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Biological characteristics and biomass estimates of squid, *Loligo pealei* and *Illex illecebrosus*, on mid-Atlantic and Southern New England shelves

by

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Introduction.

After several years of exploratory squid surveys on Nova Scotia, Georges Bank and Southern New England areas, interpretative schemes of growth and life cycles of Loligo pealei and Illex illecebrosus accounting for the different size groups met were proposed (MESNIL, 1976). It was shown that there are in fact 2 cycles following from each other and determined by the action of external factors on the induction of maturation in females, as was demonstrated for European species.

The need however arose of sampling a larger part of the distribution area of these species since geographical variations of the size (age) structures were suspected. This was made during a cruise carried out aboard R/V CRYOS in october-december 1976, the results of which are presented here. The size structures analyzed are compared with those observed in previous years, in relation with the hypothetical life cycles, and biomass and stock size estimates of the squid populations in the area surveyed are provided.

- Methods -

The data discussed in this paper were collected during a cruise carried out from October 28 to December 6, 1976, on Northern Georges Bank, Nantucket Shoals area and Mid Atlantic shelf.

The trawling sites were selected randomly in the stratified design currently adopted for Groundfish Surveys in this area. 105 stations, each consisting of a standard 30 minute trawling tow with a Lofoten trawl and a BT or XBT cast, were occupied in strata 21-25, 1-15 and 61-76 (Fig. 1A-1B).

The squid caught, or a representative random subsample, were sexed and measured, each sex apart, to the half-centimeter below and their maturity stage was recorded. In some stations where mixed very small and large Loligo were present, the sample was stratified ; the large individuals, above $\pm$ 15 cm, were sorted and all of them measured since they were relatively few, while only a random subsample of the very numerous small squid was studied. This led to a much better characterization of the large squid as will be pointed out.

The length frequency distributions - of Loligo particularly - were analyzed using the graphical method of Cassie (1954).

The biomass and stock size estimates were calculated from the catches in weight and number in each individual stratum by aerial expansion. The factor is the ratio of the total area of the stratum considered to the total area swept by the trawl in the same stratum. The latter area is calculated on the basis of an horizontal opening of 13.5 m at the wings, as observed during trials of the trawl used, in the 3.5-4 knots speed range. The towing distance is measured on the navigation charts between the Loran or Decca positions of beginning and end of the tow.

As the results of analysis and abundance of squid in each individual stratum could not be given in a synthetic presentation, they were summed within 5 sets of strata : I (61-68), II (69-76), III (1-8), IV (9-15) and V (21-25). Georges Bank itself was not studied so that no estimate of abundance is given for this area that was surveyed at the same period by R/V ALBATROSS IV.

- Results and dicussions -

The biological characteristics of the populations of Loligo pealei and Illex illecebrosus sampled will be presented before stock size estimates are discussed.

I - Loligo pealei.

Some 65,200 individuals, weighing 2.8 tons, were caught during the whole cruise and Loligo was the second most numerous species, the first being the butterfish, Poronotus triacanthus. They were distributed in the whole surveyed area, if we except strata 21 and 22 on the northern edge of Georges Bank and some of the deepest stations. The highest catches were recorded on stratum 74 (650 kg in 4 stations) and 63 (340 kg in 1 station). As usual, their abundance decreases from the Mid-Atlantic shelf to Georges Bank and from shallow to deeper areas and probably many of them could have been found in inshore waters in spite of the spectacular decrease of temperatures in november. They still were abundant in shallow strata 1 and 73 of the central part of the shelf but to the north and to the south as well, the maximum density is observed in somewhat deeper waters.

The length frequency distributions were analyzed and the following size groups were identified : (Table 1)

1) Some 56 p.cent of the individuals caught belong to the youngest group in which size ranges and means are 2 - 8.1 - 12 cm and 1 - 7.6 - 11 cm for males and females respectively. Their relative importance and their mean size are much smaller towards the southernmost set of strata, a tendency already observed by SUMMERS (1971) and during one of our cruises in september-october 1974 but difficult to explain if not by a longer summer spawning season in the south.

2) 32 p.cent of the males and 42 p.cent of the females have mantle lengths ranges and means 7 - 11.9 - 16 cm and 7 - 11.1 - 14 cm respectively. They form the most important group in the southern strata while only the largest of them are present in the New England area.

As in the previous years, the last 7 p.cent of the sample consist of a mixture of age groups. The stratification of the samples where these large individuals were present provides an improved representation of their size distribution although their irregular frequency in the corresponding size classes does not yet allow an accurate resolution into normal components. The following distinction is proposed :

3) Some 6 p.cent of the males and 9 p;cent of the females are squid with mantle lengths 14 - 19.0 - 26 cm and 12 - 16.6 - 22 cm respectively. They were encountered at every latitude and more frequently in the 15 - 60 fathom depth level.

4) The largest individuals of the populations are so scarce that the characteristics of their group are doubtful. Ranges and mean lengths of 22 - 29.3 - 35 cm and 20 - 24.5 - 28 cm are estimated for males and females respectively. Males may in fact belong to different age groups.

Sexual maturity of the squid sampled was recorded and it was observed that most of them were immature. Nearly all of the young squid in groups 1) and 2) were fully immature although very few of the males had reached stages I or II if not full maturity even at very small size. The relative number of maturing males increases in group 3) but many of them, in spite of their large size, still are immature. Most males in group 4) are mature or at maturing stage II. Females observed were immature with the surprising exception of 5 maturing and 9 mature individuals, belonging to the three oldest groups, caught in strata to the south of Hudson Canyon. Their presence remains exceptionnal in this season so that our hypothesis relative to the process of maturation in females is not to be modified. It may be due to the higher summer temperature of inshore waters in the south that induce a faster or earlier maturation in some specimens.

The structure of the population sampled is quite alike that observed in previous years (Fig. 2). The usual 3 main components are present : 2 groups of young squid spawned in spring and summer of the same year, and a group of large individuals that is a mixture of age groups from the previous year. We only notice a delay in growth and maturation as mean lengths of the young squid are shorter and their maturity development at earlier stages than usual. This shift may be due to the fact that a much larger area was surveyed this fall ; the characteristics of the sample thus account for the geographical variations already noticed from the results of previous cruises.

In any case the similarity in structure and biological characteristics of the population of Loligo pealei gives no reason for a modification of the life cycle proposed formerly.

II - Illex illecebrosus.

During the summer of 1976, the short-finned squid Illex illecebrosus was present in great abundance in the whole Northwest Atlantic, after several years of relative scarcity. It was also one of the most important species in the catches during our fall survey with 61,770 specimens weighing a total of 19.2 tons, second in weight after the dogfish, third in number after the butterfish and the long-finned squid. The species was distributed at every latitude with

higher abundance in the deepest strata where catches of several metric tons were frequently recorded. The largest catches were performed on strata 4 (8.2 T in 3 sets), 64 (2.5 T in 3 sets), 72 (2 T in 3 sets), 76 (1.9 T in 2 tows) and 68 (1.6 T in 2 tows)., that are all the deepest strata of the Mid-Atlantic shelf. Large quantities were also caught on the northern slope of Georges Bank and East of Cape Cod as Illex were plentiful in Gulf of Maine last summer. Mass strandings occured on the beaches of Northwest Cape Cod where squid were trapped in the Bay and killed by the severe decrease of temperature caused by strong northwest winds. The major abundance in deep waters and big differences between tows there indicate that the offshore migration was developing, so that many large squid were already out of reach of the trawl.

The size frequency distributions in the samples were analyzed and the following groups are identified :

1) About 1 p.cent of the catch in number consist of very young squid 5-15 cm with mean length of 10.7 cm for both sexes.

2) The intermediate group is very badly represented with only 0.2 p.cent of the total number of specimens. Males have mantle length range and mean 13 - 16.7 - 20 cm, females 13 - 18.1 - 22 cm.

The small and medium squid from these 2 groups were mainly encountered on strata 3, 74 and 75 and very scarce elsewhere.

3) More than 98 p.cent of the catch consist of the large squid commonly found in this season. Males range 19 to 25 cm with mean length of 22.8 cm, females from 21 to 31.5 cm with mean length of 27.0 cm. Females tend to have a bimodal size distribution with secondary modes on the 25 and 28 cm classes. Males and females show very little geographical variations of their mean length.

Each of the size groups mentionned is related to particular maturity stages, as far as males are concerned, females being all immature. Males in group 1) all are immature, those in group 3) all mature, while most members of group 2) are at maturing stages I or II with some of the largest mature and some of the smallest immature. A noticeable exception to the usual rule is the presence of a mature 24 cm female caught in stratum 68.

Thus the structure and characteristics of the population surveyed are quite similar to those observed in preceeding years but there are some interesting differences with the size distributions observed last fall (Fig. 3).

The groups of young and medium squid were widely dominant in the whole area surveyed in autumn 1975 (MESNIL et al., 1976) and

this called for a new representation of the life cycle of the species. The youngest squid are assumed to hatch in late summer in deep waters where they are spawned, to appear more or less regularly on the shelves as small squid in fall, and to form the group of medium squid migrating onto the shelves in spring. From this hypothesis, we suggested that the great abundance of these small autumn squid in 1975 would provide a strong class of Illex in spring and summer of 1976, and this actually was the fact as can be seen with the still strong group 3).

The problem with the young autumn squid is that the modalities of their migrations at that time are unknown. Most often, they are very scarce on the shelf and may remain offshore where they are spawned till the first spring, unless they are still pelagic at that stage and thus hardly catchable with bottom trawls. A reason could be the scattering of the pelagic larvae by oceanic currents and the migration towards the shelves would be possible only for the most developped individuals. The same questions arise when the medium squid are concerned since they are also irregularly present in autumn samples. Consequently, we cannot determine the actual level of recruitment for next spring and summer fisheries, only supposing that it will be lower than in 1976. We may however expect that these small squid should be numerous in some place since they were spawned by the group of medium squid that was relatively important in the previous fall.

If we refer to our schemes, the large amount of adult squid this fall should allow a successful winter reproduction and, if the mortality rate is not too high, a good recruitment of medium squid in late 1977 providing a high stock level in the course of 1979. This favourable prospect is permitted since the hypothesis concerning the life cycle of the species were confirmed by the results discussed here.

III - Biomass and stock size estimates.

As most biological and dynamical parameters cannot be determined and included into models yet, the simplest way of estimating stock sizes is the method of aerial expansion although it is far from being plainly satisfactory. However, it is interesting to take advantage of the stratified random sampling adopted for the cruise that minimizes some biases.

In each stratum i, the total area of which is Ai, let ni be the number of stations, bi the total area swept during the ni tows ($bi = ni \times b$ if b is a standard or mean surface swept), and Yi the total catch in the stratum (weight or number). The stock size in each stratum i is given by :

$$Bi = \frac{Ai}{bi} \times Yi \text{ (or, with a standard b, } Bi = \frac{Ai}{b} \times \frac{Yi}{ni} = \frac{Ai}{b} \times \overline{Yi})$$

and for any set of strata, $B = \mathrm{Sum}_i\ (Bi)$.

If now s_i^2 is the variance calculated between the results of the ni tows realized within the ith stratum, the variance of B is given by :

$$S_B^2 = \mathrm{Sum}_i\ \left(\frac{Ai^2}{bi^2} \times ni \times s_i^2\right),\ \left(\text{or} = \mathrm{Sum}_i\ \left(\frac{Ai^2}{b2} \times \frac{Si^2}{ni}\right)\right)$$

The square root of this variance, standard error of the estimate B, is thus affected by the aerial expansion factor and by the variance between hauls in each stratum and is inversely proportionnal to the number of strations in each stratum of the set since bi = ni x b.

In 3 strata (63, 14 and 15) where only one tow was realized, the catches were pooled with those in the nearest stratum at the same depth level (67, 11 and 12) and a common variance was attached to each pair. The results of calculations of stock sizes ans standard errors are summarized in table 2. As already pointed out, the estimates relative to each stratum could not be presented easily and were thus summed into 5 sets of strata labelled I to V from south to north, the first 3 of which grossly correspond to ICNAF subareas 5 Zw and 6 A to C.

For Loligo pealei, the total estimates come to 74,200 T and 1.7 billion individuals, with 67,600 T in the 3 southern zones. The precision is rather correct with a standard error of about 10 p.cent of the estimates. This may be due to the fact that Loligo has a true benthic mode of life so that it can be sampled accurately with bottom trawls, and that its distribution pattern is quite regular with even gradients according to latitude and/or depth so that the different strata are homogeneous units with low inner variance. Moreover, it is distributed mainly over the large mid-shelf strata where sampling effort is most intense. There remains an important gap with the absence of data concerning the inshore areas where lots of squid, that might show different age structures, could probably be found, and our figures thus are certainly underestimates.

The estimates of abundance of squid Loligo have some interest since all the age groups encountered this fall will be represented in fisheries next spring and summer when they come back to spawn of feed inshore. At that time, the mean weight of the young squid, that are 98 p.cent of the population sampled, will be about twice the present 40 g. On the basis of 1 billion individuals, the biomass could then approach 100,000 T. With regard to the shortness of the life cycle, the high reproduction potential and the extreme post-breeding mortality, the present level of the TAC at 44,000 T could be an overcautious, if not wasting, measure.

The same calculations were made for Illex illecebrosus of which biomass and stock size are estimated at 95,000T and 307 millions individuals in the surveyed area. The confidence level of these estimates is rather low as the standard error is important : 20-25 p.cent of the estimates, and this is obviously visible in the raw data. The very important variances observed in some strata and particularly in those where the highest catches were performed may be due to the following reasons : first of all, Illex is more a nektonic than strictly benthic species, migrating to upper layers at night, and the catchability with our shallow opening trawls is therefore low and irregular. Moreover, the species is actively migrating and many individuals had already reached the deep waters of the southern slope of the Mid-Atlantic shelf, while the young and medium squid were hardly represented in shallow strata. This results in irregular distribution and catches within the strata considered and high inner variances, thus certainly a strong underestimation of the biomass. Let us stress also the fact that Illex is distributed over a very large area in the Northwest Atlantic constituting an unique stock out of which a very little part was actually sampled during our cruise.

In any case, the figures are of little interest, except for giving a short term picture of possible abundance, since 98 p.cent of the individuals considered belong to an age group that will spawn and die during the coming months and be anyway lost for the fisheries. In that point of view, the regulations tending to locate the fishing efforts on outer shelf in fall rationalize the exploitation of the population of Illex in the area.

As for the aerial expansion method used, its intrinsic deficiencies are well known (SISSENWINE, 1976). Errors come primarily from inaccuracy in the determination of distances and actually swept areas, plus variations in geographical and vertical distributions of the species considered that affect catchability and consequently the precision (as measured by the standard error) of the estimates. The use of data from stratified random sampling however attenuates some of these deficiencies. The stratification provides a partition of the expected distribution into homogeneous subunits among which only those where the species is present are considered, with their particular density, thus fitting better to the true distribution, while the random selection of stations avoids biases due to schooling and other similar phenomenons.

Although some reserves are to be maintained, the figures presented may give useful indications.

Summary.

- The structure of autumn populations of squid Loligo pealei and Illex illecebrosus on Southern New England and Mid Atlantic shelves is analyzed with regard to size and sexual maturity.

- The population of Loligo pealei shows its classical structure in this season with a majority of young squid from spring and from summer brood, plus some larger individuals hatched in the previous year. The great abundance of the youngest squid in southern strata, the lower mean size and late induction of maturity of the young-of-the-year are noticed. If not fully confirmed, the hypothesis concerning the growth and life cycle of this species remains consistent.

- As for Illex illecebrosus, one of the component life cycles is confirmed as the large autumn squid, grown from the medium spring and from the exceptionnally numerous small squid in late 1975, were particularly abundant in 1976. On the contrary, the young-of-the-year were scarcely represented in the catches ; even so, their presence indicates that the typical structure is with 2 groups of young-of-the-year : immature summer brood and maturing spring brood, and a group of larger squid hatched in the previous year among which the males are mature.

- Biomass and stock size estimates of squid in Subarea 5 Zw and continental shelf parts of Statistical Area 6 were calculated by aerial expansion method on data from stratified random sampling. It results in a probable estimate of 1.7 billion Loligo weighing some 74,000 T and certainly underestimated 95,000 T and 307 millions of Illex.

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Table 1. *Loligo pealei* - Analysis of size distribution - October-December 1976.

Zone		1	2	3	4
I	M	2 - 6.8 - 11 ; 39 %	6 - 12.0 - 17; 55 %	13 - 18.8 - 25; 5 %	17 - 25.2 - 31; 1 %
Str. 61 - 68	F	1 - 6.4 - 11 ; 30 %	7 - 11.5 - 15; 61 %	10 - 15.0 - 24; 8 %	16 - 22.0 - 28; 1 %
II	M	2 - 8.3 - 14 ; 68 %	3 - 10.7 - 20; 25 %	12 - 17.8 - 26; 7 %	25 - 35 - 0.3 %
Str. 69 - 76	F	2 - 8.2 - 14 ; 66 %	5 - 10.9 - 18; 25 %	13 - 17.5 - 22; 8 %	18 - 22.6 - 26; 1 %
III	M	2 - 8.0 - 12 ; 44 %	5 - 10.8 - 19; 49 %	13 - 20.7 - 28; 6 %	22 - 29.0 - 35; 1 %
Str. 1 - 8	F	2 - 8.0 - 12 ; 44 %	5 - 10.9 - 16; 50 %	12 - 17.7 - 24; 5 %	22 - 28 ; 1 %
IV + V	M	2 - 8.3 - 15 ; 73 %	7 - 12.5 - 18; 23 %	16 - 20.4 - 24; 3 %	25 - 29 ; 1 %
Str. 9 - 15 + 23 - 25	F	2 - 7.8 - 14 ; 79 %	8 - 12.7 - 16; 17 %	15 - 18.2 - 22; 3 %	22 - 25 ; 1 %
TOTAL	M	2 - 8.1 - 12 ; 62 %	7 - 11.9 - 16; 32 %	14 - 19.0 - 26; 6 %	22 - 29.3 - 35;0.3%
	F	1 - 7.6 - 11 ; 49 %	7 - 11.1 - 14; 42 %	12 - 16.6 - 22; 9 %	20 - 24.5 - 28;0.2%

Table 2. Catches, biomass, and stock size estimates and their standard error - weight and number.

Zone	Number of Stations	Loligo pealei			Illex illecebrosus		
		Catches	Stock	Standard error	Catches	Stock	Standard error
I	23	609 kg	6 367 T	1 279 T	4 183 kg	8 747 T	3 933 T
Str. 61-68		13 078	179 M	49.8 M	15 388	32 M	6 M
II	25	1 355.5 kg	33 445 T	5 620 T	4 368 kg	11 970 T	4 042 T
Str. 69-76		32 704	768 M	144 M	14 837	47 M	14 M
III	26	717.5 kg	27 851 T	3 388 T	8.941.5 kg	42 934 T	17 688 T
Str. 1-8		15 520	572 M	88.5 M	26 265	130 M	52 M
IV	17	135 kg	6 347 T	940 T	602 kg	11 555 T	10 449 T
Str. 9-15		3 417	153 M	22 M	1 929	37 M	32 M
V	14	14 kg	243 T	115 T	1 065 kg	19 814 T	5 105 T
Str. 21-25		499	10 M	4 M	3 215	61.5 M	16 M
TOTAL W	105	2 831 kg	74 253 T	6 752 T	19 159 kg	95 020 T	21 907 T
N		65 218	1 682 M	177.5 M	61 634	307.5 M	64.6 M

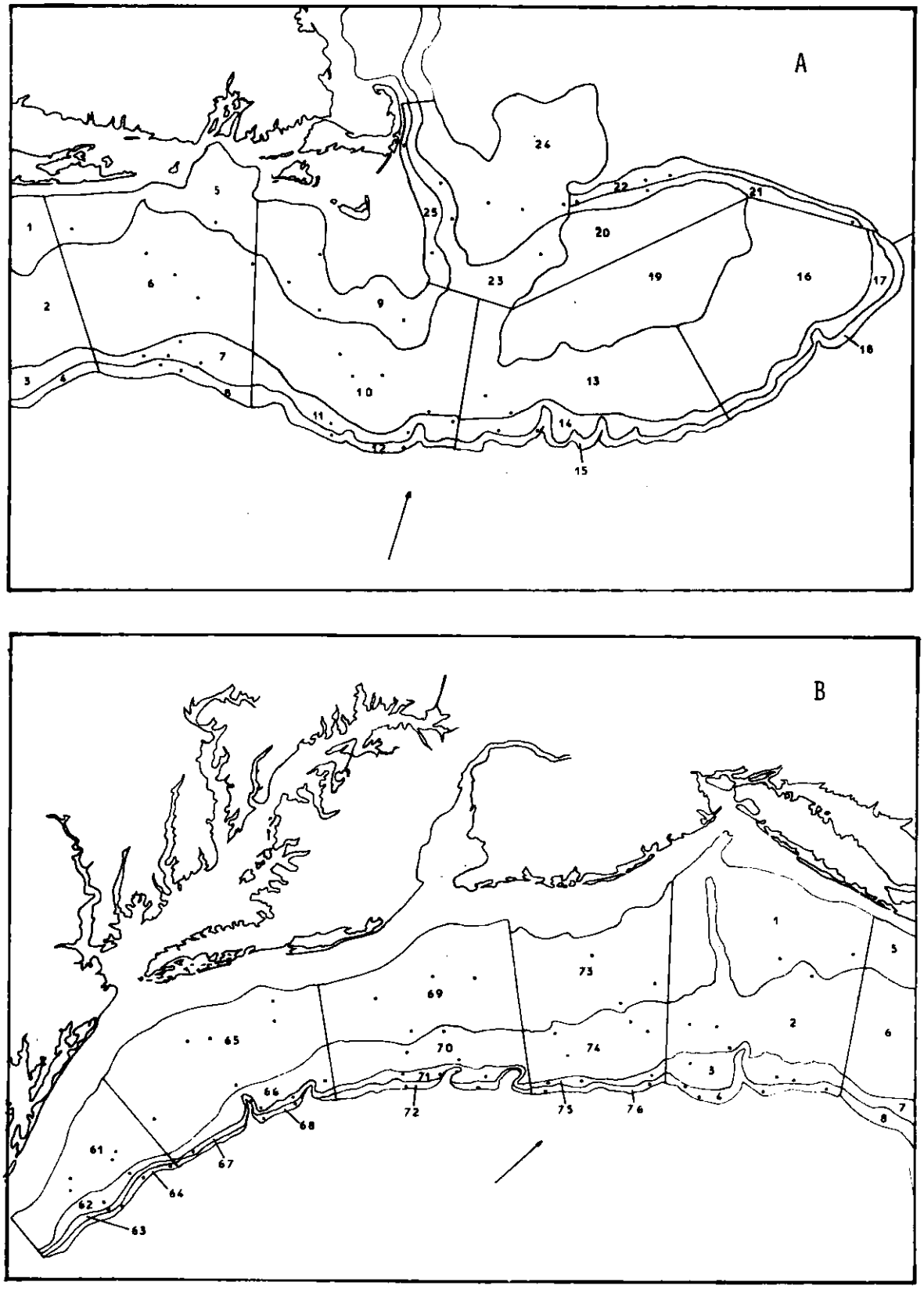

Fig. 1. R/V *Cryos* cruise - 28 October-6 December 1976 - Positions of stations.
A = northern part; B = southern part.

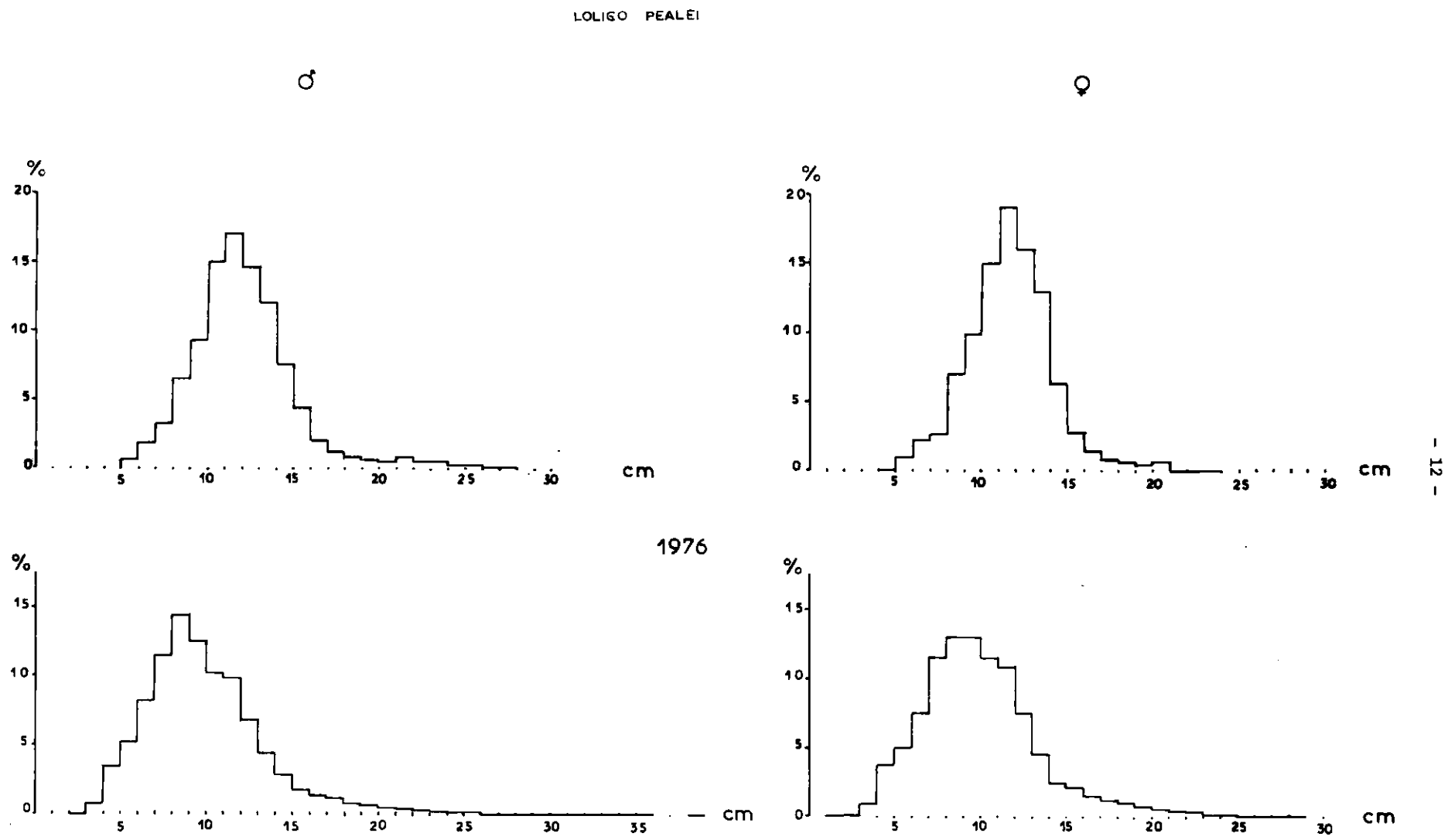

Fig. 2. *Loligo pealei* - Length frequency distributions in 1975 and 1976 autumn surveys.

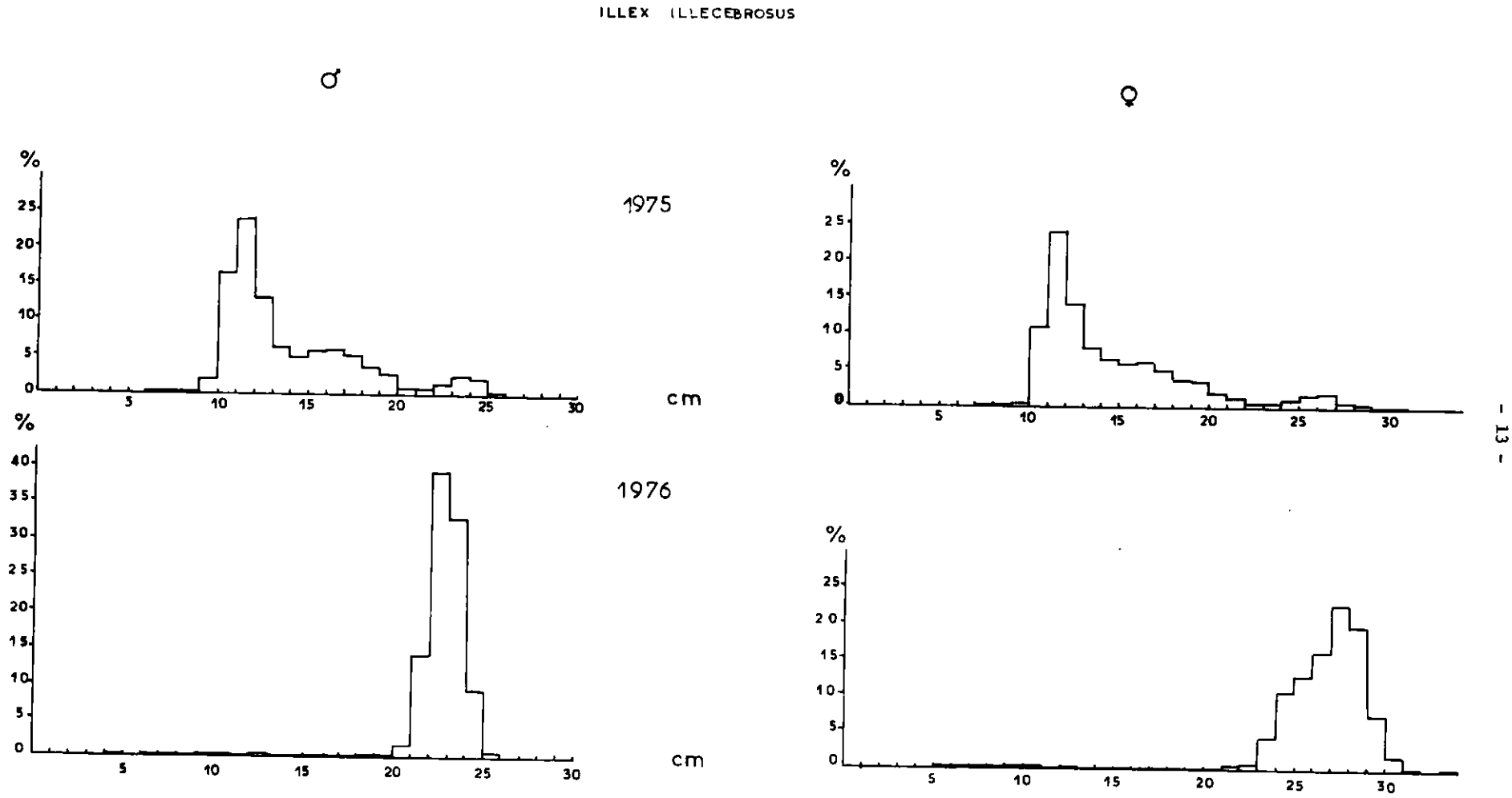

Fig. 3. *Illex illecebrosus* - Length frequency distributions in 1975 and 1976 autumn surveys.