Fol. 4/ G

International Council for
the Exploration of the Sea

ICES CM 1990/G:47
Demersal Fish Committee
Ref. Pelagic Fish Committee

Growth of Polar cod (Boreogadus saida) in the Barents Sea

by

Harald Gjøsæter and Adnan M. Ajiad
Institute of Marine Research
P.O. Box 1870, Nordnes
N-5024 Bergen, Norway

ABSTRACT

Observed length-at-age, and backcalculated lengths based on otolith measurements, from samples of polar cod collected in the Barents Sea in autumn of 1987 to 1989, were analysed.

An increase in individual length growth of one-year-olds was observed from 1987 to 1989. Indications of a slower growth among the fish collected in the eastern areas compared to those sampled further west, were evident all three years. The growth histories of the year classes 1984 and 1985 showed similar patterns, while the fishes of the year class 1986 had a faster growth in their second year of life. The growth seemed to be quite linear up to age three for the first two year classes, while the 1986 year class showed a decreasing trend in growth with age. For all three year classes there is a gradual decrease in growth for increasing age.

INTRODUCTION

Polar cod Boreogadus saida is the most important endemic species from the arctic region from a fisheries point of view. In the beginning of the 1970'ies, catches in the order of one to two hundred thousand tonnes were landed by USSR and Norwegian fishermen from the Barents Sea. After 1976, the landings have never exceeded 25 000 tonnes apart from in two years; 1982 and 1983, when the Soviet fleet landed 90 000 and 37 000 tonnes respectively. In the last years the catches of this species has been negligible, and there are strong evidences that this is caused by a large reduction in stock size in recent years. Since 1986 the stock size has been acoustically measured once a year (autumn) on a joint Soviet-Norwegian multispecies survey covering the whole Barents Sea. An analysis of these data shows that the natural mortality has increased, probably due to predation. Although this species is an important food fish, and hence plays a key role in the ecosystem, and is also a potential for harvesting by man, little is known about its biology, in particular its growth and mortality, in the Barents Sea.

The aim of this paper is to study the growth, based on backcalculation of individual fish lengths from otolith measurements at the time of catch, and observed length-at-age data from the stock.

MATERIAL AND METHODS

The material used in this study was sampled at surveys in the Barents Sea during September-October 1987 to 1989.

As part of the standard sampling procedure for biological samples, the total length was measured and distributed on 1/2 cm length groups. The longest diameter of the otoliths (sagittae) were measured at 16X or 40X magnification in a binocular microscope, to the nearest unit of measurement. One unit of measurement equals 0.025 mm at 40X and 0.063 mm at 16X magnification.

For the method of backcalculation of fish lengths from otoliths measurements to be applicable, two conditions have to be met. Firstly, a relationship between fish size and otolith size must be described and, secondly, regular time markers must exist in the otoliths.

To check if a linear relationship could be used to describe the fish size/otolith size relationship, regression analyses between fish length and otolith diameter (mean values in age groups) were undertaken. Results for the sexes separated and combined are shown below. Individuals below 8 cm, which are not sexed, are included in the combined regression.

Group	Linear regression	r	n
Females	TL = 1.015 + 2.495 OD	0.991	8
Males	TL = 1.240 + 2.479 OD	0.989	8
Combined	TL = 1.135 + 2.486 OD	0.989	16

TL = fish length (cm), OD = otolith diameter (mm)

An analysis of covariance revealed that there was no significant difference between sexes at 5% level; (Intercept: $F = 0.589$, $df = 1,13$; Slope: $F = 0.007$, $df = 1,12$) consequently the data were pooled and shown in Fig. 1. We concluded that there exists a linear relationship between fish size and otolith size for this polar cod stock, which can be used for backcalculation of fish lengths.

The next step was to check if the "winter rings" found in polar cod otoliths really represent winter growth, and therefore can be regarded as regular time markers.

To check this, we calculated the mean distance from the outer otolith ring to the otolith margin for the four quarters of the year separately. This gave the results 0.2, 0.7, 1.7, and 1.6 mm for the four quarters respectively. We concluded that one winter ring is deposited in the otolith each year, and this deposition probably starts in late autumn.

Backcalculation on an individual basis, from the observed length and otolith diameter at catch along a straight line towards a theoretical otolith diameter at zero fish length (Gjøsæter, 1986) was chosen. Finding the theoretical otolith diameter at zero fish length is somewhat problematic, as one have to extrapolate outside the interval of measurements. Using a functional relationship (Ricker, 1973) may in such cases give a "better" estimate than an ordinary predictive regression. Another approach, probably equally suitable, and giving a nearly identical result, is to fit a straight line by eye. This method was chosen, yielding an intercept of 1.7 cm, which was used in the calculations.

To study geographical variation in growth, data were grouped according to position within a predefined system of regions (Mehl, 1989). These eight regions were defined to fill the purpose of area division of a multispecies model being built at the IMR, Bergen (Fig. 2).

Figure 1. The relation between otolith diameter and fish length

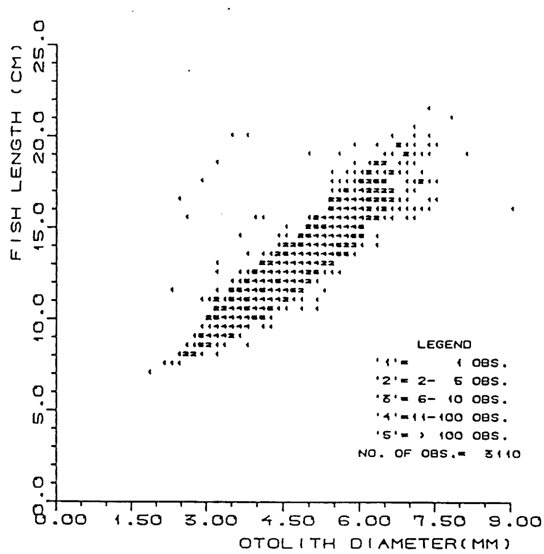
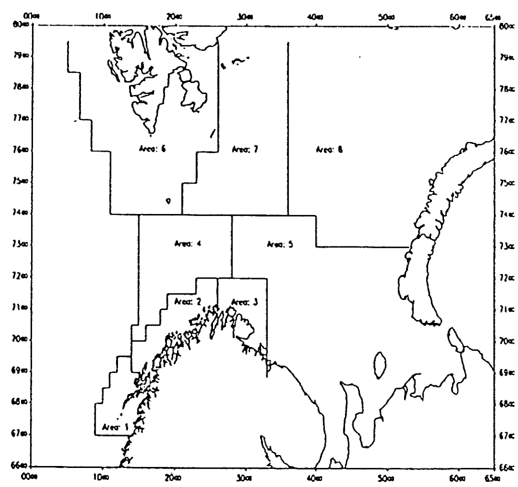


Figure 2. Map of Barents Sea showing division into regions

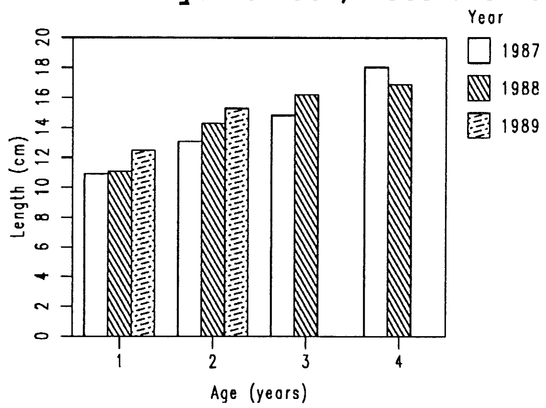


RESULTS

Comparison of growth in different years

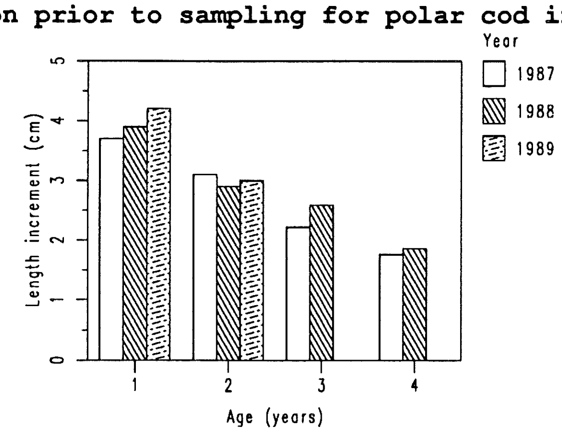
Figure 3 shows that with the exception of the 4-year-olds, the mean lengths increased from 1987 to 1989. Less than 10 individuals were sampled of the 3- and 4-year-olds in 1989 and were left out of the figure. Only 12 individuals were aged 4 years in 1988, and consequently this exception to the rule of increasing growth should not be overemphasized. An analysis of variance was undertaken to check if the length-at-age of one- and two-year-olds varied significantly between these three years. The 0-hypothesis of equal lengths had to be discarded both for one-year-olds (Lengths: 10.9, 11.1, 12.5 cm; ANOVA, F=150.9, df=4,1600, p=0.0000), and for two-year-olds (Lengths:13.9, 14.3, 15.3 cm; ANOVA, F=23.3, df=2,911, p=0.0000).

Figure 3. Observed length-at-age of polar cod in the years 1987, 1988 and 1989



The length-at-age is not a direct measurement of growth within a specific year, but represents accumulated growth over two or more growth seasons. However, for one-year-olds, the same pattern of increasing growth is evident when the growth in the last growth season only is considered, calculated as the difference between the measured length at sampling and the backcalculated length the previous winter (Fig. 4). For two-year-olds, there is seemingly no such tendency. Analysis of variance confirms these findings (One-year-olds: Growth: 3.7, 3.9, 4.2 cm; ANOVA: F=21.1, df=2,1600, p=0.0000; two-year-olds: Growth: 3.1, 2.9, 3.0 cm; ANOVA: F=1.6, df=2,911, p=0.1914).

Figure 4. Growth in length in the last growth season prior to sampling for polar cod in 1987-89

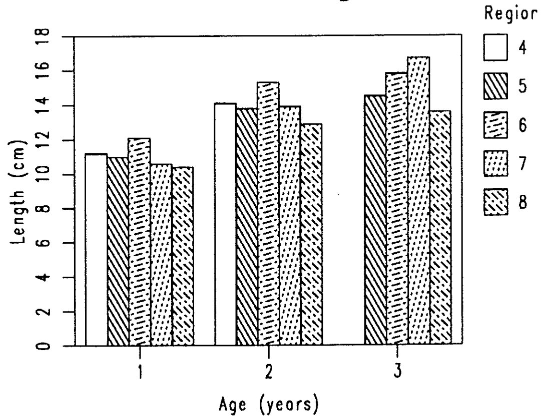


Comparison of growth between different areas

To trace possible geographical differences in growth within the total distribution area of the polar cod in the Barents Sea, data from 1987 were chosen. This year the samples covered a large geographical area, and were grouped according to the fixed regions nos. 4 to 8 (Fig 2).

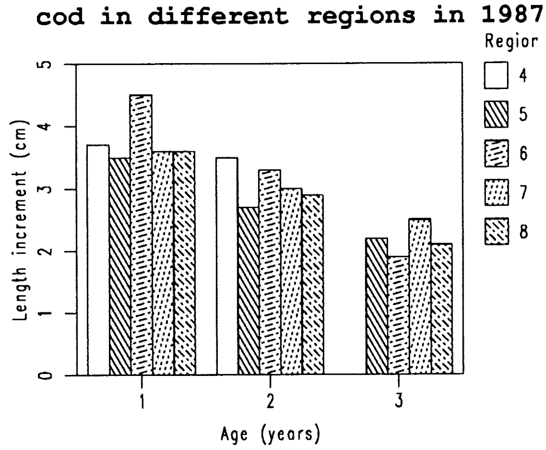
The mean length-at-age of one and two years old polar cod was slightly higher in the western areas (4 and 6) compared to the central and eastern areas (Fig. 5). The differences were small, but highly significant both for the one-year-olds (Lengths:11.2, 11.0, 12.0, 10.6, 10.4 cm; ANOVA, F=55.3, df=4,1180, p=0.0000) and two-year-olds (Lengths:14.1, 13.8, 15.3, 13.9, 12.9 cm; ANOVA, F=41.9, df=4,685, p=0.0000). The three-year-olds were not tested because of small samples and lacking data.

Figure 5. Observed mean length of polar cod in different regions in 1987



The data on growth in the last growth season (Fig. 6) support this tendency of higher growth in the western parts of the sea, both among the 1-year-olds (Growth: 3.7, 3.5, 4.5, 3.6, 3.6 cm; ANOVA, F=41.2, df=4,1180, p=0.0000) and 2-year-olds (Growth: 3.5, 2.7, 3.3, 3.1, 2.9 cm; ANOVA, F=8.7, df=4,685, p=0.0000). Again, the three-year-olds were not tested for equal means, as data for region no. 4 is lacking and the rest of the material is scarce.

Figure 6. Growth in length of polar cod in different regions in 1987

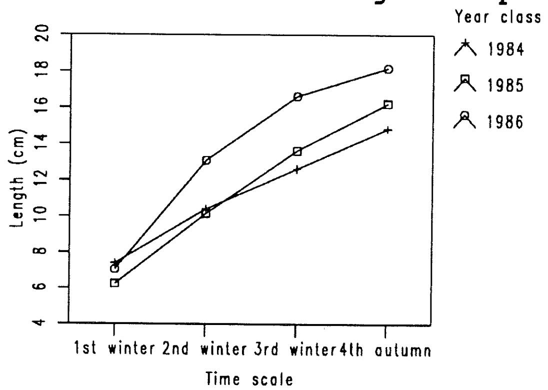


In the years 1988 and 1989, the geographical distribution of the polar cod was more limited, only occupying the regions 5 to 8, and the number of fish sampled was low. However, for both one and two years old fish the 0-hypothesis of equal growth in the regions had to be rejected with significance well beyond the 1%-level, a faster growth in the west, as was found in 1987, was evident also these two years.

Growth histories of the year classes 1984 - 1986

Based on the three years old fish, all samples combined, the backcalculated length growth history were calculated for three year classes (Fig 7). The fish of the 1986 year class were longer than those of the two former year classes at ages greater than one year. This difference seemed to stem from a higher growth in their second year of life. The growth between the first winter up to the fourth autumn seemed to be linear for the year classes 1984 and 1985, while the 1986 year class showed a decreasing growth with age in this age interval.

Figure 7. Backcalculated lengths of polar cod



DISCUSSION

Backcalculation of fish lengths based on otolith measurements have been applied for polar cod both in the Barents Sea and elsewhere. Frost & Lowry, (1981), working in Alaskan waters, found that the otolith/body length relation was linear, and their regression line resembles very much that in the present paper, having an intercept of 1.6 cm. Gjøsæter, (1973), working in the Barents Sea, found that two separate linear regression lines gave the best fit to the otolith/body length relationship, with a dividing point at approximately 10 cm. He also concluded that one winter ring is formed each year, seemingly starting to form in late autumn.

Gjøsæter (1973) did not compare growth in separate years, but constructed a generalized growth curve based on autumn data from three years (1970-72). His results shows lengths of 9.3, 13.4, and 16.6 for 1, 2, and 3 years old fish (in autumn) respectively. These lengths are smaller than those of corresponding age groups in 1987-89 (Fig. 3), as far as one- and two-year-olds are concerned.

Neither did Gjøsæter (1973) investigate possible growth differences between subareas inside the total distribution area, apart from a comparison of backcalculated lengths in the first winter (L_1) of fish sampled in the eastern part of the Sea and in the Spitzbergen area. He found significantly smaller L_1s near Spitzbergen, and concluded that these individuals probably stemmed from a separate stock component spawning in that area. A discontinuous 0-group distribution, with smaller individuals near Spitzbergen compared to the eastern Barents Sea, observed for many years, gave evidences for such a conclusion.

In the present material, of the three year classes 1986, 1987, and 1988 examined as one-year-olds, only the year class 1988 showed smaller L_1s in region 6 (near the western spawning area) than in region 5 (near the eastern spawning area). However, from the reports of the 0-group surveys from the relevant years (Anon 1986, 1987, 1988), it is seen that only in 1988 was there a significant difference between the polar cod 0-group in these two areas; in 1987 the difference was small and in 1986 the 0-group was slightly larger in the western area.

Shleinik (1973) concluded that the polar cod found in the central and eastern parts of the Barents Sea was smaller than that found in the western part. This is in accordance with our observation (Fig. 6) that the growth is slower in the eastern and central area.

The growth histories presented in Fig 7 resembles that presented by Gjøsæter 1973, with a fitted von Bertalanffy growth curve ($L=29.0(1-e^{(-0.23(t+0.75))})$). However, having only data for fish up to age four, and since the growth seems quite linear in this phase, no growth curve was fitted to the present data set.

Lowry and Frost (1981) studied the growth of polar cod collected in three different areas; the Bering, Chukchi, and Beaufort Seas. In the two last mentioned areas they observed that the growth in length was fastest during the second year of life, as did Hognestad (1968) in the Barents Sea. In both of these investigations, it appears that the "first-year growth" is not the growth during the first year of life, nor is it the growth during the first growth season. In stead, they considered the growth in a 10 - 12 months period after the transition from larvae to juveniles had taken place, at about 4.0 cm in August-September. Therefore, their results cannot be directly compared to ours, which partitions the growth into growth seasons (up to the first winter, up to the second and so on, Fig. 7). However, when we take the observed lengths of 0-group fish in August the relevant years, as reported in Anon (1986, 1987, and 1988), and subtract these from the observed lengths at sampling in September the following years, we attain mean length increments of 7.9 cm for the 13 months from August the first year to September the second, and 3.0 cm from September the second to September the third year. Consequently, our results contradict Lowry & Frosts (1981) findings in the Chukchi and Beaufort Seas and do not give evidence for their hypothesis that the greatest growth in length takes place during the second year of life. It is not quite clear whether Hognestads (1968) length measurements of one- and two-year-olds stem from the autumn period, but if they do, the three year classes included in the present study have had a considerable faster growth up to stage I and a slower growth from stage I to II, as measured during the autumn.

REFERENCES

Anon, 1986. Preliminary report of the International 0-group fish survey in the Barents Sea and adjacent waters in August-September 1986. ICES C.M. 1986/G:78:1-27.

Anon, 1987. Preliminary report of the International 0-group fish survey in the Barents Sea and adjacent waters in August-September 1987. ICES C.M. 1987/G:38:1-31.

Anon, 1988. Preliminary report of the International 0-group fish survey in the Barents Sea and adjacent waters in August-September 1988. ICES C.M. 1988/G:45:1-37.

Frost, K.J., and L.F. Lowry, 1981. Trophic importance of some marine gadids in northern Alaska and their body-otolith size relationships. Fish.Bull.Vol 79(1):187-192.

Gjøsæter, H., 1986. Growth of the Barents Sea capelin compared to stock size and geographical distribution. ICES, C.M. 1986/H:38: 1-16.

Gjøsæter, J., 1973. Preliminary results of Norwegian polar cod investigations 1970-1972. ICES C.M. 1973/F:8:1-23.

Hognestad, P., 1968. Observations on polar cod in the Barents Sea. ICES Rapp. Proc.-Verb. des Reunions 158:126-130.

Lowry, L.F. and K.J. Frost, 1981. Distribution, Growth, and Foods of Arctic Cod (Boreogadus saida) in the Bering, Chukchi, and Beaufort Seas. Canadian Field-Naturalist 95(2):186-191.

Mehl S., 1989. The Northeast Arctic cod stock's consumption of commercially exploited prey species in 1984 - 1986. Rapp. P.-v. Reun. Cons. int. Explor. Mer, 188:185-205.

Ricker, W., 1973. Linear regressions in Fishery Research. J.Fish.Res. Board Can. 30:409-434.

Shleinik, V.N., 1973. Sastaiania zabasa i prespective promysel saika (Boreogadus saida) v Barentseva Moria. Trydy PINRO, vep:33,pp225-236. (In Russian).