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Daily growth increments observed in otoliths from juvenile East Baltic cod

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Abstract

Difficulties in age determination of adult cod from the Baltic east of Bornholm by means of their otoliths were the reason for beginning this study. As especially there is some doubt regarding the growth within the first year of life the work is entirely concerned with young cod. Thin sections of otoliths from juvenile cod showed a number of uniform growth zones each of which seems to correspond to daily growth. The number of growth zones were counted in order to establish the approximate birthdate for each cod. These dates were in some cases different from the known spawning period by possibly a few weeks suggesting that an unknown number of growth zones in the central part of the otolith have escaped detection and that the methods ought to be improved.

Introduction

Otolith growth rings are usually the best indicators for determining the age of cod and several other species of fish. For most of the Danish fishing areas the growth structure of cod otoliths provides a sufficient periodicity for age reading purposes. The summer zones are clearly separated by winter zones.

This principal rule applies to the cod populations of the North Sea, the Skagerrak, the Kattegat, the Belt Sea and the Baltic west of the island of Bornholm.

But a major part of the cod population living east of Bornholm produces otoliths containing erratical seasonal growth patterns, which create difficulties for a uniform age determination in the biological work. The reason for this peculiar way of otolith growth is not quite obvious, and as exact data on age at length are necessary for assessing the virtual population it seemed worthwhile to make a closer examination of the otolith growth.

Especially there is some uncertainty regarding the growth of cod during its first year of life. Therefore the work has been aimed entirely at young fish below a length of 26 cm.

The cod living east of Bornholm form a separate stock, Baltic cod (*Gadus morhua callarias* L.), while cod from all areas west of Bornholm belong to the stock Atlantic cod (*Gadus morhua morhua* L.) (ICES 1978). The border between the two stocks is, however, a rather blurred one due to fluctuations in the relative proportions of the stocks and to different hydrographical situations.

The spawning season for Baltic cod is long, beginning in March and ending in August. The most intensive spawning period is usually May-June. It varies from year to year, however, depending on temperature, salinity and oxygen conditions. (Bagge and Müller, 1976).

Material and methods

Otoliths of 138 young cod from the E. Baltic fishing grounds of Gotland Deep, Slupsk Furrow and Bornholm Deep were utilized. Of these 71 were caught in the spring and 67 in the autumn. The aim was to obtain a thin slice of the otolith in a right angle to the length axis in such a way that it would contain the growth from the nucleus to the edge.

The otolith was placed in a mould and embedded in a two-component epoxy resin. When hardened the block containing the otolith was ground from one end until the nucleus began to show. Then the ground surface was pasted to a glass slide by means of the above mentioned medium and the grinding process was continued from the other end of the otolith leaving the desired slice on the glass slide. The grinding was done on a wet grinding machine with two rotating discs. One disc had grinding paper of fineness 220 grit for coarse grinding while the other disc was covered with grinding paper of fineness 800 grit for finish. Due to the grinding process being controlled by fingertip feeling only, the resulting slices had varying thickness, but they generally were below 0.1 mm.

When viewed under microscope by transmitted light and using a magnification of ×150-200 the otolith slice reveals a very regular structure consisting of concentric growth zones (Fig. 1).

Results

An attempt was made to count the number of growth zones in the above mentioned 138 cod otoliths. Some of the otoliths especially those from smaller cod did show a perfect system of growth increments from centre to edge, but the majority displayed scattered patches of ring systems which were combined to represent the total growth. The reason for these breaks of the pattern is the uneven deposition of material on the dorsal side of the otolith making this surface rather rough.

The procedure of combining the rings from the various parts of the larger otoliths did create some uncertainty as regards the resulting number of growth zones. In most cases, however, the concentric features were present which guided the counting work from one part of the otolith to the other.

A closer examination of the otolith slices shows some reoccurring features (Fig. 2). The central part is more or less blurred. Then follows a series of about 30-50 comparatively broad growth rings of uniform thickness. They are interrupted by a short termed irregular structure indicating a distinct change of the daily life cycle of the cod (the arrow in figure 2). A likely change at this stage could be the transition from pelagic to demersal life. After this interruption the growths increments are again regular with occasional variations in thickness only.

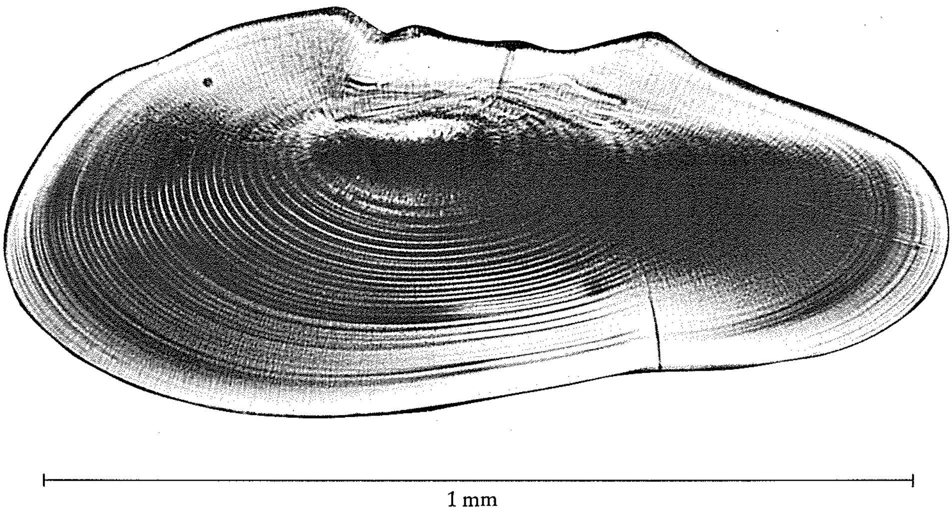

Fig. 1. Cross section of cod otolith. Length of cod 6 cm. Caught November 14th in Bornholm Deep. 46 daily growth zones.

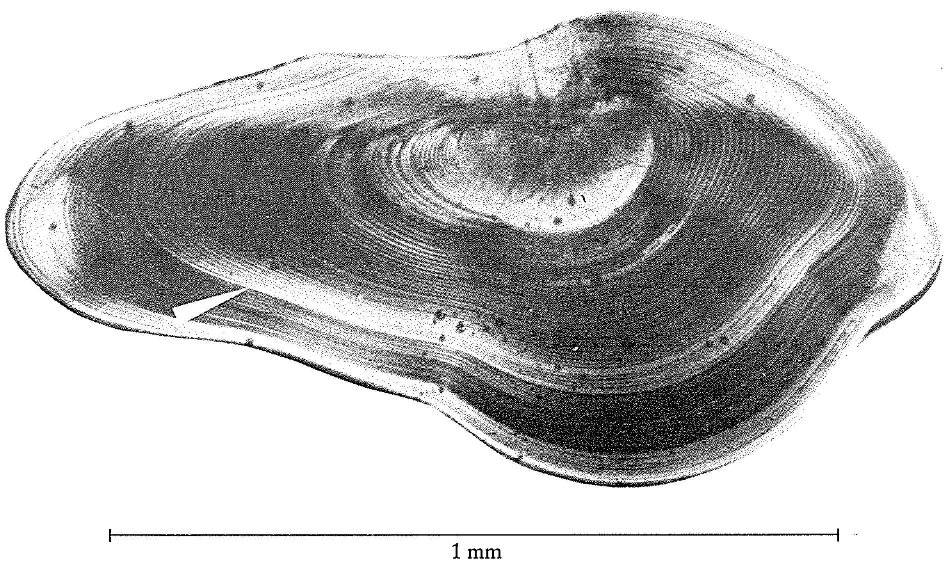

Fig. 2. Cross section of cod otolith. Length of cod 7 cm. Caught November 17th in Slupsk Furrow. 91 daily growth zones. Arrow indicates change of structure, possibly due to transition from pelagic to demersal life.

On the assumption that the growth zones observed represent daily growth increments the next step was to count the number of zones in order to establish some sort of birthday for each individual fish. For this purpose it is essential to know the date of capture for the fish concerned.

In fig. 3 is shown the mean number of growth zones plotted against the relevant length-groups of cod. The material was split into spring and autumn catches. For each length group the standard deviation was calculated from the results of individual countings and are shown as horizontal lines. In brackets are the numbers of observations per length group.

The correlation coefficient for the mean number of growth zones was calculated for each season and gave 0.94 for spring captures and 0.99 for autumn captures suggesting a high degree of correlation. In order to find the approximate birthdates the numbers of growth zones were counted backwards on a calendar from the date of capture.

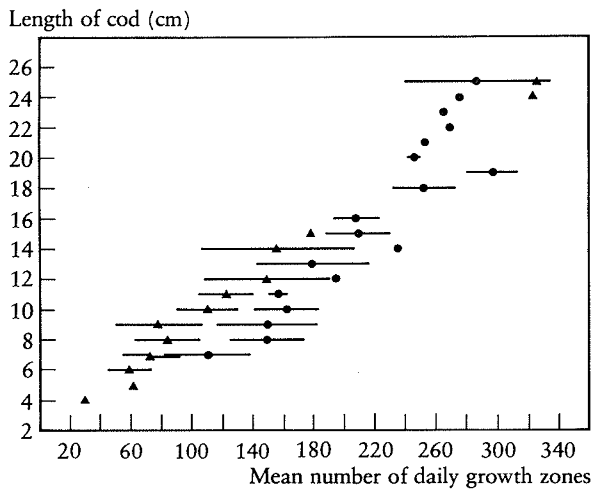

Fig. 3. Mean number of daily growth zones per cm group of cod. Total number of observations = 138. The standard deviation for number of growth zones is calculated for each length group and shown as horizontal lines.

● = Caught in spring. ▲ = Caught in autumn.

Correlation coefficient for spring catches: 0.9380.
Correlation coefficient for autumn catches: 0.9942.

The actual spawning or hatching dates are earlier than the birthdates thus estimated. Some rings are lost at the otolith centre due to inaccurate grinding and time may have elapsed after hatching before the otolith was deposited.

There is also evidence that rings are produced all year even if body growth slows down or possibly stops due to the drastic reduction in food intake during the winter months.

Fig. 4 shows the date of capture with the corresponding 'date of birth' for the individual observations in each length group of cod. It appears that otoliths from juvenile cod of one length group caught in spring display a higher number of growth zones than those of the same length group caught in the autumn. This is most clearly demonstrated for the length groups 7, 8, 10 and 11 cm. The higher number of growth zones indicates slow or no body growth during winter which is

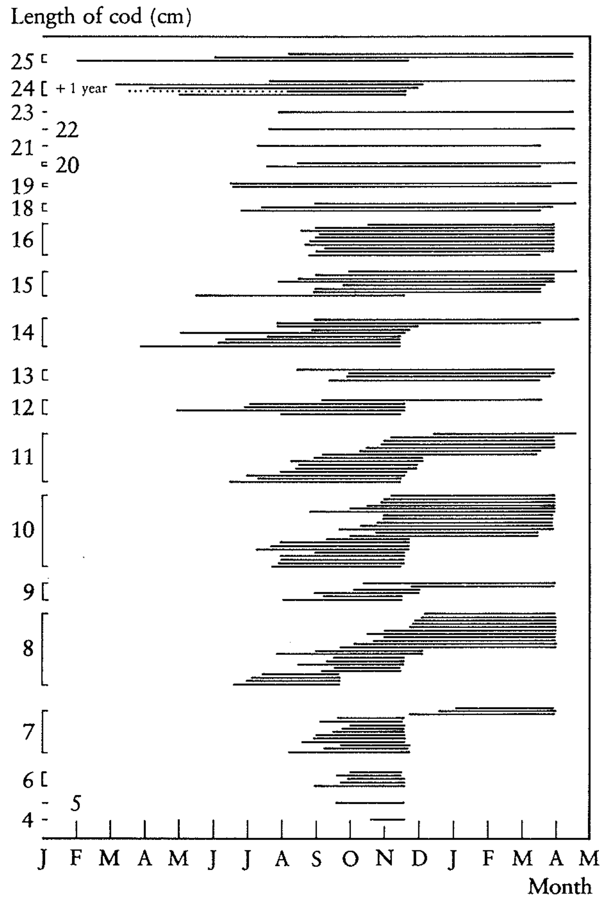

Fig. 4. Calculated life-span of each cod estimated from number of daily growth zones observed. Left end of line represents the birth date and right end indicates the date of catch.

in accordance with the higher number of empty stomachs found in adult cod at the same time of the year during feeding investigations.

The calculated birth dates were arranged according to months (Table 1) and again a difference between the captures from spring and autumn respectively appeared. Within the same length group cod caught in the spring seem born later in the year than those caught in the autumn.

Figs. 5 and 6 shows that a pronounced difference in the length of fish is not always followed by a corresponding difference in the number of growth zones. Fig. 5 shows the cross section of a cod otolith from Gotland Deep. The cod had a length of 7 cm and was caught 22nd November, 1972. When viewed under microscope 110 growth zones were counted. Evidently there have been two disturbances during the deposition of growth zones. The disturbance nearest to the centre is possibly caused by the transition from pelagic to demersal life. After this disturbance the growth zones become more narrow and are again interrupted by what looks like a dark band (arrow in the figure). This band contains 4 growth zones

Table 1. Distribution of calculated birth dates on month and length group for spring and autumn catches respectively. Spring/autumn.

Length of cod, cm	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
25		/1				1/		1/				
24			/1	/1	/1		1/	/1*				
23							1/					
22							1/					
21							1/					
20							1/	1/				
19						2/						
18						1/	1/	1/				
17												
16								5/	4/	1/		
15					/1		1/	3/	3/			
14			/1		/1	/2	1/2	1/1				
13								1/	1/	1/	1/	
12				/1		/1	/2		1/			
11						/2	/2	/4	1/	2/	1/	1/
10							/7	1/1	1/1	10/	1/	
9								/2	/1	1/1	1/	
8						/2	/3	/2	1/4	5/	3/	2/
7	1/							/4	/7		1/	1/
6								/1	/4			
5									/1			
4										/1		
3												
2												
1												
Total	1/	/1	/2	/2	/3	4/7	8/16	14/16	12/18	20/2	8/	4/
%	1.4/	/1.5	/3.0	/3.0	/4.5	5.6/ 10.4	11.3/ 23.9	19.7/ 23.9	16.9/ 26.9	28.2/ 3.0	11.3/	5.6/
% both seasons combined	0.7	0.7	1.4	1.4	2.2	8.0	17.4	21.7	21.7	15.9	5.8	2.9

* 480 growth zones, i.e. more than one year old.

and indicates a short change in the mechanism regulating the composition of growth zones, but the reason for such a change is not quite obvious.

The otolith in Fig. 6 is of a cod 14 cm long caught on 30th November 1972 in Bornholm Deep. 140 growth zones were counted, but the central part of the otolith is rather confused because the nucleus was not precisely hit when grinding. In spite of the confused appearance at the photo it was actually possible to find growth zones in this part as well when examined under microscope. Considering the fact that both cod were caught at the end of November which implies hatching and growth under more or less the same conditions there is a conspicuous difference in the correlation between number of growth zones and length of cod.

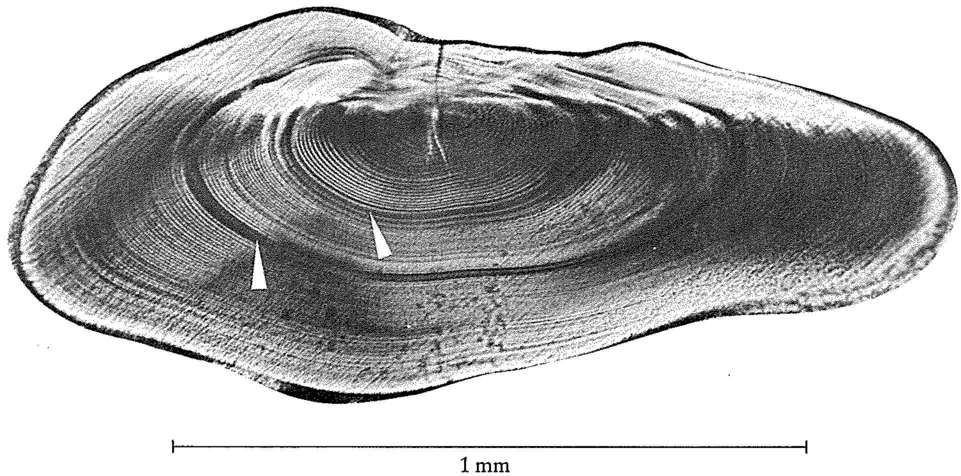

Fig. 5. Cross section of cod otolith. Length of cod 7 cm. Caught November 22nd in Gotland Deep. 110 daily growth zones. Arrows indicate disturbances in the deposition of growth zones (See text).

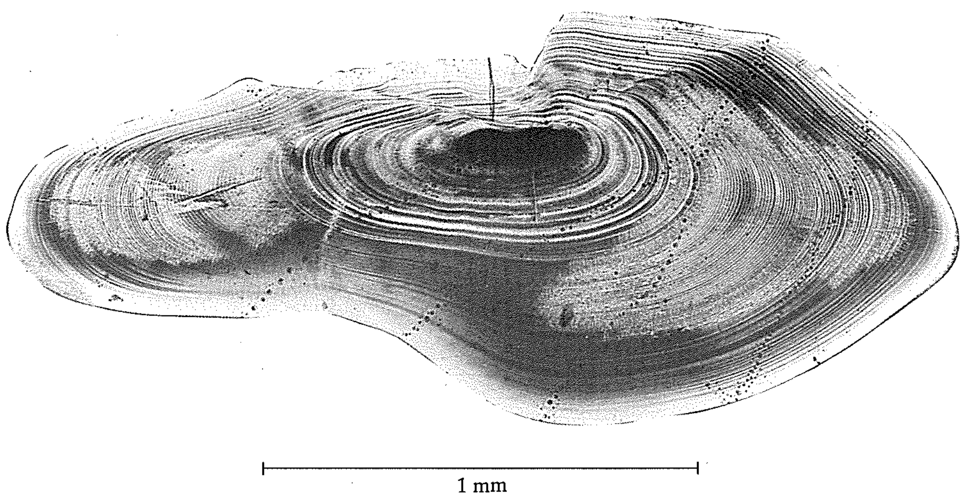

Fig. 6. Cross section of cod otolith. Length of cod 14 cm. Caught November 30th in Bornholm Deep. 140 daily growth zones.

Discussion and conclusion

Apparently some unknown factor is incessantly provoking the internal chemical system of the fish into depositing $CaCo_3$ and other compounds on the surface of the otolith. But what conditions might during short time intervals be able to influence the chemistry of a fish into leaving imprints on the otolith?

Food intake, temperature fluctuations, salinity variations and the alternation between day and night are some of the recurrent events which could be anticipated as being of importance in this connection.

The amount of food and the feeding times are hardly constant enough to be the factor looking for. Equally doubtful are temperature and salinity changes during shorter periods taking into account with which precision the rings are formed. On the other hand seasonal temperature changes are most likely responsible for the formation of annual rings. But day and night are cyclic events and are probably the answer we have been looking for, which again means that the growth zones observed in fact represent daily growth increments.

This is in agreement with finding of other authors (Panella 1971, 1974, Brothers *et al.*, 1976).

The growth zones developed in the otolith of the juvenile cod are an essential part of the subjective impression received when age determining adult cod. Some otoliths from adult cod have a number of wide rings in the centre suggesting birth in late summer, while others exhibit a series of narrow rings indicating birth in winter.

Most likely these two types of centres contribute to the uncertainty of the otolith reader when reading more or less difficult otoliths.

The birth dates calculated from the number of growth zones seem somewhat late in the season when compared with the known duration of spawning, but most likely the missing days are to be found in the so far unexplored central parts of the otolith slices. It has not so far been possible in the literature to find any information on the relation between the growth in length and time of cod larvae and fry.

Ehrenbaum (1905-1909) states that the length of the cod larvae at hatching is about 4 mm and that just after the yolk-sac absorption it is about 4.5 mm.

According to Brothers *et al.* (1976) laboratory reared larvae from pike, *Esox mordax*, did show daily growth increments in the otoliths immediately after completion of yolk-sac absorption. With improved methods it should be possible to prove if this applies to cod as well.

Considering the size of a newly hatched cod larva the nucleus of its otolith must be proportionally small implying that the first growth zones cannot have the same dimensions as the ones observed. Accordingly the number of initial growth zones hidden in the confused part of the cross section might be essential and once detected would help moving the calculated birth date further back into the known spawning period.

As the spawning season for cod in the E. Baltic is rather long, a difference between the growth of the fry hatched in the spring and the ones hatched in late summer is expected. It seems that a cod born in March can attain a length of at least 15 cm on January 1st, but it is not possible to give the exact upper limit because the length groups above 15 cm of cod caught in November-December are poorly represented in the samples.

Some few observations of 24 cm cod caught around December 1st however suggest that the 0-group may extend to this length.

Judged from the difference in the number of daily growth increments of young cod of equal length, but caught either in the autumn or in the spring there seems to exist a slow growth and a fast growth season like those found for adult cod.

Due to the extended spawning season for E. Baltic cod it is to be expected that the appearance of the central part of otoliths from adult cod may vary with its birth date.

From the number of daily growth zones counted it appears that the 0-group cod are able to reach a length of 15 to 25 cm at the time on entering the I-group on January 1st.

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