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PRELIMINARY RESULTS OF NORWEGIAN POLAR COD INVESTIGATIONS 1970-1972

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INTRODUCTION

The Polar cod, Boreogadus saida (Lep.), has been subjected to increasing exploitation during the last years and besides its commercial importance, the species form a very important link in the food web of Arctic waters.

Facts about its biology, distribution and behaviour have accumulated, but still much is unknown. Few data concerning the size of the stock and its dynamics are recorded.

In this report which is based on Norwegian investigations during 1970-1972, data is given on size, composition and distribution of the stock, on age, growth and mortality, and on the Norwegian polar cod fishery.

MATERIAL AND METHODS

Since 1970 Polar cod has been studied on several cruises in the

Barents Sea (BLINDHEIM *et al*. 1971, DRAGESUND og NAKKEN 1972, GJØSÆTER *et al*. 1972, HYLEN, GJØSÆTER og SMEDSTAD 1972, HYLEN *et al*. 1972, GJØSÆTER og BJERKE 1973).

During these cruises the acoustical equipment was run continuously. Samples,for identification of the echo recordings and for biological analysis, were taken by pelagic and bottom trawls.

Echo integrators (NAKKEN og VESTNES 1970) were used on most of the cruises. Stock size was estimated by using a method described by MIDTTUN and NAKKEN (1971) and BLINDHEIM and NAKKEN (1971).

From most catches, random samples of approximately 100 specimens were taken for biological analysis. Total length was measured to the nearest mm, and grouped to the nearest half cm below. Otoliths were removed for later analysis and stored in envelopes.

Samples were also taken from commercial landings. These were frozen and sent to the laboratory in Bergen for analysis.

Otoliths were cut transversely through the nucleus, and viewed under a binocular microscope by using transmitted light. Total diameter and diameters of the 3 first hyaline zones were measured by an eye-piece micrometer.

RESULTS AND DISCUSSION

Studies of the otoliths

In some samples the edges of the otoliths were recorded according to the following scale:

1 narrow opaque
2 broad -"-
3 narrow hyaline
4 broad -"-

The result (Fig. 1) indicates that the opaque zones are formed during autumn. Although spring samples are lacking, it appears reasonable to conclude that the opaque zones are formed only once a year.

Some otoliths made transparent by using absolute ethanol and glycerol were used to check the sensitivity of diameter measurements to variation in the breaking point.

Diameters of 1. hyaline zone were measured parallel to the short axis of the otoliths through the centre and at 0.4 mm on both sides of these (Fig. 2). The results (Table 1) show that measurements at a section 0.4 mm from the centre give inaccuracies between

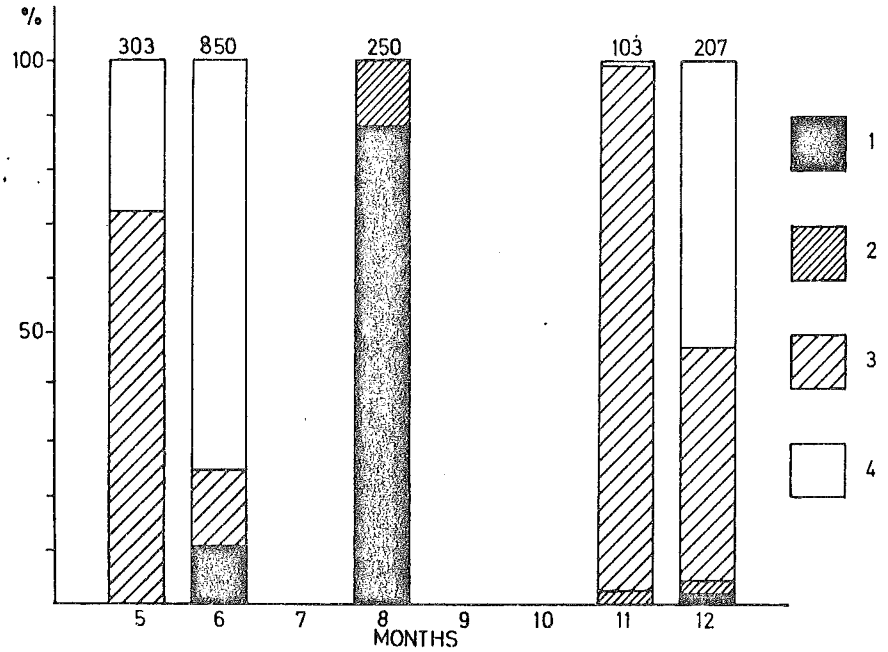

Fig. 1. Distribution of otolith edge characters.
1, Narrow, 2, broad opaque, 3, narrow,
4, broad hyaline.

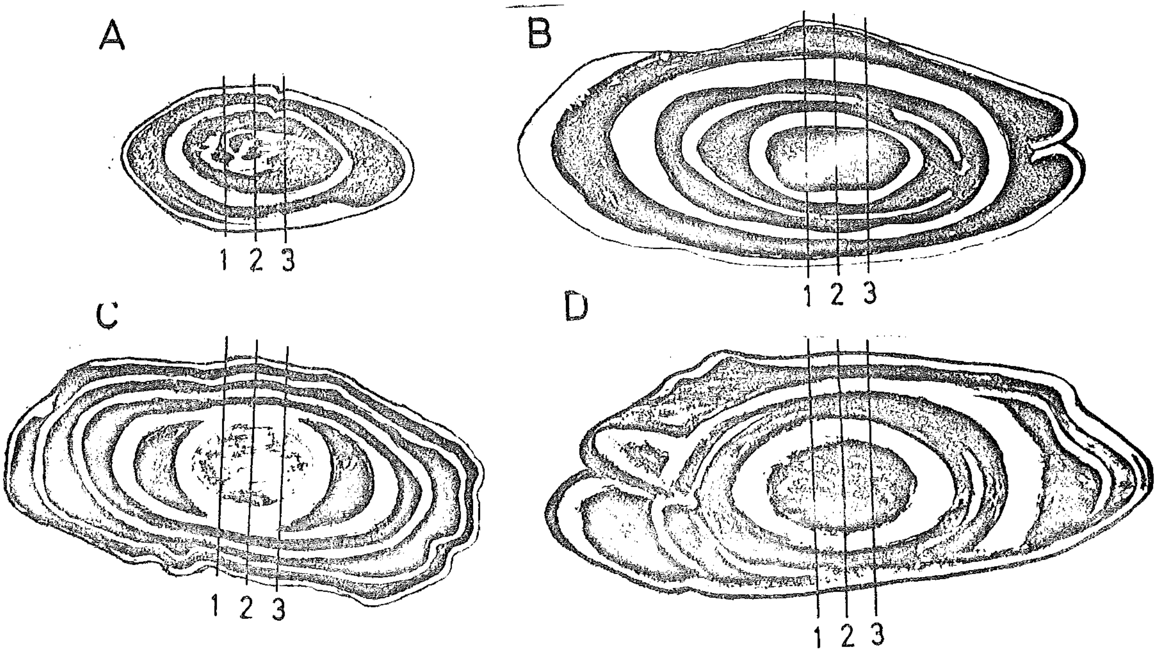

Fig. 2. Measurements of hyaline zones in transparent otoliths.

Table 1. Diameters of 1 hyaline zone (in ocular units) and back calculated fish lengths (see (Fig. 2)

Otolith no.	Measurement no. 1 d	1 %	2 d	2 %	3 d	3 %	Back calculated lengths in cm highest	lowest
A	22	92	24	100	24	100	7.2	6.8
B	20	100	20	100	20	100	6.4	6.4
C	24	100	24	100	22	86	7.2	6.8
D	24	86	28	100	26	93	7.9	7.2

0 and 4 %. In most cases, the plane of breaking will be nearer the centrum than 0.4 mm. Back calculation from the first hyaline zone will introduce an underestimation of fish length. The inaccuracy in measurements of the other hyaline zones and the total diameter will be smaller.

A trial plot of otolith diamaters against fish lengths indicated that two nearly straight lines could be fitted, one for the smallest fish and one for fish longer than approx 10cm. Therefore the material was divided at a fish length of 10 cm for correlation studies. Both linear and logarithmic regression lines were calculated. As the logarithmic regressions gave the highest correlation coefficients, only these are used (Fig. 3):

<u>L < 10 cm</u>

$$\lg L = 0.6103 \lg d + 0.0144, \quad R = 0.8806, \quad N = 67 \qquad (1)$$

<u>L > 10 cm</u>

$$\lg L = 1.2225 \lg d - 0.8708, \quad R = 0.8711, \quad N = 1643 \qquad (2)$$

L = fish length in cm
d = otolith diameter in ocular units
R = correlation coefficient
N = number of observations

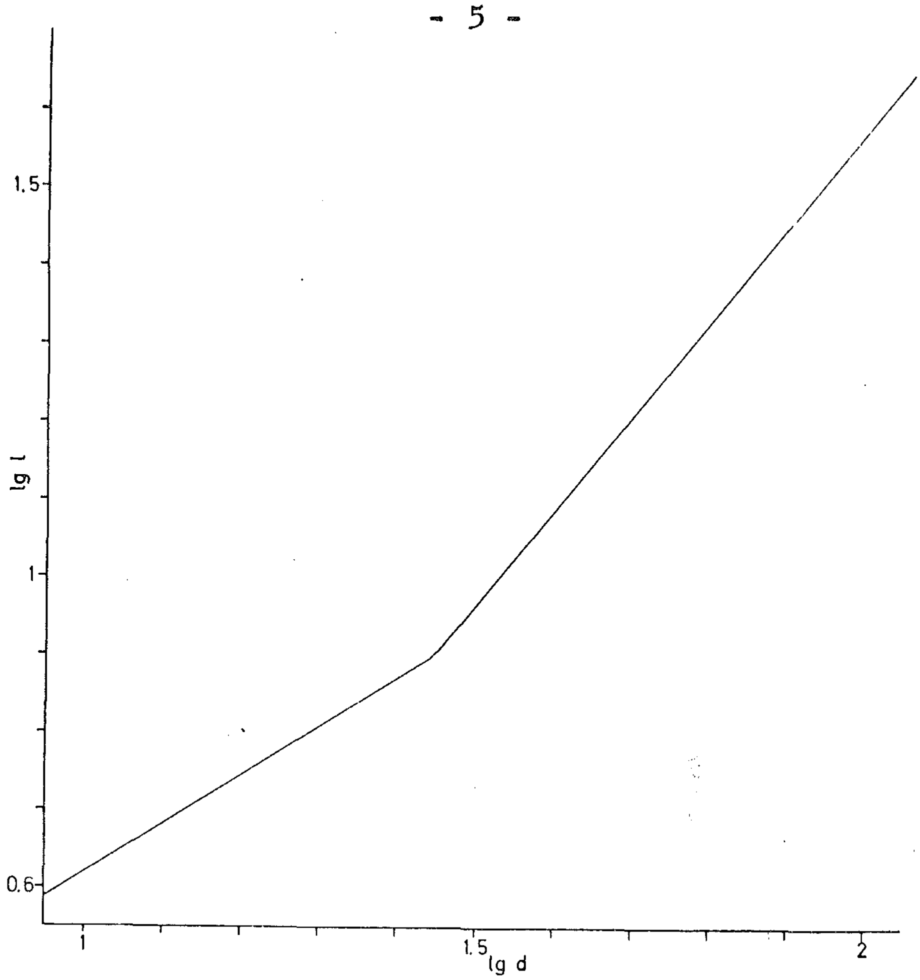

Fig. 3. Logarithmic regression lines for logarithms of fish lengths (in cm) on logarithms of otolith diameters (in occular units = 0.05 mm).

Stock units

The distribution of 0-group polar cod (eg BENKO et al. 1970) suggests that there are two separate spawning areas in the Barents Sea. One area is situated in the south-eastern part of the sea. The exact locality of the other one is not known, but based on the general current system, it is probably found east of Spitsbergen.

Although exeptions exist 0-group polar cod from the Spitsbergen area, caught in September, are usually shorter than those caught in the south-eastern Barents Sea (BENKO et al.1970, ANON 1970, 1972, 1973). If the two spawning areas belong to separate populations, the size difference in the 0-group should be reflected in the first hyaline zone of the older fish provided that the hyaline zones are formed approximately simultaneously in the two areas. If a significant mixing takes place the difference in the hyaline zone should decrease as the fish grow older. Fig. 4 shows a highly significant difference in diameter of the first hyaline zone, and no decrease in the difference is observed. Unfortunately, the material of fish more than 4 years old from the northwestern area is too sparse for comparison.

The measurements are mainly based on the 1968 and 1969 yearclasses, which at the 0-group stage differed approximately 2 cm in length between the two areas.

Polar cod first spawn when they reach an age of 3 or 4 years, and apparently spawn in the area where they were born, for at least the first one or two times.

Although further work should be done on the relationship between these stocks, it appears justified to treat them separately until final evidence is produced.

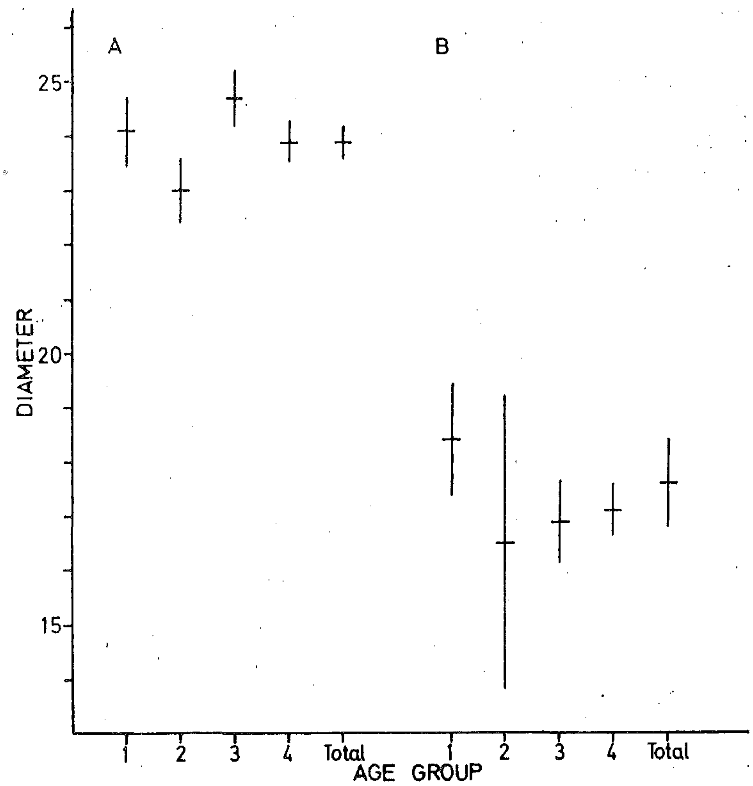

Fig. 4. Mean diameters (in occular units) and 95 % confidence intervals for 1. hyaline zone in otoliths from A, eastern Barents Sea and B, the Spitsbergen area.

Stock size

During August 1972 a quantitative assessment of the polar cod stock in the eastern Barents Sea was undertaken. An area integration of the echointegrator values (Fig. 5) gave 2.7 x 10^6 mm (nautical mile)^2. The high values along the northern and eastern border of the area surveyed, indicate, however, that there was much polar cod outside this area. The total stock is therefore larger than this number indicates.

To determine the absolute size of the stock, a constant C, depending on species and size distribution must be known (BLINDHEIM and NAKKEN 1971, MIDTTUN and NAKKEN 1971). This constant is not calculated for polar cod, but based on experience from other species, it is tentatively set to 0.14 ton/mm (nautical mile)^2 (NAKKEN pers. comm.). About 4 mill. tons of polar cod was present in the area studied. Even if C= 0.10 ton/mm (nautical mile)^2 which is a definite underestimate, there was nearly 3 mill. tons of polar cod within the investigated area. It is therefore concluded that the total stock of polar cod in the eastern Barents Sea is greater than 5 mill. tons.

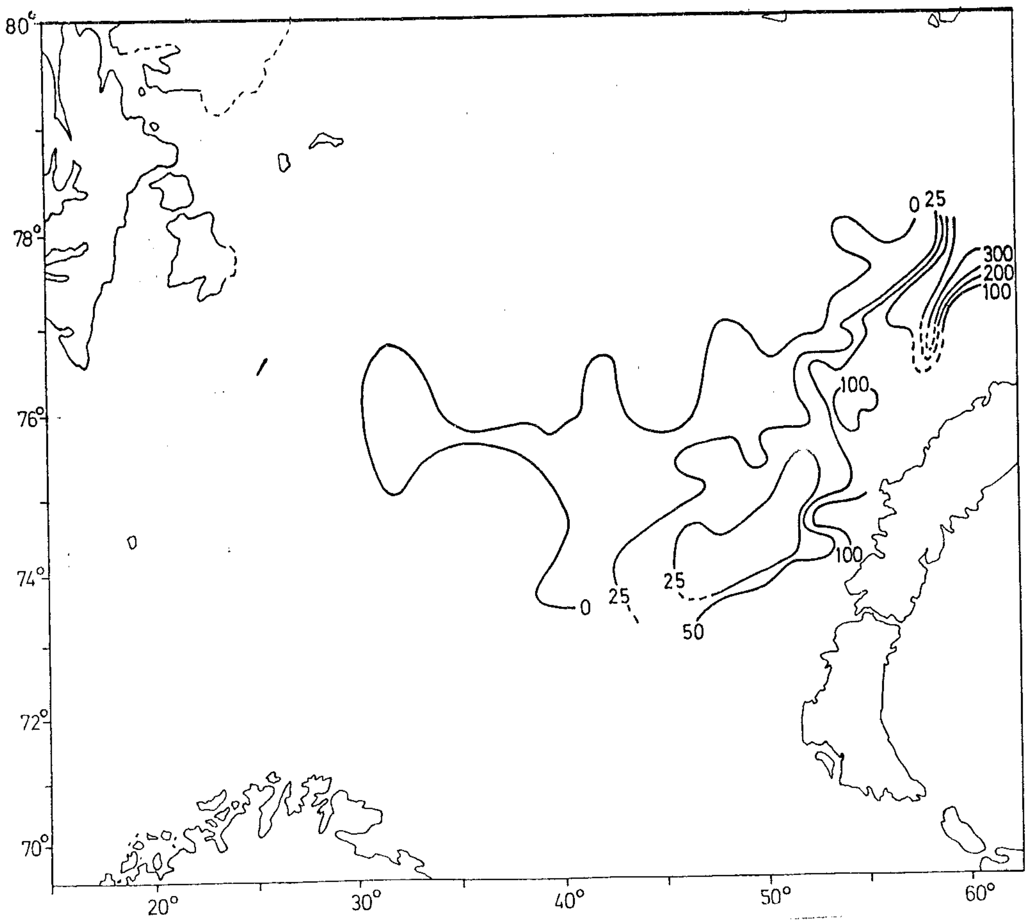

Fig. 5. Echo abundance (mm deflection) of polar cod 5-20 August 1972. (From Gjøsæter *et al.* 1972).

DISTRIBUTION

1970

In June 1970, only a small part of the Barents Sea was investigated. Very dense concentrations were observed between 74°00' - 75°30'N and 44°00' - 47°00'E (Fig. 6) (GJØSÆTER og BJERKE 1973).

In August-September a more extensive part of the southern and western Barents Sea was studied. Dense concentrations were found in the same area as in June. However, Fig. 7 suggests that most of the stock was distributed north and east of the investigated area (BLINDHEIM *et al*. 1971). During November, polar cod were caught by bottom trawls in most of the Barents Sea. The greatest quantities were observed northwest of Goose Bank (HYLEN *et al*. 1972).

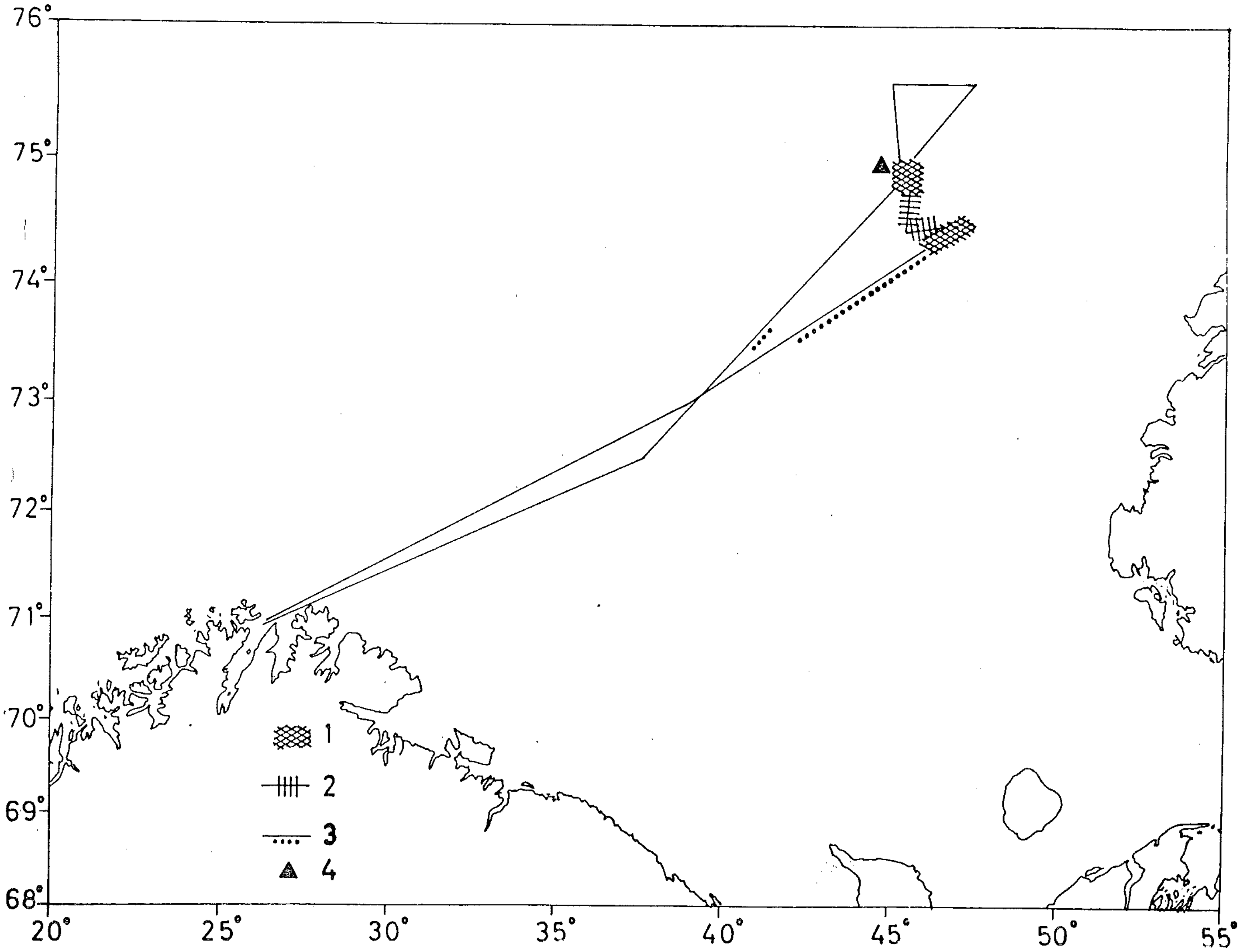

Fig. 6. Recordings of polar cod in June 1970.
1, very dense, 2, dense and 3, scattered recordings, 4, trawl station. (From Gjøsæter og Bjerke 1973).

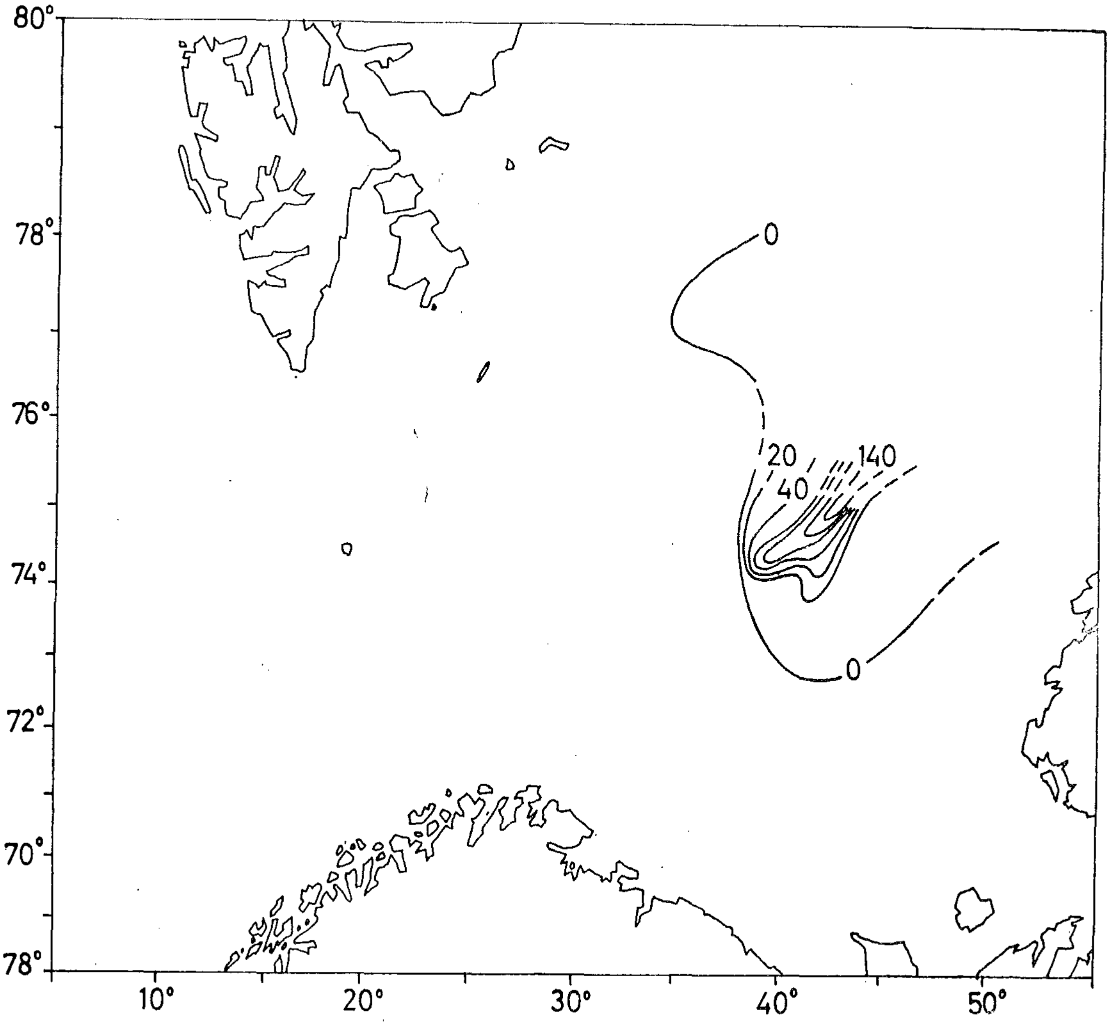

Fig. 7. Echo abundance (mm deflection) of polar cod during August-September 1970. (From Blindheim *et al.* 1971).

1971

In May and June 1971 scattered recordings of polar cod were made at 73°30'N 45°00'E and between 72°00' - 72°30'N, 37°00' - 40°00'E. Fairly dense concentrations were observed in the area 73°00' - 74°00'N 45°00' - 53°00'E (GJØSÆTER og BJERKE 1973). During the same period HYLEN, GJØSÆTER og SMEDSTAD (1972) observed polar cod in an area 71°00' - 73°00'N, 38°00' - 45°00'E. Polar cod distribution in May-June is shown in Fig. 8.

Polar cod observations made during August-September are shown in Figs. 9-10 (DRAGESUND og NAKKEN 1972). The most dense concentrations were observed in the northeastern part of the area, and probably an extensive part of the stock was found north of the investigated area.

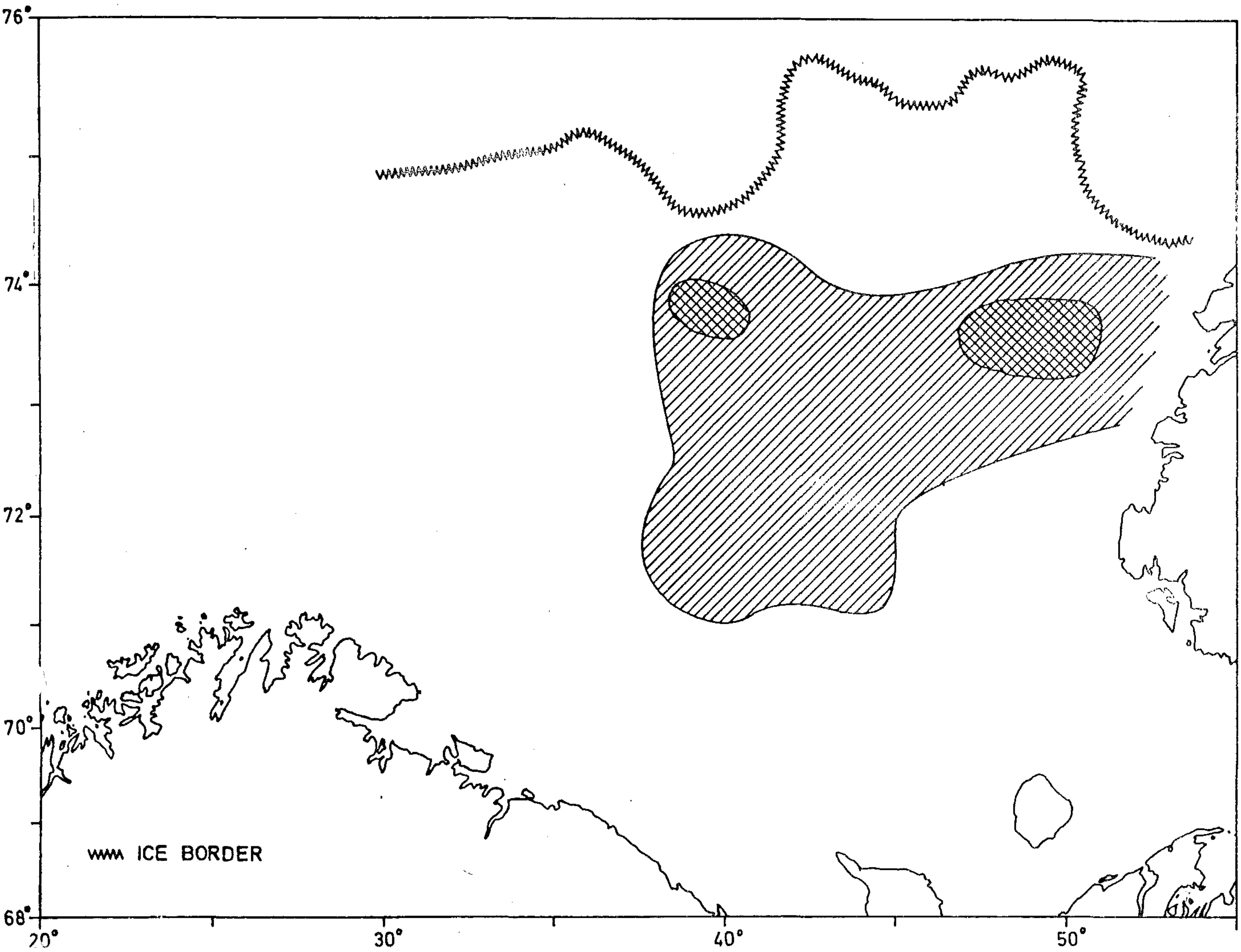

Fig. 8. Recordings of polar cod during May-June 1971. (Modified from Gjøsæter og Bjerke 1973, and Hylen, Gjøsæter og Smedstad 1972).

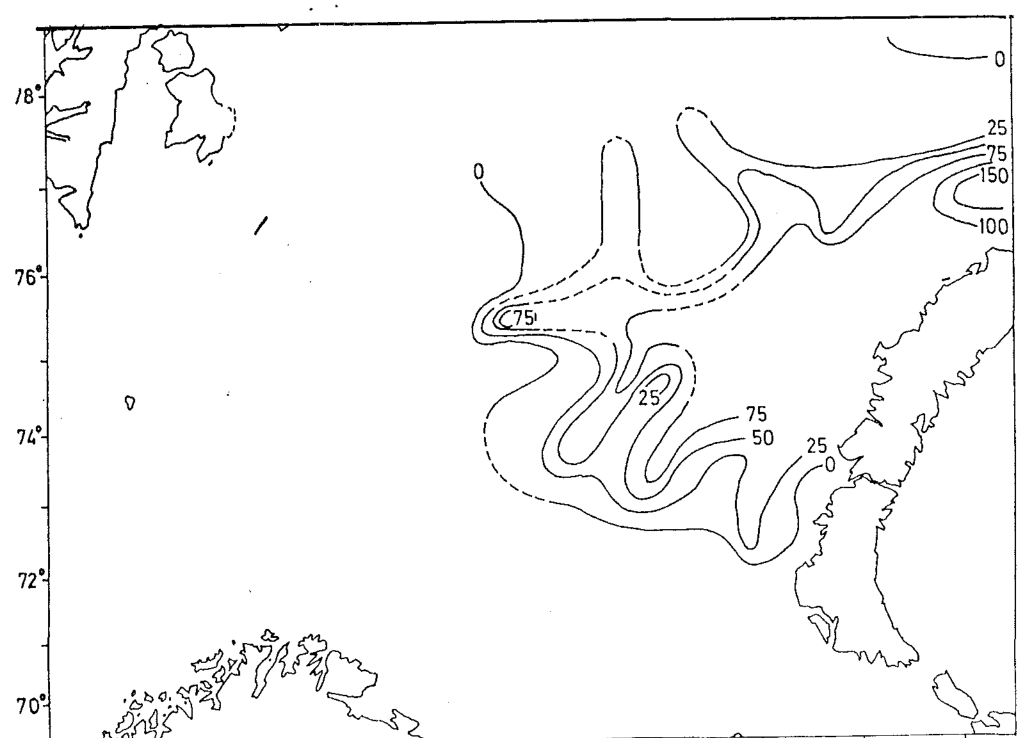

Fig. 9. Echo abundance (mm deflection) of polar cod 23 August-9 September 1971. (From Dragesund og Nakken 1972).

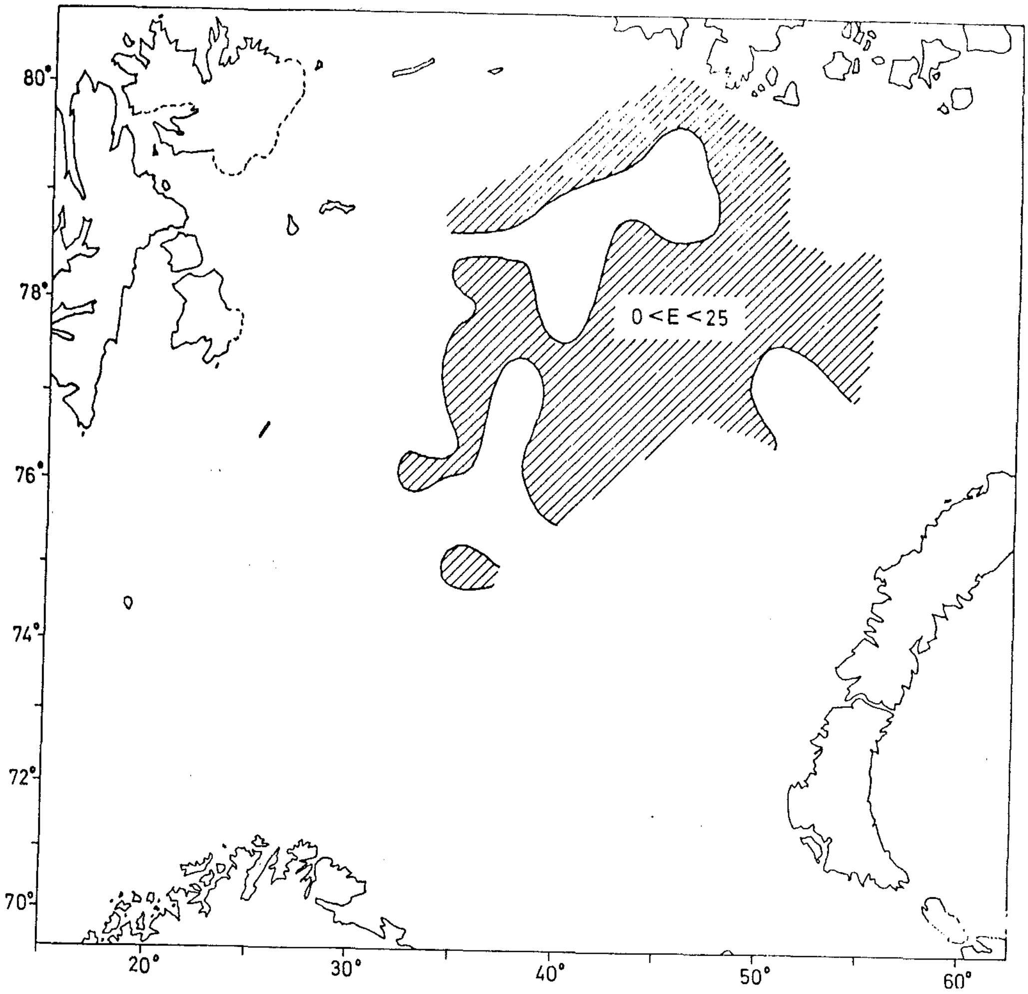

Fig. 10. Echo abundance of polar cod 12-29 September 1971. (From Dragesund og Nakken 1972).

1972

In May 1972 scattered observations of polar cod were made between 72°00' - 73°00'N, 40°00' - 50°00'E. In the first part of June polar cod were observed in small concentrations between 72°30' - 73°30'N, 42°00' - 44°00'E. Denser concentrations were observed in a zone from 73°N 52°E and northwestwards to approximately 75°N 45°E (Fig. 11) (GJØSÆTER og BJERKE 1973).

In August-September an extensive part of the Barents Sea was surveyed and polar cod were observed over wide areas. Dense concentrations were observed along Novaya Zemlja (Figs. 5,12) (GJØSÆTER et al. 1972).

In November-December MONSTAD (p.comm.) observed polar cod in dense concentrations at 38°E between 71°00'N and 72°00'N. The eastward extentation of these concentrations was not observed. North of 73°00'N smaller quantities of polar cod were observed (Fig. 13).

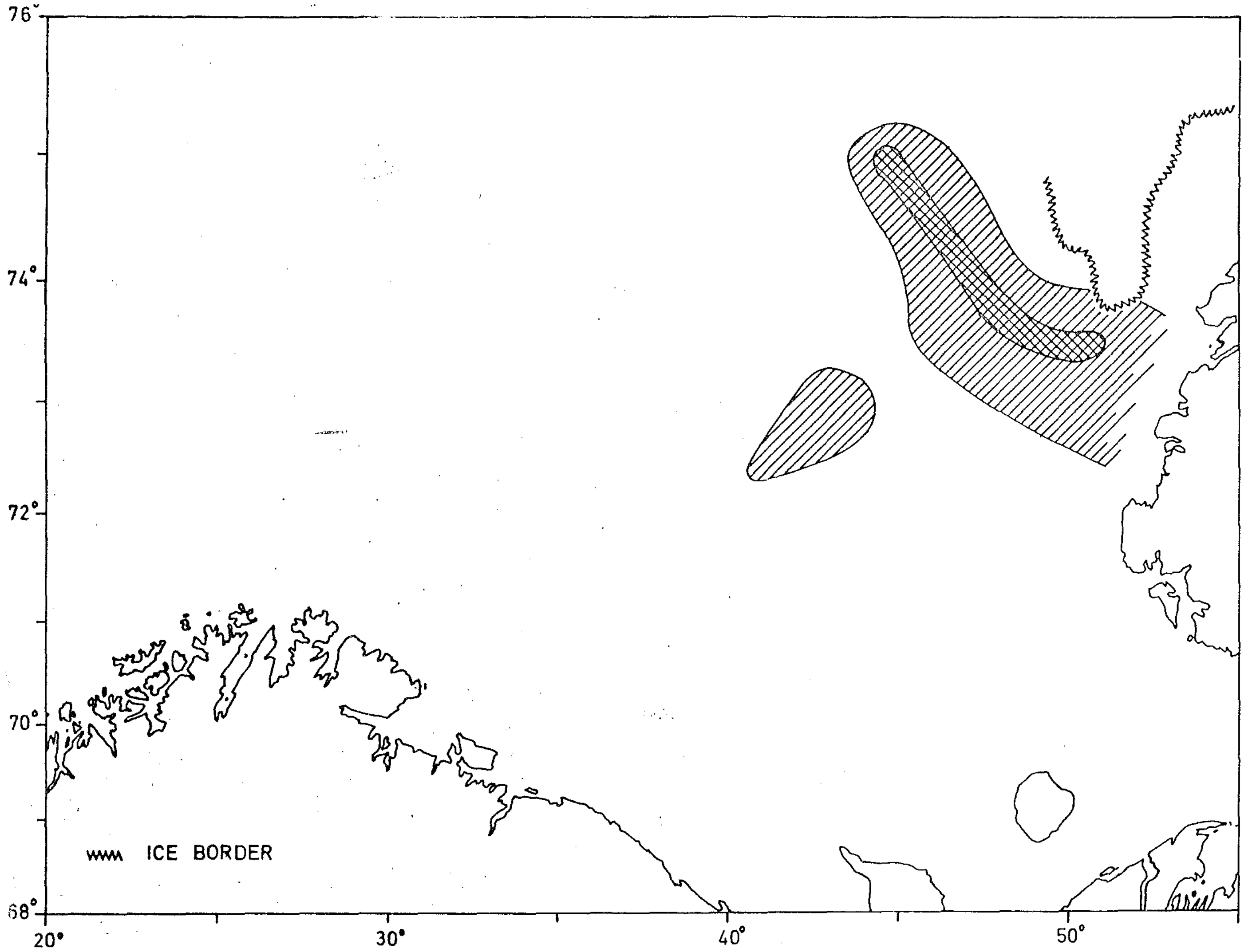

Fig. 11. Recordings of polar cod June 1972. Symbols as Fig. 8. (Modified from Gjøsæter og Bjerke 1973)

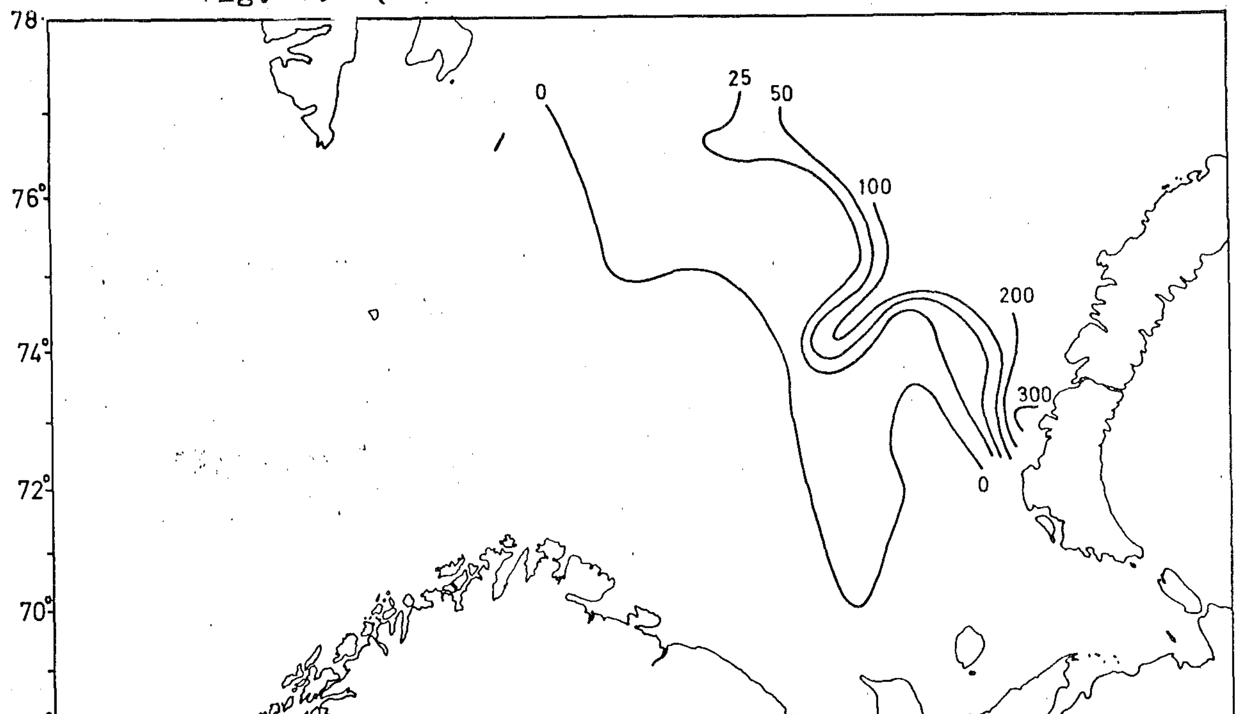

Fig. 12. Echo abundance (mm deflection) of polar cod 27 August-11 September 1972. (From Gjøsæter *et al*. 1972).

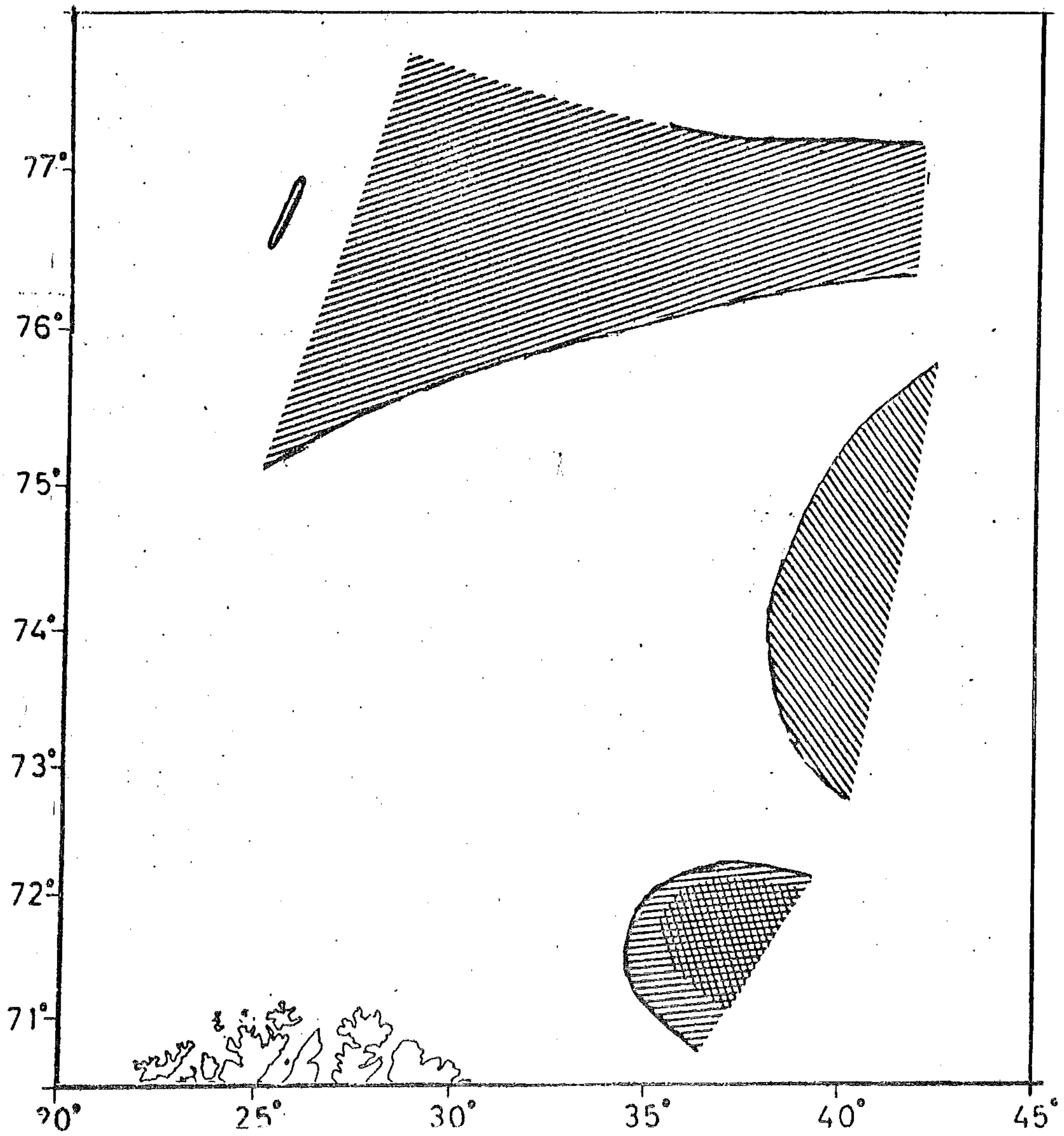

Fig. 13.
Echo abundance (mm deflection) of polar cod, November-December 1972.

Discussion

In the southwestern part of the distribution area, the concentrations of polar cod were highest in 1970, lower in 1971 and lower still in 1972. This seems to be true both for the period May-June and for August-September.

In the northeast, concentrations were higher during August 1972 than in 1971. No data is available from 1970. There is no Norwegian data for comparison of winter distribution.

In the northern and eastern parts of the Barents Sea polar cod in small quantities are usually caught by bottom trawl, also in areas where no echo recordings are obtained.

During summer and autumn the mean length of polar cod seems to increase from the west to the east. An increase in the northern direction has also been observed (HYLEN, GJØSÆTER og SMEDSTAD 1972, GJØSÆTER et al. 1972, GJØSÆTER og BJERKE 1973).

Investigations in 1971 indicated that a northward migration had taken place between June and September (Fig. 8,9). In 1972 a migration, mainly in the northern direction, was observed during May-June (GJØSÆTER og BJERKE 1973). Between August and September at least parts of the stock had started a southward migration (Fig. 5,12), and in December dense concentrations were observed south to 71°N and west to 38°E (Fig. 13).

During all the surveys in May-June, the best recordings of polar cod were made in water with temperature between 0° and -1.4°C. During autumn too, polar cod were mainly recorded at temperatures below zero, although single catches were taken at temperature as high as 2.3°C. Fig. 14 shows examples of vertical distribution of polar cod, in relation to temperature, at three localities from the eastern Barents Sea in September 1972.

At least during summer, polar cod may shift very fast between pelagic and demersal appearance, and they may be very difficult to detect by the acoustical equipment when standing close to the bottom. Therefore, the distribution areas are likely to be wider than those observed.

During spring and summer polar cod is sometimes found in the same area as capelin, and occasionally it is observed feeding on O-group capelin.

During the autumn of 1971 polar cod and capelin were fairly well separated, while an extensive mixing between the two species was observed in 1972 (MIDTTUN and NAKKEN 1972). In areas with mixing, the polar cod are often found at the bottom or pelagically below the capelin.

Mixture of polar cod and young cod has been observed in the area west of Goose Island.

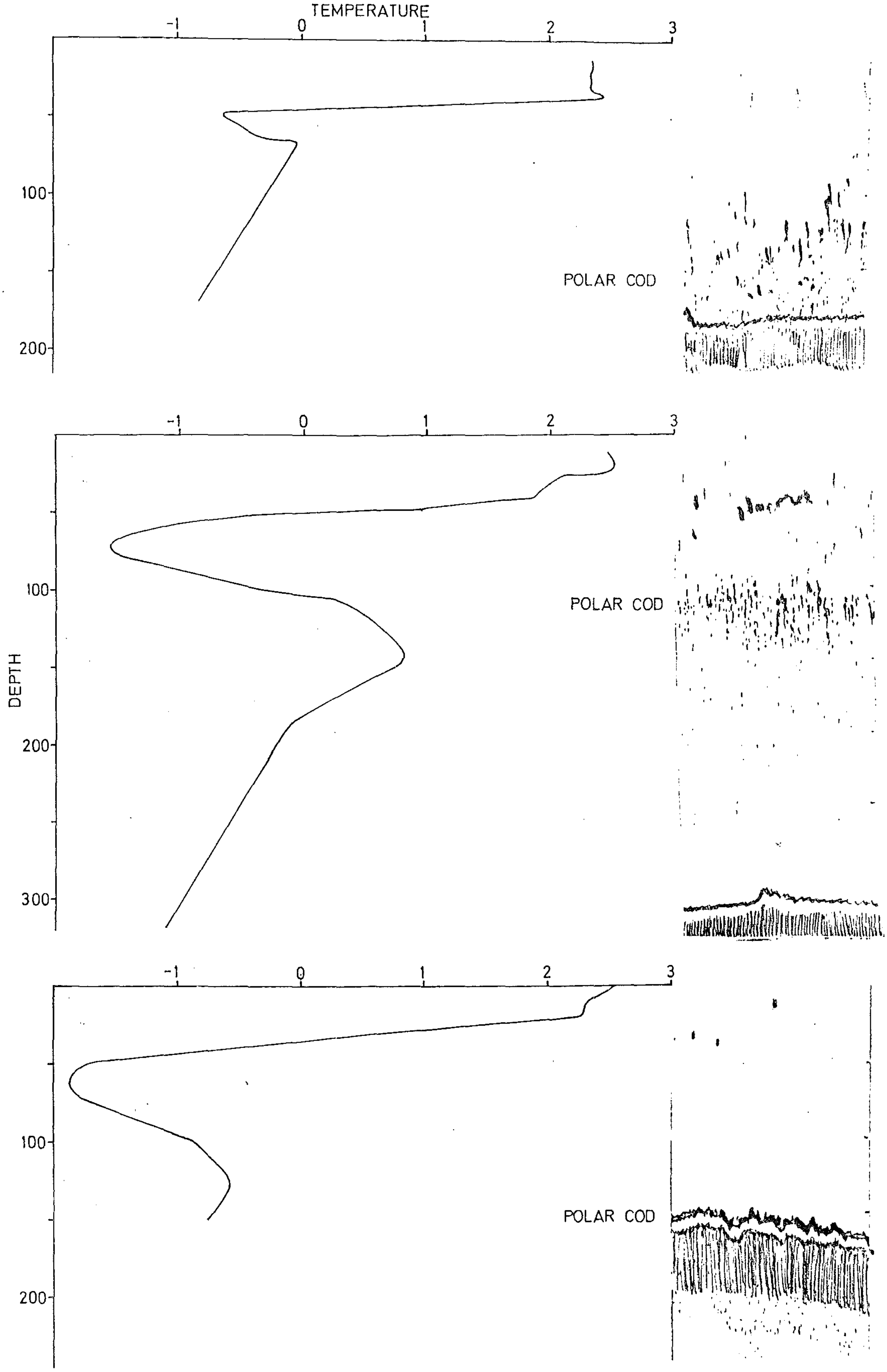

Fig. 14. Temperature distribution and echo recordings of polar cod at three localities in the eastern Barents Sea September 1972.

Growth

Mean lengths with standard deviations of polar cod caught during summer (May-June), autumn (July, August, September) and winter (November, December), are shown in Table 2 and Fig. 14. Only the southern and western parts of the stock were sampled satisfactory during summer and winter. In autumn a lower number of specimens were available, but they were taken more representatively from the whole stock. Growth calculation was therefore based on the autumn material. Von Bertalanffys growth equation was fitted by a graphical method described by RICKER (1958), and the resulting equation was

(3) $$l_t = 29.0 \left(1 - \exp\left[-0.23\,(t + 0.75)\right]\right)$$ (Fig. 14).

The curve fits well to the observed mean lengths.

Mean lengths of 1, 2 and 3 year old fish were also obtained by back calculation. Mean diameters of the hyaline zones of the otoliths were found, and fish lengths corresponding to these lengths were calculated, using equations 1 and 2. Hyaline zones are formed during winter and spring, and the calculated lengths should therefore correspond to this period (Fig. 14). The back calculated values fit very well to the growth curve.

The growth data obtained are fairly similar to those given by OLSEN (1962) and HOGNESTAD (1968), at least for fish younger than 5 years old (Table 3).

Table 2. Length and age composition of polar cod.

	Observed lengths									Back calculated lengths	
	Summer			Autumn			Winter				
Age	l	S	N	l	S	N	l	S	N	l	N
0											
1	9.3	0.727	15	9.3	0.764	102	10.9	1.043	142	7.2	1517
2	12.1	1.311	144	13.4	0.887	84	12.7	1.112	109	12.0	1351
3	15.0	1.210	299	16.6	1.184	92	14.5	1.659	50	15.1	1144
4	17.8	1.325	595	19.1	1.402	194					
5	20.5	1.527	615	21.2	1.323	81					
6	22.8	1.828	127	22.9	2.123	17					

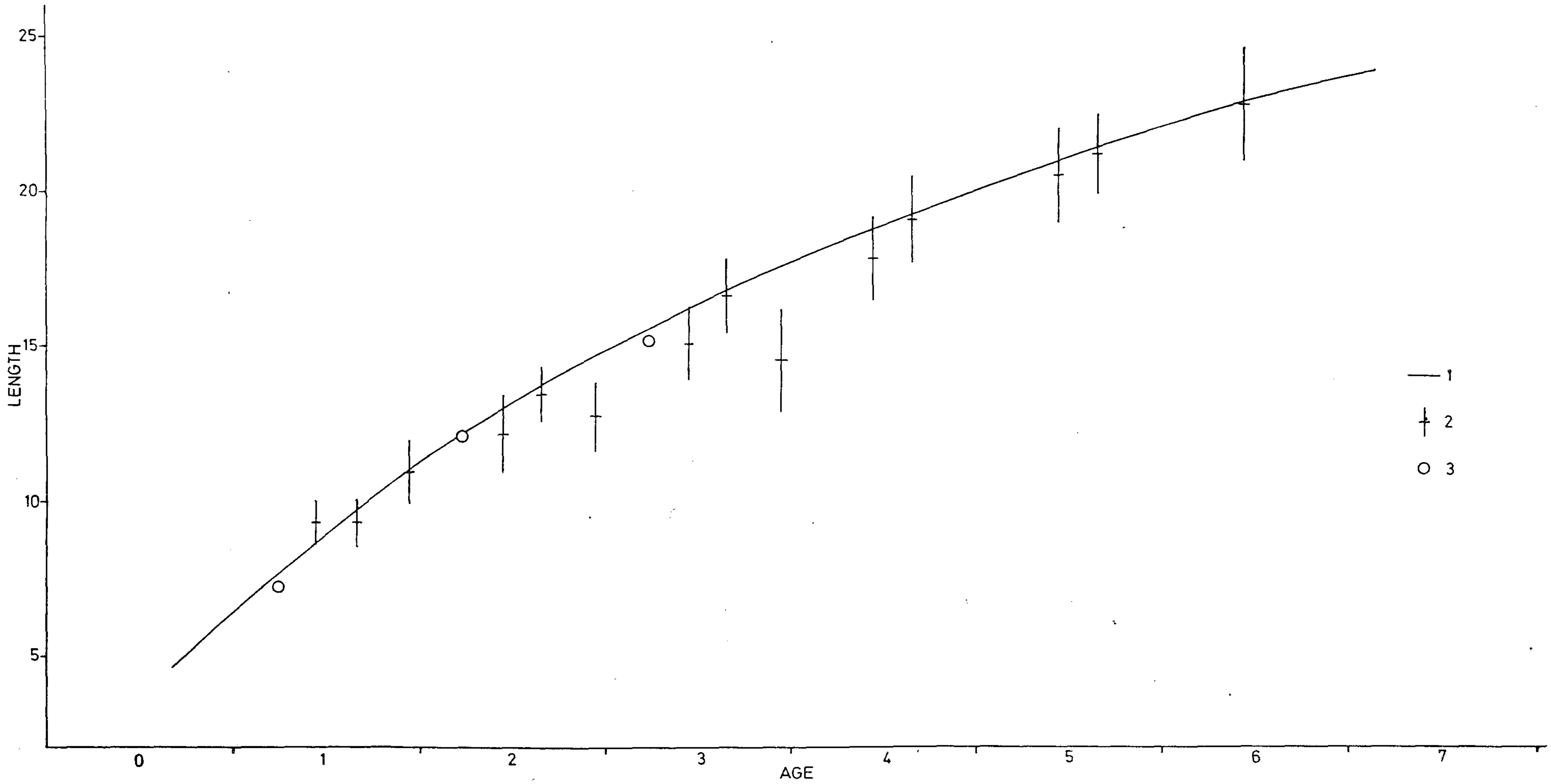

Fig. 14. The Bertalanffy growth curve $l = 29.0\,(1-\exp[-0.23\,(t+0.75)])$ of polar cod (1), mean lengths with 2 standard deviations for summer, autumn and winter (2), and back calculated lengths (3).

Table 3. Growth data from the equation $l_t = 29.0 (1 - \exp[- 0.23 (t + 0.75)])$ compared with data from other sources.

Age	Author	HOGNESTAD (1968)	OLSEN (1962)
0	4.5	4.2	4.7
1	9.6	9.3	-
2	13.6	14.9	13.8
3	16.7	17.8	16.6
4	19.3	19.8	19.9
5	21.3	22.7	23.4
6	22.9	24.3	-

Mortality

Catch curves for all scientific samples, taken during autumn, and for commercial landings are shown in Fig. 15. They indicate that the polar cod are fully recruited neither for sampling or for commercial fishery before they reach an age of 4 years. It also appears that there is no constant mortality after this age. Instantaneous mortality rates between the 4th and the 5th year are 0.61, 0.86 and 0.13 calculated from curve A, B and C respectively. Between the 5th and 6th year the corresponding values are 1.54, 1.59 and 1.50.

Differences in distribution and behaviour between young and old fish may explain the catch curves. But it also seems possible that polar cod older than 5 years suffer a very high natural mortality. At an age of 7 years polar cod are considered as senile (PECHENIK and SHEBEL 1970).

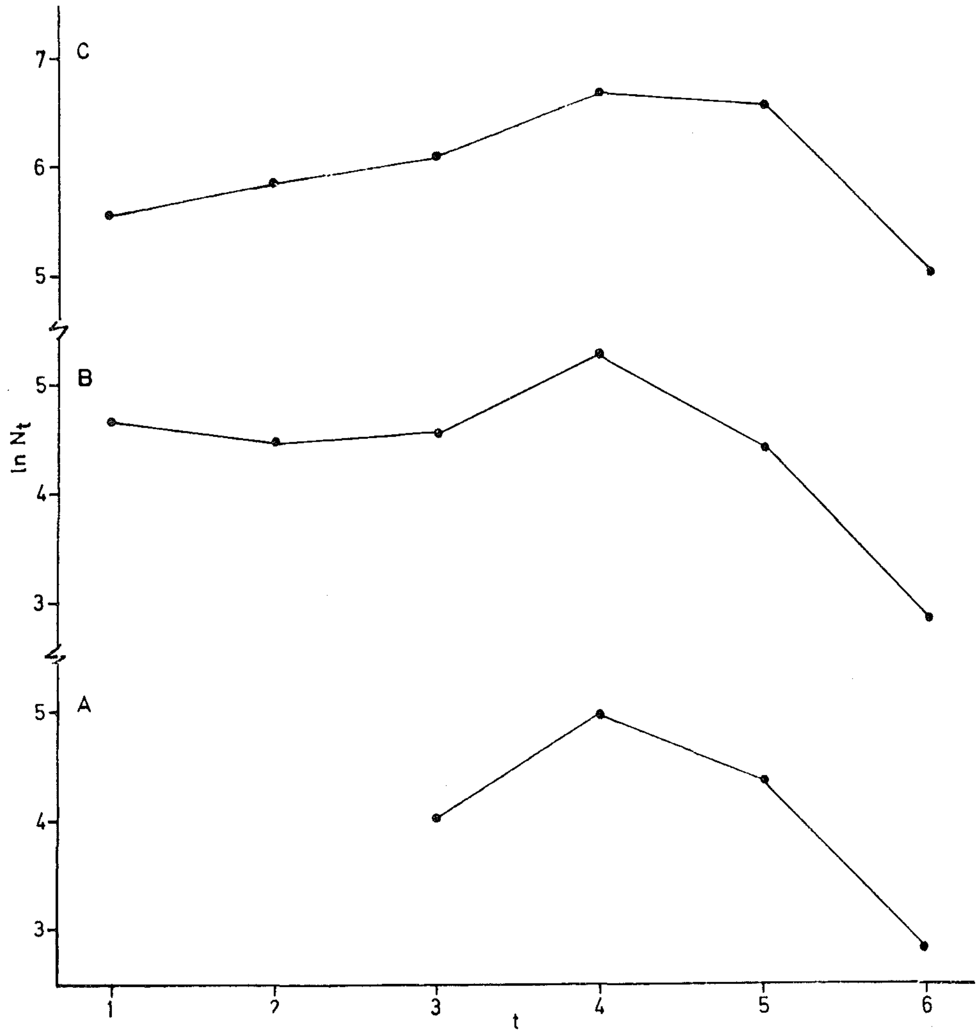

Fig. 15. Catch curves for, A, commercial landings, B, scientific samples from autumn, and C, all scientific samples.

Norwegian polar cod fishery

The Norwegian polar cod fishery started in 1969. It has mainly been carried out during May and June in the area 72° - 74°N, 38° - 43°E. Only occasionally catches have been taken further north and east. Most catches have been taken by pelagic trawls, but purse seine has also been used. Both effort and total catch have been low (Table 4).

Table 4. Catch and effort in Norwegian polar cod fishery.

Year	Catch tons	No.of ships participating
1969	18183	52
1970	8948	20
1971	16483	16
1972	387	2

Table 5. Age composition in Norwegian catches of polar cod (in per cent).

Year	Age 2	3	4	5	6	7
1970	1	23	62	12	2	
1971	4	21	42	29	4	
1972	3	13	41	34	9	1

Age composition (Table 5) is based on samples from commercial landings and on samples from research vessels working in the same area and at the same time.

Four years old fish dominated, followed by age group 3 and 5. Two and 6 years old fish were caught infrequently.

Data from Soviet investigations (SHLEINIK 1972, 1973) shows a slightly higher mean age, although 4 years old fish also dominated in their catches. The lower mean age in Norwegian catches is probably due to these catches being taken near the southwestern limit of the distribution area, where small fish usually dominate.

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