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The Influence of Temperature on the Formation of Zones in Scales and Otoliths of Young Cod

BY

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The Flødevig Sea-Fish Hatchery

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INTRODUCTION

Since the beginning of this century, the zones in scales, bones, and otoliths have been of fundamental importance for the study of age and growth of fishes.

For practical purposes it is essential to know the exact season during which the zones are formed. And much work has been devoted to this problem.

The results differ, however, from species to species, and even among different populations of the same species. It will therefore be appropriate to try to elucidate what factors influence the formation of zones.

In this paper I will report the results of some experiments on the effect of temperature on the formation of zones in scales and otoliths of young cod. The cod have been kept in aquaria at constant temperatures.

Sigfred Hansen, technical assistant, has been in charge of the experiments. Finn Otterbech, scientific assistant, has revised the otoliths. The photos and sclerite-measurements have been made by Ragnvald Løversen, technical assistant.

EARLIER EXPERIMENTS

Before giving the results of these experiments I will give an account of results of earlier rearing performed at Flødevigen at normal temperatures.

In 1919 we placed 150 0-group cod between 8 and 12 cm in our salt-water pond (750 m^2 with a max. depth of 5 metres). Samples of the fish were taken during the following years – the last one in May 1923.

The results (Dannevig 1925) indicate that narrow sclerites are formed in late summer, for slow growers also during winter. The forma-

tion of wide sclerites normally takes place in late autumn and winter.

The results were verified by further experiments in 1927–30 (Dannevig 1933). The cod were partly kept in an aquarium in the laboratory, and partly in boxes in the sea. As only two individuals – of different length – were kept in each compartment it was possible to ascertain the individual length increment, as well as the consumption of food for each of the two individuals.

In this case scale samples from the living fish were taken at intervals of a few months.

At the same time samples were collected from the sea. The results are summarized as follows:

«Measurements of the sclerites in the scales show that minimum sclerites as a rule occurred first when the fish had a computed length of 5–8 cm, which the fish normally reach during the month of August. The minimum sclerites are soon followed by large sclerites; maximum values are found when the fish reach a length of about 11 to 20 cm.» This refers to the 0-group.

And for the older fish:

«Scales with narrow sclerites at the margin are found in all months of the year, but it is evident that August is the principal time for the formation of the narrow zones. Broad sclerites predominate at the margin from November to July. As the great majority of the scales (in one case 100 %) have narrow sclerites at the margin in early autumn it is reasonable to assume that the zones found at other seasons are supernumerary. As it is impossible to distinguish between the zones formed in the different seasons, some errors must be expected when using the zones in the scales for age determination.

«The study of the otoliths, however, revealed the fact that the transparent zone here occurred at he margin only in summer and autumn, at times to an extent of 100 %. Opaque zones at the margin predominated (occasionally 100 %) from November to May. The occurrence of the zones in the otoliths is thus much more regular, and as they are easily distinguished they are to be preferred for age estimations.»

Variations in scales and otoliths of different populations from the Skagerack coast are described in an earlier paper. (Dannevig 1949).

It is proved that the scales of cod from the open Skagerack coast, and from the outer and inner Oslofjord differ so much that they can be used as an indicator of the populations in question. Near the coast the zones are very clear, less so in the outer fjord. In the insulated inner Oslofjord the sclerites are so uniform, or the variation in the width of the sclerites so irregular, that no regular zones are formed.

The same also occurs in the otoliths. Near the coast and in the outer fjord the zones are distinct – in the inner fjord the picture is disturbed by secondary zones making the reading very difficult. (Finn Otterbech 1954).

The chemical composition of the otoliths has been examined by Eva Henly Dannevig. From a manuscript now in the press I have been permitted to quote the summary:

«A complete analysis of the inorganic and organic material in cod-otoliths shows their composition to be 76.39 % $CaCO_3$ (aragonite), 11.44 % CaO, 11.49 % H_2O + organic material, and 0.68 % other compounds. The organic material is a protein, conchiolin. Its amino-acid constituents are given. The calcium-compounds are deposited in all parts of the otoliths. The transparent zone (formed in the marine «summer») contains only inorganic compounds, and the opaque zone (formed in «Winter») contains both calciumcompounds and conchiolin.»

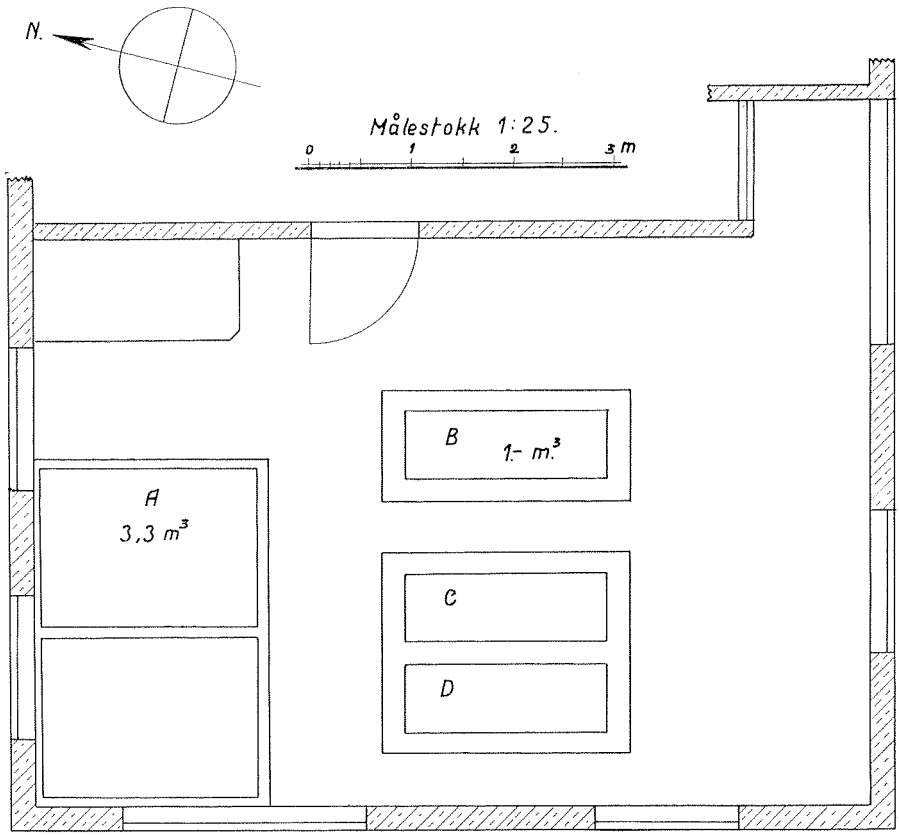
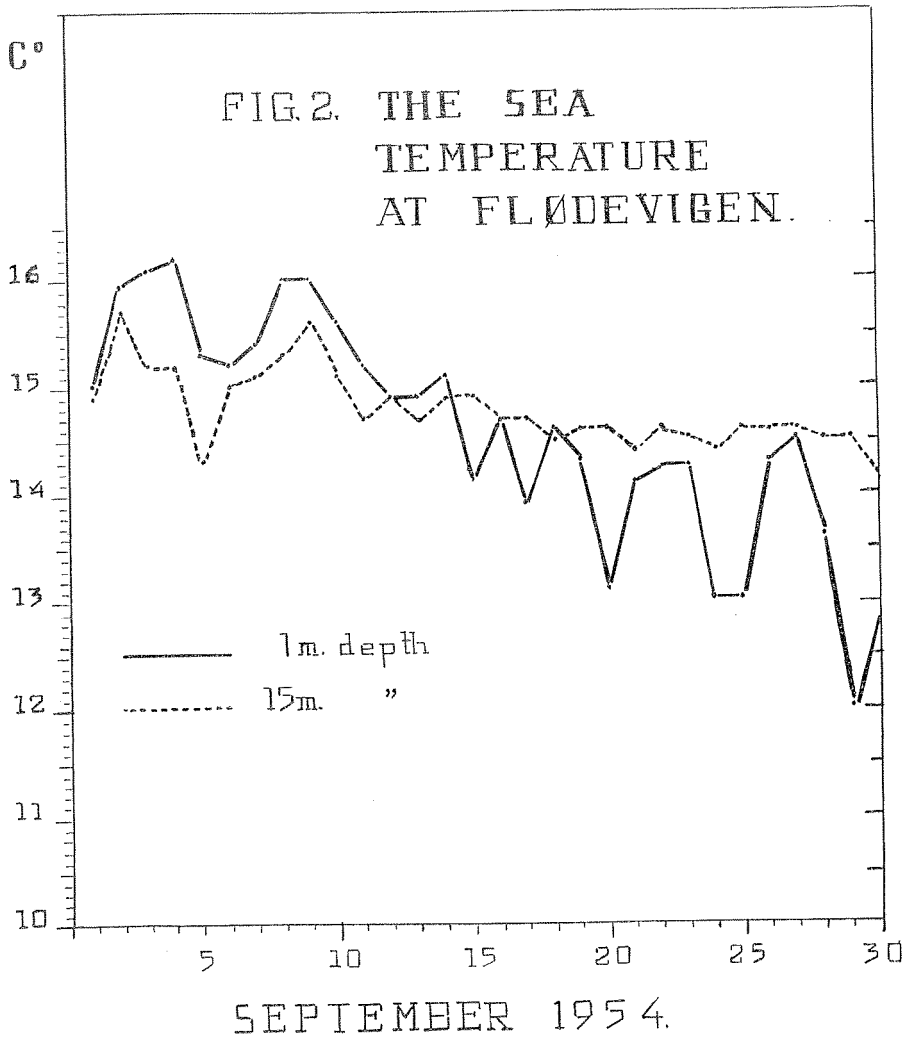


Fig. 1. Groundplan of laboratory.

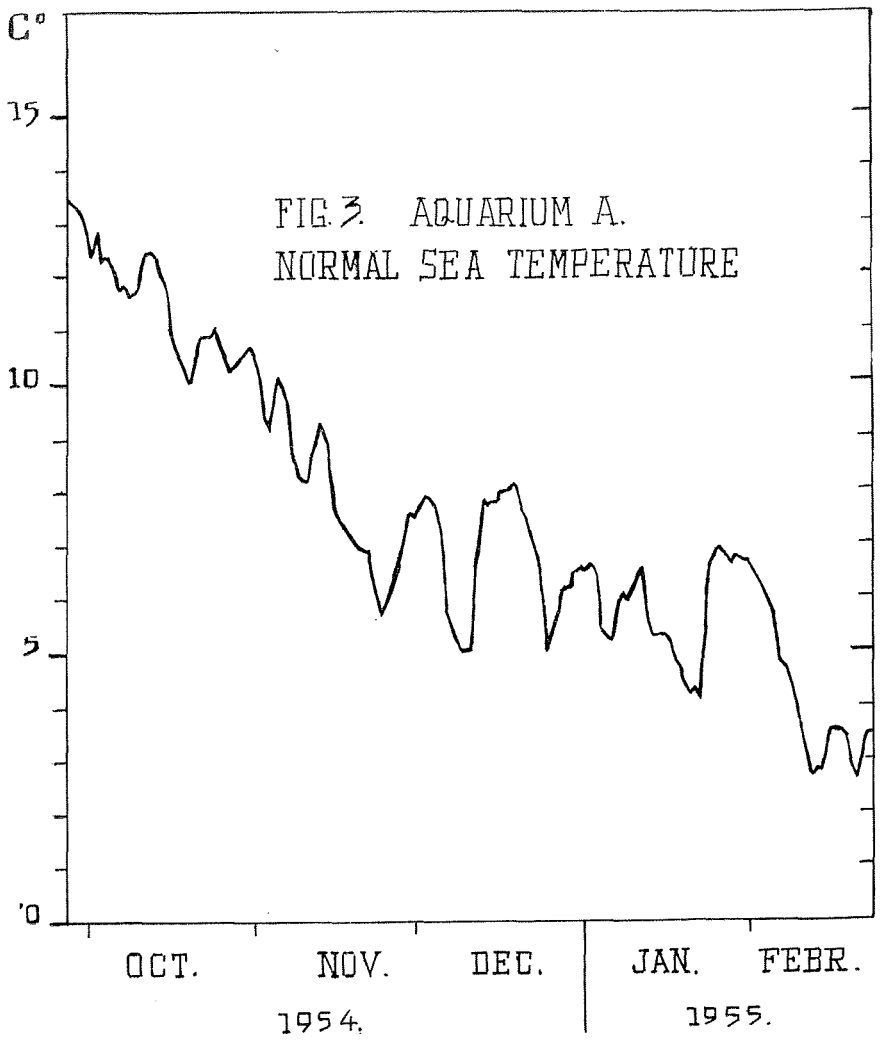


EXPERIMENTS 1954/55.

In spring 1954 we were able to install a heating-cooling device for the sea-water used in the laboratory. The temperature of the running sea-water is thermoregulated separately for each aquarium.

Fig. 1 illustrates the aquaria used.

In September 1954 we caught some 0-group cod in the littoral region near Flødevigen. On 27th September the codlings were placed in three insulated aquaria which were supplied with running sea-



water of constant teperatures, and in one uninsulated aquarium supplied with sea-water from the pipe.

The temperature of the sea at depths of 1 and 15 metres in September 1954 is illustrated in fig. 2.

The temperature in the uninsulated aquarium, experiment *A*, is given in fig. 3.

In experiment B the temperature was, within three weeks, lowered to about 4°C. In C the temperature was, within one week, lowered to about 8° C, and in D to 12° C.

The temperatures were kept constant till 23rd February 1955

Tab. 1. The length of the Cod at the beginning and at the end of the experiments.

Length	A. Norm. t.		B. 4° C.		C. 8° C.		D. 12° C.	
cm.	27/9-54	23/2-55	27/9-54	23/2-55	27/9-54	23/2-55	27/9-54	23/2-55
7	Not measured		4		1		1	
8			9		10		20	
9			15		18		6	
10			7	1	5		10	
11		1	3	4	2		2	
12		2	2	10	4			
13		2		5			1	4
14		3		1				
15		1		1		4		3
16		1		6				1
17		1		2				
18		2		1		3		1
19		1		2				
20		1		1				
21		1						1
22								1
23						1		
24								
25						2		
		16	40	34	40	10	40	11

when the experiments had to be discontinued. The aquaria were then needed for other experiments.

Between 29th October and 3rd November the cooling system failed, and the temperatures in B and C rose to 10—11° C.

The codlings were fed with the soft parts of Mytilus edulis and some fish. Some cannibalism complicated the feeding programme. The consumption of food will therefore not be discussed on the basis of this experiment. New experiments on that problem are now in progress.

The length of the cod at the beginning and at the end of the experiments is shown in tab. 1. The fish have grown well in all experiments — and the length attained corresponds with that normally found in nature.

At 4° C the length of the majority of the fish is somewhat less than at ordinary winter temperature. At 8 ° C and 12° C it seems somewhat greater. In those experiments, however, the cannibalism was most predominant. We must assume that the smaller ones have been eradicated.

The causes for the great individual differences in length increment within the same experiment cannot be discussed on the basis of this material. The question of races and their behaviour to different temperatures, comes into the problem.

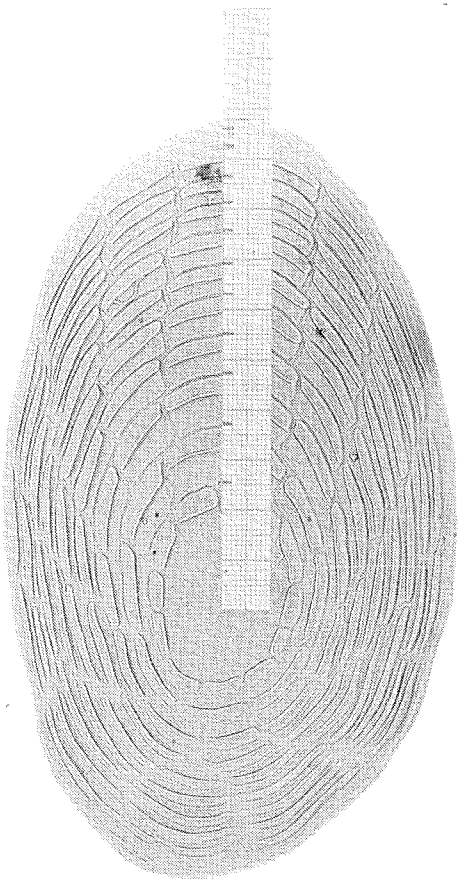


Fig. 4. Scale of cod, 9.8 cm. October 11 th 1919.
Illustrates the measurements of the sclerites.

By chemical analysis of the proteins of the 0-group cod at Fløde-vigen in 1955 it is demonstrated that different types of cod are present (Eva Henly Dannevig, unpublished).

The sclerites of the scales were measured, and diagrams constructed on the basis of proportionality between the growth of the fish and the scale.

The measuring of the sclerites is illustrated in fig. 4. In an Edingers apparatus the scale is projected on a screen. A slip of mm-paper is placed in the centre of the scale picture, and each sclerite is

marked. The slip is then — by Lea's board — brought into a constant relation to the length of the fish.

In the diagrams the abscissa represents the length of the fish — and the relative width of the sclerites. The ordinate represents the actual width of the sclerites. The last sclerite is normally not fully developed.

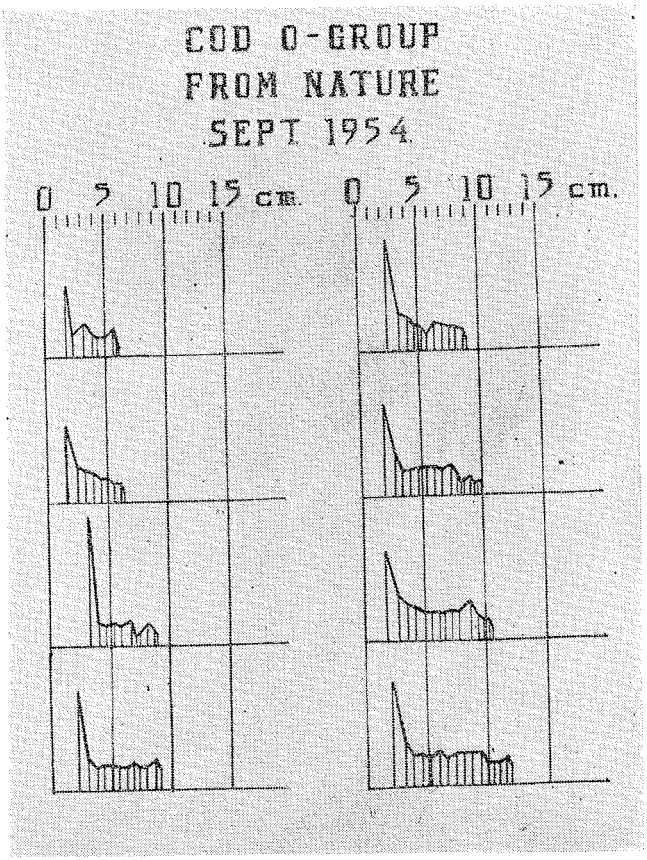


Fig. 5. Sclerite diagrams.

In this way it is possible to ascertain at what length of the fish the sclerites are formed, and the curves of one individual may be compared with that of another.

Fig. 5 gives the diagrams for some codlings of different sizes caught in nature when the experiments were started in September 1954. As will be seen from the figure, the length of the fish varied between 6 and 12 cm. The curves have a sloping tendency indicating the for-

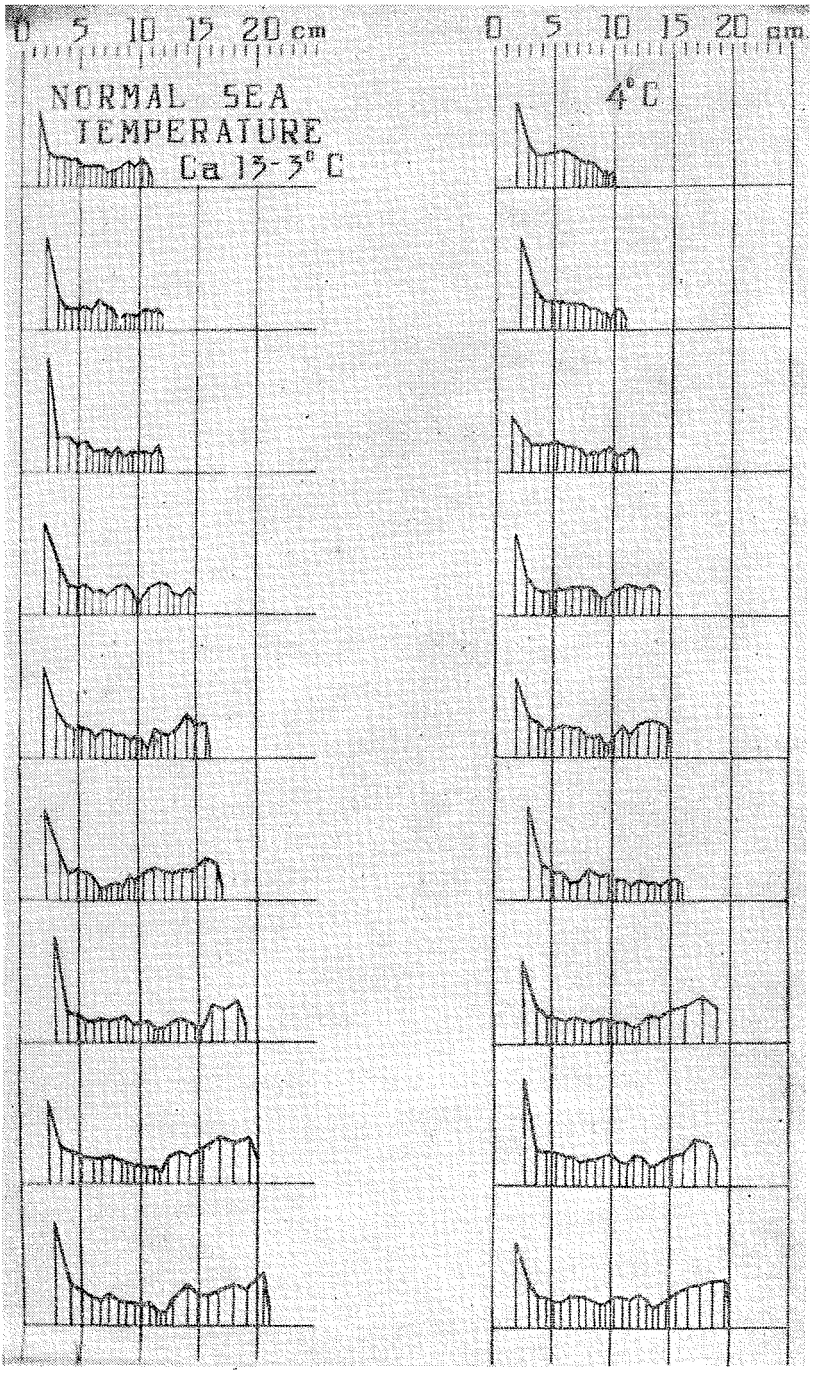


Fig. 6. Sclerite diagrams.

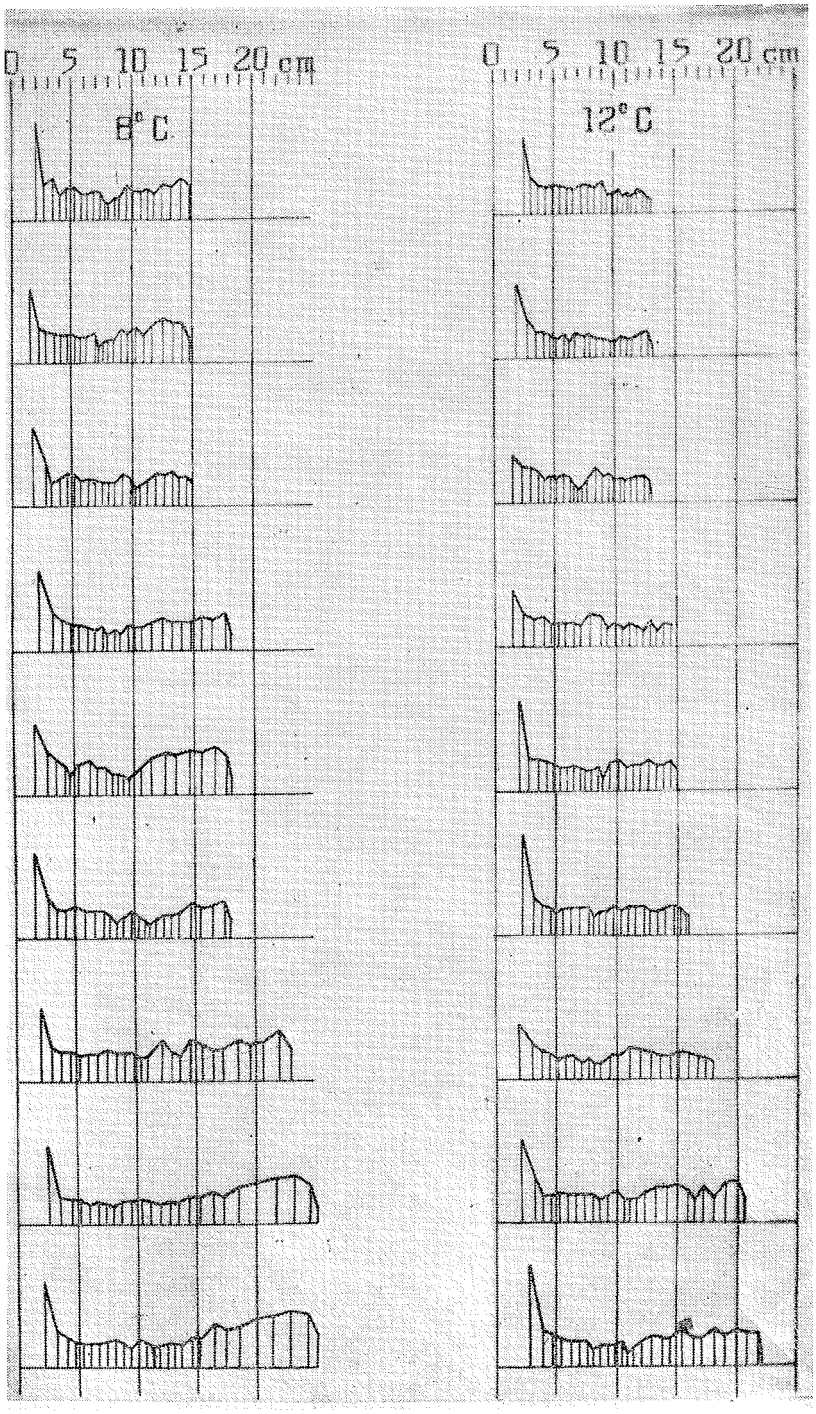
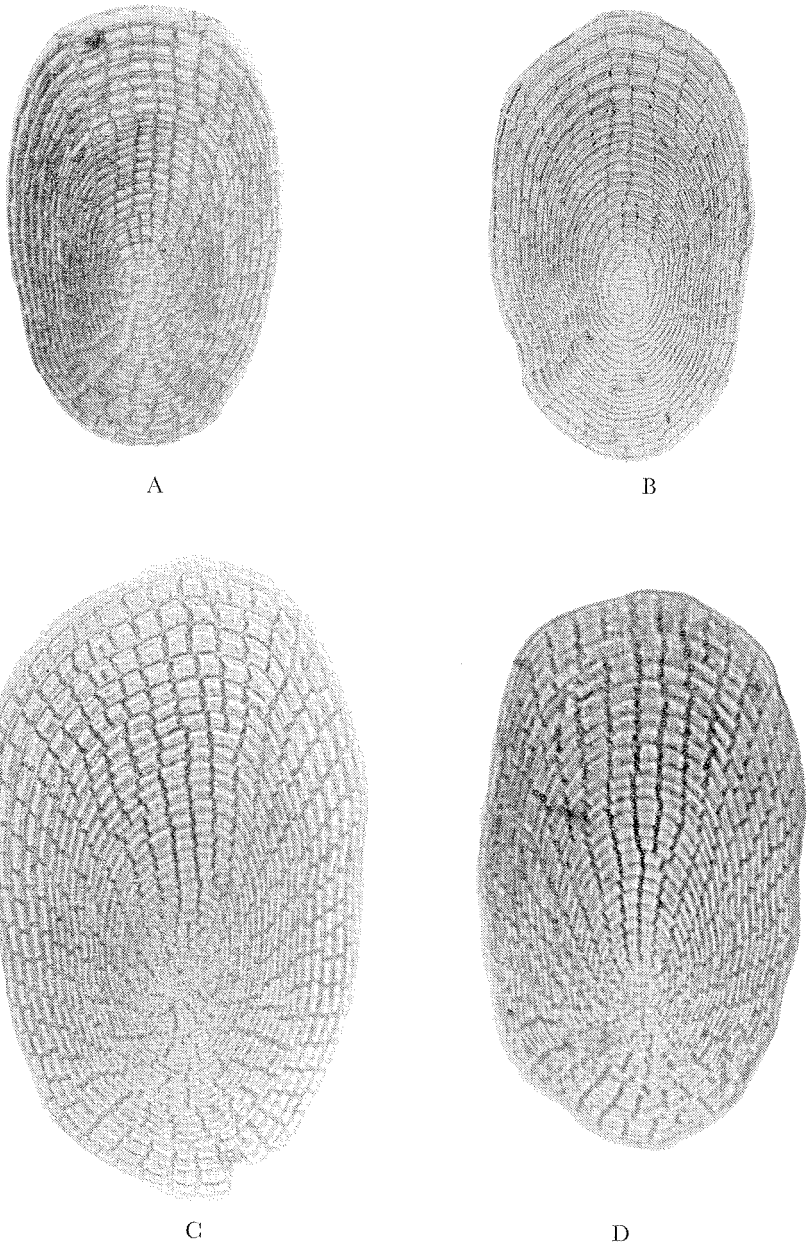


Fig. 7. Sclerite diagrams.



A B C D

Fig. 8. Cod scales.
A. Normal seatemperature. B. 4° C. C. 8° C. D. 12° C.

mation of small sclerites near the margin. The «winter»-zone is forming.

Fig. 6 gives the figures for the cod reared until 23rd February 1955, at normal sea temperature and at 4° C. In the scales of the smallest individuals, 11 and 12 cm, the sclerites are relatively narrow towards the margin. The medium and large individuals have small sclerites when the fish had a computed length equal to the length when the experiment was started. But then follow large sclerites to the very margin of the scale. The sclerite diagrams for the cod reared at 4° C are thus nearly identical with those reared at normal temperatures.

Fig. 7 represents the sclerites from the 8° C and 12° C experiments At 8° C we lack slow growers — and in all individuals we have large sclerites towards the margin. For the 12° experiment the sclerite diagrams lack — nearly totally — large sclerites, even from the largest specimens.

In fig. 8 photos of scales from the different experiments are reproduced.

By inspecting the otoliths it became evident that those from cod kept at normal temperature and at 4° C were quite in conformity with otoliths from nature, an opaque centre, one distinct transparent zone and one opaque zone outside.

In the otoliths from the 8° C experiment the zones were diffuse and not distinct.

In the otoliths from cod kept at 12° C only the centre was opaque — the rest to the very edge was more or less transparent. Only in the otoliths from one cod it was — by good will — possible to observe some difference between the ordinary transparent zone and the opaque zone outside.

Photos representing otoliths from the different experiments are not given. It is very difficult to get «true» pictures of the zones of the otoliths. Differences in the thickness of the otoliths, a small variation in time of exposure etc. will to a high degree influence the picture. —Median cuts may give nice pictures (fig. 9), but in this case all the otoliths were used for chemical analysis.

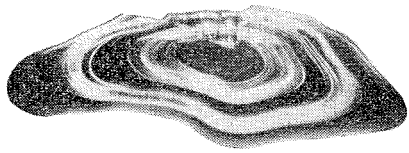


Fig. 9. Cuts of a otolith from cod. L. 26 cm. 16/6—1924.

The analyses made by Eva Henly Dannevig on the content of organic matter demonstrate that it is highest in the 4°C experiment, indicating a relatively high content of opaque material.

SUMMARY AND DISCUSSION

From 27th October 1954 to 23rd February 1955 0-group cod from the littoral region at Flødevigen were kept in aquaria, and furnished with running sea-water of different temperatures:

A: The temperature was normal for the season. It varied between 14.3° C at the start, to 2.6° C on 20th February.

In the other experiments the temperatures were lowered within a few days, and later kept constant:

B: At 4° C.
C: At 8° C
D: At 12° C.

The individual length increment varied within wide limits in all experiments. The cause of the variations may tentatively be ascribed to different races being involved in the material collected.

The length attained in all experiments (tab. 1), was of the same order as that normally found in nature, and there was no considerable difference between codlings kept at different temperatures.

At the start in September 1954 the scales showed narrow sclerites near the margin. A zone was forming. When the codlings were killed on 23rd February 1955 the scales of the smallest individuals still had narrow sclerites at the margin — irrespective of temperature. The medium and large individuals in all experiments except at 12° C had a wide space of large sclerites. At 12° C the sclerites were small or moderate, irrespective of quick growth.

We may draw the following conclusions:

a. Narrow sclerites are formed when the sea-temperature is high.
b. Narrow sclerites are also formed at low temperatures in slow-growing individuals.
c. Wide sclerites are formed at low temperatures in medium and quick growers.

The results — as to the season of the formation of zones — are in full conformity with those referred to from nature.

It is evident, however, that narrow sclerites cannot be used as an indication of slow growth of the fish.

There seems to be a chance of correspondence between wide

sclerites and quick growth. But quick growth at relatively high temperatures may be associated with narrow sclerites.

In slow growers small sclerites will be predominant.

The otoliths were quite normal in cod at winter-temperature and 4° C. There is an opaque centre, and a tranparent zone surrounded by an opaque zone. At 8° C the transparent zone was generally more diffuse and not so well marked. At 12° C the transparent zone seemed to proceed more or less diffuse to the margin of the otolith.

This indicates that the tranparent zone is formed at relatively high temperatures, the opaque zone at relatively low. This is in accordance with the results arrived at by examining young cod from nature (Dannevig 1933).

Chemical analysis revealed that the formation of organic-opaque material was highest at 4° C.

The results of the experiments indicate that the formation of zones in the scales and otoliths of the cod is influenced by temperature directly or indirectly.

To what degree other factors – food, light or an inherited rhythm – also come into the problem will be discussed on the basis of further experiments.

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