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Aspects on the Spawning Season, Distribution and Migration of Short-finned Squid (*Illex illecebrosus*) in Larval and Juvenile Stages in the Northwest Atlantic

(Results obtained by JAPAN/CANADA/USA Joint Survey on
Short-finned Squid by R/V KAIYO MARU in Jan.-Mar. 1982)

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INTRODUCTION

The life history of the short-finned squid (Illex illecebrosus) in the Northwest Atlantic waters could be divided into three periods, namely early growing period from egg to pre-recruit young, growing and feeding period on continental shelf and breeding period from emigration to spawning. Up to the present, a considerable amount of the biological information on the period on shelf was obtained (Squires, 1967; Amaratunga, 1980; Lange and Sissenvine, 1981; and Amaratunga et al., 1979). In recent years, Canada and USSR carried out several research surveys from February to June in the waters off the Scotian Shelf and off Grand Banks, and obtained the distributional information on juvenile and young squid (Amaratunga et al., 1980; Fedulov and Froerman, 1980; Dawe et al., 1981; and Froerman et al., 1981). Roper and Lu (1979) obtained 14 larvae of the short-finned squid from among the samples from the waters off the Cape Hatteras northwards to the Georges Bank. Durward et al. (1979) reported the aspects of spawning and larval development in captivity. However, the information in the two oceanic periods, emigration to spawning and egg to pre-recruit young, is still insufficient.

The objectives of Japan/Canada/USA Joint Survey by R/V Kaiyo Maru were to obtain the biological and oceanographic information of short-finned squid in the oceanic periods. This report provides the results obtained on the distributions of larvae and juveniles, on spawning season and ground estimated from the locality of larvae taken, and on migrations of larvae and juveniles with growth.

METHODS OF SURVEY

1. First Research Leg (16 Jan.,'82, New York - 5 Feb.,'82, Halifax)

In the original plan, 7 transects were settled in the off-shelf area including the northern part of the Sargasso Sea between 56° W and 74° W, and a total of 35 stations was set at every 30 minutes along these transects. However, the stations were re-settled every day in the vicinity of the prearranged transects, taking account of the actual positions of the respective water-types distinguished by the water temperature in the field and by the Satellite Sea Surface Temperature Chart. The stations were allocated to the boundary waters, between the Gulf Stream and the Slope Water, where larvae of Illex were expected to be most abundant, and also allocated to each of the Shelf Water, warm core eddies, the Slope Water, the Gulf Stream and the Sargasso Sea Water. On the transect of 62° W, however, stations were set regularly at every 30 minutes in order to obtain a straight profile of oceanographic conditions from the Sargasso Sea to the Scotian Shelf. On each station, at least one item of oceanographic observations and/or towing of research gears were carried out, as follows.

a) Oceanographic Observation: The stations are shown in Fig. 1. Nansen Bottles and X-BT were casted at each station and the transparency was observed by the Secchi Disk when the observations were made in the daytime. Only a X-BT was casted at the halfway stations between transects. The Nansen Bottles used were of 1.3-litre type and the standard depths adopted were 0, 10, 20, 30, 50, 100, 150, 200, 300, 400, 500, 600, 800 and 1000 m.

b) Survey on Illex Larva: A double oblique tow of 0-200 m by Bongo Net (Model 1271 with the nets of 0.5 mm mesh) was made usually at each station except the halfway station between transects. The wire speed was 30 m per minute in sinking and was 20 m per minute in retrieving, and ship's speed was kept at 2 kts., as a rule. The number of tows made by water-types are given in Table 1.

The depth-stratified samplings were made at 4 stations where fairly large numbers of larvae had been taken by oblique tow. The current ran at 2.0 to 4.0 kts. at these stations and sometimes strong wind shifted the ship, therefore a radar buoy was thrown down for keeping the ship at the position. Tows were made in each layer of surface, 0-50, 50-100, 100-200 and 200-300 m in the daytime and at night. However, troubles of the opening-closing apparatus of Bongo Net frequently happened, and tows in layers deeper than 100 m were failed in most of the sets. Consequently, only a complete set of depth-stratified tows could be successfully made at night.

c) Survey on Adult Illex: A oblique tow of midwater trawl was made at each of 23 stations. As a rule, towing speed of net was about 3.0 kts. against water, and one-hour 1000-0 m tows were made at night. But occasionally, fixed depth or stepped oblique tows were tried, and some of the tows prearranged at night were made in the daytime to recover the delay in schedule. The greatest depth atained by one particular tow was 1745 m. Number of tows in each water-type and the locality of stations are given in Table 1 and Fig. 3, respectively.

The trawl net (KMT Net) provided a cod-end with the liner of 18.3 mm mesh. The estimated distance between the both wing nets was about 25 m and the net height at the rear end of head rope was about 18 m under the condition of 3 kts. in towing speed. The detailes of the gear are shown in Appendix Fig. 1.

d) Other Survey: Squid jiggings were tried at 14 stations by hand jigger. Search light or so-called fish luring light of 1500 W were occasionally used. Number of jigging stations by water-types and the locality are given in Table 1 and Fig. 3, respectively.

2. Second Research Leg (11 Feb.,'82, Halifax - 5 Mar.,'82, Bermuda)

In the original plan, 37 stations on 5 transects were settled in the area between 56° W and 68° W. However, the stations were re-settled every day taking account of the locality of the respective water-types in the field in the same way as the first research leg.

At about the middle of the leg, research gear was changed from the rectangular net to midwater trawl gear with a intension of increasing the catch of juvenile Illex. Furthermore, the eastmost transect was abandoned to avoid the bad weather and the ship returned to the area west of 62° W. Most of the tows of midwater trawl during the last three days were made in boundary area between the Gulf Stream and the Slope Water, as it was expected that the juveniles were most abundant in this area.

a) Oceanographic Observation: Oceanographic observations were carried out in nearly the same way as that in the first research leg. These stations are shown in Fig. 4.

b) Survey on Illex Larva: A double oblique tow of Bongo Net was made at each of 28 stations, as are shown in Fig. 5. Gear, mesh and towing method were the same as the first research leg. The number of stations towed by water-types are shown in Table 2. Depth-stratified tow was not carried out in this leg because of the minor catch of Illex larvae.

c) Survey on Juvenile Illex: A tow of rectangular net (KYMT Net) was scheduled at each of 20 stations. However, the catch of juvenile was unexpectedly small, therefore the gear was switched to midwater trawl at about the middle of the leg. As aforementioned, the boundary area between the Gulf Stream and the Slope Water west of 62° W was re-examined by midwater trawl toward the end of this leg. The number of stations by water-types and the locality are given in table 2 and Fig. 6, respectively.

The mouth of rectangular net was 3x3 m, and mesh sizes of main net and cod-end were 3.6 and 1.7 mm in length of each leg of square mesh, respectively. The detailes of the net are shown in Appendix Fig. 2. At the early days of the leg, double oblique tows of 1000-0 m were made, but subsequently, tows of 300-0 m or stepped oblique tows were tried to increase the towing times in shallower waters. The net was towed for 1 hour, generally, at the speed of 3 kts. against water. The greatest depth towed was 1089 m.

The midwater trawl (KMT Net) had a liner of 11.0 mm mesh. This mesh was smaller than that for the first research leg. The net was towed obliquely from 100 m at most of the stations, based on the results of depth-stratified tows, and the towing speed was about 3 kts.

The depth-stratified samplings by rectangular net with opening-closing apparatus (KOC-T Net) were carried out at two stations, one at night and the other in the daytime. Tow was made in each layer of 0-50, 50-100, 100-200 and 200-400 m. The towing speed and the mesh size used were the same as the regular oblique tows.

d) Other Survey: A squid jigging was tried at one station by hand jigger. The position is given in Fig. 6.

3. Processing of Samples

a) Sample by Bongo Net: Samples in the right and left nets were handled separately. At first, sample of one net was divided into two groups, cephalopods and others, then Illex larvae and juveniles were picked up and the number of specimens was counted. These samples were preserved by staff scientists from Canada and USA for further studies. The sample of the other net was divided into three groups, cephalopods, fishes and others, then number of Illex larvae and juveniles was counted. Furthermore, the growth stages of Illex from this net were observed during the returning cruise to Japan and the number by stages was recorded. The species identification and the criteria on growth stages of Illex larvae were based upon Roper and Lu (1979). Other two groups of fish and others were not processed on board.

b) Samples by Rectanglar and Midwater Trawl Nets: The number and weight of each species caught were measured. As for Illex, mantle length and body weight were measured within the limit of 300 specimens, and then some of them were stored in 5 to 7 % formalin and the remainders were frozen for further analyses in the laboratories. Of other animals caught, length frequency measurements of some dominant species were made. The remainders were discarded after the enough specimens were sampled for identification and other analyses. Identification works on fishes and cephalopods were made on board. However, according to the absence of taxonomist for crustacea, only a preliminary work was made for shrimps.

RESULTS

1. Oceanographic Condition

The detailed aspects of oceanographic conditions will be described in the research report (Kaiyo Maru, 1982). In this section the characteristics of each water-type and its distribution are briefly mentioned, and the relationships between oceanographic conditions and the distribution of Illex in early growth stages will be described later.

a) Water-types: The water-types found in the survey area were determined by T-S Diagram. The characteristics of each water-type are summarized in Table 3. Although two boundary waters, shown by the names of boundary(L) and boundary(H) in the table, could not be classified as a category of water-type in the real meanings, both of the boundary waters were regarded as one of the water types, because they played the important role in the distribution of Illex in early growth stages as will be mentioned later.

b) Distribution of Water-types: The location of each water-type in the surface layer was schematically shown in Fig. 7, based on observed data in the survey and on Satellite Sea Surface Temperature Chart by Canadian Forces Metoc Center. Some clear changes were observed between both of the legs. The meandering of the Gulf Stream became stronger in the second leg. Warm core eddies shifted to the west in cases of 81-F and another one centering at 41°N, 58°W, and to the east in case of 82-A. The axis of the Gulf Stream moved to northward in the area east of 60° W, and consequently the slope water in this area was greatly reduced.

Generally speaking, the thickness of the Shelf Water was about 80 to 100 m in the southern edge. The Slope Water occupied the layers shallower than about 200 m and intruded under the southern edge of the Shelf Water. The warm core eddy attained to the depth from 100 to 400 m. The thickness of the Gulf Stream was 300 to 500 m. The oxygen minimum layer below 3.5 ml/l lied beneath the Slope Water and the Gulf Stream.

2. Distribution of Short-finned Squid

a) Larva: The distribution of larvae was estimated from the catch by Bongo Net. The catch included three stages of Illex; Rhynchoteuthion, transition and juvenile. Although the juvenile should not be categorized to the larva in a strict sense, all of the Illex caught by Bongo Net were regarded as "larva" for the convenience's sake of analysis, and the analysis by stages will be made in Section 4.

Prior to the analysis, the tows in the northern edge of the Gulf Stream and in the boundary(H) in the first leg where the larvae were caught abundantly were used in order to check the day-and-night effect of Bongo Net.

Time period	Water-type	St. No. (Tow No.)	Filtered water volume (m^3)	No. of larvae caught
Daytime	Boundary(H)	15 (B39)	1711	26
Night	Northern Edge	04 (B05)	1426	37
	Boundary(H)	07 (B24)	1140	21
		10 (B27)	1568	108
		25 (B47)	1568	14

As is shown above, the number of tows made in each of these water-types is not sufficient, however considerable amount of larvae was caught in both of daytime and night. Posgay and Marak (1980) made a experiment for the day-and-night effect of 61 cm Bongo Net, and did not distinguished any differences between day and night catches of zooplankton. Therefore, it was assumed for the following analyses that the day-and-night effect of Bongo Net was insignificant for larval Illex.

a-1) Horizontal Distribution: Number of larvae caught by each of 0-200 m double oblique tows of Bongo Net is shown in Fig. 8 for the first leg and Fig. 9 for the second leg with surface temperatures observed in the survey. The number of larvae caught and the catch rate (number per 1000 m^3) in each water-type are given in Table 4.

Larvae of Illex widely occurred in the survey area between 72° W and 59° W, and they were caught in the boundary(L), the warm core eddy, the Slope Water, the boundary(H), the Gulf Stream and the Sargasso Sea Water. However, the larvae were abundant especially in both of the boundary(H) and the northern edge of the Gulf Stream during the first research leg.

In the second research leg, a large catch (22 specimens) was obtained only on 15 February, and the catch over 5 individuals per tow was not taken afterwards, in spite of the fact that 9 more tows were made in the boundary(H) and the northern edge of the Gulf Stream. It may be suggested that the spawning or incubating season was over in the second half of Feburuary.

a-2) Vertical Distribution: The temperature profile by X-BT and amount of Illex larvae caught at each Bongo Net station are shown in Fig. 10 for the first leg and Fig. 11 for the second leg.

In the first research leg, surface water temperature at the stations where the larvae occurred ranged from 15° to 21° C except St. 26, and large catch over 10 specimens were obtained at the stations where the strong thermocline was observed in the layer shallower than 200 m. The area characterized by this range of surface temperature and the thermocline is explicitly the boundary(H) and/or the northern edge of the Gulf Stream. Also, 33 larva specimens were caught by a tow in the northern edge of the warm core eddy (St. 28). On the contrary, the large catch was never obtained from the station where surface temperature was higher than 15° C without clear thermocline.

In the second research leg, the Illex larvae taken were a few even at the stations where suitable temperature and thermocline were observed. This might indicate the end of incubating season, as aforementioned.

The results of the depth-stratified samplings are given in Table 5 and Fig. 12. The opening-closing apparatus of Bongo Net failed to work almost, and consequently only one tow was made successfully in the layer deeper than 100 m. At St. 10 where the samplings were made at night, catch rate (number of larvae per 1000 m^3 of filtered water) showed a level of 53 to 71 individuals in the layers shallower than 100 m, but was extremly lower in the layers deeper than 100 m. The strong thermocline was observed at the depth of about 100 m at this station, so this pattern of larval distribution may be affected by the thermocline.

The catch rates by depths and by times of the day are shown in Fig. 13. The larvae were hardly found on the surface of the sea, and they were more abundant in the layer of 50-100 m than of 0-50 m in the daytime . However, the rates were nearly equal in any of the layers shallower than 100 m at night. The diurnal movement was suggested, such as the larvae distribute uniformly in the density in the layers above the thermocline at night, but they move down from surface layer to deeper waters in the daytime.

b) Juvenile: The juveniles of Illex were caught by rectanglar and midwater trawl nets, and the mesh size of liner of midwater trawl net was different between the first and second legs. Consequently, 3 different meshes of net were used for catching the juveniles. The comparison of efficiencies among three gears have not been made yet, but day-and-night effect on each gear was examined prior to the analyses.

As for rectanglar net, the tows only in the boundary(H) were used because the catch of the juvenile was unstable in other water-types. Also, the juveniles appeared mainly in the layers shallower than 100 m, as will be mentioned later. Accordingly, hours towed in the layer deeper than 100 m were eliminated from the calculation of catch rate. The catch rates in the daytime and at night are shown in Table 6. The rates at night were 2.3 and 4.0 times, respectively, of the value in the daytime at St. 63 where three tows, one in the daytime and other two at night, were made. Generally, catch rates at night were higher than those in the daytime at other stations, and the average rate at night was 2.9 times of that in the daytime. Therefore the value of daytime was standardized by multiplying by 2.9 for the following analyses.

In case of midwater trawl, tows only in the boundary(H) were also used for the same reason. Furthermore, as the towing time in the layer of 0-100 m was only a few minutes in the course of the oblique tow of 0-1000 m, these tows were abandoned. Therefore, only the tows from 100 m and stepped oblique tows which were made under longer duration in shallower layers were used. The catch in number per hour in layers shallower than about 100 m are given in Table 7. The value in the daytime were extremely lower than those at night in both of the legs. Consequently, the values in the daytime were not used for the following analyses in case of midwater trawl.

b-1) Horizontal Distribution: Number of the juveniles caught by rectanglar and midwater trawl nets are shown in Fig. 14 for the first leg and Fig. 15 for the second leg. The juveniles appeared in most part of the survey area, but they were never caught in the central Gulf Stream and in the Sargasso Sea Water.

The catch rates of the juveniles by water-types are given in Table 8. The values fluctuated unexpectedly in the first leg, because hours towed in the layer above 100 m were so short in case of 0-1000 m oblique tow. However, the largest catch in number was obtained from the boundary (H) and the catches from the Slope Water and the northern edge of the stream followed it. The same tendency was also observed in either cases of the gears in the second research leg.

b-2) Vertical Distribution: The temperature profile by X-BT at stations towed at night are shown in Fig. 16 for rectanglar net and Fig. 17 for midwater trawl. The juveniles appeared at each station where water temperature ranged from 10° to 21° C except a few stations. The large catches over 100 juveniles were taken from the stations where surface temperature was within 16° to 19° C and thermocline lay in the layer shallower than 100 m. The water characterized by this temperature range and the depth of thermocline was clearly composed of the water of boundary(H). Exceptionally, a catch over 100 juveniles was obtained at St. 72 where surface temperature was about 11° C. Four juveniles were caught at two stations in the Shelf Water where surface temperature was below 5° C. However, The Slope Water (about 10° C) intruded under the Shelf Water at the depth of about 100 m at these stations, so the juveniles seems to be caught from this warmer waters.

Depth-stratified samplings by rectanglar net were made in the boundary(H) area, and the results are shown in Table 9. The juveniles appeared in the layer above 50 m in the daytime and above 100 m at night. In case of night tow, 10 juveniles were caught from 0-100 m layer (R17), but most of them might be taken in the layer above 50 m, taking account of the catch rate for another tow (R20) in 0-50 m layer at the same station. No juvenile was caught in the layers deeper than 50 or 100 m (R19: 200-425; R24: 50-100 m), but a few juveniles were caught during retrieving of the net. Furthermore, in case of R25, a stepped tow was made in the layer of 0-50 m on the way of retrieving, and 7 juveniles were taken. Thus, it seems that the juveniles were distributed in the layer from sea surface to about 50 m at these stations.

Temperature profile by X-BT and the catch rate of juvenile in each layer are given in Fig. 18. There was a strong thermocline in the depth of 30 to 70 m at these stations, and the catch rates were nil or negligible under the thermocline. Therefore, it is assumed that the juveniles were distributed exclusively above the thermocline.

c) Adult: A total of 39 tows was made in the area from the Sargasso Sea to the Shelf Water, and 22 of them were trawled from about 1000 m and one from 1745 m. Fifteen squid jiggings were also made in all of the water-types. However, no adult *Illex* was caught. Two reasons could be pointed out, namely there was no adult in the area surveyed, or the gears and the methods were not appropriate for catching adult. As will be seen later, the first reason seems to be more reliable, though no definite information is available so far.

3. Spawning Season and Ground of Short-finned Squid

No adult was caught as aforementioned, and no egg of *Illex* was also found from the samples of Bongo Net. However, the information on time and place larvae appeared, current speed in the place and the number of days required for incubation makes it possible to approach the spawning season and ground.

a) Spawning Season: The larvae were caught first on 19 January and a considerable amount of larvae was taken till 15 February. However, no large catch was taken afterwards, in spite of the fact that 9 more tows were made in the boundary(H) and the northern edge of the Gulf Stream.

It is assumed that the larvae appeared at least during the period from 19 January to 15 February.

O'Dor et al. (1981) reported that the egg of Illex required 11 days at 14° C and 8 days at 21° C for incubation, respectively, and the mantle length of larva hatched was about 1 mm. The larvae caught in the survey ranged from 2 to 10 mm (including the juvenile) in mantle length. Therefore, they must have spent some days before they were caught. Although there is no information on the growth in larval stage, the larval period seems to be not so long, taking account of the fact that the larvae disappeared in a short time. Therefore, it could be guessed that, if the larvae caught spent 15 days after they were spawn, the spawning season began in early January and ended in late January.

The adult squid emigrate from the Scotian Shelf to off-shelf area in November, and then the male has spermatophores but maturation is activated for the female (Amaratunga, 1980). No information on copulation and spawning in the field is available so far. If the spawning season is assumed to be January, the duration of emigration from shelf to spawning ground is assumed to be two months. This assumption is rather acceptable, comparing with Japanese common squid (Todarodes pacificus) whose copulation takes place two to three months before the spawning.

b) Spawning Ground: The water-type suitable for spawning will be discussed in the first place. O'Dor et al. (1981) reported that the normal development of embryo appears to require minimum temperatures within the range of 10° to 13° C. Taking account of this results, suitable water-types are limited to the Slope Water, the Gulf Stream including warm core eddy and the Sargasso Sea Water.

As mentioned in Paragraph 2-a), the larvae of Illex were distributed mainly in the Gulf Stream and the related water-types, and they were most abundant in the northern edge of the stream and the boundary(H). This suggests a pattern that the larvae hatch out in the Stream and they are accumulated in the northern edge and the boundary(H) by the convergence effect of the current. On the contrary, if the larvae are born in the Slope Water and/or in warm core eddy, they can not be diverged into the Gulf Stream and the Sargasso Sea Water beyond the boundary(H). There is a possibility that the larvae originate from the Sargasso Sea Water, such as European eel (Anguilla anguilla), but a considerably long time will be required for their transportation from the Sargasso Sea Water to the northern edge of the stream and to the boundary(H). Thus, the Gulf Stream will be the most possible water-type as the spawning ground.

Geographical location of possible spawning ground will be discussed. The current velocity was the strongest in the boundary(H) and in the northern edge of the Gulf Stream. The observed speed on sea surface in these areas was within the range of 2.0 to 4.0 knots and the average attained 2.9 knots. As aforementioned, if the larvae spent 15 days after spawning in the stream, they could be shifted about 1000 nautical miles at maximum. The large catches of the larvae occurred in the area between 72° W and 62° W, and the length of meandering Gulf Stream in this range was a little less than 600 n. miles. Therefore, the larvae even at the east end (62° W) can be originated from the area far from the survey area to the southwest. The positions upstream 1000 n. miles along the Gulf Stream from 62° W and 72° W are situated off the south Carolina and off the tip of the Florida Peninsula, respectively. However, as the egg and larva were not always in the strongest current, the actual distance transported must be considerably shorter than 1000 n. miles. Therefore, it is suggested that the spawning ground lies somewhere between the west end of the survey area and off the Florida Peninsula. This could be supported by the fact that no adult squid was found in the survey area.

Furthermore, as the water temperature above 13° C was observed in the waters shallower than about 800 m in the Gulf Stream and if the bottom is required for spawning as suggested by O'Dor et al.(1981), the spawning ground must be located in the place where the Gulf Stream runs near to the coast. The stream comes close to the coast off the Florida Peninsula and runs away from the coast off Cape Hatteras. Therefore, the area from the peninsula to Cape Hatteras seems to be the most possible place as the spawning ground.

4. Migration of Short-finned Squid in Larval and Juvenile Stages

Illex caught by Bongo Net ranged from 2 to 10 mm in mantle length, and they were sorted into three groups based on Roper and Lu (1979), i.e., Rhynchoteuthion with a complete proboscis,"transition" with a triangular opening at the base of proboscis, and juvenile with two tentacular arms.

On the other hand, the "juvenile" caught by rectangular and mid-water trawl nets were within the range of 6 to 58 mm and 10 to 115 mm in mantle length, respectively. Although they include actually both stages of juvenile and young, there is no criterion to divide them. Accordingly, the mean length and length range are used for indicating the degree of growth in juvenile-to-young stage.

a) Larval Stage: The survey area was divided into three regions; western, middle and eastern; by two longitudinal lines of 69° and 65° W. Number of larvae caught are shown by stages and by regions in Table 10. In the first research leg, the percentage of "transition" is the highest in the eastern region. Namely, the percentage in boundary(H) was 9, 14 and 28 % in each of the regions from west to east. On the other hand, no significant difference in percentage was recognizable among water-types in each region, though the available data are not sufficient. Therefore, it is suggested that the short-finned squid spend the Rhynchoteuthion and "transition" stages in the northern edge of the Gulf Stream and in the boundary(H) while they are transported eastwards from the spawning ground by the current. In the second research leg, the number of larvae caught was too few to get any assumption on the problem, but the percentage of "transition" increased from 14 % in the first leg to 28 % in the second leg. This seems to be due to the time-lag of around one month.

b) Juvenile Stage: The size range and mean length of the juveniles caught by rectangular and by midwater trawl nets are shown by water-types and by regions in Table 11. Any particular trends in length range and mean length in the west-east direction were not found in case of the juveniles. The mean lengths in the boundary(H) were nearly the same between western and middle regions in the first leg, and between middle and eastern region in the second leg.

On the other hand, the difference in size of the juveniles among water-types was conspicuous, namely the larger animals were caught in the cooler water-types. The length frequency distributions in each water-type are given in Fig. 19. The sizes were similar among the northern edge of the Gulf Stream, the boundary(H) and warm core eddy, while the sizes became larger in the order of the Slope Water, the boundary(L) and the Shelf Water. Accordingly, it is assumed that the short-finned squid spend their early juvenile stage mainly in the boundary(H) and then migrate gradually into cooler water-types as they grow larger.

Although the mesh size of liner attached midwater trawl net in the second leg was smaller than that in the first leg, the juveniles caught in the second leg were generally larger in size. This must be owing to the growth during the time-lag between first and second legs. The juveniles caught by rectangular net were considerably smaller than those by midwater trawl net. It seems to indicate the effect of mesh selectivity of the gear.

DISCUSSION

Illex illecebrosus is distributed widely in the Northwest Atlantic, and also *I. oxygonius* is known in the area from the Gulf of Mexico to Cape Hatteras (Roper et al., 1969). Roper and Lu (1979) studied ommastrephid larvae collected from the area off Cape Hatteras northwards to Georges Bank, and identified C' type Rhynchoteuthion as *I. illecebrosus*. However, they did not refer the larva of *I. oxygonius*. Although the present survey was carried out outside of the known habitat of this species, there seems to be a possibility for occurrence of larvae of *I. oxygonius* in the survey area.

The boundary(H) played a important role in the distributions of larva and juvenile of *Illex*. The temperature-salinity (T-S) curves are shown in Fig. 20, in order to examine the characteristics of water of the boundary(H). It is noticeable that the water of the boundary(H) is not a simple mixture of the Gulf Stream and the Slope Water but has some particular features, namely the specific gravity was nearly equal to that in the northern edge of the Gulf Stream and was the lowest of all of the water-types in the survey area except a part of the Shelf Water. It is estimated that the boundary(H) was derived from the surface water of the Gulf Stream because it was continuous in specific gravity with the northern edge of the stream but discontinuous with the Slope Water. The meaning of this low specific gravity in the aspect of adaptation in larval and juvenile stages is quite interesting but it is difficult to discuss the problem at present for the lack of further information.

The large amount of the juveniles was caught by the USSR and Canada's surveys carried out in 1979 and 1981 (Fedulov and Froerman, 1980; Dawe et al., 1981; and Froerman et al., 1981). Although the spatial area and water temperature that the juveniles were caught are similar to those in the present survey, the aspect of their vertical distribution is completely different. Although the data obtained from depth-stratified samplings is insufficient, the results indicate that the juvenile is a typical epipelagic animal. On the other hand, Dawe et al.(1981) reported that "below 100 m catch was greatest at maximum depth (1000 m)", and Fedulov and Froerman (1980) and Froerman et al.(1981) reported the juvenile catch in 500 m or so. However, they used Engel Midwater Trawl gear (EMT) without opening-closing apparatus, and Dawe et al.(1981) pointed out also a possibility for the occurrence of catch during the retrieval of the gear.

Froerman et al.(1981) reported that "the length of young increased from the Gulf Stream to the shelf", but Dawe et al.(1981) observed "a pronounced increase in mean length in the west-east direction". The results obtained by this survey ascertained the former estimation.

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SUMMARY

The Japan/Canada/USA joint survey by R/V Kaiyo Maru was carried out from 16 January to 5 March of 1982 to obtain the biological and oceanographic information on short-finned squid in the oceanic periods in the Northwest Atlantic. The results obtained are summarized as follows.

1. The water-types of the Shelf Water, the Slope Water, warm core eddy, the Gulf Stream and Sargasso Sea Water were found in the survey area (58°-74° W), and the characteristics of these water-types were summarized in Table 3.

2. The spatial distribution of water-types in the survey period are schematically shown in Fig. 7.
3. The larvae of <u>Illex illecebrosus</u> were distributed in the Slope Water, warm core eddy, the Gulf Stream and the northern part of Sargasso Sea in the area surveyed.
4. The larvae were most abundant in the boundary(H) and in the northern edge of the Gulf Stream, and they were distributed mainly in the layers shallower than about 200 m above thermocline.
5. The diurnal movement of the larvae was indicated. The larvae abundant in the sub-surface layer at night but abundant in deeper layers in the daytime.
6. The juveniles occurred in the area from the southern edge of the Shelf Water to the northern edge of the Gulf Stream, but they did not appear in the Sargasso Sea Water.
7. The juveniles were most abundant in the layer shallower than 50 m above thermocline in the boundary(H), and the density in the slope Water followed it. However, they were sparsely distributed in the northern edge of the Gulf Stream where the larvae were abundant.
8. The spawning seems to take place mainly in January.
9. The spawning ground seems to be situated in the area off the Florida Peninsula to Cape Hatteras in the Gulf Stream.
10. It is surmised that the larvae hatched in the Gulf Stream spend their larval and early juvenile stages in the stream, while they are accumulated gradually in the northern edge and the boundary(H) by convergence effect of the current while they are transported eastwards by the stream.
11. It is assumed that the juvenile of 20 to 30 mm in mantle length migrate from the boundary(H) to the cooler water-types near to the shelf as they grow larger.

REFERENCES

Amaratunga, T. 1980: Growth and maturation patterns of the short-finned squid (<u>Illex illecebrosus</u>) on the Scotian Shelf. NAFO SCR Doc., 80/II/30.

_______, J. D. Neilson, D. J. Gillis and L. G. Valdron 1979: Food and feeding of the short-finned squid, <u>Illex illecebrosus</u>, on the Scotian Shelf in 1978. ICNAF Res. Doc., 79/II/11.

_______, T. Rowel and M. Roberge 1980: Summary of Joint Canada/USSR Research Program on short-finned squid (<u>Illex illecebrusus</u>), 16 February to 4 June, 1979, spawning stock and larval survey. NAFO SCR Doc., 80/II/38.

Dawe, F. G., P. C. Beck and M. 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.

Durward, R. D., E. Vessey, R. K. O'Dor and T. Amaratunga 1979: Aspects of maturation, mating, spawning, and larval development of Illex illecebrosus relevant to field studies. ICNAF Res. Doc., 79/II/13.

Fedulov, P. P., and Yu. M. Froerman 1980: Effect of abiotic factors on distribution of young short-finned squid, Illex illecebrosus (LeSueur, 1821). NAFO SCR Doc., 80/VI/98.

Froerman, Yu. M., P. P. Fedulov, V. V. Khalyukov, E. N. Shevchenko and T. Amaratunga 1981: Preliminary results of R/V Atlant research of short-finned squid, Illex illecebrosus, in NAFO Subarea 4 between 3 March and 4 May, 1981. NAFO SCR Doc., 81/VI/41.

Lange, A. M. T. and M. P. Sissenvine 1981: Evidence of summer spawning of Illex illecebrosus (LeSueur) off the northeastern United States. NAFO SCR Doc., 81/VI/33.

Posgay, J. A. and R. R. Marak 1980: The MARMAP Bongo Zooplankton Samplers. J. NW. Atl. Fish. Sci., 1:91-99.

Roper, C. F. E. and C. C. Lu 1979: Rhynchoteuthion larvae of ommastrephid squids of the western north Atlantic, with a first description of larvae and juveniles of Illex illecebrosus. Proc. Biol. Soc. Wash., 91(4):1039-1059.

_______, _______ and K. Mangold 1969: A new species of Illex from the western Atlantic and distributional aspects of other Illex species (Cephalopoda: Oegopsida). Proc. Biol. Soc. Wash., 82:295-322.

Squires, H. J. 1967: Growth and hypothetical age of the Newfoundland bait squid, Illex illecebrosus illecebrosus. J. Fish. Res. Bd. Canada, 24(6):1209-1217.

Table 1. Number of tows and jiggings made in the first research leg.

Water-type*	Bongo Net Oblique	Bongo Net Surface	Bongo Net Depth-strat.	Midwater Trawl	Squid Jigging
Shelf Water	5	-	-	3	1
Boundary (L)	2	-	-	1	1
Warm Core Eddy	4	-	-	3	-
Slope Water	7	1	-	4	2
Boundary (H)	4	1	13	5	5
Gulf Stream	4	-	17	3	3
Sargasso Sea Water	5	-	-	4	2
Total	31	2	30	23	14

* See Table 3

Table 2. Number of tows and jiggings made in the second research leg.

Water-type*	Bongo Net Oblique	Rectangular Net Oblique	Rectangular Net Depth-strat.	Midwater Trawl	Squid Jigging
Shelf Water	4	4	-	-	-
Boundary (L)	4	3	-	2	-
Warm Core Eddy	4	3	-	2	-
Slope Water	4	1	-	2	-
Boundary (H)	7	3	9	7	-
Gulf Stream	5	3	-	2	1
Sargasso Sea Water	-	-	-	1	-
Total	28	17	9	16	1

* See Table 3

Table 3. Characteristics of each water-type in surface layer (0-50 m) observed in the survey area from 16 January to 5 March, 1982.

Water-type	Temperature (°C)	Salinity (‰)	Dissolved Oxygen (ml/l)	Density (σ_t)
Shelf Water	0.4-9.2	31.2-34.3	5.5-8.0	25.0-26.3
Boundary (L)	Narrow band between Shelf Water and Slope Water or warm core eddy			
Warm Core Eddy	16.8-17.4	36.1-36.4	4.7-5.3	26.1-26.7
Slope Water	9.3-17.7	34.6-35.8	5.0-6.3	26.1-26.7
Boundary (H)	Narrow band between Slope Water and Gulf Stream			
Gulf Stream	18.3-22.2	36.1-36.6	4.6-5.0	25.0-26.4
Sargasso Sea Water	17.6-19.5	36.4-36.5	5.0-5.2	25.9-26.5

Table 4. Number of *Illex* larvae caught in each water-type by 0-200 m double oblique tow of Bongo Net.

Period	Water-type*	Number of Tows	Filtered Vol. (m^3)	Larvae Caught Number	Larvae Caught /1000 m^3
First Research Leg	Shelf Water	5	7698	-	-
	Boundary (L)	2	3279	-	-
	Warm Core Eddy	4	7270	40	5.5
18 Jan - 4 Feb 1982	Slope Water	7	10549	5	0.5
	Boundary (H)	4	5987	169	28.2
	Northern Edge of Gulf Stream	1	1426	37	25.9
	Central Gulf S.	3	5845	10	1.7
	Sargasso Sea W.	5	8838	6	0.7
Second Research Leg	Shelf Water	4	7413	-	-
	Boundary (L)	4	7555	2	0.3
	Warm Core Eddy	4	6985	5	0.7
12 Feb - 2 Mar 1982	Slope Water	4	6700	2	0.3
	Boundary (H)	7	12259	7	0.6
	Northern Edge of Gulf Stream	3	5702	23	4.0
	Central Gulf S.	2	3279	-	-

* Classification based on surface water

Table 5. Number of <u>Illex</u> larvae caught by depth-stratified sampling of Bongo Net.

Date and Time	St. No.	Tow No.	Depth (m)	Filtered Vol. (m^3)	Larvae Caught No.	Larvae Caught /1000 m^3	Remarks
Daytime	04	B06	Surface	855	-	-	
19 Jan 1982		B07	0-60	932	111	119.1	
10:35-11:41		B08	57-102	790	120	151.9	
Dusk-Night	04	B10	Surface	855	-	-	
19 Jan 1982		B11	0-61	647	-	-	
17:05-20:47		B13	0-120	205	4	3.3	2nd messenger failed
		B12	0-182	875	3	3.4	2nd messenger failed
Night	04	B17	Surface	428	13	30.4	
20 Jan 1982		B14	0-70	790	11	13.9	
00:52-02:54		B15	57-148	466	-	-	one side door closed
		B16	0-219	1100	15	13.6	2nd messenger failed
Night-Dawn	04	B18	Surface	713	1	1.4	
20 Jan 1982		B19	0-55	395	4	25.6	one side door closed
04:23-07:48		B22	23-60	502	19		
		B20	44-91	647	11	17.6	
		B21	0-141 (66-141)	1331 (867)	22 (10)	 (11.5)	2nd messenger failed estimated from B19,22
Night	10	B28	Surface	855	48	56.1	buoy dropped
22 Jan 1982		B29	0-52	1075	76	70.7	
02:32-05:40		B30	44-80	790	42	53.2	
		B31	92-150	439	5	11.4	
		B32	153-230	582	1	1.7	
Daytime	11	B33	0-32	790	41	51.9	
22 Jan 1982		B34	47-70	932	159	170.6	
10:19-12:14		B35	91-122	724	1	1.4	storm, abnormal tow
Daytime	12	B37	Surface	998	1	1.0	
23 Jan 1982		B36	0-40	790	21	26.6	buoy dropped
11:04-15:35		B38	0-118 (56-118)	716 (505)	11 (5)	 (10.6)	2nd messenger failed estimated from B36
Daytime	25	B48	Surface	855	-	-	
30 Jan 1982 12:35-13:49		B49	0-41	855	26	30.4	

Table 6. Number of juvenile <u>Illex</u> caught by rectangular net in the daytime and at night in the boundary(H).

Time of Day	St. No.	Tow No.	Maximum Depth (m)	Minutes towed* (above 100 m)	Juveniles caught Number	Juveniles caught /Hour
Daytime	63	R16	311	69	5	4.3
	64	R21	63	59	2	2.0
	64	R25	200	46	7	9.1
	Total			174	14	4.8
Night	44	R03	160	28	2	4.3
	48	R06	238	28	12	25.7
	63	R17	100	60	10	10.0
	63	R20	43	62	17	17.0
	Total			178	41	13.8

* juveniles appeared in the layer shallower than 100 m, as shown in Table 9

Table 7. Number of juvenile Illex caught by midwater trawl in the daytime and at night in the boundary(H).

Research Leg	Time of Day	St. No.	Tow No.	Depth* Towed(m)	Minutes* Towed	Juveniles Caught Number	/Hour
First	Daytime	15	M10	45-130	19	1	3.2
		25	M15	45-130	37	-	-
		Total			56	1	1.1
	Night	13	M09	35-110	76	115	90.8
Second	Daytime	76	M32	45-95	73	7	5.8
		80	M36	55-120	60	-	-
		81	M37	60-120	15	3	12.0
		Total			148	10	4.1
	Night	68	M25	35-103	60	174	174.0
		77	M33	40-93	60	1028	1028.0
		79	M35	55-110	60	2368	2368.0
		81	M38	60-110	60	389	389.0
		Total			240	3959	989.8

* in case of stepped oblique tow, the part deeper than arpund 100 m is neglected for the same reason as that in Table 6

Table 8. Number of juvenile Illex caught in each water-type by rectanglar and by midwater trawl nets. Only the minutes towed in the layer above 100 m or so were used in case of stepped oblique tow from about 1000 m and catch in the daytime was revised in case of rectangler net.

Period and Gear	Water-type*	Number of Tows	Minutes Towed	Juveniles Caught Number	/Hour
First Research Leg	Shelf Water	2	95	4	2.5
	Boundary(L)	1	1	4	240.0
18 Jan - 4 Feb 1982	Warm Core Eddy	3	81	1	0.7
Midwater Trawl	Slope Water	4	35	18	30.9
	Boundary(H)	3	80	139	104.3
	Northern Edge of Gulf Stream	1	1	7	420.0
	Central Gulf S.	1	2	-	-
	Sargasso Sea W.	2	38	-	-
Second Research Leg	Shelf Water	4	124	-	-
	Boundary(L)	3	85	-	-
12 Feb - 22 Feb 1982	Warm Core Eddy	3	86	3	2.1
Rectanglar Net	Slope Water	1	26	1	2.3
	Boundary(H)	3	125	29	13.9
	Northern Edge of Gulf Stream	2	24	2	5.0
	Central Gulf S.	1	41	-	-
Second Research Leg	Slope Water	1	60	114	114.0
22 Feb - 3 Mar 1982	Boundary(H)	4	240	3959	989.8
Midwater Trawl					

* classification based on surface water

Table 9. Number of juvenile *Illex* caught by depth-stratified sampling of rectanglar net.

Date and Time	St. No.	Tow No.	A Cod (Fixed Layer) Depth (m)	Mins. Towed	Catch No.	Catch /Hr.	B Cod (Upper Layer)** Depth (m)	Mins. Towed	Catch No.	Catch /Hr.
Night	63	R20	0-50	62	17	16.5	-	-	-	-
19-20 Feb 1982		R17	0-100 (50-100)	60 (25)	10 (0.4)	10.0 (0.2)	- estimated from R20	-	-	-
19:45 - 02:32		R18	100-200	60	-	-	0-100	8	-	-
		R19	200-425	60	-	-	0-200	13	3	11.3
Daytime	64	R21	0-63	59	2	2.0	-	-	-	-
20 Feb 1982		R24	50-100	60	-	-	0-50	4	2	30.0
		R23*	100-200	Catch → B Cod			0-200	68	-	-
08:15 - 16:50		R25	200-380	60	-	-	0-200	58	7	7.2

* opening apparatus did not work

** assuming that there is no catch during the sinking of net down to the fixed layer

Table 10. Number of *Illex* larvae by stages in the respective regions caught by Bongo Net.

Region and Period	Water-type*	Rhyncho-teuthion	Transi-tion	Juvenile	Total
First Research Leg	Boundary(H)	10	1	-	11
Western(74°-69°W) 18-21 Jan 1982	Northern Edge of Gulf Stream	180	24	2	206
	Central Gulf S.	3	-	-	3
	Total (%)	193 (88)	25 (11)	2 (1)	220 (100)
Middle(69°-65°W) 21-23 Jan 1982	Boundary(H) (%)	224 (84)	37 (14)	5 (2)	266 (100)
Eastern(65°-60°W) 26 Jan - 4 Feb 1982	Warm Core Eddy	14	6	-	20
	Slope Water	1	-	-	1
	Boundary(H)	20	8	1	29
	Central Gulf S.	1	-	1	2
	Sargasso Sea W.	-	-	1	1
	Total (%)	36 (68)	14 (26)	3 (6)	53 (100)
Total 18 Jan - 4 Feb 1982		453 (84)	76 (14)	10 (2)	539 (100)
Second Research Leg	Boundary(L)	-	1	-	1
Middle(68°-65°W)	Slope Water	1	-	-	1
12 Feb - 2 Mar 1982	Boundary(H)	3	1	-	4
	Northern Edge of Gulf Stream	11	4	-	15
	Total (%)	15 (71)	6 (29)	- (-)	21 (100)
Eastern(65°-58°W)	Warm Core Eddy	2	1	-	3
17-25 Feb 1982	Slope Water	1	-	-	1
	Total (%)	3 (75)	1 (25)	- (-)	4 (100)
Total 12 Feb - 2 Mar 1982		18 (72)	7 (28)	- (-)	25 (100)
Grand Total (%)		471 (84)	83 (15)	10 (2)	564 (100)

* classification based on surface water

Table 11. Length range and mean length of Juvenile Illex in the respective water-types caught by rectanglar and midwater trawl nets.

Research Leg and Gear	Region and Period	Water-type*	Specimens Measured	Mantle Length (mm) Range	Mean
First Midwater Trawl Liner 18.3 mm	Western (74°-69°W) 18-21 Jan 1982	Boundary(L)	4	48-93	66
		Slope Water	16	22-41	30
		Boundary(H)	19	19-27	23
		Norhtern Edge of Gulf Stream	4	17-26	22
		Total	43	17-93	29
	Middle (69°-65°W) 21-23 Jan 1982	Boundary(H)	119	10-26	20
	Eastern (65°-58°W) 26 Jan - 4 Feb 1982	Shelf Water	6	42-115	78
		Warm Core Eddy	1	24	24
		Slope Water	2	19-27	23
		Boundary(H)	1	11	11
		Total	10	11-115	55
	Total 18 Jan - 4 Feb 1982	Shelf Water	6	42-115	78
		Boundary(L)	4	48-93	66
		Warm Core Eddy	1	24	24
		Slope Water	18	19-41	29
		Boundary(H)	139	10-27	20
		Northern Edge of Gulf Stream	4	17-26	22
		Total	172	10-115	24
Second Rectanglar Net Cod-end 1.7 mm	Middle (69°-65°W) 14-16 Feb 1982	Warm Core Eddy	1	10	10
		Slope Water	1	58	58
		Boundary(H)	14	8-27	12
		Northern Edge of Gulf Stream	2	11-16	13
		Total	18	8-58	15
	Eastern (65°-61°W) 19-21 Feb 1982	Boundary(H)	45	6-28	12
	Total 14-21 Feb 1982	Warm Core Eddy	1	10	10
		Slope Water	1	58	58
		Boundary(H)	59	6-28	12
		Northern Edge of Gulf Stream	2	11-16	13
		Total	63	6-58	12
Second Midwater Trawl Liner 11.0 mm	Middle (69°-65°W) 1-3 Mar 1982	Boundary(H)	666	13-65	28
	Eastern (65°-59°W) 22 Feb - 1 Mar 1982	Boundary(L)	6	21-42	34
		Warm Core Eddy	16	14-28	18
		Slope Water	117	14-49	33
		Boundary(H)	481	11-56	28
		Total	620	11-56	29
	Total 22 Feb - 3 Mar 1982	Boundary(L)	6	21-42	34
		Warm Core Eddy	16	14-28	18
		Slope Water	117	14-49	33
		Boundary(H)	1147	11-65	28
		Total	1286	11-65	28

* classification based on surface water

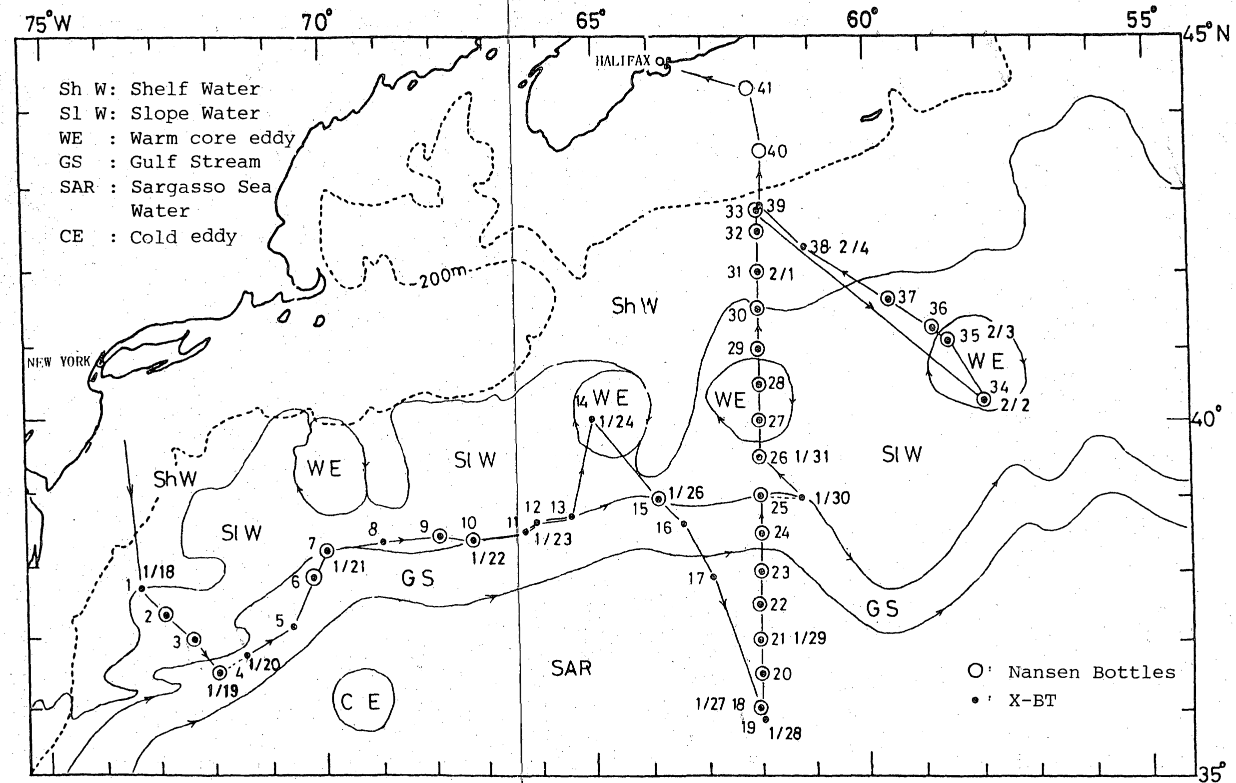


Fig. 1. Oceanographic stations in the first research leg. The numerals in the figure indicate station number (fine) and the date investigated (bold). Position of each water-type was based on the data observed and the Satellite Sea Surface Temperature Chart.

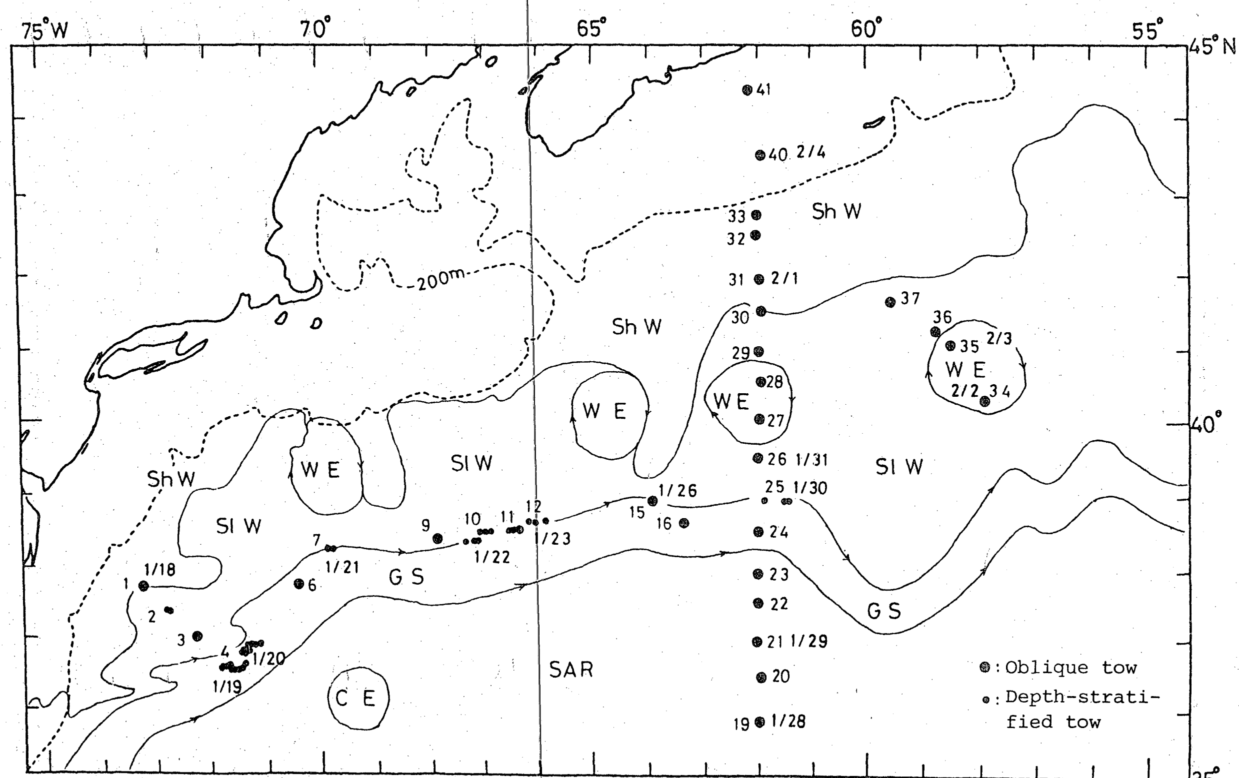


Fig. 2. Bongo Net stations in the first research leg. See Fig. 1 as to the drawing method of the figure.

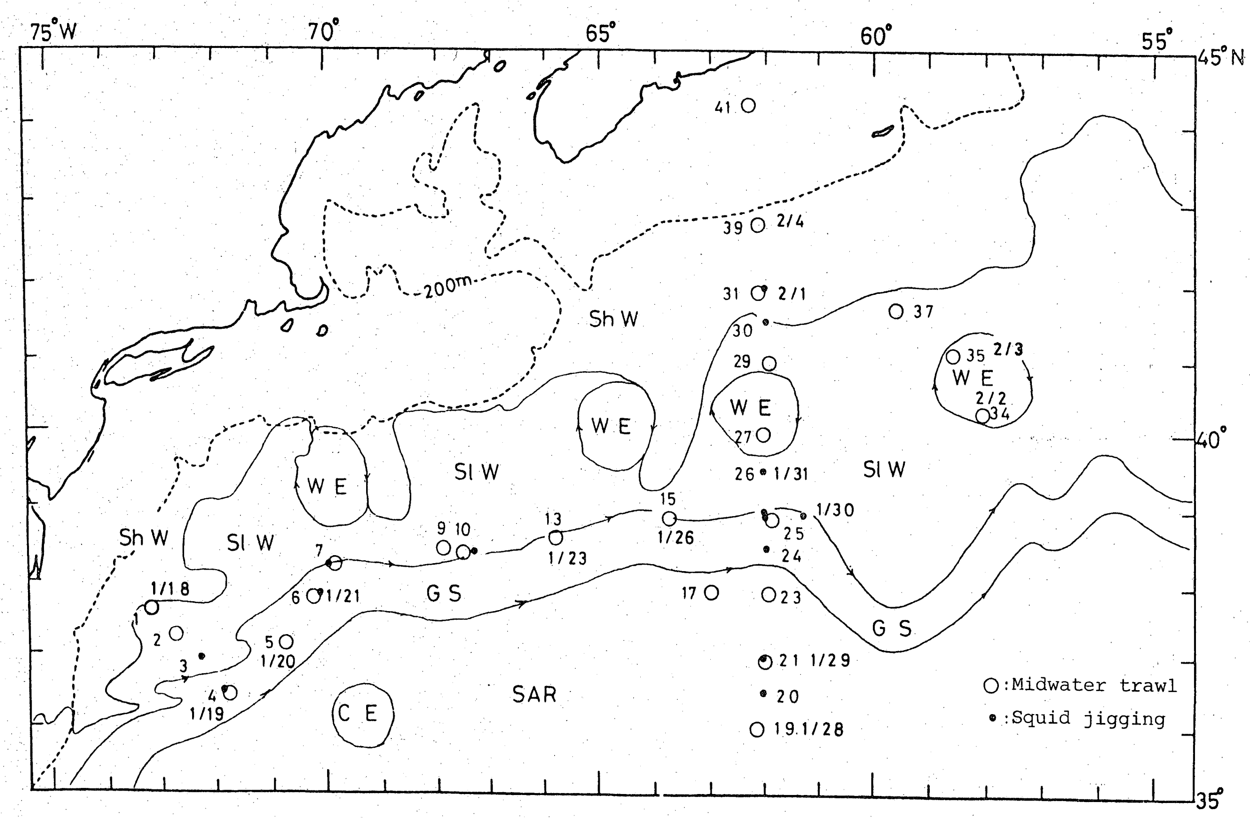


Fig. 3. Midwater trawl and squid jigging stations in the first research leg. See Fig. 1 as to the drawing method of the figure.

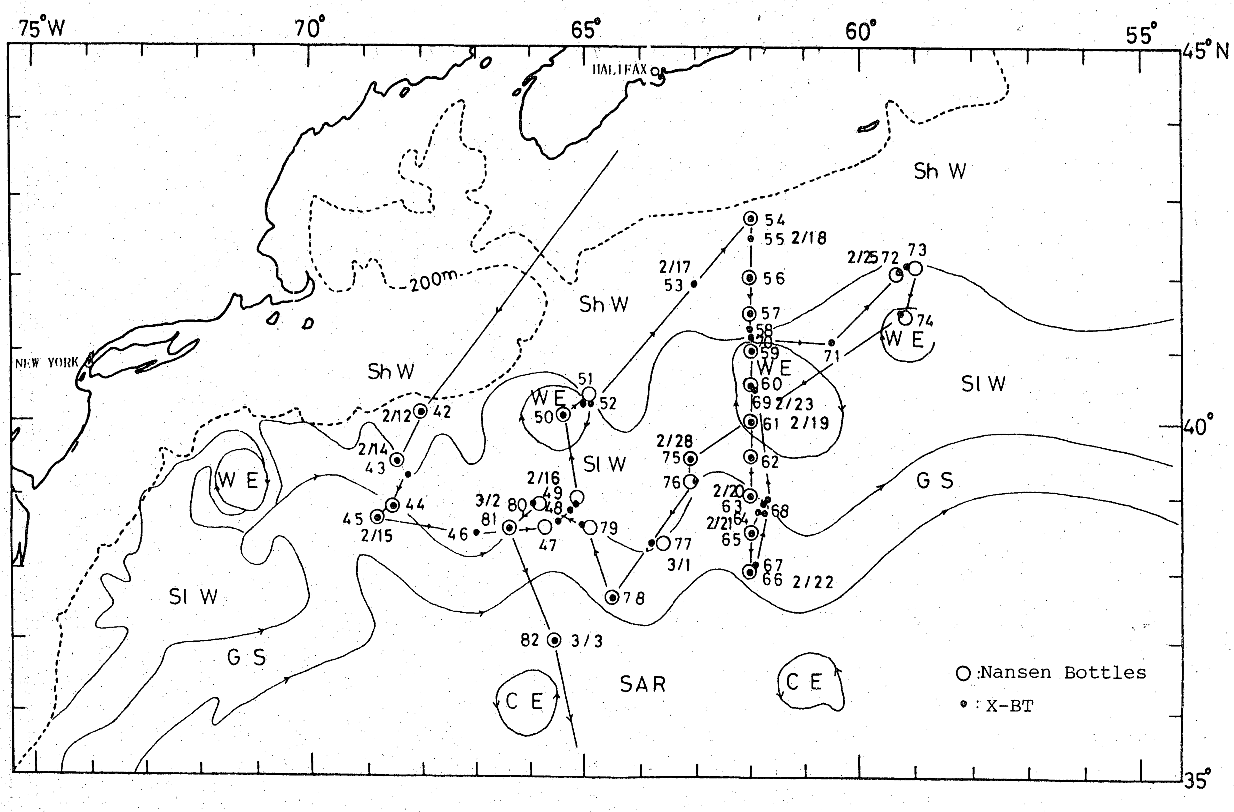


Fig. 4. Oceanographic stations in the second research leg. See Fig. 1 as to the drawing method of the figure.

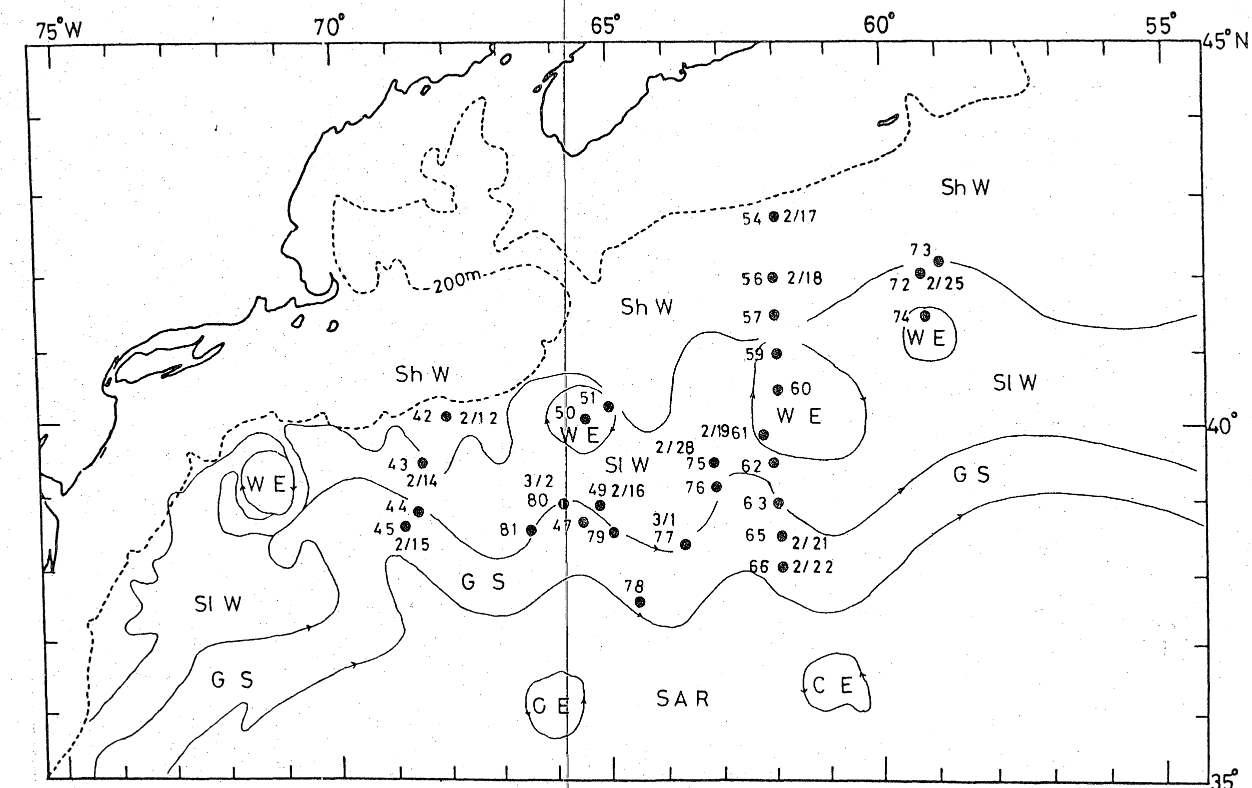


Fig. 5. Bongo Net stations in the second research leg. See Fig. 1 as to the drawing method of the figure.

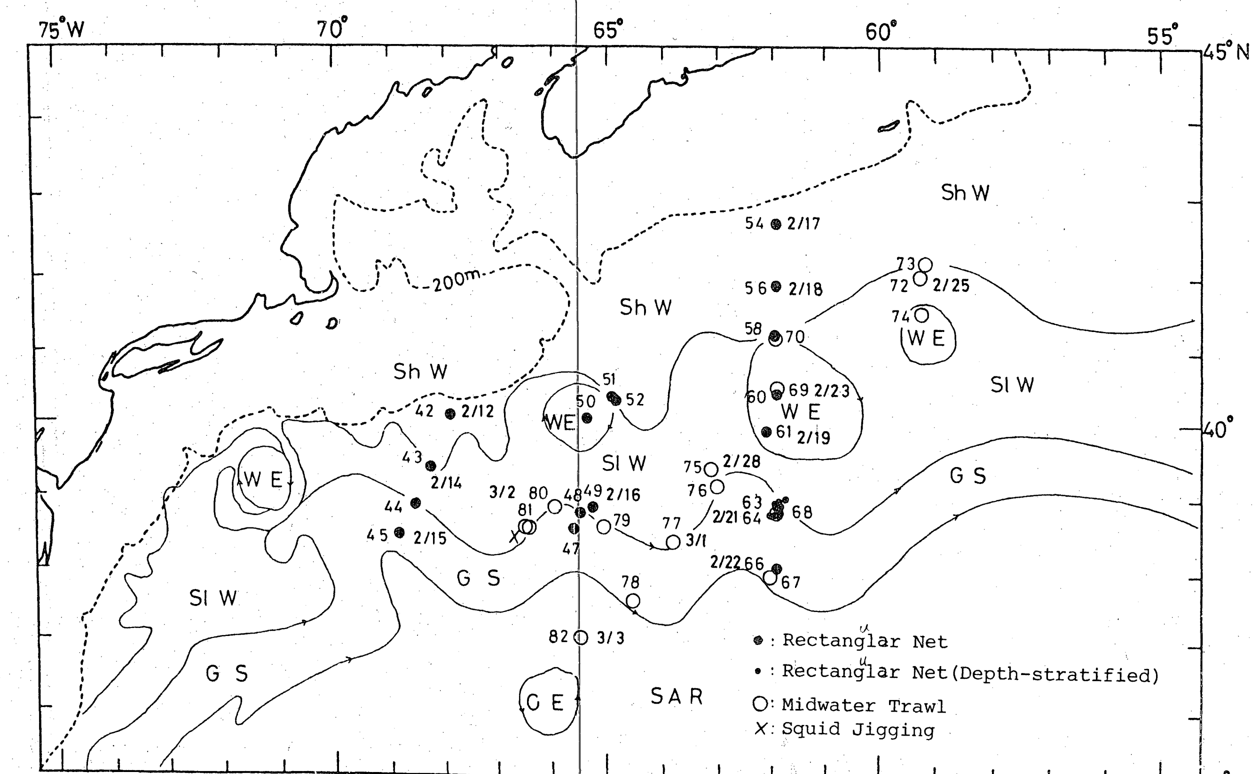


Fig. 6. Rectanglar net, midwater trawl and squid jigging stations in the second research leg. See Fig. 1 as to the drawing method of the figure.

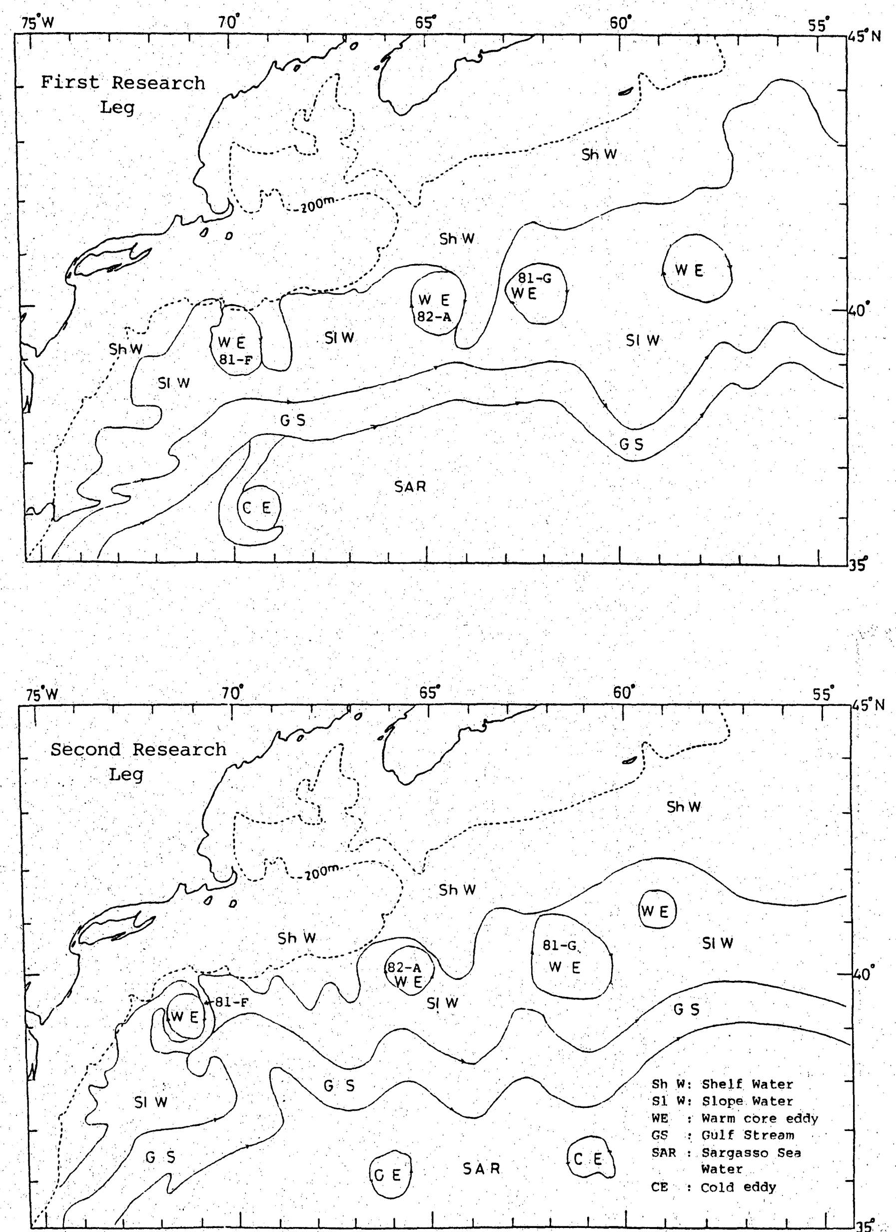


Fig. 7. Distribution of water-types in the survey period. See Fig. 1 as to the drawing method of the figure.

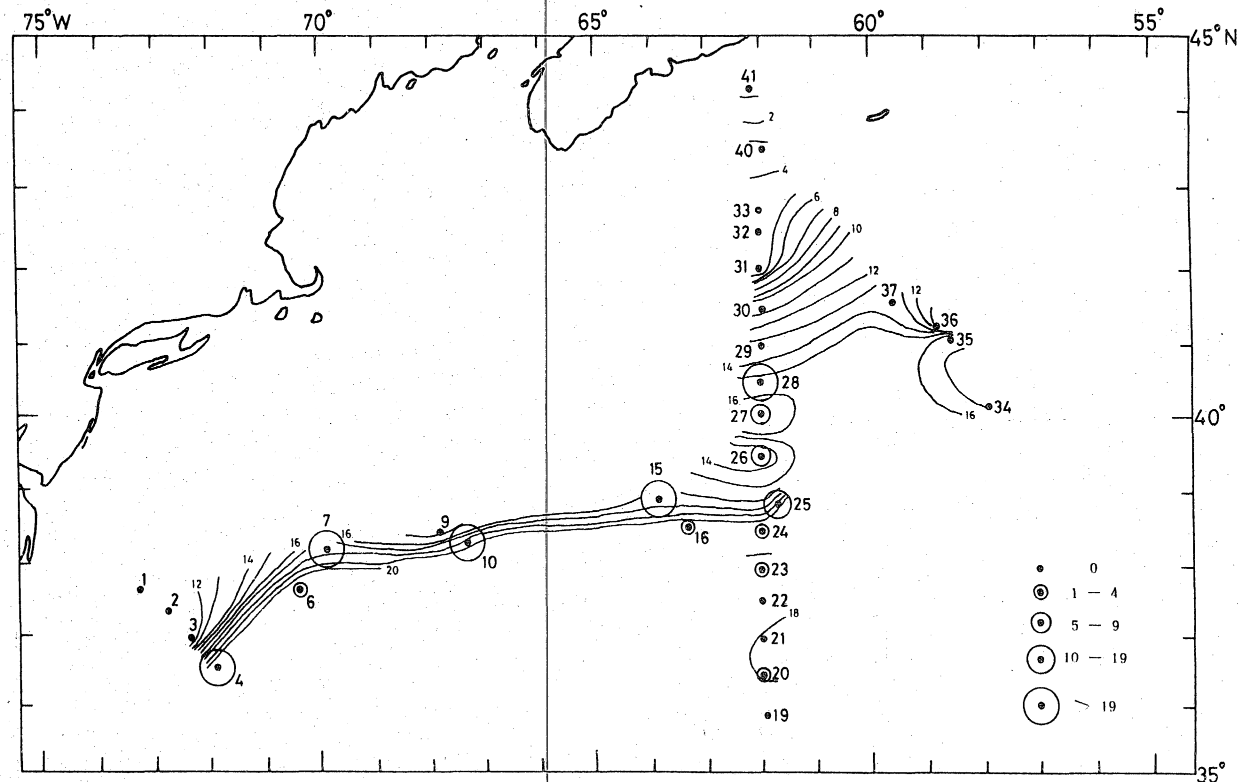


Fig. 8. The number of Illex larvae (shown by the circle) caught by 0-200 m double oblique tow of Bongo Net and isotherms of surface water temperature in the first research leg. Small and large numerals in the figure indicate the surface water temperatures in ° C and the station number, respectively.

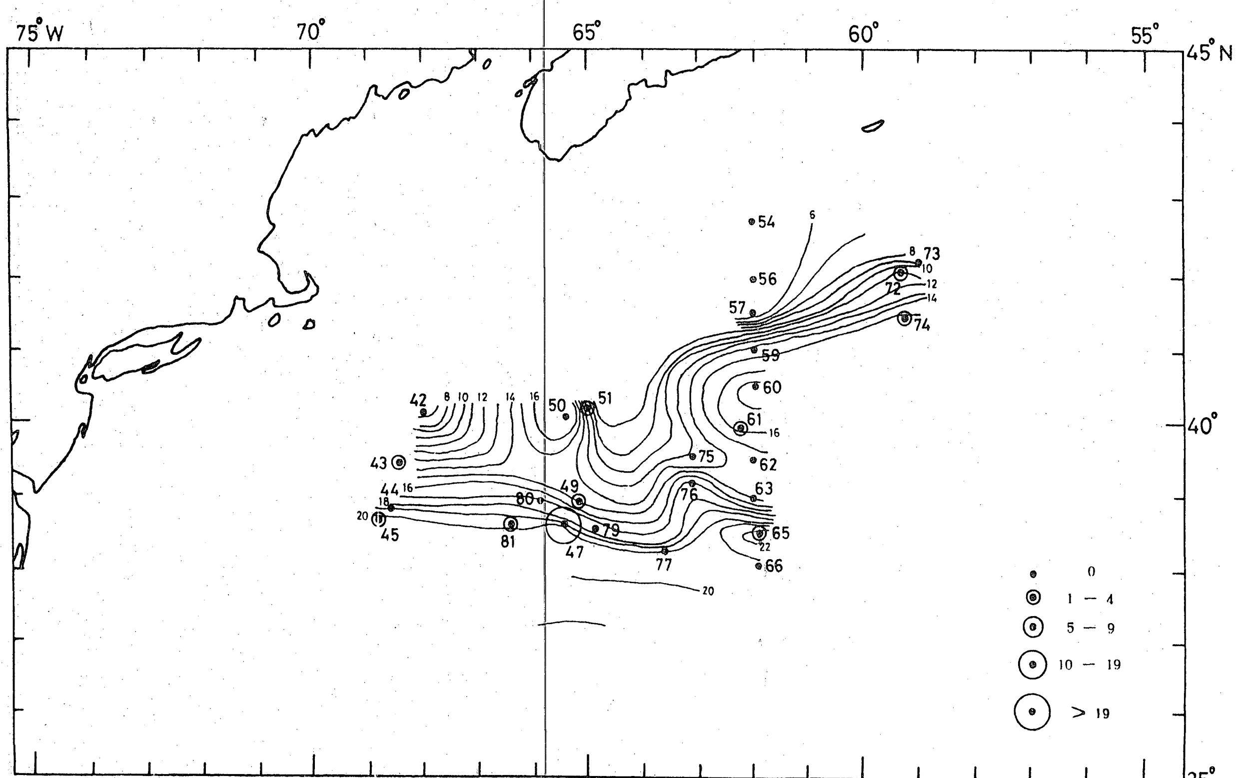


Fig. 9. The number of Illex larvae caught and isotherms of surface water temperature. See the explanatory note of Fig. 8.

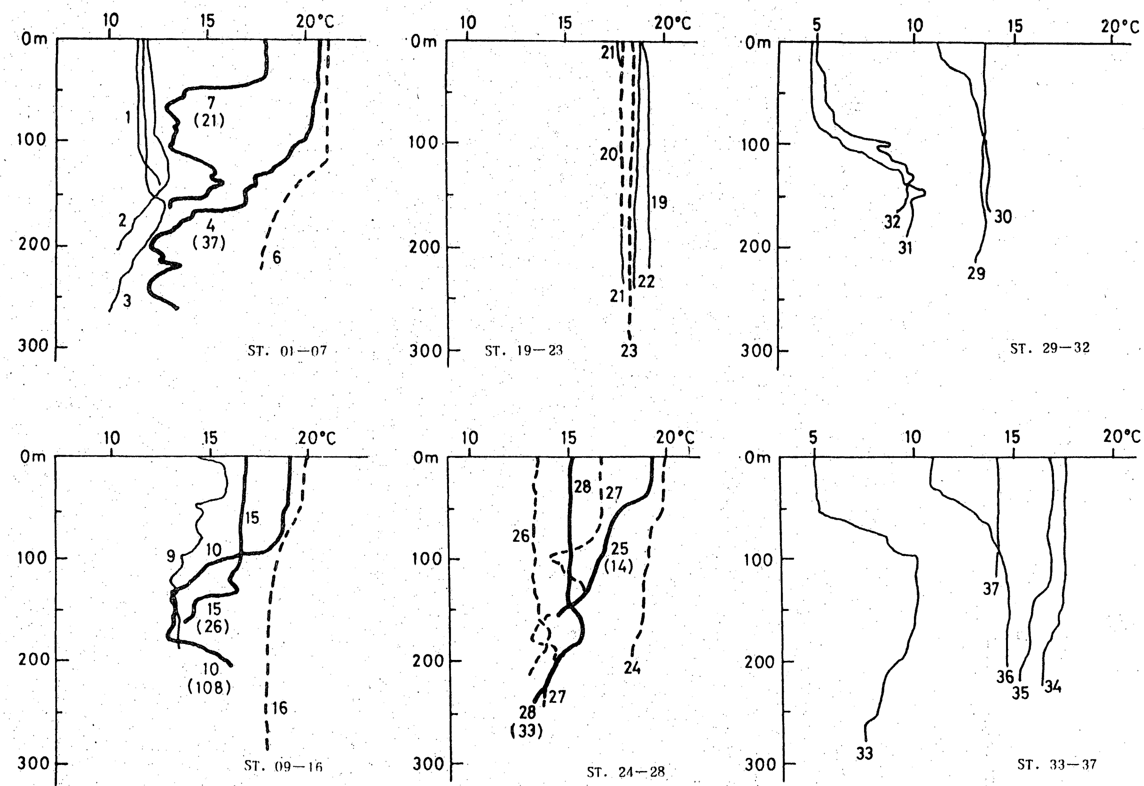


Fig. 10. Temperature profile by X-BT at the station where oblique tow of Bongo Net was made in the first research leg. Thick, broken and fine lines indicate the catch of <u>Illex</u> larvae in number over 10, 1-9 and nil, respectively. Numerals in the figure indicate station number and number of larvae caught (in parentheses).

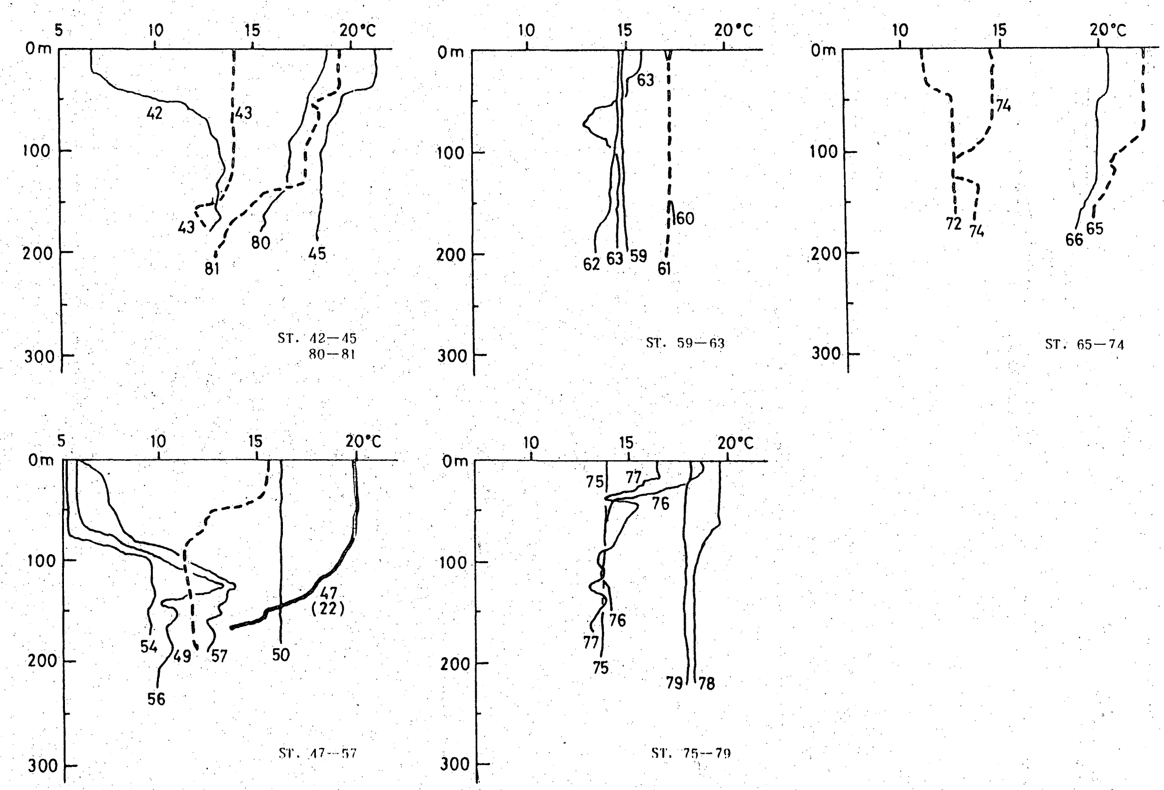


Fig. 11. Temperature profile by X-BT at the station where oblique tow of Bongo Net was made in the second research leg. See the explanatory note of Fig. 10.

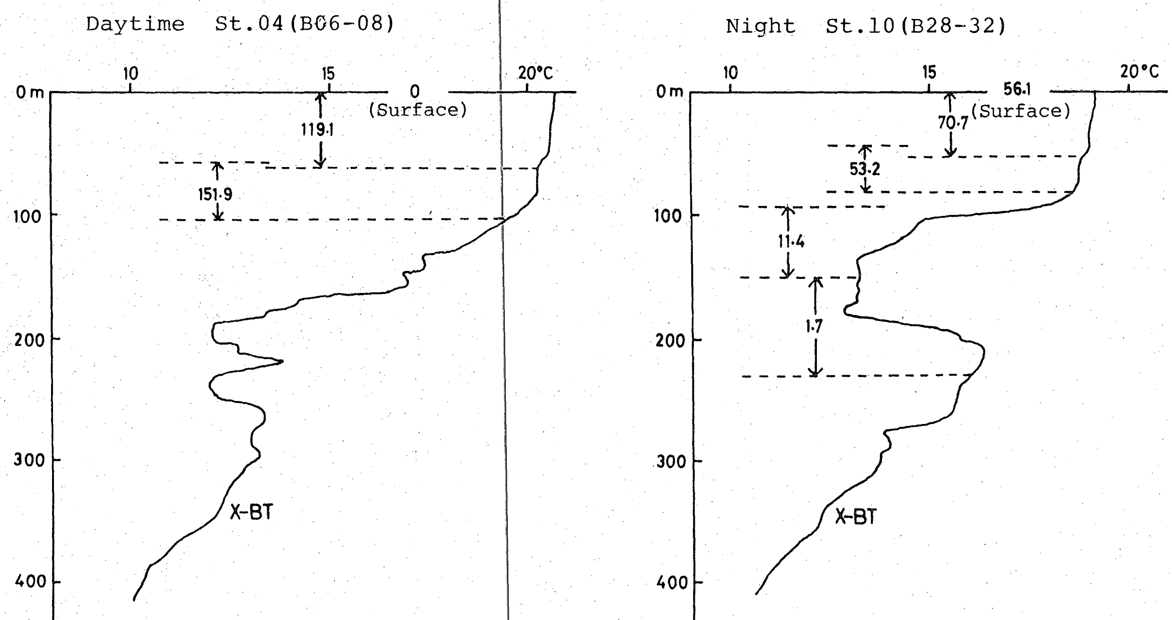


Fig. 12. Number of Illex larvae caught per 1000 m^3 of filtered water by depth-stratified sampling of Bongo Net and temperature profile by X-BT.

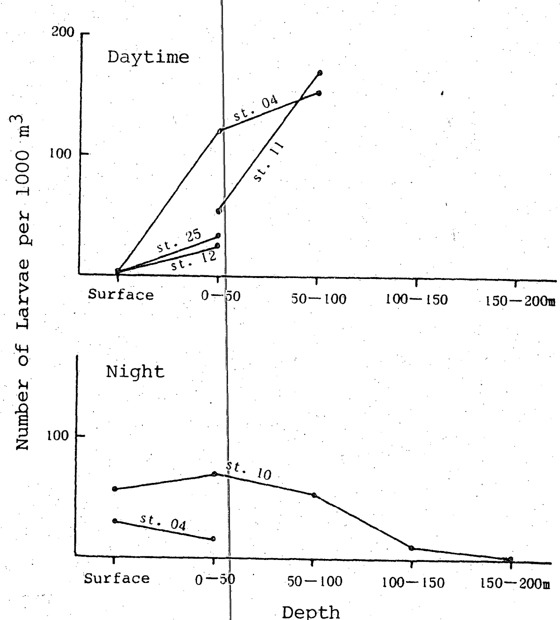


Fig. 13. Depth-dependent changes in the number of Illex larvae caught per 1000 m^3 of filtered water in the daytime and at night.

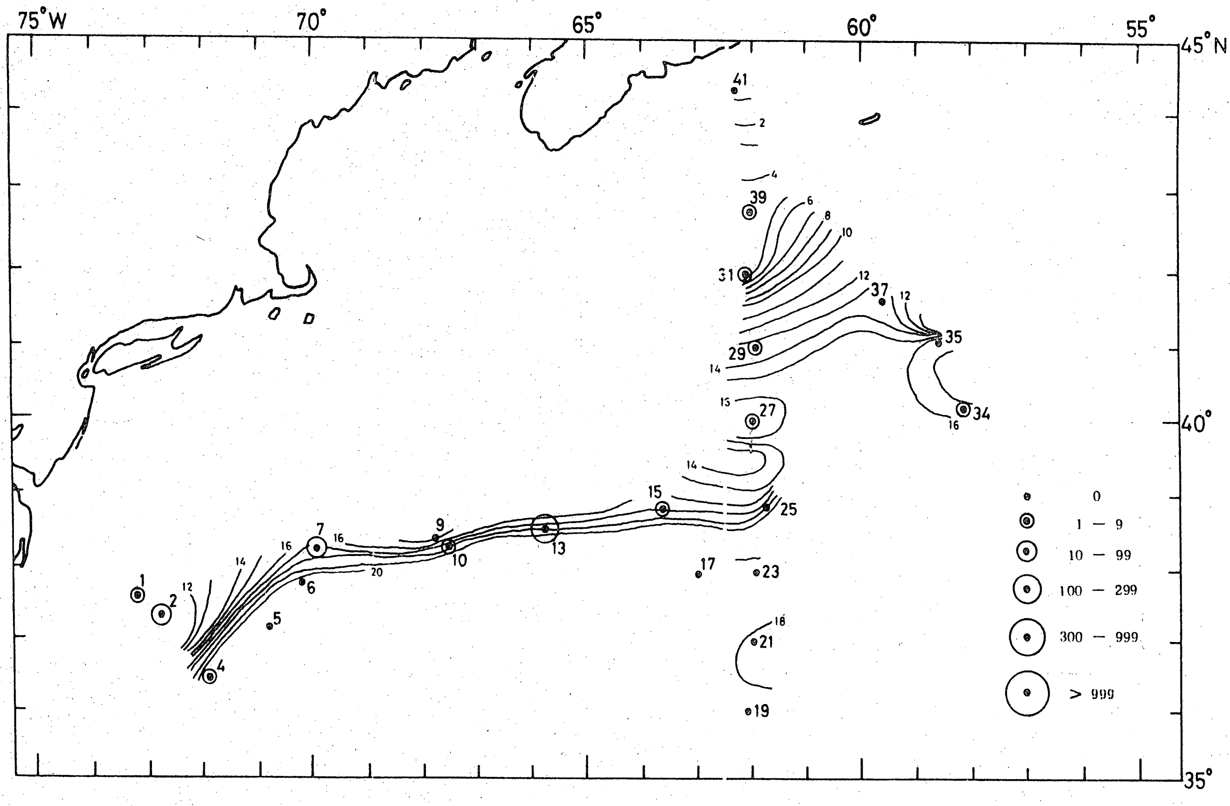


Fig. 14. The number of juvenile Illex (shown by the cilcle) caught by midwater trawl and isotherms of surface water temperature in the first research leg. Smalll and large numerals in the figure indicate the water temperature in °C and the station number, respectively.

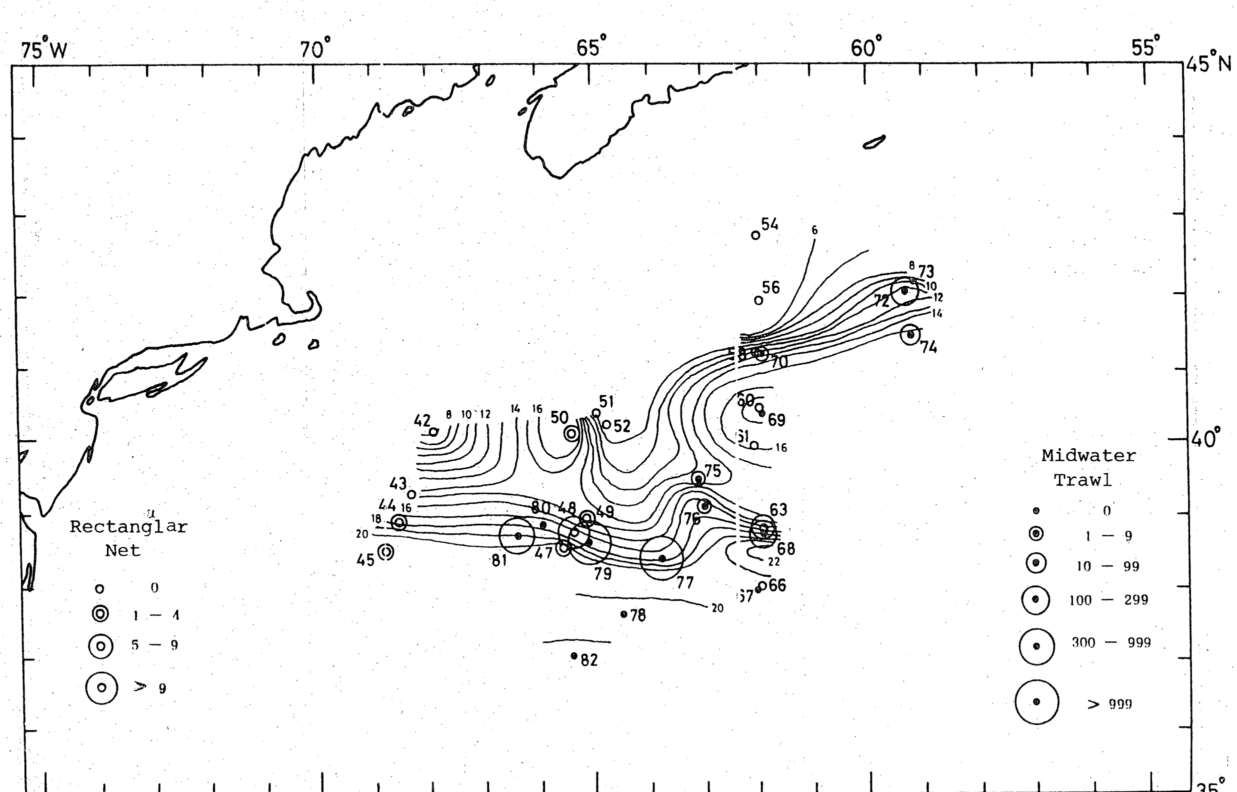


Fig. 15. The number of juvenile Illex (shown by the circle) caught by rectangular and midwater trawl nets and isotherm of surface water temperature in the second research leg. See the explanatory note of Fig. 14.

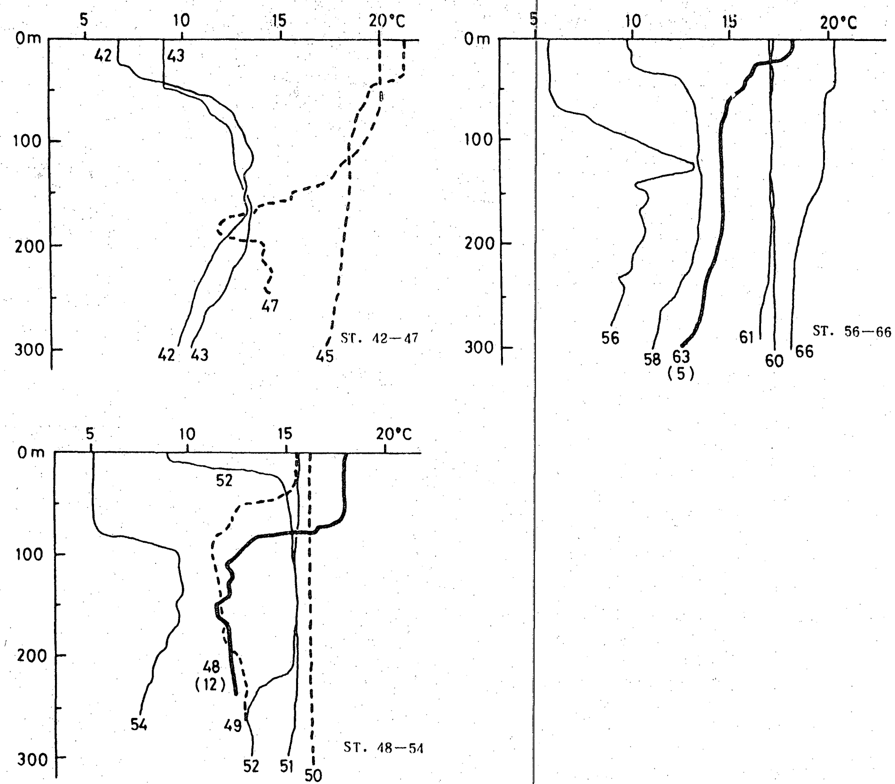


Fig. 16. Temperature profile by X-BT at the station where rectangular net was towed. Thick, broken and fine lines indicate the catch in number of juvenile Illex over 5, 1-4 and nil,respectively. Numerals in the figure indicate station number and number of larvae caught (in parentheses).

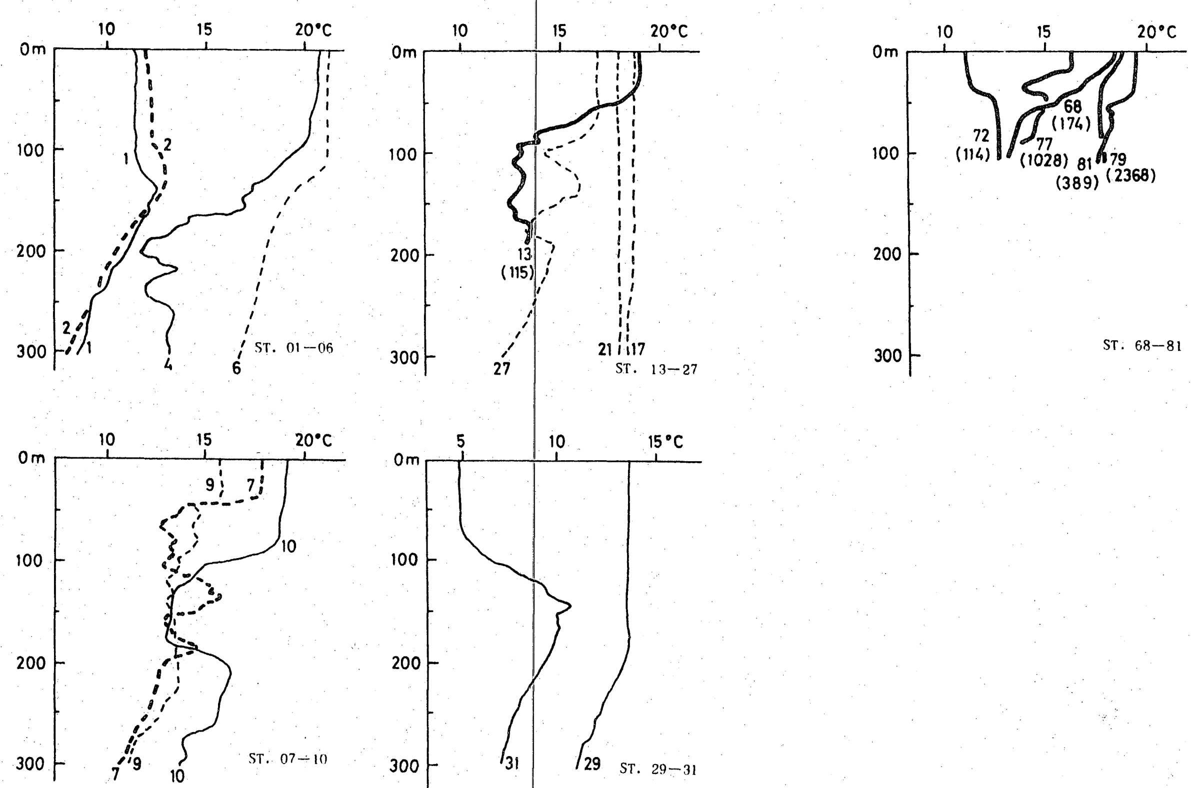


Fig. 17. Temperature profile by X-BT at the station where midwater trawl was made. Thick, thick broken, fine and fine broken lines indicate the catch in number of juvenile Illex over 100, 10-99, 1-9 and nil, respectively. Numerals in the figure are the same as those in Fig. 16.

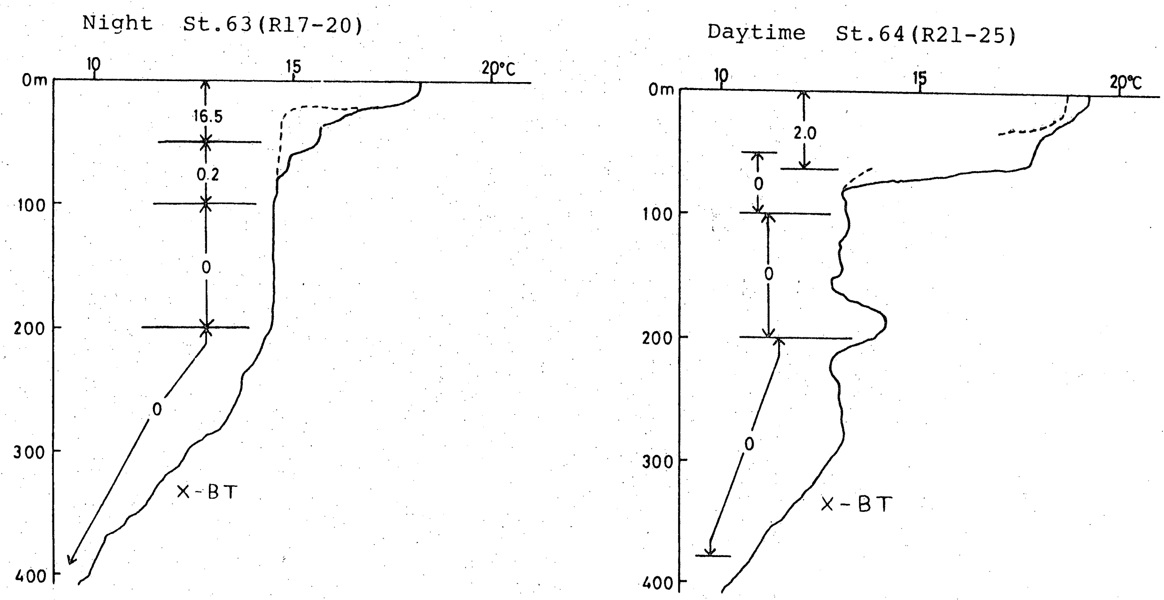


Fig. 18. Number of juvenile Illex caught per hour by depth-stratified sampling of rectangular net and temperature profile by X-BT (solid line) and by time-depth recorder (broken line).

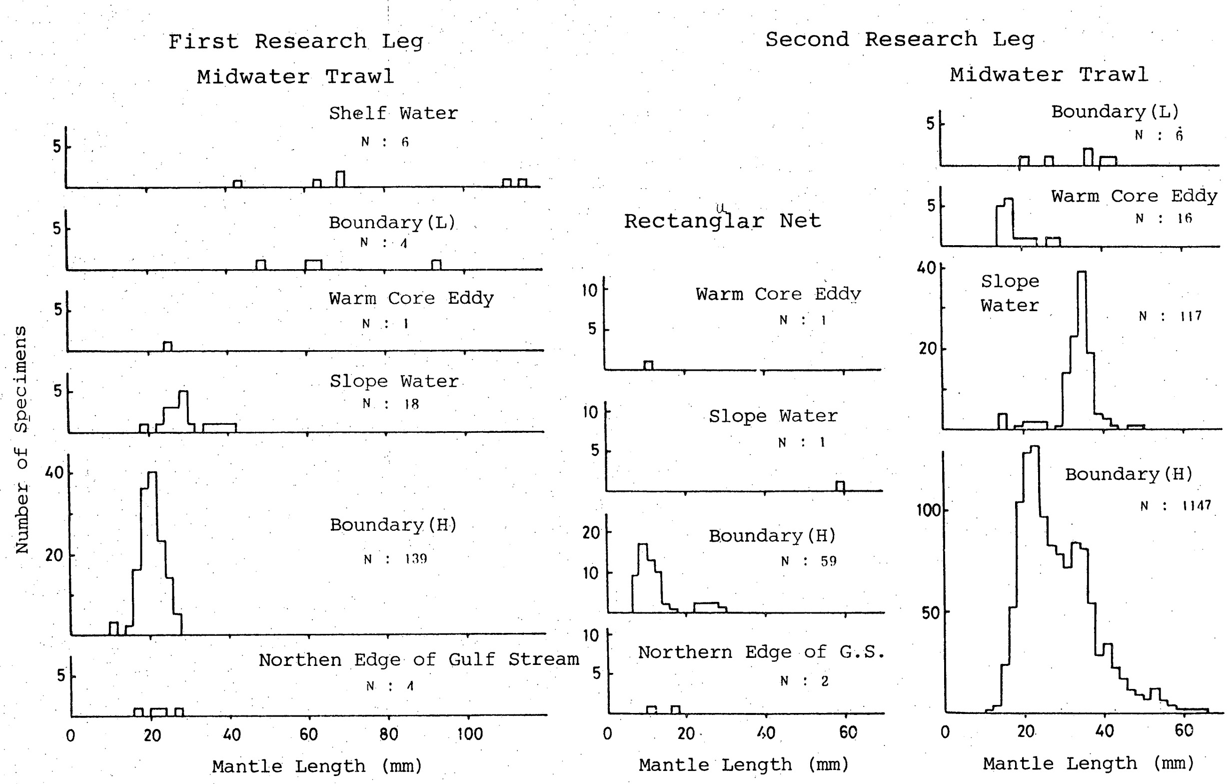


Fig. 19. Length frequency distribution of juvenile Illex by water-types. N indicates number of specimens measured.

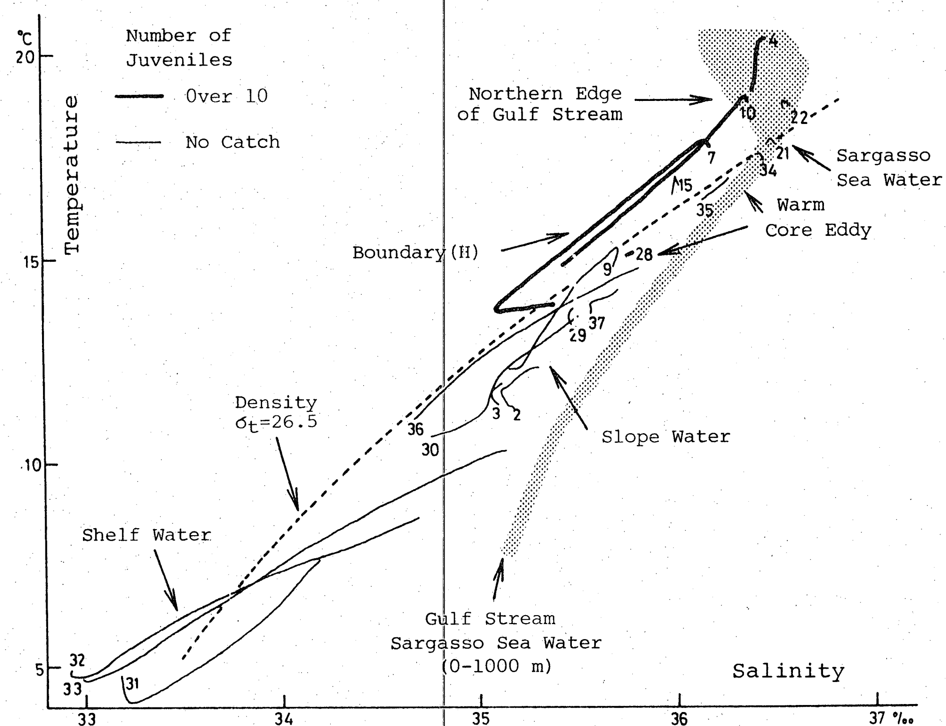
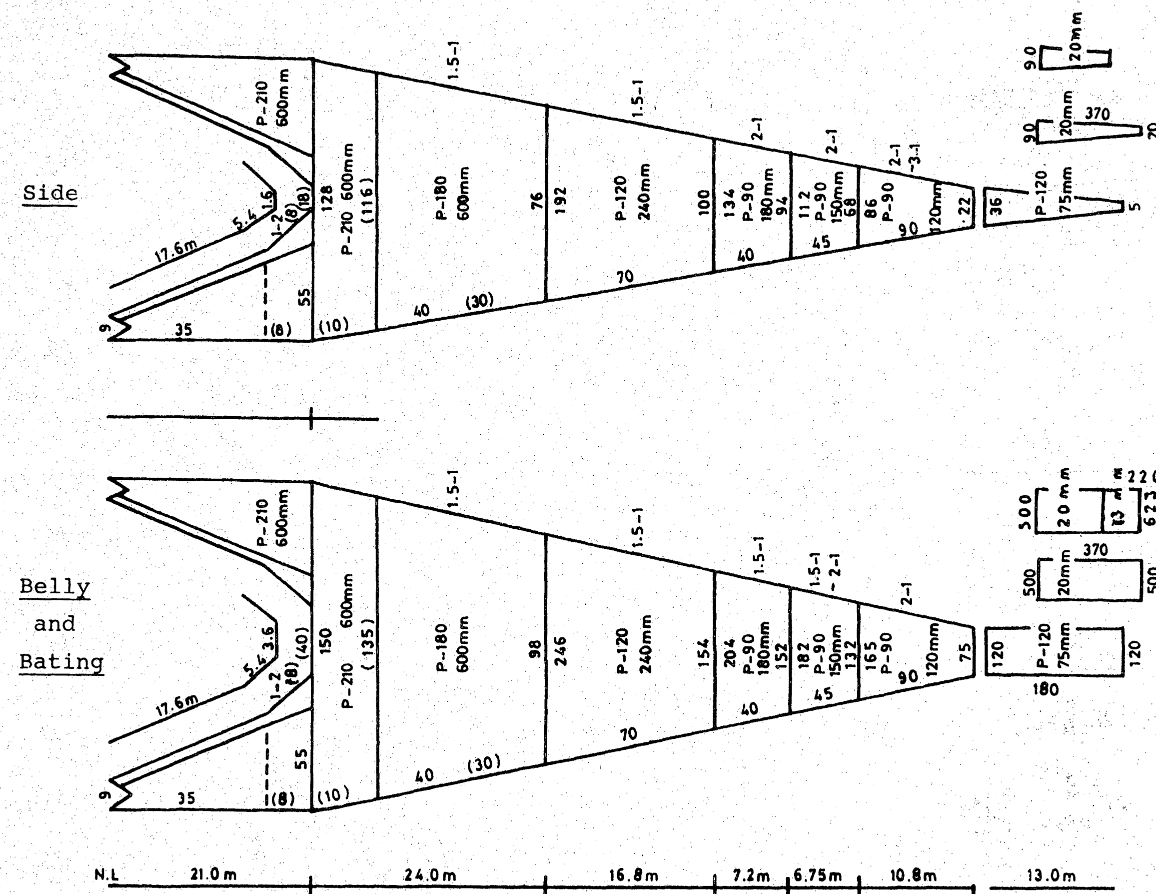
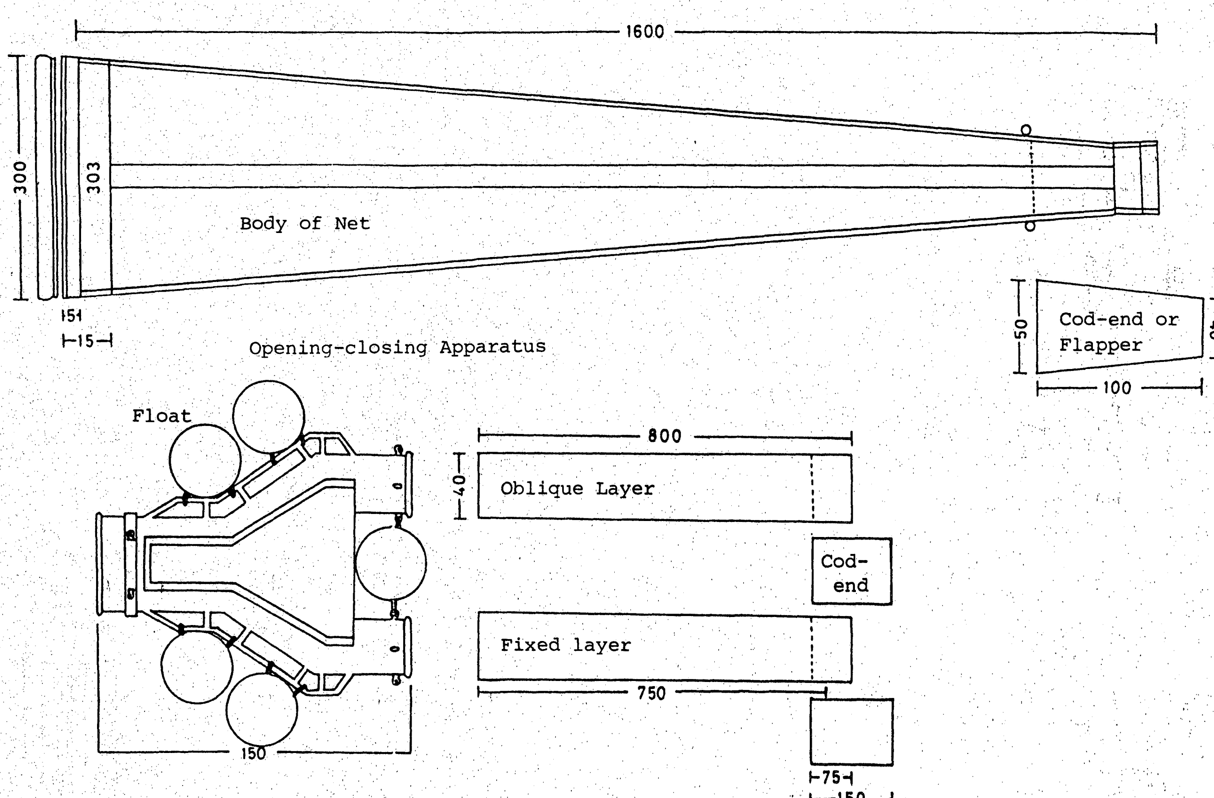


Fig. 20. Typical T-S curves in the layer above 100 m at Bongo Net stations. The amount of Illex larvae caught expressed in the thickness of the curve.



Appendix Fig. 1. KMT type midwater trawl net.



Appendi Fig. 2. KYMT type rectangular net and the opening-closing apparatus. The latter is used for depth-stratified sampling. Numerals in the figure show the length in cm.