b and c grades fullness increased.

Interestingly, the squid from both length-groups were not practically caught in a layer of maximum temperatures (Layer C).

In the process of a micro-scale survey around the diurnal station location, towings at the daytime were made above the oxygen minimum layer (Layer D) while at night trawls were set in the layer of increased temperatures (Layer B). At one station (56) a test towing was made in Layer C.

The area east of the diurnal station location was found to be practically free of squid. Large catch of *Illex* of a 5 cm length-group was once taken at Station 116, west of the diurnal station. Larger squid (8 cm length-group) kept to the Layer D at all stations during the day while at night the animals moved up in small numbers.

Data from Station 56, north of the diurnal station location (Fig. 2) well justify the fact that the larger youngs concentrated within the Layer D in the daytime. Two trawl sets were made at 130 and 200 m in Layers C and D, respectively, but *Illex* were found only in the latter catch (45 specimens; Fig. 4).

2. Other cephalopods

At the diurnal station a total of 655 cephalopods belonging to 21 species from 13 families was caught.

Besides *Illex illecebrosus* in the trawl catches, the squid *Gonatus fabricii* was abundant (406 specimens); its mean weight was 1.6-1.8 g. In the daytime animals of this species concentrated in the mesopelagic layers (Layer E and deeper) while at night they moved closer to the surface into the epipelagic layers and were caught in Layers B-D; maximum catches were taken from Layer D.

Data on the vertical distribution of other cephalopod animals caught in limited numbers at the diurnal station are presented in Table 4. From this table an interesting pattern of occurrence of rear cephalopod species in the layers distinguished can be seen. Both in the daytime and at night maximum numbers of species were recorded in the catches from Layers B and D, and minimum, from Layer

C (Table 4.)

3. Euphausiidae, Fish

Vertical distribution of euphausiidae was to some extent, similar to that of *Gonatus fabricii*. At night these crustaceans were caught in great numbers (82% of all euphausiid biomass taken at the diurnal station) at all depths while maximum catches were taken from the upper epipelagic layers (Layer B; Fig. 10a).

In the daytime, the euphausiidae were taken only from the mesopelagic layers. It is probable, that their major concentrations were located deeper than 500 m. Mean weight of the animals from all depths was almost the same (0.3-0.4 g). It was, unfortunately, impossible to identify those animals aboard the ship because of the absence of the proper key.

A significant portion of fish catches at shallower depths consisted of the anchovy from *Myctophidae* family (up to 70-80% of the catch). Fish species from this family were abundant in the catches from Layer E (32 tons/km^2) while at night they moved up into the Layers B-D (Fig. 10b). Their maximum biomass at night was taken from the layer of maximum temperatures (Layer C; biomass - approximately 20 tons/km^2).

Up to 30-40% of the deep-water catches (Layer E) was made up of bathipelagic fish species (Table 3; Fig. 10b).

2nd diurnal station

Hydrographic conditions. The second diurnal station location is presented in Fig. 1B in relation to the surface temperature field.

Vertical structure of the waters remained practically unchanged through day and night. The pattern of vertical distribution of the oceanographic features was generally similar to that observed at the first diurnal station.

Major differences were as follows (Fig. 6):

a) the oxygen minimum layer lay at 200 m that is much shallower than at the first station;
b) sea surface temperature was significantly higher here (10.6°C) and a layer of minimum temperatures though lying at the same depth (30 m) was characterized by much higher temperature (8.2°C); and
c) a Slope water layer with maximum temperature and salinity at 100-200 m was more clearly defined: water temperature there was 11.0 ÷ 12.8°C and maximum salinity of 35.60°/₀₀ was recorded at 150 m.

The whole water column was stratified into layers similar to those at the first station (Fig. 6b).

Layer A (0-30 m) was occupied by Shelf water (T°C = 8.0 ÷ 10.5; S°/₀₀ = 33.25 ÷ 33.75).
Layer B (30-75 m) was an intermediate one between Shelf and Slope waters (T°C = 8.0 ÷ 11.0; S°/₀₀ = 33.75 ÷ 34.85).
Layer C (75-200 m) was occupied by Slope water (7°C = 10.5 ÷ 12.7; S°/₀₀ = 34.85 ÷ 35.60).
Layer E (200-500 m) stretched from the oxygen minimum depth down to the upper boundary of the North Atlantic Central water (T°C = 10.5 ÷ 5.0; S°/₀₀ = 34.85 ÷ 35.25).

In contrast to the first diurnal station we did not distinguish Layer D here since the depth of oxygen minimum at the second station coincided with the lower boundary of the Slope water (that is with Layer C).

Distribution of squid

Only data on the short-finned squid caught at the second diurnal station were treated. *Illex* was present in 7 catches out of 14 taken, total catch being 1,588 animals. All specimens were at maturity stage 1; sex ratio was 1:1.

The length of squid varied within the smaller range as compared to the animals from the first station (from 2.0 to 6.5 cm; Fig.). A unimodal distribution with a mode of 3.5 cm was characteristic for those squid.

The squid was caught in two layers, B and C. Practically all squid of *Illex* species concentrated in Layer B through the day and its numbers there were great (57 thous. specimens per km^2). At night a small portion of those aggregations moved down into a warmer layer (Layer C) while the others remained in Layer B (Table 3; Fig. 10f).

All *Illex* sampled had their guts empty and it was therefore impossible to study their patterns of diurnal feeding behaviour.

Discussion

In spring the young of *Illex illecebrosus* migrated through Slope water towards the shelf (Fedulov and Froerman, 1980) and concentrated in the area in front of the cold Shelf water before their immigration onto the shelf. For this period we present a description of diurnal movements of young *Illex* of different length-groups at hydrographic situation typical for waters off Nova Scotia Shelf.

Illex illecebrosus of 3 cm length-group. These animals concentrated at day and night in the upper epipelagic layers in a transitional zone between Slope and Shelf waters (Layer B). At any point in time during the day and night, they were caught with trawl approximately in equal numbers (Table 3, 6) which justified the fact that the trawl catchability for *Illex* of this length-group was the same both at night and in the daytime. These small squid seem to be semi-pelagic animals at this stage of development and are not able to escape from the trawl.

There are a lot enough of planktonic organisms in a transitional zone (Layer B) on which the young squid feed probably during both day and night. Since the metabolism rate of small animals is high enough, it is not a surprise that guts from those squid were empty. *Illex illecebrosus* seem not to be affected greatly by predatory stress in Layer B because only small numbers of potential predators (meso- and bathipelagic fish) rise into this layer at night. All this makes favourable conditions for young *Illex* of this length-group to remain in the layer all day and night.

Illex illecebrosus of 5 cm length-group. Squid of this group were abundant in the catches from Layer B (Fig. 10e). During the daytime *Illex* catches were not large (3-4 specimens per set; Table 2) and were taken mainly from Layer D. These data should be treated as reliable enough since we obtained similar data through three nights and two days of the first diurnal station (Table 2).

It is possible that major portion of those *Illex* remained in Layer B both at night and in the daytime while a smaller portion migrated into Layer D. Squid of this size are active nektonic animals and they are lead mainly by their eyesight when moving in the water. In the daytime, when the illumination in Layer B is good, they easily escape from the trawl while at night they are caught in great numbers because of, probably, poor illumination.

Data on the diurnal feeding behaviour can serve as an indirect indication of the fact that these animals kept mainly to Layer B both at night and in the daytime. Guts sampled from *Illex* of this length-group contained mainly the remnants of euphausiidae (easily identified by their red colour) which were abundant in Layer B at night. In the daytime, when euphausiidae moved into deeper waters, nearly all guts taken from *Illex* caught were empty. During the night period the squid preyed on euphausiidae which was justified by maximum portion of filled guts sampled at night. (If *Illex* of this length-group had moved into Layers D and E in greater numbers in the daytime, first, they would have been caught in equal numbers at night and in the daytime and, secondly, have been feeding through the whole day, as it was observed for *Illex* of 8 cm length-group described below. It can be assumed, therefore, that squid of this size remained mainly in Layer B during the whole day.)

Illex illecebrosus of 8 cm length-group. These animals as well as the previous length-groups were caught in large numbers in a layer of sharp temperature gradient, but under the Slope water (Layer D) that is above the layer of oxygen minimum. They were practically not caught at greater depths. In the daytime the illumination at 200-300 m was much lower as compared to the upper 100 m and squid, therefore, did not escape from the trawl and were caught in large numbers both at night and in the daytime.

Both fish and euphausiidae remained in Layer D in sufficient numbers (Fig. 10a, b; Table 5) through the whole day. Portions of full guts sampled in the second half of the light period and at night were approximately equal (Fig. 9b) while they sharply increased by morning. During this period squid were probably feeding on fish and euphausiidae which were moving down into mesopelagic layers to stay there in the daytime.

Thus, we may conclude that the patterns of vertical distribution and migration are different for *Illex illecebrosus* of different length-groups.

It seems appropriate to calculate time coefficients for different *Illex* length-groups separately when using these coefficients to estimate squid biomass in the daytime (Froerman, 1980).

Based on our observations, time coefficient for the daytime for *Illex* of 3 cm length-group at 100 m was a little lower than 1. For animals of 5 cm length-group at 100 m, it was much higher than 1 (approximately 10-15 times) and it equalled approximately 1 for squid of 8 cm length-group.

It is hard to judge on the types of aggregations which migrating *Illex illecebrosus* form in the Slope water. We may hypothesize that young animals move in the water forming sufficiently large concentrations. Such an intensive and mass migration of squid of 5 cm length-group was observed on the second day of our first diurnal station at 30 m. From Fig. 3a, it can be seen that animals of this size could come into the station area either from the west or from the north-west since we were almost not success to catch such squid in other locations during our micro-scale survey. Judging by the micro-scale survey data, waters in the area off our diurnal station were transported in the same direction.

Other cephalopods. All other cephalopods caught by trawl at our first diurnal station can be subdivided into a few main types according to their pattern of vertical movements.

1. Animals inhabiting bathi- and mesopelagic layers. Squid of this type remain in the lower mesopelagic and bathial layers (deeper than 500 m) in the daytime while at night they move upwards to the layer of temperature increase and oxygen minimum (Layer D). Characteristic species for this group of cephalopods were: *Brachioteuthis risii, Histioteuthis bonnellii, Chiroteuthis veraniji, Mastigoteuthis* sp., and *Galiteuthis armata*.

2. Another group of cephalopods closely related to the first one is also mainly found in the lower meso- and bathipelagic layers in the daytime while at night they move up to the layer of maximum temperatures (Layer C) - *Octopoteuthis* sp. - and even shallower - into Layer B (*Onychoteuthis banksi, Ctenopteryx sicula, Tetronychoteuthis dussumieri, Teuthowenia megalops*), and a pelagic octopus (*Alloposus mollis*).

   Two squid species, *Gonatus fabricii* and *Leachia* sp., can be placed a little aside from those animals as to their vertical migration pattern.

   The first one was abundant in the catches taken from almost all layers at night (Layers B-E; Fig. 10c; Table 4) while in the daytime the majority of squid moved down into the lower mesopelagic layers (depths of approximately 500 m) though smaller portion of the aggregation remained in the upper layers.

   Second species, *Leachia* sp., was caught both at night and in the daytime in almost equal numbers though in the daytime almost all animals concentrated in Layer E and at night they moved closer to the surface into a layer of maximum temperatures (Layer C).

3. Cephalopod species inhabiting epipelagic and upper mesopelagic layers. They include all squid species from *Enoploteuthidae* family. During the day, *Pyroteuthis margaritifera*, *Pterygioteuthis gemmata*, and *Abralia* sp., were mainly located in a layer of sharp temperature increase above the oxygen minimum (Layer D) and at night they partially moved up into the upper layer of temperature gradient (Layer B).

The directions of *Abraliopsis hoylei* diurnal movements were opposite: in the daytime the animals remained mainly in the upper epipelagic layers (Layers B and C) while at night they moved down into Layer D.

Vertical distribution pattern of cranchiid squid *Helicocranchia pfefferi* was absolutely different from other observed patterns. This squid species was regularly caught by trawl in Layer D in the daytime but was not found in the night catches at all. It may be supposed that either the animals of this species were not caught at night only occasionally (a total of 6 specimens was caught; the species is quite a rare one) or they moved down into the lower mesopelagic layer during this time interval.

Cranchia scabra, *Ancistroteuthis lichtensteini* and *Ornithoteuthis antillarum* were presented in the catches from our diurnal station only by one specimen each and no vertical movement patterns of these squid species can, therefore, be discussed.

From the data on all species summarized it can be seen that Layers B and D are most abundant in terms of squid species composition. These Layers are transitional ones, the ecotonic zones. Layer B is a transition between cold Shelf and warm Slope waters, while Layer D between Slope and deep North Atlantic Central water masses.

The reason for the fish species composition in Layer D is easily understood. On the one hand, animals from lower mesopelagic and bathial layers come here at night, and on the other hand, not all epipelagic squid move into the upper epipelagic layers; some portion of their aggregations remain in Layer D. A phenomenon of wide variety of tropical and sub-tropical squid species not in a layer of maximum temperatures (Layer C) but in Layer B remains not understood.

Summary

1. Vertical structure of the waters is characterized by presence of layers which are significantly different from one another either by their hydrographic parameter values or by patterns of those parameter changes within the layers.

2. *Illex illecebrosus* of 3 cm length-group are not characterized by well-defined vertical movements and remain in the zone lying between Shelf and warm Slope water masses (Layer B) through day and night.

3. *Illex illecebrosus* of 5 cm length-group also remain mainly in Layer B. Its daytime catches are significantly smaller than the night ones since in the daytime they may be active enough to escape from the trawl.

4. *Illex illecebrosus* of 8 cm length-group remain mainly in Layer D moving partially into Layer B at night.

5. Other species of cephalopods can be sub-divided into three groups as to their pattern of vertical movements: a) bathi- and mesopelagic species which move up at night, into Layer D; b) bathi- and mesopelagic species which rise into Layer B at night, and c) epipelagic species which remain in the epipelagic layers both at night and in the daytime.

6. Layers B and D are the most abundant ones in terms of the squid species composition.

References

AMARATUNGA, T. and R. D. DURWARD. 1978. Field guide to data collection for the squid, *Illex illecebrosus*. NAFO SCR Doc. 78/11/5, Ser. No. N5157.

DAWE, E. G., BECK, P. C., and H. J. DREW. 1981. Distribution and biological characteristics of young short-finned squid (*Illex illecebrosus*) in the Northwest Atlantic, February 20–March 11, 1981. NAFO SCR Doc. 81/VI/23, Ser. No. N302.

FEDULOV, P. P., and Yu. M. FROERMAN. 1980. Effect of abiotic factors on distribution of young shortfin squid, *Illex illecebrosus* (LeSueur, 1821). NAFO SCR Doc. 80/VI/98, Ser. No. N153.

FROERMAN, Yu. M. 1980. Biomass estimates of young *Illex illecebrosus* (LeSueur, 1821) from a survey in Subareas 3 and 4 in March–April 1979. NAFO SCR Doc. 80/II/36, Ser. No. N067.

HATANAKA, H., T. KAWAKAMI, E. FUJII, K. TAMAI, T. AMARATUNGA, J. YOUNG, D. CHAISSON, T. MCLANE, A. LANGE, L. PALMER, J. PREZIOSO, and M. SWEENEY. 1982. Aspects on the spawning season, distribution and migration of short-finned squid (*Illex illecebrosus*) in larval and juvenile stages in the Northwest Atlantic. NAFO SCR Doc. 82/VI/32, Ser. No. N520.

NESIS, K. N. [Concise key to the world ocean's cephalopods]. Moscow, "Lyogkaya i pitc.pr.", 1982, 360 p. (In Russian)

Table 1. Numbers of trawl sets at the diurnal stations by time interval and depth (m).

Depth (m)	1st diurnal station			2nd diurnal station		
	1901–0500	0501–1200	1201–1900	1901–0500	0501–1200	1201–1900
25	–	–	–	1	–	–
35	3	1	1	1	1	–
50	3	1	1	1	1	1
100	3	2	1	1	1	1
150	1	2	1	–	1	–
200	2	1	1	2	1	–
300	3	1	1	–	–	1
500	2	1	1	–	–	–
Σ	17	9	7	6	5	3

Table 2. Numbers of *Illex illecebrosus* of two length-groups (5-cm and 8-cm) in catches taken at the first diurnal station (27-30 April 1983) by depth and time interval. (Numbers in parentheses indicate length-groups in cm.)

	Apr 27	Apr 28				Apr 29				Apr 30	
Depth (m)	1901-2400	0001-0500	0501-1200	1201-1900	1901-2400	0001-0500	0501-1200	1201-1900	1901-2400	0001-0500	0501-1200
35	9(5) 3(8)		-			-		234(5)		6(8)	
50		22(5) 3(8)	3(5)		5(5) 6(8)			2(5) 1(8)		20(5) 8(8)	
100	52(5) 1(8)		-	-	96(5) 9(8)		1(5) 3(8)		144(5) 11(8)		
150			-		6(5)		1(5) 1(8)				-
200				3(5) 41(8)		5(5) 43(8)	2(5) 3(8)			3(5) 3(8)	
300		9(5) 5(8)	3(8)		6(5)			12(5) 109(8)		1(5) 10(8)	
500				-		-		-	-		

Table 3. Numbers of *Illex illecebrosus* in catches taken at the 2nd diurnal station (24 May 1983) by depth and time interval. (Numbers in parentheses indicate modal length in cm.)

	Time interval			
Depth (m)	0001-0500	0501-1200	1201-1900	1901-2400
25				-
40	216(3.5)	250(3.5)		
60	1(3.5) 2(5)	4(3.5)	1127(3.5) 1(5)	
100	7(3.5) 4(5)	-	2(3.5)	
150		-		
200	-	-		-
300			-	

Table 4. Total catch (numbers) and calculated numbers (specimens per km^2) of various cephalopod species in the different layers at the first diurnal station during daytime and at night.

Cephalopod species	Daytime (0500-1900 hr) Number caught	Calculated numbers by layer B	C	D	E	Nighttime (1900-0500 hr) Number caught	Calculated numbers by layer B	C	D	E
Family <u>Ommastrephidae</u>										
Illex illecebrosus (5 cm)	27	199	68	1502	–	378	9056	1237	1678	–
Illex illecebrosus (8 cm)	161	103	29	13873	–	108	1237	–	4727	–
Ornithoteuthis antillarum	1	–	–	71	–	0	–	–	–	–
Family <u>Enoploteuthidae</u>										
Pyroteuthis margaritifera	11	155	–	530	–	27	375	618	707	–
Pterygioteuthis gemmata	11	93	–	706	–	9	212	–	71	–
Abraliopsis hoylei	15	303	309	177	–	16	93	–	954	–
Abralia sp.	8	70	–	424	–	4	71	–	106	–
Family <u>Onychoteuthidae</u>										
Onychoteuthis banksi	2	33	–	–	441	39	963	–	141	–
Ancistroteuthis lichtensteini	1	–	–	71	–	0	–	–	–	–
Family <u>Ctenopterygidae</u>										
Ctenopteryx sicula	0	–	–	–	–	2	–	40	–	–
Family <u>Octopoteuthidae</u>										
Octopoteuthis sp.	4	–	–	176	883	7	–	41	141	1324
Family <u>Lepidoteuthidae</u>										
Tetronychoteuthis dussomieri	1	–	–	71	–	6	44	–	212	441
Family <u>Brachioteuthidae</u>										
Brachioteuthis risii	1	–	–	71	–	7	141	–	106	441
Family <u>Cranchiidae</u>										
Teuthowenia megalops	1	–	–	71	–	9	163	–	71	883
Leachia sp.	11	33	–	176	3534	26	304	1835	282	441
Galiteuthis armata	1	–	–	–	441	2	–	–	–	883
Helicocranchia pfefferi	6	–	–	353	–	0	–	–	–	–
Cranchia scabra	1	–	–	71	–	0	–	–	–	–
Family <u>Histioteuthidae</u>										
Histioteuthis bonnellii	2	–	–	–	883	8	–	–	530	883
Family <u>Chiroteuthidae</u>										
Chiroteuthis veranyi	0	–	–	–	–	7	–	–	141	2208
Family <u>Mastigoteuthidae</u>										
Mastigoteuthis sp.	0	–	–	–	–	21	–	–	1413	2208
Family <u>Gonatidae</u>										
Gonatus fabricii	62	706	203	619	14137	344	1678	7377	15020	13253
Family <u>Alloposidae</u>										
Alloposus mollis	3	–	–	71	883	9	71	–	353	441
Number of species found per layer.		8	3	16	7		12	6	16	11

Table 5. Total catch and fish and euphausiid biomass (kg per km²) by layer at the first diurnal station.

	Catch (kg)	Daytime (kg/km²) by layer				Catch (kg)	Nighttime (kg/km²) by layer			
		B	C	D	E		B	C	D	E
Euphausiidae	8.6	35	9	1222	4417	76	9368	2606	5274	7676
Fish	48.0	93	62	3931	31986	184	6650	20410	11897	20109

Table 6. Number of 3-cm *Illex illecebrosus* caught and calculated numbers (specimens per km²) by layer at the second diurnal station.

	Number caught	Daytime (No./km²)			Number caught	Nighttime (No./km²)		
		B	C	E		B	C	E
Illex illecebrosus	1381	57612	347	-	217	27052	2421	-

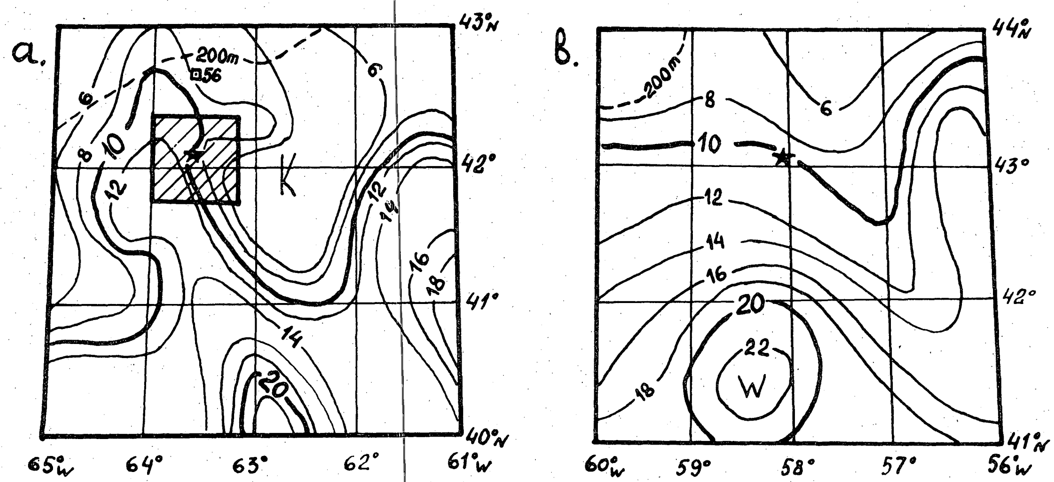

Fig. 1. Location of the first (a) and second (b) diurnal stations (indicated by asterisks) in relation to sea surface temperature field. Dashed square - the area of a micro-scale survey.

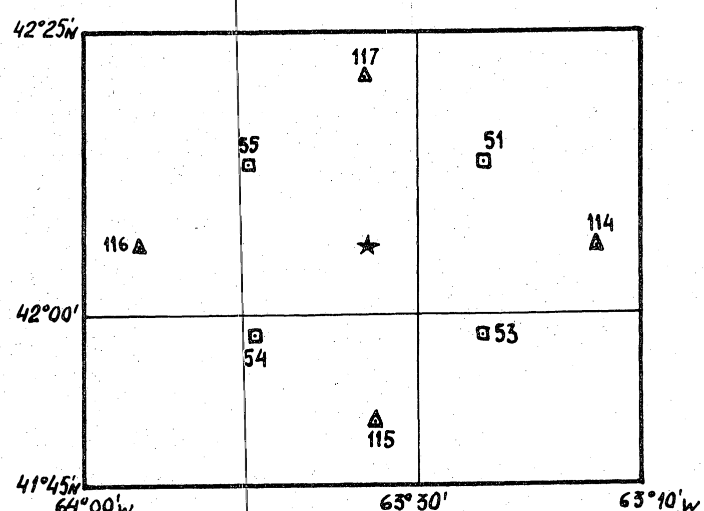

Fig. 2. Location of stations in the area of micro-scale survey. Hydrographic stations are indicated by triangles; TO_2D-zond casts by squares.

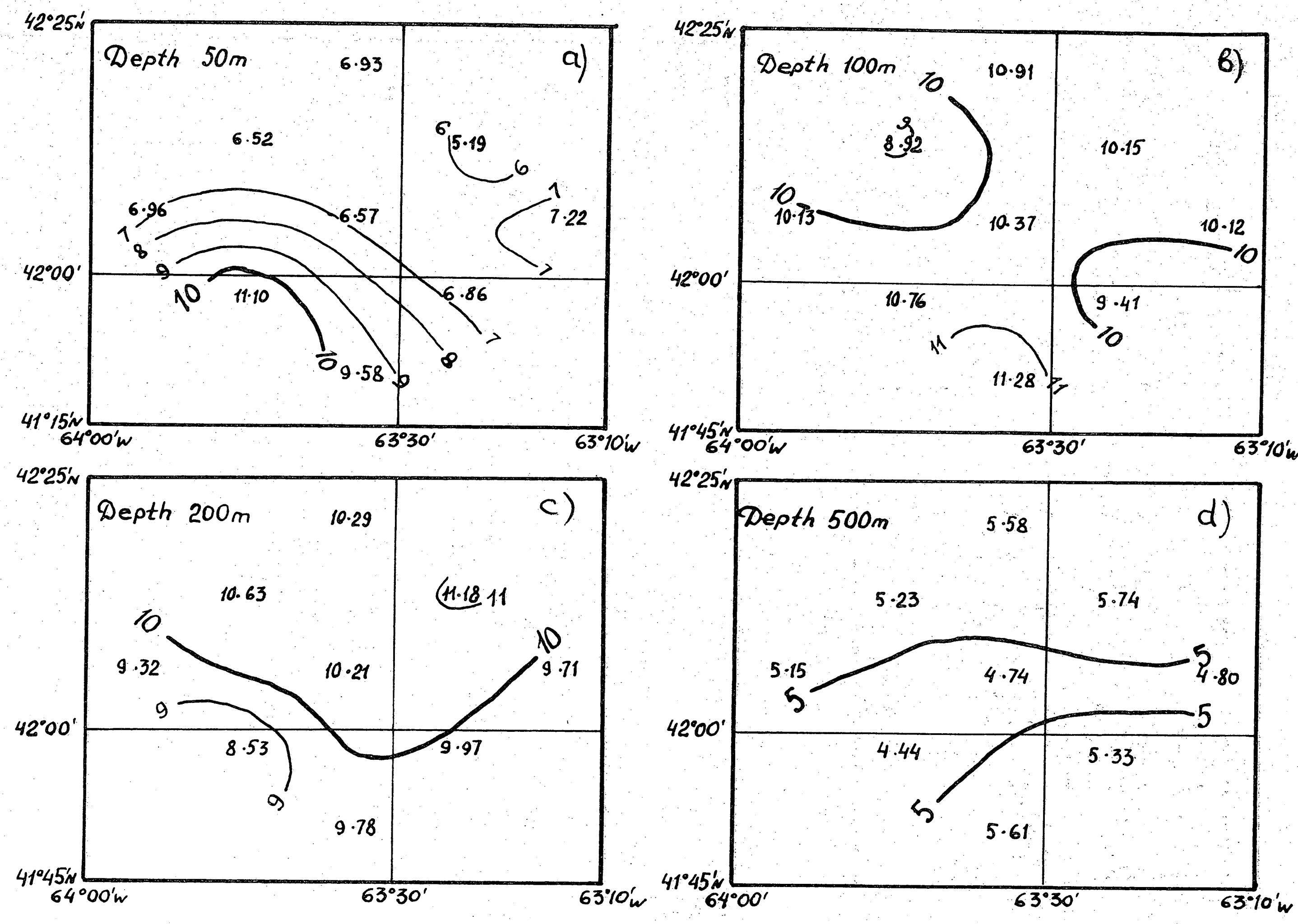

Fig. 3. Temperature distribution in the area of micro-scale survey by depth: (a) - 50 m; (b) - 100 m; (c) - 200 m; (d) - 500 m.

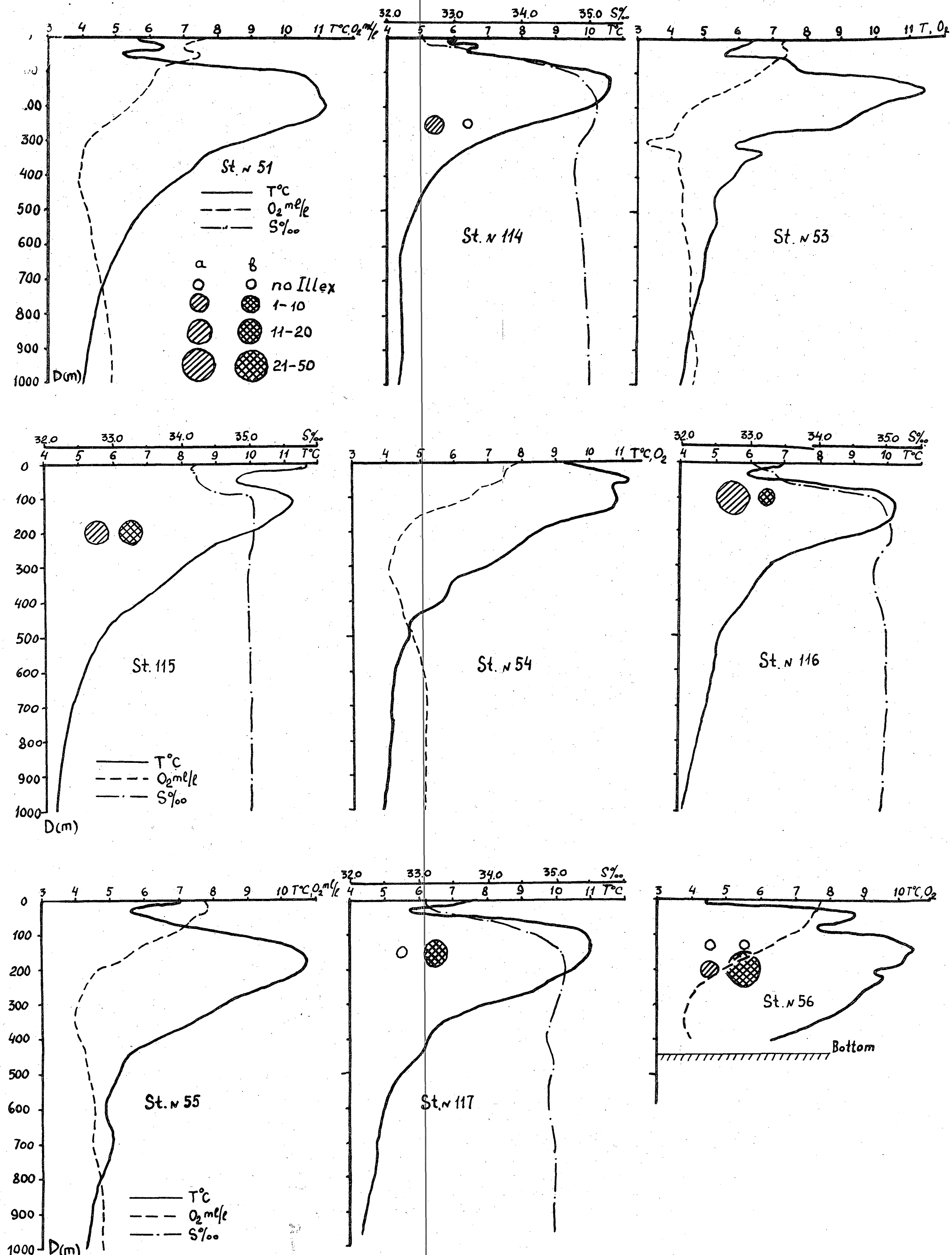

Fig. 4. Vertical distribution of hydrographic parameters at the micro-scale survey stations temperature (T°C), oxygen content (ml/l), and salinity (°/∘∘). Numbers of *Illex* are indicated by dark circles; a - modal length of 5 cm; b - modal length of 8 cm.

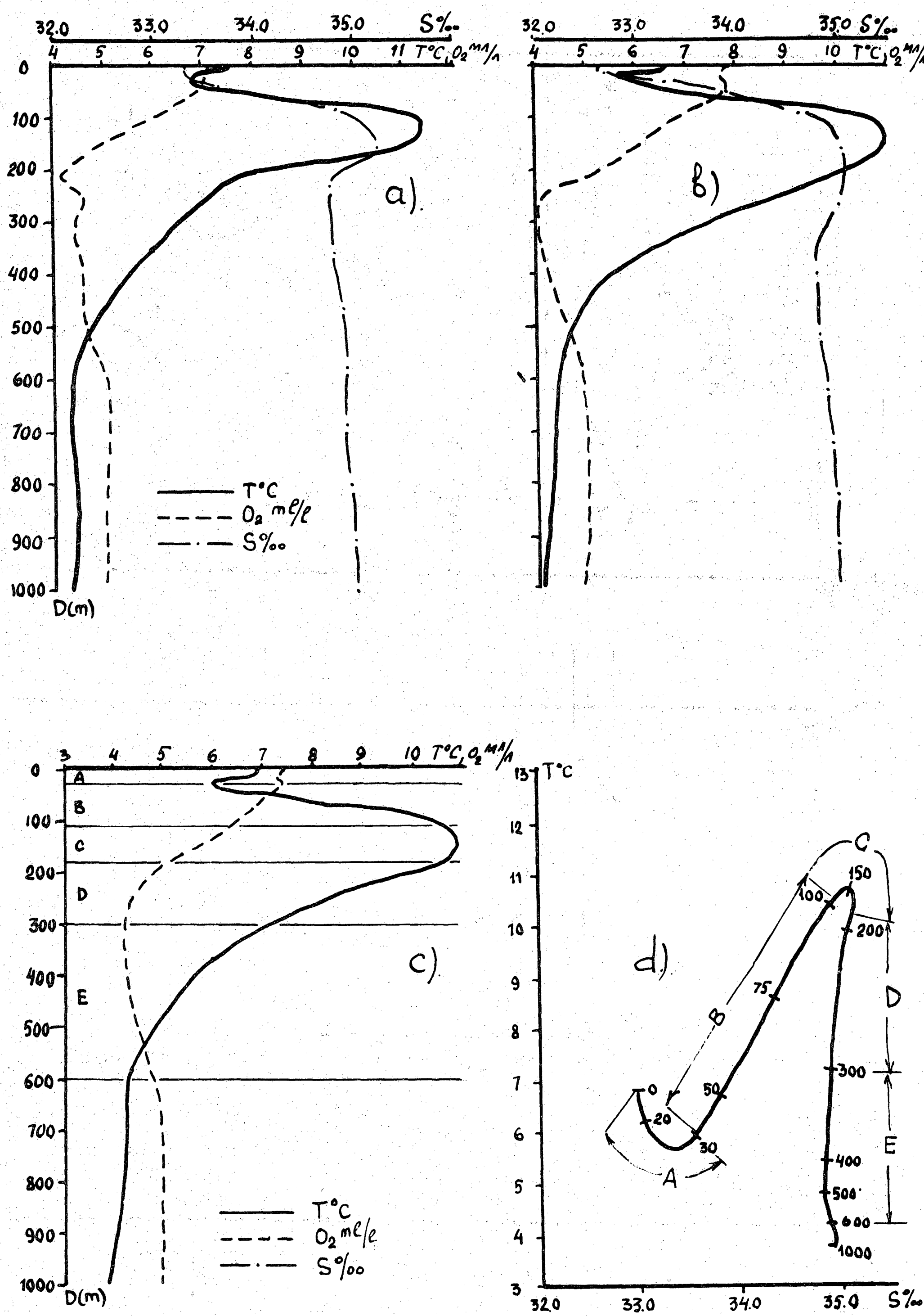

Fig. 5. Vertical distribution of hydrographic parameters at the first diurnal station; a - at the start of the station; b - at the end of the station; c - averaged for the whole period of station operations; d - averaged T-S diagram (numerals indicate depth in meters). A, B, C, D - layers with definite parameter values or definite changes in hydrographic parameters.

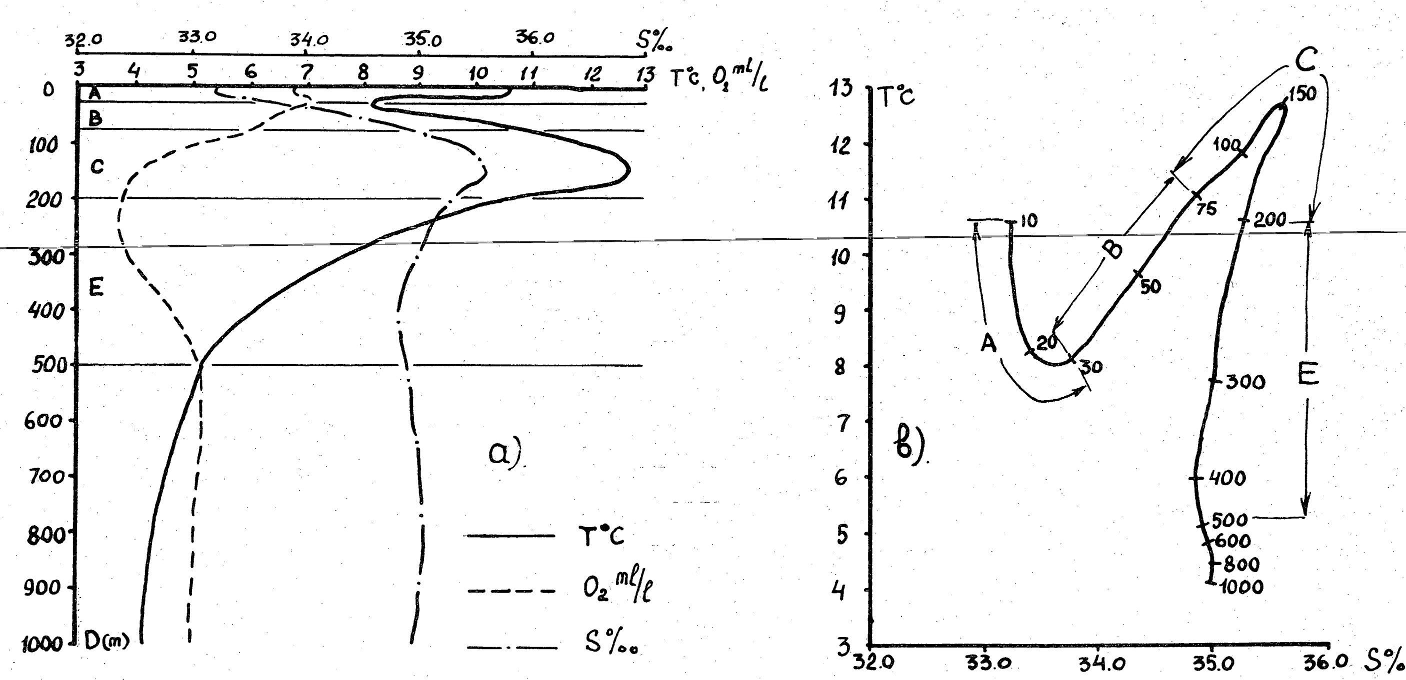

Fig. 6. Vertical distribution of hydrographic parameters at the second diurnal station; a - averaged for the period of station operations; b - averaged T-S diagram. Legend is the same as in Fig. 5.

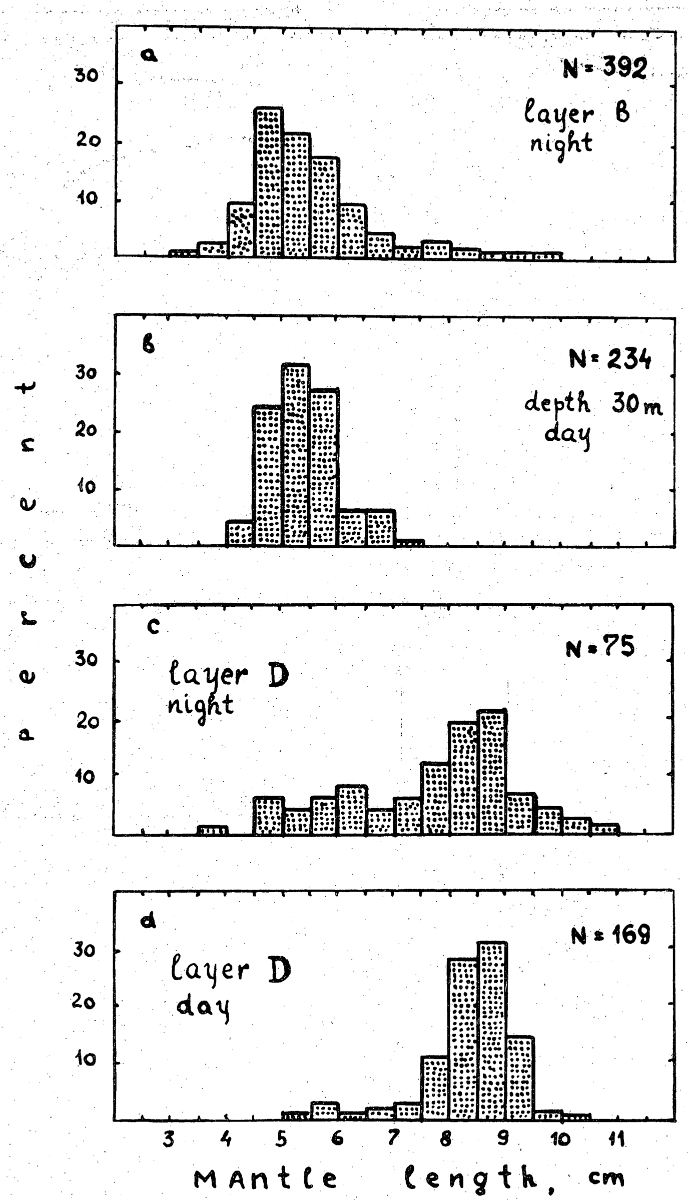

Fig. 7. Length composition of *Illex illecebrosus* in the layers distinguished, at night and in the daytime at the 1st. diurnal station.

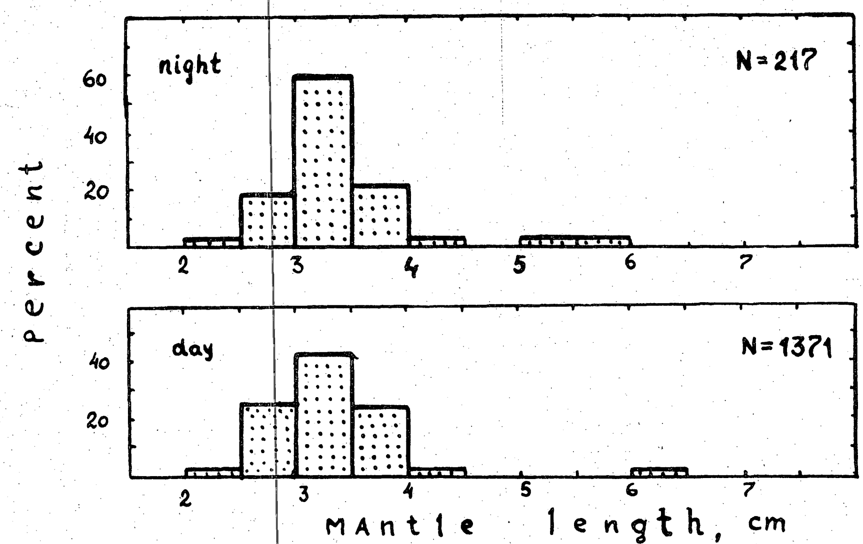

Fig. 8. Length composition of *Illex illecebrosus* in Layer B at night and in the daytime at the 2nd diurnal station.

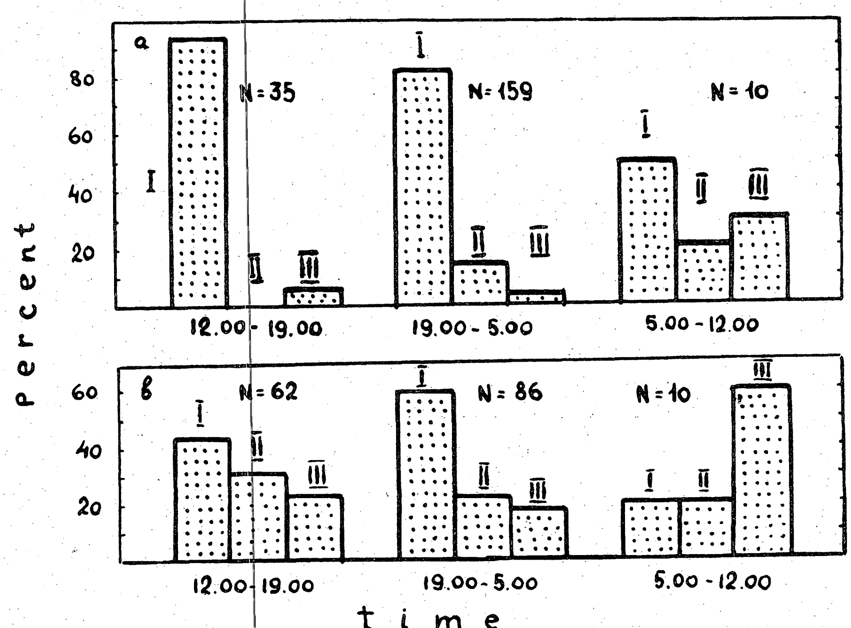

Fig. 9. Diurnal feeding behaviour of *Illex illecebrosus* at the 1st diurnal station; a - 5 cm length-group; b - 8 cm length-group. I(a), II(b), and III(c) - gut fullness grades.

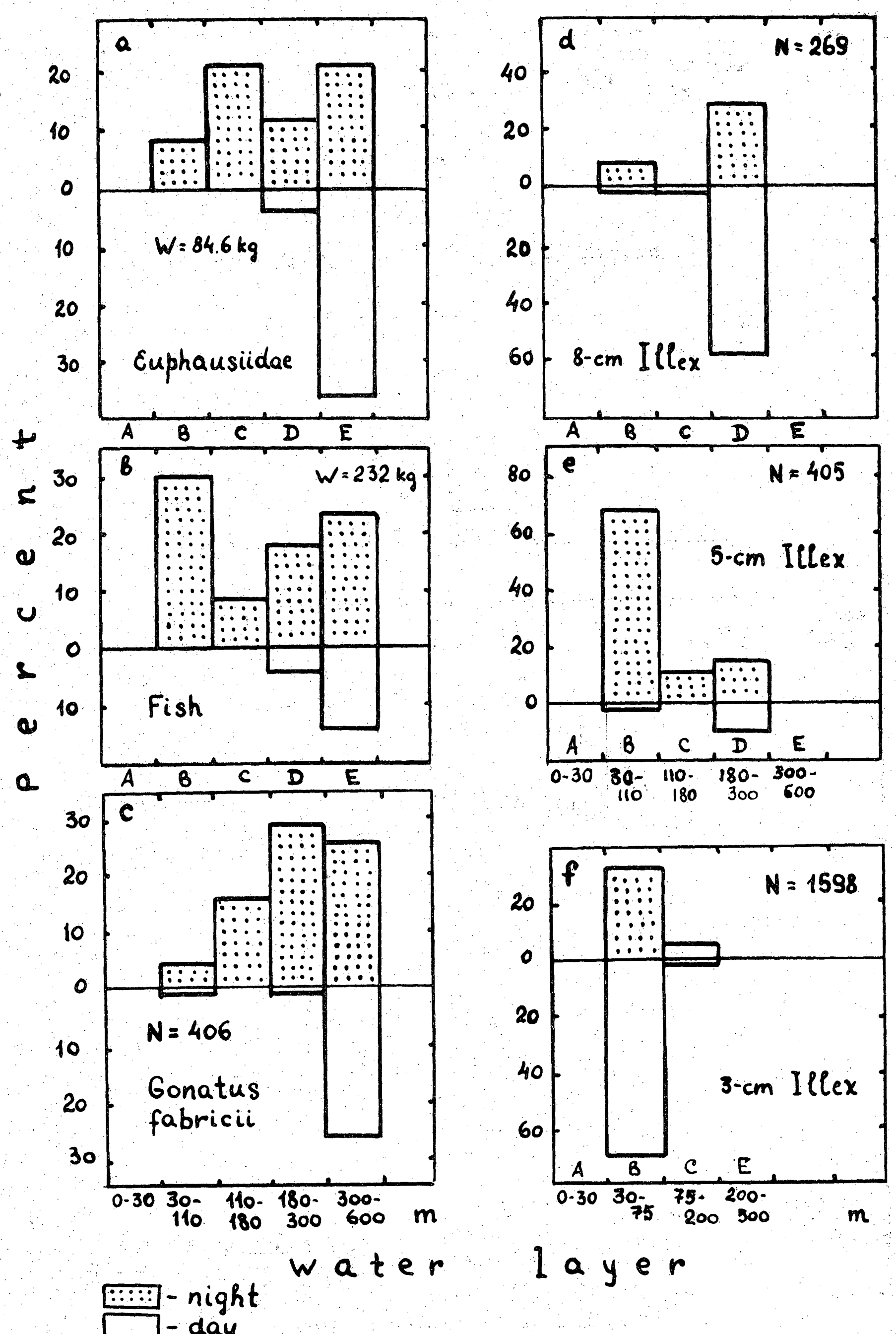

Fig. 10. Numbers of different animals caught from distinguished layers at night and in the daytime at the first (a, b, c, d, e) and second (f) diurnal stations.