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Larval and Juvenile Distribution of the Short-finned Squid (Illex illecebrosus) in the Cape Hatteras-Florida Straits Area in the December-January Period, 1984-1985

by

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INTRODUCTION

Since 1979, major research efforts have been directed at determining the early life history and distribution of the short-finned squid (Illex illecebrosus). Prior to these efforts, knowledge of the biology and distribution of Illex was largely restricted to the May through December period of adult residency in the on-shelf fishing areas (Verrill 1881, Mercer 1969a, 1969b, 1970, 1973, Squires 1967, Lange 1980). Neither the spawning or larval and juvenile distribution were known.

Roper and Lu (1979) and Vecchione (1979) described the Rhyncoteuthion type "C" larvae of Illex illecebrosus from a small number of plankton samples taken in the mid-Atlantic Bight area off New Jersey and Virginia. However, it was not until February, 1979, that joint Canada/USSR surveys provided the first large collections of juveniles from the region between the Gulf Stream and the Scotian Shelf edge and suggested the possible importance of the Gulf Stream system in the life history (Amaratunga et al. 1980, Fedulov and Froerman 1980).

Trites (1983) modelled the oceanographic features likely to influence both spawning distribution and transport of larvae and juveniles and concluded that the area of spawning was most likely over the Shelf-Slope region southwest of Chesapeake Bay. Rowell et al. (1984) reviewed both the biological and oceanographic aspects relative to the life history of Illex and reported on the results of a February, 1983, survey designed to sample the Frontal Zone between Gulf Stream Water and Slope Water in the area southwestward from Chesapeake Bay to Florida, for mature or spawning adults as well as for larval and juvenile Illex concentrations. Squid larval and juvenile captures during the 1983 survey continued to point to the Frontal Zone of the Gulf Stream/Slope Water as the preferred area of presence and indicated that both larvae and juveniles were intermixed throughout the entire Frontal Zone. It appeared that spawning probably occurred in the Frontal Zone over the southern Blake Plateau and that larvae and juveniles were likely concentrated above the salinity maximum which was centered at approximately 100 M depth. Additionally, the high velocity Gulf Stream, together with Frontal Eddies and filaments appeared to play an important role in mixing animals over a wide size and geographic range.

The December, 1984, and January, 1985, cruises reported here were designed to further determine larval and juvenile distributions in relation to geographic location and to particular water masses and their dynamics.

MATERIALS & METHODS

Hudson

Between December 11-15, 1984, a zig-zag series of transects were run over the more northern area of the Blake Plateau and the Shelf-Slope area immediately north of Cape Hatteras. Along these transects, 28 stations were occupied in the general area of the Gulf Stream/Slope Water Frontal Zone.

Biological sampling at each station consisted of a standard MARMAP bongo haul using a 60 cm frame and 505 μ mesh net. Oblique tows were made from either 150 meters depth or from 20 meters above bottom in areas of shallow bottom.

Hydrographic sampling at each station consisted of CTD casts to either 300 meters or to within 15 meters of bottom at shallower stations. XBT casts were made midway between sampling stations.

Plankton samples were immediately preserved in 5% buffered formalin and subsequently all cephalopods were sorted and identified at the Halifax Fisheries Laboratory. Rhyncoteuthion larval types "A", "B" and "C" were identified according to Roper and Lu (1979). Dorsal mantle lengths were measured to the nearest 0.5 mm using an ocular scale.

Alfred Needler

Between January 7-22, 1985, five transects were run through the Gulf Stream/Slope Water Frontal Zone between Cape Hatteras and southern Florida; between approximately 36°00'N and 25°30'N. Each transect was occupied for several days, allowing a number of replicate passes along the transect and replication of station occupation. On each transect, stations were occupied every 5-10 nautical miles. At each station, biological sampling consisted of a standard MARMAP oblique bongo haul from 150 meters using a 60 cm frame and 505 μ net and on most stations an oblique mid-water trawl (MWT) from 150 meters. The Diamond IX MWT was fitted with a 12 mm knotless nylon codend liner. Where shallower bottom depths were encountered, the gear was fished to within 20 meters of bottom. Hydrographic sampling at each station was intended to consist of a CTD cast to 300 meters and as well as surface temperature and salinities (salinity determinations for surface samples were conducted at the Bedford Institute of Oceanography). Unfortunately, early failure of the CTD required reliance on XBT casts and occasional Nansen bottle casts. XBT casts were also made midway between sampling stations.

During transect IV an attempt was made to track a "packet" of larvae and juveniles for several days using a surface high-flyer attached to a drogue at 30 m depth.

Additional experiments included: (1) an attempt to radio track a pseudo-egg-mass and evaluate the influence of the salinity maximum in keeping egg-masses in the near surface water masses where they may be transported by the Gulf Stream system; and (2) a comparison of oblique bongo, vertical bongo and vertical meter net hauls for the capture of larval squid. These latter experiments are not reported here.

All plankton samples were preserved in 5% buffered formalin for two days and then the formalin changed or the sample transferred to 70% ethanol.

MWT samples of juvenile cephalopods were initially fixed in 10% formalin for three days and, where sorted at sea, transferred to 70% ethanol. Occasional samples of Illex juveniles were preserved directly in 70% ethanol for future ageing studies.

Final sorting and identification of all cephalopods was carried out in the Halifax Fisheries Laboratory according to Roper and Lu (1979). Dorsal mantle lengths of larvae were measured to the nearest 0.1 mm using an ocular scale. Juveniles were measured to the nearest 1 mm using hand held vernier calipers.

RESULTS AND DISCUSSION

General Oceanographic Features in Relation to Catch

(A) HUDSON Cruise 84-049

The cruise track in relation to the surface location of the Gulf Stream/Slope front, as depicted in the NOAA/NESS satellite derived oceanographic maps of 11 and 13 December, 1984 is shown in Figure 1. The cruise track, STD and bongo tow location in relation to the 200M depth contour are shown in Figure 2. Temperature distribution at 200M, together with results of bongo tows (presence or absence of Illex) are shown in Figure 3. Catches were taken at 15 of the 28 stations (with juveniles taken only at two of them) and are summarized in Table 1. In relation to the 15°C isotherm at 200 M depth, most of the catches were made on the seaward side, suggesting, as a first approximation, that at most stations squid are being transported in the Stream. At each station a rough measure of current speed and direction was taken by logging the ship's drift during the time taken for an STD. Ship drift velocities are shown in Figure 4. At most stations the current was flowing in a northeasterly direction at speeds varying from about 0.8-1.5 ms^{-1}. At stations 24, 25, and 26, where catches were made, the drift was negligible. Likewise the drift was negligible at stations 45, 46, and 47, north of Cape Hatteras, but no catches were taken. Largest and most frequent catches were taken at stations 23-27, in the area of the Charleston Bump. Catches in relation to the oceanography of this area is particularly interesting. Figure 5, shows an XBT/STD temperature section between stations 22 and 25. Bongo tows were made at 5 stations, with catches made at all but the most seaward one. Of particular note is the upward 'doming' of the isotherms between station 23 and 24. The doming is most marked below 200M, but its effect is seen at all depths. Of interest is the 21-22°C water which at the point midway between stations 23 and 24 occupies the water column from the surface to 70M depth, whereas at station 22 it is confined to a layer about 10M thick at a depth ranging from 115-125 M depth. Likewise at station 25 it is also only about 10M thick at a depth ranging from 80-90 M. The catch made in the area of maximum upwelling, at stations 23 and 24, is from 3 to 10 times larger than those made at other sites on the section. Unfortunately, there are no salinity measurements available for the site midway between stations 23 and 24, owing to a temporary computer malfunction. However, the close T-S relationships at stations 23 and 24, combined with XBT's taken at 3 sites between stations 23 and 24 enable one to compute a fairly reliable salinity section (Figure 6). In the upwelling area, surface layer salinities are higher than in other parts of the section. Also the salinity maximum has been reduced in intensity, and is nearly absent.

The distribution of temperature (Figure 7) and salinity (Figure 8) are shown in cross-section for stations 25-28 inclusive. Although not as marked as for the previous section, evidence of limited upwelling is apparent at station 27, the location of maximum catch in the section. The upwelling seen in this area may be a semi-permanent feature or a transient one. At the time this area was sampled a tongue of Shelf Water extended northeastward at the surface reaching nearly to the Gulf Stream Front. It may be that this feature is also related in some way to the upwelling dynamics.

Rowell et al. (MS 1984), found that the T-S characteristics of the water mass in the upper 100 M, where catches were made, were closer to Continental Edge Water as defined by Wennekens (1959), than to those of the waters further offshore, defined as Yucatan Straits Water. T-S plots for the upper 150 M, at stations with catches (Figure 9) appear mostly to lie roughly midway between Continental Edge Water and Yucatan Straits Water. If only the upper 50 M of the water column is considered the envelope becomes very small, being bounded in temperature by 22.5°C and 25.5°C and in salinity by 36.3 and 36.4.

Catches of type "C" (Illex) larvae are shown in Table 1 along with less detailed information on type "A" and "B" larvae. Although the data are limited, they do appear to show an increase in minimum size of type "C" larvae as one progresses northward along the Gulf Stream from sampling station 2 to 23. The smaller larvae (between 0.8 and 1.0mm ML) seen in sampling stations 2, 5, and 6 are very recently hatched (Durward et al. 1980, O'Dor et al. 1982, Dawe and Beck 1982, Rowell et al. 1984). There is no apparent increase in maximum size of larvae captured as the cruise track proceeds northward.

The capture of type "B" larvae throughout the extent of the survey area, including an overlap with type "C", and the lack of overlap of type "A" larvae with type "C" is also of interest.

(B) NEEDLER Cruise 85-001

Locations of the 5 transects and one drift station occupied during the cruise is shown in Figure 10. All transects were designed to occupy a section from just shoreward of the 200 M depth contour to a point seaward of the High Velocity Core of the Gulf Stream. An indication of the changing temperature and flow patterns along the Slope/Gulf Stream Front is shown in Figure 11. The surface location of the front is taken from the NOAA/NESS satellite derived oceanographic maps. During the time Transect I was occupied, and in the days immediately preceding this, the front in the area appears relatively free of meanders or frontal filaments. Transect II appears to be cutting across a small meander or filament which is seen to be developing on 8 January. A meandering front was seen to exist in the area of Transect III on 3 January, but by 8 January until after work was completed on this transect, no major changes in surface features are noted. In the area of Transect IV, a small filament was seen on 15 January, and may have moved northward and expanded by the 17 January. In the early part of the month (8, 10

Jan.) a filamentous structure in the area just south of Transect V was present, but no other filaments were seen in the area during the cruise period.

Catches of larvae and juveniles were made in all transects (but not all stations) and are summarized in Tables 2 and 3. The relative positions of replicate station occupations during repeated passes on each transect are shown in Figure 12 along with number and median size of larvae and juveniles at each station.

A temperature section taken during the second pass of Transect I shows a very sharp, well defined front separating the Gulf Stream from the Slope Water (Fig. 13). Larvae were caught at only one site in this section, located near XBT station 20, in the Frontal Zone, where from ship drift observations, a current of 1.3 ms^{-1} at 067°T was computed. At the seaward end of this section a current of 2.3 ms^{-1} at 106° existed. Two juveniles were caught at sampling station 14 (see Fig. 13), well shoreward of the Stream.

The temperature distribution during the first occupation of Transect II is shown in Figure 14. The Slope/Gulf Stream Front is not sharply defined here, and appears to be spread over an appreciable horizontal distance. Maximum current determined from ship drift of 1.3 ms^{-1} at XBT station 40 with a gradual weakening to 0.3 ms^{-1} at 072°T between stations 33 and 34 suggests that if there were higher velocities in the Gulf Stream at this time they were probably located further offshore. On the other hand, the surface boundary between Gulf Stream Water and Slope Water is probably located shoreward of the section. The rather diffuse nature of the frontal zone probably is related to the meander or filament that was seen on the satellite imagery for both 8 and 10 Jan (Figure 11). Larvae were caught at only one site (between XBT stations 34 and 35) during this occupation of the transect. Juveniles were caught at 5 of the seven sampling stations occupied.

Temperature along Transect III, during the second pass, is shown in Figure 15. An important feature seen in this section is the upward 'doming' of the isotherm in the area of Stations 90-92. Although catches were made at most sites along this transect, a peak value (12 larvae and 24 juveniles) occurred at XBT station 92, where surface drift was computed to be 0.2 ms^{-1} at 200°T. At station 89 the current was computed to be 1.9 ms^{-1} at 089°T.

'Doming' is evident on the first occupation of this transect, but is not as marked as on the second occupation. The third and fourth occupations although only covering part of the transect likewise show evidence of doming.

Temperature distribution along Transect IV (second occupation) is shown in Figure 16. Based on ship-drift measurements, the Front was located near XBT station 136. Seaward of this site, currents were northward at about 1.7 ms^{-1}, while shoreward currents were also northward but at lower speeds (0.6-0.9 ms^{-1}).

Larvae were caught at almost every site sampled during the 3 days and 3 occupations of the transect, with maximum average catches taken in the Frontal Zone. On this particular occupation, larvae were taken in all 6 bongo tows. Juveniles were caught in 3 of the four mid-water trawls.

On Transect V, temperature distribution during the second occupation is shown in Figure 17. Based on the slope of the isotherms, highest velocities appear to be at or near XBT station 161, although there is some indication that higher values may be present seaward of XBT station 156. Ship drift computations indicate the highest value of 1.9 ms^{-1} occurred at XBT station 161, although a value in excess of 2.3 ms^{-1} was computed for the seaward end of the transect during its first occupation. On this occupation of the transect, larval catches were made at all stations except for the one at the seaward end of the transect. Juveniles were taken only at two stations at the shoreward end of the transect (Figure 16), with about 250 animals being caught at sampling station 98.

<u>Drift Station:</u> The first occupation of Transect IV was interrupted in order to track and sample a larval "patch" in time (Figure 10). A drogued "high-flyer" was launched and tracked for about 22 hours, with repeated bongo tows and mid-water trawls being taken near the high-flyer during its drift. During the tracking experiment the high-flyer moved northward more than 70 miles. Mean velocity during the period was 1.65 ms^{-1} at 355°T. The vertical-longitudinal distribution of temperature during the tracking experiment is shown in Figure 18. During the first 12 hrs the high-flyer gradually moved from shallow water (100 M depth) to deeper water (350 M depth), and thereafter moved more nearly parallel to the bathymetry. Interestingly the larval catch stayed at relatively high levels for the first 12-15 hours and then dropped to relatively low values as the high-flyer drifted into deeper waters and closer to the core of the Stream. Juveniles were taken in the mid-water trawl at 6 of the 7 sets, but no clear pattern is evident. Although currents remained relatively constant throughout the experiment, the gradually deepening thermocline (by about 25-30 M) suggests that the high-flyer was continuing to penetrate normal to the Stream, and may have moved about 10 km further into the Gulf Stream. It is possible that the bulk of the larvae did not move at the same speed and direction as the high-flyer. Larval sampling extended obliquely to 150 M (depth permitting), whereas the high-flyer was drogued at a single depth (30 M). Alternatively, the bulk of the larvae may have been concentrated in a subsurface temperature-salinity structure which was located at greater depths, over the deeper water, resulting in a proportionately smaller volume of "larval bearing water" being sampled as the feature deepened.

The rapid downstream transport of larvae (about 77 miles/day), demonstrates the difficulty in sorting out time/space effects. If, for example, the currents present during the tracking experiment existed at comparable values along the Gulf Stream from the Florida Straits northward to the Charleston area, then some of the larvae in the area of Transect IV at the start of its occupation would have reached Transect III by the time the work on the Transect was completed (3 days later). Similarly, some of the larvae taken during the last occupation of Transect IV, might have been located at Transect V, when Transect IV was commenced.

Biological Characteristics Relative to Distribution

General Distribution Patterns and Larval/juvenile Sizes

The numbers and mantle length characteristics, by transect, of larvae (bongo net capture) and juveniles (mid-water trawl capture) taken in the January Needler survey are given in Tables 2 and 3. Only 5 larvae were captured in the 38 sets of the two most northerly transects (I and II). Almost equal numbers (39 and 40 larvae) were taken in the 27 and 17 stations sampled respectively in transects III and V. The highest catch (123 larvae) and highest catch-rate was from the 16 stations of transect IV, in the area off Cape Canaveral. As in the December, 1984 Hudson cruise, there is a suggestion, based on very low numbers of animals, of an increase in minimum size of larvae captured between the southern and the two more northerly transects. The evidence is very weak, however, in that the size of larvae captured are well within the range of sizes seen in the southern transects.

Juvenile captures followed a somewhat similar pattern, except that the largest catches and highest catch-rates occurred further north, at transect III. Juveniles were also captured in relatively larger numbers than were larvae in the two most northerly transects. The range in mantle length varied considerably from transect to transect, primarily at the upper end, but mean and median values suggest no real progression in size either north or south.

Length Frequencies in Relation to Probable Area of Spawning

Examination of length frequencies by transect in Figure 19 does indicate differences in the larval and juvenile populations sampled along the transects. The larval size distribution at transect IV, both from the standard transect stations and the drogue stations, is much more symetrical, with a strong mode at 1.8-1.9 mm ML, than in the other transects where the distribution is generally very flat. The juvenile size distribution on transect IV is also very different from those seen in the other transects, with a very tight clustering of mantle lengths between roughly 12-17 mm and a mode at 13-14 mm. The next most northerly transect (III) shows an almost normal distribution with the mode(s) shifted to the right, as do the two most northerly transects (I and II). The distribution at transect V is broader and flatter than all other transects, with several apparent modes (11-14 mm, 18-20 mm, 28-30 mm, and possibly one at roughly 39 mm).

The generally tight length frequencies of both larvae and juveniles from transect IV suggest that this transect may be near the main spawning area. The relatively low maximum size (3.4 mm ML) of larvae and the low mean and median size of juveniles (15.2 mm and 14.9 mm respectively) found on this transect also suggest proximity to the spawning area. While the wide range of larval and juvenile sizes seen throughout the entire survey area tends to confuse the picture, it must be born in mind that the Gulf Stream system is highly complex and mobile. The possibility for very rapid egg mass, larval, and juvenile transport in the High Velocity Core of the Stream exists along with the possiblity of southward movement in the water mass shoreward of the Gulf Stream. As previously noted, filaments or shingles have been observed along the shoreward edge of the Stream during the course of this survey and at times are present through the Straits of Florida in the area of Key West and northward to and beyond Cape Hatteras. The possibility also exists that there is more than one spawning area (i.e., those larvae and juveniles captured in transect V may have originated in the Gulf of Mexico or even the Carribean and been transported northeastward in the Yucatań Current). The question of species also may be a factor; transect V being in an area where Illex coindetii and Illex oxygonius are reported (Roper et al. 1984).

Larval Versus Juvenile Captures

Table 4 presents data on the relative success of capturing juveniles and larvae on the same stations. Rowell et al. (1984) noted in a 1983 survey over the Blake Plateau that, while at all stations where bongo sets caught larvae, juveniles were caught in the mid-water trawl; the converse was not true (i.e., when the mid-water trawl caught juveniles, larvae were often not caught in the associated bongo tows). This suggested that a portion of the juvenile population overlapped the larval population, while another portion of the juveniles had a distribution not associated with the larvae. Captures at paired stations in this survey do not indicate such a separation, except in the two most northerly transects where very few larvae were captured. When the northern transects, I and II, are eliminated from the comparison, the converse is found; larvae being more likely to be caught where juveniles are caught. Table 4 also presents a comparison of simple capture success or failure of bongo (larvae) and mid-water trawl (juvenile) sets. The percentage of successful bongo sets peaks on transect IV, while that for mid-water trawls is relatively high throughout all transects. This would appear to reflect a generally more limited distribution of larvae in the two most northern transects. As will be seen below, the low success rate in the more northern transects may in part be indicative of nothing more than sampling error associated with larvae 4 mm ML or greater.

Table 5 presents the numbers and the ratios of larvae to juvenile catch by transect, both un-normalized and normalized. With the exception of transect IV, the ratio is roughly 0.1. In transect IV, the normalized ratio is 0.73, indicating a much higher abundance of larvae relative to juveniles. This, again, suggests proximity to the main spawning area.

Larval Juvenile Distribution Across the Front Zone

Preliminary examination of larval and juvenile catches and mantle lengths in relation to the Frontal Zone (Fig. 12) gave some suggestion of increasing larval size as one proceeded shoreward from the High Velocity Core of the Stream (see pass 2 of transect III in Fig. 12). In order to examine this further, grouped length frequencies for selected stations, deemed on the basis of drift rate data to be clearly shoreward of the Frontal Zone or in the High Velocity Core of the Gulf Stream, were prepared for each transect. These are presented in Figures 20 and 21, for larvae and juveniles respectively. Because of the low numbers or lack of animals in some of the selected station groups, the histograms are not shown for all transects. In the case of larval catches, the data appear insufficient to show any differences in the population structures of the shoreward or High Velocity Core larvae. However, for juveniles, the smaller individuals of transect II appear to be concentrated in the shoreward group of stations (Fig. 21 and Fig. 19). The juvenile length frequencies for the shoreward component of transect III (Fig. 21) correspond closely with that shown for the transect as a whole in Figure 19, but there is no clear indication of a size difference between these and the small sample of juveniles in the High Velocity Core. In transect IV, the juvenile length frequency distribution for animals above 18 mm ML in the High Velocity Core (Fig. 21) is identical to that for these sizes in population as a whole (Fig. 19). The strong mode of smaller animals seen in Fig. 19 is clearly shoreward of the High Velocity Core. Overall, there does therefore appear to be a pattern among the juveniles of smaller sizes in the shoreward component of the population.

Sampling Limitations

In comparing the larval and juvenile catches, it became apparent that a considerable portion of the population was not being sampled. Very few juveniles under 10 mm ML were captured; approximately 98% of juveniles were 10 mm ML or larger. At the same time, approximately 98% of larvae were 4 mm ML or less. Squid in the 4-10 mm ML range are therefore essentially unsampled. One may speculate that the larger larvae and transition stages are more capable of avoiding the bongo net and that the smaller juveniles tend to pass through the lining mesh of the mid-water trawl. Smaller juveniles are, simply by virtue of their size, also less likely to be seen when removing the catch from the mid-water trawl liner.

SUMMARY DISCUSSION

Upwelling in the outer shelf area off Charleston, seen on transect III of the Needler cruise and on the Hudson cruise, was also present during the 1983 curise of the Needler (Rowell et al., 1984, Figs. lla, b, c). Studies (Lee and Atkinson 1983; Chew et al., 1985), of the low-frequency current and temperature variability in the Gulf Stream frontal zone along the outer shelf between Cape Canaveral, Florida, and Cape Romain, South Carolina, reveal the presence of cyclonic, cold-core Gulf Stream frontal eddies. These disturbances travelled northward at speeds of 0.5 to 0.7 ms^{-1} with periods of 5 to 9 days throughout the experiment and produced cold cyclonic perturbations of the northward mean flow and temperature fields over an along-shelf coherence scale of 100 km. Frontal eddies are short-lived phenomena, forming in only a few days and possibly dissipating on a comparable time scale. Satellite imagery suggests that the total cycle takes place in 1 to 3 weeks. Lee and Atkinson (1983) concluded that frontal eddies have considerable influence on primary production on the outer shelf. They concluded that upwelling in the cold core, together with onshore flow in the cyclonic circulation, transports deeper nutrient-rich Gulf Stream waters into the euphotic zone for phytoplankton uptake. Upwelling velocities of about 10 md^{-1} were estimated. Rapid utilization of newly upwelled nutrients results in elongated patches of high chlorophyll concentrations that propagate with the cold core and have similar dimensions (Yoder et al., 1981). The higher larval Illex concentrations in and near upwelling areas may be associated with higher food levels and better survival rates. Detailed vertical sampling within these elongated, cold-core frontal eddies are needed to determine whether food is a key factor linking larval concentrations and the physical environment.

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REFERENCES

Amaratunga, T., T. Rowell, and M. Roberge. 1980. Summary of joint Canada/USSR research program on short-finned squid (Illex illecebrosus), 16 February to 4 June 1979: spawning stock and larval survey. NAFO SCR Doc. 80/II/38, Ser. NO69, 36 pp.

Chew, Frank, John M. Bane, Jr., and David Brooks. 1985. On vertical motion, divergence, and the thermal wind balance in cold-dome meanders: A diagnostic study. J. Geophy. Res. 90, C2, 3173-3183.

Dawe, E.G., and P.C. Beck. 1982. Rhynchoteuthion larvae from the Northwest Atlantic and aspects of distribution of larval Illex. NAFO SCR Doc. 82/VI/26, Ser, No. N514, 13 pp.

Durward, R.D., E. Vessey, R.K. O'Dor, and T. Amaratunga. 1980. Reproduction in the squid, Illex illecebrosus: first observations in captivity and implications for the life cycle. ICNAF Sel. Pap. 6: 7-14.

Fedulov, P.P. and Yu. M. Froerman. 1980. Effect of abiotic factors on distribution of young shortfin squids, Illex illecebrosus (LeSueur, 1821). NAFO SCR Doc. 80/VI/98, Ser, No. N153. 22 pp.

Lange, A.M.T. 1980. The biology and reproduction dynamics of the squids, Loligo pealei (LeSueur) and Illex illecebrosus (LeSueur), from the northwest Atlantic. M.Sc. Thesis, University of Washington, 178 pp.

Lee, Thomas N., and Larry P. Atkinsen. 1983. Low frequency current and temperature varriability from Gulf Stream Frontal Eddies and Atmospheric forcing along the southeast U.S. Outer Continental Shelf. J. Geoph. Res. 88, C8, 4541-4567.

Mercer, M.C. 1969a. A. T. CAMERON Cruise 130, otter-trawl survey from southern Nova Scotia to Cape Hatteras, March-April 1967. Fish. Res. Bd. Canada Tech. Rep. No. 103: 24 p.

Mercer, M.C. 1969b. A.T. CAMERON cruise 150, otter-trawl survey of the mid-Atlantic Bight, August-September 1968. Fish. Res.Bd. Canada Tech. Rep. No. 122: 47 p.

Mercer, M.C. 1970. A.T. CAMERON Cruise 157, otter-trawl survey of the southwestern North Atlantic, February 1969. Fish. Res. Bd. Canada Tech. Rep. No. 199: 66 p.

Mercer, M.C. 1973. Distribution and biological characteristics of the ommastrephid squid Illex illecebrosus (LeSueur) on the Grand Bank, St. Pierre Bank and Nova Scotian Shelf (Subareas 3 and 4), as determined by otter-trawl surveys, 1970-1972. ICNAF Res. Doc. No. 79, Ser. No. 3031.

O'Dor, R.K., N. Balch, E.A. Foy, R.W.M. Hirtle, D.A. Johnston, and T. Amaratunga. 1982a. Embryonic development of the squid, Illex illecebrosus, and effect of temperaure on development rates. J. Northw. Atl. Fish. Sci. 3: 41-45.

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

Rowell, T.W., R.W. Trites, and E.C. Dawe. 1984. Larval and juvenile distribution of the short-finned squid (Illex illecebrosus) in relation to the Gulf Stream Frontal Zone in the Blake Plateau and Cape Hatteras area. NAFO SCR Doc. 84/IX/111, 37 p.

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

Trites, R.W. 1983. Physical oceanographic features and processes relevant to Illex illecebrosus spawning areas and subsequent larval distribution. NAFO Sci. Coun. Studies. 6, 34-55.

Vecchione, M. 1979. Larval development of Illex (Steenstrup, 1880) in the northwestern Atlantic, with comments of Illex larval distribution. Proc. Biol. Soc. Wash. 91(4): 1060-1074.

Verrill, A.E. 1982. Report of cephalopods of the northeastern coast of America. Rep. U.S. Comm. Fish. 1879, 211-455.

Wennekens, M.P. 1959. Water mass properties of the Straits of Florida and related waters. Bull. of Marine Science of the Gulf and Caribbean. Vol. 9(1), 1-52.

Yoder, J.A., L.P. Atkinson, T.N. Lee, H.H. Kim, and C.K. McClain. 1981. Role of Gulf Stream frontal eddies in forming phytoplankton patches on the outer southeastern shelf. Limnol. Oceanogr. 26: 1103-1110.

Table 1. Number and size of Type "C" (Illex) larvae, and associated catches of larval Types "A" and "B", over the Blake Plateau December 1984.

Bongo Station number	STD Station number	No. of Type "C" larvae	Mantle Length (mm) of Type "C" larvae				No. of Type "A" larvae	No. of Type "B" larvae
			Range	Median	x̄	S.D.		
01	22							
02	23	2	>0.8- 2.2	-	1.5	0.99		3
03		23	1.6- 4.2	2.2	2.43	0.63		
04	24	7	2.2- 3.8	2.6	1.5	0.52		1
05	25	3	1.0- 2.0	1.8	1.6	0.53		1
06	26	3	1.0->1.7	1.6	1.4	0.38		2
07	27	6	1.8- 2.6	2.0	2.1	0.28	1	
08	28							
09	29						4	3
10	30							
11	31						1	
12	32							1
13	33	1	1.8				1	
14	34							
15	35	2	2.0- 2.7	-	2.4	0.49		
16	36	1	2.2					
17	37							
18	38	1	1.8					
19	39							
20	40	1	2.4					4
21	41	1	4.2					
22	42							
23	43	4	2.3- 3.1	2.7	2.7	0.41		
24	44							
25	45							
26	46							
27	47							
28	48							
Total		55					7	16

Table 2. Number and size of Type "C" (Illex) larvae captured on transects between Cape Hatteras and the Straits of Florida, January, 1985.

Transect	Consecutive Days Occupied	No. of Stations	No. of Larvae	Range of Mantel Lengths (mm)	Median Size (mm)	Mean Mantle Length (mm)	Standard Deviation
I	1-3	19	2	3.2-6.4	4.8	4.8	2.26
II	3-5	19	3	1.1-6.3	4.6	4.0	2.65
III	6-9	27	39	0.8-6.0	1.8	2.4	1.56
IV	10-13	16	123	1.0-3.4	2.0	1.9	0.55
V	14-16	17	40	0.8-5.6	1.8	2.0	1.08

Table 3. Number and size of juvenile *Illex* captured on transects between Cape Hatteras and the Straits of Florida, January, 1985.

Transect	No. of midwater trawls	No. of juveniles	Range of mantle lengths (mm)	Median Size (mm)	Mean mantle length (mm)	Standard deviation
I	12	20	11-29	20.5	20.0	4.15
II	14	80	11-41	18.6	19.2	6.32
III[a]	25	~616	7-57	20.6	21.0	6.88
IV	13	136	9-33	14.9	15.2	3.41
V[b]	17	~297	9-60	23.8	25.1	10.80

[a]Stations 45 and 60 were subsampled (166 animals measured).

[b]Station 98 was subsampled (82 animals measured).

Table 4. Relative success of capturing juveniles at the same stations where larvae were caught and vice versa. Percentage of successful sets with bongos (larvae) and MWT (juveniles) are also presented.

Transect	Juveniles captured at same station where larvae caught			Larvae caught at same station where juveniles caught			Percentage of sets with catch	
	Yes	No	%Yes	Yes	No	%Yes	Bongo (larvae)	MWT (juv.)
I	-	-	-	0	5	0	6	42
II	1	-	100	1	6	17	11	50
III	8	7	53	8	4	67	44	48
IV	7	5	58	7	1	88	94	62
V	8	5	62	8	2	80	76	59
Total (I-IV)	24	17	59	24	18	57		
Total (III-IV)[a]	23	17	58	23	7	77		

[a]Since larval catches were so low in transects I and II (5 animals in total), a more meaningful comparison may be made on the basis of transects III-V.

Table 5. Numbers and ratio of larvae to juvenile catch numbers by transect. The ratios were normalized by number of sets made by bongo or MWT in each transect.

Transect	Number Captured		Larval/Juvenile Ratio	
	larvae	juveniles	un-normalized	normalized
I	2	20	0.10	0.07
II	3	80	0.04	0.03
III	39	616	0.06	0.06
IV	123	137	0.90	0.73
V	40	294	0.13	0.14

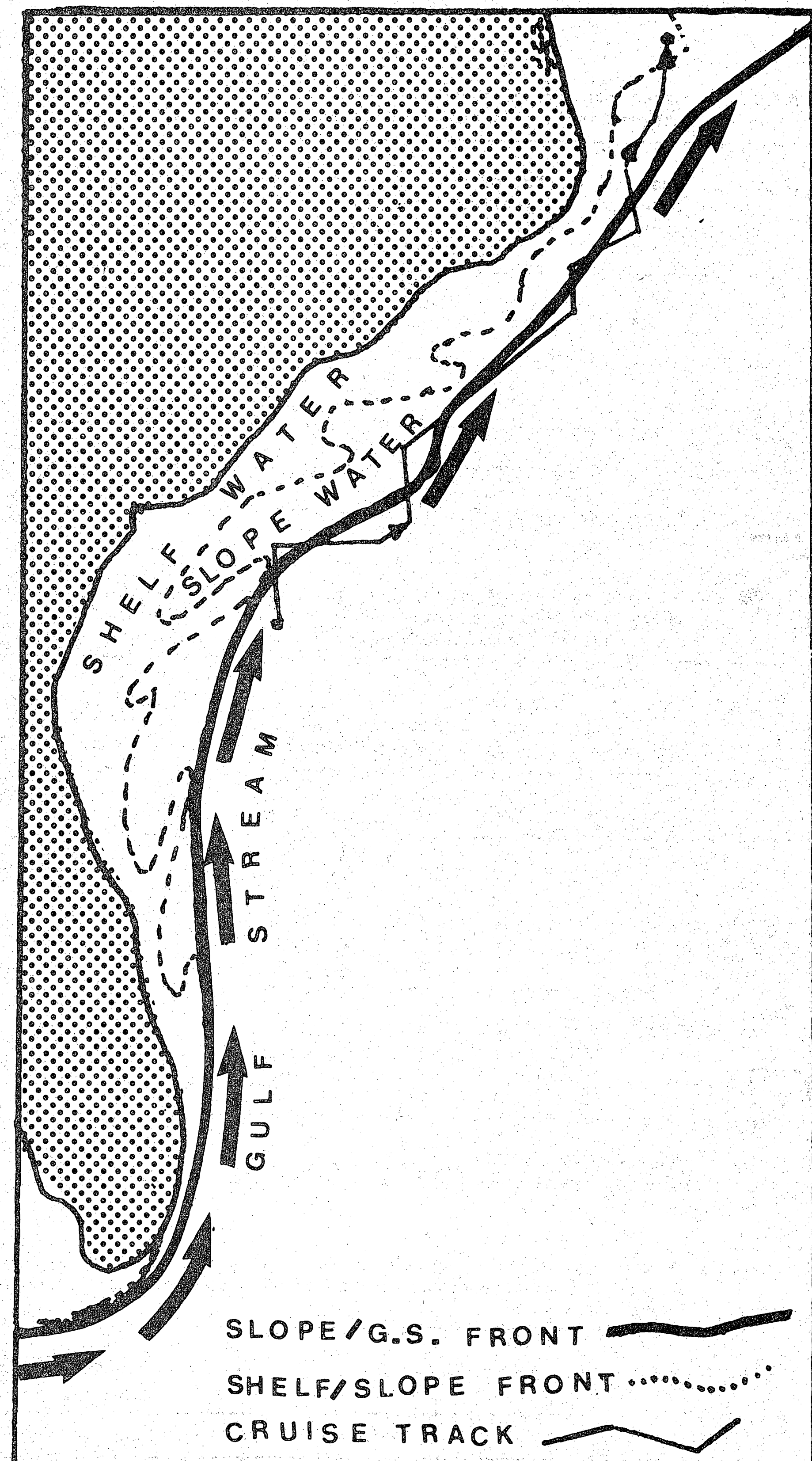

Figure 1 Map showing the cruise track for Hudson cruise 84-049 during the larval Illex survey phase of the cruise, 11-15 December 1984. The location of the Shelf/Slope Water and Slope/Gulf Stream fronts, extracted from NOAA/NESS satellite-derived oceanographic analysis maps for 11 and 13 December is also shown.

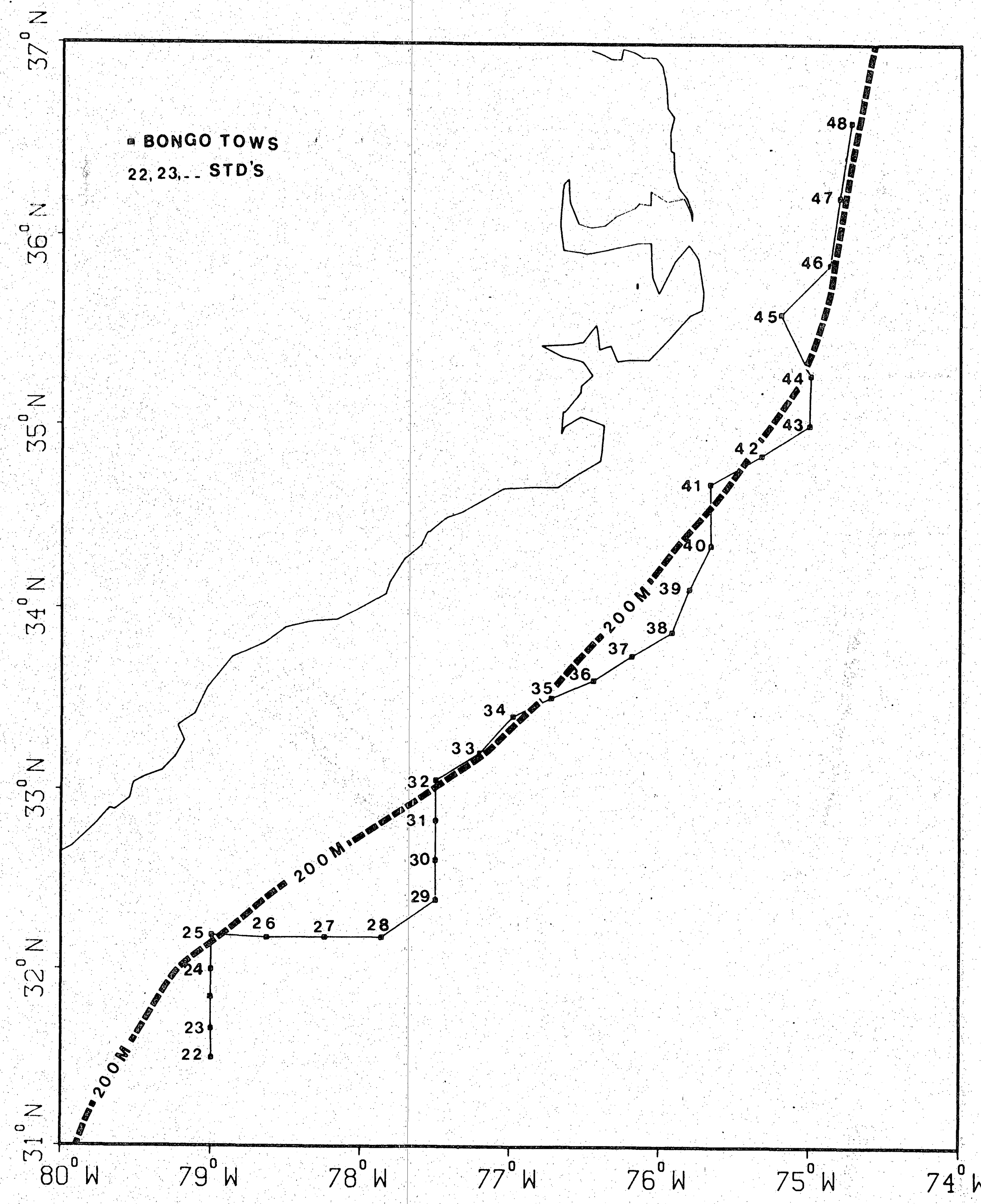

Figure 2 Cruise track, location of bongo tows, and STD station numbers for Hudson cruise 84-049, 11-15 December 1984.

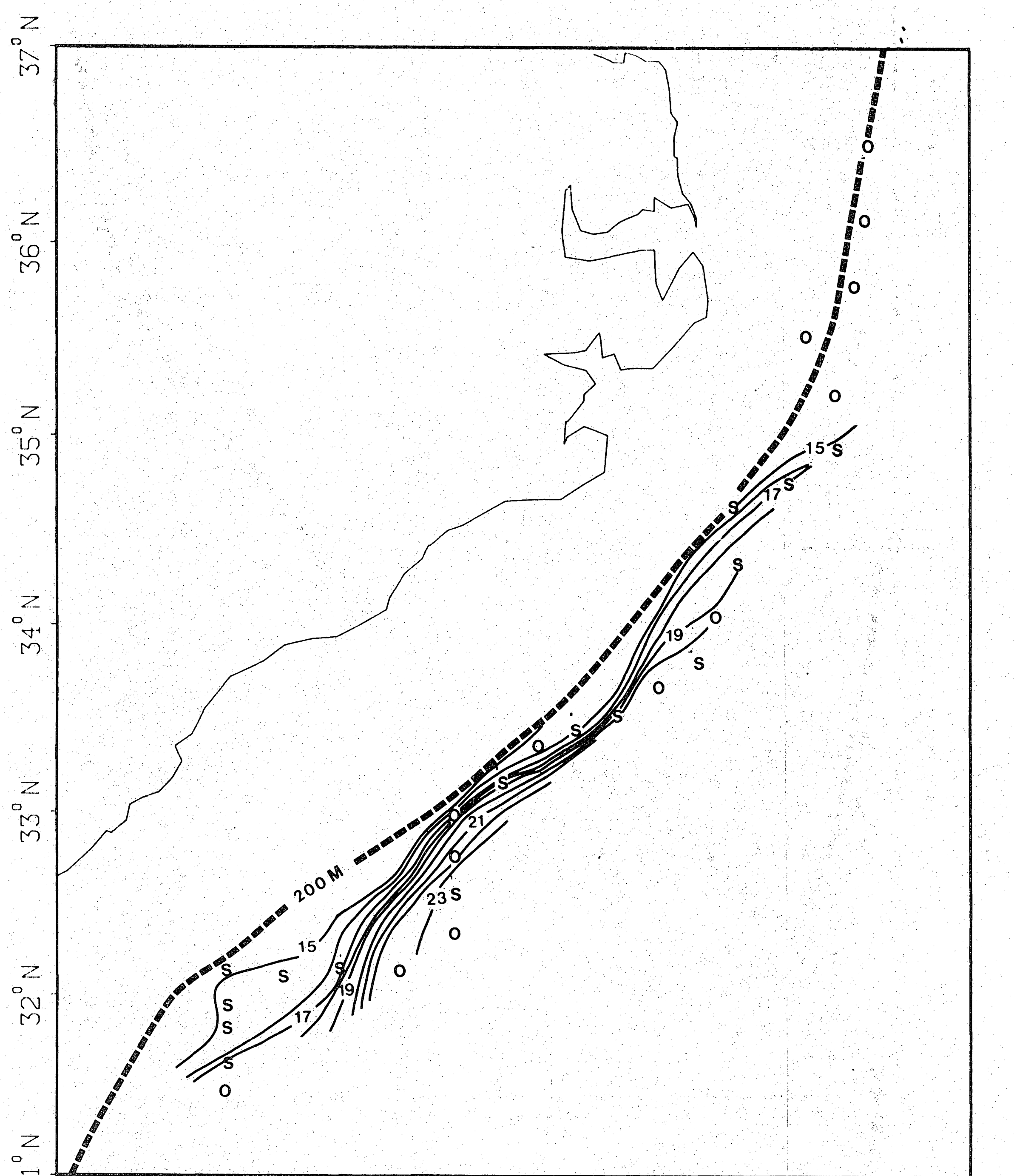

Figure 3 Temperature distribution (°C) at 200 M depth. Location of bongo tows with catch of <u>Illex</u> larvae or juveniles shown as an "S". Sites with no catches designated as "O".

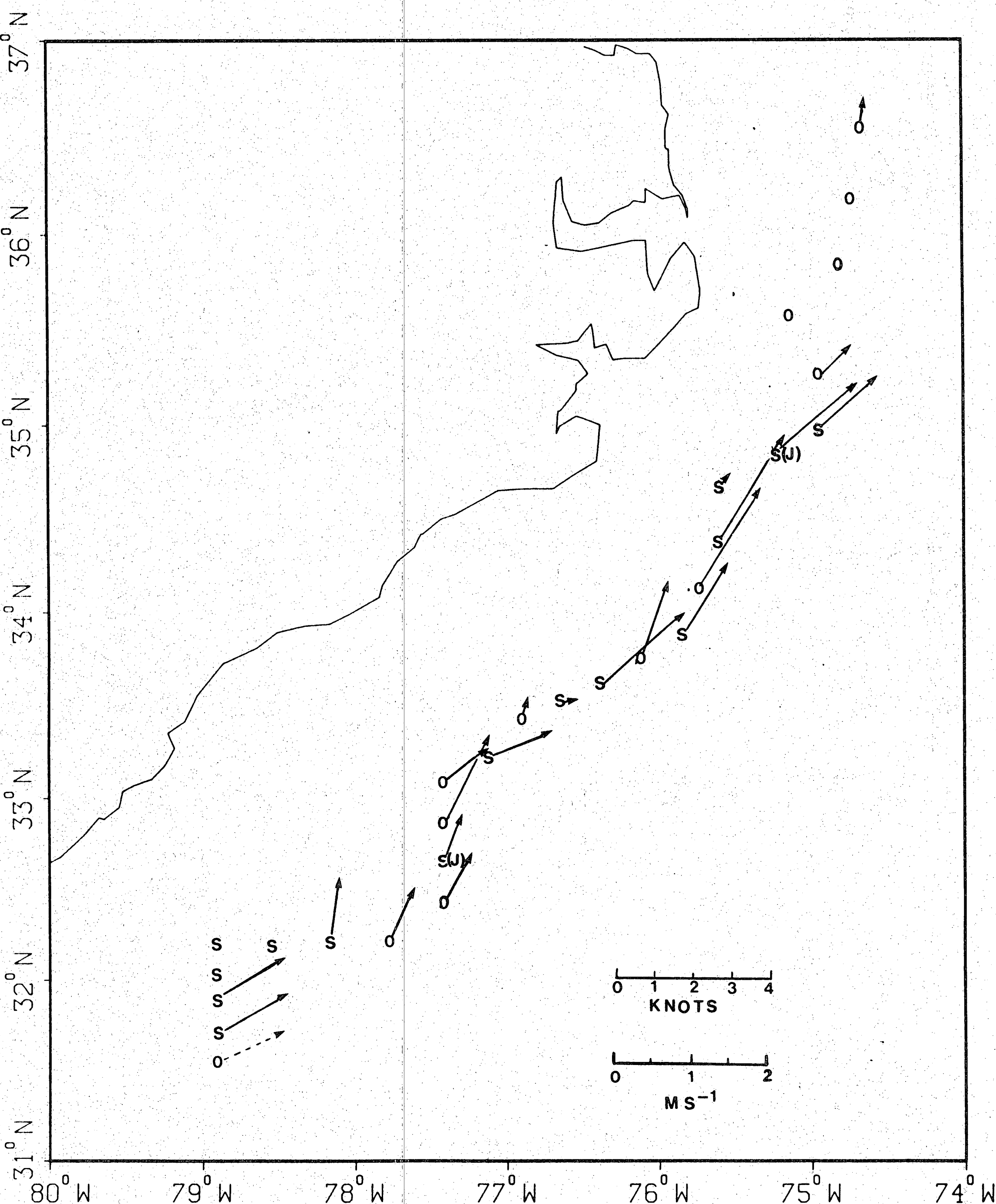

Figure 4 Surface currents as computed by measuring ship drift during STD lowerings. Location of bongo tows with catch of Illex larvae shown as "S", juveniles as "S(J)" and no catch "O".

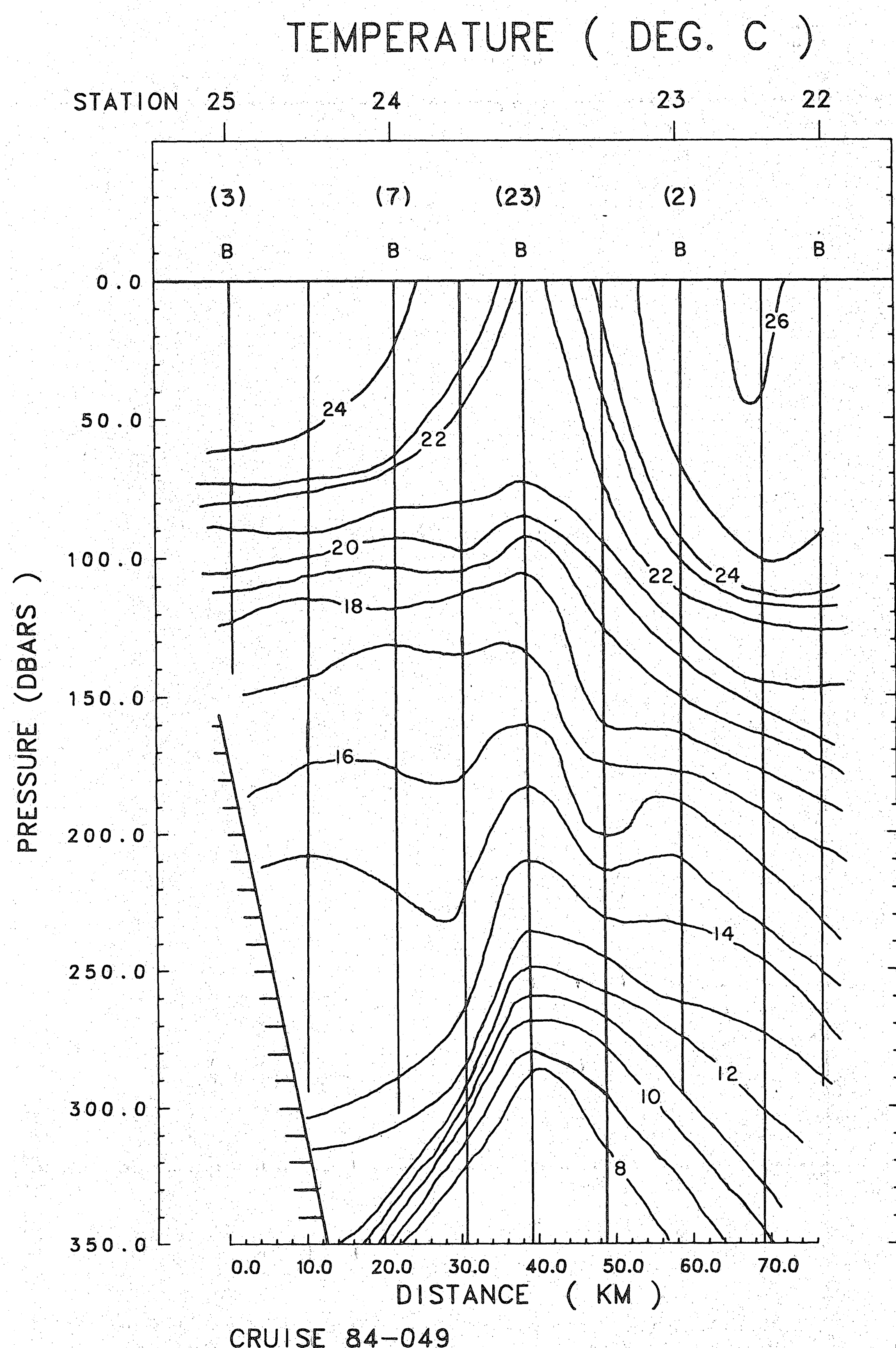

Figure 5 Plot of temperature distribution between stations 22 and 25. Sites where bongo tows were taken are shown with a "B", vertical lines show where temperature was measured; numbers in brackets are numbers of larvae caught at each station.

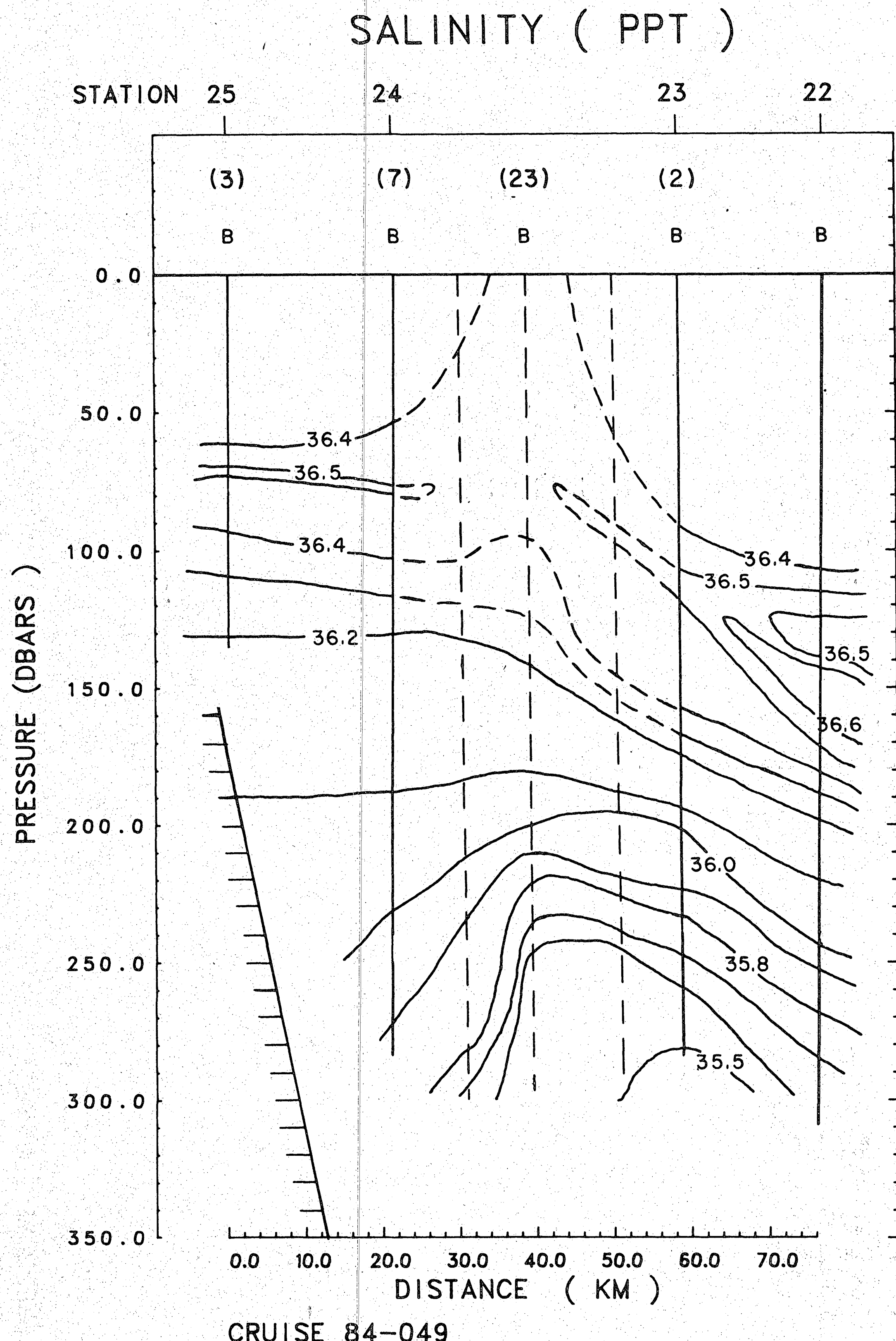

Figure 6 Plot of salinity distribution for stations 22-25. Sites where bongo tows were taken are shown with a "B", vertical lines show where temperature was measured; numbers in brackets are numbers of larvae caught at each station.

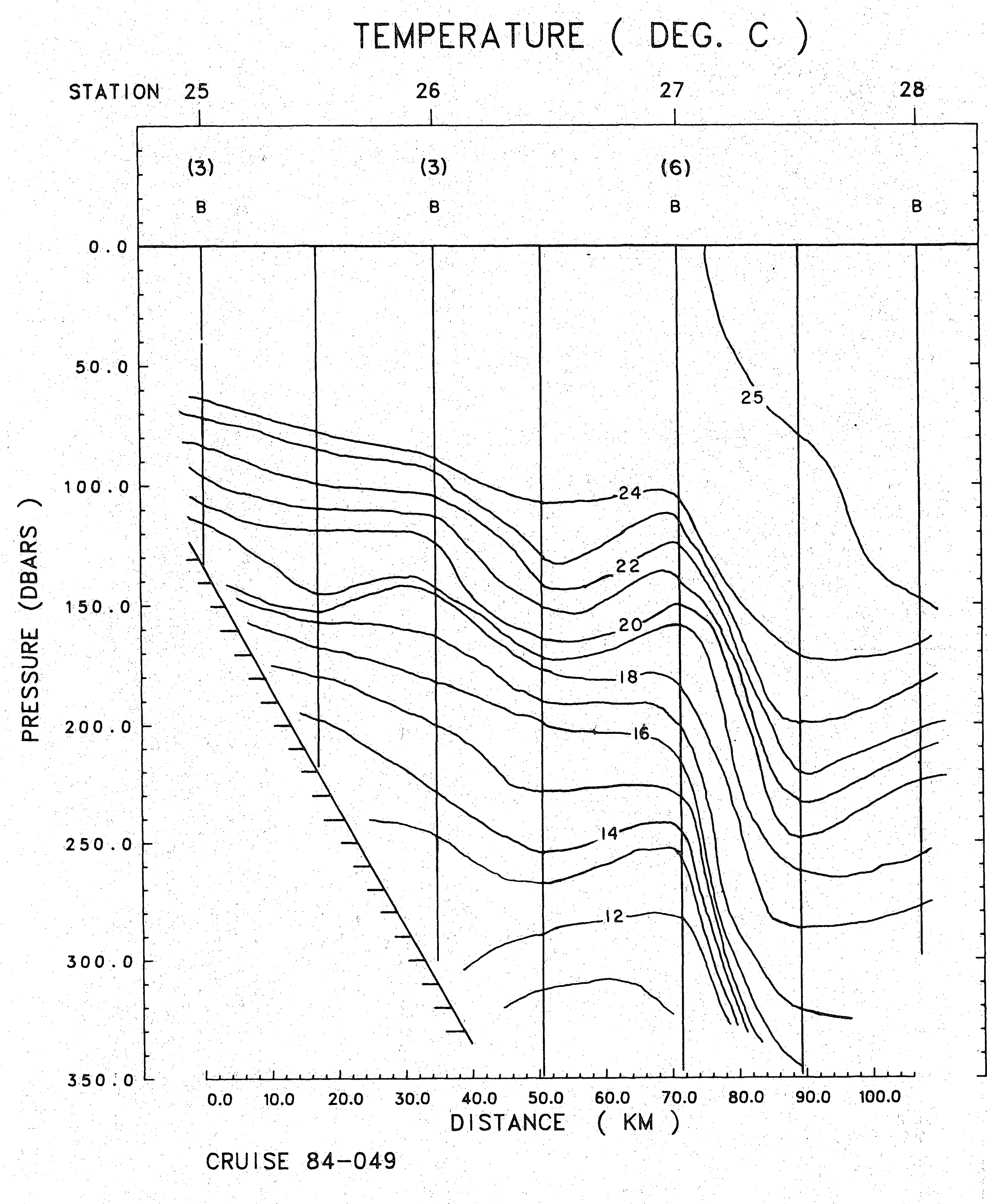

Figure 7 Plot of temperature distributions for stations 25-28. Sites where bongo tows were taken are shown with a "B", vertical lines show where temperature was measured; numbers in brackets are numbers of larvae caught at each station.

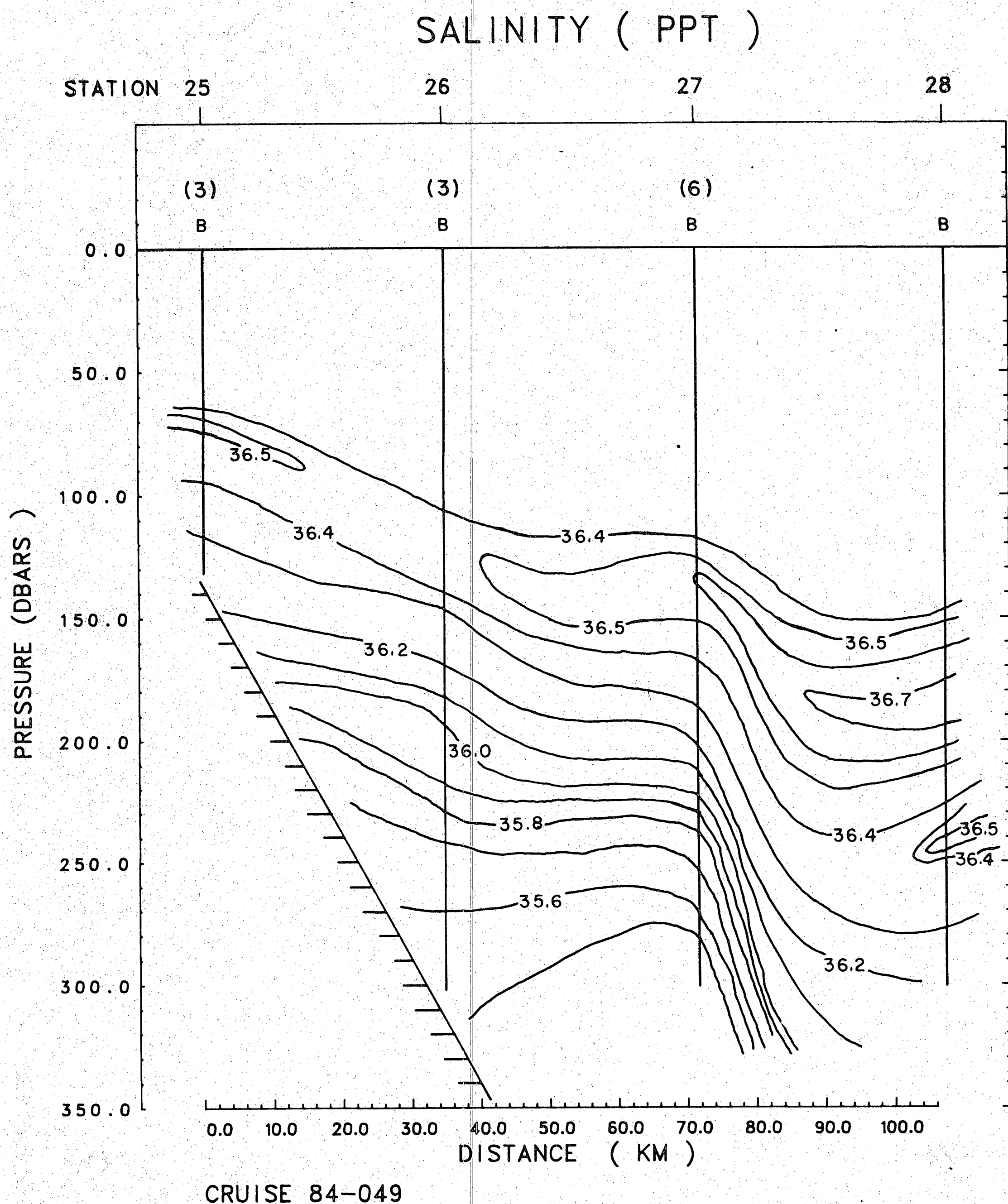

Figure 8 Plot of salinity distribution for stations 25-28. Sites where bongo tows were taken are shown with a "B", vertical lines show where temperature was measured; numbers in brackets are numbers of larvae caught at each station.

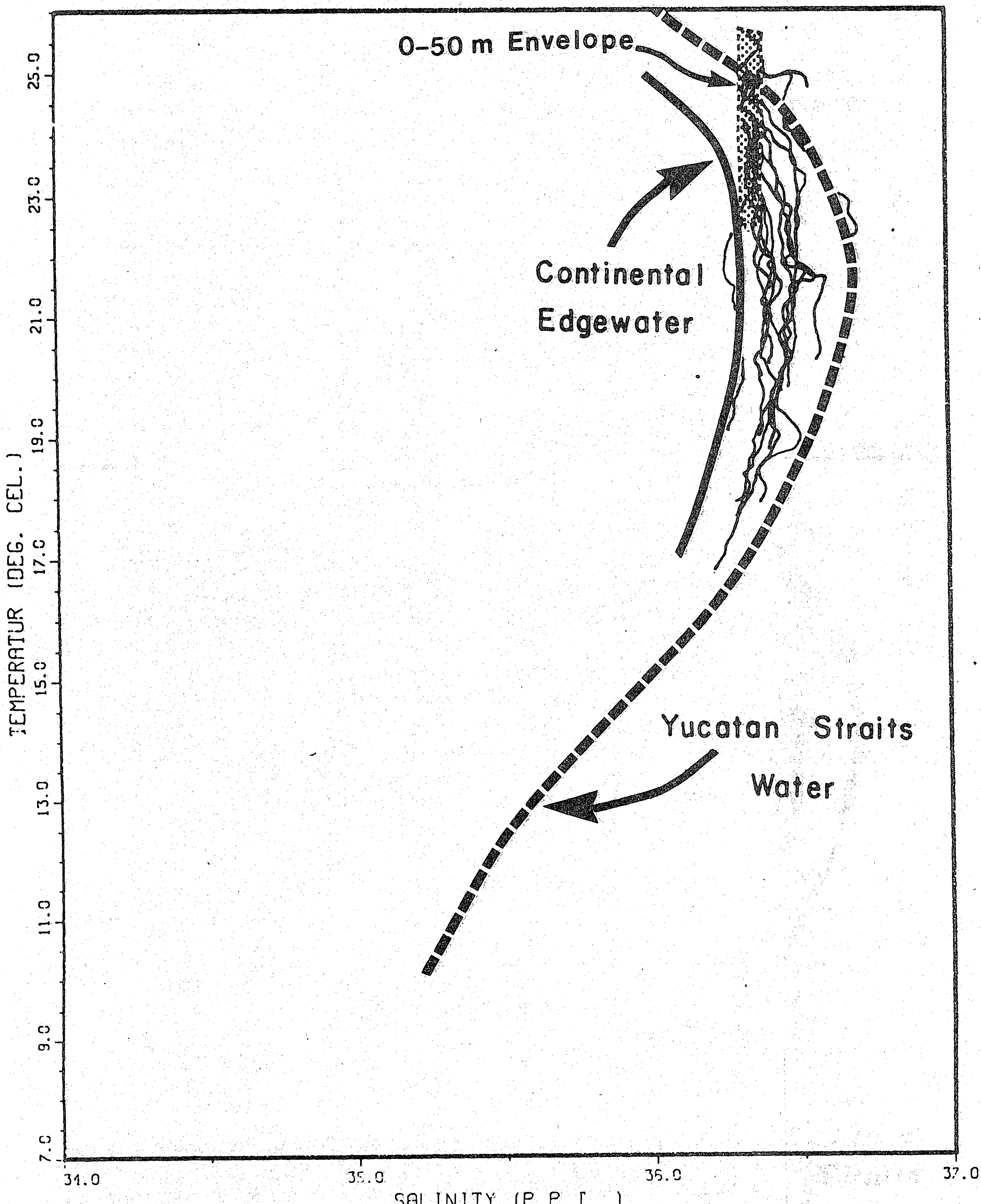

Figure 9 T-S plots for all stations (to 150 M depth) where <u>Illex</u> were caught. Hatched area is envelope of upper 50 M of water column. Yucatan Straits and Continental Edge Water T-S curves shown for reference.

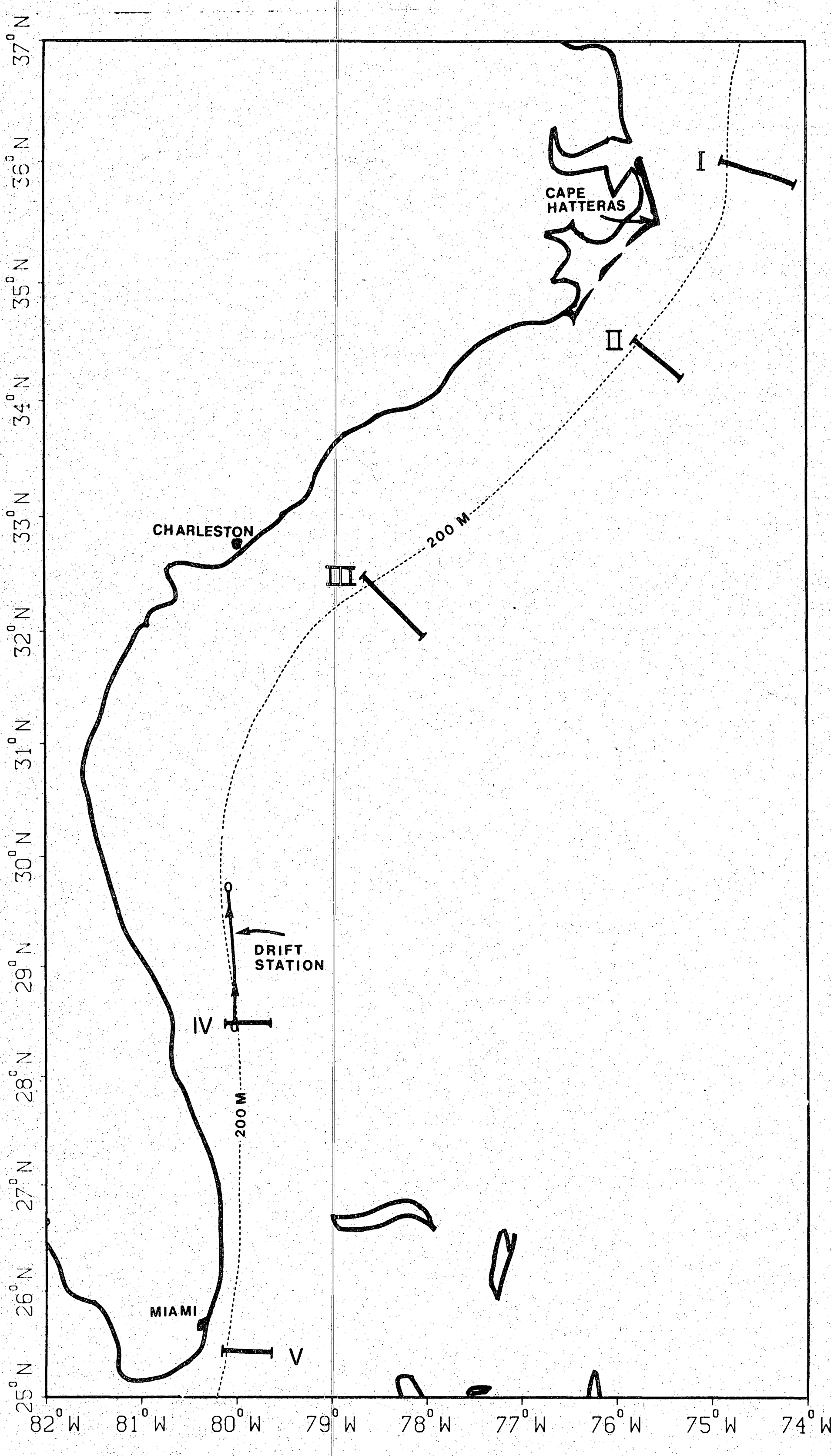

Figure 10 Map showing location of transects and drift station occupied during Needler cruise 85-001 during period 7-22 January 1985.

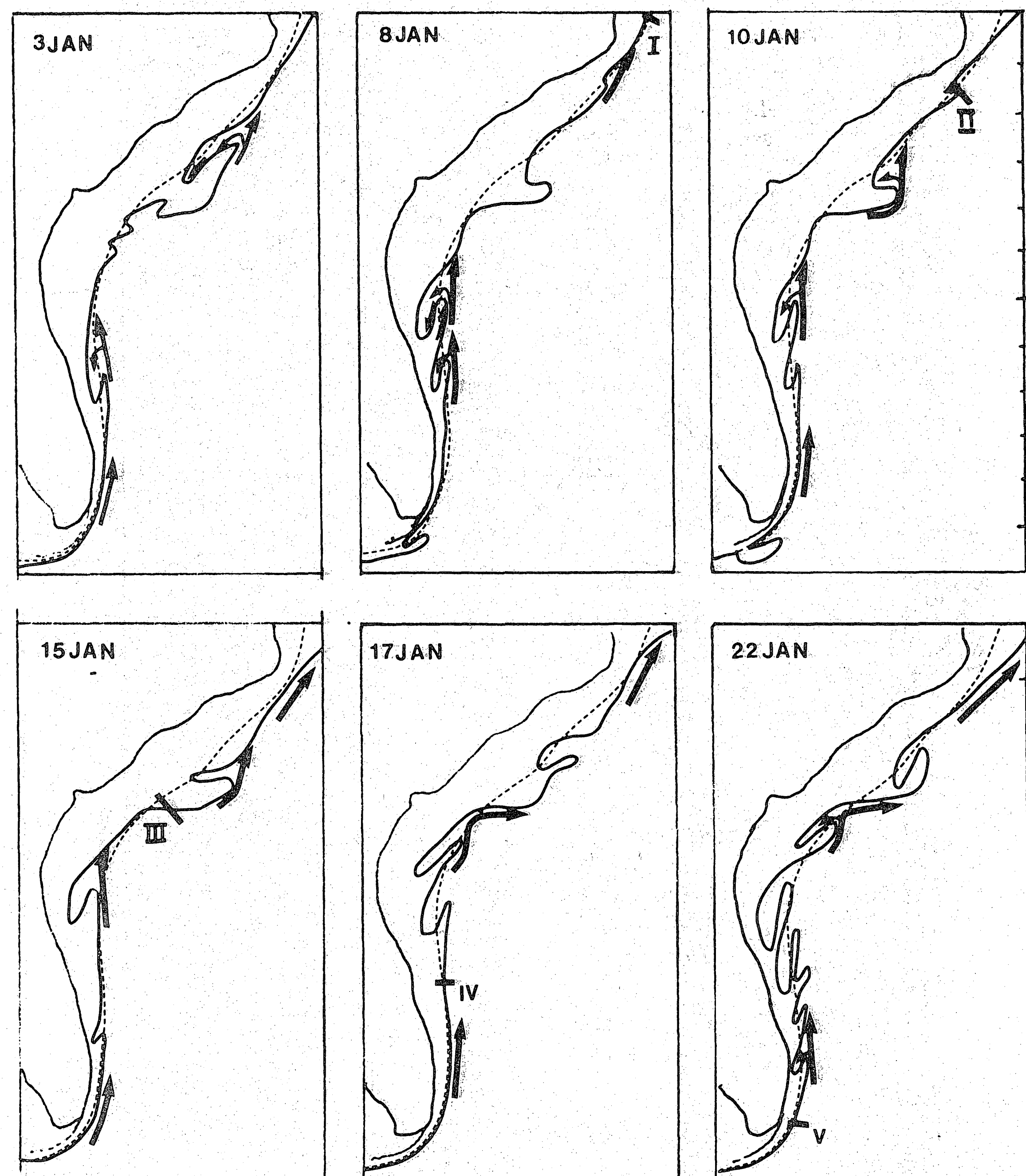

Figure 11 Maps showing location at surface of Slope/Gulf Stream front (solid line) in relation to the 200 M depth contour (dashed line) on 6 occasions in the 3-22 January 1984 period. Extracted from NOAA/NESS satellite-derived oceanographic analysis maps.

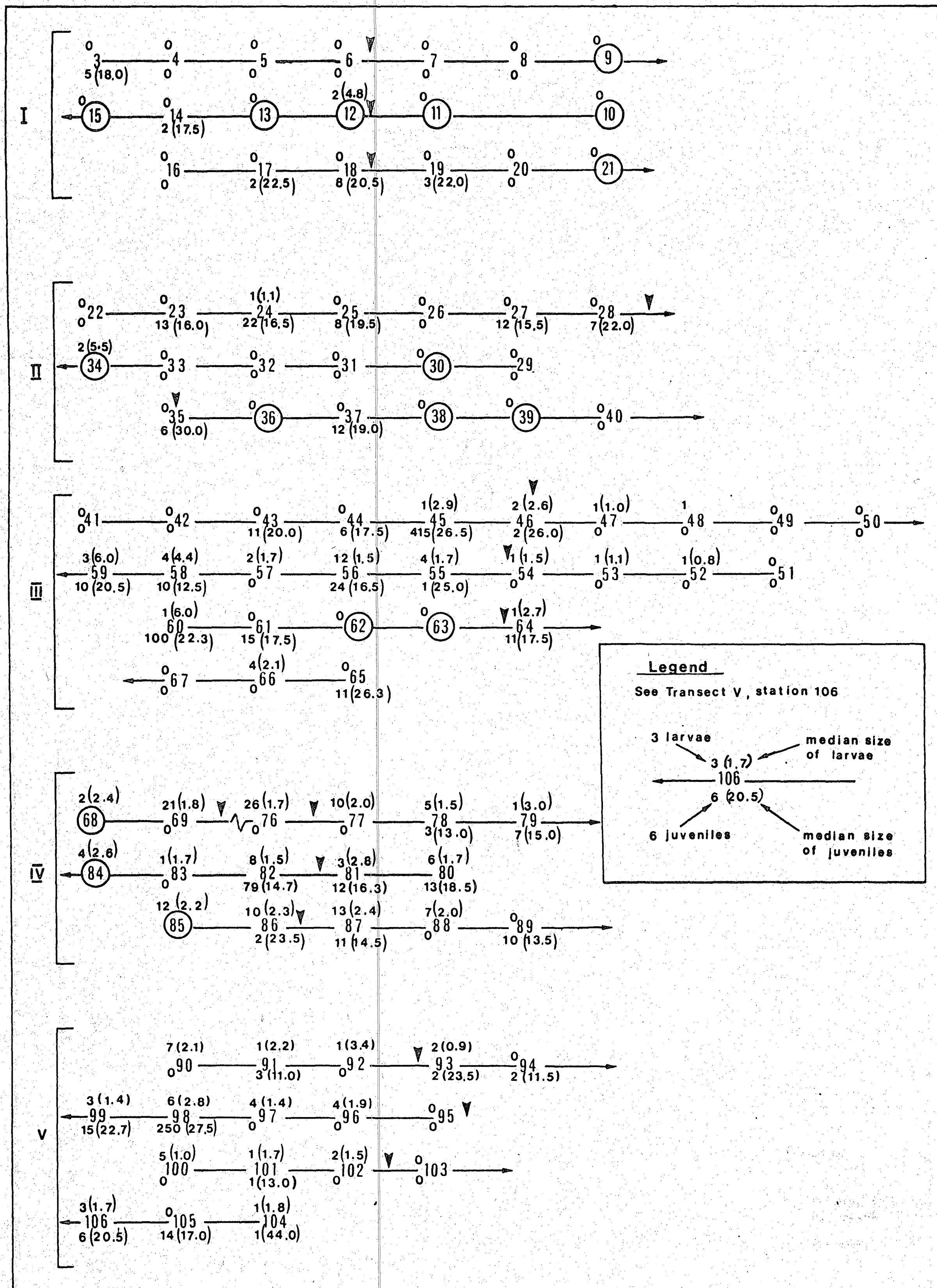

Figure 12 Relative positions of replicate station occupations during repeated passes on each transect, and number and median mantle length (mm) of larval and juvenile captures at each. A circled station number indicates no mid-water trawling (bongo only). Vertical arrowhead denotes estimated location of the high velocity core of Gulf Stream.

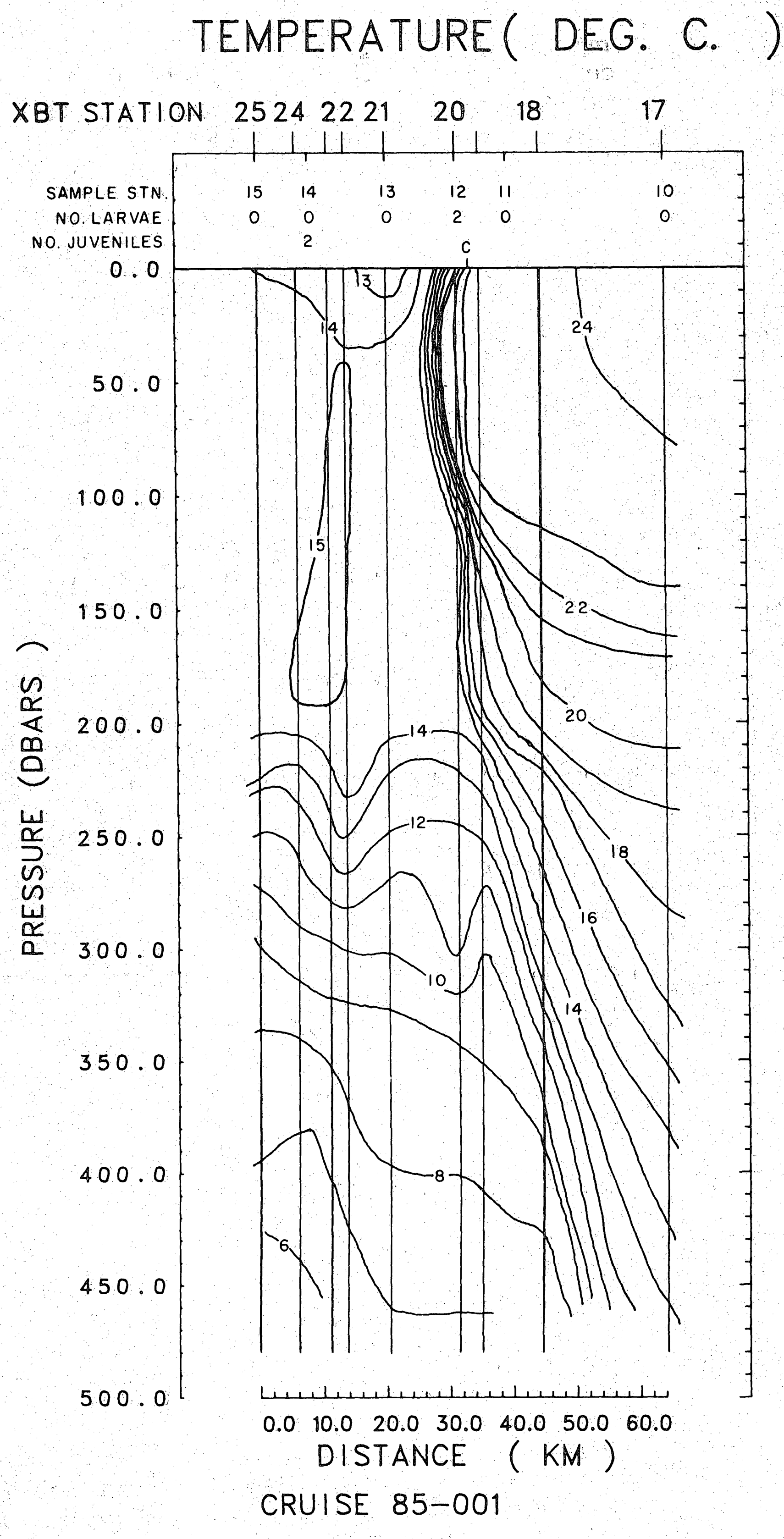

Figure 13 Temperature cross-section for XBT stations 17-25, during second occupation of Transect I, 7-8 January 1985. Larval and juvenile <u>Illex</u> sampling stations and catches are shown at top of section.

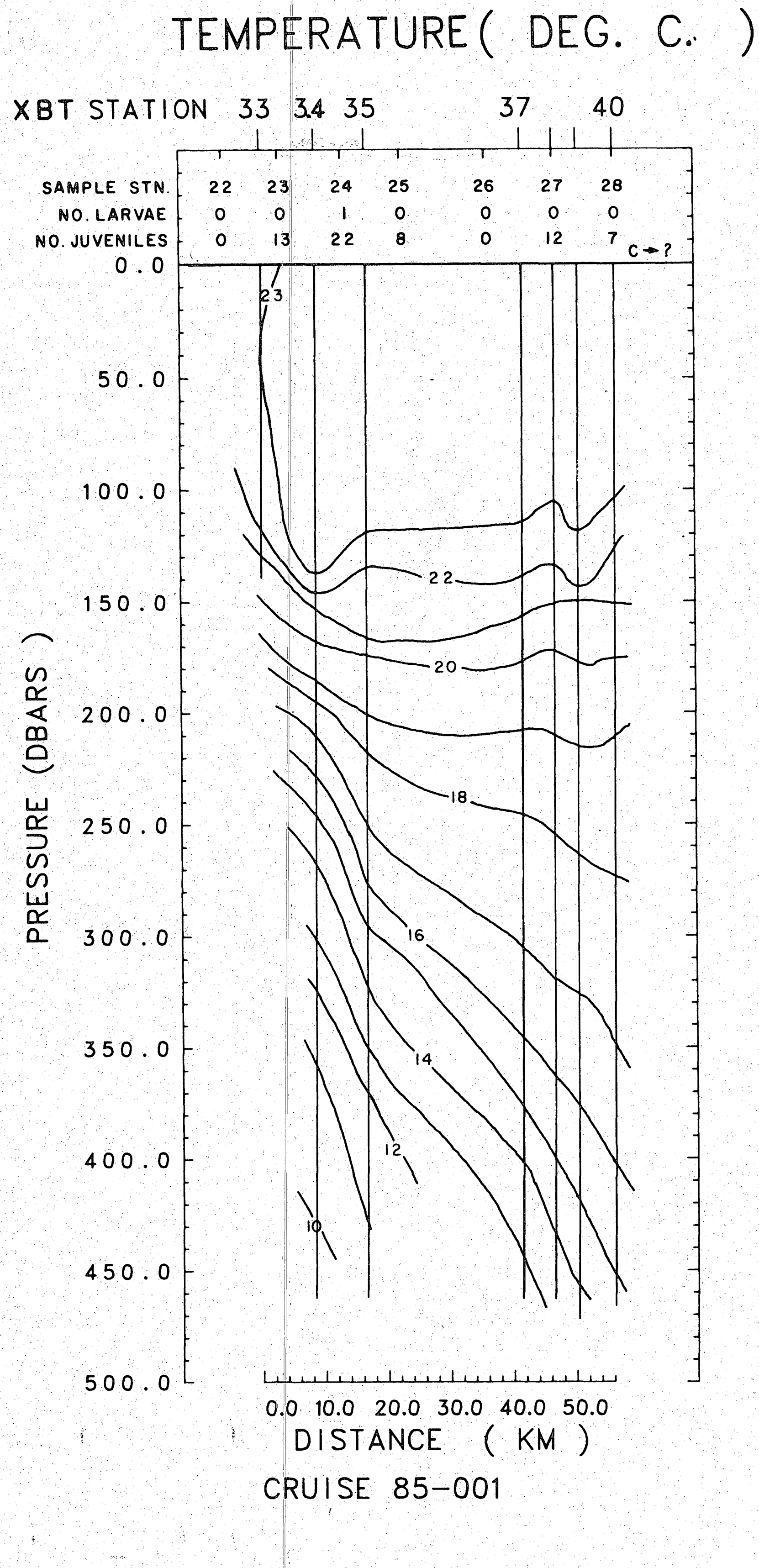

Figure 14 Temperature cross-section for XBT stations 33-40, during first occupation of Transect II, 9-10 January 1985. Larval and juvenile <u>Illex</u> sampling stations and catches are shown at top of section.

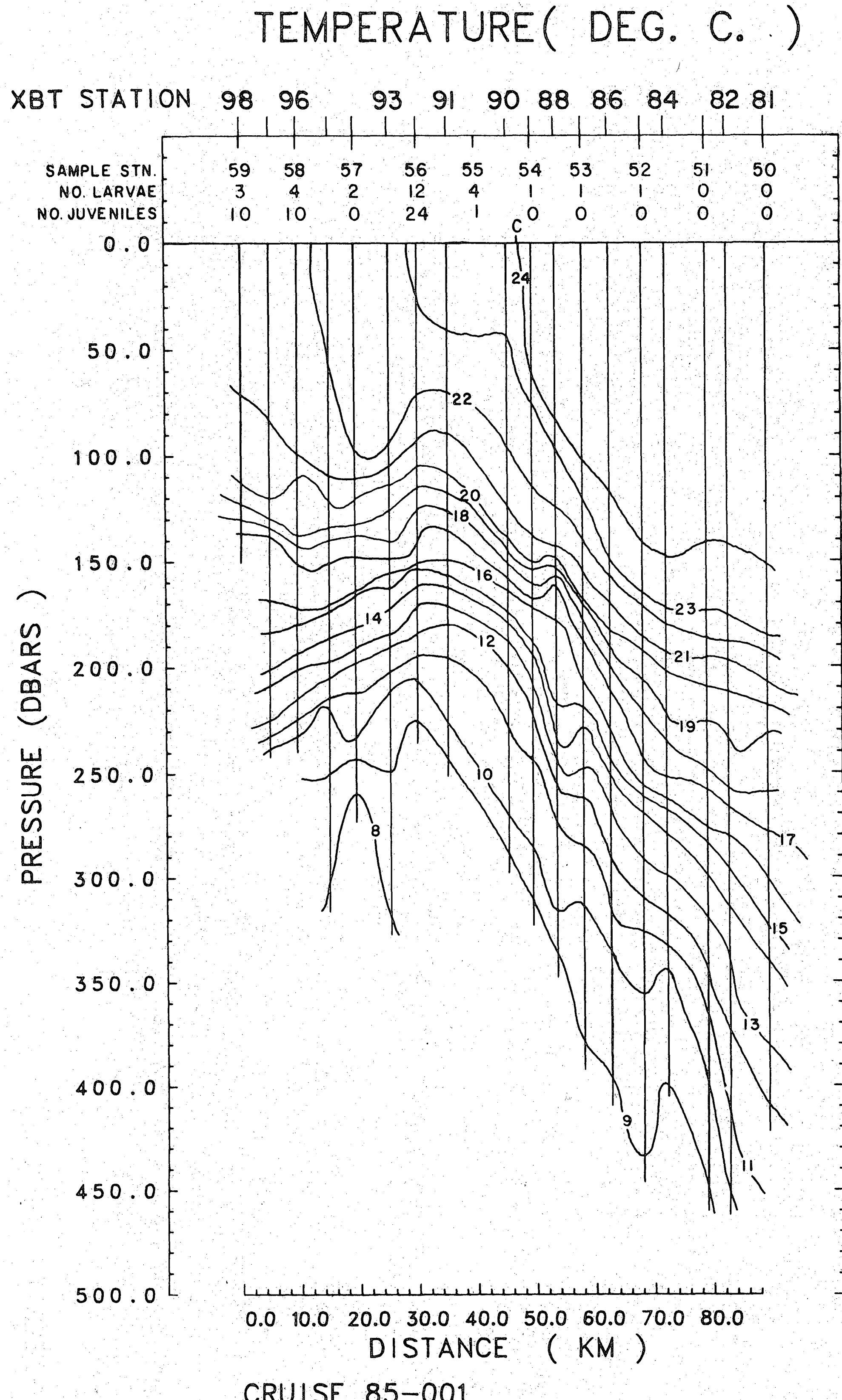

Figure 15 Temperature cross-section for XBT stations 81-98 during second occupation of Transect III, 13-14 January 1985. Larval and juvenile Illex sampling stations and catches are shown at top of section.

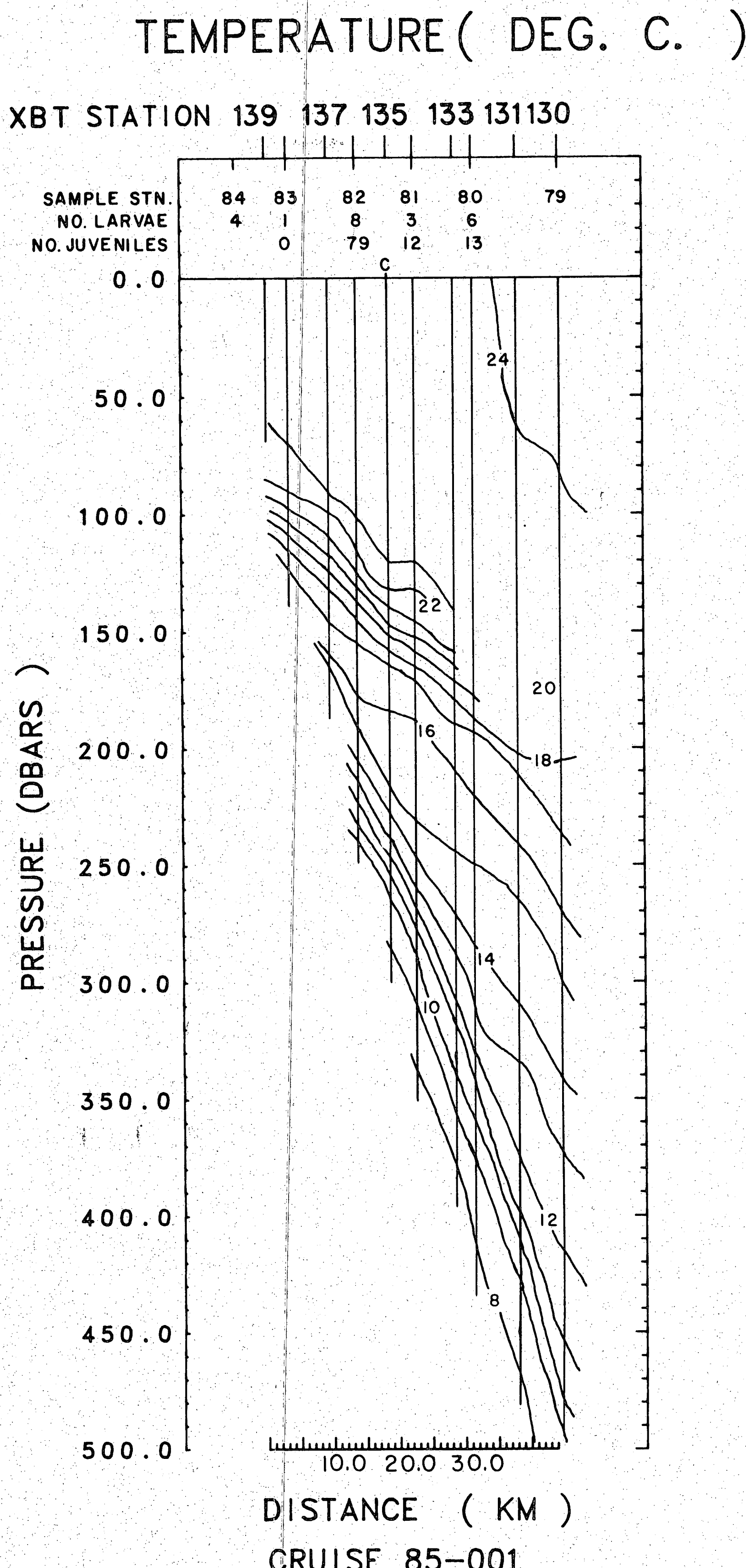

Figure 16 Temperature cross-section for XBT stations 130-139 during second occupation of Transect IV, 18 January 1985. Larval and juvenile Illex sampling stations and catches are shown at top of section.

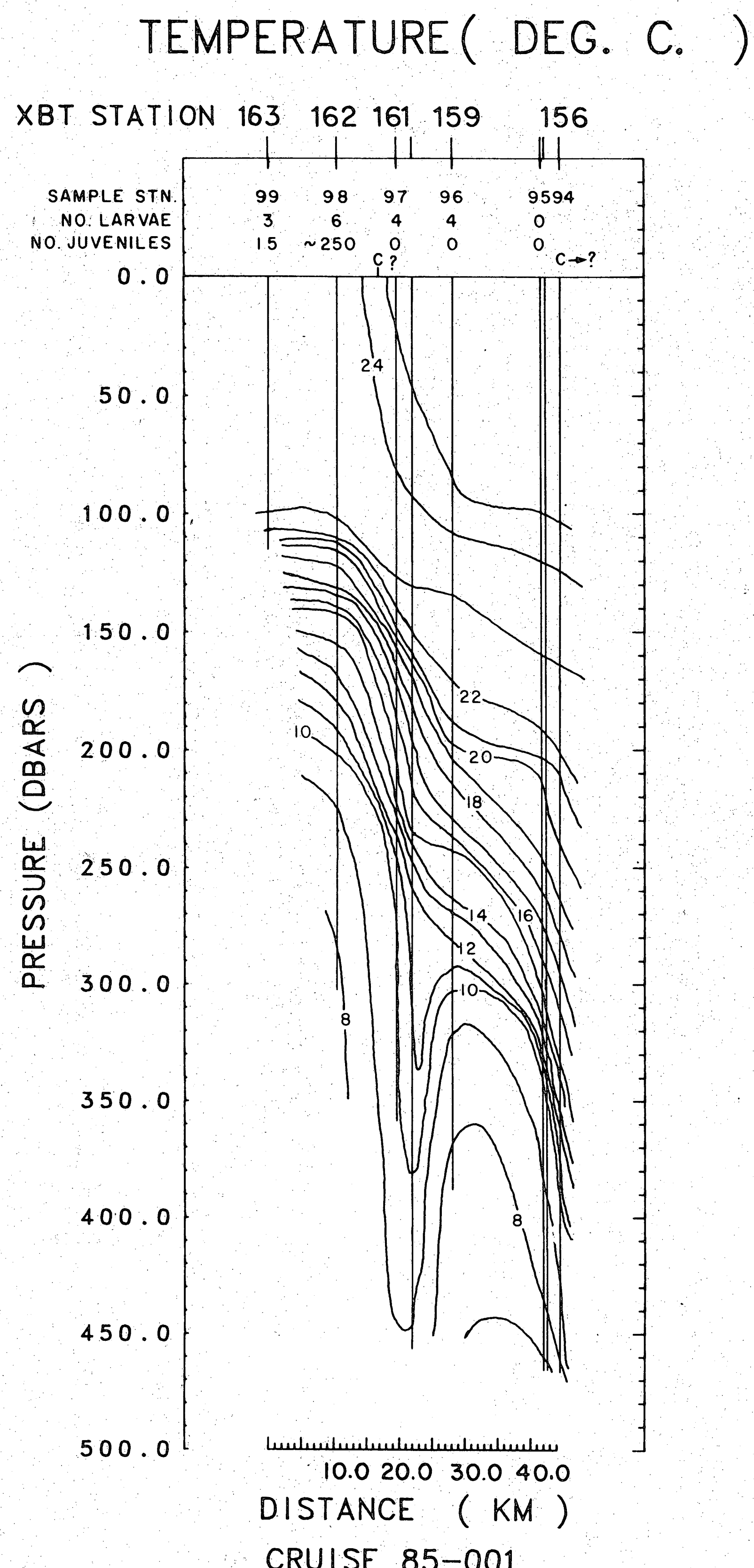

Figure 17 Temperature cross-section for XBT stations 156-163 during second occupation of Transect V, 20-21 January 1985. Larval and juvenile *Illex* sampling stations and catches are shown at top of section.

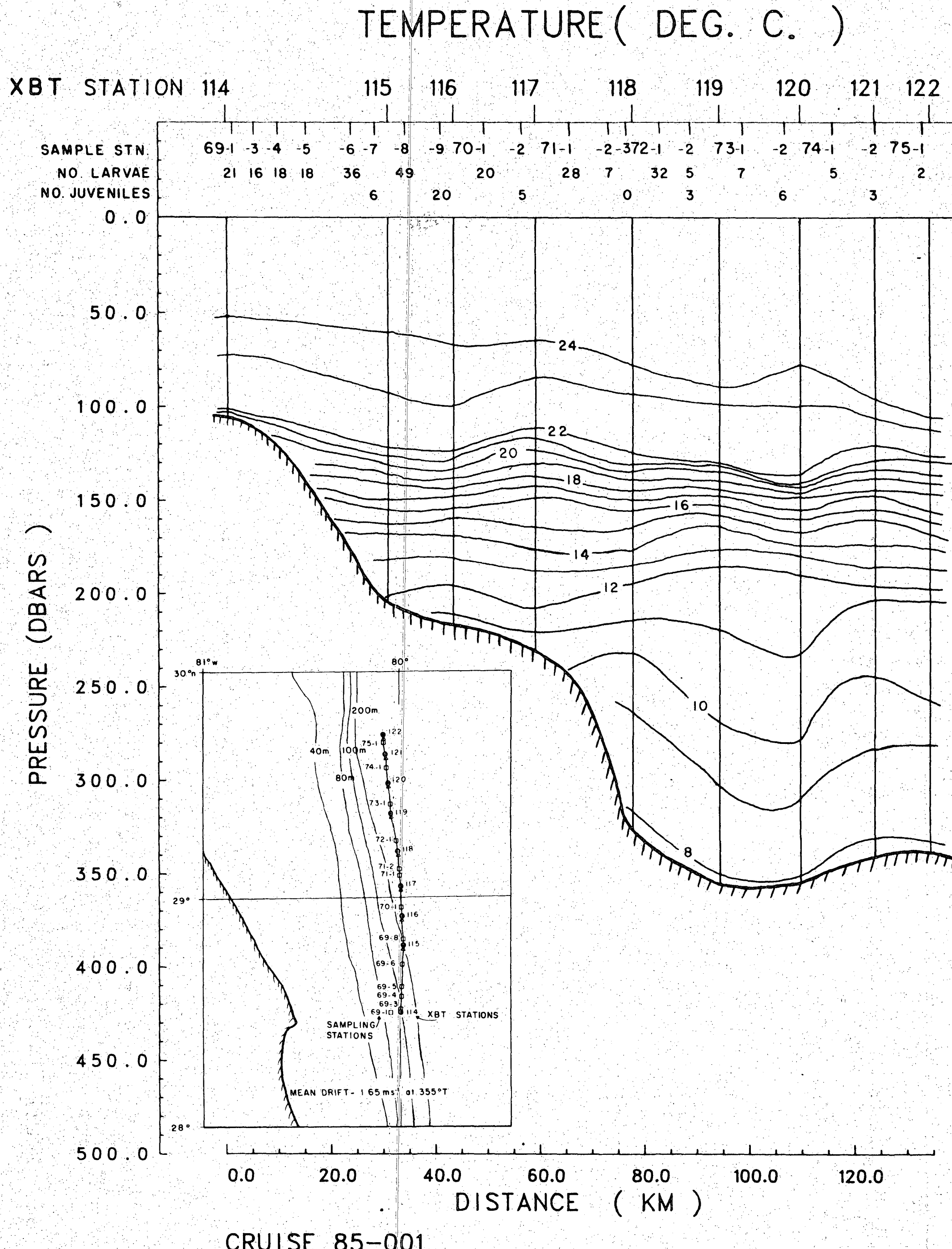

Figure 18 Vertical-longitudinal temperature section for drift station, 16-17 January 1985. Larval and juvenile Illex sampling stations and catches are shown at top of section. Location of XBT's, sampling stations, and current vectors shown in inset.

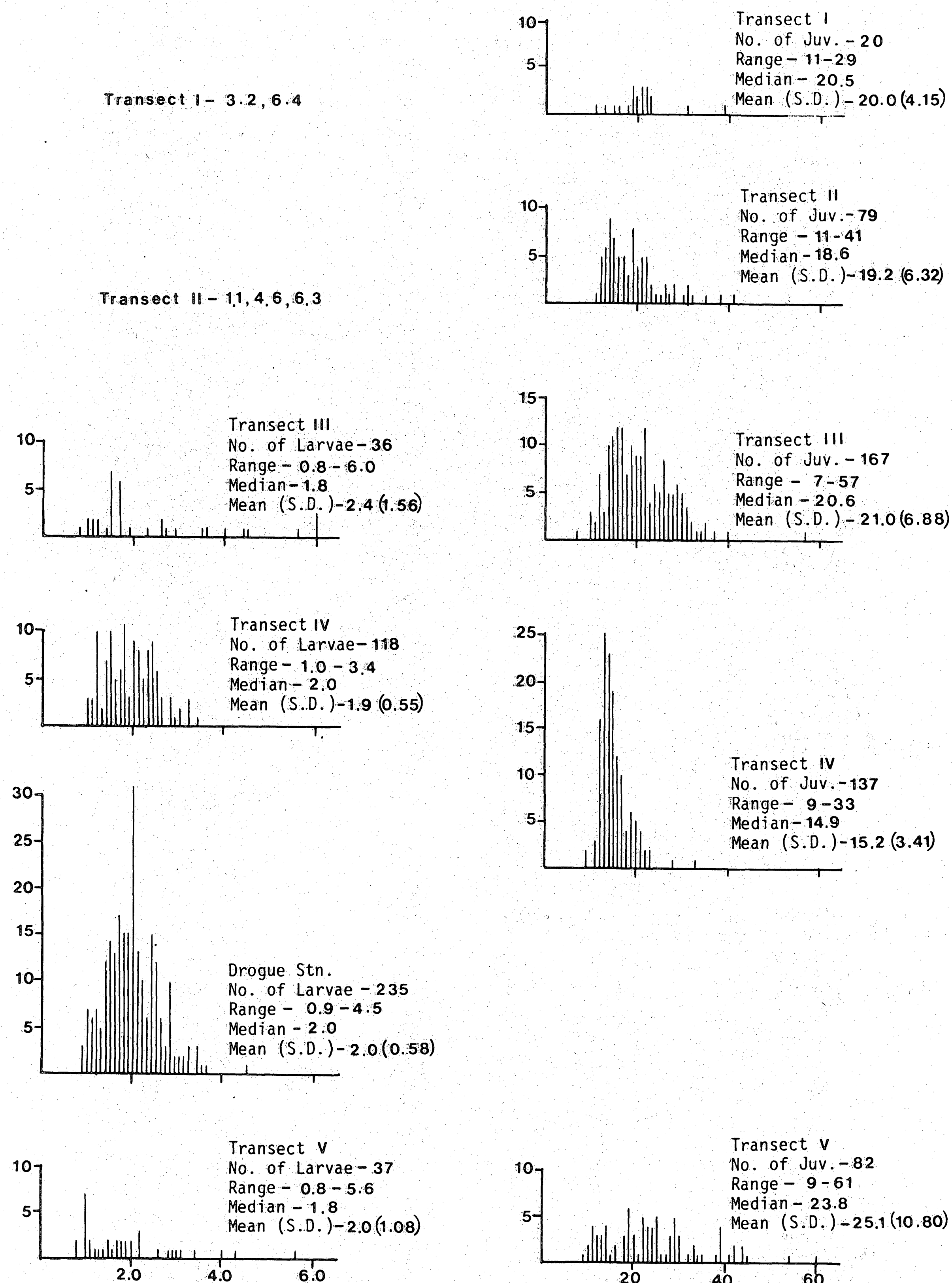

Figure 19 Length frequencies (mantle length in mm), range, and measures of central tendancy, by transect, for larval and juvenile Illex.

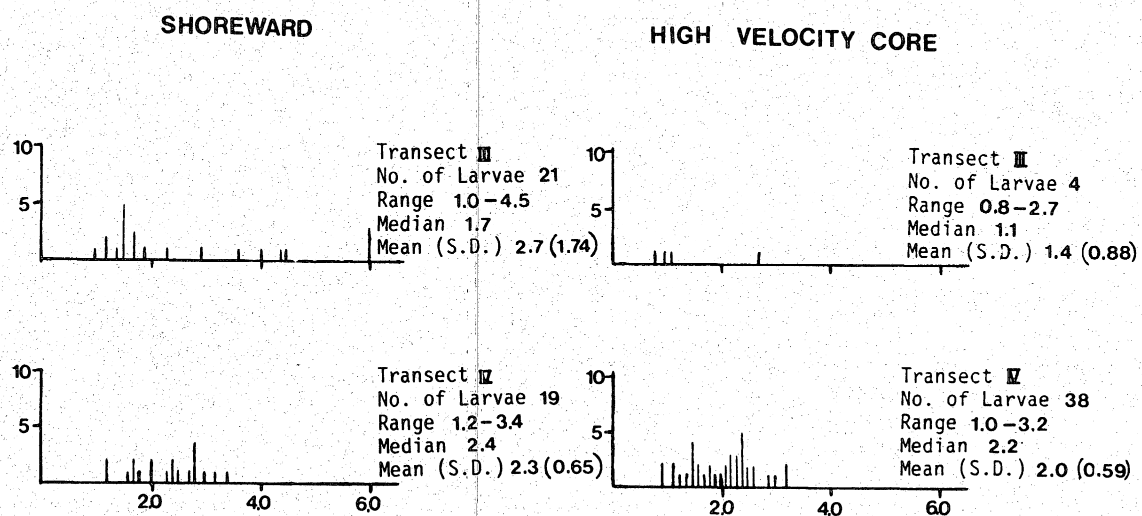

Figure 20 Length frequencies (mantle length in mm), range, and measures of central tendancy for larval captures at grouped stations shoreward of the Frontal Zone and in the High Velocity Core of the Gulf Stream.

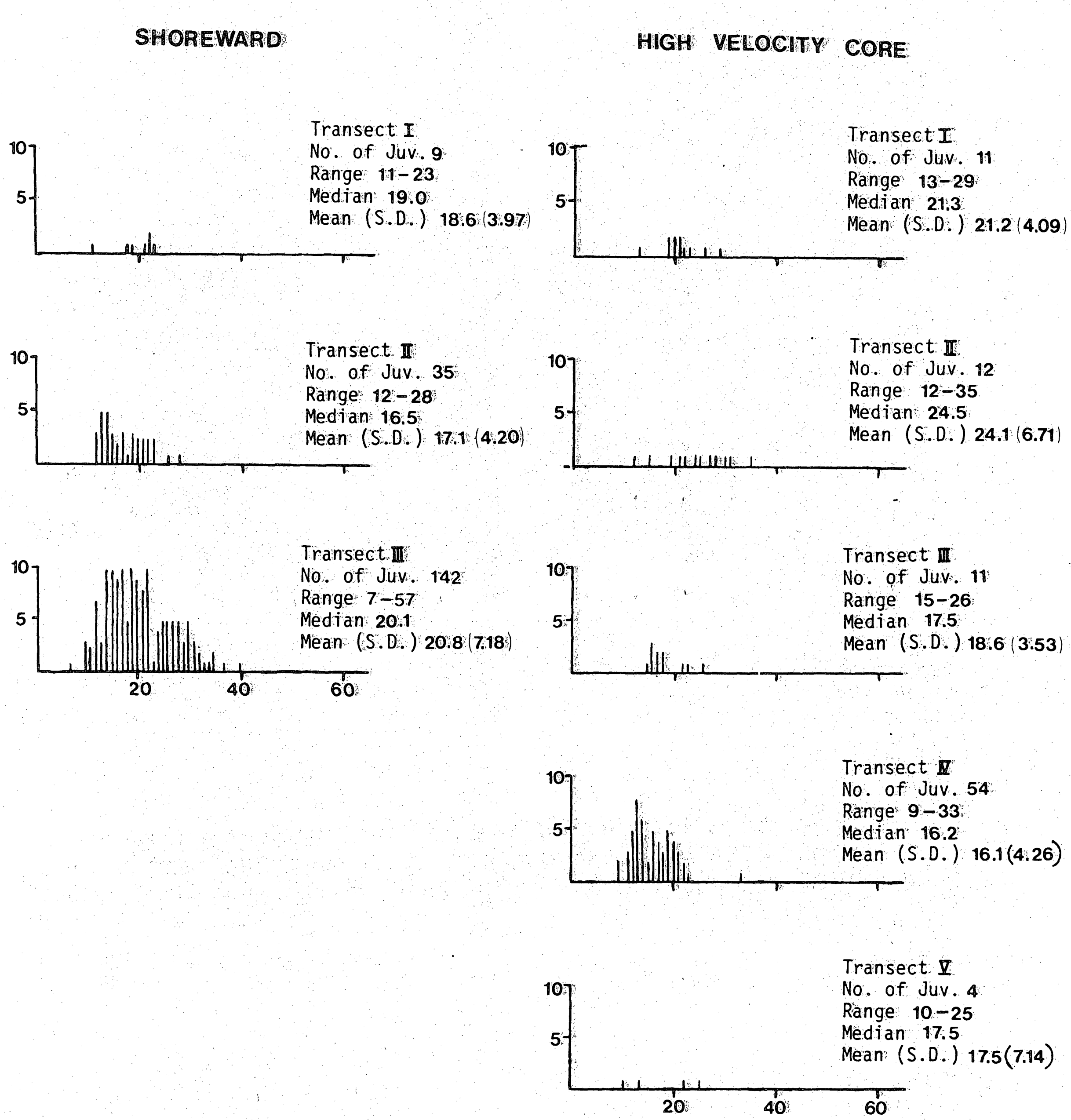

Figure 21 Length frequencies (mantle length in mm), range, and measures of central tendancy for juvenile captures at grouped stations shoreward of the Frontal Zone and in the High Velocity Core of the Gulf Stream.