RESTRICTED

International Commission for the Northwest Atlantic Fisheries

Serial No. 3274
(D.c.2)

ICNAF Res.Doc. 74/60

ANNUAL MEETING - JUNE 1974

Growth of the otoliths of young herring (*Clupea harengus harengus* L.) in the Bay of Fundy (ICNAF Div. 4X)

by

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Introduction

Otoliths have been used for a long time in ageing Atlantic herring (Birtwistle and Lewis 1923; Lissner 1925). Except for the work of Hempel (1959) and Wood (1962) who studied otolith growth in North Sea herring, little has been done in studying otolith development and growth in relation to fish length, especially in their early stages. In the ICNAF area it appears that the only report on herring otolith growth is by Watson (1964). In his study on ageing young Maine herring, he examined the relationship between the otolith length and fish length, but his samples included fish ranging only from 85 to 285 mm in length.

In the present study, young herring (0-1 group) were examined to study their development and growth. The study of otolith growth, particularly in the young stages, is essential for elucidating the nature of the central area and first winter zone, and subsequently for better understanding the fish age and growth.

Materials and methods

Sixteen samples including 217 fish were collected from Passamaquoddy Bay and adjacent area in the New Brunswick side of Bay of Fundy in 1968 through 1970 (Table 1). Fish lengths ranged from 32 to 115 mm. Otoliths (sagittae) were extracted from the sacculii of the labyrinth by dissecting the skull in front of the occipital, and removing the otoliths with a pair of fine forceps. For the smaller fish, dissection was carried out under a microscope.

Otoliths were cleaned, dried, and examined under magnification 25X, both in dry and wet (70% alcohol) conditions. Some samples were examined for detailed structures, using magnification 50X. Otolith images were projected and traced on cards by the use of camera lucida. Focusing, once set up, was not changed until the sample had been completed. The otolith pair from the same fish was found almost identical hence, one otolith (right side) was arbitrarily chosen for examination.

Except for two samples (Campobello, 26 June 1968; St. Andrews, 19 July 1969) which were measured in preserved condition (70% alcohol), all fish lengths were measured from fresh specimens to the nearest millimetre. The preserved samples, however, included only 18 fish (8.3% of the total samples).

Otolith lengths were plotted against fish lengths, and regression lines of the form Y = a + bx were fitted by the least squares method.

Results

Otolith development

The shapes of the otoliths for representative fish sizes are shown in Fig. 1 and 2. The otolith of the smallest herring larvae examined (32 mm) measured 0.24 mm in diameter (largest diameter). In transmitted light, it appears translucent, and under reflected light, slightly opaque. The otolith is oval in shape (Fig. 1-A); distal side is convex, and the proximal side is almost flat.

The otoliths of the 40 mm length group fish are similarly oval in shape (Fig. 1-B). They measure twice as much as in the previous stage (0.48 mm for a fish measuring 41 mm in length). The beginning of the formation of the rostrum can be seen in some specimens. The otolith shapes begin to be changed in the 45 mm length group fish. Otoliths in this category have different shapes, but looking from the distal side, in general are pear-shaped (Fig. 1-C). The position of the excisura major can be seen easily, and the excisura minor shows in some specimens. On the distal side, a slight circular depression, presumably the nucleus, could be seen. This is more clear when looked at by different angles of the reflected light. Under transmitted light, this depression is slightly more hyaline than the surroundings, but no defined contour is found around the nucleus. From the proximal side, a shallow oval groove can be seen (Fig. 2). At this stage the rostrum is more defined than in previous stages.

Otoliths of the 55 mm fish length group (Fig. 1-G) have well developed rostra. The postrostra and pararostra are more developed, and the nuclei are more clear. For fish in the 75 mm length group (Fig. 1-I), the otoliths took the usual shape of herring otoliths. The antirostrum is well developed. A hyaline zone can be seen on the margin of some specimens (samples collected in October). The size of the nucleus varied in different specimens, presumably related to the time of spawning. In some samples, especially in the 80 mm length group and larger groups, overgrowth on the nucleus was observed. In some cases, most of the nucleus was covered with this overgrowing material, leaving only small fissions in the centre of the nucleus (Fig. 2 B-C).

An interesting observation is the presence of an unclear hyaline ring around the otolith nucleus in some samples (Fig. 2). This ring was more easily seen when the otolith was soaked in alcohol, and looked at on a black background. It is worthy to note that these rings are similar in shape and size to the otoliths of the 40-45 mm length groups shown in Fig. 1 B-C.

Relationship between otolith length and fish length

Otolith lengths of all samples were plotted against fish lengths (Fig. 3). The scatter diagram indicated a roughly linear relationship. A regression line was fitted by the method of least squares, and the equation was calculated as follows:

$$Y = -10.12 + 0.591X$$

There was an indication of a point of inflection in the growth rate of the otoliths at the 65-70 mm length groups. Hence, the data were separated into two stanzas; the first included fish ranging from 30 to 65 mm length group, and the second included fish of 70-115 mm group. The equation of the two stanzas were found as follows:

$$Y_1 = -12.656 + 0.615X$$

$$Y_2 = 4.138 + 0.432X$$

and the regression lines were accordingly fitted (Fig. 3).

Discussion

The relationship between otolith length and fish length for herring, in the size range under examination, could be described by linear equations. At fish length of about 70 mm, the rate of increase in otolith length with fish length slightly decreases. Watson (1964) found a linear relationship for Maine herring ranging from 85 to 285 mm in length. Wood (1962), on the other hand, reported on the growth of otolith lengths and widths in relation to fish length for herring in the North Sea. He found that neither regression was linear.

It is recommended that for the purposes of reconstructing herring growth from their otoliths, a linear relationship could not be assumed unless the calculations are made from small fish (probably < 3 years old). For older fish, however, the type of relationship between otolith length and fish length should be established prior to its use in back-calculations.

The hyaline ring which was observed in the middle of the first summer zone around the nucleus in some of the samples constitutes an interesting feature. This ring appears to be masked in older fish by opaque material from subsequent growth, overgrowing the central area of the otolith. The existence of these rings could lead to erroneous interpretation in ageing herring even in the younger ages. The nature of this 'false ring'; its possible association with the fish metamorphosis, and relation to the habitat in which the 0-group stage is spent will need further investigation.

References

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Table 1. Otolith lengths (mm/25) of juvenile herring separated by fish lengths (total length), collected from different localities in Passamaquoddy Bay and adjacent waters (ICNAF Division 4X). Numbers of fish are in parantheses.

Fish length group (5 mm below)	30/5/68 St. Andrews	10/6/68 Clam Cove Hd.	18/6/68 Deer Is.	26/6/68 Campo-bello Is.	19/7/68 St. Andrews	8/8/68 St. Andrews	11/9/68 Passama-quoddy Bay	19/9/68 Hardwood Is.
30								
35	11.0(1)							
40	12.0(1)	13.0(1)		11.0(1)				
45	13.8(6)	14.3(4)		13.0(4)	17.0(1)			
50	17.0(1)	16.5(11)	16.8(5)		19.3(3)			
55		19.0(4)	20.0(4)	20.0(5)	24.3(3)			
60					24.0(1)			
65								
70						31.6(11)		
75						34.7(7)		
80						32.0(1)		
85						36.0(1)		40.0(1)
90								44.5(2)
95								45.8(4)
100							45.0(2)	46.5(2)
105							48.0(2)	59.0(1)
110							50.0(1)	
115							52.0(2)	
n	9	20	9	10	8	20	7	10

Fish length group (5 mm below)	15/10/68 Musquash Hd.	23/10/68 Hardwood Is.	6/11/68 W. Quoddy Hd.	22/11/68 Hardwood Is.	28/11/68 Hardwood Is.	10/1/69 Hardwood Is.	31/3/69 Hardwood Is.	8/5/70 Clam Cove
30								6.0(1)
35								10.0(1)
40								12.0(2)
45								13.5(4)
50								15.0(1)
55							25.0(1)	
60								
65				26.0(1)		30.7(3)	30.0(1)	
70	36.5(2)		35.0(1)	35.0(1)		34.5(2)	35.8(4)	
75	38.5(14)			38.2(5)		38.3(3)	35.8(5)	
80	41.2(9)			39.2(5)		41.0(2)	40.5(2)	
85			40.3(3)	43.0(1)	42.0(2)		41.2(5)	
90			43.6(9)	45.5(2)	40.7(3)		42.0(2)	
95		48.0(1)	44.0(4)	46.0(1)	42.8(4)			
100		48.5(2)	48.5(2)	45.0(2)				
105		49.3(4)	50.0(1)	51.5(2)	47.0(1)			
110		51.5(2)						
115		51.0(1)						
n	25	10	20	20	10	10	20	9

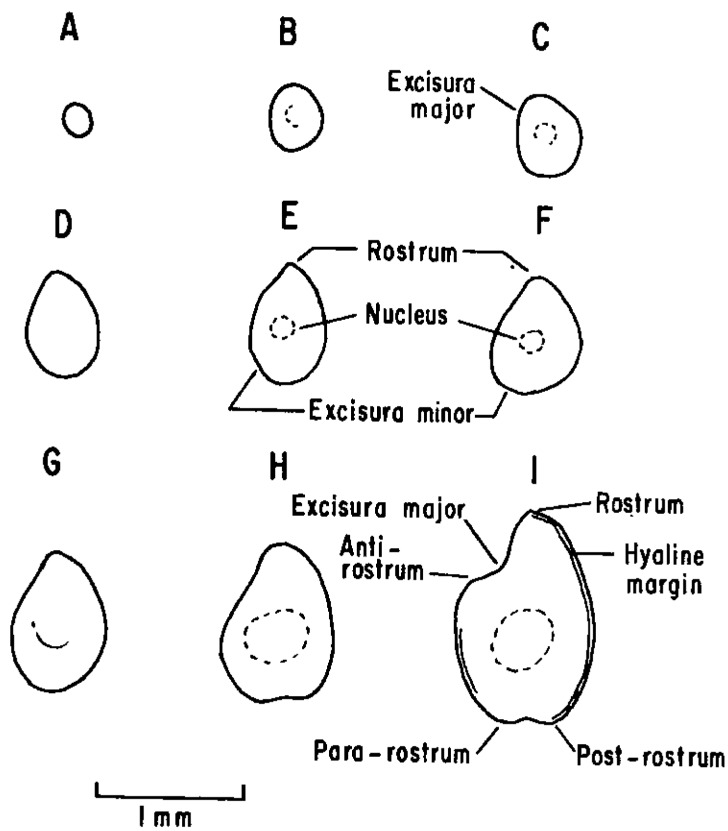

Fig. 1. Herring otoliths from fish of different sizes showing their development and growth.

A. Clam Cove, May 8, 1970; Fish length 32 mm.
B. Clam Cove, May 8, 1970; Fish length 41 mm.
C. Clam Cove, May 8, 1970; Fish length 47 mm.
D. Clam Cove, June 10, 1968; Fish length 54 mm.
E. Deer Is., June 18, 1968; Fish length 57 mm.
F. Campobello Is., June 26, 1968; Fish length 59 mm.
G. St. Andrews Bay, July 19, 1968; Fish length 60 mm.
H. St. Andrews Bay, August 8, 1968; Fish length 72 mm.
I. Musquash, October 15, 1968; Fish length 79 mm.

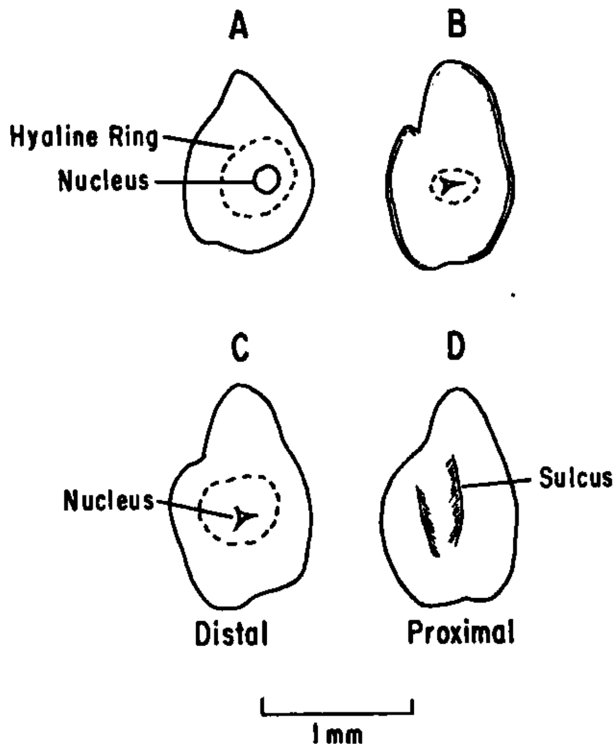

Fig. 2. Samples of herring otoliths showing (A): false ring, (B): hyaline margin, (C) overgrowth on the nucleus, and (D): the sulcus.

A. St. Andrews Bay, August 8, 1968; Fish length 71 mm.
B. Hardwood Is., March 31, 1969; Fish length 47 mm.
C. Hardwood Is., January 10, 1969; Fish length 81 mm.
D. Same as (C); proximal side.

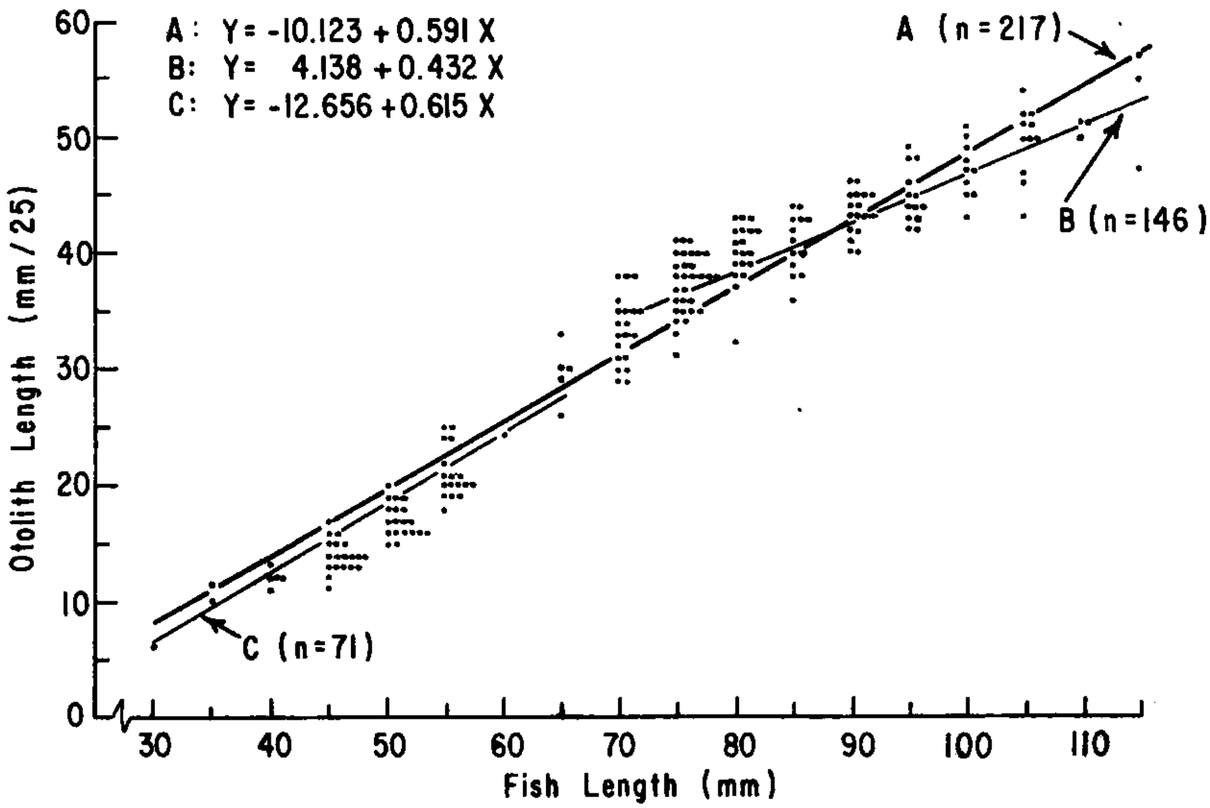

Fig. 3. Scatter diagram showing the relationship between herring length and otolith length. Lines fitted by the least squares method.