International Council for the Exploration of the Sea

C.M. 1977/H:37
Pelagic Fish (Northern) Committee

ON THE INTERPRETATION OF THE CENTRAL ZONE IN OTOLITHS OF CAPELIN FROM THE BARENTS SEA

by

Johannes Hamre
Institute of Marine Research
P.O.Box 1870-72 N-5011 Bergen, Norway

ABSTRACT

The present paper deals with biological aspects associated to the width of the central zone in capelin otoliths. It is found that the central zone represent the 0-group growth even in cases when the radius of the zone is as small as 0.05 mm. The investigation shows that the capelin with central zones less than 0.20 mm are mainly distributed in the south-eastern part of the Barents Sea during their first year of life. The component of this small 0-group capelin constitutes a major part of the strong yearclasses recruited after 1970. The bulk of the small 0-group capelin, which may be recruited from summer spawners, matures as spring

spawners at 5 years of age, whereas the recruits of the spring spawners, which is far the dominating spawning group, normally mature at 4 years. The increased strength of the small 0-group capelin has thus changed the age composition of the spawning stock and added a new cohort to the immature part of the population. This has to a large extent effected the Norwegian capelin fishery.

INTRODUCTION

Scales of capelin do not develop during the first year of life. Otoliths has therefore been prefered in age readings. The zones in capelin otolith are relative well pronounsed, except for the first one which may be difficult to detect particularly in older sepcimens.

Various ways of reading and interpreting the central zone in capelin otoliths are described in the literature. Some workers have omitted the central zone in their age reading(RAKHMANOVA 1928, PITT 1958), others have counted the central zone as the first winter ring (HANSEN 1943, KANNEWORFF 1968, VILHJALMSSON 1968, PROKHOROV 1968), and some workers have counted the central zone in special cases only, according to size and structure of the otolith center (TEMPLEMAN 1948, 1968, WINTER 1974).

Norwegian scientists have previously used the method described by PROKHOROV (1968). PROKHOROV, who worked on Barents Sea capelin suggested that even the smallest sign of an inner center should be counted as the first winter ring.

In recent years, when abundance eastimates of capelin by the acoustic method became available, it turned out that using the age reading suggested by PROKHOROV the density distribution of the 1-ringers in early summer did not correspond to that observed in late autumn. On the other hand the abundance estimates of

1-ringer coinside well when the zone is interpreted as described by TEMPLEMAN (1948, 1968). Based on these evidences we decided to change our age reading accordingly.

The present paper deals with recent research carried out to check the validety of the methods used in our age reading.

Templeman's method of age determination

An outline of the method of age reading described by TEMPLEMAN (1948, 1968) is necessary for the understanding of the problems involved in the present study. TEMPLEMAN's work refers to Newfoundland capelin which spawn during summer and autumn.

In reflected light the center of the capelin otoliths does normally appear as a broad tranclusent nucleus, without the inner limit which makes a typical winter zone look like a narrow tranclusent ring. In the cases of small sentral zones, the otolith center of capelin appears to be somewhat similar to the otolith center of an autumn spawning herring. TEMPLEMAN interpreted this center to be assosiated to the larval growth up to some 3 cm in body length, i.e. that the tranclusent structure of the center was independent of the time of the year the center was formed. TEMPLEMAN assumed that the 0-group capelin was a fast growing fish which in case of summer spawned fry could obtaine a modal length of some 7 cm at the end of the year. The tranclusent center was therefore regarded as an extended otolith nucleus which he termed the larval chech ring. These central zones were omitted in his age reading.

The Newfoundland capelin stock has however also components which spawn in late summer and autumn. The 0-group capelin from these late spawning components should therefore be considerably smaller at the end of the year. In such cases it was reasonable to assumed that no visible opaque otolith material was laid down between the tranclusent center and the first tranclusent winter ring. The otoliths of these smallest 0-group capelin would therefore be characterized by an extended center including bouth the larval check ring and the first winter ring.

TEMPLEMAN observed that the alternate opaque summer zone and the tranclusent winter band corredponded to ridges and grooves on the otolith surface. TEMPLEMAN used this observation to identify the small size 0-group fish, in which the otolith center also included the first winter ring. The specimens which had a broad tranclusent zone and a groove in the center were aged according to the number of tranclusent zones (winter rings), whereas the otoliths lacking the central groove were aged one year younger.

MATERIAL AND METHODS

The Barents Sea capelin stock consist of spring spawners mainly, but some components spawn also in summer and autumn (PROKHOROV 1968). In recent years, the stock has been assessed by acoustic method twice a year, in the summer (June-July) and in the autumn (September-October). When TEMPLEMAN's age readings is applied to the Barents Sea stock one should expect to find:

1. a relative low abundance of 1-ringers in the summer survey,
2. a considerably increase in the abundance of 1-ringers in the autumn survey, and a decrease in the average width of the otolith central zones,
3. a considerably number of post larvae in July with a modal length corresponding to the body length when the larval rings are completed (3-4 cm).

The results of the previous summer surveys compared to those obtained in the autumn are in agreement with the expectations with respect to 1 and 2 whereas the post larvae of the expected size in July has not yet been observed or reported. The low abundance of 1-ringers recorded during the summer survey could be explained by an underestimate of the 1-group fish, because these are often found near the surface and above the range of the echo sounder transducer (DOMMASNES and NAKKEN 1975). However, the corresponding decrease in the width of the otolith center indicated that a new component of 1-ringers enters the stock in the autumn. If TEMPLEMAN's method of age readings was not valid for the Barents Sea stock, i.e. that the central zone always reflect the 0-group growth, a component of small 1-ringers should be found somewhere in July, presumably in the south-eastern part of the Barents Sea.

In order to obtain data for a study of the larval growth and the size and distribution of 1-group capelin, a relevant sampling programme was incorporated in the summer survey in 1976, lasting from 6 June to 10 July. The survey was carried out by the R/V "G.O. Sars", the survey routes and stations are shown in Figure 1. The larvaes were caught by a Bongo 60 net, mesh size 500 μ, towed in 15 min. in 2-15 meters depth. The 1-group capelin were caught by the pelagic trawl used in the international 0-group surveys. The trawl was towed in the surface layers (0-20 m) by the use of additional floats on the headline. The trawl was lowered to deeper layer when echo traces of capelin were observed. In the area south of 71 degrees north no capelin was recorded on the echo-sounder and the trawl stations here are surface hauls only.

Data on density, back-calculated l_1 and distribution of the 1-ringers obtained during the autumn survey in 1976 are given for comparison (Figures 4 and 5). In order to show the effect of the first year growth on the maturing capelin stock, back-calculated l_1 distirbutions of the yearclasses 1970 to 1972 as mature fish are included in the present study (Table 1, Figure 7).

With respect to the sampling programmes and prosessing of the data, reference is made to DOMMASNES (1977).

RESULTS

Figure 2 shows the mean lenght of l-ringers by stations in June-July 1976. It is seen that the size of the l-ringers in the south-eastern area is considerably smaller than in the north-western one, although no well pronounced boundery between size groups does appear from Fig. 2. The largest concentration of l-ringers (trawl catches above 10.000 individuals) was found in the central area (73 to 74 degrees north, 32 to 36 degrees east) and in the south-eastern area (70.30 degrees north, 45 degrees east). In the latter area the capelin were not detectable by our acoustic equipment and the trawl stations were taken at random. The density distribution of the small size l-group capelin was therefore difficult to estimate, but the observation indicate that this was probably the area from which the small l-ringers, entering the stock in the autumn, were recruited.

In Figure 3 are shown length frequency distributions of the radius (R) of the central zone. The samples are grouped in 0.05 mm groups by two areas, east and west of 37 degrees east respectively. The corresponding back-calculated body length (l_1), was obtained according to the equation given by GJØSÆTER and MONSTAD (1977). The curve of the western area is more or less identical to the observation made in previous summer cruises. The length distribution of R is nearly symmetrical, with a peak corresponding to a back-calculated body length of 5.6 cm. Most of these capelin have a l_1 above 4.5 cm. The curve of the eastern area demonstrate larger range in R, and containe a considerably amount of capelin having a l_1, below 4.5 cm, i.e. within the range of the "larval check ring".

The investigation during the summer cruise indicated the existance of two different size groups of 1-ringers, but it was difficult to separate the groups because the smallest fish could not be detected by the available acoustic equipment. Being aware of this possibility, special attention was paid to the problem during the following autumn survey.

Figure 4 shows the density distribution of 1-ringers obtained by acoustic technique in September-October 1976 (DOMMASNES and RØTTINGEN 1977). Two main concentration of 1-ringers appear from this chart, one centered at 76 degrees north, 35 degrees east, the other at 74 degrees north, 36 degrees east. Figure 5 shows the length- and back-calculated l_1-distributions (A and B) of the two components, the samples grouped according to the area north and south of 75 degrees and 15 min. north. The Figures show two different groups of 1-ringers, both with regard to distribution area, and length distribution pattern. The l_1-distribution of the northern one is identical to the l_1-distribution of the largest 1-ringers in Figure 3 whereas the component containing the small sized fish is better pronounced as a separate group in the autumn survey, when the two groups could be located by the acoustic method. The modal $l_1 = 4.2$ cm correspond to the l_1 interpeted as the larval ring.

Figure 4 shows the density distribution in volum. The area integrated total volum, converted to number are $11.8 \cdot 10^{10}$ and $13.6 \cdot 10^{10}$ for the southern and northern one respectively, i.e. the two components are approximately of equal abundance in number.

The component of 1-ringer found in the southern part of the surveyed area in the autumn is obviously the small 1-ringers found in the summer which have migrated north and westward during the periode between the cruises. The interpretation of the central zones in the otolith has thus become a question of the age of the small 1-ringers, which have a modal l_1 of 4.2 cm. In the samples collected in the first week of July, a l_1 of 4.2 cm (R = 0.15 mm) correspond to a body length of 5.8 cm.

Figure 6 shows the catch in number and mean length of the capelin larvae by stations. It is seen that even at the boarder of the larval drift towards north and east the mean length of the larvaes is less than 2 cm (range 0.9 - 2.4 cm). This observation and the small increament in larvae length in the direction of the larval drift provide evidence to conclude that the capelin larvaes do not grow fast enough to reach a model length of 5.8 cm in early July, even in the case of the most early hatched fry. Consequently, the central zone in the capelin otolith with a radius of 0.05 mm or more reflects the first year growth and should thus be counted as the first winter rings.

In Figure 7 are shown the l_1-distribution of the yearclasses 1970, 1971 and 1972 by age of spawning. The data are collected in the winters 1974 to 1976, and consist of capelin in maturity stages 3 or above (DOMMASNES 1977). Details of the plots are shown in Table 1.

The capelin normally spawns only ones (PROKHOROV 1968) and the figure shows a close relationship between the l_1-distribution and the age at which the capelin is maturing. The 3 year old spawners consist of the largest 1-ringers, and those who spawns as 5 year old the smallest one. It may also be noted that the l_1-distriburion of the 4 years old spawners are similar for the 3 yearclasses and coinside to the l_1-distribution of the northern component of 1-ringers found during the 1976 cruises, whereas the l_1-distribution of the 1971-yearclass which spawned as 5 year old fish is similar to the l_1-distribution of the small l-ringers which were found in the southern part of the Barents Sea in 1976 (Fig. 5B).

DISCUSSION AND CONCLUSIONS

The hatching of the capelin larvae in 1976 started in the first week of May, and the front of the larval drift found in June corresponde with the drift of the larvaes as observed during a larvae survey in May. The Bongo net used was tested in August and caught larvaes up to 31 mm in length. Gear selectively should therefore not constitute any serious source of error in the observation on the distribution and growth of the larvae population. Although the area off the Murmansk coast is not properly covered with respect to the larval drift, it seems reasonable to conclude that the southern component of l-ringers with a mean length of 6 cm in July can not originate from the larvae produced that year.

These findings confirm the method of age reaching for capelin proposed by PROKHOROV (1968). Even the smallest central zones should be counted as the first winter ring and the first ring may be overseen unless special attention is paid to the problem, particularly in reading otoliths of older capelin. The l_1-distribution of the 5 year old spawners of the yearclass 1971 compared to that of the yearclass 1975 indicate that rings less than 0.15 mm may have been lost in readings of the old ones (Figures 7 and 5). Such an error should however result in a corresponding "transfer" of individuals to the yearclass 1972. This would be specimens with an extraordinary large inner ring (above 0.30 mm), and the number with large R would be higher. Since this is not observed it may be assumed that such an error is negligible in our readings.

PROKHOROV (1968) assumed that the small inner zones indicated recruits of summer and autumn spawning capelin, but found no reason to separate the stock in different populations. The l_1-distribution of the 1971 yearclass which spawned as 5 years old fish during the spring 1976 confirm this view.

According to PROKHOROV (1968), summer and autumn spawning capelin have been observed in various areas on the Murmansk coast, but the contribution from these late spawning components to the stock was assumed to be relative small. According to our observations some increase in the abundance of summer spawning capelin has taken place since the summer 1975. Although abundance estimate of summer spawning capelin is lacking this component is obviously very small compared to the spring spawning stock.

DOMMASNES and NAKKEN (1977) give abundance estimates of the spawning stocks in the years 1974 to 1976. These estimates have been grouped according to the age composition of the spawning stock and the resulting figures are included in the last column (B) of Table 1. It is seen from the table that the component of the 1971 yearclass spawning as 5-year old fish is of the same order of magnitude as the component spawning at an age of 4 years. Subjected to mortality in one year more than the latter group, including a record catch in the summer fishery of 1975, the component recruited from the summer spawners must therefore have been the dominating group of the 1971 yearclass. This may also be the case with respect to the yearclass 1975. The abundance of the small 1-ringers in the south were probably underestimated in the autumn survey in 1976, due to their frequent occurrence in the surface layers and also due to lacking coverage of their distribution area to the south (Figure 4).

The composition of the yearclasses 1972-1974 are not yet assesst with respect to the relative abundance of the two groups of

1-ringers. Preliminary analysis of samples based on immature fish indicate however that the contributions of the small 1-ringers are considerable, particularly in the yearclass 1973.

In case the small 1-ringers are recruited from the summer spawners only, this imply that the parent stock/recruitment relationship must be quite different for the two groups. Other factors as late hatching of spring spawned eggs and slower growth rate of the larvaes in the south-eastern Barents Sea may however play an important role to this relationship. Further research is therefore needed to provide conclusive evidence to the origin of the small size 0-group capelin.

The capelin yearclasses 1971 to 1973 are extraordinary strong. The increased recruitment has resulted in a corresponding increase in the immature stock, with respect to number, but in terms of biomass the immature stock has more or less remained on the same size level as in 1971 (DOMMASNES and NAKKEN 1975). This imply that the average weight of the fish has decreased. This is partly assosiated to decreased average length, but the weight/length relationship (the condition factor) of the immature capelin has decreased considerably since 1973 (DOMMASNES and NAKKEN (1975). Taking into account that the feeding area of capelin is strictly limited by the ice boarder to the north and east, and by the warm atlantic water current to the south and west, it seems fair to associate this finding to a density-depending phenomenon.

The yearclasses 1974 and 1975 are weaker than the previous ones. The biomass of the immature stock remains however on the same high level, and also in terms of numbers the stock level remains high. The reason to the high number (although recruitment has decreased) is the delay in age of spawning which add a new cohort to the immature stock consisting of 4 years old fish.

Taking into account that the yearly catches of capelin in the years under study have increased by 3 to 5 times compared to the catches in the 1960-ies, it may be assumed that the survival of capelin larvaeshas increased considerably in recent years. One may speculate whether this is associated to the disappearence of the herring from the Barents Sea in the late 1960-ies.

The delay in maturing of the 1971-yearclass had a serious effect on the Norwegian capelin fishery during the winter 1975. Although the yearclass was the most aboundant yearclass so far recorded (DOMMASNES and NAKKEN 1977) the winter fishery became the poorest since 1969. However, this was to some extent compensated by a record catch in the capelin fishery of the following summer and autumn. The summer fishery is mainly based on capelin above 11 cm, and the immature capelin of the 1971-yearclass constituted an additional cohort to the catchable stock in the summer fishery in 1975. More over this cohort, probably recruited from the south eastern Barents Sea, had a more eastern distribution pattern than the remaining juvenile stock. In late June 1975 they were found in large concentrations north of the Skolpen Bank, and formed the main bases for the Norwegian capelin fishery in July-August. This eastern area of the Barents Sea had not previously been fished by the Norwegian capelin seiners during summer. The winter fishery in 1976 became very good and 38 % of the catch consisted of the 1971 yearclass.

REFERENCES

BELTESTAD, A., NAKKEN, O. and SMEDSTAD, O. 1977. Investigations on diel vertical migration of Opgroup fish in the Barents Sea. FiskDir.Skr.Ser.HavUnders.,16 (In print).

DOMMASNES, A. 1977. The Norwegian research program on the Barents Sea capelin stock. Coun.Meet.int.Coun. Explor.Sea,1977 (H:36): 1-8. 3 figs. Mimeo.

DOMMASNES, A. and RØTTINGEN, I. 1977. Capelin investigation in the Barents Sea in September-October 1977. (In press).

DRAGESUND, O., GJØSÆTER, J. and MONSTAD, T. 1973. Estimates of stock size and reproduction of the Barents Sea capelin in 1970-1972. FiskDir.Skr.Ser.HavUnders., 16: 105-139.

GJØSÆTER, J. and MONSTAD, T. 1977. Growth of the Barents Sea capelin of the yearclasses 1967-70. Coun.Meet. int.Coun.Explor.Sea, 1977 (H.37): 1-15. Mimeo.

HANSEN, P.M. 1943. Capelin (*Mallotus villosus*). Greenland. Annls.biol., Copenh., 1: 121-124.

KANNEWORFF, P., 1968. Preliminary results and some problems concerning capelin investigation in Greenland. Rapp.P.-v.R´eun.Cons.perm.int.Explor.Mer,158: 30-40.

MONSTAD, T. 1971. Alder, vekst og utbredelse av lodde (*Mallotus villosus*) i Barentshavet og ved kysten av Nord-Norge i 1968-1970. Thesis (cand.real), Univ. Bergen, 80 p. Mimeo.

NAKKEN, O. and DOMMASNES, A. 1975. The application of an echo integration system in investigations on the stock strength of the Barents Sea capelin (Mallotus villosus, Müller) 1971-1974. Int.Coun.Explor.Sea Coun.Meet. 1975(B:25): 1-9. Mimeo.

NAKKEN, O. and DOMMASNES, A. 1977. Acoustic estimates of the Barents Sea capelin stock 1971-76. Int.Coun. Explor.Sea Coun.Meet. 1977 (H:36) Mimeo.

OLSEN, S. 1968. Some results of the Norweigan Capelin investigations, 1960-1965. Rapp.P.-v.Réun.Cons.Perm.Int. Explor.Mer, 158: 18-23.

PITT, T.K. 1958. Distribution, spawning and racial studies of the capelin Mallotus villosus (Müller) in the offshore Newfoundland area. J.Fish.Res.Bd.Can. 15(3): 275-293.

PROKHOROV, V.S. 1968. Materials on the ecology of capelin in the Barents Sea. Rapp.P.-v.Réun.Cons.Perm.Int.Explor. Mer, 158: 23-31.

RAKHMANOVA, S.I. 1928. Reference is made to Prokhorov 1968.

TEMPLEMAN, W. 1948. The life history of the capelin (Mallotus villosus O.F. Müller) in Newfoundland waters. Nfld. Government Lab.Res.Ser.Bull. 17: 1-151.

TEMPLEMAN, W. 1968. Review of some aspects of capelin biology in the Canadian area of the Northwest Atlantic. Rapp.P.-v.Réun.Cons.Perm.Int.Explor.Mer, 158: 41-53.

VILHJALMSSON, H. 1968. A contribution to the knowledge of the Icelandic capelin. Rapp.P.-v.Réun.Cons.Perm.Int. Explor.Mer, 158: 32-38.

WINTERS, G. 1974. Back-calculation of the growth of capelin (*Mallotus villosus*) in the Newfoundland area. ICNAF Res.Doc. 74/7, Serial No. 3150, Ann.Meeting June 1974.

Table 1. Measurements of the radius of the central zone (R) in capelin otoliths. The figures show frequency (in %) by 0.05 mm groups, by age and years of spawning (n) number measured B) spawning component in mill.tons .

Year of spawning	Age	R_1 in mm $\cdot 10^{-2}$										
		10	15	20	25	30	35	40	45	$\overline{R}_1$	n	B
1974	3		6	20	29	25	12	5	3	27.2	65	0.12
	4	1	11	26	29	23	8	2	0	25.2	332	0.63
	5		4	21	31	28	14	2		26.7	133	0.25
1975	3		3	13	22	25	21	12	4	30.0	106	0.08
	4	2	10	26	29	21	9	2	1	24.9	794	0.65
	5	8	18	23	23	15	8	2	2	23.1	92	0.07
1976	3		5	28	33	23	9	2		25.5	43	0.11
	4		11	30	34	18	5	2		24.1	389	1.01
	5	7	38	33	17	4	1			18.8	260	0.68

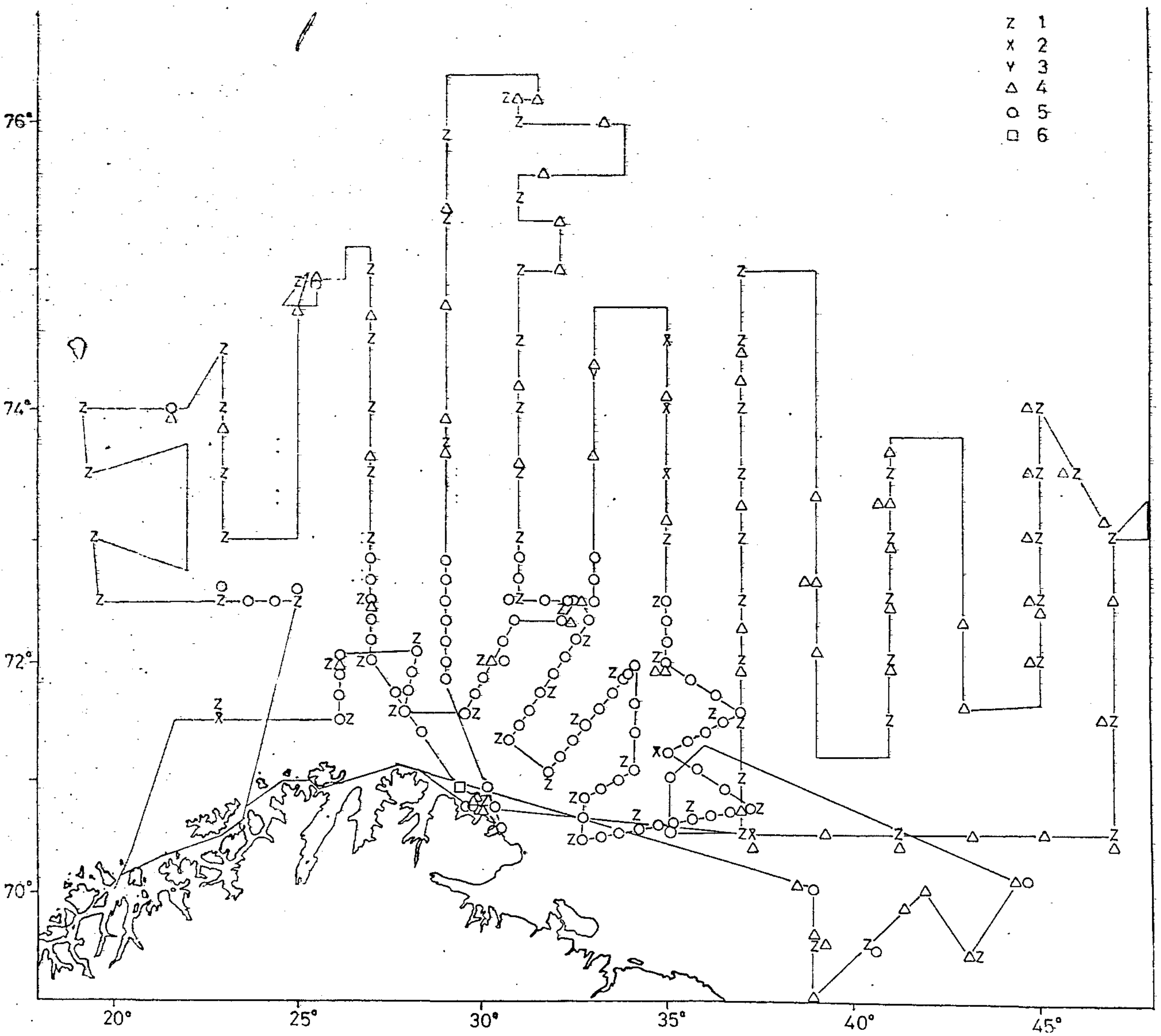

Figure 1. Survey routes and grid of stations, R/V "G.O.Sars" 9 June - 9 July 1976. [1) CTD-sonde, 2) hydrographic station with water bottles, 3) bathytermograph, 4) pelagic trawl station 5) larvae station, 6) bottom trawl station].

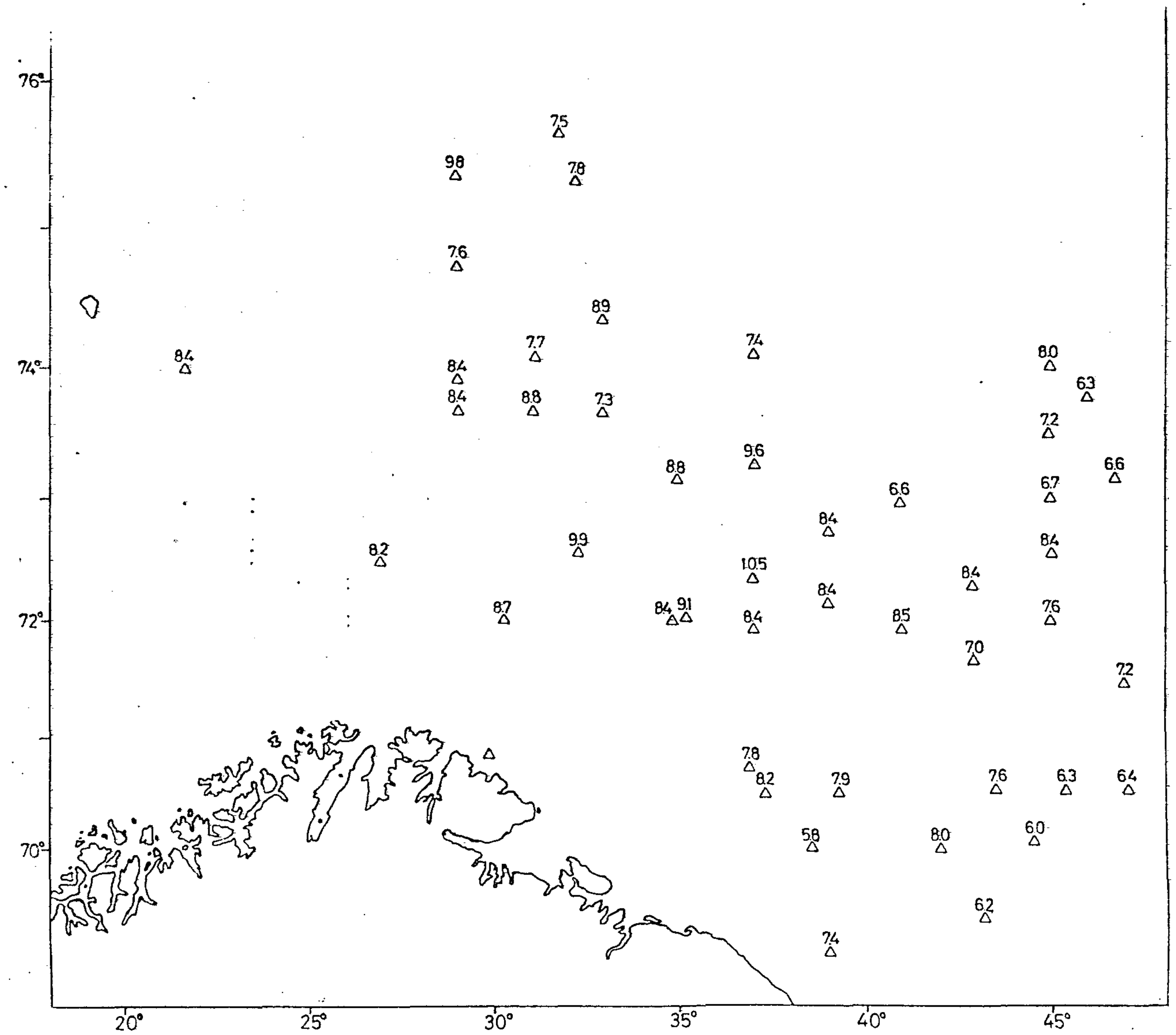

Figure 2. Mean length (in mm) of 1-group capelin by station, 9 June - 9 July 1976.

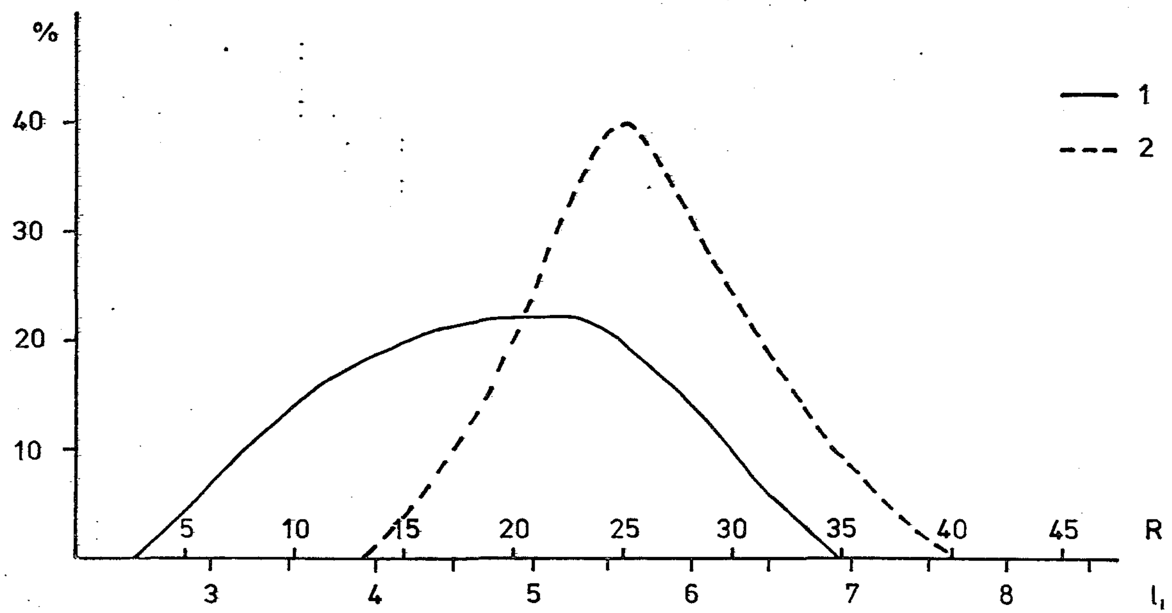

Figure 3. Back-calculated l_1-distribution (in cm) of 1-group capelin in June-July 1976.
[1) The Barents Sea west of E 37^o.
2) Barents Sea east of E 37^o, R) radius of the otolith central zone in mm $\cdot 10^{-2}$].

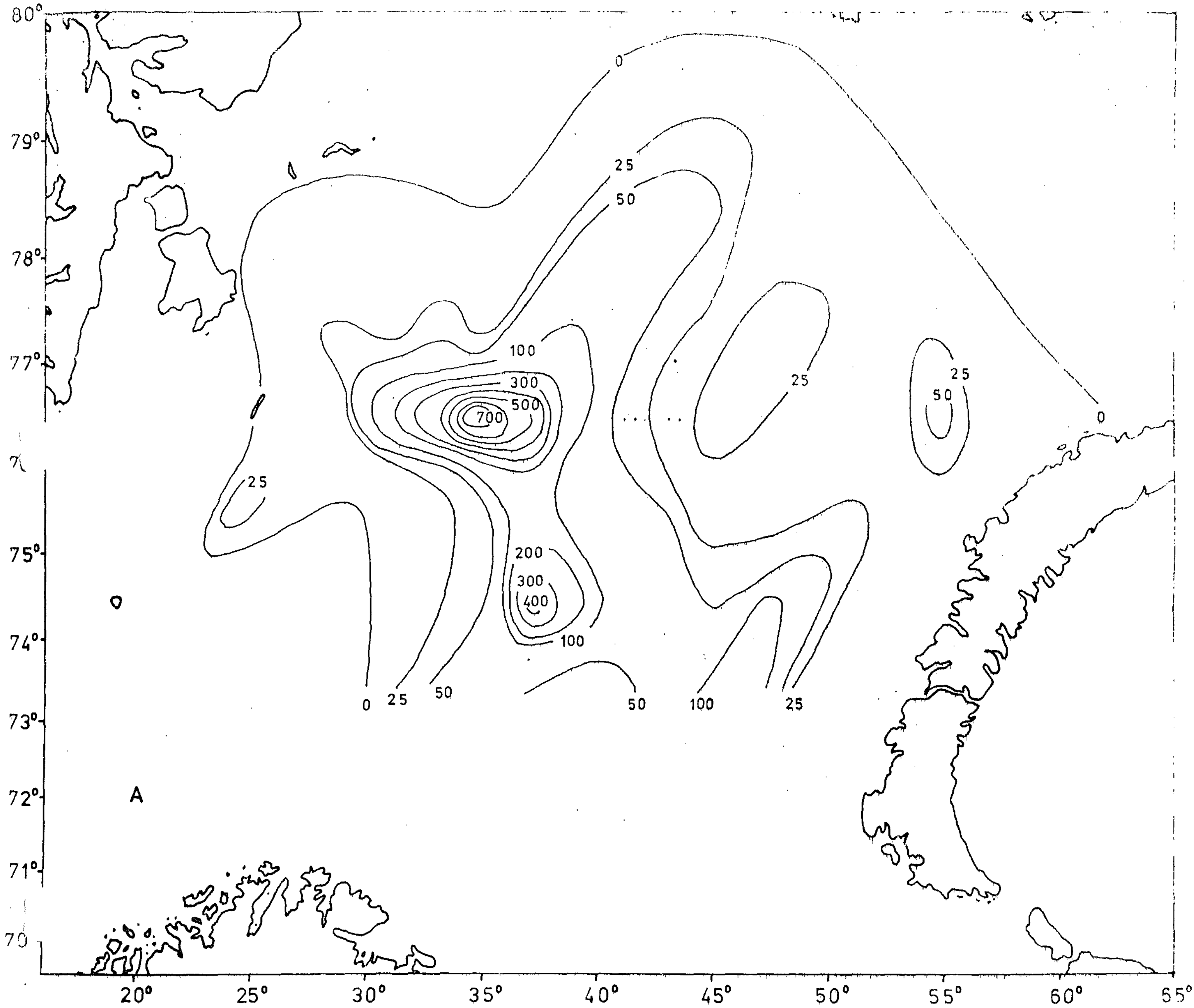

Figure 4. Estimated density distribution of 1-group capelin in September-October 1976 [hl per (nautical mile)^2].

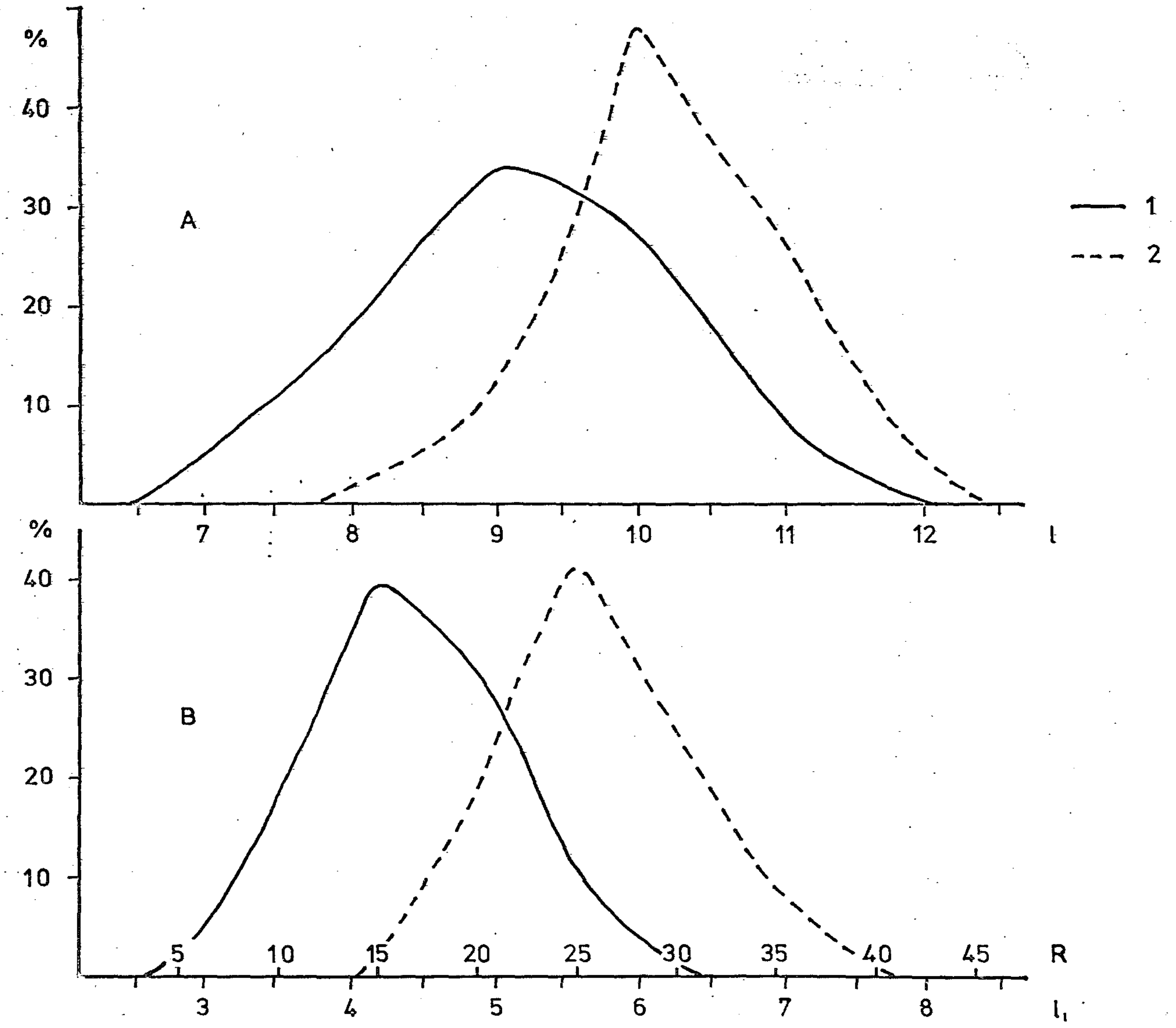

Figure 5. Length frequency curves (A) and back-calculated l_1-distribution (B) of 1-group capelin (l in cm) in September-October 1976. [1) Barents Sea north of N75°15', 2) Barents Sea south of N75°15', R) radius of the otolith central zone in mm · 10^{-2}].

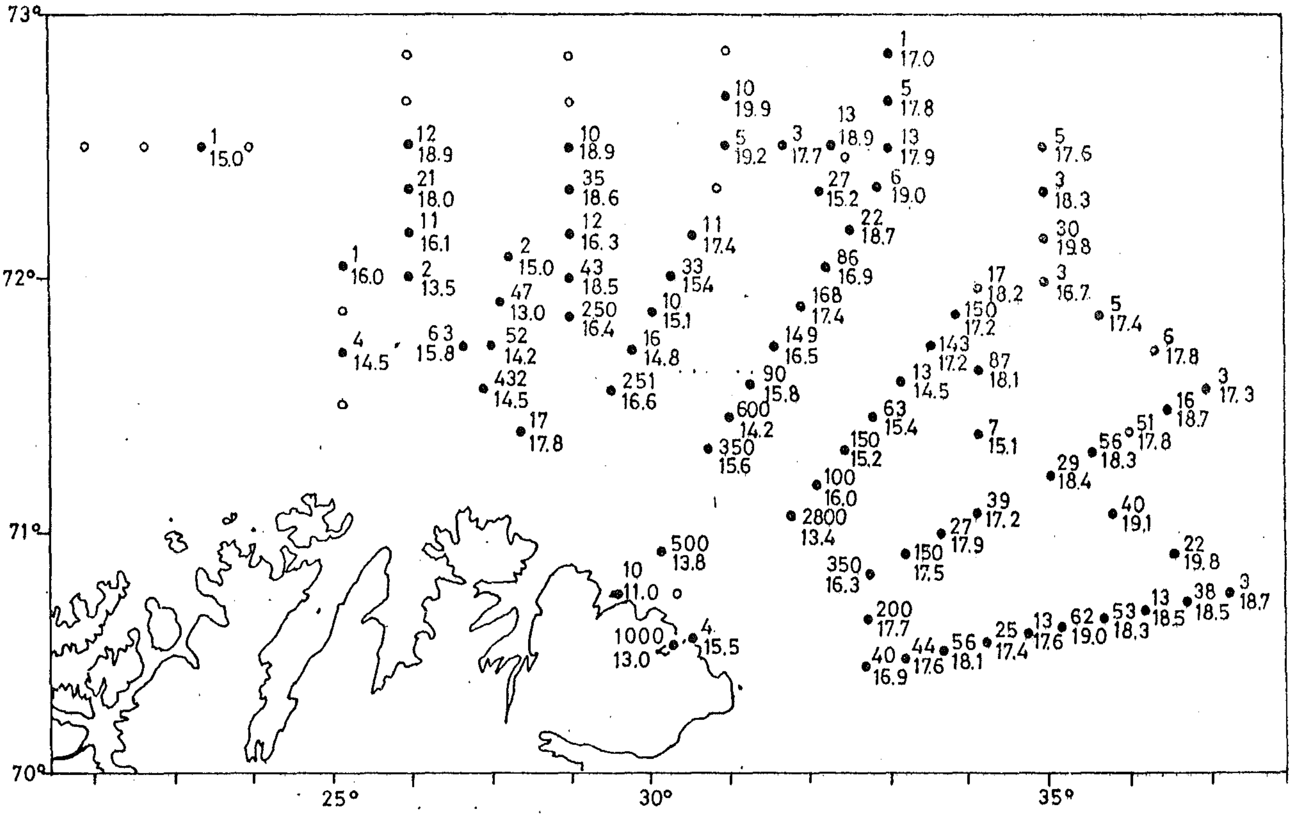

Figure 6. Larvae stations 10-25 June 1976. Number of capelin larvae and the mean length of the larvae in mm by station.

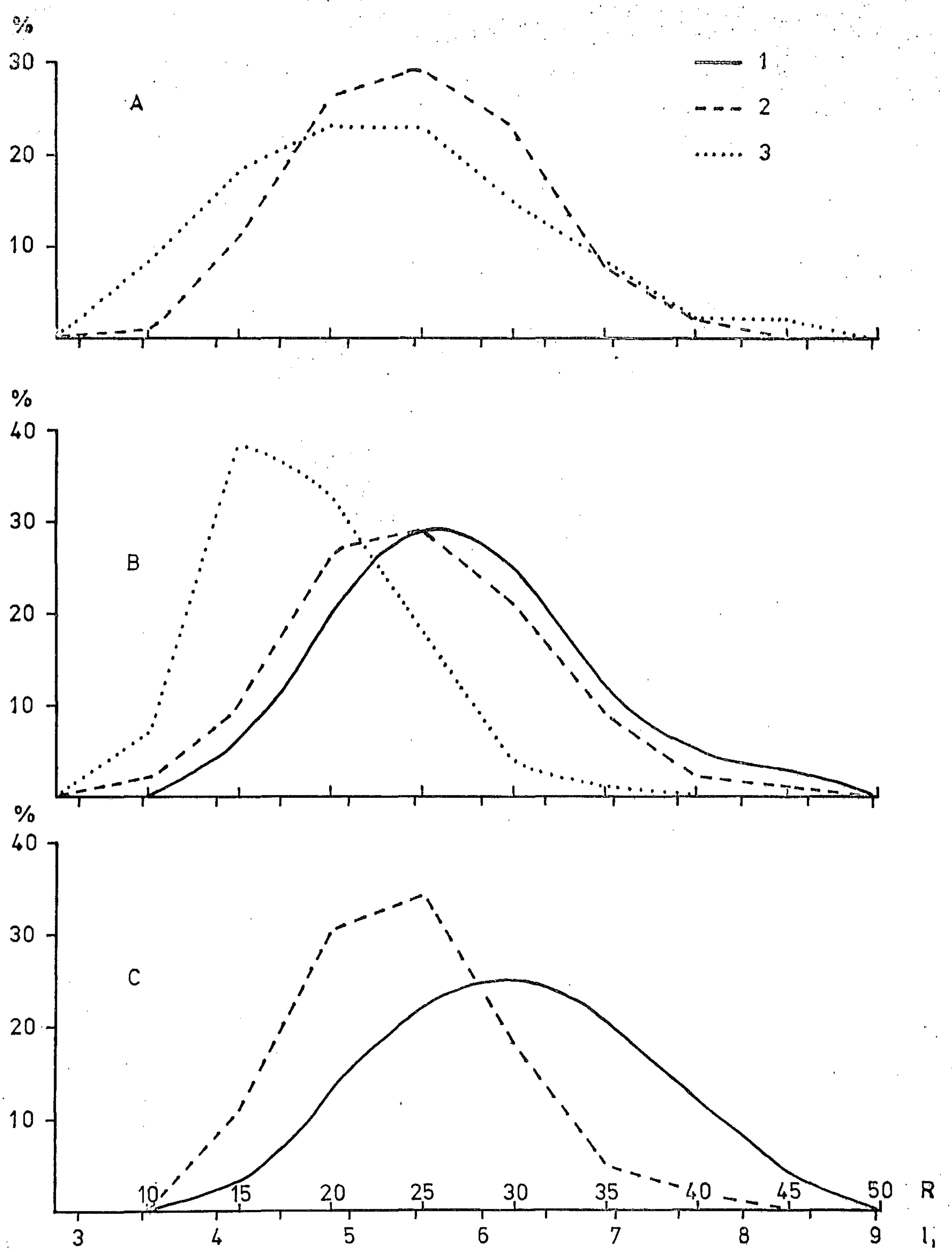

Figure 7. Back-calculated l_1-distribution of the capelin yearclasses 1970(A), 1971(B) and 1972(C).
[1) 3 years old spawners, 2) 4 years old spawners, 3) 5 years old spawners, R) radius of the otolith central zone in mm · 10^{-2}].