FiskDir. Skr. Ser. HavUnders., 17: 521–528.

PRIMARY GROWTH RINGS IN OTOLITHS OF BARENTS SEA CAPELIN

By

JACOB GJØSÆTER
Department of Fisheries Biology, University of Bergen

and

TERJE MONSTAD
Institute of Marine Research, Bergen

ABSTRACT

GJØSÆTER, J. and MONSTAD, T. 1985. Primary growth rings in otoliths of Barents Sea Capelin. *FiskDir. Skr. Ser. HavUnders., 17: 521–528.*

Formation of primary growth rings in otoliths of Barents Sea capelin was studied both for fish of known age, from rearing in a basin, and for field-sampled fish. The numbers of growth rings were related to fish length and age. Correlation of the number of rings and length of larvae indicates that fastgrowing specimens form more rings per unit time than slowgrowing ones. This seems also to be the case in juveniles and adults. The results of the present study suggest that primary growth rings are formed daily in capelin up to an age of about one year.

INTRODUCTION

The capelin, *Mallotus villosus,* is routinely aged using annual zones in their otoliths. There are, however, problems in interpreting the first hyaline zone in some of the otoliths. This makes the ageing uncertain, thus justifying the search for an alternative method.

In recent years, primary growth rings have been observed in the otoliths of many fish species (PANNELLA 1971, 1974; see ANON. 1982 for bibliography). Most studies have indicated that under normal growth conditions rings are formed at a rate of one per day.

The aim of one of the present paper is to study the formation of primary rings, and their relation to age, known or estimated from counting annual zones, and size of fish. The study is based on larvae and juveniles from a rearing experiment in Flødevigen and on juveniles and adults from the Barents Sea.

MATERIAL AND METHODS

The capelin of known age were reared in a large outdoor basin (volume 2000 m^3) in Flødevigen in southern Norway. The eggs were sampled from natural spawning beds in Finnmark, transported to Flødevigen and hatched in laboratory at a temperature of 5° ± 0,5°C. They then were transferred to the basin where the temperature increased from 6 to 13°C near the bottom and reached a maximum of 20° near the surface. Further details are given by MOKSNESS (1982).

The field material was sampled from various parts of the Barents Sea with the research vessels of the Institute of Marine Research. The capelin were preserved in 70 % ethanol or frozen. Otholiths were picked out, washed in alcohol, and generally stored in 70 % alcohol before final treatment.

The otoliths, except for the smallest, were ground on both sides until a thin section through the nucleus was obtained. They were mounted in Canada balsam on glass slides and covered with cover slides. The otoliths were read under microscope with 400–1000 × magnification. The statical methods of analysis are described by ZAR (1974).

RESULTS

PRIMARY GROWTH RINGS IN JUVENILES OF KNOWN AGE

Otoliths from 98 larvae from the basin in Flødevigen were used for counting primary growth rings. These larvae were taken from seven samples extracted 61 to 127 days after 50 % hatching (Table 1). The number of rings ranged from 31 to 150 (Fig. 1).

A predictive regression was fitted to the data, resulting in the equation:

$$r = 1.20\ d - 27.0$$

where r is the number of rings and d is the number of days since 50 % hatching (Fig. 1). The coefficient of determination was 0.569 and confidence limits (95 %) of the coefficient of regression $0.96<b<1.44$. The confidence limits of the intercept was $-9.0<a<-44.9$.

The regression is highly significent ($F_{1.97} = 126$, $p<<0.001$), but explains only 57 % of the variance in number of rings. The slope of the regression line is not significantly different from one, which would indicate the formation of one ring per day within the studied age range. The intercept with the age-axis is significantly different from zero, indicating that ring formation did not start at hatching, or that less than one ring was formed per day during the period before the sampling was started (Fig. 1).

The number of rings was also regressed on the length of the larvae. This gave a coefficient of determination of 0.542, which is slightly, but not significantly, lower than that of the regression of number of rings on days since hatching.

Table 1. Numbers of primary growth rings in capelin of known age.

Age (days)	No. of fish	Rings in otoliths mean	SD	range	Length (mm) mean	SD	range	Correlation coefficient
61	1	41			23.0			
68	20	54.0	10.1	38–75	21.0	2.7	15.0–26.5	0.78
75	18	61.6	16.0	31–77	23.3	3.9	16.8–30.7	0.64
82	20	72.1	18.0	41–128	24.7	3.0	18.2–29.2	0.51
89	19	82.6	9.1	65–97	27.2	3.2	20.0–32.7	0.20^{ns}
96	15	90.3	13.7	56–102	30.1	2.5	25.8–35.3	0.50
127	5	120.2	31.4	80–150	30.0	3.9	24.0–34.0	0.89

ns: not significant

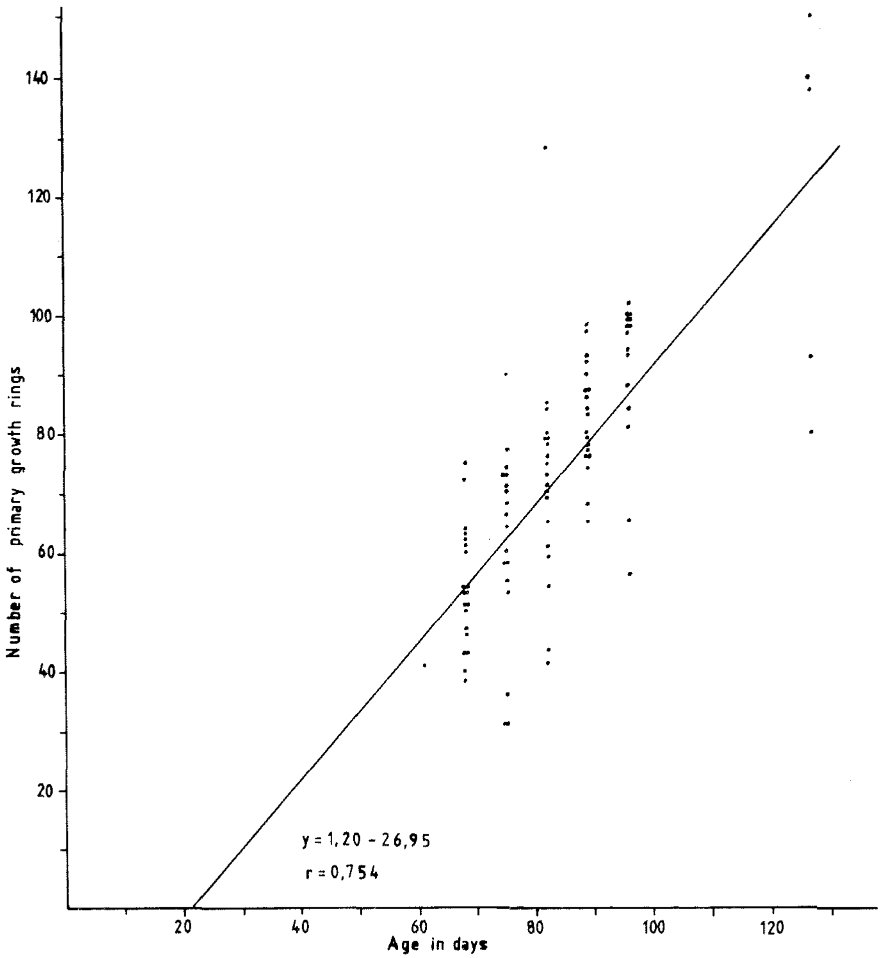

Fig. 1. Relationship between numbers of primary growth rings and days since 50 % hatching in basin-reared capelin.

There was also, with one exception, a significant correlation between number of rings and length of the larvae within the samples of equal age (Table 1).

A multiple regression was also fitted to the data:

$$r = 0.76\ d + 2.18\ l - 45.25$$

where r is the number of rings, d is the number of days since 50 % hatching, and l is the length of the larvae in millimeters. The coefficient of determination was 0.677, indicating that 68 % of the variance in ring counts is explained by a multiple linear regression on age and length.

PRIMARY GROWTH RINGS IN FIELD SAMPLED CAPELIN

Otoliths from 138 capelin from the Barents Sea were collected for counting primary growth rings. According to the reading of annual rings, their age ranged from about 9 to 50 months reckoned from January in their year of birth. Samples with three or more otoliths are included in Table 2 and Fig. 2.

Table 2. Age as calculated from annual rings, length and number of primary growth rings in capelin from the field samples.

Year class	Age at capture (days)	No. of fish	Length (mm) mean	Length (mm) conf.int.	Rings in otoliths mean	Rings in otoliths conf.int.	Correlation coefficient
81	195	55	49.15	1.24	140.96	4.89	0.83
81	180	17	36.71	3.33	101.88	8.76	0.63
78	170	10	51.50	4.14	122.60	8.48	0.90
76	1000	3	116.67		700.00		
77	635	3	105.00		645.00		
78	300	7	57.86	4.52	341.29	51.68	0.91
76	1025	6	126.67	13.13	650.83	84.49	−0.53
75	1385	6	156.67	14.71	902.50	184.51	0.94
76	1420	16	150.25	7.27	638.75	44.53	0.81^{ns}
78	890	4	121.25	10.00	456.00	103.07	

ns: not significant.

When the total material is considered, the following predictive regression can be fitted:

$$r = 0.47\ d + 21.79$$

with a coefficient of determination of 0.826. If length were considered as the independent variable, the coefficient of determination would be 0.876. The multiple regression

$$r = 0.03\ d + 5.08\ l - 97.14$$

explains 87.7 % of the variance in number of rings.

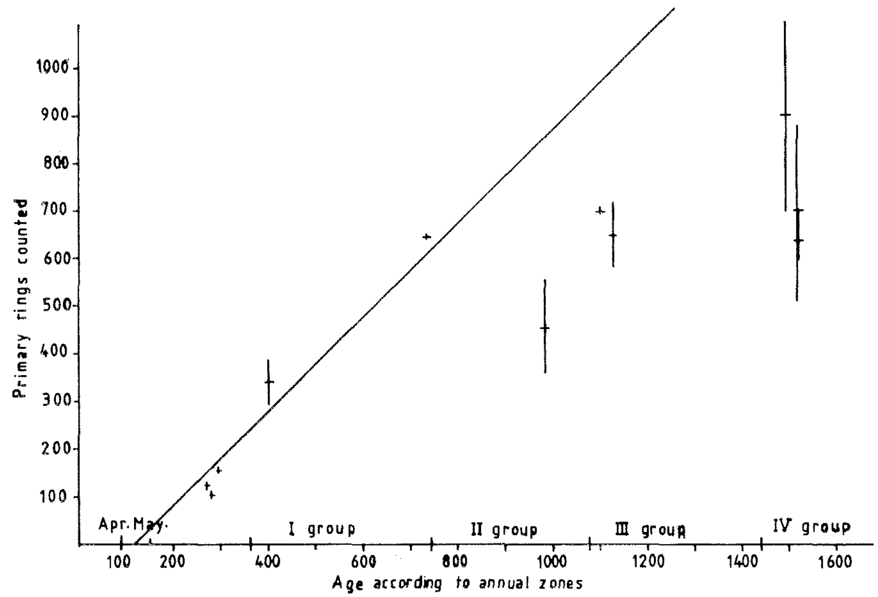

Fig. 2. Relationship between numbers of primary growth rings and age estimated from annual-zone counts in field-sampled capelin. The 45°-line shows the theoretical relationship provided the rings are formed daily. Vertical bars show confidence intervals.

The correlation between number of primary growth rings and length was also studied within samples where the age according to annual zone counts was constant. Out of seven samples with six or more fishes, five gave a significant positive correlation, one gave a significant negative correlation, and one did not give a significant correlation (Table 2).

CALCULATED TIME OF BIRTH

Three samples of 0-group capelin were used to back-culculate the time when ring formation started (Fig 3). It is usually assumed that ring formation starts at the end of the yolk sac stage, or at the beginning of feeding (PANNELLA 1974). In capelin the yolk sac will last for about 2 weeks (HELGESEN 1977), and feeding will start some days earlier (BJØRKE 1976). Therefore, if capelin form one ring a day under natural conditions, the fish studied probably hatched in May and early June. This agrees well with the observed time of hatching.

GROWTH STUDIES

Growth based on annual zone counts and on primary ring counts is shown in Fig. 4. The data suggest a linear relationship between the number of primary rings and the length of the fish. As both variables have a variance, a functional regression was fitted (RICKER 1975). This gave the slope b = 0.174 and coefficient of determination, 0.876. This indicates a growth rate of 0.17 mm/day, which is likely for young capelin, but not for adults.

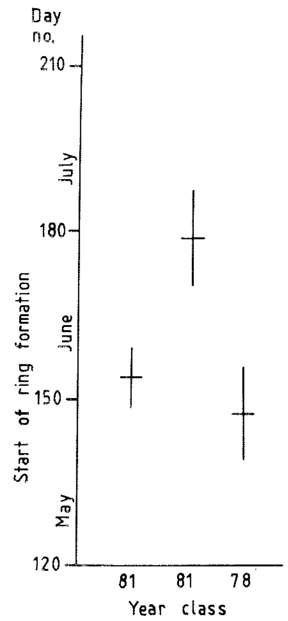

Fig. 3. Estimated time of start in growth ring formation for three samples of 0-group capelin.

DISCUSSION

The age of the larvae used in this study was taken as days since 50 % hatching. According to Moksness (1982), the hatching started on 14 May, reached 50 % on 16 May, and the larvae were transferred on the basin on 19 May. The larvae, therefore, could hatch during a period of five days.

The variation in number of rings counted in the otoliths of larvae from a sample with constant age since 50 % hatching is, however, much larger than the variation in hatching time. Counting error probably accounts for some of the variance, but apparently there is also a real difference in ring numbers among larvae of the same age. The correlation between number of rings and length of larvae suggests that the fast-growing larvae form more rings per unit time than the slow-growing larvae (Table 1). There seems to be a similar situation in juvenile and adult fish (Table 2). Geffen (1982) showed that the number of otolith rings were dependent on the growth rate in larvae of herring *(Clupea harengus)* and turbot *(Scophthalmus maximus)*. Bergstad (1984) has made similar observations on cod larvae *(Gadus morhua)* Timola (1977) has found that adult smelt *(Osmerus eperlanus)* do not form primary rings during the winter season when there is no growth. Under experimental conditions, Taubert and Cable (1977) showed that both growth and primary ring formation stopped in several ciclidae when temperature was lowered. Therefore, although the mechanisms are not known, there is evidence that, when growth is ceased or lowered below a certain limit, ring formation is reduced or stopped.

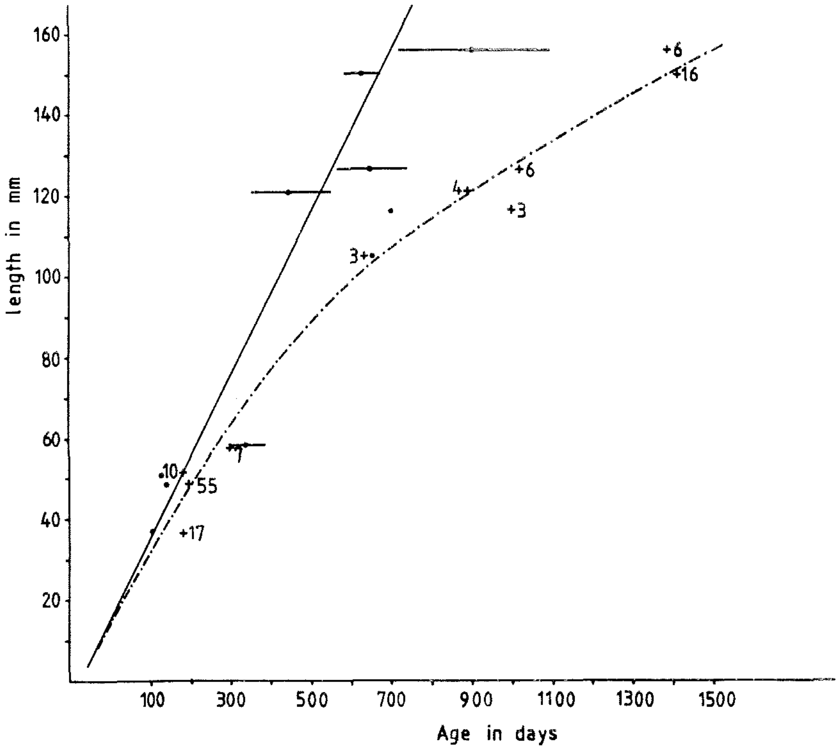

Fig. 4. Growth pattern of capelin as estimated from counts of daily growth rings (points and full line, with horizontal lines giving confidense limits) and from counts of annual zones (crosses and dotted line fitted by hand). The age is reckoned in days from 1 January.

During a period when the larvae were about 40–50 days old, the growth apparently stopped for a period of time (MOKSENESS 1982 Fig. 8, MOKSENESS and ØIESTAD 1979). This may partly account for the highly negative intercept of the age axis (a = −27), as the ring formation may also have stopped during this period (Fig. 1).

When interpreting the results of the present study of larval material, it should also be noted that the larvae were subjected to a much higher temperature than in their normal habitat.

In the field material, the correlation between number of rings and length of fish was slightly better than that between number of rings and age estimated from annual zones. During the considered period, about 0.5–4 years, the mean rate of ring deposition was about 0.5 ring/day. If fish younger than 1 year are considered separately, the back-calculated time of first ring deposition fits well with the usual time of hatching, when a deposition rate of 1 ring/day is assumed.

Based on this evidence, it is concluded that the rings, interpreted as primary growth rings here, do not form daily in adult capelin. It is likely, however, that they are formed daily in capelin up to an age of about 1 year.

ACKNOWLEDGEMENT

We wish to thank E. Moksness, who provided material of capelin from his rearing experiments. We also want to thank H. Ludvigsen who worked up the otoliths.

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Received 15 June 1984

Printed 8 February 1985