International Council for the
Exploration of the Sea

C.M. 1962
Herring Committee
No. 134

Herring Otolith Investigations in the North-Eastern Baltic

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In the north-eastern Baltic the spawning periods of the spring and autumn spawning herring races are rather extended - the spring herring spawn from the beginning of May to the beginning of July (Rannak, 1954), the autumn herring from the beginning of August to the beginning of November and the period between the main spawning periods is short - only about one to one and a half month. Herring also spawn in this interval, though only with a small intensity. Therefore, there is a considerable overlapping in the maturity stages of the spring and autumn herring. The method of herring race discrimination by means of investigating the maturity stages of their gonads may, therefore, give misleading results even in the spawning periods. In the other seasons of the year we cannot expect satisfactory results by using this method in the north-eastern Baltic. Furthermore, the identification of the herring races is complicated by the presence of young immature herring in the catches. By means of the maturity stages only their race cannot be determined with any certainty.

It is shown by several authors (Einarsson, 1951; Parrish and Sharman, 1958, 1959; Postuma and Zijlstra, 1958; Raitt, 1961 etc.) that the otolith characters can be successfully applied for discriminating herring races and groups. Kändler (1942) and Popiel (1955) have noted, that it is also possible to distinguish spring and autumn herring in the western and southern Baltic on the basis of their otolith structure. In order to establish the validity of the identifying principle used by the authors mentioned above, for discrimination of the seasonal races in the north-eastern Baltic, otoliths of about 12,000 spring and autumn herring were examined. The otoliths were sampled from fixed net, kakuan and trawl catches in the Gulf of Finland and Gulf of Riga as well as in the open Baltic in 1957-1961.

The main features of the differentiation of spring and autumn herring are the size of the nucleus and the appearance of the first growth zone in the otolith. The radius of the nucleus of the otoliths of the autumn herring is usually 0.20-0.25 mm, whereas in the spring herring it is 0.15 mm only. For distinguishing the otoliths of spring and autumn herring in cases where this cannot be made by the size of the nucleus (the otoliths of older individuals, etc.) the appearance of the first growth zone can be applied. The otoliths of one year-old spring and autumn herring differ both by the size of the nucleus and by general appearance (Fig. 1). In the spring herring otolith there are deeper sulci and the angle between the rostrum and antirostrum is larger as compared with the autumn herring otolith. In addition to the size of the nucleus and the shape of the first growth zone, for distinguishing the otoliths of the races, the following features can be applied:-

(1) The size of the growth zones is more even in the otoliths of spring herring than in those of autumn herring. The first growth zone of the autumn herring otolith is considerably larger than in the spring herring otolith. (Fig. 2).

(2) The otoliths of spring herring are smoother, thinner and more frail as compared with those of autumn herring.

(3) In the otoliths of spring herring the winterzones are usually thin and smooth, whereas in those of autumn herring the winter zones beginning with the 3rd-4th zone, are very rough and wide.

Discrimination of the otoliths of spring and autumn herring by the features presented above is usually rather easy. Attention should be drawn to the cases where some of the criteria are invalid:-

(1) The radius of the nucleus of the 'giant' herring otolith can reach 0.20 mm, resembling in some cases the autumn herring otoliths by this feature. But 'giant' herring otoliths can be distinguished from those of the autumn herring by the other features (the appearance of the first summer zone, etc.).

(2) A number of the older spring herring caught in the open sea have considerably thicker otoliths than is usual in spring herring. In such otoliths the size of the first growth zone as well as the relative size of the growth zones may be similar to the corresponding features of the otoliths of autumn herring. Such otoliths of the spring spawners can be

discerned from the otoliths of autumn herring mainly by the appearance of the first growth zone, for, due to a considerable thickness of the opaque material the hyaline nucleus cannot be seen in these otoliths.

In general, the race determination by means of the otoliths is more complicated in the herring caught in the open sea than in the individuals caught in the Gulfs because the otoliths of the herring from the open sea consist of more opaque material than the otoliths of herring from the Gulfs. In spite of this, in distinguishing the seasonal races in the open sea the error probably does not exceed 5-10%. The race discrimination in herring from the Gulfs can be made far more accurately owing to the thin and transparent quality of the otoliths.

In order to prove the method of race discrimination by the otoliths, the numbers of vertebrae were counted and the average vertebral number of the spring and autumn herring, discriminated by means of the otoliths, was calculated in some samples taken from trawl catches from the feeding grounds in the Gulf of Riga, Gulf of Finland and the open Baltic. Comparing the average vertebral counts of the herring races discriminated by means of the otoliths with the average numbers of vertebrae of the corresponding seasonal races in the spawning populations good accordance can be seen (Table 1). This fact gives evidence for concluding that the error in distinguishing the herring seasonal races by means of the otoliths can be of no particular importance. Therefore, the method can be successfully applied in the north-eastern Baltic.

As already stated, the seasonal races of the Baltic herring cannot be completely identified by the maturity stages. But the race of some part of the herring can always be identified by their maturity stages. Usually the race of the fish determined by the maturity stages coincided with the race determined on the basis of the otolith characters. However, in some individuals there was no correspondence between the otolith characters and the maturity stages. Thus, amongst the herring caught by fixed net on the spawning grounds in the beginning of the autumn spawning season two herring in maturity stages IV and V (after the six-range scale used in the U.S.S.R.) were found to have typical spring herring otoliths (7. August 1960 and 18. August 1961).

The problem if the otoliths of the herring caught in various areas have some differences by which different herring groups typical to the areas could be distinguished, was also studied.

The most characteristic feature of the otoliths of the herring caught in various areas of the north-eastern Baltic is the relative size of the summer zones. The different growth-rate and the different relative size of the growth zones in the scales of the herring caught in various areas of the north-eastern Baltic have already been ascertained by Dementjeva (1954) and Rannak (1954, 1960).

According to this and some additional characters, the otoliths of the autumn herring of the Gulf of Riga and adjacent waters can be divided into the following types (Fig. 2):-

I. The second and third summer zones, sometimes also the fourth, are considerably larger in comparison with the following growth zones. The otolith surface is smooth. There are no additional rings in the otolith or they occur in negligible numbers only.

II. The second growth zone is considerably larger than the following ones. The otolith is smaller and its surface is more rough as compared with the former type. In some otoliths the additional rings can be seen.

III. Small otoliths with a comparatively narrow second growth zone. In younger herring the otoliths of this type have a rather angular appearance. A considerable number of sulci and additional rings is found in the otoliths of this type and their surface is rough. A high percentage of partly hyaline otoliths occurs in this type.

The appearance of the first winter zone is largely used for tracing the migrations of the North Sea herring (Parrish and Sharman, 1958, 1959; Raitt, 1961, etc.) and the otoliths of the north-eastern Baltic autumn spawners can also be divided into groups with narrow and wide first winter zones. The percentage of otoliths having a narrow first winter zone is the largest in the type III otolith whereas in type I they are rarely found.

The autumn herring of type I otolith is characteristic for the open Baltic. But in the spawning and pre-spawning populations in the Gulf of Riga they are also encountered in great numbers. Outside the autumn spawning period the herring with otoliths of this type is seldom found in the Gulf of Riga. The autumn herring having type II otoliths occur chiefly in the Irben Sound region and can also be found in the Gulf of Riga and in the open Baltic. The autumn herring with type III otoliths are typical for the coastal regions of the Gulf of Riga, especially the eastern and southern parts of the Gulf. Amongst the Gulf of Finland autumn herring, individuals having type III otoliths dominate, with a

comparatively numerous admixture of herring with type II otoliths. In summer and autumn, in the central part of the Gulf, the herring having type I otoliths can be found in negligible numbers only.

The growth pattern of autumn herring with the different types of otoliths caught on the spawning grounds, differs evidently (Fig. 3). For comparison, the growth of the autumn herring (calculated without discriminating the otolith types), caught by trawl in the Gulf of Riga in the late autumn of 1961, is also shown. It can be seen that the growth patterns of herring having type III otoliths and of herring from the Gulf of Riga are rather similar. All the growth data given in Figure 3 are obtained from the otoliths by the back calculation method, as shown by Dzin-Gi-Jun and Popiel (1961). Only the otoliths of herring of the 1956 year-class, caught in 1961 were used.

The otoliths of the spring herring were divided into the following types (Fig. 2):-

I. The first growth zone is generally large. The second, third and fourth summer zones are wide. Large, smooth otoliths having a comparatively long rostrum.

II. The first growth zone is generally large. The second and third summer zones are obviously larger than the following ones.

III. The first growth zone is usually small. The second summer zone is considerably larger in comparison with the following zones. The otoliths are rather small and rough having relatively numerous sulci and additional rings.

In all the otolith types of spring herring it is also possible to differentiate the otoliths with wide and narrow first winter zones. In a number of otoliths having a wide first winter zone, exceptionally small first growth zones are found. The second summer zones of such otoliths are comparatively larger than usual in the spring herring otolith. In general, the spring herring with types I, II, and III otoliths is typical for the same areas as the autumn herring having the corresponding otolith types (Table 2). But both in the Gulf of Riga and in the open Baltic the spring herring of the different otolith types are more mixed than the autumn herring.

The main part of the spring herring taken by trawl in the Gulf of Finland in summer and autumn of 1959 had otoliths belonging to type III. Type II was met less and type I was absent in the catches.

In the Gulf of Riga and open Baltic a certain regularity is found in the average number of vertebrae and in the range of variation in the vertebral counts of autumn herring having differentotolith types (Table 3). The highest average number of vertebrae and the smallest variation is found in type I herring, whereas in type III herring the average number of vertebrae is the smallest and the range of variation is the largest.

In distinguishing the herring groups by means of the otoliths it must be taken into account that feeding conditions might, to some extent, change the relative width of the growth zones in the different years. But probably the width of the otolith growth zones depend not only on the provision of food in the main feeding period but chiefly on the duration of feeding. It is known that the feeding period of the herring is much longer in the open Baltic than in the Gulf of Riga (Nikolaev, 1956).

In all the otolith samples examined, at least two types were found in both the spring and autumn race (Table 2). To some extent it can be explained by mixture with the herring of the neighbouring areas (e.g. mainly the older age-groups of herring with type III otoliths present in the open sea) and partly by different growth patterns of herring inhabiting the same area. It must also be borne in mind that all the characters of the otolith classification are relative and between the otolith types many transitional forms can be found. For these reasons it is not possible to discriminate completely the herring of the different areas by means of the otoliths. But owing to the fact that especially type I and III otoliths are characteristic of the different areas, by the presence of herring having these otolith types in the catches, it is possible to determine the migrations and localities of the spawning grounds of the herring originating from the different areas.

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Table 1

Vertebral number of spawning populations of spring and autumn herring distinguished by means of the otoliths

Locality		Vertebral number 50	51	52	53	54	55	56	57	Unclassified	No. of fish	M ± m	Average vertebral number in the spawning populations
Gulf of Riga and open Baltic	Spring	-	-	2	10	185	622	266	16	8	1101	55.08 ± 0.02	54.833 - 55.227[x]
	Autumn	1	1	1	1	31	176	176	27	-	414	55.45 ± 0.04	55.45
	Spring	-	-	1	2	78	352	180	20	-	633	55.21 ± 0.03	55.154 - 55.354[x]
	Autumn	-	-	-	1	16	127	102	15		261	55.44 ± 0.04	55.45

x) after Rannak (1954)

Table 2

Otolith types of spring and autumn herring taken in the Gulf of Riga and the open Baltic in the period 30. August to 5. September 1961

Sampling area	Age	Otolith types (%) Spring herring I	II	III	Autumn herring I	II	III
Open Baltic (Ventspils region)	to 3 years	-	5	-	2	2	-
	over 3 years	15	26	15	20	12	3
	Total	15	31	15	22	14	3
Irben Sound	to 3 years	-	28	19	-	7	9
	over 3 years	-	-	7	6	15	9
	Total	-	28	26	6	22	18
Eastern part of the Gulf of Riga	to 3 years	-	13	49	-	3	20
	over 3 years	-	1	6	-	1	7
	Total	-	14	55	-	4	27

Table 3

Vertebral number of the spring and autumn herring determined by otolith types

Race	Fishing gear	Sampling area	Otolith type	Number of vertebrae 50	51	52	53	54	55	56	57	58	No. of fish	M ± m
Spring	Trawl	Gulf of Finland	I	-	-	-	-	-	-	-	-	-	-	-
			II	-	-	-	-	8	43	17	1	-	69	55.16 ± 0.08
			III	-	-	1	2	78	352	180	20	-	564	55.22 ± 0.03
		Gulf of Riga and open Baltic	I	-	-	-	1	13	43	17	-	-	74	55.03 ± 0.08
			II	-	-	2	3	58	228	107	8	-	406	55.13 ± 0.04
			III	-	-	-	6	114	351	142	8	-	621	55.05 ± 0.03
———		Gulf of Finland	I	-	-	-	-	-	-	2	-	-	2	-
			II	-	-	-	-	6	49	41	4	-	100	55.43 ± 0.07
			III	-	-	-	1	10	78	59	11	-	159	55.43 ± 0.06
Autumn		Gulf of Riga and open Baltic	I	-	-	-	-	-	2	5	2	-	9	-
			II	-	-	-	-	4	42	30	9	-	85	55.52 ± 0.08
			III	1	1	1	1	27	133	140	16	-	320	55.41 ± 0.05
	Fixed net	Gulf of Riga	I	-	-	-	-	5	65	50	6	-	126	55.45 ± 0.06
			II	-	-	-	2	13	145	129	9	-	298	55.44 ± 0.04
			III	-	1	-	2	12	119	80	11	2	227	55.36 ± 0.05

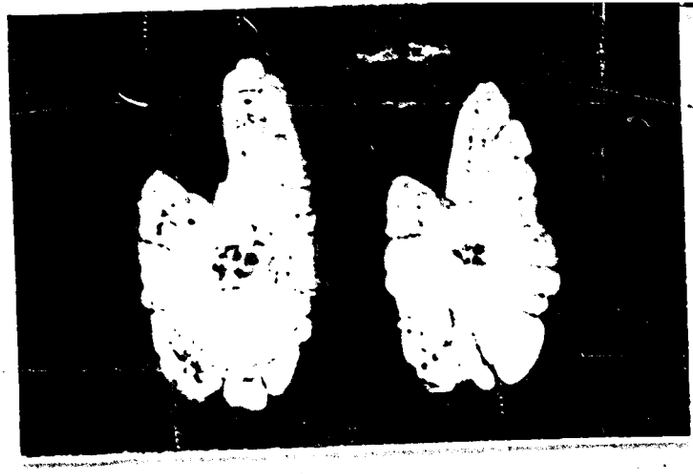
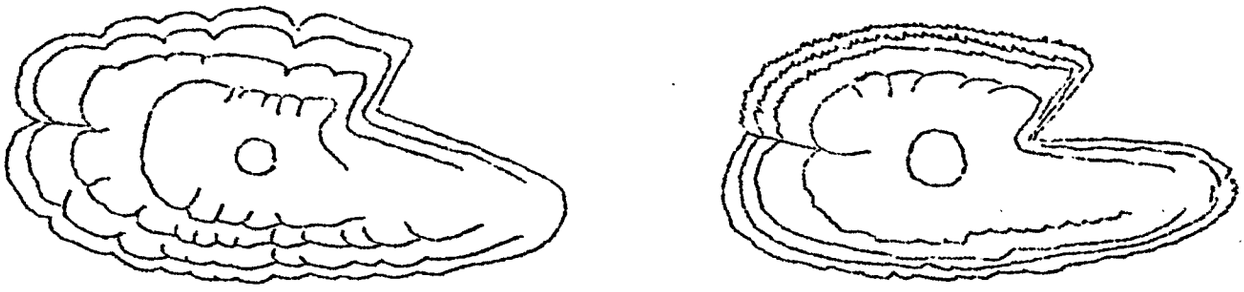


Figure 1. Otoliths of the one-year-old spring (right) and autumn (left) herring.

SPRING HERRING AUTUMN HERRING

I TYPE

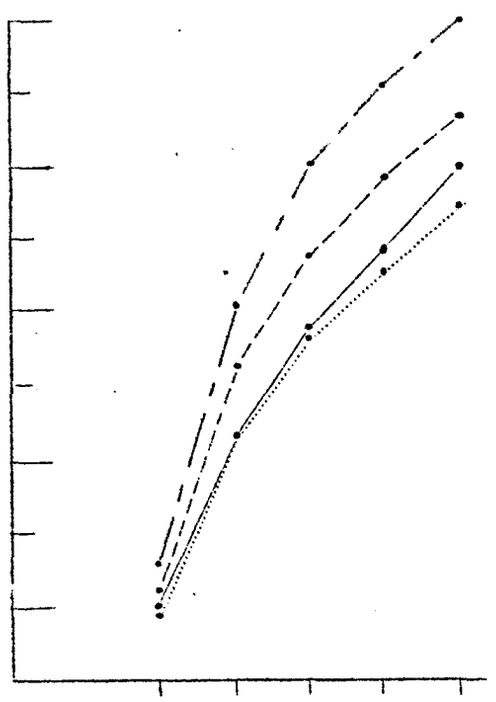


II TYPE

III TYPE

Figure 2. Otolith types of the spring and autumn herring in the north-eastern Baltic.

Figure 3. Growth pattern of the 1956 year-class autumn herring in fixed-net catches on the spawning grounds.



I Otolith type

II Otolith type

III Otolith type

In trawl catches in the Gulf of Riga in October and December 1961 (no otolith types discriminated).