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THE AUTUMN SPAWNING GROUP OF HERRING IN THE NORTHEASTERN NORTH SEA

By

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INTRODUCTION

The Norwegian herring fishery in the North Sea started in 1898 (IVERSEN 1904). During the first half of this century the effort was low, particularly due to good profitability in other herring fisheries; i.e. those based upon the Norwegian spring spawning stock. The decline in the catches of the Norwegian winter herring fishery in the end of the fifties, however, induced the fishermen to a heavier exploitation of the herring stocks in the North Sea. The landings from the North Sea, which before the end of the fifties were below 100 000 hl, rose to nearly 200 000 hl in

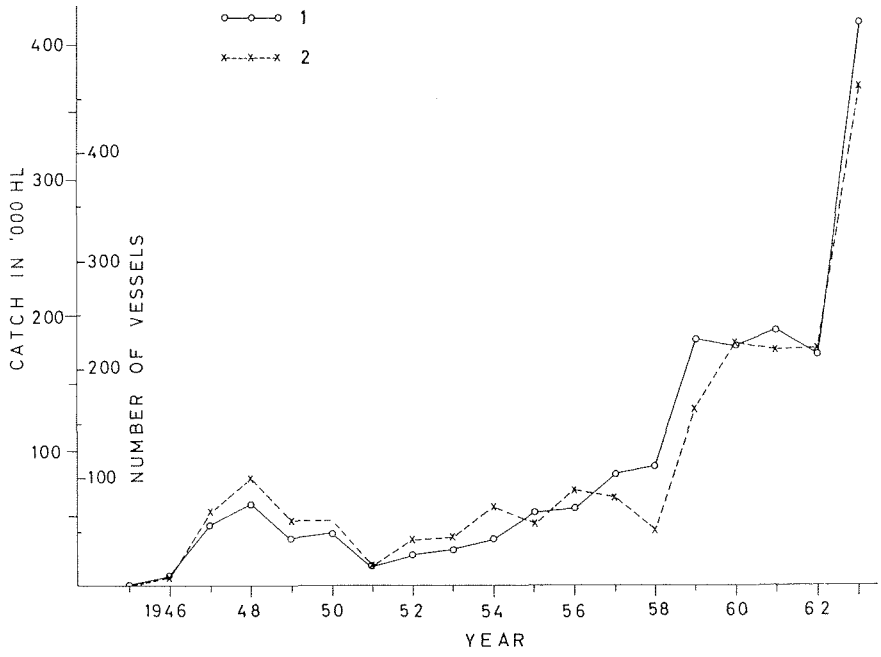

Fig. 1. Total catch of herring from the North Sea and Skagerrak and number of vessels participating in the fishery, 1945—1963. 1) total catch, 2) number of vessels.

the years 1959—62 and in 1963 to more than 400 000 hl. The total catches and number of vessels participating in this fishery during the period 1945—63 are shown in Fig. 1.

The official statistics of the effort in the herring fishery include all vessels with catches to a value of more than 5 000.—N. Kr.

The majority of these vessels were mainly fishing for other species than herring, particularly Norway Pout and shrimps. The herring fleet in the early sixties consisted only of approximately 60—70 vessels.

The main gear used in the herring fishery was bottom trawl and from 1959 onwards also pelagic pair trawl. A few drifters have occasionally participated in this fishery, and during autumn 1963 some catches were also made by purse seiners.

At the beginning of this century the major part of the catches was made during summer in the area east of Shetland and during autumn on the Viking Bank. From the end of the fifties the fishery has been concentrated to the northeastern North Sea and the western entrance of the Skagerrak, particularly along the western slope of the Norwegian Channel. Except for the months June—July, when the trawlers switched over to fish Sand Eel, the herring fishery went on throughtout the year. The distribution of the main areas of fishing in 1962 are summarized in Fig. 2. The landings from the various areas have been grouped into two-monthly periods. From this figure a regular pattern of movement emerges. In January—February the majority of the catches came from the area west of Utsira.

During March—April good catches were taken further north, between Utsira and Bergen about 20—40 nautical miles off the coast.

In July—August the main area of capture shifted to southwest and more seaward, especially to the West Bank area. A productive fishing continued on this fishing ground in September and October, while good catches were also taken on the Fladen Ground.

In November—Desember the main centre of activity was in the Egersund Bank—Coral Bank area.

The northeastern North Sea is supposed to be a mixing area of various populations of spring and autumn spawned herring. The spring spawning group of herring, which in recent years contribute a minor part of the herring stocks in this area, have been investigated earlier (Haraldsvik 1968). The autumn spawned herring in the north-eastern North Sea is supposed to originate from:

1) The «Bank» herring stock (Buchan and Dogger spawners). Spawning grounds from Shetland in the north to the Dogger Bank in the south. Spawning time from August to October.

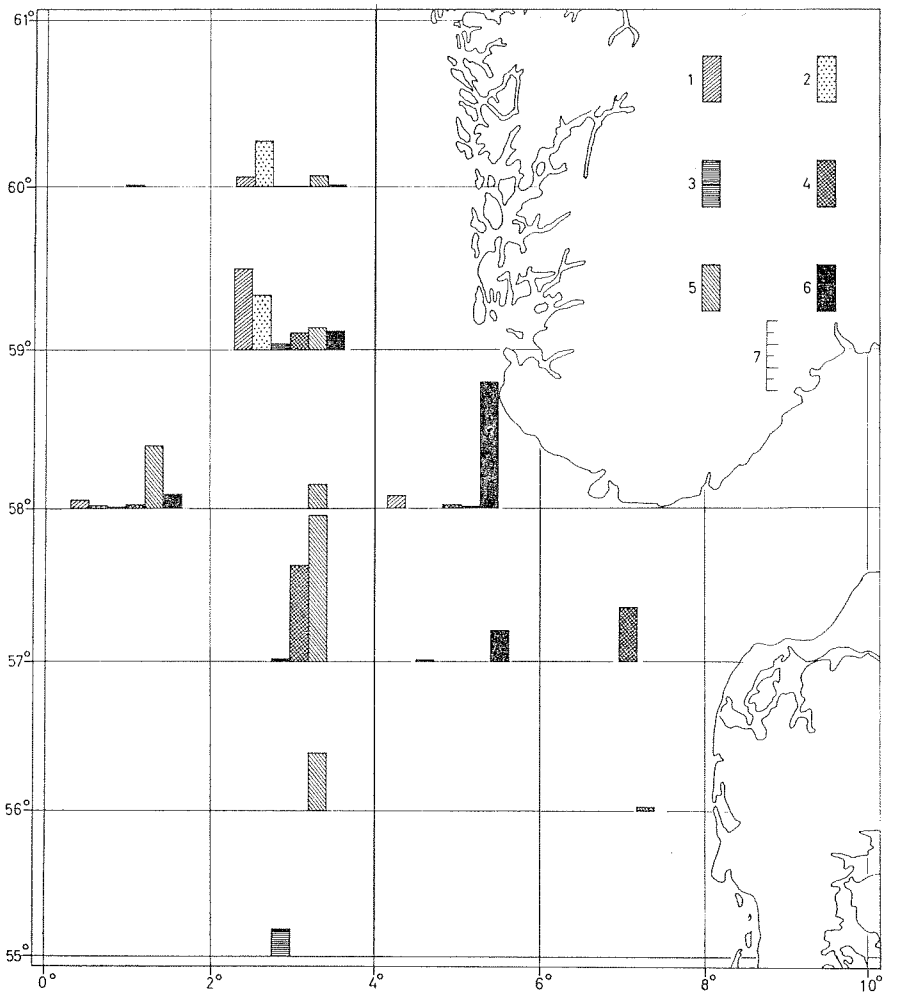

Fig. 2. Distribution of the Norwegian North Sea herring catches (two-monthly periods) in 1962. 1) Jan.—Febr., 2) March—April, 3) May—June, 4) July—Aug., 5) Sept.—Oct., 6) Nov.—Dec., 7) frequency scale in 1 000 hl.

2) The «Downs» herring stock, Spawning grounds in the southern North Sea and eastern English Channel. Spawning time in November and December.
3) The northern Kattegat herring stock (Koppergrund). Spawning grounds in the northeastern Kattegat. Spawning time in September and October.

The non spawning distribution of these stocks are to some extent known from investigations on meristic characters and tagging experi-

ments. A review of the migration pattern of these stock is given by PARRISH AND SAVILLE (1965).

The differences in meristic characters between spawning populations may be a results of differences in genotype, or of differences in environmental factors operating on one genotype, or of both these effects acting together. The plasticity in meristic characters presents the greatest difficulties in distinguishing the individual fish in samples of mixed populations. However, using several characters and comparing data from same year-classes, this method can undoubtedly prove successful in determining the various populations present in an area of mixing.

This report present some results of such analyses carried out on the autumn spawning group of herring in the northeastern North Sea during the years 1961—63.

The origin of this herring has been investigated by comparing meristic characters with those of the Kattegat autumn spawning stock and the «Bank» and «Downs» stocks.

MATERIAL AND METHODS

Twentythree samples were collected from September 1961 to May 1963. Most of the material originate from commercial catches, but 6 samples were collected onboard research vessels.

Otolith characters were used to separate spring and autumn spawned herring (PARRISH AND SHARMAN 1958). This procedure left 2 632 autumn spawners to be studied.

Sampling localities, gears and proportion of spring and autumn spawners are given in Table 1. There was no trend in length composition of the herring taken by different gears, and the samples are, therefore, presumed to give a fairly correct picture of the exploited stocks in the northeastern North Sea.

All the herring were examined as to age, number of vertebrae and stage of maturity. Both scales and otoliths were used for age determinations. Stage of maturity were dertermined according to the maturity scale recommended by the ICES Herring, Committee in 1962 (ANON. 1963).

The first growth zone measurement in otoliths and the l_1, l_2 and l_3 lengths were determined for a part of the material. 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 was estimated by back calculations of scales and applying the modified growth formula by LEA (1938).

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

Sample number	Date	Locality	Gear	Spring spawners	Autumn spawners	Uncer-tain	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	3 825

The quality of the herring examined varied between samples. Except the 6 samples taken onboard research vessels, the samples were from 2 to 10 days old before examination. These samples had either been on ice or been frozen. No adjustments for shrinkage in length for these herring were made.

Frozen material may also give some inaccuracy in the maturity determination. Especially do the eggs tend to get hyaline after being frozen. The amount of hyaline eggs is the main character when distinguishing between the maturity stages IV and V and between the stages V and VI. Owing to diffuse limits between the different stages it is impossible to adjust these data.

RESULTS AND DISCUSSION

AGE COMPOSITION

According to DAHL (1907), CLARK (1933), HODGSON (1934) and WOOD (1951) the formation of the scales begin when the young herring is about 4—5 cm in length, which is approximately the size increment of the autumn hatched herring during the autumn and winter months. The first winter ring on the scales therefore will reflect the second winter condition. The validity of age determination has previously been discussed by ANDERSSON (1946).

He suggested that some «Bank» herring hatched in August might lay down a winter ring at an age of three to four months, thus giving a group of herring whose age was overestimated by one year. The scales of these herring had a small size of the central area. No such scales were observed in the present material, and from information about the growth rate of larval and post larval herring it seems unlikely that substantial numbers of herring will lay down a winter ring during the first winter, as proposed by ANDERSSON.

The otoliths, on the other hand, are present from the larval stage onwards. Herring hatched between August and January will lay down otoliths in winter condition, and consequently get otoliths with a hyaline nucleus.

The number of winter rings on the scales were always in accordance with those on the otoliths (outside the nucleus), which again demonstrates that the first winter ring on the scales is formed during the second winter. Not all scales and otoliths were suited for age determination, mainly due to secondary rings within the summer growth zones, regenerated scales and transparenty otoliths. A following scale for readability of scales and otoliths has been used:

Table 2. Percentage distribution of readability 0—4 of scales and otoliths of autumn spawned herring from northeastern North Sea, 1961—63.

		Readability					N
		0	1	2	3	4	
Trawl	Scale	36.2	9.1	4.6	26.8	23.3	1 953
	Otolith	69,8	9.2	9.6	11.4	0.1	1 953
	S+O[2])	77.7	9.1	6.7	6.6	—	1 953
Drift net	Scale	60.8	11.8	7.9	18.2	1.3	595
	Otolith	73.8	11.4	8.4	6.4	—	595
	S+O	85.2	8.1	4.0	2.7	—	595
Purseseine	Scale	59.8	11.0	12.2	17.1	—	82
	Otolith	65.9	13.4	8.5	12.2	—	82
	S+O	78.0	11.0	6.1	4.9	—	82
Total	Scale	45.2	9.8	5.6	24.6	17.6	2 630
	Otolith	70.6	9.8	9.3	10.3	+[1])	2 630
	S+O	79.4	8.9	6.1	5.6	—	2 630

[1]) < 0.05, [2]) scale and otolith combined.

0: certain
1: fairly certain, deviation of one year may occur.
2: uncertain.
3: regenerated scales, transparency otoliths, scales and otolith did not fit for age determination.
4: scales and otoliths lacking.

Table 2 summarizes the results of the observations on readability of scales and otoliths. The trawl and driftnet herring were frequently lacking scales, or the remaining scales were small and were not suited for age readings, which may explain the great discrepancy of the readability 0 for these gears. The percentage of readability 0 for the otoliths was high for all gears, and this investigation suggests that the otoliths are more suitable than scales for age determination. However, a reservation must be taken when the samples are dominated by older year-classes. Otoliths of autumn spawners were frequently impossible to read when dealing with herring of more than eight years.

The age determination of the samples is based upon readability 0 for either scales or otoliths. In this way positive age determinations were achieved for about 80 per cent of the material. The remaining 20 per cent of the material was most likely dominated by older herring, and this infers that the age composition of the samples is slightly biased

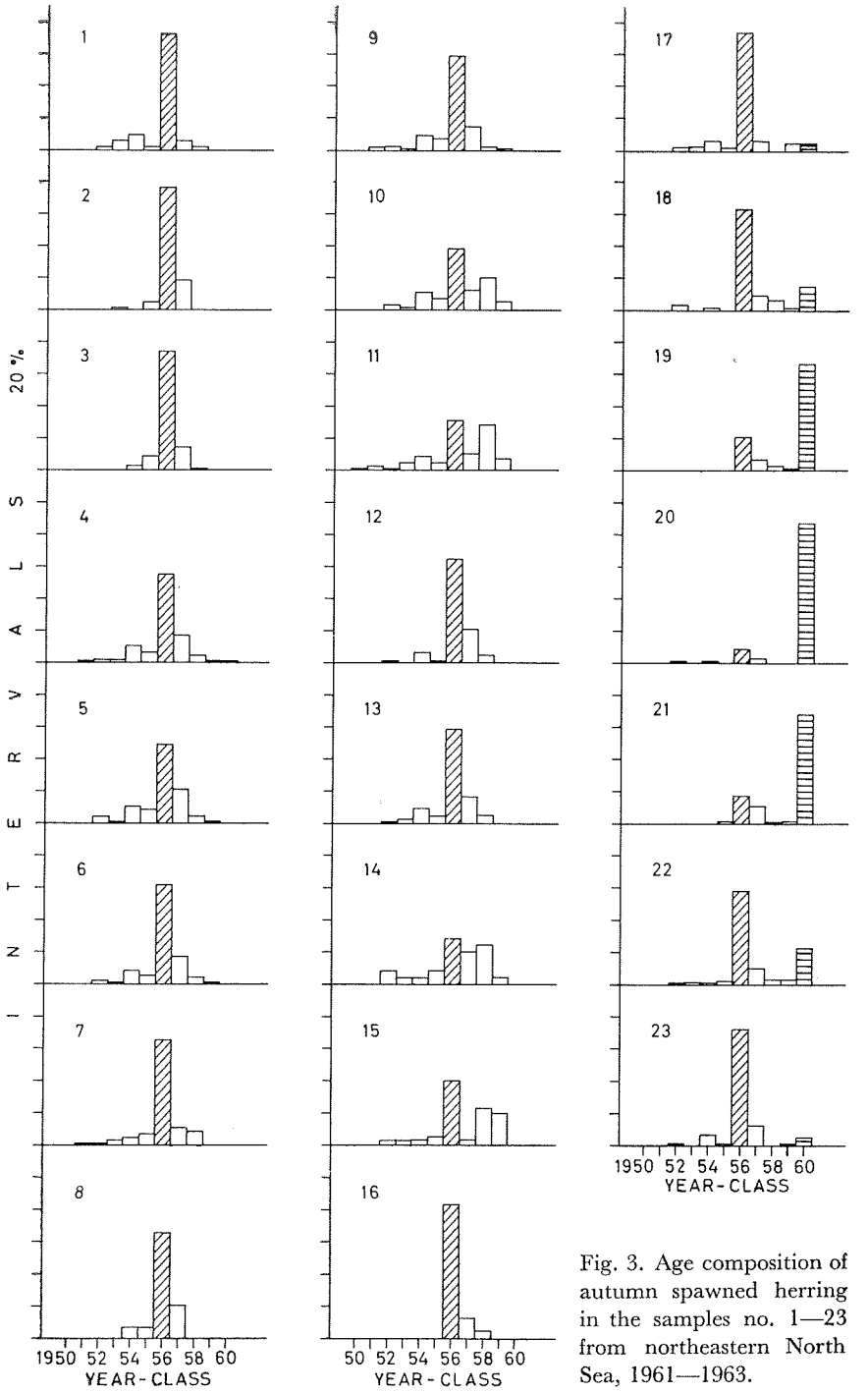

Fig. 3. Age composition of autumn spawned herring in the samples no. 1—23 from northeastern North Sea, 1961—1963.

(Fig. 3). The age composition in the samples from September 1961 to April 1962 is characterized by a strong 1956 year-class and comparatively strong 1954 and 1957 year-classes. During summer some of the samples from the southern and western part of the area (samples No. 10, 11, 14, 15) contained a higher admixture of younger year-classes, while the age composition in the northern part (samples No. 12, 13, 16) remained unchanged. From end of September 1962 the age composition changed considerably, due to a heavy inflow of two year old herring. This 1960 year-class did, however, not increase in abundance north of latitude 59°N.

Although the samples are few, and the number in some cases is low, the material may permit some tentative conclusions. The homogenous age composition of the autumn spawning group during autumn and winter 1961/1962 (September to April) may indicate that the area was visited by a single stock. The change of age composition in the region south of latitude 59°N during spring and summer (April to September) was probably caused by a segregation or an immigration of herring. Since the catches went down during this period the former explanation seems most reasonable. Members of a year-class first recruit the southern part of the region in autumn at an age of two years, and they will during the following winter mainly be distributed south of latitude 59°N.

In Fig. 4 is given the age composition of herring from the western, the central and the southern part of the North Sea. The material from the Bressay Shoal and the Fladen Ground is supposed to be representative

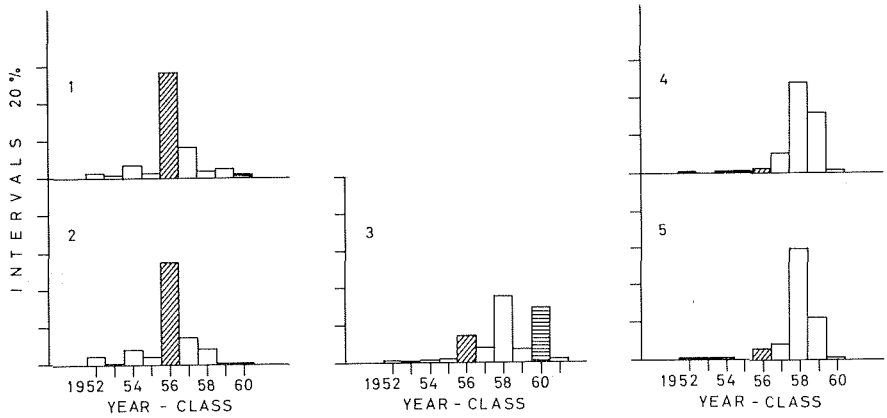

Fig. 4. Age composition of herring from western, central and southern part of the North Sea in 1962. 1) Bressay Shoal, June—Aug., N = 665, 2) Fladen Ground, July—Sept., N = 470, 3) Dogger Bank, Aug.—Oct., N = 4.297, 4) Sandettié, Nov.—Dec., N = 501, 5) Channel, Nov.—Dec., N = 485.

for the age composition of the «Bank» herring, and the material from Sandettié and Channel the «Downs» herring. The Dogger Bank area is during autumn supposed to be a mixing area of spawning «Bank» herring and mature «Downs» herring. This comparison shows a striking resemblance between the «Bank» herring and the autumn spawners in the northeastern North Sea during autumn and winter 1961/62 and during winter 1963 (north of latitude 59°N). Further, Fig. 4 shows that the 1958 year-class, which was dominating the «Downs» herring, also was abundant in some of the samples from spring and summer 1962 in the southern part of the investigated area.

In 1963 the age composition on the spawning grounds in western and southern part of the North Sea changed as a consequence of the strong 1960 year-class. The 1960 year-class constituted this year about 80 % and 70 % of the «Bank» and «Downs» stocks respectively (SAVILLE, MCPHERSON AND PARRISH 1965 AND GILIS 1965). There is no information of the age composition of the Kattegat autumn spawners in 1962, but in autumn 1963 the 1960 year-class contributed about 90 % of this stock (HÖGLUND 1965).

Due to the strength of the 1960 year-class in all autumn spawned herring, it is impossible to identify the various stocks in the northeastern North Sea south of the latitude 59°N during autumn and winter 1962/1963 by means of the age composition.

VERTEBRAE

The vertebral number is one of the most common characters used in distinguishing different herring stocks. This character is probably phenotypic, and the observed differences in mean vertebrae number between different stocks may be attributed to environmental conditions on the the spawning grounds.

In an area where different herring stocks are mixing it is reasonable, to assume that the mean vertebral number will fluctuate in proportion to the abundance of the different stocks.

In Table 3 are given the frequency distributions of the vertebrae counts of the sampled herring. The means varied between 56.35 and 56.66, but no trend in time and space was observed. An analysis of variance has been applied, and the result showed that the differences of vertebrae count within samples were insignificant compared with the differences between means of samples (Table 4). Consequently, one may consider the samples to be drawn from the same stock or same mixture of stocks. This assumption presupposes, however, that there is a real difference in vertebrae number between the various autumn spawning

Tabell 3. Vertebrae number in autumn spawners from northeastern North Sea, 1961—63.

Sample number	Date	Vertebral number							N	$\bar{\times}$ [1]	σ^2
		53	54	55	56	57	58	59			
1	11/ 9—61	—	—	3	24	42	5	—	74	0.6622	0.4459
2	24/ 9—61	—	—	1	39	44	2	—	86	0.5465	0.3213
3	16/10—61	—	—	3	82	84	4	—	173	0.5145	0.3326
4	19/12—61	—	—	4	72	86	2	—	164	0.5244	0.3245
5	19/12—61	—	—	5	69	75	2	1	152	0.5066	0.3841
6	19/ 1—62	—	—	4	78	101	13	—	196	0.6276	0.4093
7	20/ 1—62	1	1	4	78	87	9	—	180	0.5333	0.4961
8	1/ 3—62	—	—	2	35	51	7	—	95	0.6632	0.4172
9	24/ 3—62	—	1	7	69	95	3	—	175	0.5257	0.4002
10	6/ 5—62	—	—	2	32	23	4	—	61	0.4754	0.4536
11	7/ 5—62	—	—	6	49	38	8	—	101	0.4752	0.5319
12	22/ 5—62	—	—	6	46	27	4	—	83	0.3494	0.4740
13	7/ 6—62	—	—	4	66	48	3	1	122	0.4344	0.4130
14	27/ 7—62	—	—	—	19	15	1	—	35	0.4857	0.3160
15	28/ 8—62	—	—	2	21	13	2	—	38	0.3947	0.4616
16	3/ 9—62	—	—	1	19	14	1	—	35	0.4286	0.3697
17	25/ 9—62	—	—	1	38	35	1	—	75	0.4800	0.3070
18	9/10—62	—	—	—	33	39	3	—	75	0.6000	0.3243
19	28/11—62	—	—	4	63	64	7	—	138	0.5362	0.4111
20	22/ 1—63	—	—	6	57	65	4	—	132	0.5076	0.4045
21	20/ 2—63	—	—	4	70	79	6	1	160	0.5625	0.4112
22	23/ 3—63	—	—	8	81	86	5	—	180	0.4889	0.3965
23	3/ 5—63	—	—	2	40	35	4	—	81	0.5062	0.4031
Total		1	2	79	1 180	1 246	100	3	2 611	0.5243	0.4028

[1] $\bar{\times}$ = average excess above the «working mean», 56 vertebrae.

Table 4. Analysis of variance of vertebrae number.

Source	Sum of squares	Degrees of freedom	Mean squares	
Within samples	11.5301	22	0.5241	$F = 1.3047$
Between means of samples.....	1039.7032	2 588	0.4017	$P < 0.05$
Total	1051.2333	2 610		

stocks. Earlier investigations have shown that the mean vertebrae number has an increasing trend from north to south, with low values on the Buchan spawning grounds and high values on the Sandettié and English Channel spawning grounds.

According to ANON. (1961) no large difference in mean vertebrae number was found between pre-and post-war investigations on «Downs» herring, and for the period 1952—1959 their means ranged from 56.53 to 56.59.

The mean vertebrae count of herring from the Dogger area varied in the period 1952—1959 between 56.51 and 56.56 with an overall mean of 56.55 (ANON. 1961). This figure is significantly higher than pre-war observations (WOOD 1936). The spawning herring in the Buchan area had in pre-war years a mean vertebrae number of 56.42. During the years 1952—1955 the mean number was slightly different from pre-war data, but after 1955 the vertebrae number had a marked rise and up to 1960 the means ranged from 56.54 to 56.58 (ANON. 1961).

The Kattegat autumn spawners had in 1915 and 1922 a mean vertebrae number of 56.35 and 56.11 (JOHANSEN 1924). The vertebrae number for this stock in recent years is unkonwn. The low means in some of the samples from summer 1962 can however, indicate an admixture of this stock in the northeastern North Sea.

The total mean vertebrae number (56.52) in the sampled material was in good agreement with those for the «Bank» and «Downs» stocks, and it may be concluded that these stocks, without intimate anything about the mutual abundance, inhabited the northeastern North Sea and constituted the dominant part of the autumn spawning group.

MATURITY

Fig. 5 shows the percentage frequency distribution of the maturity stages among the autumn spawned herring. The samples were collected throughout the year and it is suggested that this figure gives fairly coherent picture of the maturity cycle for the autumn spawning group of herring.

Transistional cases between two stages have been included under the higher stage. Difficulties in distinguishing between stage VIII and an advanced stage II occured frequently. Especially for herring which had spawned only once, criteria such as striation of gonad walls and size of blood vessels were not distinct, and these herring could therefore be confused with herring in stage II. In these doubtful cases the amount of

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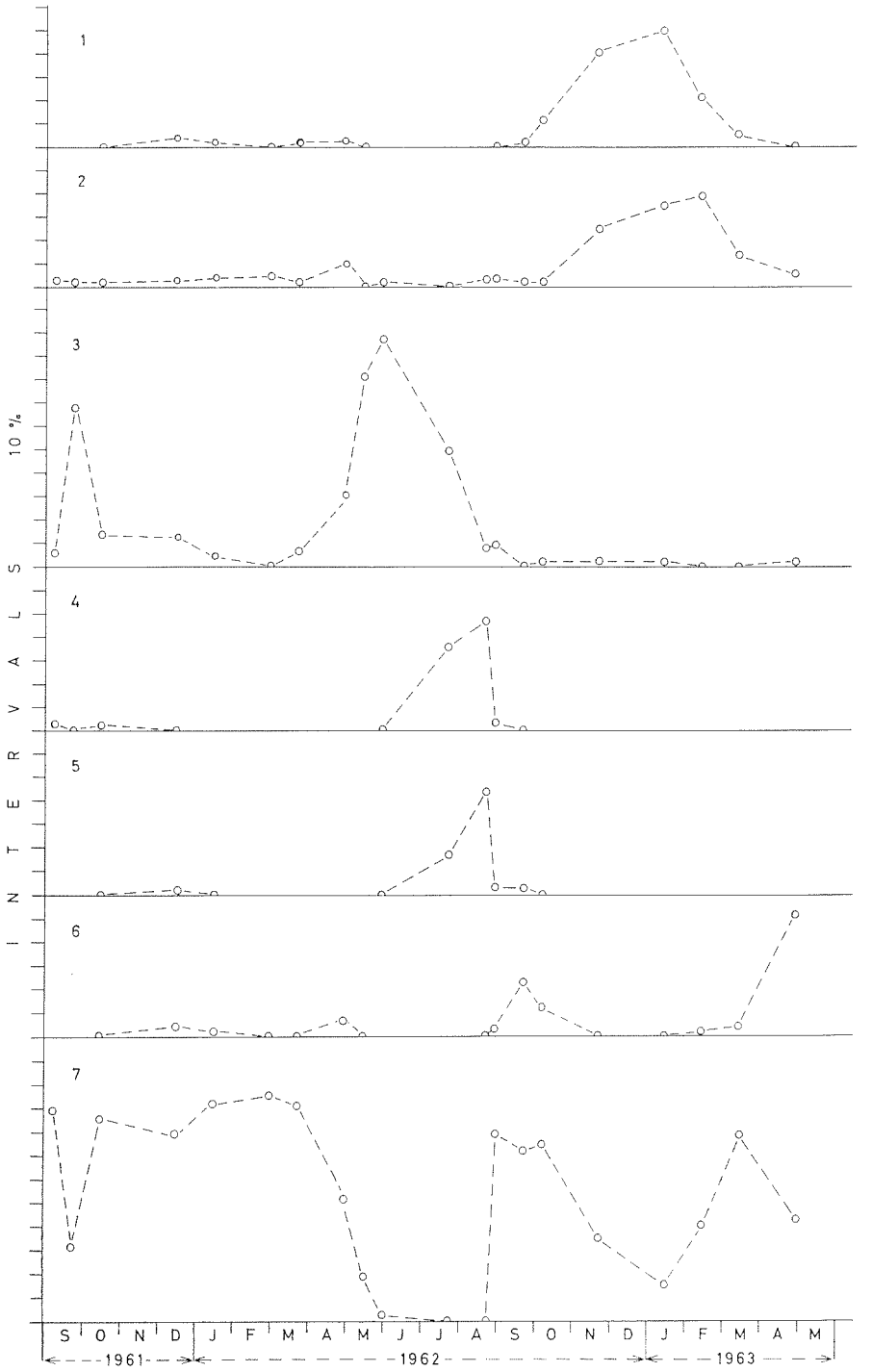
Fig. 5. Percentage composition of maturity stages in autumn spawned herring from northeastern North Sea, 1961—1963. 1) maturity stage I, 2) maturity stage II, 3) matiruty stage III, 4) maturity stage IV, 5) maturity stage V, 6) maturity stage VII, 7) maturity stage VIII.


1
2
3
4
5
6
7
10 %
INTERVALLS
S O N D J F M A M J J A S O N D J F M A M
1961
1962
1963

intestinal fat have been decisive; e.g. herring with moderate or large quantities of fat were determined to belong to stage II and herring with no or little fat, were determined to belong to stage VIII.

Immature herring, stages I and II, were scarce in the material up to October 1962. During autumn and winter 1962/1963 however, these stages dominated the samples due to the immigration of the strong 1960 year-class. Stage III occured in most of the samples, but were predominant in September 1961 and in May, June and July in 1962. The stages IV and V were present during July and August with maximum in second half of August. Due to emigration of mature herring from the northeastern North Sea to the spawning grounds during summer and early autumn these stages will probably cover a longer period than indicated in Fig. 5.

Spent herring, stage VII, were represented during December and January 1961/1962, and during September and October 1962. This fact points to an immigration of late and early autumn spawning components. From Fig. 5 it is noticed that stage VII also was present during spring in 1961 and 1962, which may indicate an alternation of the spawning season for these herring. According to PARRISH AND SHARMAN (1958) a small number of herring with «summer-autumn» characters in the otoliths have been recorded in spawning condition in spring in the Firth of Forth and the North Minch areas. There is also observations of spawning herring in August with distinct and definite «winter-spring» otoliths in an inlet on the west coast of Norway. Racial characters as scale pattern, l_1, vertebral number of these herring were in agreement with the Norwegian spring spawning stock. An alternation of the spawning season may therefore occasionally occur, but on the other hand, if a part of the autumn spawned herring in the northeastern North Sea have changed their spawning season, this should be reflected in a two-peaked curve of the various maturity stages.

The samples collected in spring and containing stage VII, had all been frozen and were in bad condition when examined. It seems most likely, therefore, that the maturity determination of these samples must be erroneous.

The maturity cycle of the autumn spawning group in the northeastern North Sea is characterized by a long duration of the recovering stage VIII, almost 8 months, and a rapid maturation during spring and summer. Stage VIII passes into stage III at the beginning of May.

According to ILES (1964) the timing of the onset of the maturation cycle varies little as does the time spent in the earlier maturation stages for the various autumn spawning stocks in the North Sea.

Spent and recovering herring in September and first half of October

belong probably to the «Bank» herring, but otherwise it seems impossible to distinguish between the various autumn spawning stocks by means of this characters.

AGE AT FIRST SPAWNING

The autumn spawners had no typical spawning rings on scales and otoliths. The age at first spawning has been based upon the maturity composition by age in the samples collected during autumn and winter.

Herring in stage III in this period are classified as uncertain, i.e. they may be immature and will not spawn before the next autumn, or they may have spawned and already recovered their gonads. The percentage composition of immatures (stages I and II), uncertain (stage III) and spent herring (stages VII and VIII) in each age group is illustrated in Fig. 6. It will be seen that first time spawners occured amongst two to six year old herring, but the majority of first time spawners, about 70 %, were spawning at an age of three. This feature is common, in the autumn spawning stocks in the North Sea and the Kattegat (CUSHING AND BURD 1957, PARRISH AND CRAIG 1957, HÖGLUND 1965). The age at first spawning shows a marked change from the inter-war years, when only a small proportion of the herring matured as three years olds, and the major recruitment to the spawning shoals took place as four year old herring. The marked change in age at first spawning occured widely

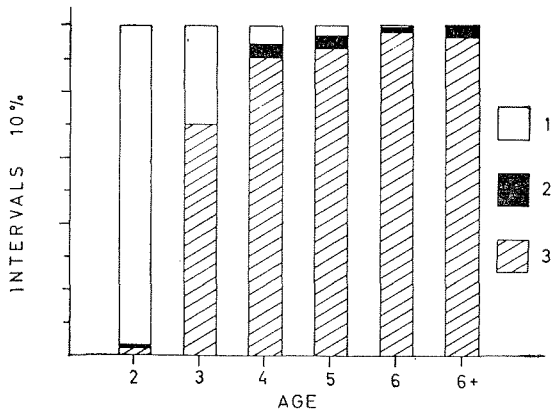


Fig. 6. Composition of immature herring, herring in maturity stage III and mature herring amongst 2—6 + year old autumn spawners from northeastern North Sea. 1) maturity stage I—II, 2) maturity stage III, 3) maturity stage IV—VIII.

over the North Sea in the early fifties and have been associated with an increase in growth rate during the adolescent and pre-recruit phases. This has resulted in an earlier movement from the nursery areas, and in an earlier maturation of herring recruiting both the «Bank» and «Downs» stocks (BURD 1962).

It should be noted that the average length by age decreased again in the southern North Sea between 1955 and 1961, but no obvious reversal of the recruitment pattern had taken place up to 1963.

OTOLITH TYPES

In recent years special attention has been paid by a number of herring workers to features of the herring otoliths (EINARSSON 1951, PARRISH and SHARMAN 1958, POSTUMA and ZIJLSTRA 1958).

PARRISH and SHARMAN (1958) found differences in the forms of the first winter zone and in the sizes of the first growth zone of members of the North Sea autumn spawning group. These features are probably phenotypic, but they may give some important hints to nursery areas from which herring of different spawning grounds are derived, and to a certain extent give information on the mixing of early and late autumn spawning herring. Two main types of otoliths were described:

1. Otoliths with a «wide» first winter zone and a relatively small first growth zone.
2. Otoliths with a «narrow» or a thin and sharp first winter zone and a relatively large first growth zone.

According to DAS, POSTUMA and ZIJLSTRA (1959) the «narrow» type was dominant amongst spawning herring in the Dogger Bank area, while the «wide» type was prominent on the spawning grounds in the southern North Sea and in the eastern part of the English Channel. On the Buchan spawning grounds the «narrow» type constituted a greater part than in the Dogger area (PARRISH and SHARMAN 1959 a), and a decreasing trend of the «narrow» otolith type from north to south seemed to exist.

The occurence of the two otolith types in the samples from north-eastern North Sea is given in Table 5. This table also include otoliths which could not be categorized under either of these major types, and they contributed about 7 % of all the otoliths examined.

Table 5. Percentage distribution of otolith types amongst autumn spawners from northeastern North Sea, 1961—63.

Sample number	Date	«Narrow»	«Wide»	Uncertain	N
1.....	11/ 9—61	87.8	4.1	8.1	74
2.....	24/ 9—61	82.6	9.3	8.1	86
3.....	16/10—61	88.4	5.2	6.4	173
4.....	19/12—61	84.1	6.1	9.8	164
5.....	19/12—61	79.6	7.2	13.2	152
6.....	19/ 1—62	84.7	4.1	11.2	196
7.....	20/ 1—62	82.2	11.7	6.1	180
8.....	1/ 3—62	87.5	8.3	4.2	96
9.....	24/ 3—62	85.2	8.5	6.3	176
10.....	6/ 5—62	91.8	6.6	1.6	61
11.....	7/ 5—62	83.5	9.7	6.8	103
12.....	22/ 5—62	91.6	3.6	4.8	83
13.....	7/ 6—62	88.5	6.6	4.9	122
14.....	27/ 7—62	78.4	10.8	10.8	37
15.....	28/ 8—62	79.5	10.3	10.3	39
16.....	3/ 9—62	91.4	—	8.6	35
17.....	25/ 9—62	92.1	2.6	5.3	76
18.....	9/10—62	89.3	5.3	5.3	75
19.....	28/11—62	93.1	2.8	4.1	145
20.....	22/ 1—63	96.2	0.8	3.0	132
21.....	20/ 2—63	90.7	3.7	5.6	162
22.....	23/ 3—63	83.4	10.5	6.1	181
23.....	3/ 5—63	87.8	7.3	4.9	82
Total		86.8	6.4	6.8	2 630

From Table 5 it is seen that the «narrow» type dominated in all the samples, and no trend neither in time or in space was observed in the frequency of the two otolith types. It is interesting to note that the frequency of the «wide» otolith type either is increasing during the summer feeding season nor is decreasing during the spawning season for the «Downs» stock, which may indicate that members of this stock do not immigrate into the northeastern North Sea.

In Table 6 is given the percentage distribution of otolith types amongst age groups for the years 1961—1963. The most important features of these data are as follows:

1) «Wide» zoned otoliths were not found in the 2 year old herring.
2) The proportion of the two otolith types differed between year-classes. The 1958 year-class had a relatively high proportion of the «wide» type as three to six year olds.

Table 6. Percentage distribution of otolith types by age amongst autumn spawners in northeastern North Sea, 1961—63. (N = «Narrow» type, W = «Wide» type, U = unclassified.)

Year \ Age / Type	2			3			4			5			6			7			7+			N
	N	W	U	N	W	U	N	W	U	N	W	U	N	W	U	N	W	U	N	W	U	
1961	100	—	—	69	23	8	87	6	7	83	8	9	82	3	15	89	6	5	94	6	—	513
1962	99	—	1	92	4	4	83	12	5	82	10	8	86	8	6	96	4	—	83	6	1	1 101
1963	—	—	—	98	1	1	86	14	—	80	20	—	79	9	12	81	12	7	75	19	6	473

There was no evidence from the data of an increase in the proportion of «wide» otoliths with age as found by PARRISH and SHARMAN (1959 b) in the northwestern North Sea. The high proportion of «narrow» typed otoliths in the samples suggests a connection between the «Bank» stock and the autumn spawning herring in the northeastern North Sea. However, it is impossible to verify this statement, as long as the otolith type composition amongst the Kattegat autumn spawning stock is unknown.

FIRST GROWTH ZONE MEASUREMENT ON OTOLITHS

The frequency distribution of first growth zone measurements for the two otolith types exhibited marked differences. The ranges and means for the «wide» and «narrow» types are presented in Table 7. The percentage frequency distributions for the two otolith types are illustrated in Fig. 7. It appears that the first growth zone measurements for «wide» type were smaller than for «narrow» type, and further, that the distributions and means within each type were similar in the years investigated. The high means for «narrow» type in samples no. 19—21 are probably caused by growth differences between year-classes. As mentioned before, the 1960 year-class dominated these samples, while the 1956 year-class was dominant in the others. Considering the total material the first growth zone measurements for «narrow» otoliths ranged from 20 to 39 units (one unit = 0.0409 mm), and had a mean value of 29.8 units. The corresponding figures for «wide» otoliths were 18—30 units and 24.6 units.

The ranges and means for the «narrow» and «wide» otoliths from northeastern North Sea were somewhat lower than the values obtained for the «Bank» herring in the years 1953—1956 (PARRISH and SHARMAN 1959 b). These differences were, however, small and probably inside the expected range when dealing with material consisting of different year-classes.

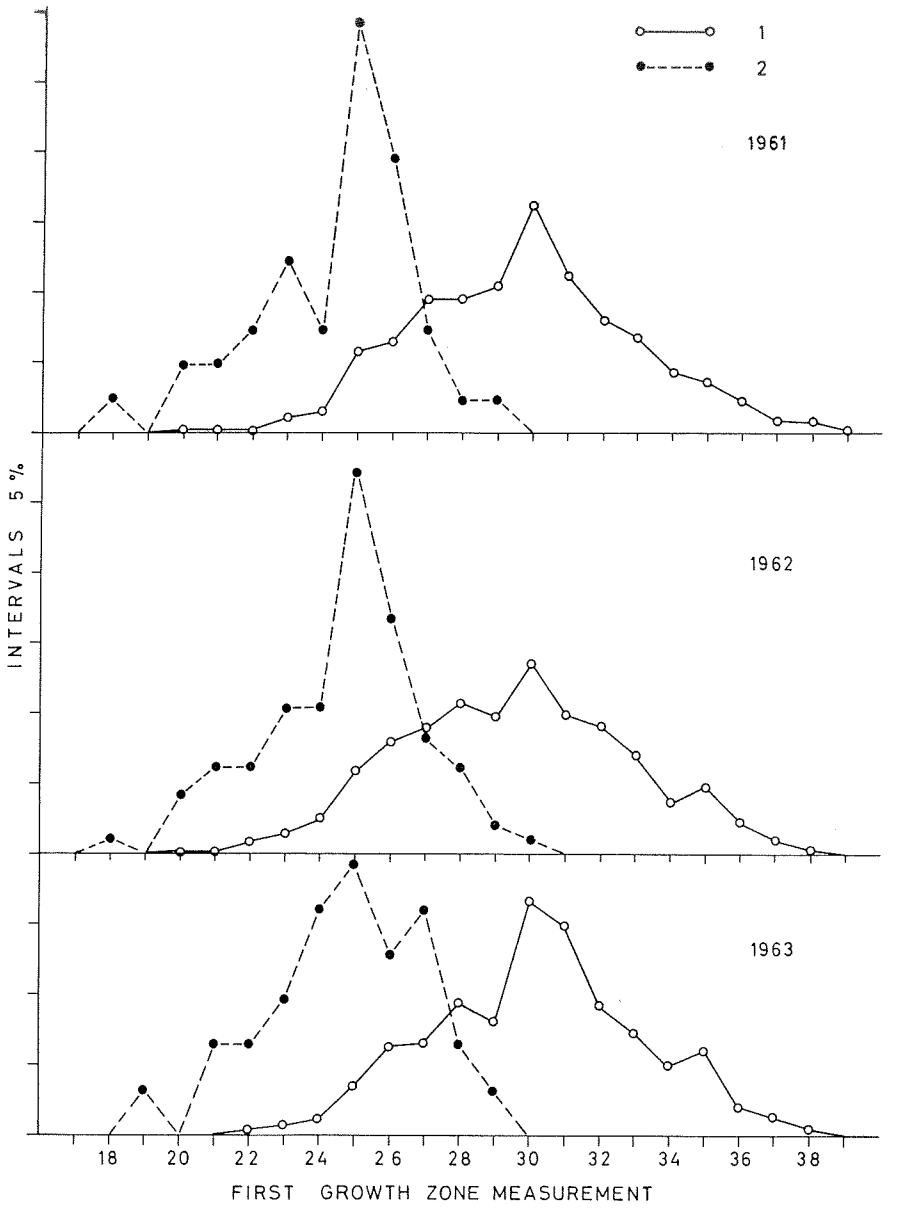


Fig. 7. Frequency distributions of otolith zone measurements of autumn spawned herring in northeastern North Sea, 1961—1963. 1) «narrow» otolith type, 2) «wide» otolith type.

Table 7. Ranges and means of first growth zone measurement on «narrow» and «wide» otolith types amongst autumn spawners from northeastern North Sea, 1961—63 (1 unit = 0.0409 mm).

Sample number	Date	«Narrow»			«Wide»		
		Range (unit)	Mean	N	Range (unit)	Mean	N
1.....	11/ 9—61	23—39	29.7	64	25—26	25.3	3
2.....	24/ 9—61	23—37	30.4	68	23—26	24.9	8
3.....	16/10—61	22—38	30.1	149	22—29	25.3	9
4.....	19/12—61	20—38	29.6	137	20—27	24.1	10
5.....	19/12—61	23—38	29.1	115	18—28	23.2	11
Sum 1961 .		20—39	29.8	533	18—29	24.4	41
6.....	19/ 1—62	23—37	30.0	159	23—29	25.1	9
7.....	20/ 1—62	22—38	29.7	144	20—29	25.5	21
8.....	1/ 3—62	21—37	29.1	81	20—30	23.9	8
9.....	24/ 3—62	23—38	29.7	146	22—28	25.3	15
10.....	6/ 5—62	22—36	29.0	56	21—26	23.3	4
11.....	7/ 5—62	22—38	29.2	82	20—26	23.0	10
12.....	22/ 5—62	22—38	29.2	74	21—26	23.1	3
13.....	7/ 6—62	22—36	28,8	108	22—27	24.4	8
14.....	27/ 7—62	22—35	28.2	28	24—25	24.8	4
15.....	28/ 8—62	24—33	27.8	31	18—26	23.3	4
16.....	3/ 9—62	26—36	30.0	31	—	—	0
17.....	25/ 9—62	20—37	29.3	69	25—26	25.5	2
18.....	9/10—62	23—37	30.2	65	24—28	26.3	4
19.....	28/11—62	22—37	31.0	129	21—27	24.3	4
Sum 1962		20—38	29.6	1 203	18—30	24.6	96
20.....	22/ 1—63	24—38	30.8	117	25	25.0	1
21.....	20/ 2—63	23—37	30.4	142	24—29	26.4	5
22.....	23/ 3—63	23—37	30.0	145	21—27	24.4	19
23.....	3/ 5—63	22—38	29.7	69	19—28	24.5	6
Sum 1963		22—38	30.3	473	19—29	24.8	31
Grand Total		20—39	29.8	2 209	18—30	24.6	168

In Table 8 is the present material compared with the means of the first growth zone measurements for the two otolith types amongst herring from the Dogger area (Bohl 1960). In both areas the 1956 year-class was dominating, as 2 year olds in the Dogger area and as 5—7 year olds in the northeastern North Sea.

Table 8. Mean first growth zone measurement (mm) on «narrow» and «wide» typed herring from Dogger Bank and northeastern North Sea.

Type	Dogger Bank	N	NE North Sea	N
«Narrow»	1.23	928	1.22	2 209
«Wide»	1.02	332	1.01	168

The good conformity indicates a connection between pre-recruits in the Dogger area and mature herring in the northeastern North Sea.

The result of this investigation provide some pointers to the supply and composition of the autumn spawners in the northeastern North Sea. However, at present it is not possible to assess the full biological significanse between the two otolith types and the usefulness of this character in herring «racial» studies. It is suggested that the differences between the growth zones of the «wide» and «narrow» types are due to an early or late time of hatching or to a difference in growth rate. The differences between the size of the first winter zone in the two otolith types are probably a result of growth and metabolism differences between herring inhabiting different areas.

It should also be noted that there was no differences in vertebrae number between «narrow» and «wide» typed herring. The frequency distributions of Vert.S. for the two types are given in Table 9 ($t = 0.8589$, $0.3>p>0.4$).

Before the usefulness of otolith features in herring «racial» studies can be assessed, more information of the otolith types amongst the spawners from the Dogger, the Southern Bight and the northern Kattegat areas are needed. Also extensive studies of herring in different nursery areas must be carried out, and the effect of food and temperature on ring formation should also be investigated.

Table 9. Vertebrae number of «wide» and «narrow» typed herring amongst autumn spawners from northeastern North Sea, 1961—63.

Type	Vertebral number						N	$\overline{\times}$ [1]	σ^2
	54	55	56	57	58	59			
«Wide» . . .	—	5	75	85	1	—	166	0.4940	0.3242
«Narrow» .	2	63	1 023	1 082	93	3	2 266	0.5340	0.3999

[1] $\overline{\times}$ = average excess above the «working mean», 56 vertebrae.

GROWTH

LEA (1910, 1938) has shown that the relation between scale length and total length of the herring is approximately linear. The differences in spawning time and nursery areas between the various stocks are assumed to be reflected in the l_1 values, and the l_1 distributions have been one of the main characters used for identifying herring in mixing areas. In the North Sea the differences of the l_1 distributions between the «Bank» and «Downs» herring are clearly demonstrated by BURD (1962). BURD also showed that the differences between the l_1 distributions of «Bank» and «Downs» herring were much greater than the differences between year broods and the differences within a year brood.

The l_1 distributions have been obtained by projection and proportioning the scales of six year old herring (1956 year-class). For calculating the l_1 values, the modified growth formula of LEA (1938) was applied

$$l_1 = \frac{s_1}{S_n} L + \left[1 - \frac{s_1}{S_n}\right]$$

where s_1 and S_n refer to measurements on the scale from the basal line to the first winter-ring and the edge respectively, L is the total length of the fish, l_1 is the calculated length at the formation of the first winter-ring. The obtained data are illustrated in Fig. 8, and for comparison is shown the l_1 distribution of four year-olds (1954 year-class) «Bank» and «Downs» herring (ANON. 1962, BURD 1962). A weakness with this comparison is that different year-classes are compared and that the l_1 data are based upon different growth formulas. The l_1 data for the «Bank» and «Downs» herring in Fig. 8 are calculated by LEA's first formula, i.e. these data are in average $\left[1 - \frac{s_1}{S_n}\right]$ cm lower than the l_1 data presented for the autumn spawners in northeastern North Sea.

The differences in growth by using the two formulas are for 6 year old herring estimated to be 0.5 cm. Notwithstanding this disadvantage, it is concluded that there is good agreement between the l_1 data for the autumn spawning herring in the northeastern North Sea and the «Bank» herring stock.

The differences found in first growth zone measurements in the «narrow» and «wide» typed herring suggest that similar differences would be found in the l_1 data of these two groups of fish. In Fig. 8 is also the l_1 distribution separated on otolith types. The good correspondance, when comparing with the l_1 data for the «Bank» and the «Downs» herring could indicate that the «wide» type was originating from the «Downs» stock and the «narrow» type from the «Bank» stock. Good

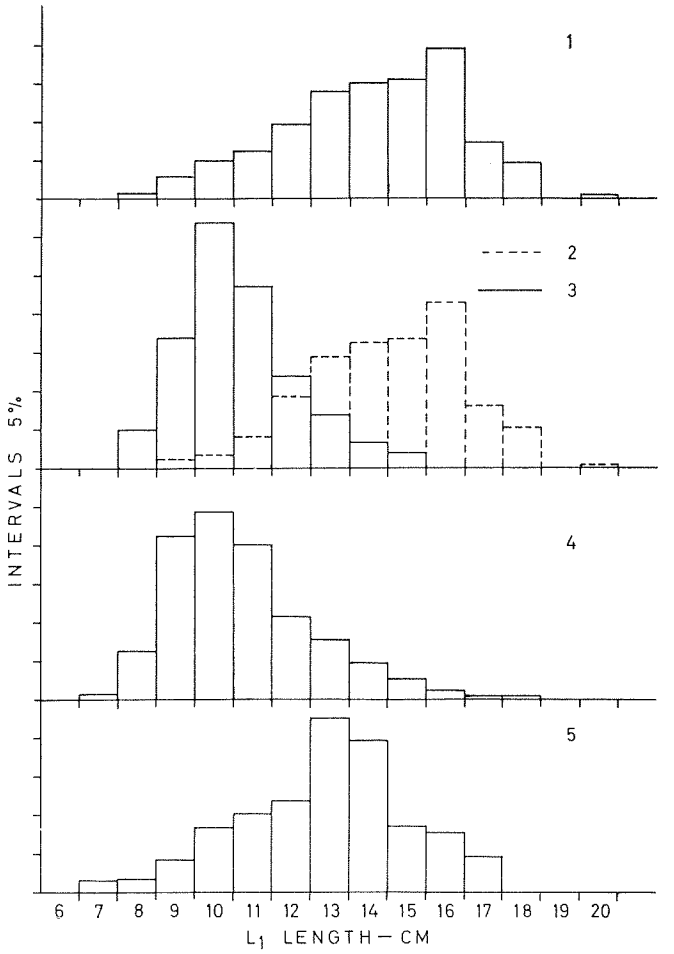


Fig. 8. Frequency distribution of l_1 for 6 year old (1956 year-class) autumn spawned herring (also separated in «narrow» and «wide» types) in northeastern North Sea, compared with the l_1 distribution for 4 year old (1954 year–class) «Bank» and «Downs» herring. 1) Autumn spawned herring northeastern North Sea, 2) «Narrow» typed herring northeastern North Sea, 3) «Wide» typed herring, northeastern North Sea, 4) «Downs» herring, 5) «Bank» herring.

Table 10. The length (l) of 1, 2, ... 5 year-old «narrow» and «wide» typed herring amongst autumn spawners from north-eastern North Sea.

A. «Narrow» type.

Year-class	l_1 cm			l_2 cm			l_3 cm			l_4 cm			l_5 cm		
	Mean	$\pm \frac{2\sigma}{\sqrt{N}}$	N	Mean	$\pm \frac{2\sigma}{\sqrt{N}}$	N	Mean	$\pm \frac{2\sigma}{\sqrt{N}}$	N	Mean	$\pm \frac{2\sigma}{\sqrt{N}}$	N	Mean	$\pm \frac{2\sigma}{\sqrt{N}}$	N
1960	16.79	0.30	99	—	—	—	—	—	—	—	—	—	—	—	—
1959	16.13	2.02	4	24.50	—	1	—	—	—	—	—	—	—	—	—
1958	16.50	0.98	11	23.31	1.32	8	25.25	0.50	2	—	—	—	—	—	—
1957	15.31	0.45	58	22.38	0.34	52	25.51	0.23	52	27.10	0.36	10	—	—	—
1956	14.77	0.31	171	22.56	0.23	154	25.45	0.18	153	26.85	0.15	135	28.11	0.51	35
Total	15.51	0.22	343	22.56	0.19	215	25.46	0.14	207	26.87	0.14	145	28.11	0.51	35

B. «Wide» type.

Year-class	l_1 cm			l_2 cm			l_3 cm			l_4 cm			l_5 cm		
	Mean	$\pm \frac{2\sigma}{\sqrt{N}}$	N	Mean	$\pm \frac{2\sigma}{\sqrt{N}}$	N	Mean	$\pm \frac{2\sigma}{\sqrt{N}}$	N	Mean	$\pm \frac{2\sigma}{\sqrt{N}}$	N	Mean	$\pm \frac{2\sigma}{\sqrt{N}}$	N
1960	15.50	—	1	—	—	—	—	—	—	—	—	—	—	—	—
1959	12.50	—	1	22.00	—	1	—	—	—	—	—	—	—	—	—
1958	12.17	1.01	12	20.55	1.15	11	24.25	1.16	8	—	—	—	—	—	—
1957	12.59	0.67	17	20.84	0.35	16	24.63	0.28	15	26.17	0.33	3	—	—	—
1956	10.96	0.39	60	19.28	0.37	59	23.42	0.27	50	25.37	0.26	53	26.66	0.40	22
Total	11.49	0.36	91	19.76	0.33	87	23.73	0.25	81	25.41	0.25	56	26.66	0.40	22

correlation between l_1 and otolith types have also been found by RAITT (1961), who estimated a critical length at 11.5 cm for formation of «narrow» and «wide» otoliths, i.e. herring longer than 11.5 cm in the second winter would lay down a «narrow» ring and herring smaller than 11.5 cm a «wide» ring. The proportion of herring longer and smaller than 11.5 cm in the «Bank» and «Downs stocks will differ by virtue of the 3—6 months difference in spawning time, and consequently the composition of otolith types in the two stocks will also be different. On this basis a comparison between l_1 of «wide» typed herring and «Downs» herring (where «wide» type is dominating) and between l_1 of «narrow» typed herring and «Bank» herring (where «narrow» type is dominating) will always give good conformity.

The two otolith features point to the presence of distinct nursery areas for the smaller and larger herring during their second winter. By analogy with the origins of «northern» and «southern» scale types identified by LEA (1929) it is probably that the «narrow» zoned type are from a colder second winter nursery area than the «wide» zoned type.

A difference of nearly 4 cm between modal length at formation of the first winterring of these two groups of fish is suggested to be so much that they will maintain a difference in growth throughout their life. The resulting data of backcalculation of «narrow» and «wide» typed herring are summarized in Table 10, giving the mean values of l_1, l_2, ... l_5 and their standard errors for the various year-classes. From this table it is clear that the «narrow» and «wide» typed herring differed in growth rate. Mean lengths by age were significant higher for all age groups amongst the «narrow» typed herring. The difference in growth between the two types of herring may well be attributable to the original difference in l_1. The «narrow» and «wide» herring are probably, as suggested above, both belonging to the «Bank» herring stock. The good comformity in growth between the «wide» typed herring in the present material and the «Downs» herring may, however, indicate that this component have some similarities with the «Downs» stock, such as nursery areas, feeding grounds or feeding times.

CONCLUDING REMARKS

To outline the origin of the autumn spawning group of herring in the northeastern North Sea, some biological characters for this group of herring have been compared with the «Bank», the «Downs» and the

Kattegat autumn spawning stocks. Due to the plasticity in these characters and the large degree of overlap of values between the stocks it is difficult to attain a complete identification of the herring by this method. However, using several characters this method may give valuable pointers to the stock composition within the autumn spawned herring in this part of the North Sea.

The age composition in the samples from September 1961 to May 1962 showed a striking conformity with the «Bank» herring stock (Fig. 4). According to otolith type composition (Table 5) and the Vert. S. (Table 3) in these samples it seems obvious that the intermingle of herring from other stocks was negligible during that period.

In the samples from May to September 1962 it was more difficult to identify the stock composition. The samples during this period had a low first growth zone measurement in the «narrow» otoliths (Table 7) together with low values of Vert. S. (Table 3). These changes could be a consequence of a segregation, i.e. the older year-classes have emigrated from the area, resulting in a stronger dominance of the 1958 and 1959 year-classes (Fig. 3), or an immigration of other herring stocks had taken place. An analysis of variance of Vert. S. showed that the differences within year-classes were insignificant compared with the differences between year-classes. It should, however, be noted that the 1958 and 1959 year-classes had the lowest values of Vert. S., with means of 56.467 (60) and 56.368 (19) respectively. Due to the low values of Vert. S. and the high proportion of «narrow» typed otoliths (Table 5) it is suggested that the immigration of «Downs» herring to the north-eastern North Sea was negligible. One sample of Kattegat autumn spawners (kindly sent me by Dr. HÖGLUND, Lysekil) had a high proportion of «narrow» typed otoliths (96.9 %) and a low first growth zone measurement (27.35 units). To what extent these values are representative for the Kattegat autumn spawners is unknown, but these values together with the low values of Vert. S. could indicate that the autumn spawned herring in the northeastern North Sea in the period May to September 1962 were mixed up with Kattegat autumn spawning herring.

During autumn 1962 the 1960 year-class immigrated the north-eastern North Sea south of latitude 59°N. This year-class proved to be strong amongst the «Bank», the «Downs» and the Kattegat autumn spawning stocks, but the high vertebral count (Table 3), the high proportion of «narrow» typed otoliths (Table 5) and the high valvues of the first growth zone measurement (Table 7) should argue for that the herring of this year-class in the northeastern North Sea mainly did derive from the «Bank» herring stock. North of latitude 59°N, however, there was during the winter 1963 a striking conformity in age composi-

tion, vertebral number, composition of «narrow» and «wide» typed otoliths between the sampled herring and the «Bank» herring stock.

From this investigation it is concluded that the autumn spawning group of herring in the northeastern North Sea is mainly constituted of the «Bank» herring stock. This stock is prevailing amongst the autumn spawning group of herring during autumn, winter and spring, but is during summer probably mixed up with Kattegat autumn spawners in areas south of latitude 59°N.

SUMMARY

1. The present report deals with the autumn spawning group of herring in the northeastern North Sea and an analysis of some biological characters as age composition, maturity cycle, otolith type composition, first growth zone measurement on otoliths and growth. The material consists of 23 samples, collected during the period September 1961 to May 1963.
2. The otoliths were more suitable than the scales for age determination. The 1956 year-class was dominating in the samples up to autumn 1962 in the whole area and also in the samples taken north of latitude 59°N during the winter 1963. In autumn 1962 the 1960 year-class immigrated the southern area and made up between 65—85 % of the autumn spawned herring.
3. An analysis of the vertebrae number showed that the differences of the variance within samples were insignificant compared with the differences between means of samples. The mean vertebrae number of the total material was 56.524 ($\pm$ 0.025).
4. The maturity cycle of the autumn spawned herring has been considered. The maturity stage VIII had a duration of about 8 months, and dominated the samples from September to May. Stage III dominated from mid May to the end of July. The stages IV and V were present during July and August with a maximum in the second half of August. Spawning of herring was not recorded in the area investigated.
5. An analysis of the composition of «narrow» and «wide» zoned otoliths showed that the proportion of «narrow» typed herring was in majority in all the samples and constituted 87 % amongst the autumn spawned herring.

6. Measurements of first growth zone in «narrow» and «wide» otoliths gave mean values of 29.78 ($\pm$ 0.14) and 24.59 ($\pm$ 0.35) units for the two types respectively (1 unit = 0.0409 mm).
7. The l_1 distribution and the mean lengths by age showed a significant difference between the «narrow» and «wide» typed herring in the northeastern North Sea. Both types of herring were most likely of the «Bank» herring stock.
8. The relationship between the autumn spawning group of herring in the northeastern North Sea and the «Bank», the «Downs» and the Kattegat autumn spawning stocks have been examined. The «Bank» herring evidently dominated the autumn spawning group during autumn, winter and spring. During summer, however, the autumn spawned herring in the areas south of latitude 59°N in the northeastern North Sea was probably mixed up with members of the Kattegat autumn spawning stock. The occurrence of «Downs» herring seemed to be lacking or negligible in the sampled material.

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