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INVESTIGATIONS ON HERRING, *CLUPEA HARENGUS L.*, FROM THE NORWEGIAN SKAGERAK COAST DURING THE YEARS 1963–64

By

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INTRODUCTION

A quite good herring fishery took place on the Norwegian Skagerak coast in the last part of the last century. The available data on the output of this fishery (ANON. 1884—1962) shows a rapid decrease in the inner part of the Norwegian Skagerak coast (Fig.1). After 1895 the catches were small except for a very short period about 1905. The fishery during the last war was also slightly better than usual, but in both cases considerably lower than during the good period in the previous century. A similar change has taken place in the fishery on the Swedish Skagerak coast (ANDERSSON 1960). This fishery was to the turn of the century carried out in the skerries, and the most important gear was land seine and net. In this century the Swedish Skagerak fishery have mostly been an open sea fishery. According to investigations by ANDERSSON (1958) it has since 1914 been based on North Sea autumn spawning, Kattegat autumn spawning and Skagerak spring spawning herring. Kattegat autumn spawners migrate as full herring from the North Sea to the Kattegat in late summer and form together with the Skagerak spring spawners the basis of the fishery in the first part of the season. From November—December most of the herring are North Sea autumn spawners which is the far biggest of the three races, but periodically the autumn spawners fail to appear.

On the Norwegian Skagerak coast the fishery in the last century started in November—December and lasted to February—March. There were no herring investigations in these years, and it is therefore not known which herring races the fishery was based on.

The fishery in the inner part of the Norwegian Skagerak coast now takes place in the skerries in late summer and autumn as a purse seine fishery with light. In the spring when only spring spawning herring are caught, net is the most important gear.

The present paper gives the results of an investigation on herring from the Telemark coast (Fig. 2) during the period July 1963—September 1964.

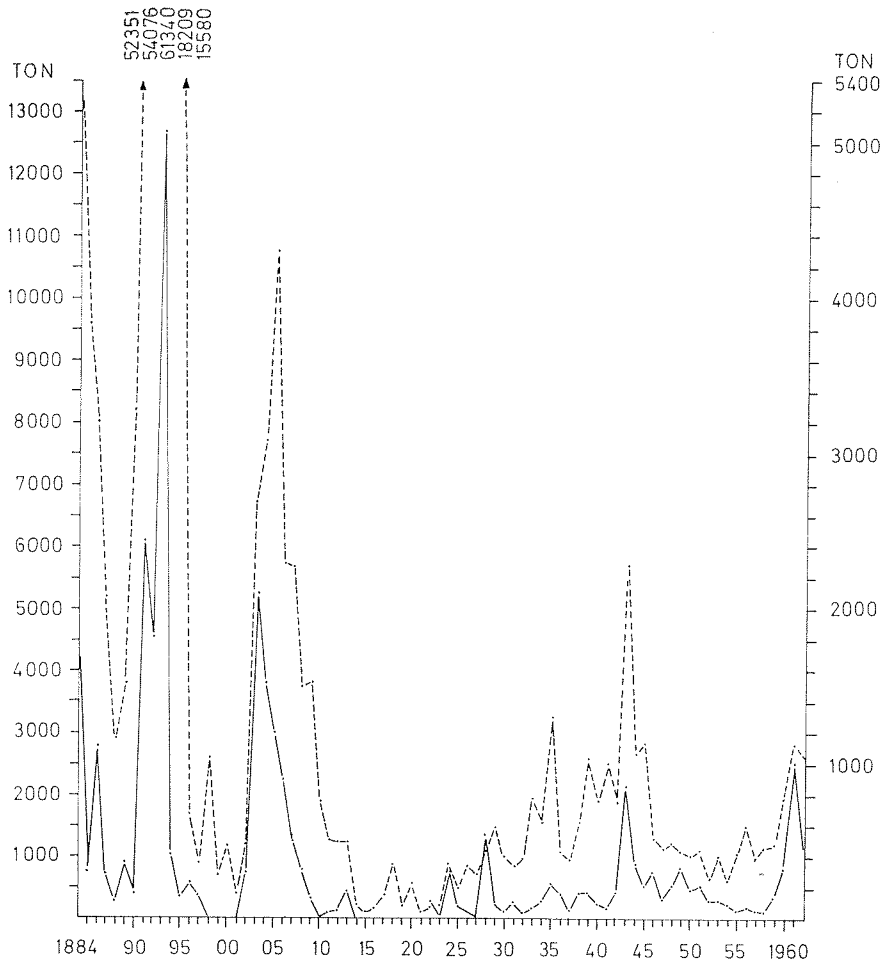


Fig. 1. Yearly output of the herring fisheries from 1884 to 1962. The inner Skagerak coast from the Aust-Agder border to the Swedish border (dotted lines). The Telemark coast (straight lines). The Skagerak coast (left scale). The Telemark coast (right scale).

MATERIAL AND METHODS

The material has been obtained from commercial catches taken in the fjords or between the skerries. The number of fish in the samples varied considerably, from 86 in sample no. 11 to 202 in sample

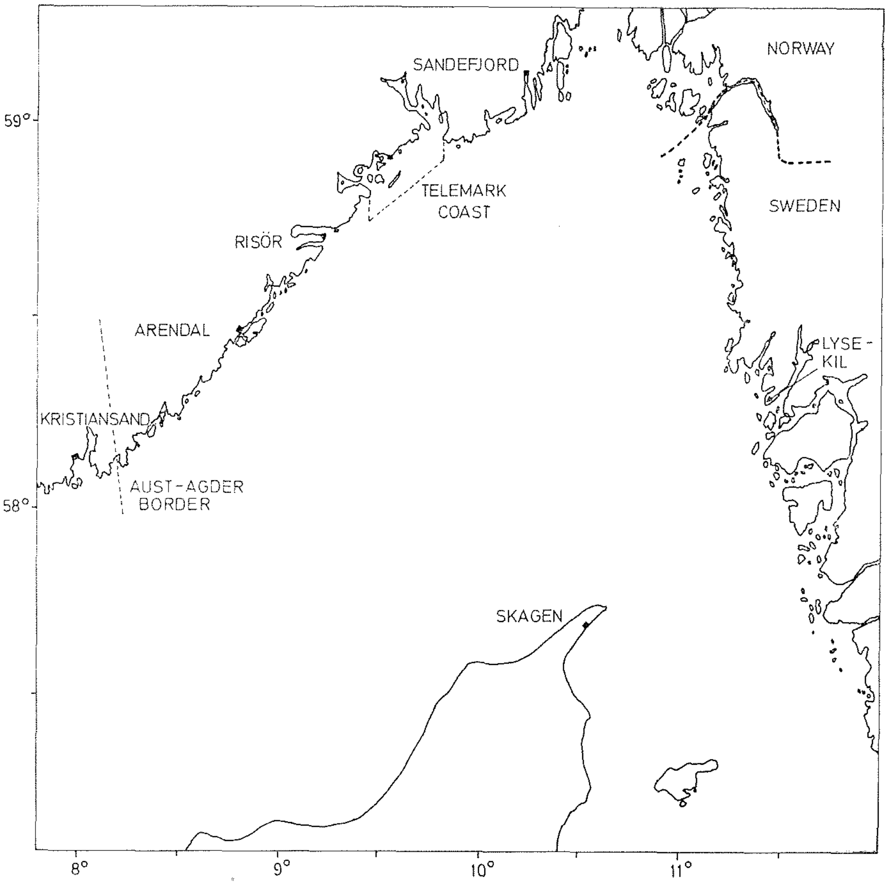


Fig. 2. The Skagerak coast.

Table 1. Mean vertebrae count, mean length and mean weight in the samples

Sample no.	Date	Vert. S.	Length	Weight	N
1	25/ 7—63	57.077	29.37	241.31	130
2	14/ 8—63	56.693*)	26.96	184.10	150
3	12/ 9—63	56.879	28.33	211.97	99
4	17/10—63	56.987	27.97	210.46	154
5	22/10—63	56.668*)	25.43	148.98	202
6	5/11—63	57.092	30.25	260.88	119
7	27/ 2—64	57.082	28.30	169.35	184
8	20/ 4—64	57.017	28.37	172.64	121
9	28/ 7—64	56.733*)	27.44	204.01	135
10	25/ 8—64	56.832*)	28.99	229.46	137
11	30/ 9—64	57.012	30.12	246.98	83

*) Samples tested not to be homogeneous according to the «Student-t» test.

no. 5 (Table 1). Efforts were made to obtain samples every month, but this was not possible. In the period July—November nine of the samples were taken, while only two were taken in the spring. In the samples no. 2 and 9 some herring were too damaged to be examined. The samples were taken from purse seine catches except samples no. 7 and 8 which were taken with nets.

The following data were collected from each individual: total length, weight, stage and weight of gonads, intestinal fat content, vertebrae number and scales. In addition otoliths were taken from the last 5 samples.

The total length of the fish was measured with the lobes of the tail in the mid line. The readings were made to the nearest half cm, using a measuring board with an offset of 0.25 cm.

Each individual has been weighed to the nearest 5 g and the gonads to the nearest 1 g.

The maturity stage of gonads was at first determined according to a scale introduced by SIVERTSEN (1937). However, during the investigations the scale with four stages proved to differentiate insufficient, and therefore the scale adopted by the ICES Herring Committee in 1962 (ANON. 1963) was applied from sample no. 7 onwards.

The content of the intestinal fat was determined after a scale with 4 stages used by HJORT (1914).

The otoliths were cleared in xylene for about half a minute (PARRISH and SHARMAN 1958) and mounted on black plates.

The urostyle was included in the vertebrae count.

The growth was backcalculated from the scales according to the method introduced by LEA (1910). The lengths of l_1, l_2 etc. were grouped to the half cm below (ANON. 1963).

RESULTS

VERTEBRAE COUNTS

There were great variations in mean vertebrae number of the different samples (Table 1). The samples no. 7 and 8 were regarded as belonging to the same race as all the individuals were spawning. «Student-t» tests showed significant differences ($p > 0.05$) between the mean vertebrae number, 57.056, of the samples no. 7 plus 8 and the mean vertebrae number of the samples no. 2, 5, 9 and 10 (Table 1). It was therefore concluded that these four samples were mixtures of two or more races.

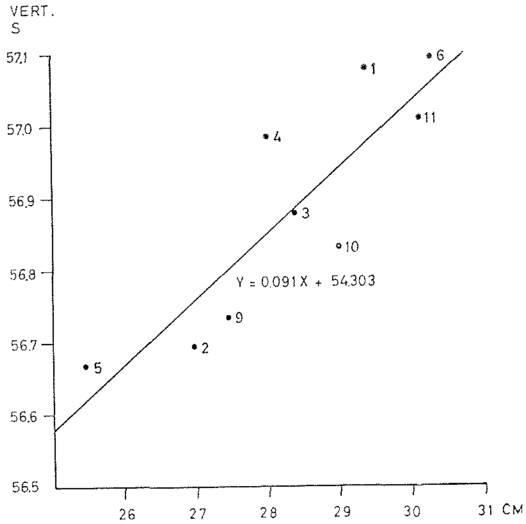


Fig. 3. Correlation between the mean length and the mean vertebrae count in the samples.

In Fig. 3 is showed the regression of mean lengths on mean vertebrae numbers (the samples no. 7 and 8 excluded), given by the equation:

$$y = 0.091\,x + 54.303$$

The correlation coefficient is 0.87. The equation is an approximate expression for the linear relationship between the length of individuals and vertebrae number. The figure indicates that the low vertebare number in the mixed samples are caused by small individuals.

Table 2 shows the mean vertebrae number in the different winter ring groups in the samples and indicates, though the number of individuals are small, that the herring with 2 winter rings have lower mean vertebrae number in the mixed samples (no. 2, 5, 9 and 10) than in the others.

AGE

Different herring races were expected to inhabit the investigated area. In Fig. 4 are shown the frequency distributions of winter rings inside the scale edge. These distributions are assumed to be similar to the age distributions, but small errors may occur. The autumn spawners may in some cases form scales the first winter (ANDERSSON 1951), and therefore autumn spawners belonging to the same year-class may show a difference of one winter ring.

There were very few fish with more than 10 winter rings and therefore, fish assumed to be more than 9 years are grouped together.

Table 2. Mean vertebrae number in the different winter-ring groups in the samples. No. of individuals in brackets.

Sample no.	Number of winter-rings										
	1	2	3	4	5	6	7	8	9	10	> 10
1		56.724 (29)	57.175 (63)	57.105 (19)	57.571 (7)						56.800 (5)
2	55.000 (5)	56.520 (75)	57.149 (47)	56.667 (9)	56.714 (7)				57.000 (1)		
3	56.333 (3)	56.875 (24)	56.977 (43)	56.786 (14)	56.667 (6)	57.000 (1)				57.500 (2)	
4	56.920 (25)	56.722 (36)	57.143 (35)	56.867 (15)	57.174 (23)	57.250 (4)	57.000 (1)	57.000 (5)		57.000 (1)	57.667 (3)
5	56.661 (59)	56.500 (68)	56.808 (52)	56.833 (6)	57.250 (4)		58.000 (1)	58.000 (1)			
6	56.500 (2)	56.933 (15)	57.027 (37)	57.059 (17)	57.333 (33)	57.667 (3)	56.000 (1)	57.167 (6)			57.000 (1)
7		56.986 (73)	57.246 (61)	57.053 (19)	57.042 (24)	58.000 (1)	57.000 (1)			56.000 (1)	56.000 (2)
8		56.877 (57)	57.140 (50)	56.667 (6)	57.667 (3)	57.500 (2)			58.000 (1)		
9	56.800 (5)	56.286 (42)	57.000 (57)	57.200 (15)	57.000 (3)	57.000 (1)	56.000 (2)				57.000 (2)
10	56.333 (6)	56.481 (27)	56.778 (36)	57.023 (43)	57.000 (15)	57.429 (7)	58.000 (1)	56.000 (1)			57.000 (3)
11	57.000 (1)	56.500 (12)	56.941 (17)	57.115 (26)	56.500 (10)	57.750 (12)		57.000 (1)	58.000 (1)		56.000 (1)

Fig. 4 shows that only few individuals had more than 5 or 6 winter rings. In sample no. 7 and 8 there were mainly 3 and 4 years old fish, that is individuals belonging to the 1960 and 1961 year-classes.

GROWTH

The samples differed considerably in length frequency distribution (Fig. 5). In samples no. 6 and 11 the 31 cm group was most numerous, and the mean length was above 30 cm (Table 1). The size distribution of the samples no. 7 and 8 differed significantly from the other samples. These two samples consisted entirely of spawning herring, and therefore small herring were not present. The selectivity of the net was supposed to have excluded most of the large herring from the catches.

According to the assumption that the herring in the samples no. 2, 5, 9 and 10 consisted of more races and therefore could have differed in growth rate from the herring in the other samples in the first years, l_1 and l_2 were measured in all the samples. The l_1 and l_2 frequency distributions are shown in Fig. 6. The l_1 distributions show no marked difference between the samples, but in the samples no. 2, 5 and 9 there are more small l_2 values than in the other samples, sample no. 5 showing a bimodal l_2 curve. The samples no. 2, 5 and 9 had also the lowest mean vertebrae number.

The growth rate, (Fig. 7) for the spawning herring, samples no. 7 and 8, was calculated from scale readings, and so was also the growth

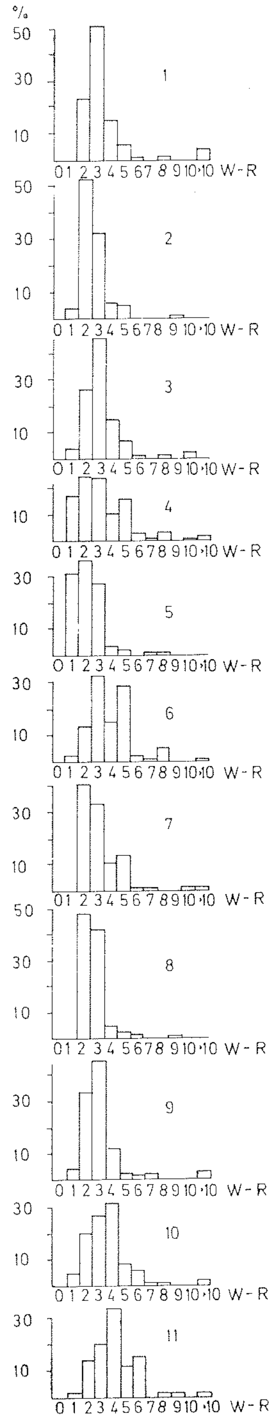


Fig. 4. Age frequency distribution based on the number of winter rings inside the edge. 1) sample no. 1, 25/7—63, 2) sample no. 2, 14/8—63, 3) sample no. 3, 12/9—63, 4) sample no. 4, 17/10—63, 5) sample no. 5, 22/10—63, 6) sample no. 6, 5/11—63, 7) sample no. 7, 27/2—64, 8) sample no. 8, 20/4—64, 9) sample no. 9, 28/7—64, 10) sample no. 10, 25/8—64, 11) sample no. 11, 30/9—64.

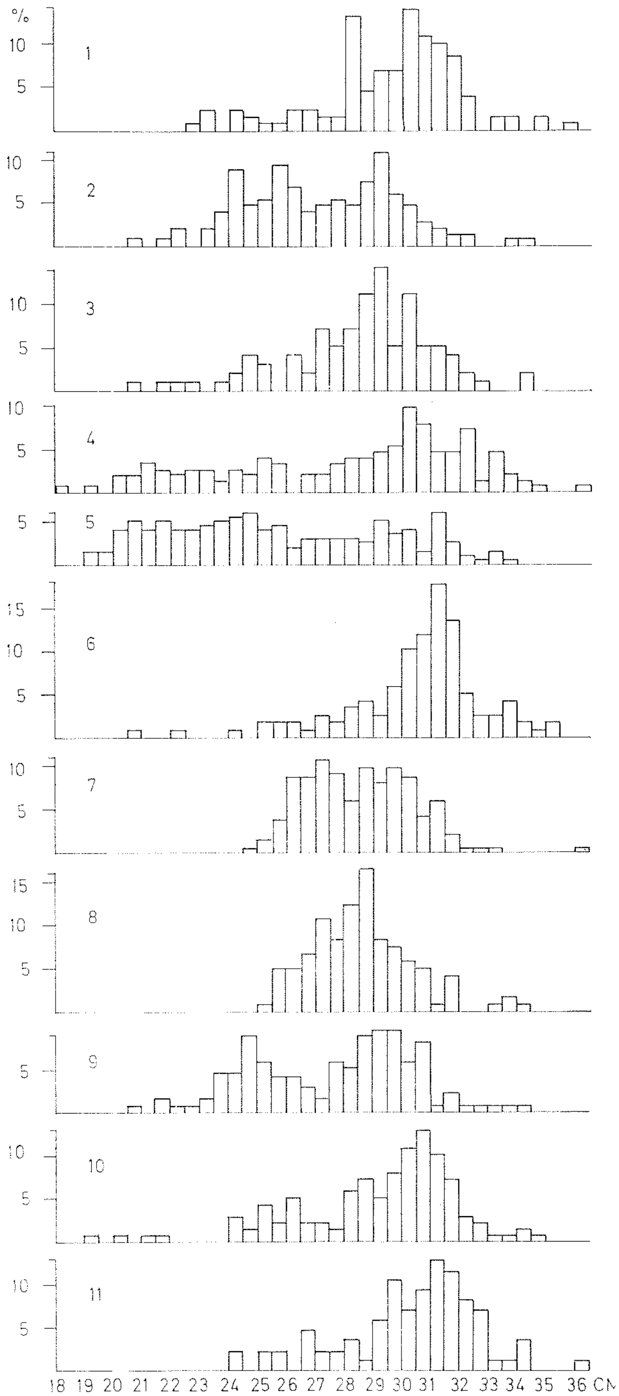
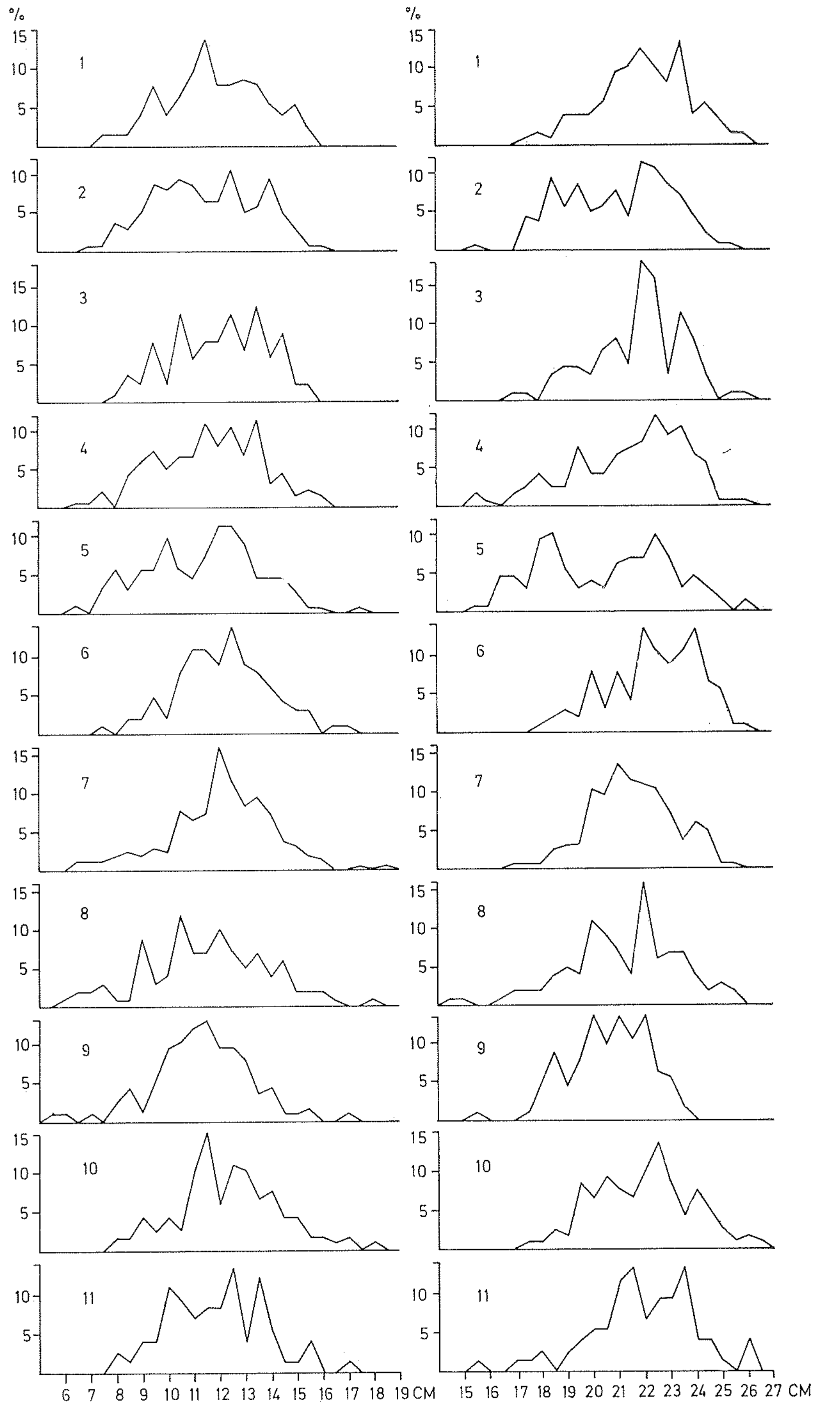


Fig. 5. The length frequency distribution. 1) sample no. 1, 25/7—63, 2) sample no. 2, 14/8—63, 3) sample no. 3, 12/9—63, 4) sample no. 4, 17/10—63, 5) sample no. 5, 22/10—63, 6) sample no. 6, 5/11—63, 7) sample no. 7, 27/2—64, 8) sample no. 8, 20/4—64, 9) sample no. 9, 28/7—64, 10) sample no. 10, 25/8—64, 11) sample no. 11, 30/9—64.

Fig. 6. The frequency distribution of l_1 to the left and l_2 to the right. 1) sample no. 1, 25/7—63, 2) sample no. 2, 14/8—63, 3) sample no. 3, 12/9—63, 4) sample no. 4, 17/10—63, 5) sample no. 5, 22/10—63, 6) sample no. 6, 5/11—63, 7) sample no. 7, 27/2—64, 8) sample no. 8, 20/4—64, 9) sample no. 9, 28/7—64, 10) sample no. 10, 25/8—64, 11) sample no. 11, 30/9—64.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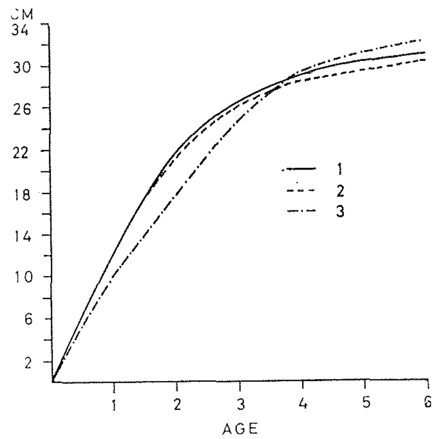

Fig. 7. The growth of the herring. 1) caught with purse seine, samples no. 1, 3, 4, 6 and 11, 2) caught with net, samples no. 7 and 8, 3) Norwegian winter herring, S 2 + 1. from Østvedt (1964).

rate of the herring which were found to belong to one and the same race, sample no. 1, 3, 4, 6 and 11 (Fig. 7). The growth rates were not calculated for herring older than six years as there were too few of them in the samples. There is good conformity between the two growth curves for the first three years. The samples no. 7 and 8 have slightly lower values after the third year. A possible explanation is that the number of the most fastgrowing individuals in these two samples are not representative for the spawning herring due to mesh selection.

SCALE AND OTOLITH CHARACTERS

The size of the central field in scales of the spring spawners may vary considerably. The first winter ring is often very diffuse, and may be difficult to recognize. The other winter rings, however, have more uniform character. Two specimens had scales with the same appearance as scales from the northern type of the Norwegian winter spawning herring. The appearance of the scales in the mixed samples did not differ significantly from the scales of the spring spawners.

The otoliths of spring spawners caught in spawning condition, had an opaque or a small hyaline nucleus (Fig. 8 a and b). The size of the central field varied considerably also in the otoliths (Fig. 8 b and c), but the majority was medium sized. The majority of the otoliths from the samples no. 9, 10 and 11 showed the same characteristics as the otoliths from the samples no. 7 and 8. Some otoliths with one or two winter rings had, however, a large hyaline nucleus and a wide central field (Fig. 8 d and e).

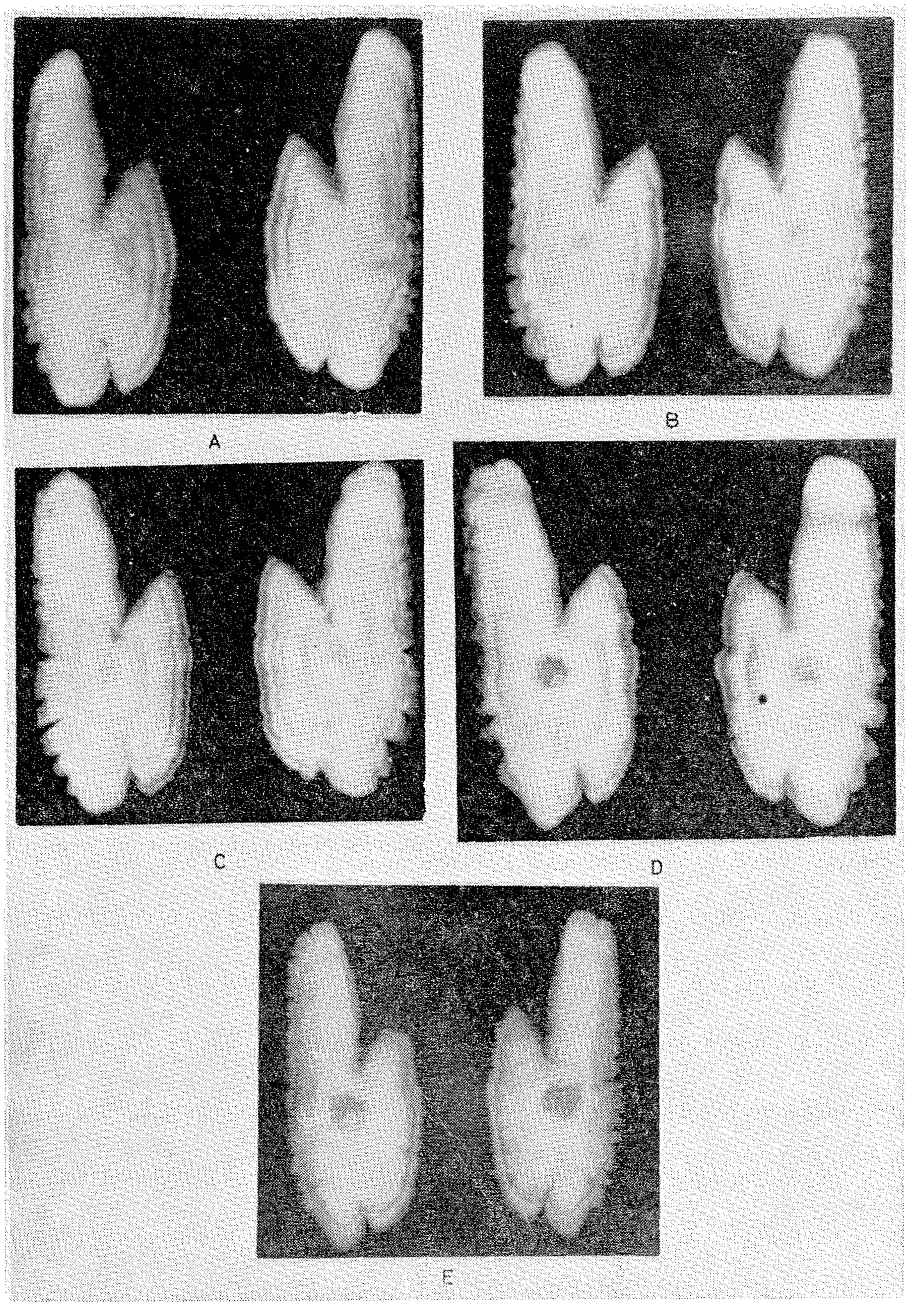

Fig. 8. Different types of otoliths. Further explanation in the text.

Table 3. Maturity stage by month in percent. Sample no. 1 to 6 with four, and sample no. 7 to 11 with eight maturity stages.

1963

Maturity stage	Samples no.					
	1 July	2 Aug.	3 Sept.	4 Oct.	5 Oct.	6 Nov.
I	34.5	63.0	27.7	31.1	58.9	8.0
II	23.1	28.3	60.6	58.2	40.1	91.2
III			7.6	10.8	0.5	0.8
IV						
IV/II	41.5	8.7	4.0		0.5	

1964

Maturity stage	Samples no.				
	7 Febr.	8 Apr.	9 July	10 Aug.	11 Sept.
I			20.6	7.2	8.2
II			18.4	11.5	3.5
III			16.9	30.9	25.9
IV			2.9	24.5	43.5
V	3.8		1.5	5.8	18.8
VI	73.0	84.5			
VII	23.2	14.9			
VIII		0.8	39.7	20.1	

SEXUAL MATURITY AND FAT CONTENT

The maturity stages by month are given in Table 3. The two scales used are not directly comparable, and in trying to get a better impression of the maturity cycle, the «Maturity factor», M_f, was calculated (AASEN 1952). The monthly frequency distribution of the maturity factor is given in Fig. 9. The October distribution contains both samples no. 4 and 5. It appears that M_f increase gradually towards February and April when the samples consisted entirely of spawning herring. In these two samples, M_f varies considerably because some individuals were allready spent.

To get a numeric quantity of the amount of intestinal fat, the fat index, F_i (WULFF 1954), was calculated separatly for each sample. The

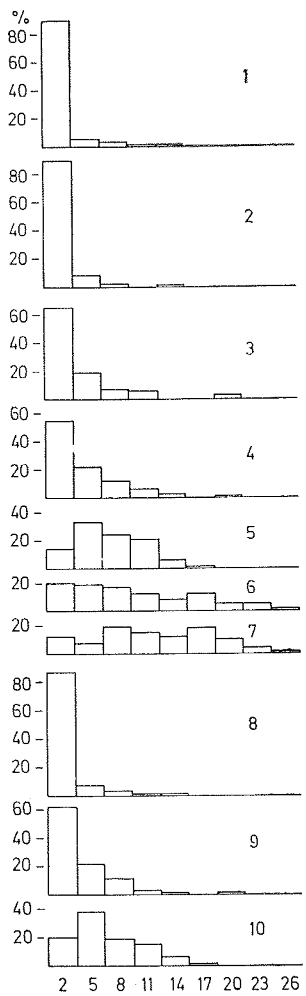

Fig. 9. Monthly variations in the distribution of M_f during the sampling period. 1) July 1963, 2) August 1963, 3) September 1963, 4) October 1963, 5) November 1963, 6) February 1964, 7) April 1964, 8) July 1964, 9) August 1964, 10) September 1964.

fatindex was calculated per 100 individuals, and the values therefore are between 100 and 400. In Fig. 10 are given the monthly mean values of M_f and F_i. The value for October represents the mean of the two samples from that month. The November observation of the fatindex is high compared with the October value, but it should be mentioned that these values are based on subjective examination of the intestinal fat. Where observation are lacking the curves are stippled. The maximum value of M_f is in the period February to April, and the minimum value of F_i is in the same period. The minimum of M_f is in the period just after the spawning with a value of about one. F_i has probably its maximum in July. Observations for June, however, are lacking.

DISCUSSION

The two samples of the spring spawning herring were taken with an interval of two months, and the material indicates that they belong to the same race.

The other samples, which were found to be homogenous, had the same scale and otolith characters as the samples of spawning herring. Neither did the other characters examined show any significant differences between these two groups of samples. It seems likely that all these samples have been drawn from the same population.

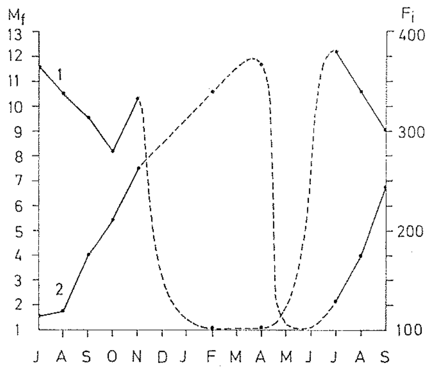

Fig. 10. Cycles of maturity factor and intestinal fat based on monthly mean values. 1) intestinal fat, 2) maturity factor.

As the samples were obtained from different localities along the Telemark coast, the distribution of this population is not limited to a certain fjord. There are no samples in the material from other parts of the Skagerak coast, but observations indicate that this herring population occur not only on the Telemark coast. It is a good correlation in the yearly output (Fig. 1) between the Telemark coast and the Skagerak coast. Spring spawners from the Skagerak coast which were examined by RUNNSTRØM (1941), had approximately the same high vertebrae number as the herring in the present material. RUNNSTRØM supposed them to be Kattegat spring spawners or Skagerak spring spawners as they now are named (ANDERSSON 1956). The spring spawners showed also the same characters as the Skagerak spring spawners from Sandefjord examined by HØGLUND (1964). It is, therefore, reasonable to conclude that the spring spawners in the present material belong to the Skagerak spring spawners.

As mentioned before some of the samples were mixed with young herring with lower vertebrae number, appearently belonging to one or more other races. No spring spawning herring from the adjacent area is known to have such a low mean vertebrae number, and they must therefore belong to autumn spawning races. Previous investigations have demonstrated that autumn spawning herring occur on the Skagerak coast. BROCH (1908) found an intermingling of autumn spawners in one of the samples from the Risør district. RUNNSTRØM (1941) had a strong admixture of the North Sea autumn spawners in samples taken at various parts of the Skagerak coast during the summer and autumn. According to HØGLUND (1964), one and two years old herring of the

North Sea autumn spawners are always found in varying numbers in the Skagerak area.

ANDERSSON (1958) separates the Kattegat and North Sea autumn spawners on the basis of scale characters, the former having a considerable larger central field than the latter. The Skagerak spring spawning herring have a greater variation in the size of the central field (ANDERSSON 1958). This is confirmed in the present material. It is, therefore, on the basis of the scale characters and the maturity stage of the young herring not possible to separate all the sampled individuals in spring and autumn spawners.

EINARSSON (1951) found in Icelandic waters that the otoliths of the spring spawners had an opaque and the summer spawners a hyaline nucleus. PARRISH and SHARMAN (1958) were able to separate spring and autumn spawners from the North Sea on this character. The same procedure was used for the mixed samples no. 9 and 10. Table 4 shows that the herring with opaque and hyaline nucleus in the otoliths have different vertebrae number. The otoliths with opaque nucleus resemble the otoliths in the present samples containing Skagerak spring spawners. Some of the otoliths with hyaline nucleus (Fig 8 e) resemble otoliths found by PARRISH and SHARMAN (1958) in Buchan herring, and later also in herring from the Bløden Ground, but it could not be concluded whether these autumn spawners belonged to the North Sea or the Kattegat autumn spawners or if it was a mixture of them. It seems, however, possible to separate spring and autumn spawners by otolith characters also on the Norwegian Skagerak coast.

The Skagerak spring spawners in the samples have a fast growth during the first three to four years. Comparing the growth rate with the most fastgrowing type of the 1950 year-class, S 2+1, of the Atlanto-Scandian herring (ØSTVEDT 1964) (Fig. 7) it appears that the Skagerak spring spawners grow faster up to an age of three years, but

Table 4. Mean vertebrae count in the two groups of otoliths in sample no. 9 and 10. a) Otoliths with an opaque or a little hyaline nucleus. b) Otoliths with a hyaline nucleus. Number of individuals in brackets.

Sample no.	a)	b)	% of doubtful cases
9	56.882 (102)	56.409 (22)	6.1
10	56.947 (114)	56.412 (17)	4.3

are then passed by the other. It is not, however, the same year-classes which are compared, but ØSTVEDT (1964) shows that the Atlanto-Scandian herring have had an increased growth rate and that the most marked increase was in the period from 1951 to 1963. The difference in growth rate between the two races in the first years, therefore, is probably not of the size shown in Fig. 7.

In accordance with the findings of HØGLUND (1964) the 1960 year-class dominates the present homogenous samples both in 1963 and 1964, except sample no. 4 and the two samples with spawning herring. The age frequency distribution of the spawning herring seems to show that a great part of the Skagerak spring spawners are first time spawners at an age of three years. This is earlier than for the southern type of the Atlanto-Scandian herring which ØSTVEDT (1958) over a long period of years found to be first time spawners at a nearly constant mean age of about 4.4 years.

The maturity and the intestinal fat cycles were inversed, with a quicker building up of the intestinal fat than the breaking down, and opposite with the maturity factor as found by AASEN (1952). The maturity factor showed a maximum in February to April and a minimum in May — June, while the intestinal fat had a maximum in July, and thereafter gradually decreased to a minimum in the winter months as also observed by AASEN (1952) for the spring spawning herring in Lusterfjord.

SUMMARY

1) The material was collected on a little part of the Norwegian Skagerak coast in 1963—1964.
2) The following data were sampled: total length and weight, stage and weight of gonads, intestinal fat content, vertebrae number and scales. Otoliths were taken from the last 5 samples.
3) Most of the herring examined appeared to be Skagerak spring spawners with a mean vertebrae number of about 57. Some of the herring with one and two winter rings were autumn spawners, belonging to either the North Sea autumn spawners or the Kattegat autumn spawners.
4) The otoliths of the Skagerak spring spawners had an opaque or a little hyaline nucleus with varying size of the central field. Some of the otoliths in the autumn spawners resemble otoliths previously found in the North Sea.

5) The Skagerak spring spawners had a rapid growth the first three years, and were spawning for the first time at three years age.
6) The maturity and the intestinal fat cycles appeared to be inversed.

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