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THE SPRING-SPAWNING GROUP OF HERRING IN THE NORTH-EASTERN NORTH SEA

by

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Introduction

It has been stated by several workers (Broch 1909, Bjerkan 1917, Johansen 1924, Krefft 1954, Haraldsvik 1966) that the north-eastern North Sea is a mixing area for spring and autumn-spawning groups of herring.

Early in this century spring-spawners dominated the catches from this part of the North Sea during spring, summer and autumn (Bjerkan 1917). In recent years, however, the autumn-spawning component has been dominant almost throughout the year, and spring-spawners have been in majority only during the short season from late July to early September (Haraldsvik 1966).

The spring-spawning group in the northern North Sea is suggested to be a mixture of several stocks of Atlanto-Scandian herring, such as Shetland spring-spawners (Wood 1936), Viking Bank spring-spawners (Runnstrøm 1941), Skagerak spring-spawners (Andersson 1949) and the Norwegian spring-spawning stock. The occurence of Norwegian spring-spawners has been demonstrated by morphological characters (Broch 1909, Hjort and Lea 1911, Bjerkan 1917) and tagging experiments (Aasen 1953).

Since 1960, when the Norwegian spring-spawning stock shifted spawning grounds to the north of Stad, herring in prespawning condition have arrived at the west coast of southern Norway in January, spawned in inshore water in March and April, and disappeared again in May. According to length, age, and scale type these herring differed from herring at the spawning grounds further north, and it has been suggested that the southern herring originate from the North Sea.

Recent Norwegian North Sea herring investigations have been in progress since 1961 and the results relating to the autumn-spawners have been dealt with elsewhere (Haraldsvik 1966).

The object of this report is to submit data on the spring-spawning group of herring in the north-eastern part of the North Sea. In particular an attempt is made to ascertain the degree of admixture in these waters of the two stocks of spring-spawning herring which occur along the coast of Norway.

Material and methods

The material was collected from September 1961 to May 1963 and consists of 23 samples, comprising a total of 3.825 specimens. Most of the material originate from commercial catches, but 6 samples were collected onboard research vessels.

Otolith characters (Parrish and Sharman 1958) were used to separate spring-spawning herring from autumn-spawners, and this procedure left 956 specimens of spring-spawners to be studied.

Sampling localities, gears, and the proportion of spring- and autumn-spawners in the samples are given in Table 1.

The samples of the spring-spawning stock on the west coast of southern Norway (comprising 400 specimens) were collected to the west and south of Bergen during March and April 1962 and 1963.

For comparison of growth 4 samples were also secured from east Icelandic waters during July and August 1962. The members of the Norwegian spring-spawning stock in these samples, totalling 239 specimens, were separated from the Icelandic spring and summer-spawning herring by scale characters.

All the herring were examined as to age and stage of maturity, whereas number of vertebrae, first growth zone measurement on otoliths and l_1, l_2 and l_3 lengths were determined for part of the material.

Both scales and otoliths were used for age determinations. However, secondary rings within the summer growth zones, transparency of otoliths, regeneration of scales sometimes complicated the determinations or made the readings impossible. In the samples from trawl and drift-net, several specimens also had lost all suitable scales. Therefore, ages could only be determined for 55 per cent of all specimens by the scales and for 85 per cent by the otoliths. Considering the two methods, however, positive age determinations were achieved for about 90 per cent of the material.

Stages of maturity were determined according to the maturity scale recommended by the ICES Herring Committee in 1962 (Anon 1963).

The first growth zone in otoliths was measured from the centre of the opaque nucleus to the distal edge of the first winter-ring, along an axis to the post-rostrum.

The growth of the herring have been determined according to back-calculations from scales, and the modified growth formula by Lea (Lea 1938) has been applied.

Age composition

The samples from the north-eastern North Sea have been grouped into 4 monthly periods, and the age compositions are illustrated in Figure 1. Taken as a whole the ages ranged from 1 to 12 years, but with a strong dominance of the younger year-classes. The 1959 year-class was dominant in 1961 and 1962. In 1963, however, it was replaced by the 1961 year-class. The reduction of the 1959 year-class in winter/spring 1963 may either be due to an emigration or a high abundance of the 1961 year-class. The latter explanation seems more reasonable since the 1961 year-class proved to strong in the north-eastern North Sea in both 1964 and 1965 (Haraldsvik in press).

In Figure 2 is shown the age composition of pooled samples collected in 1962 north and south of latitude 59°N. From these diagrams it appears that the 1 and 2-year old herring were most abundant in the southern area. This may indicate that the spring-spawning group of herring in the north-eastern North Sea is recruited from the south.

The age compositions for the spring-spawners at the west coast of southern Norway are shown in Figure 3. It appears that the 1958 and 1960 year-classes were more abundant in 1962 and 1963 respectively, than among the spring-spawners in the north-eastern North Sea.

The Norwegian spring-spawning stock was in the years 1961 and 1962 dominated by the 1950 year-class, which contributed about 60 per cent. The 1958 and 1959 year-classes were represented by less than 1 per cent during the same years (Devold and Østvedt 1963, 1964).

The age compositions therefore do not indicate any evident connection between the spring-spawning group of herring in the north-eastern North Sea and the two spring-spawning stocks along the coast of Norway.

Vertebrae

The vertebrae counts have traditionally been used to identify different herring stocks. The frequency distributions of the vertebrae count in the samples from the north-eastern North Sea are given in Table 2. The mean vertebrae counts ranged from 56.90 to 57.32, but no trend in space or time was observed. An analysis of variance showed that the differences of vertebrae counts within samples were insignificant compared with the differences among means of samples ($F = 1.076$, $p < 0.05$). It may therefore be concluded that the samples are drawn from the same stock or mixture of stocks. However, it is then presupposed that a real difference in vertebrae number occur between the various spring-spawning stocks. In Table 3, the vertebrae frequency distribution of the spring-spawning group from the North Sea is compared with those of the

Norwegian spring-spawning stock and the spring-spawners at the west coast of southern Norway. The significances of the differences in mean vertebrae count have been tested, giving t= 1.588 ($0.1 < p < 0.2$) between the spring-spawners from the North Sea and the Norwegian spring-spawning stock, and t= 2.931 ($p < 0.01$) between the spring-spawners from the North Sea and those from the west coast of southern Norway. It should, however, be noted that the result of this test is unreliable.

Different year-classes are dominating in the different groups of herring considered, and further, the mean vertebrae count of the spring-spawners from the west coast of southern Norway is based upon only three samples in which the mean counts varied considerably (57.31, 57.20, 57.09).

Wood (1936) found mean vertebrae counts ranging from 57.01 to 57.08 in spring-spawners from Shetland waters, and Runnstrøm (1941) got mean values varying between 56.98 and 57.05 in spawning and spent herring during April on the Viking Bank. The investigation on vertebrae number gives thus good conformity between the spring-spawning group in present material and the spring-spawning stocks in the northern North Sea, but due to the t-test and unreliable data an admixture of the two spring-spawning stocks from the coast of Norway cannot be excluded by this character.

Maturity

The samples from the north-eastern North Sea have been collected throughout the year and the percentage maturity composition, as shown in Figure 4, may therefore give a rough picture of the maturing cycle for the spring-spawning herring in this area. The low percentage of herring in spawning condition (a few specimens in sample No.8) and the low abundance of spring-spawners in the samples from the end of March in 1962 and 1963 (Table 1) may indicate that the spawning grounds are situated outside the north-eastern North Sea.

Spent herring (stage VII) were recorded in the samples from the end of March and the beginning of May. A duration of three weeks of this maturity stage (Jakobsson 1962) should indicate a spawning season during March and April. Recovering spent herring were in dominance from the end of March to the first half of August.

Stage III occurred in most of the samples, but were dominant from mid August to the beginning of October. The stages IV and V were found from the end of August to the beginning of March, but had their maxima before and after the turn of the year respectively.

It must, however, be emphasized that the number of samples and the number of specimens within several of the samples are few and one must therefore be very careful in generalizing from the present data.

The Norwegian spring-spawning stock and the spring-spawners at the west coast of southern Norway had in the years 1962-63 their spawning

season from the end of February to the end of March and from mid March to mid April respectively, and were thus inside the range of the spawning season for the spring-spawning group of herring in north-eastern North Sea.

The maturing cycles of the two spawning stocks at the coast of Norway are unknown. However, investigations in Icelandic waters during summer suggest that the herring of the Norwegian spring-spawning stock pass over from stage VIII to III already in the first half of July (Østvedt 1962), i.e. about one month earlier than indicated for the spring-spawning group in the north-eastern North Sea.

Age at first spawning

Beside six herring, which belonged to the northern type of the Norwegian spring-spawning stock, it was impossible to differentiate the winter-rings on the scales of the spring-spawning herring in north-eastern North Sea into "coastal", "oceanic" and "spawning" rings (Runnstrøm 1936). The age at first spawning has been based upon the maturity compositions by age in the samples collected during the period January to July. Herring in stage III in this period are classified as uncertain, i.e. they may be immature and do not spawn before the next season, or herring in stage III at the beginning of the period may reach maturity and further, herring in stage III at the end of the period may have spawned and already recovered their gonads. The percentage compositions of virgin (stage I and II), uncertain (stage III) and spawned herring (stages IV-VIII) in each age group are presented in Figure 5. It will be seen that a few herring already spawn at an age of two years, but the majority, about 77 per cent, were spawning at an age of three. Only about 2 per cent were immature amongst the four year-old herring.

The Norwegian spring-spawning stock may attain maturity at an age between three and nine years. However, in the years 1962 and 1963 the three year-old spawners were scanty represented on the spawning grounds.

The herring at the west coast of southern Norway were, on the other hand, in the same years dominated by three year-olds, which were all in spawning condition.

First growth zone measurement made on otoliths

The six herring, belonging to the northern type of the Norwegian spring-spawning stock, had typical otoliths which were easily picked out. These otoliths had thin, sharp winter-rings and a growth pattern much similar to that on the scales. Besides these six herring, it was impossible to recognize other otolith types amongst the spring-spawning group of herring sampled in the north-eastern North Sea. The major part of the otoliths had relatively large first and second growth zones and "soft" first and second winter-rings.

The ranges and means of the first growth zone measurements are presented in Table 4. It appears that the ranges and means were of the same order in the samples from 1961 and 1962. The high values obtained in 1963 can be explained by growth differences between year-classes. As stated before the 1960 year-class was dominant in the samples from 1963, while the 1959 year-class was the most prominent in both 1961 and 1962. Considering the total material the first growth zone measurements ranged from 13 to 29 units (one unit= 0.0409 mm), and had a mean value of 22.90 units (standard error= $\pm$ 0.153).

The values of first growth zone measurements were less than those recorded for the autumn-spawning group of herring in the same area (Haraldsvik 1966). These differences are probably connected to the differences in age at formation of the first winter-ring. Members of the spring-spawning group lay down a winter-ring during their first winter of life, while the autumn-spawning group of herring do not form winter-rings before the second winter.

In Figure 6 is shown the percentage frequency distributions of first growth zone measurements for the spring-spawning group of herring in north-eastern North Sea, the Norwegian spring-spawning stock and the spring-spawners at the west coast of southern Norway. The 1959 year-class is dominating in the stocks considered. This comparison shows good conformity between the spring-spawners in north-eastern North Sea and those at the west coast of southern Norway. It is suggested that the size of the first growth zone is linked to the food supply during the first year, and the good conformity in this measurement may therefore indicate that the spring-spawning herring in north-eastern North Sea and those at the west coast of southern Norway have the same feeding grounds during their first year of life.

Growth

The growth of the herring is one of the main characters used to distinguish between various herring stocks. Lea (1910,1938) has shown that the relation between scale length and total length of the herring is approximately linear. The l_1 distributions of the 1959 year-class of the spring-spawning group of herring from north-eastern North Sea, the Norwegian spring-spawning stock (S-type) and the spring-spawners at the west coast of southern Norway are given in Figure 7.
The mean l_1, l_2 and l_3 values for the same stocks are presented in Table 5. From these data it appears that the growth of the S-typed herring of the Norwegian spring-spawning stock deviated considerably from the growth of the two other stocks. The l_1 distribution and the mean values of l_1, l_2 and l_3 for the spring-spawners in north-eastern North Sea were slightly lower than those for the spring-spawners at west coast of southern Norway. It should be noted that the herring from the west coast of southern Norway were caught by net with a large mesh-size (winter herring net), and the selectivety of the net may probably affect an overestimation of the mean l_1, l_2 and l_3 values for this stock.

Taking this into consideration and assuming that the growth rate of the fish is related to the feeding, it seems likely to postulate that the spring-spawned herring in the north-eastern North Sea and those at the west coast of southern Norway have inhabited the same feeding grounds during the first, second and third year.

Concluding remarks

In an attempt to outline the connection between the spring-spawning group of herring in the north-eastern North Sea and the two spring-spawning stocks at the coast of Norway, i.e. the Norwegian spring-spawning stock and the spring-spawners at the west coast of southern Norway, some biological characters for these groups of herring have been compared.

Due to the plasticity of these characters it is impossible to identify the individual fish, but comparing several characters and large samples this method may, however, provide valuable informations in this identification work.

The age composition, age at first spawning, scale type, growth characteristics, such as otolith zone measurements and mean l_1, l_2 and l_3 values for the spring-spawning group of herring in the north-eastern North Sea deviated considerably from those obtained for the Norwegian spring-spawning stock. It is therefore concluded that the occurence of herring from this stock was negligible in the north-eastern North Sea during the years 1961-63. This is in contrary to earlier investigations by Broch (1909), Hjort and Lea (1911) and Bjerkan (1917), who found a dominance of the Norwegian spring-spawning stock within the spring-spawning group of herring in this area. The lacking of members of the Norwegian spring-spawning stock in the north-eastern North Sea in recent years may be explained by the change of spawning grounds for this stock (Devold 1963). The spawning grounds have since 1960 been situated off Møre and it is therefore reasonable to assume that the migration route to and from the feeding area in the Norwegian Sea in recent years will be north of the North Sea.

When comparing the spring-spawning group of herring in the north-eastern North Sea and the spring-spawners at the west coast of southern Norway, good agreement was found in age at first spawning, scale type, and growth rate during first, second and third year of life.
These characters are susceptible to environmental influence, and the good conformity may argue for that the herring have the same feeding and overwintering areas during the three first year of life.
These characters deviate from those of herring which have their nursery and adolescent stages in coastal waters (Runnstrøm 1936), and it is therefore suggested that the spring-spawners at the west coast of southern Norway have spent their three first years in the North Sea.

The spring-spawning stock at the west coast of southern Norway differ from the spring-spawning stocks in the northern North Sea by being spawning in inshore waters of relative low salinity and temperature, having different abundance of year-classes and probably also a higher mean vertebrae count. Outside the spawning season the various spring-spawning stocks probably mix freely in the north-eastern North Sea. The low total mean vertebrae cont, and the low abundance of the 1960 year-class among the spring-spawning group of herring in the north-eastern North Sea may, however, indicate that the spring-spawners from the west coast of southern Norway only constitute a minor part of the herring in this area.

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Table 1. Sampling localities and composition of spring and autumn spawners in the samples (%) from north-eastern North Sea, 1961-63.

Sample number	Date	Locality	Gear	Spring spawners	Autumn spawners	Uncertain	n
1	11/9-61	N 59°00' E 03°00'	Trawl	11.3	84.1	4.5	88
2	24/9-61	N 58°55' E 03°09'	Trawl	9.0	86.0	5.0	100
3	16/10-61	N 59°20' E 03°00'	Trawl	11.0	86.5	2.5	200
4	19/12-61	N 59°00' E 03°00'	Trawl	13.5	82.0	4.5	200
5	19/12-61	N 59°08' E 03°10'	Trawl	19.0	76.0	5.0	200
6	19/1 -62	N 58°07' E 04°36'	Trawl	18.4	78.4	3.2	250
7	20/1 -62	N 59°00' E 03°30'	Trawl	24.4	72.0	3.6	250
8	1/3 -62	N 59°45' E 03°35'	Drift	44.7	50.5	4.7	190
9	24/3 -62	N 60°20' E 01°50'	Trawl	4.6	89.3	6.1	197
10	6/5 -62	N 58°01' E 05°15'	Drift	22.0	61.0	17.0	100
11	7/5 -62	N 57°42' E 05°55'	Drift	16.7	68.7	14.7	150
12	22/5 -62	N 60°00' E 03°20'	Trawl	15.0	83.0	2.0	100
13	7/6 -62	N 59°00' E 03°34'	Trawl	15.3	81.3	3.3	150
14	27/7 -62	N 59°45' E 00°16'	Trawl	70.7	24.7	4.7	150
15	28/8 -62	N 57°55' E 04°50'	Drift	55.3	26.0	18.7	150
16	3/9 -62	N 59°47' E 01°35'	Trawl	78.0	17.5	4.5	200
17	25/9 -62	N 58°06' E 05°14'	Drift	19.0	76.0	5.0	100
18	9/10-62	N 57°50' E 05°40'	Drift	45.3	50.0	4.7	150
19	28/11-62	N 57°43' E 05°22'	Drift	20.0	72.5	7.5	200
20	22/1 -63	N 58°40' E 03°40'	Trawl	23.0	66.0	11.0	200
21	20/2 -63	N 58°20' E 04°04'	Trawl	15.5	81.0	3.5	200
22	23/3 -63	N 60°05' E 03°30'	Trawl	3.0	90.5	6.1	200
23	3/5 -63	N 60°28' E 04°18'	Purse-seine	11.0	82.0	7.0	100
			Total	25.0	68.8	6.2	3825

Table 2. Frequency distribution of vertebrae of spring spawners from north-eastern North Sea, 1961-63.

Sample number	Date	Vertebral Count						n	$\bar{x}$	σ^2
		55	56	57	58	59	60			
1	11/9-61	-	3	5	2	-	-	10	0.1000	0.5444
2	24/9-61	-	3	4	1	1	-	9	0.0000	1.0000
3	16/10-61	-	1	16	5	-	-	22	0.1818	0.2511
4	19/12-61	-	4	17	6	-	-	27	0.9741	0.3789
5	19/12-61	-	1	23	13	-	-	37	0.3243	0.2808
6	19/1 -62	-	4	34	7	1	-	46	0.1087	0.3213
7	20/1 -62	-	15	32	13	1	-	61	0.0000	0.5333
8	1/3 -62	1	18	53	11	2	-	85	0.0588	0.4846
9	24/3 -62	-	1	7	1	-	-	9	0.0000	0.2500
10	6/5 -62	-	2	16	4	-	-	22	0.0909	0.2771
11	7/5 -62	-	5	13	7	-	-	25	0.0800	0.4933
12	22/5 -62	-	2	10	3	-	-	15	0.0667	0.3524
13	7/6 -62	-	4	12	6	-	-	22	0.0909	0.4675
14	27/7 -62	-	20	63	21	1	-	105	0.0286	0.4319
15	28/8 -62	-	10	49	23	-	-	82	0.1585	0.3820
16	3/9 -62	1	21	92	41	-	1	156	0.1346	0.4656
17	25/9 -62	-	2	14	2	-	-	18	0.0000	0.2353
18	9/10-62	-	11	44	12	1	-	68	0.0441	0.4010
19	20/11-62	-	5	17	14	1	-	37	0.2973	0.5480
20	22/1 -63	-	11	23	11	1	-	46	0.0435	0.5758
21	20/2 -63	-	4	24	3	-	-	31	0.0323	0.2323
22	23/3 -63	-	2	2	2	-	-	6	0.0000	0.8000
23	3/5 -63	-	-	9	2	-	-	11	0.1818	0.1636
Total		2	149	579	210	9	1	950	0.0821	0.4274

Table 3. Vertebrae frequency distributions of the Norwegian spring spawning stock, spring spawners from SW of Norway and the spring spawning group in north-eastern North Sea.

Categories	Vertebral Count						n	$\bar{x}$	σ^2
	55	56	57	58	59	60			
Norwegian spring spawning stock, 1962	-	65	308	120	4	110	498	0.1325	0.1434
Spring spawners, SW coast of Norway, 1962 and 1963	-	35	176	81	7	-	299	0.2007	0.2079
Spring spawners North Sea, 1962	2	149	579	210	9	1	950	0.0821	0.4274

$\bar{x}$= average deviation from "working mean", 57 vertebrae.

Table 4. Ranges and means of first growth zone measurements on otoliths for the spring spawning group of herring in north-eastern North Sea (1 unit= 0.0409mm).

Sample number	Date	Range	Mean	n
1	11/9-61	18-25	23.2	10
2	24/9-61	22-26	23.7	7
3	16/10-61	14-28	23.2	19
4	19/12-61	15-26	22.1	22
5	19/12-61	13-25	22.2	31
Sum 1961		13-28	22.6	89
6	19/1 -62	15-26	22.2	45
7	20/1 -62	18-27	22.6	60
8	1/3 -62	17-29	23.3	83
9	24/3 -62	20-25	23.4	9
10	6/5 -62	14-27	22.4	21
11	7/5 -62	21-27	23.9	23
12	22/5 -62	19-25	22.2	15
13	7/6 -62	18-26	23.1	23
14	27/7 -62	15-28	22.4	99
15	28/8 -62	15-27	22.9	78
16	3/9 -62	15-27	22.8	138
17	25/9 -62	20-26	23.1	17
18	9/10-62	14-27	22.7	51
19	28/11-62	20-27	23.8	28
Sum 1962		14-29	22.8	690
20	22/1 -63	22-29	24.9	35
21	20/2 -63	20-27	23.2	24
22	23/3 -63	22-26	23.3	6
23	3/5 -63	21-24	22.7	11
Sum 1963		20-29	23.9	76
Grand total		13-29	22.9	855

Table 5. Mean l_1, l_2 and l_3 values of three year-old (1959 year-class) herring of the spring spawning group in north-eastern North Sea, the spring spawners on west coast of southern Norway and the Norwegian spring spawning stock.

Categories	$\bar{l}_1$	n	$\bar{l}_2$	n	$\bar{l}_3$	n
Spring spawners NE North Sea	13.00	135	22.89	135	27.68	88
Spring spawners SW coast of Norway	13.60	98	23.40	96	28.66+)	98
Norwegian spring spawning stock(S-type)	9.85	152	16.94	152	24.07	152

+) total mean length of three year-olds in April.

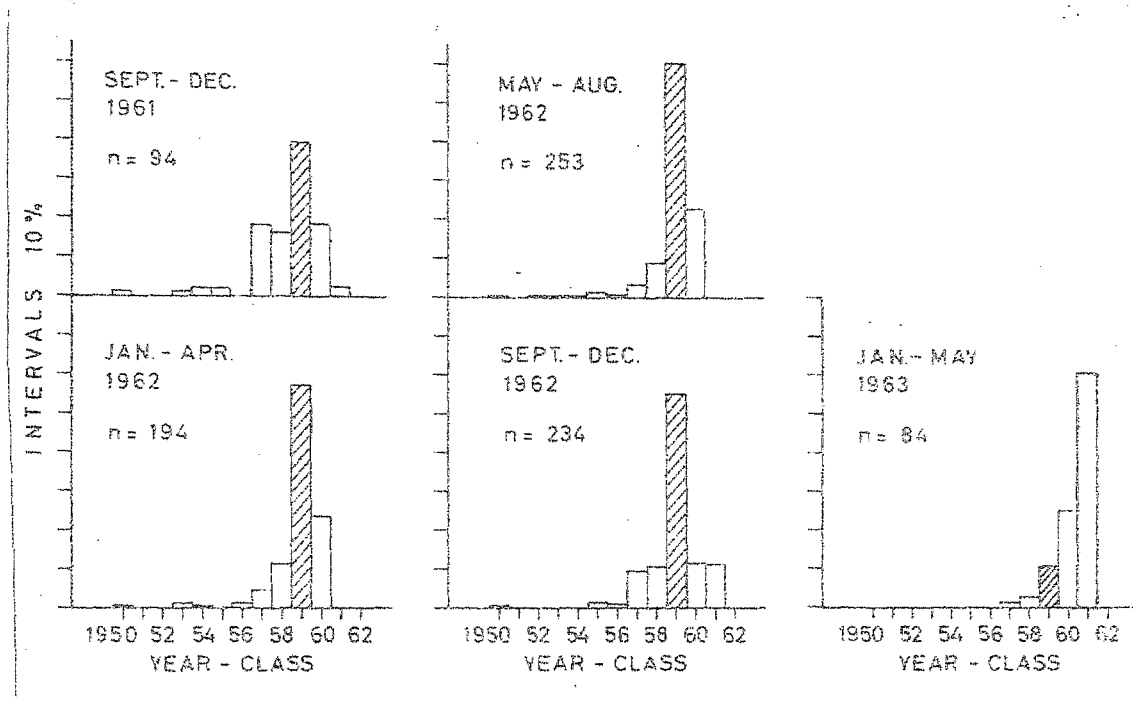

Fig. 1. Age composition of spring spawning herring from north-eastern North Sea, 1961-63.

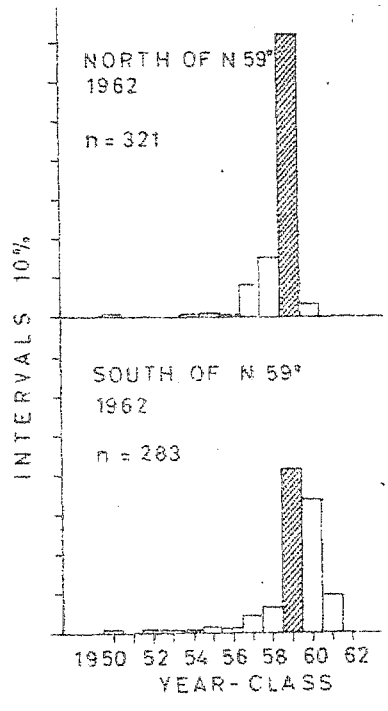

Fig. 2. Age composition of spring spawning herring sampled north and south of latitude 59° N in north-eastern North Sea, 1962

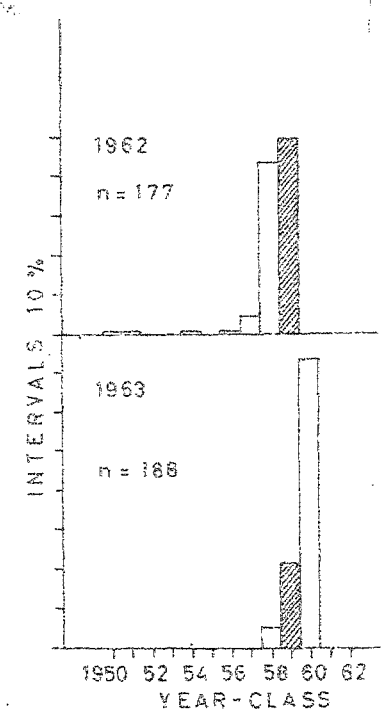

Fig. 3. Age composition of spring spawners from Western Norway, 1962 and 1963.

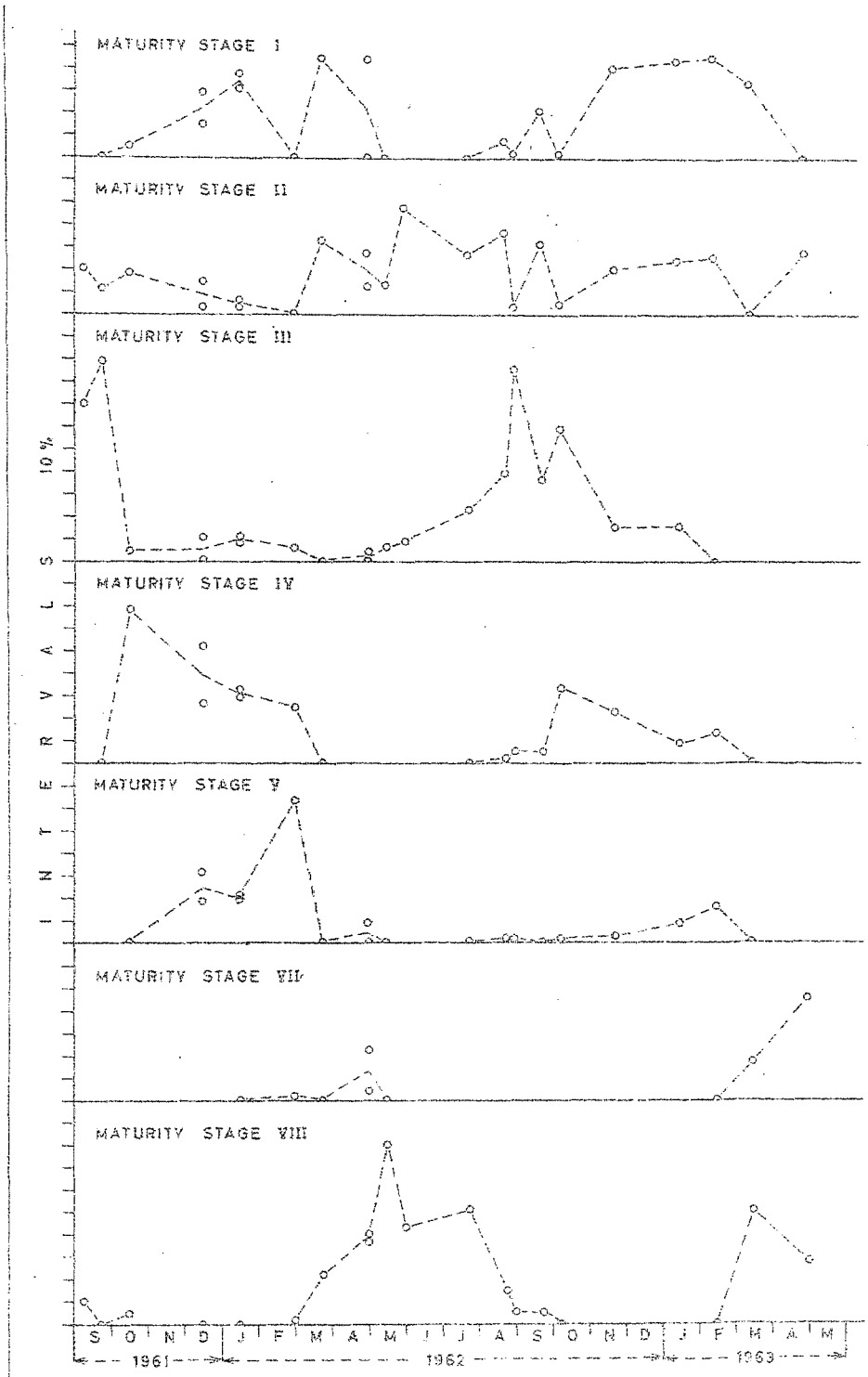

Fig. 4. Composition of maturity stages in spring spawning herring from north-eastern North Sea, 1961-63.

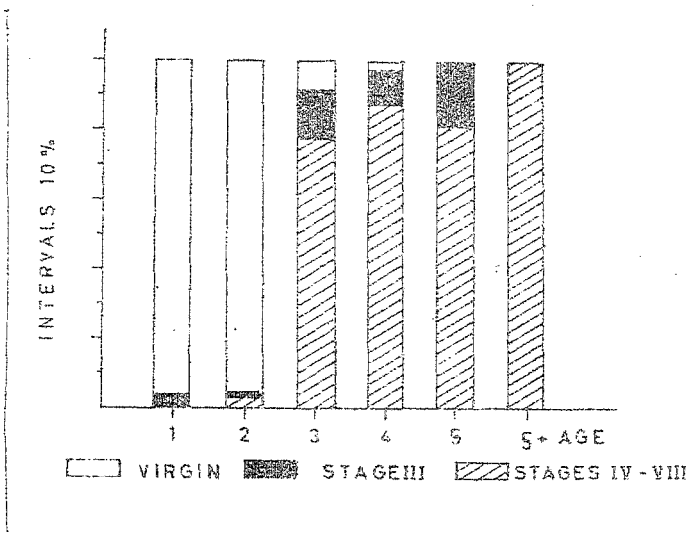

Fig. 5. Compositions of virgin herring, herring in maturity stage III and mature herring during winter and spring amongst 1-5 + year-old spring spawning herring in north-eastern North Sea.

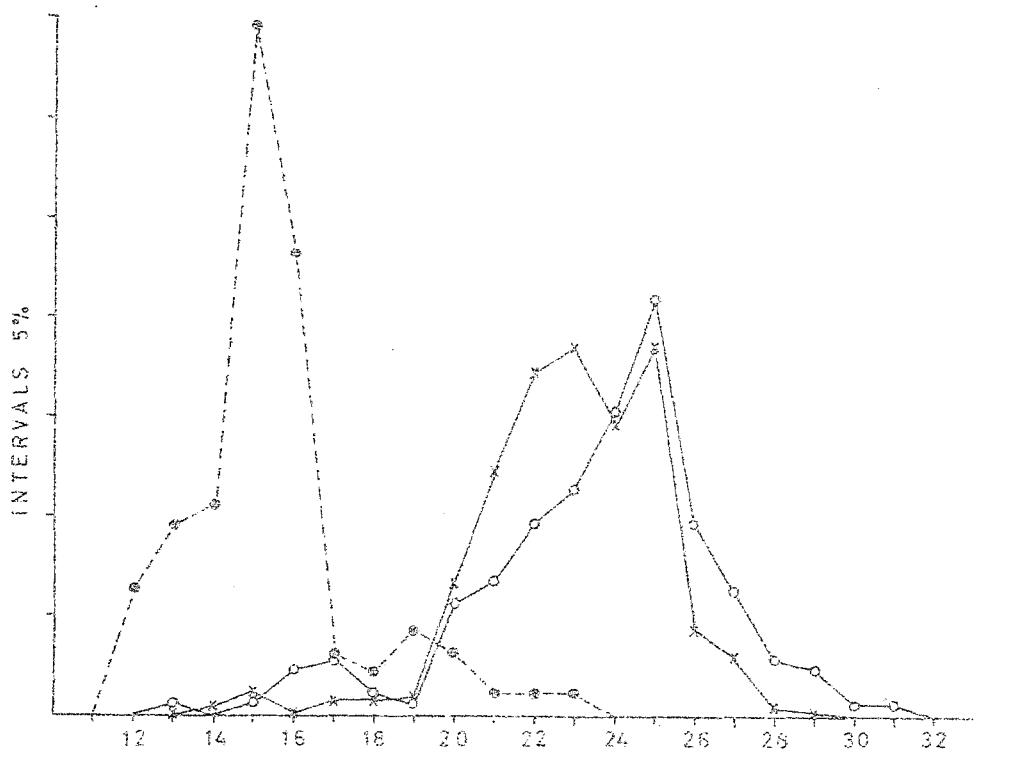

Fig. 6. Frequency distributions of otolith zone measurements for the spring spawning group of herring in north-eastern North Sea (+—+), the Norwegian spring spawning stock (●—●) and the spring spawners on the coast of Western Norway (O—O).

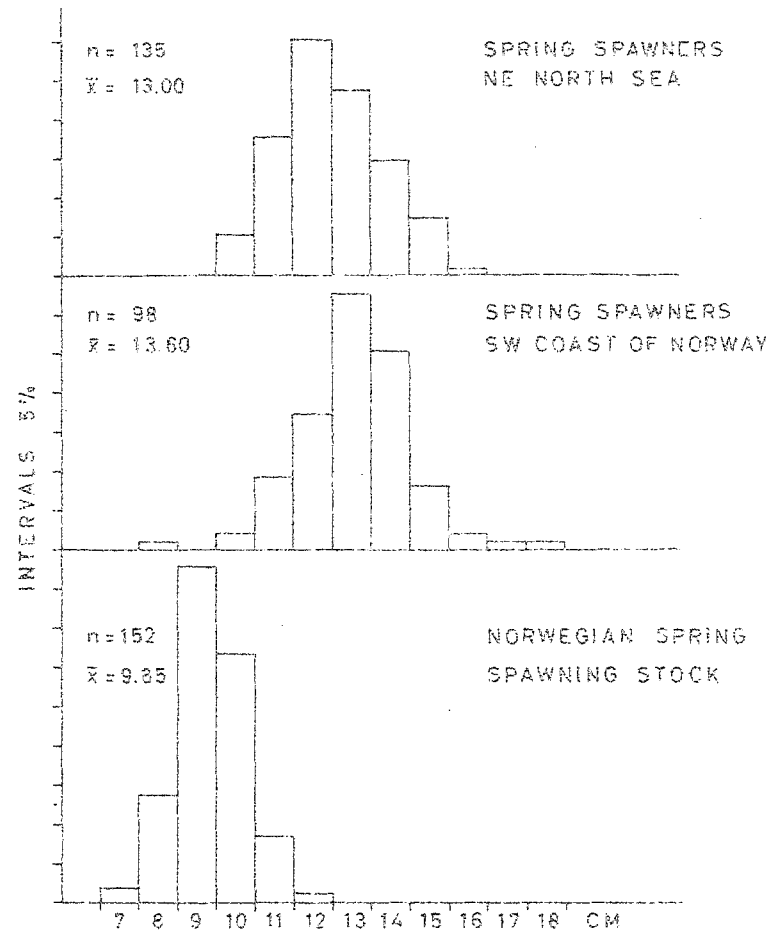

Fig. 7. Frequency distribution of 1_1 (1959 year-class) for the spring spawning group of herring in north-eastern North Sea, the Norwegian spring spawning stock and the spring spawners on the coast of Western Norway.