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PRIMARY GROWTH RINGS IN OTOLITHS OF THE BARENTS SEA CAPELIN

by

Jakob Gjøsæter
Department of fisheries biology
University of Bergen

and

Terje Monstad
Institute of Marine Research
Bergen, Norway

ABSTRACT

Formation of primary growth rings in otoliths from the Barents Sea capelin were studied. Both otoliths from fish with known age, i.e. reared in a basin, and otoliths from field sampled fish were analysed. The numbers of growth rings were related to fish length and age.

Number of rings correlated to the length of larval may indicate that fast-growing specimens form more rings per unit time than slow-growing ones. This seem also to be the case in juvenils and adults.

The results of present study, suggest that primary growth rings are formed daily in capelin up to an age of about one year, and thereafter lesser than one ring are formed daily.

INTRODUCTION

The capelin, Mallotus villosus, is routinely aged using annual zones in their otoliths. There is, however, problems in interpreting the first hyaline zone in some of the otoliths, and this makes the ageing uncertain.

In recent years, primary growth rings supposed to be formed daily, are observed in otoliths of many fish species (PANNELLA 1971, 1974; see ANON, 1982 for bibliography).

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

MATERIALS AND METHODS

The capelin with known age are reared in a large outdoor basin (volume 2000 m^3) in Flødevigen, Southern Norway. The eggs were sampled from natural spawning beds in Finnmark, transported to Flødevigen and hatched in laboratory at a temperature of $5^{o} \pm 0,5^{o}C$ and then transferred to the basin were the surface temperature was raised to 20^{o} and the temperature near the bottom reached $13^{o}C$ during the experiment. 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 usually stored in 70% alcohol before final treatment.

The otoliths, except the smallest, were ground on both sides till a thin section through the nucleus was obtained. They were mounted in Canadabalsam on glass slides and covered with cover slides.

The otoliths were read under microscope with 400-1000 x magnification.

The statistical methods used 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 7 samples taken from 61 to 127 days after 50% hatching (Table 1). The number of rings counted ranges between 31 and 150 (Fig. 1).

A predictive regression was fitted to the data, and the following equation was obtained:

$$r = 1.20\ d - 27.0$$

where r is number of rings counted and d is number of days since 50% hatching (Fig. 1).

The coefficient of determination was 0.569 and the confidence limits 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 significant ($F_{1.97} = 126$, $p<<0.001$), 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 age range studied.

The intercept with the age-axis is significantly different from zero, indicating the 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 regression of number of rings counted on length of the larvae was also estimated. 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. There was also, with one exception, a significant correlation between number of rings and length of the larvae within the samples with equal age (Table 1).

A multiple regression was also fitted to the data, and the following equation was obtained

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

where r is number of rings counted, d is days since 50% hatching and l is length of the larvae in mm. 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 reading of annual rings their age ranged from about 9 to 50 months calculated from January in their year of birth. Samples with 3 or more otoliths are included in Table 2 and Fig. 2.

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 is 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.

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 gave no significant correlation (Table 2).

Back calculated time of birth

Three samples of 0-group capelin were used to back calculate 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 is in good accordance 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 number of primary rings and length of the fish. As both variables have a variance, a functional regression was fitted (RICKER 1975).

This gave a slope, b = 0.174 and a coefficient of determination, 0.876. This indicate a growth rate of 0.17 mm/day which is likely for young capelin, but probably not for adults.

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 to 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. Probably, counting error can account for some of the variance, but apparently there is also a real difference in ring numbers between larvae with the same age. The correlation between number of rings and length of larvae suggest that the fast-growing larvae form more rings per unit time than the slow-growing larvae (Table 1). There seem to be a similar situation in juvenile and adult fish (Table 2). This also seems to be the case in Clupea harengus (A. Geffen, pers. comm.), and in Osmerus eperlanus the ring formation apparently stops when the growth falls below a certain limit (Timola 1977).

During a period when the larvae were about 40-50 days old the growth apparently stopped for a period of time (Moksness 1982 fig. 8, Moksness 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 the length of the fish was slightly better than that between number of rings and age estimated from annual zones. During the period considered (about 0.5 - 4 years) the mean rate of ring deposition was about 0.5 ring/day. If the 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 primary growth rings, as interpreted in the present study, do not form daily in adult capelin. It is, however, likely that they are formed daily in capelin up to an age of about 1 year.

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Table 1. Numbers of primary growth rings in capelin with 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

Table 2. Age as calculated from annual rings, length and number of primary growth rings in capelin from the field samples. The correlation between age and number of rings is also given.

Year class	Age at capture (days)	No.of fish	Length (mm) mean	conf.int.	Rings in otoliths mean	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	

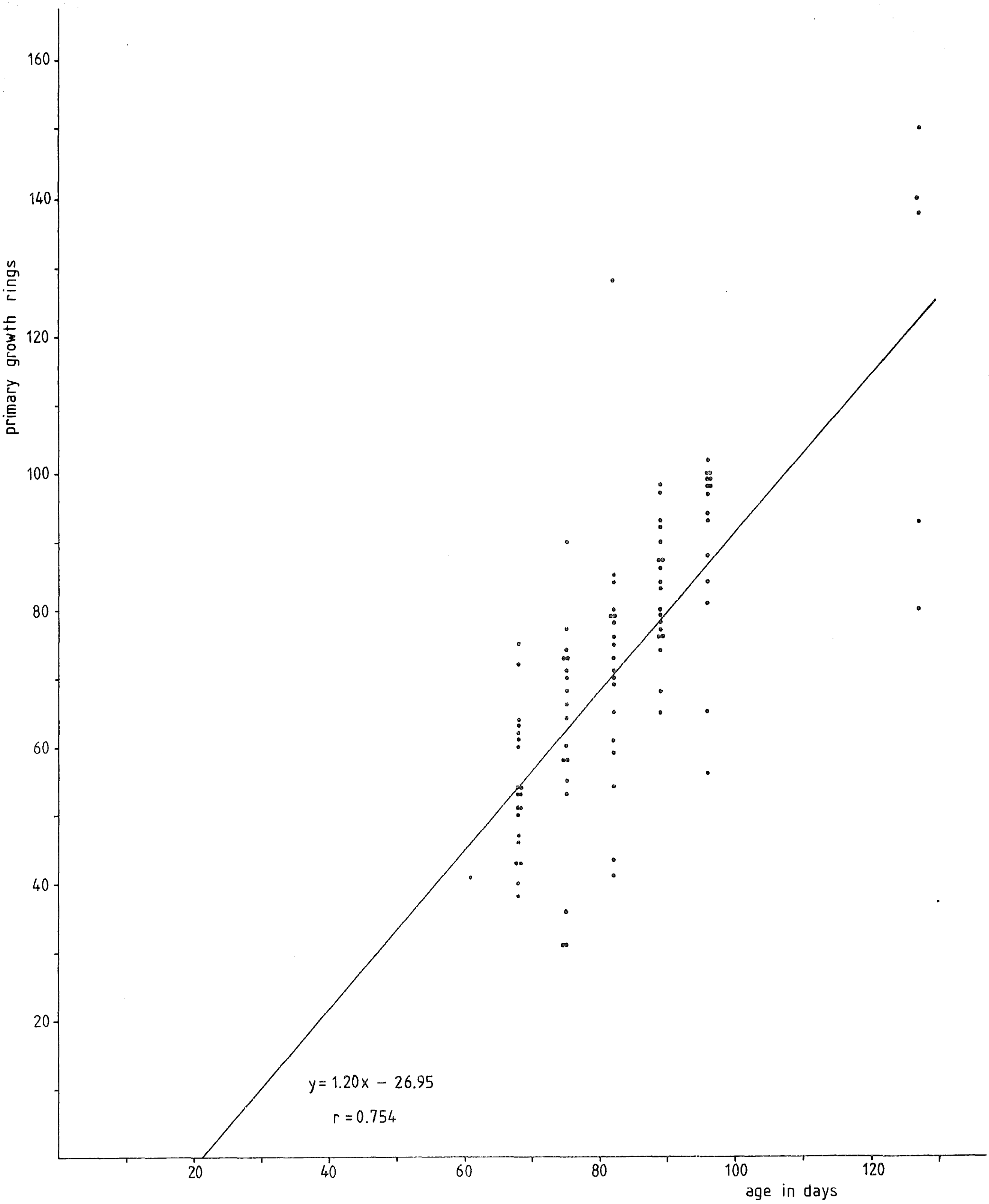

Fig. 1. Relationship between numbers of primary growth rings and days since 50% hatching in capelin reared in basin.

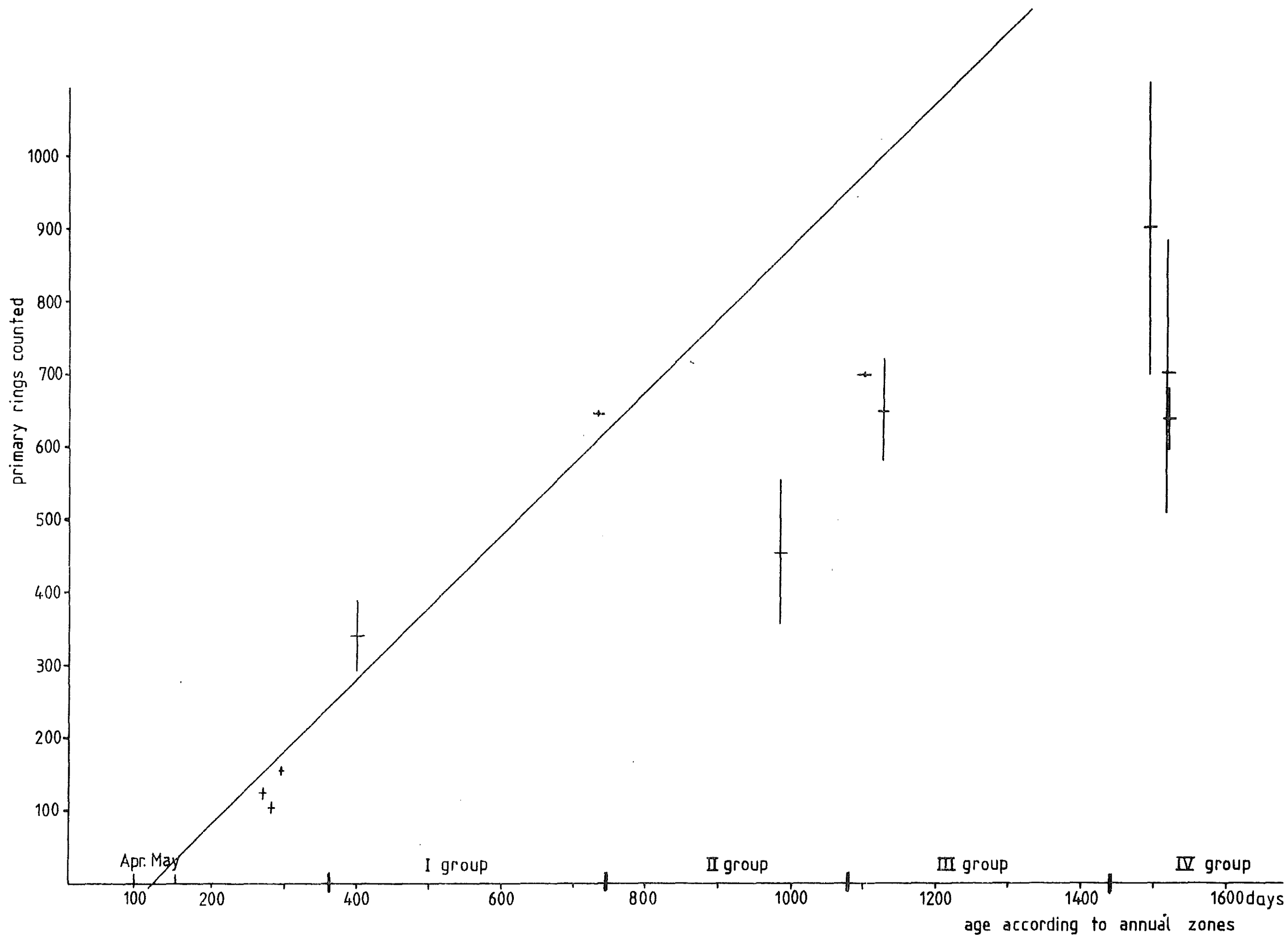

Fig. 2. Relationship between numbers of primary growth rings and age estimated from annual zone countings in capelin sampled in the field. The 45°-line shows the theoretical relationship provided that the rings are formed daily. Vertical bars show confidence intervals.

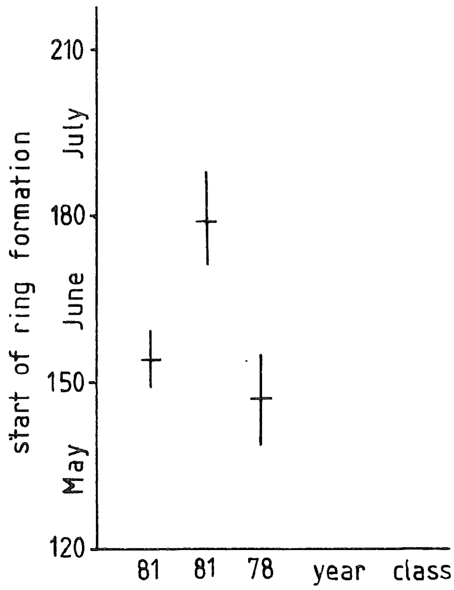

Fig. 3. Estimated time of start in growth ring formation for three samples of 0-group capelin.

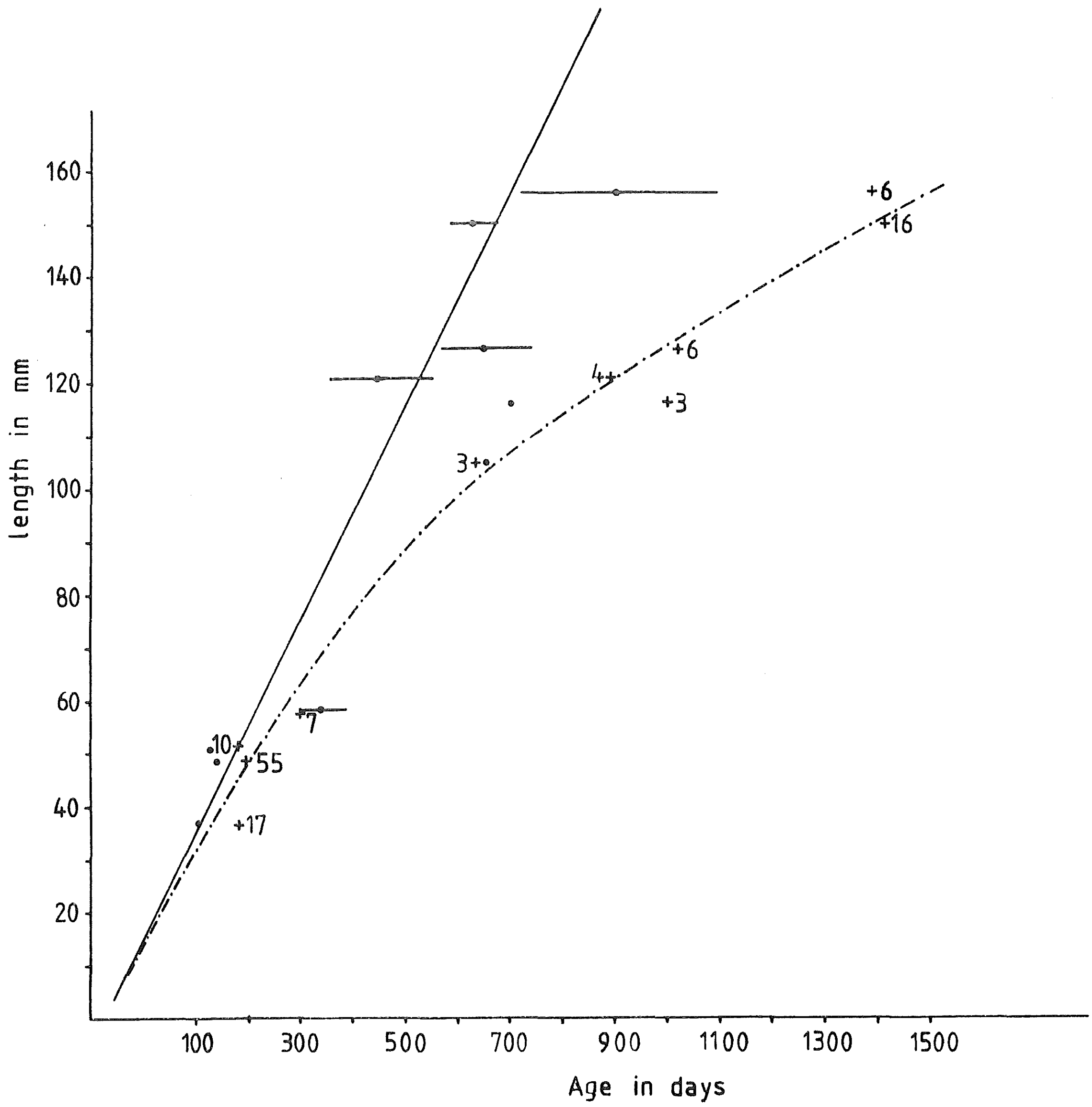

Fig. 4. Growth pattern of capelin as estimated from counting of daily growth rings (points and full line, with horizontal lines giving confidense limits) and from counting of annual zones (crosses and dotted line fitted by hand). The age is taken as days from January 1.