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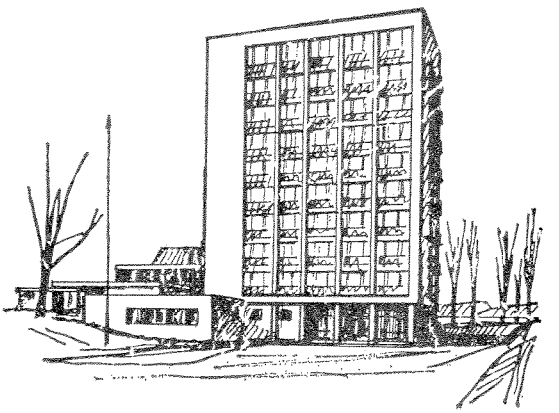

DIRECTORATE OF FISHERIES
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ZOOPLANKTON AND THE DISCONTINUITY LAYER IN RELATION TO ECHO TRACES IN THE OSLOFJORD

By

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INTRODUCTION

During cruises with R/V «Gunnar Knudsen» it was discovered that the echosounder nearly always recorded echoes from the depth of the thermocline. In accordance with the appearance of the traces (cf. Fig. 2) the term *echo-bands* was introduced.

The echo-bands might be caused by reflection from the border layer between two water masses (HASHIMOTO and MANIWA 1956, BANSE 1957, LENZ 1965) or from accumulated particles in this layer

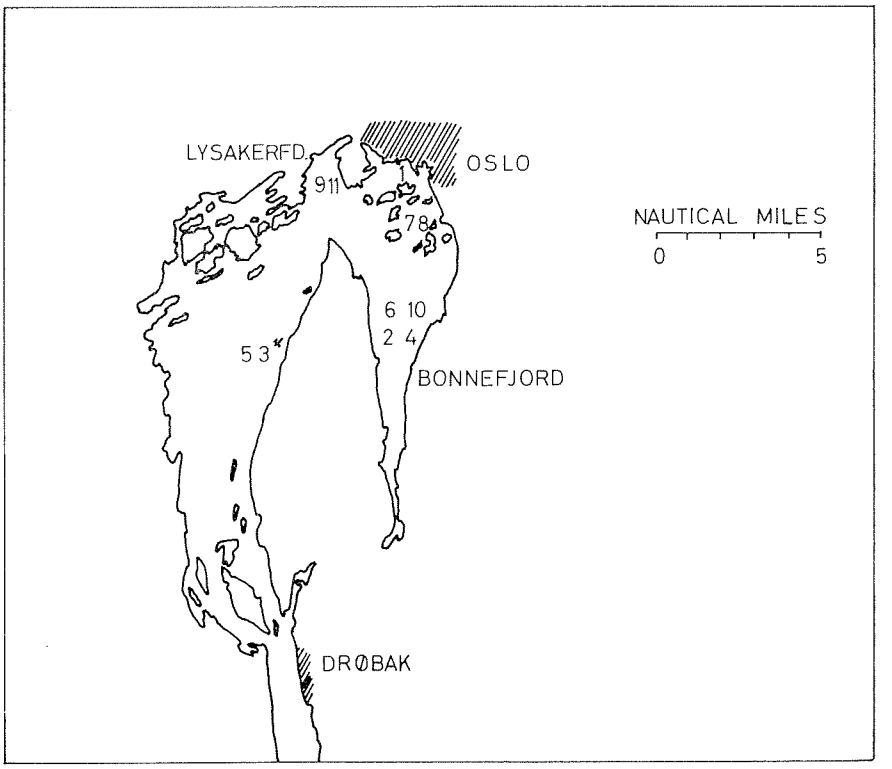


Fig. 1. The Oslofjord and observation stations.

(TROUT, LEE, RICHARDSON and HARDEN JONES 1952, CUSHING, LEE and RICHARDSON 1956, WESTON 1958, OLSEN 1960). The particles again might be living plankton concentrating in the layer or dead organisms and particles retarded in their sinking.

From June 1963 through April 1964 attempts were made to reveal the possible sources for the observed echo-bands in the Oslofjord (Fig. 1).

METHODS

The SIMRAD echosounder used in the present investigation had a frequency of 38.5 Kc/sec. and two optional puls lengths, which were 1 and 0.1 millisecond respectively. In order to obtain distinct recordings the shortest puls length was always applied. If applying the longer puls length two narrow echo-bands might coalesce and make one broad band. The speed of the wet echosounder paper was 1.3 cm per minute. The transmitted sound impuls was constant, the source level measured as sound intensity 1 m from the transducer being 105 dB// 1 μ bar, but the the received signals could be amplified. The amplifier had 11 positions and the corresponding amplifications are given in Table 1. The lowest echo that could be recorded was — 40 dB// 1 μ bar.

Table 1. Positions of the amplifier, the corresponding amplification of a received impuls and minimum recordable signal (MRS) in dB//1 μ bar.

Position	0	1	2	3	4	5	6	7	8	9	10
Amplification:	?	?	1000	4000	7500	10000	15000	30000	45000	80000	80000
M R S:			—21	—27	—30	—31	—33	—36	—38	—40	—40

To find a measure of the strength of a received echo, the amplifier was turned successively down until the echo disappeared (Fig. 2) and the last position before its disappearance was used as a measure. It was not possible to distinguish echoes above 4 m since the transmitter was submerged underneath the hull 1.3 m and the receiver had a further 2—3 m blockaded area.

The reflection factors in Table 3 are calculated from the formula:

$$\frac{I_r}{I_i} = \frac{((\varrho c)_2 - (\varrho c)_1)^2}{((\varrho c)_2 + (\varrho c)_1)^2}$$ (HORTON 1957).

I_r is the acoustic intensity of the reflected wave and I_i the acoustic intensity of the incident wave, $(\varrho c)_1$ is the specific acoustic impedance in the medium on the side containing the sound source and $(\varrho c)_2$ the specific

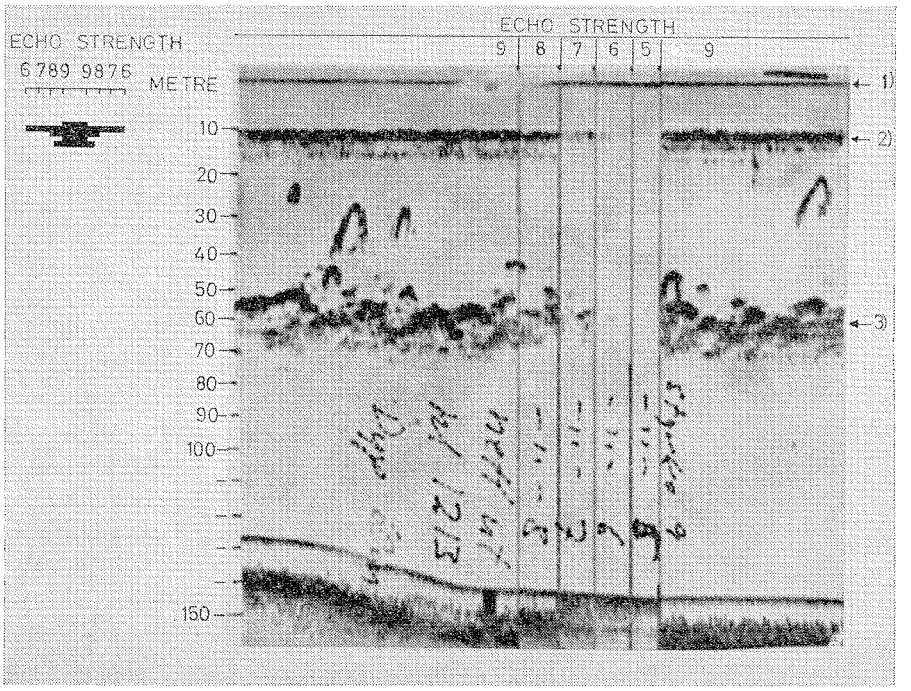


Fig. 2. Example of echo-bands reproduced in Fig. 4. 1) transmitter depth, 2) echo-band, 3) supposed herring and(or) sprat recordings.

acoustic impedance on the other side of the boundary plane. ϱ is the density and c the sound velocity in the respective media. The formula is based on the assumption that normal incident sound waves are reflected from an ideal plane surface separating two ideal fluid media which are incapable of exerting shear stresses. The acoustic pressure of the wave in the second medium must equal the acoustic pressure of the wave in the first medium, both pressures being taken immediately adjacent to the boundary plane. The component of volume velocity normal to the plane with which fluid from one side approaches it, must for an infinitesimally short distance equal the component of volume velocity normal to the plane with which fluid on the other side moves away.

The sound velocities are calculated from the formula given by MIDTTUN (1964):

$$v_{t,s,p} = 1400 + 4.9\,t - 0.044\,t^2 + (1.32 - \frac{t}{100})\,S + 0.018\,(1 - \frac{t}{100})\,p$$

$v_{t,s,p}$ is the sound velocity in m/sec. at the temperature t° C, salinity S $^0/_{00}$ and the pressure p in decibar (or metre).

Plankton samples were taken by means of a horizontally towed net. The net had a square opening 1 m by 1 m with the mesh size 1 mm by 1 mm. There was no wire in front of the opening, and the net was kept down by means of a canvas depressor. Towing time was half an hour from the net had reached the wanted depth till heaving was started. The speed of the vessel was 1.5—2.0 knots, implying that the net was towed 1300 to 1800 m in the proper depth. The percentage of plankton caught during lowering and heaving the net was assumed to be very low compared with plankton caught in the proper depth. The towing depth was determined from measuring the length and the angle of the wire. Attempts were made to sample from the strongest echo-band or the strongest part of it. The net was also towed under and over these layers.

Smaller plankton animals were collected with a two inch rotary pump (capacity 100 l/min.) equipped with an armed two inch rubber intake hose. 300 litres of water were filtered trough a fine mesh plankton net (125 μ).

The samples were preserved on bord in 4% formaldehyde in water, and the organisms were counted in the laboratory, as a rule in subsamples of one or two tenths of the entire sample. Subsamples were obtained by means of the plankton divider described by WIBORG (1951).

The bathythermograms were adjusted to the thermometer readings from the Nansen water bottles. Some samples for salinity determinations were taken from the water bottles, but the majority of the salinity determinations were made on water obtained through the pump. The intake of the hose was mounted between two horizontal circular plates with a diameter of 42 cm and a distance between the plates of 8 cm in order to as far as possible get the water from the measured depth. Comparable samples taken with water bottles and the plankton pump gave a difference in salinity corresponding to about 1 m difference in sampling depth, the water bottle always sampling above the pump. BANSE (1955) similarly found a difference of 1.5 m. It was assumed that the figures here obtained from the pump were correct, and these figures were therefore applied when available.

RESULTS

Several observations during night cruises showed that artificial light did not affect the echo-bands implying that reflections were not caused by phototactic organisms, the fact that the echo-bands were found in the same depth both day and night indicated the same. In some cases

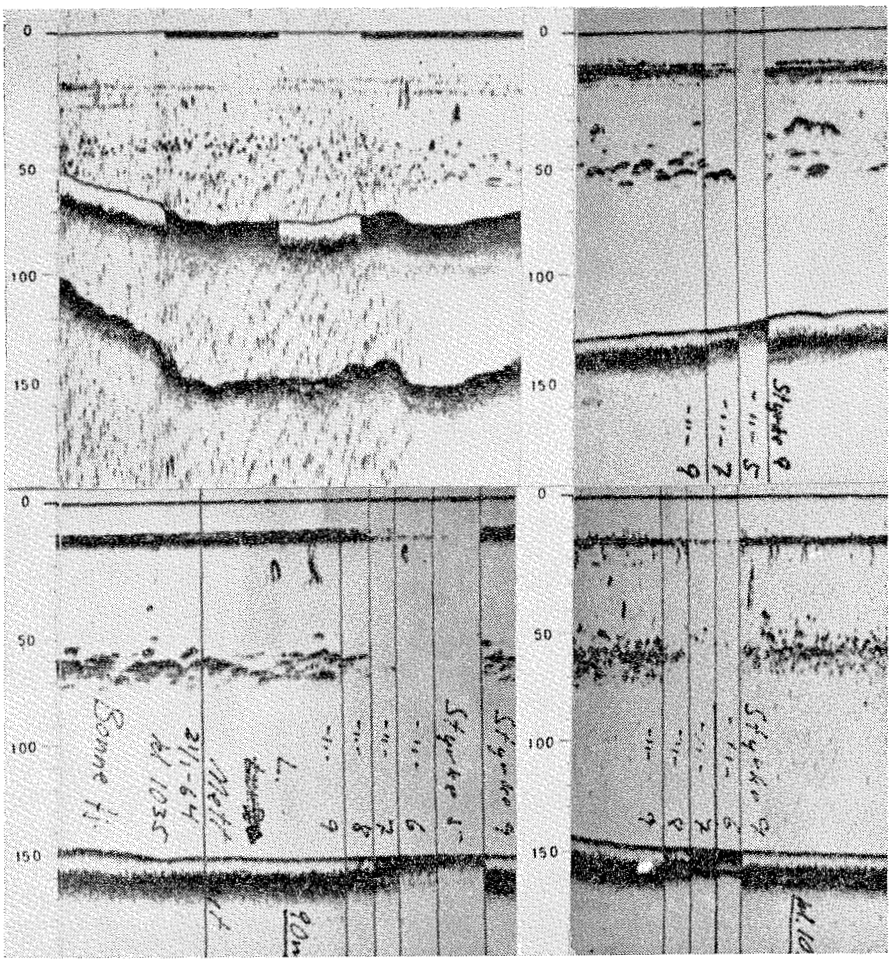


Fig. 3. Different types of echo-bands observed.

only one single echo-band was recorded, in other cases there were several ones, up to five, one just underneath the other (Fig. 3).

The results from the tow net are given in Table 2. All these samples were taken during daylight. The greatest displacement volume of plankton was found below the echo-bands at all the four stations. Correspondingly the numbers of organisms were highest below the layer except at Søndre Steilesand where a great number of fish eggs occurred. Fish eggs, when present, had always the maximum in the scattering layer, *Pleurobrachia pileus* (O. F. Müller) also showed maximum abundance there at the stations 3 and 4, but had a different distribution pattern at the stations 1 and 2 (Table 2). The big jellyfishes *Cyanea capillata* (L.) and

Table 2. Plankton animals caught with the horizontally towed plankton net. Numbers and displacement volumes of the samples above, in, and below the scattering layer.

Station 1. Vippetangen, 26. June 1963, 1130—1700 hours. Echo-bands at 10 and 12 m, strength 7. Depth in m	5	9.5	14
Rathkea octopunctata	0	0	1 854
Lensia conoidea	0	6	481
Aurelia aurita	4	6	2
Pleurobrachia pileus	1	9	72
Other organisms	3	10	267
Total	8	31	2 676
Displacement volume ml.[1])	1	1	18

Station 2. Bonnefjorden, 1. July. 1963, 1200—1600 hours. Echo-band at 11 m, strength 9. Depth in m	3.5	10	20
Rathkea octopunctata	0	0	2 180
Eutonina indicans	0	66	10
Lensia conoidea	5	74	6 340
Aurelia aurita	6	15	0
Cyanea capillata	0	10	0
Pleurobrachia pileus	3	61	many[2])
Fish eggs	5	18	10
Other organisms	29	46	150
Total	43	272	8 680
Displacement volume ml.[1])	1	43	100

Station 3. Søndre Steilesand 2. and 3. July 1963, 1000—1500 hours. Two to four echo-bands at 8—16 m, strength 9—5. Depth in m	4	11	18
Eutonina indicans	0	1	73
Lensia conoidea	0	1	3
Aurelia aurita	2	1	0
Cyanea capillata	1	4	6
Pleurobrachia pileus	0	36	25
Fish eggs	3	316	179
Other organisms	11	70	104
Total	15	393	365
Displacement volume ml.[1])	1	4	64

cont.

Table 2 cont.

Station 4. Bonnefjorden, 21. Jan. 1964, 1000—1400 hours. One echo-band at 8—14 m, maximum strength 5 at 11 m. Mesh size in this case 10 mm.

Depth in m	5	10	35
Lensia conoidea	0	17	236
Pleurobrachia pileus	0	23	1
Sagitta elegans	0	0	4
Other organisms	0	3	11
Total	0	43	252
Displacement volume ml.[1])	0	2	14

[1]) In the displacement volume *A. aurita* and *C. capillata* are not included.

[2]) A great number of *P. pileus* disintegrated because of unsuited formalin concentration.

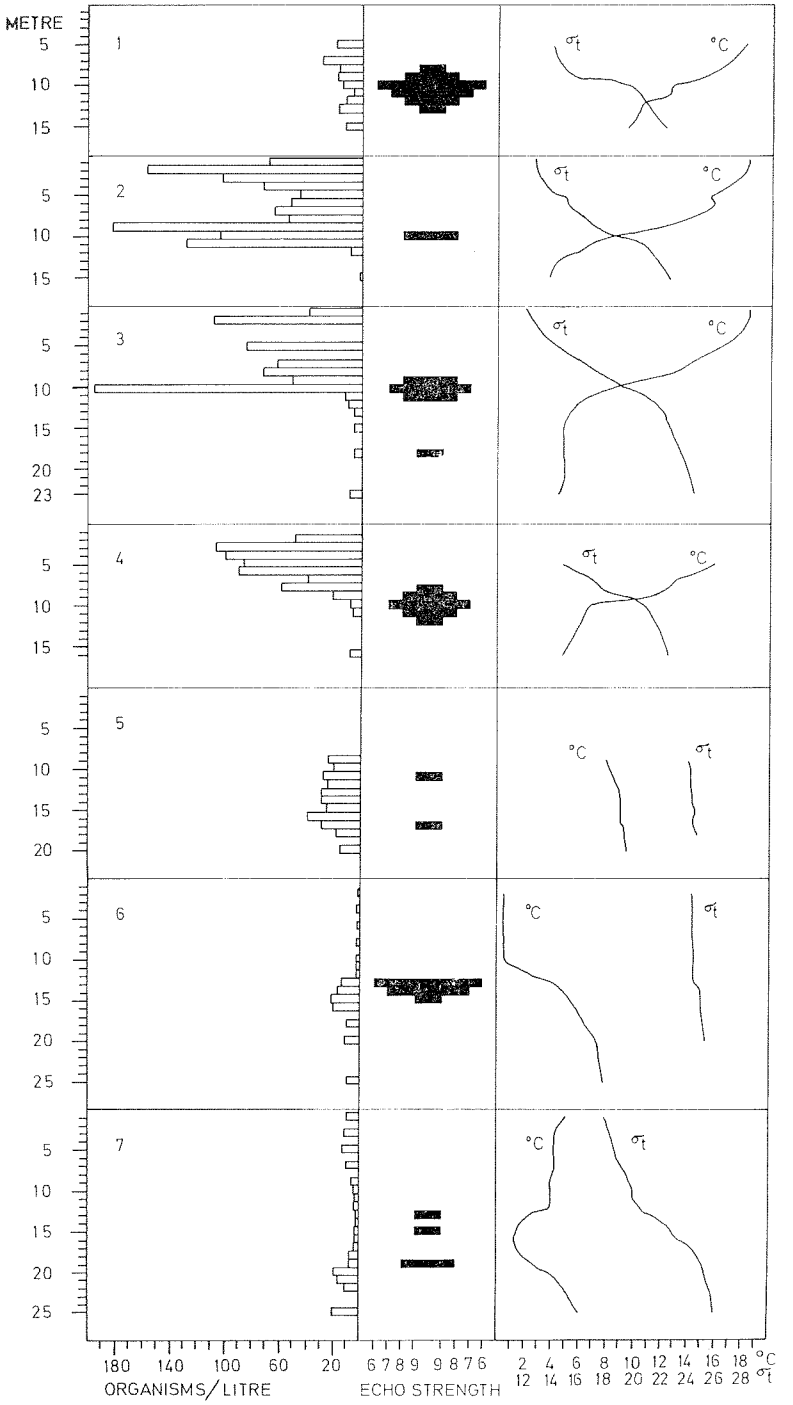
Aurelia aurita (L.) also sometimes occurred in greater numbers in the echo-band layer. Large jellyfishes may give echo-traces, but not with the appearance of an echo-band (BEYER, verbal information). The greatest concentrations of the other species were as a rule found below the level of the echo-band. Macroplankters thus seem not to present a probable source of sound scattering in the present cases.

Fig. 4 shows the distribution of smaller plankton animals taken with the pump. It appears that the observed maxima correspond fairly well with the echo-bands at the stations 6, 7 and 10. The total number of smaller plankton at the other stations have either no distinct maxima or the maxima are not in the depths of the echo-bands.

Regarding the single species, the larvae of the polychaet *Polydora ciliata* (JOHNSTON) had a very distinct maximum in the scattering layers both at St. 6 and 7, but at St. 8, taken at night, the maximum was clearly above the layer. Some other species had their maxima in the scattering layer, but never in such amounts that they could explain the echo-bands.

If we compare the echo-bands with the corresponding hydrographic condition, the echo-bands were in most cases found at depths where great gradients in salinity and(or) temperature occurred (Fig. 4).

There is no good correlation between the theoretic calculated echoes and the strengths at which they are recorded (Table 3), but the two lowest calculated echoes had corresponding echo-bands which only were recorded at strength 10 and 9.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ECHO STRENGTH
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12 14 16 18 20 22 24 26 28 σt

Table 3. Strength and properties of echoes from the scattering layers where water was sampled with one metre depth intervals. The calculations are made from two successive observations in the layer where the largest difference was recorded.

St	Date	Echo strength	Depth	t_2—t_1	σt_2—σt_1	$(\varrho c)_2$—$(\varrho c)_1$	Geometric spreading loss dB	Reflection factor dB	Theoretic echo received. dB// 1 μ bar
5	13 08 63	6	8—12	—2.00	2.88	1.17	36	—67	2
6	14 08 63	8	10	—3.00	1.71	—7.09	36	—52	17
7	15 08 63	7	9—11	—2.25	0.95	—5.51	36	—55	14
8	16 08 63	7	8—12	—4.25	1.08	—14.37	36	—47	22
9	05 12 63	9	10	0.25	0.32	2.10	36	—63	6
9		9	17—18	0.00	0.20	0.64	48	—74	—17
10	28 01 64	6	13—15	1.50	0.39	8.18	43	—51	11
11	22 04 64	9	13	—1.75	1.08	—4.56	41	—57	7
11		9	15	—0.25	0.40	0.18	45	—84	—24
11		8	19	0.75	0.27	4.23	49	—57	— 1

DISCUSSION AND CONCLUSION

If only the geometric spreading of the sound wave is considered as transmission loss, the theoretical calculated echoes should lie between 22 and — 24 dB// 1 μ bar, implying that all calculated echoes have higher intensity than minimum recordable signal for the present echo sounder, — 40 dB// 1 μ bar. In fact most of the echo-bands should have been recorded with far less amplification than they were. However, the ideal conditions required to give correct results with the formula for reflection factors are surely not fullfilled. The calculations are made from observations taken with one metre interval, and the difference between the two observations are considered to take place somewhere within this metre without having any vertical dimention. The vertical distributions of some echo-bands show that this is not the case, the sound must have been reflected from more than one plane. Hence the reflected sound waves are surely of lower intensity than calculated. However,

←

Fig. 4. Total number of plankton taken in the pump and the corresponding echo-bands, temperature and density. 1) station 5, Aug. 13, 1963, 1130—1600 hours, 2) station 6, Aug. 14, 1963, 1000—1500 hours, 3) station 7, Aug. 15, 1963, 1000—1600 hours, 4) station 8, Aug. 16—17, 1963, 2100—0030 hours (dark), 5) station 9, Dec. 5, 1963, 1330—1600 hours, 6) station 10, Jan. 28, 1964, 1000—1500 hours, 7) station 11, Apr. 22, 1964, 1030—1600 hours.

there is room for relative great reductions till the minimum recordable signal for the SIMRAD echosounder is reached. More exact conclusions will require both better acoustical equipment and more accurate hydrographical measurements.

The echograms are affected by both the situation in the sea and the electronics of the echosounder. It is, therefore, difficult to compare results obtained from different echosounders. BARRY, BARRACLOUGH and HERLINVEAUX (1962)got different recordings of the same scattering layer with a 12 Kc/sec. and a 30 Kc/sec. echosounder.

NORTHCOTE (1964) recorded 9—12 mm long Chaobourus (gnat) larvae when using a 200 Kc/sec. echosounder.

From the present investigation it is concluded that zooplankton is not responsible for the echobands, similar to what LENZ (1965) found using a 30 Kc/sec. echosounder. The strong echobands recorded during the winter, when the water was clear and contained comparatively little phytoplankton and detritus also support LENZ's findings that the phytoplankton and detritus do not cause echo-bands. The material indicates, however, that the physical border between two water masses might be the real cause of the echo-bands in the Oslofjord.

SUMMARY

1. Using high amplification on the 38.5 Kc/sec. echosounder echoes from the depth of the discontinuity layer in the inner Oslofjord were mostly observable.
2. The distribution of zooplankton was analysed from samples taken with a plankton pump and tow nets.
3. The vertical distribution of zooplankton, biomass, total number and number of the different species demostrated that such organisms were not responsible for the echoes.
4. Calculations made from hydrographic data are the bases for assuming that these special echo traces are caused by the border layer between two water masses.

ACKNOWLEDGMENTS

The present paper represents the essential parts of a Cand real. thesis in marine biology at the University of Oslo. The investigation was suggested by the University lecturer F. BEYER, and the work was performed under his supervision. Valuable help was also rendered by engineers of the SIMRAD factory (Simonsen Radio Company). All sampling was made in cooperation with E. ROSENVOLD who partly used the same material to investigate diurnally varying echotraces.

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THE AUTUMN SPAWNING GROUP OF HERRING IN THE NORTHEASTERN NORTH SEA

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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

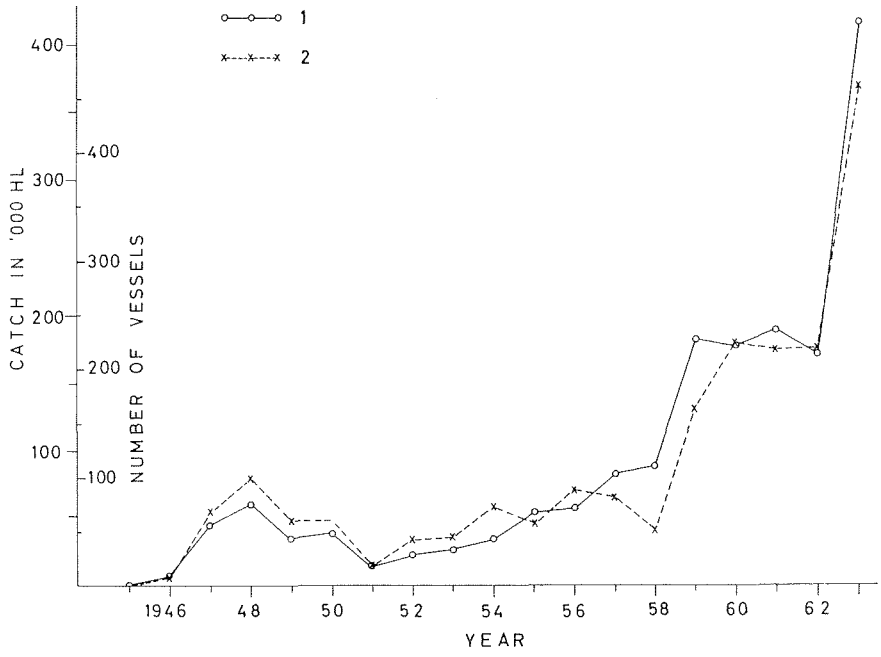

Fig. 1. Total catch of herring from the North Sea and Skagerrak and number of vessels participating in the fishery, 1945—1963. 1) total catch, 2) number of vessels.

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.

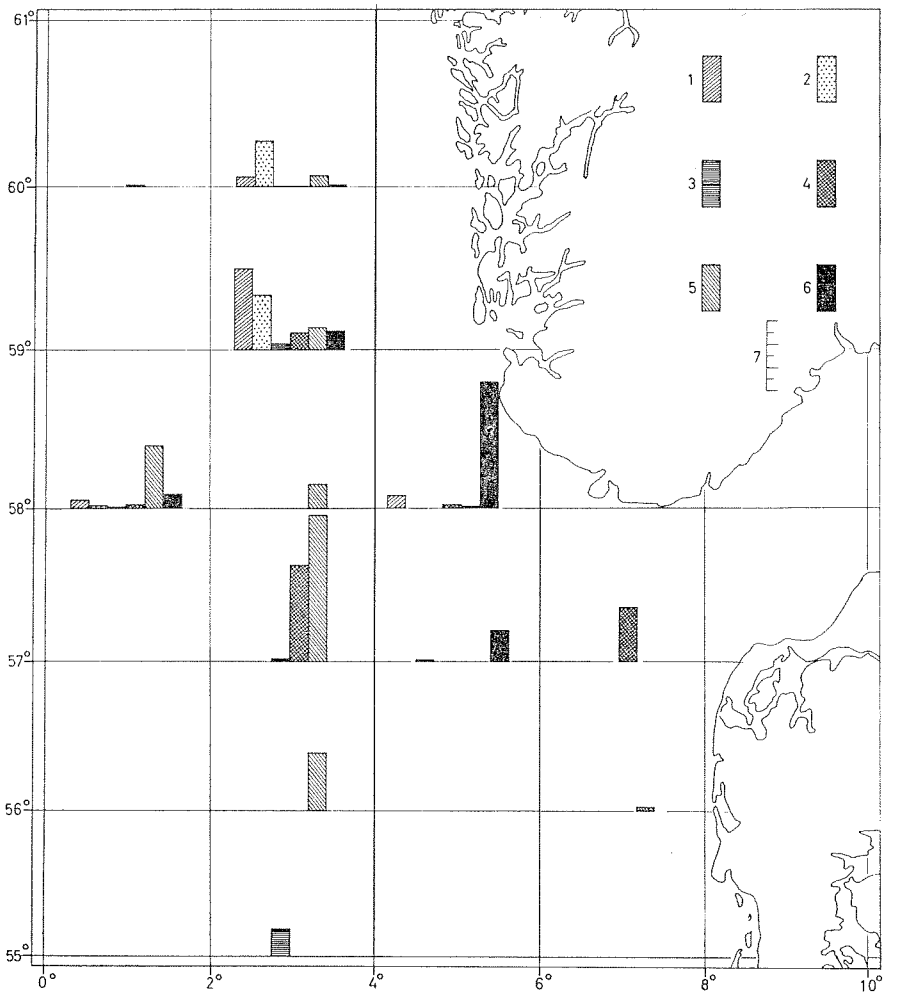

Fig. 2. Distribution of the Norwegian North Sea herring catches (two-monthly periods) in 1962. 1) Jan.—Febr., 2) March—April, 3) May—June, 4) July—Aug., 5) Sept.—Oct., 6) Nov.—Dec., 7) frequency scale in 1 000 hl.

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

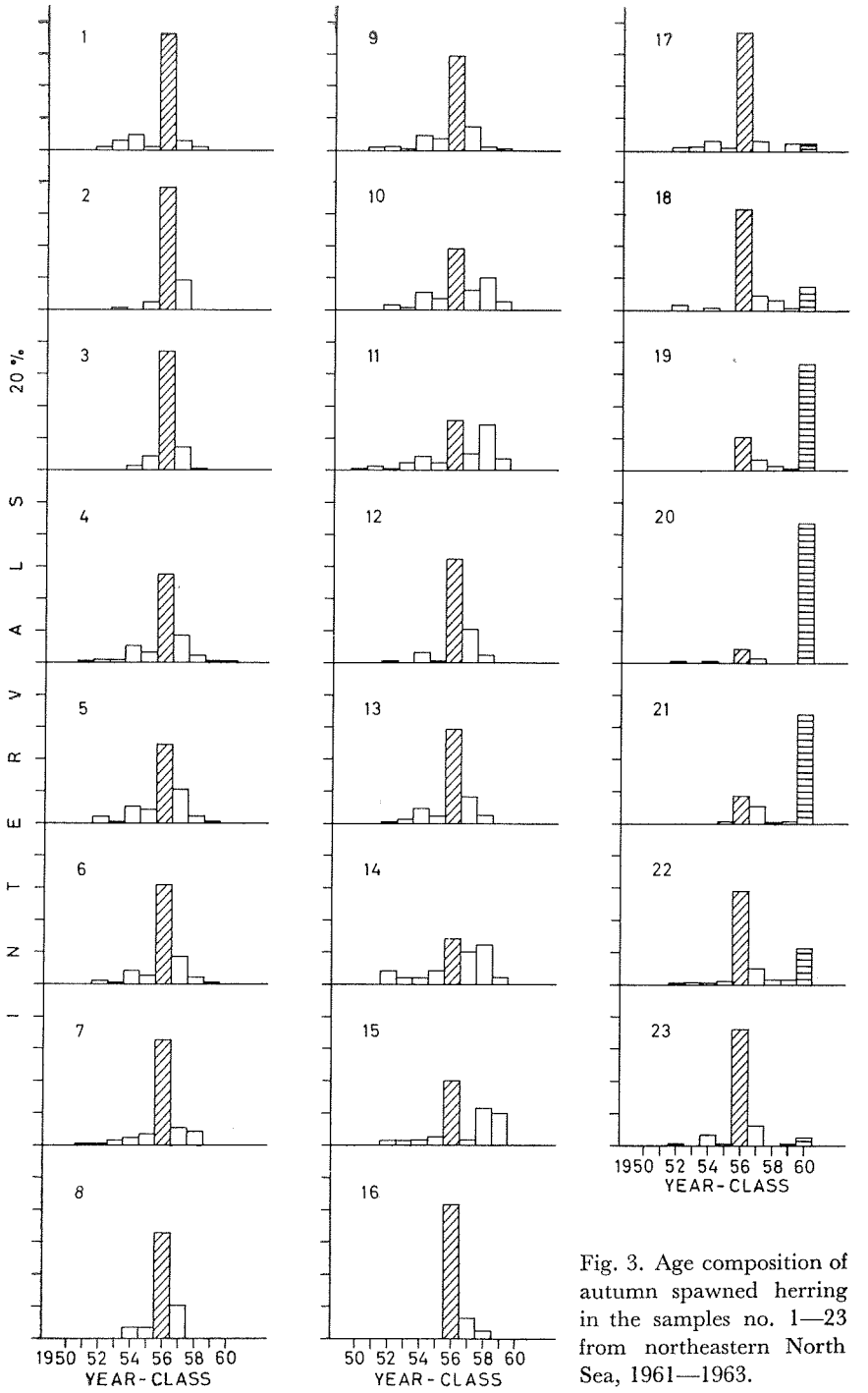

Fig. 3. Age composition of autumn spawned herring in the samples no. 1—23 from northeastern North Sea, 1961—1963.

(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

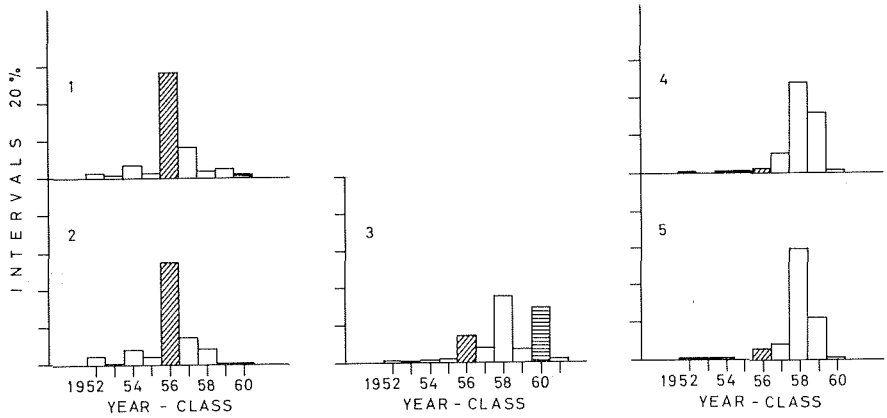

Fig. 4. Age composition of herring from western, central and southern part of the North Sea in 1962. 1) Bressay Shoal, June—Aug., N = 665, 2) Fladen Ground, July—Sept., N = 470, 3) Dogger Bank, Aug.—Oct., N = 4.297, 4) Sandettié, Nov.—Dec., N = 501, 5) Channel, Nov.—Dec., N = 485.

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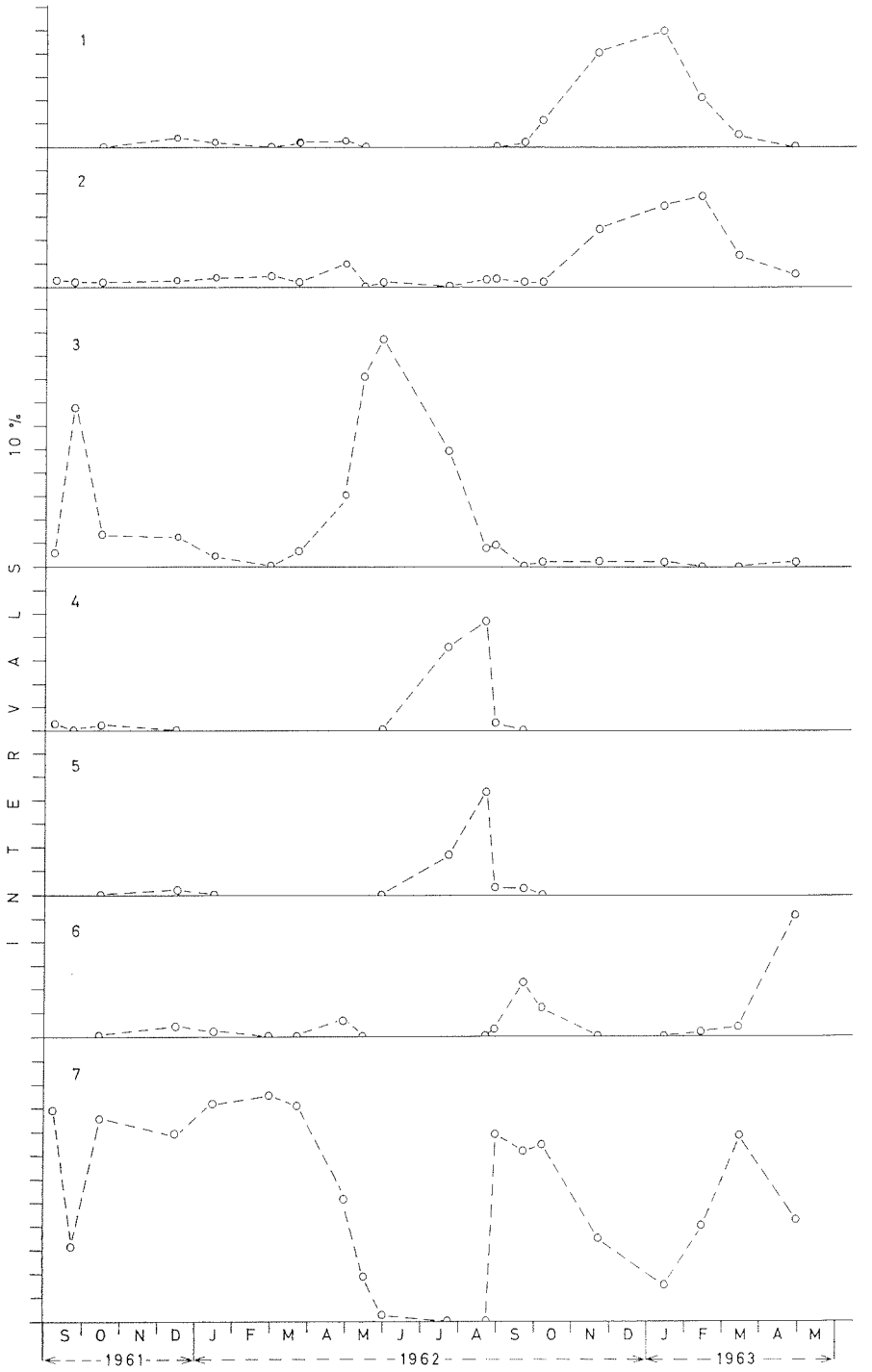
Fig. 5. Percentage composition of maturity stages in autumn spawned herring from northeastern North Sea, 1961—1963. 1) maturity stage I, 2) maturity stage II, 3) matiruty stage III, 4) maturity stage IV, 5) maturity stage V, 6) maturity stage VII, 7) maturity stage VIII.


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

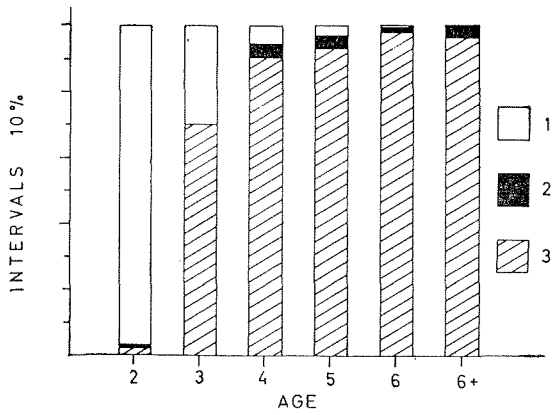


Fig. 6. Composition of immature herring, herring in maturity stage III and mature herring amongst 2—6 + year old autumn spawners from northeastern North Sea. 1) maturity stage I—II, 2) maturity stage III, 3) maturity stage IV—VIII.

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.

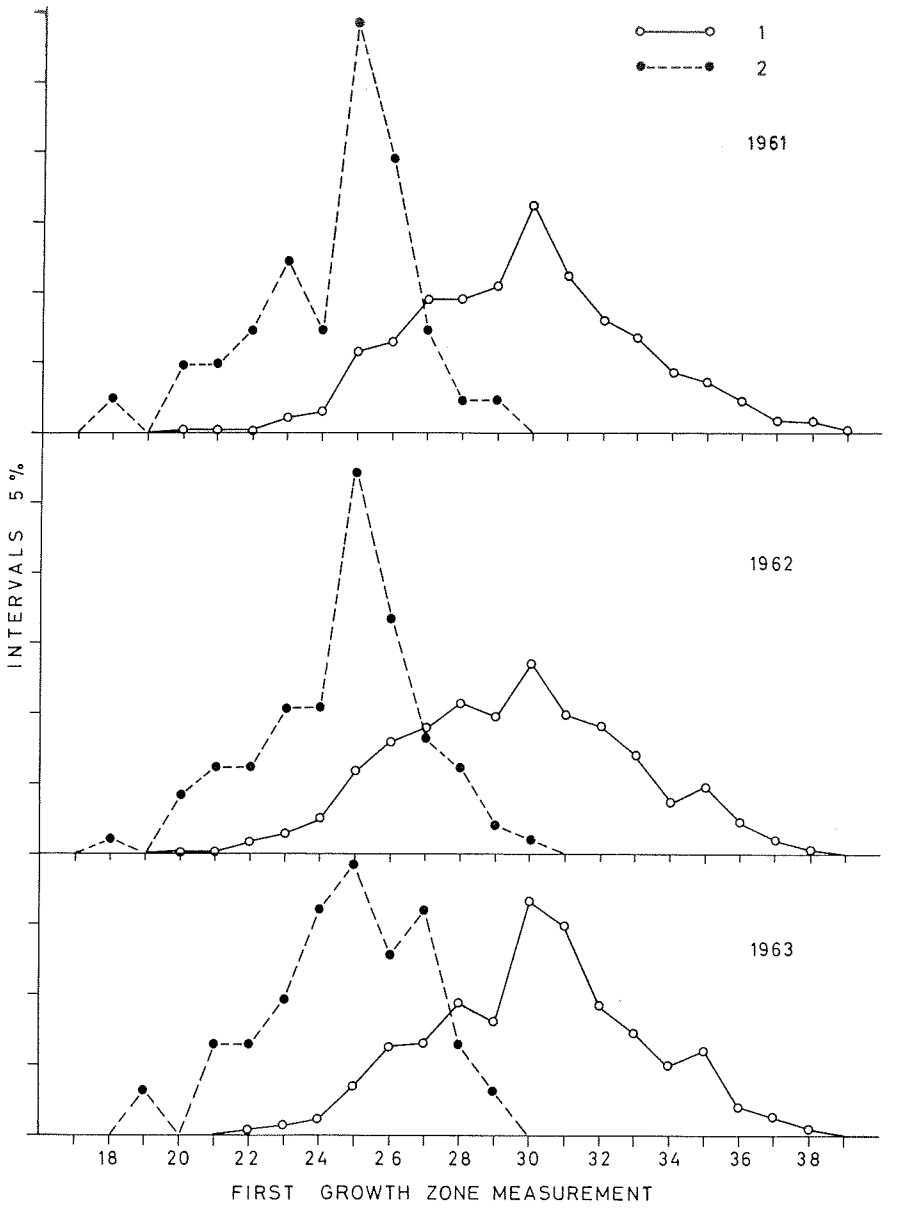


Fig. 7. Frequency distributions of otolith zone measurements of autumn spawned herring in northeastern North Sea, 1961—1963. 1) «narrow» otolith type, 2) «wide» otolith type.

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

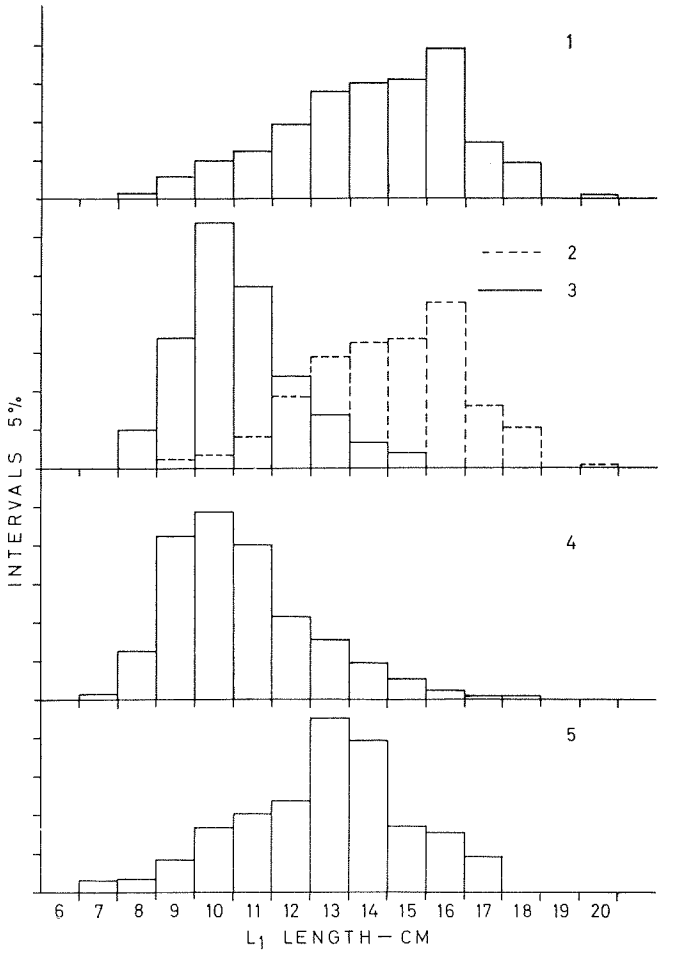


Fig. 8. Frequency distribution of l_1 for 6 year old (1956 year-class) autumn spawned herring (also separated in «narrow» and «wide» types) in northeastern North Sea, compared with the l_1 distribution for 4 year old (1954 year–class) «Bank» and «Downs» herring. 1) Autumn spawned herring northeastern 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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INVESTIGATIONS ON HERRING, *CLUPEA HARENGUS L.*, FROM THE NORWEGIAN SKAGERAK COAST DURING THE YEARS 1963—64

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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.

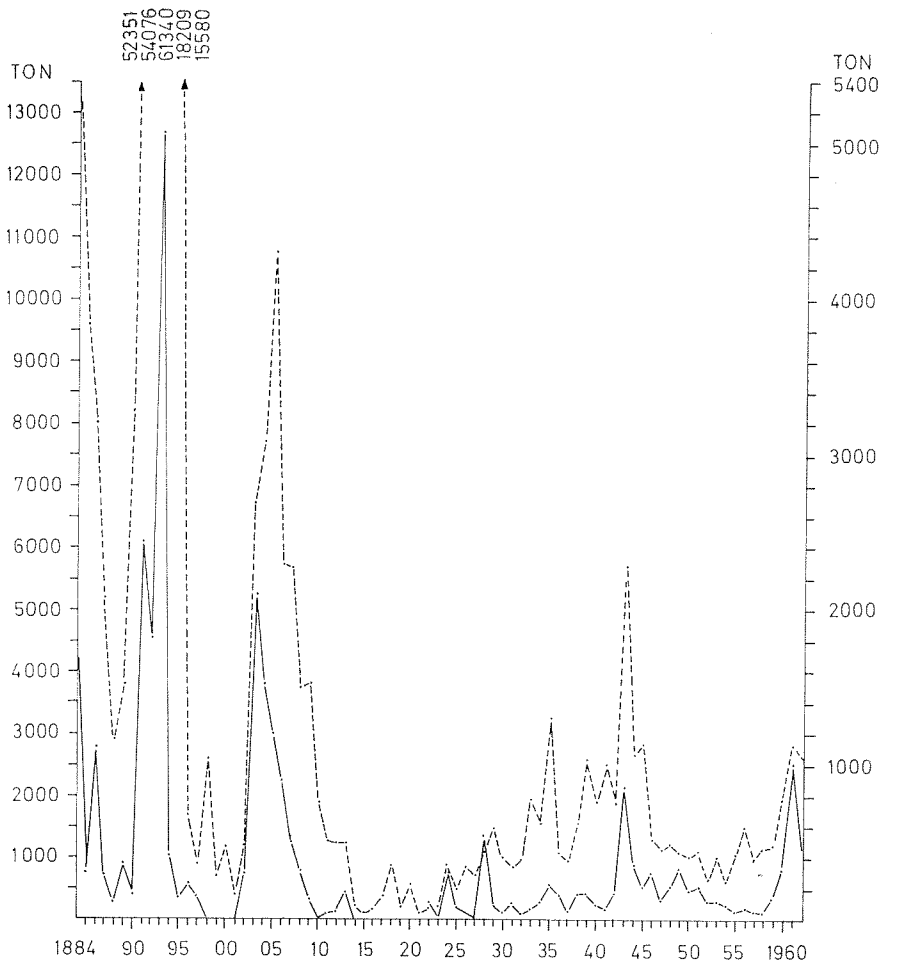


Fig. 1. Yearly output of the herring fisheries from 1884 to 1962. The inner Skagerak coast from the Aust-Agder border to the Swedish border (dotted lines). The Telemark coast (straight lines). The Skagerak coast (left scale). The Telemark coast (right scale).

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

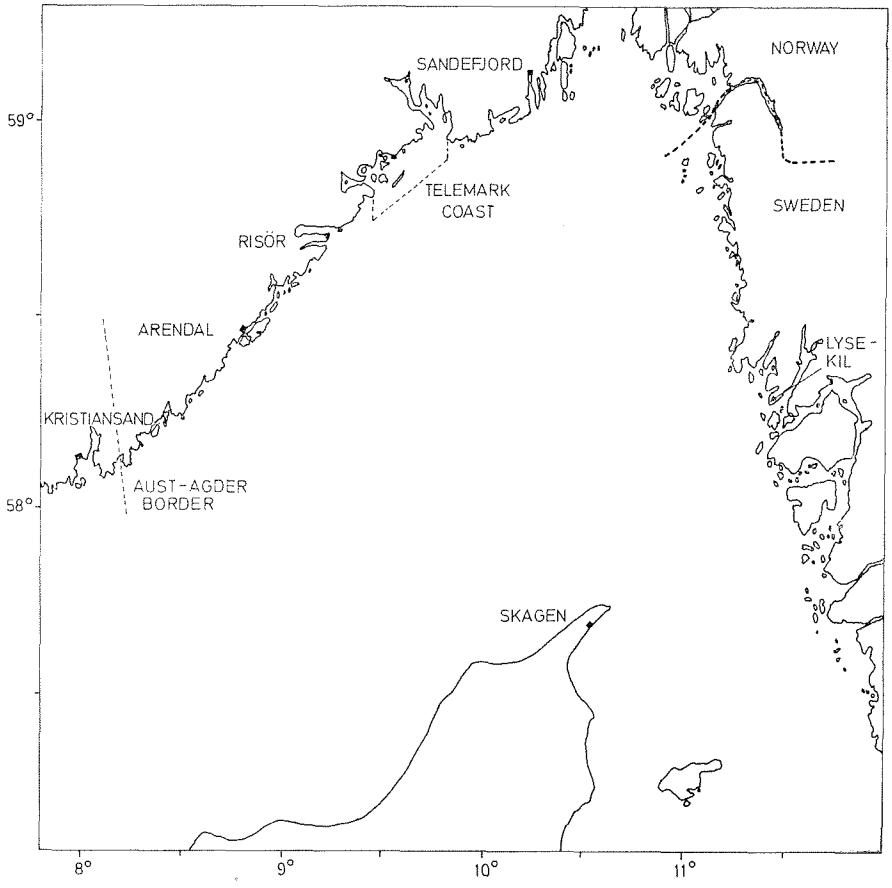


Fig. 2. The Skagerak coast.

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 1_1, 1_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.

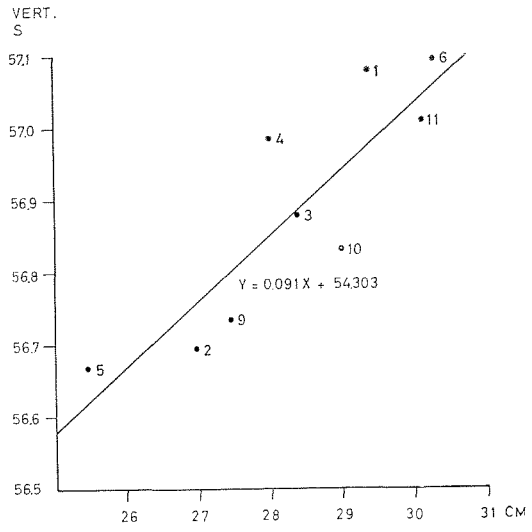


Fig. 3. Correlation between the mean length and the mean vertebrae count in the samples.

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, 1_1 and 1_2 were measured in all the samples. The 1_1 and 1_2 frequency distributions are shown in Fig. 6. The 1_1 distributions show no marked difference between the samples, but in the samples no. 2, 5 and 9 there are more small 1_2 values than in the other samples, sample no. 5 showing a bimodal 1_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

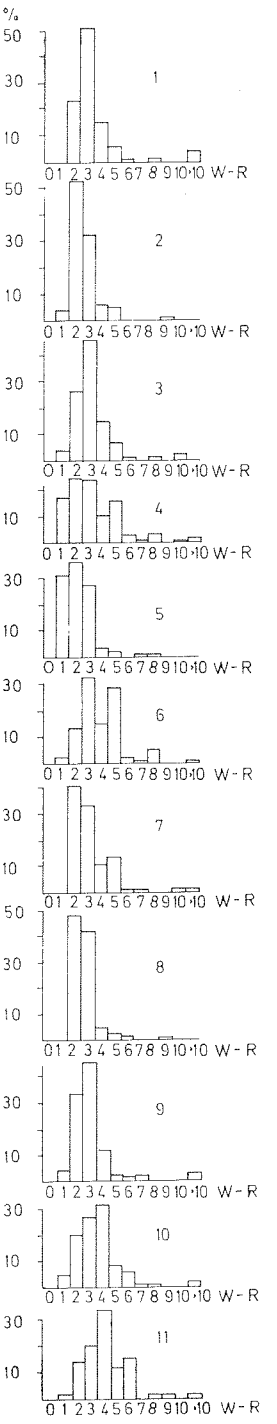


Fig. 4. Age frequency distribution based on the number of winter rings inside the edge. 1) sample no. 1, 25/7—63, 2) sample no. 2, 14/8—63, 3) sample no. 3, 12/9—63, 4) sample no. 4, 17/10—63, 5) sample no. 5, 22/10—63, 6) sample no. 6, 5/11—63, 7) sample no. 7, 27/2—64, 8) sample no. 8, 20/4—64, 9)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

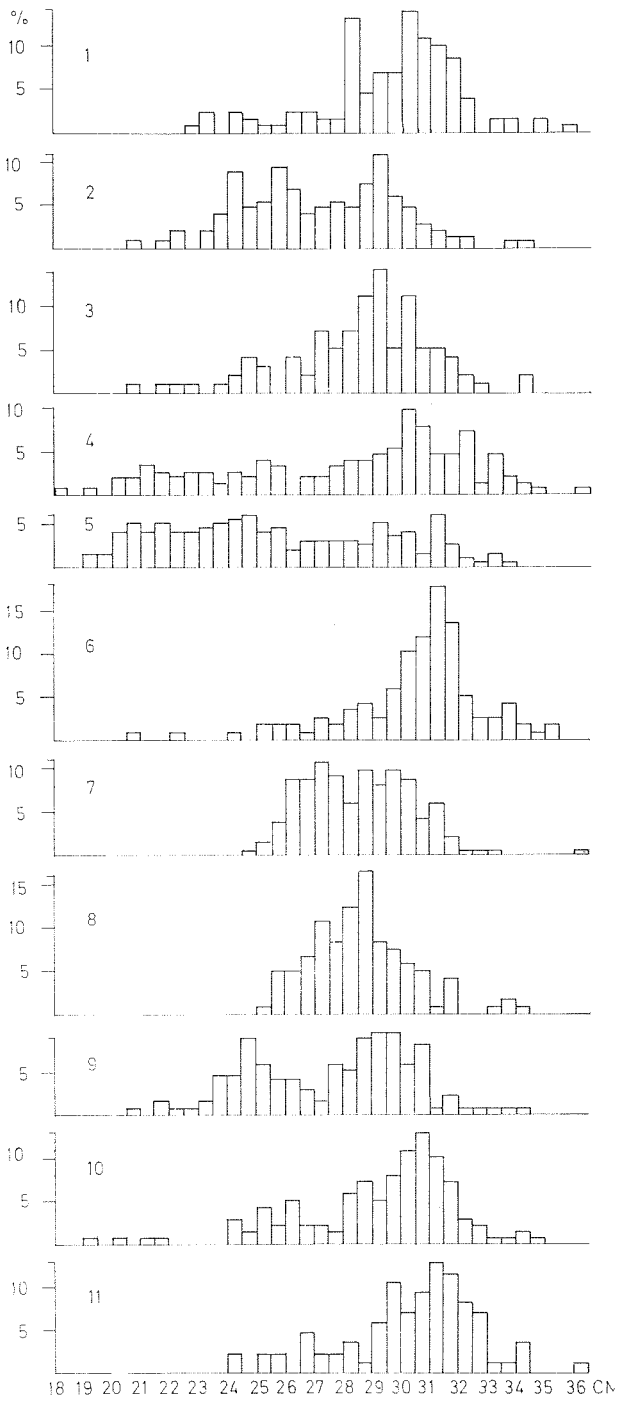
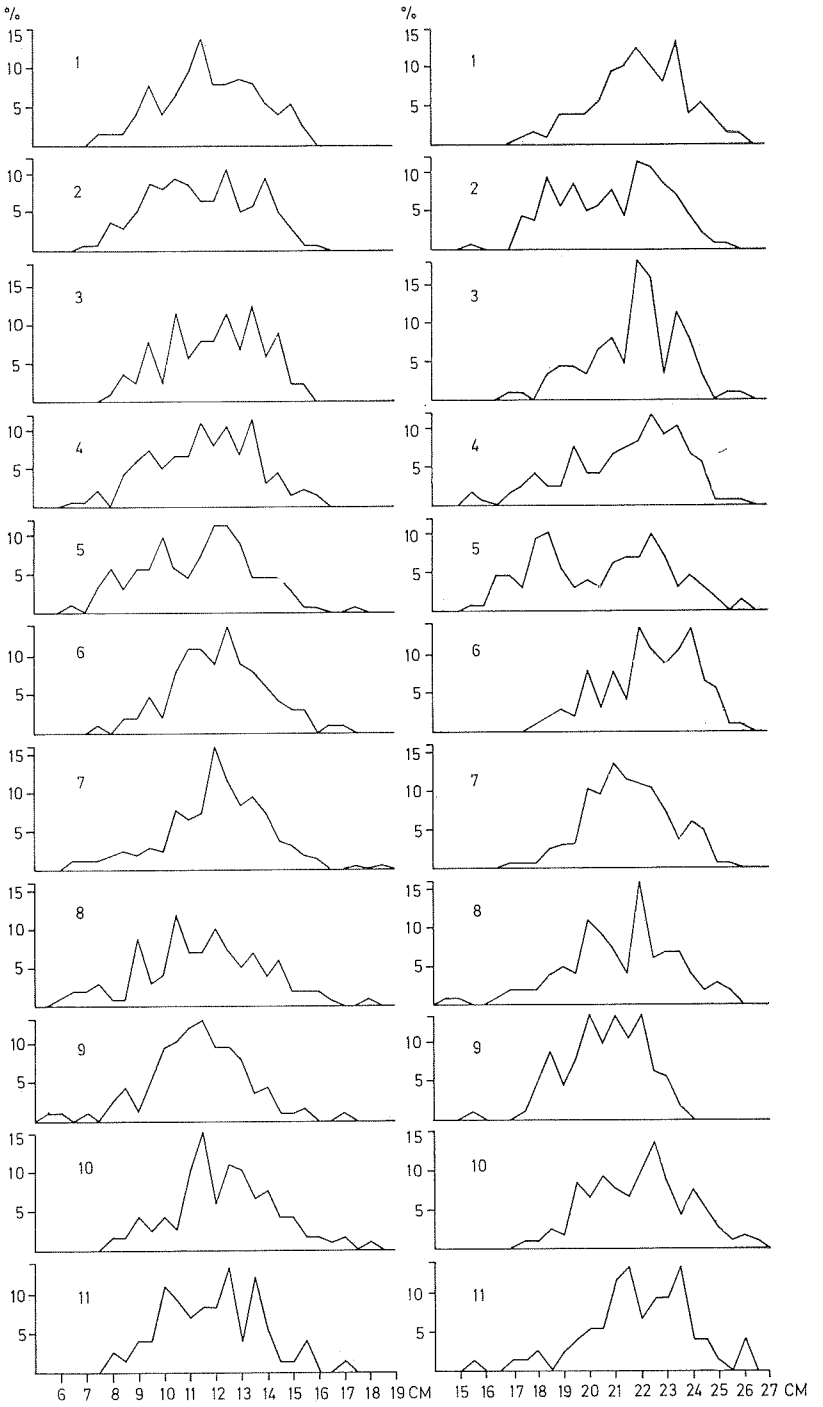


Fig. 5. The length frequency distribution. 1) sample no. 1, 25/7—63, 2) sample no. 2, 14/8—63, 3) sample no. 3, 12/9—63, 4) sample no. 4, 17/10—63, 5) sample no. 5, 22/10—63, 6) sample no. 6, 5/11—63, 7) sample no. 7, 27/2—64, 8) sample no. 8, 20/4—64, 9) sample no. 9, 28/7—64, 10) sample no. 10, 25/8—64,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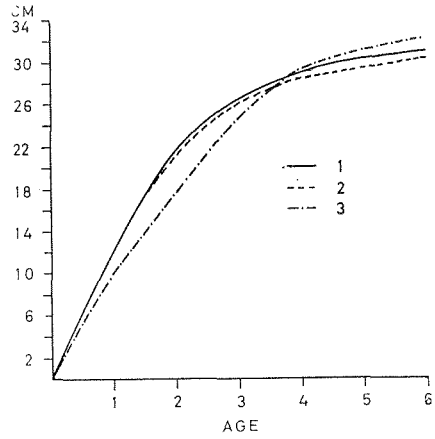

Fig. 7. The growth of the herring. 1) caught with purse seine, samples no. 1, 3, 4, 6 and 11, 2) caught with net, samples no. 7 and 8, 3) Norwegian winter herring, S 2 + 1. from Østvedt (1964).

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).

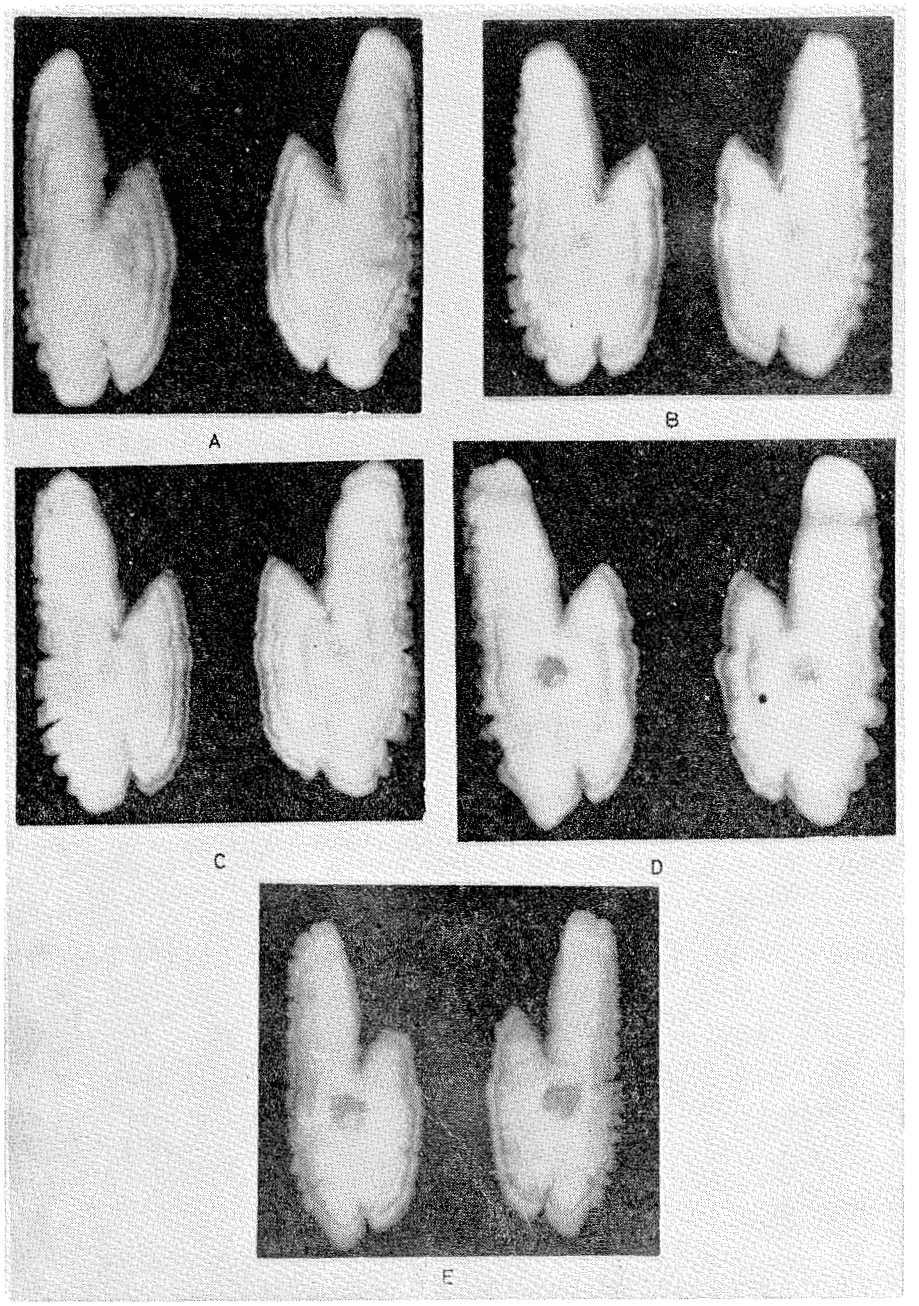

Fig. 8. Different types of otoliths. Further explanation in the text.

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

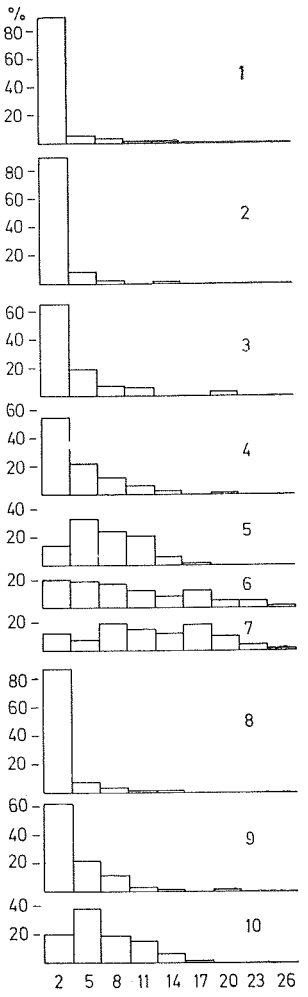

Fig. 9. Monthly variations in the distribution of M_f during the sampling period. 1) July 1963, 2) August 1963, 3) September 1963, 4) October 1963, 5) November 1963, 6) February 1964, 7) April 1964, 8) July 1964, 9) August 1964, 10) September 1964.

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.

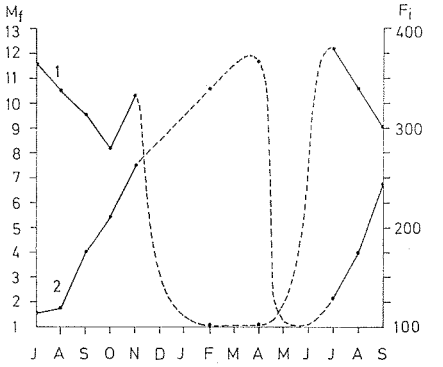

Fig. 10. Cycles of maturity factor and intestinal fat based on monthly mean values. 1) intestinal fat, 2) maturity factor.

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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STUDIES ON SERUM ESTERASE IN HERRING AND SPRAT

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INTRODUCTION

Serology and molecular biology have been used in segregation studies of herring, *Clupea harengus* L., on several occasions. SINDERMANN and MAIRS (1959) found two herring populations in the Gulf of Main by frequencies of erythrocyte antigenes. They also found variability in serum protein patterns. Some variations were found to be connected with diseases, some were probably related to age, but some offered hope of electrophoretic characterization of the populations (SINDERMANN and MAIRS 1958, MAIRS and SINDERMANN 1960). SINDERMANN and HONEY (1963) did not find intraspecific variations in electrophoretic mobility of herring hemoglobins, and WILKINS and ILES (1965) found hemoglobin types related to body length. Transferrin types were described by NÆVDAL and HARALDSVIK (1966), and ODENSE, ALLEN and LEUNG (1966) applied types of the enzymes lactate dehydrogenase and aspartate aminotransferrase in studies on Canadian herring populations.

In the present paper intraspecific variations in herring esterase phenotypes are described, and an attempt is made to reveal the genetic basis of the variations. Intraspecific variations in esterase phenotypes of sprat, *Sprattus sprattus* (L.), are also studied.

Part of the results concerning herring have been presented in a preliminary report (NÆVDAL and DANIELSEN 1967).

MATERIAL AND METHODS

Blood was sampled by cardiac puncture or by cutting the tail. The samples were sent on ice in thermo bottles to the laboratory where they were centrifuged. Most sera were analysed fresh, but some samples had to be stored deep frozen for some weeks before the analyses could be carried out.

The sera were analysed by combined starch and agar gel electrophoresis (SICK 1965, MØLLER 1966) for 75 minutes. For identification of

the esterase components, the gels were immersed in a freshly prepared solution containing 4 ml 1 % solution of 1-naphtyl acetate in acetone and 200 mg Fast Blue Salt BB in 100 ml of destilled water. The bands of esterase activity were then developed within few minutes.

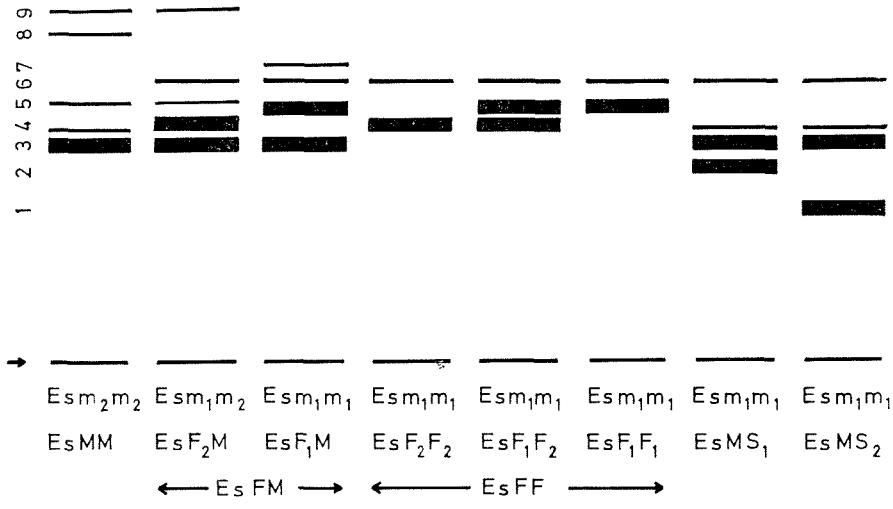
Sampling localities, numbers in samples and date of sampling are listed in Table 1 (herring) and Table 2 (sprat).

RESULTS AND DISCUSSION

HERRING

The esterase molecules moved towards the anode. One or two strong and up to six weak esterase bands were found. The electrophoretograms are outlined in Fig. 1.

In most specimens only one strong esterase band was present. This band and the corresponding esterase molecular type was named Es M (middle). Two bands of higher anodic mobility than Es M occurred



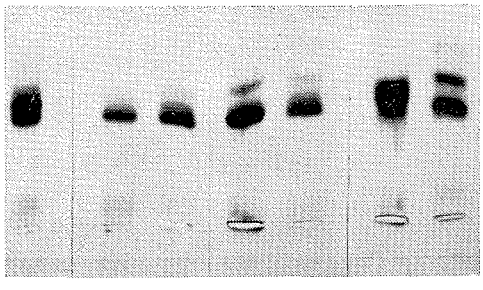


Fig. 1. Outline of serum esterase phenotypes in herring by combined starch and agar gel electrophoresis at pH 9.0, together with a photograph of patterns obtained by routine analyses. Legend: Filled in bars: Strong bands. Single lines: Weak bands. Arrow indicate the point of application.
1: Es S_2, 2: Es S_1, 3: Es M, 4: Es s(weak) and Es F_2(strong), 5: Es m_2 (weak) and Es F_1(strong), 6: Es m_1, 7: Es f_3, 8: Es f_2, 9: Es f_1.

Table 1. Observed distributions of esterase phenotypes in herring compared with expected distributions according to the Hardy-Weinberg law.

Sample no.	Locality and date of sampling	Indications of sample		Types of weak esterase zones					Types of strong esterase zones								
				Es $m_1 m_1$	Es $m_1 m_2$	Es $m_2 m_2$	No.	q_1	Es FF	Es FM	Es MM	Es MS_1	Es MS_2	No.	q_F	q_{S_1}	q_{S_2}
1.	Austfjorden, Hordal. 30 March—15 May 1967	Spring spawners in spawning condition	obs.	30	49	7	86	0.63	—	4	93	—	—	97	0.02	—	—
			exp.	34	40.1	11.8			0.04	3.8	93.2	—	—		—	—	—
2.	61°10' N, 06°00' E North Sea May 1967	Mainly immatured autumn spawners	obs.	91	21	1	113	0.90	—	7	131	—	—	138	0.03	—	—
			exp.	91.5	20.3	1.1			0.1	8.0	129.8	—	—				
3.	Masfjorden, Hordal. 12 June 1967	Immatured	obs.	67	16	3	86	0.87	1	5	89	2	—	97	0.04	0.01	—
			exp.	65.0	19.5	1.5			0.2	7.4	87.5	1.8	—				
4.	61°10' N, 00° 35' W, North Sea 17 June 1967	Adult autumn spawners	obs.	43	1	—	44	0.99	—	2	47	—	—	49	0.02	—	—
			exp.	43.1	0.9	0.0			0.02	1.9	47.1	—	—				
5.	61°10' N, 00°35' W, North Sea 17 June 1967	Adult spring spawners	obs.	47	—	—	47	1.00	—	3	46	—	1	50	0.03	—	0.01
			exp.	47.0	—	—			0.05	2.9	46.1	—	1.0				
6.	58°11' N, 03°48' E, North Sea 1 July 1967	Adult autumn spawners	obs.	87	3	—	90	0.98	—	1	96	—	—	97	0.05	—	—
			exp.	86.4	3.5	0.0			0.0	1.0	96.0						
7.	55°00' N, 06°00' E, North Sea 24/25 Aug. 1967 ..	Adult autumn spawners	obs.	78	30	1	109	0.85	—	6	112	—	—	118	0.03	—	—
			exp.	78.8	27.8	2.5			0.1	6.9	111.0	—	—				
8.	Tistam, Nordfjord . 14 Oct. 1967	0-gr.	obs.	79	3	—	82	0.98	—	13	85	—	—	98	0.07	—	—
			exp.	78.8	3.2	0.04			0.5	12.8	84.8	—	—				
9.	Borgenfj., Trøndelag 26 Oct. 1967	0-gr.	obs.	98	5	—	103	0.98	—	7	95	1	—	103	0.03	0.005	—
			exp.	98.9	4.0	0.04			0.1	6.0	95.9	1.0	—				
10.	57°35' N, 10°55' E, Kattegat 8 Nov. 1967.....	1-gr., autumn spawners	obs.	68	8	1	77	0.94	3	7	76	—	—	86	0.08	—	—
			exp.	68.0	8.7	0.3			0.6	12.7	72.8	—	—				

in some specimens. These components, named Es F_1 (fast) and Es F_2, were in most cases found together with Es M. In only one specimen Es F_1 and Es F_2 occurred together. Distinction between Es F_1 and Es F_2 was difficult in routine analyses, and therefore they were lumped together and named Es F. Two bands, named Es S_1 (slow) and Es S_2, of anodic mobility lower than Es M also occurred at low frequencies, and always in combination with Es M. The mobility of Es S_2 differed greatly from the mobility of Es M, while the mobilities of Es M and Es S_1 were little different.

The phenotype with only the Es M component was named Es MM, and the other phenotypes were named according to the components they contained, i.e. Es FM, Es FF, Es MS_1 and Es MS_2 (Fig. 1).

The three weak bands of greatest anodic mobility were supposed to belong to one group of esterase molecules and designed Es f_1, Es f_2 and Es f_3. The two weak bands of intermediate mobility were designed Es m_1 and Es m_2. Additional bands occurred near Es m_1 and Es m_2 in some specimens, but they could not be effectively separated from them by the present method, and therefore they have been omitted in the following discussion.

The slowest moving weak band, named Es s, (and partly also Es m_2) were screened by the stronger Es F bands when one of the latter was present. The relative mobilities of the various bands are shown in Fig. 1. Especially the Es f_1 and Es f_2 bands varied considerably in strength, and occasionally they were nearly as strong as the Es M component.

The phenotypes of the strong components could be determined from sera which had been frozen, but the patterns were clearer when fresh sera were used. The weak components, however, often were too diffuse to be determined from frozen sera.

The strong components may be explained as the product of separate genes (possibly allelic) named Es^F, Es^M, Es^{S_1}, and Es^{S_2} (where indices indicate the components which the genes are supposed to control). The hypothetical homozygotes Es S_1S_1 and Es S_2S_2 and the heterozygotes Es FS_1 and Es FS_2 were not found, but it appears from the distributions of phenotypes in Table 1 that the genes Es^F Es^{S_1} and Es^{S_2} were so rare that the lacking combinations should not be expected in the present samples. Except for sample 10 the population data are in fairly good accordance with expected Hardy-Weinberg distributions, and this supports the introduced hypothesis. Sample 10, however, show a surplus of hypothetical homozygotes and therefore to some extent contradict the hypothesis. If this sample is drawn from a panmixed population, the result indicates alternative explanations of the variations (genetic or non genetic).

If the variations in the weak components are genetically controlled, several gene loci must be involved, or the variations must be caused by formation of stable polymeres. For use in segregation studies of herring populations, the components Es m_1 and Es m_2 may have some importance. One or both of these occurred in nearly all specimens. When they were absent, it was always in specimens with weak total consentration of esterase or with low enzymatic activity in the sera. Three phenotypes occurred, and they were called Es m_1m_1, Es m_1m_2, and Es m_2m_2. Two allelomorphic genes, called Es^{m_1} and Es^{m_2}, were assumed to control these phenotypes. In Table 1 are listed the observed distributions of the m_1m_2-phenotypes and the calculated frequencies of the hypothetical gene Es^{m_1}. The numbers of specimens classified as m_1m_2-types were lower than the numbers classified as types of strong components, because the m_1m_2-bands in some specimens were too weak for reliable classification. When observed distributions of phenotypes were compared to expected distributions of genotypes according to the Hardy-Weinberg law, fairly good accordance was found (Table 1,) and except for sample 1 the deviations were not significant when tested by common χ^2-tests. Sample 1 gave a significant excess of hypothetical heterozygotes, and therefore contradict the hypothesis. However, the good accordance between expected and observed distributions in the other samples supports the hypothesis.

Breeding experiments have been planned to test the hypothesis of genetical control of the esterase phenotypes in herring.

There was no evidence of dependence on factors other than genetic of the variations of esterase phenotypes. The variations occurred in all age groups and in both sexes. However, it should be emphasized that the present analyses were only qualitative, and that variations in strength of esterase activity may occur which were not recorded by the present method.

Table 1 shows that there was no great variations among samples in distributions of strong esterase phenotypes. Es S_1 and Es S_2 were only found at very low frequencies in two and one sample respectively, but this did not show significant differences from the rest of the samples. The Es F bands occurred at low frequencies in most samples, but in samples 8 and 10 their hypothetical controlling gene was found at a frequency of 0.07 and 0.08 respectively, indicating real differences among the populations from which the samples were drawn.

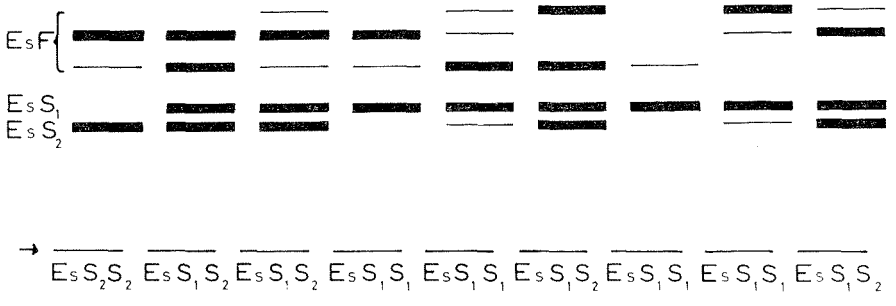
The distributions of the Es m types varied considerably, and although Es m_1m_1 occurred at high frequencies in most samples, it was found at lower frequencies in spring spawners from the coast (samples 1 and 3) and in one sample of autumn spawners from the North Sea (Sample 7).

SPRAT

Very extensive and complicated variations in serum esterase were revealed in sprat by combined starch and agar gel electrophoresis, and several patterns were found (Fig. 2). The patterns comprise variation in at least five zones of weak esterase activity. The three fastest moving components were supposed to belong to one group of esterase components and called Es F (fast) while the two slower moving were called Es S

Table 2. Observed distributions of esterase phenotypes in one year old sprat compared with expected distribution according to the Hardy-Weinberg law.

Sample no., locality and date of sampling		Esterase phenotypes			No.	q_1
		EsS_1S_1	EsS_1S_2	EsS_2S_2		
1. Kattøya, Langesund-fjorden	obs	15	35	33	83	0.39
3 Oct. 1966	exp	12.6	39.5	30.9		
2. Nå, Hardangerfjorden	obs	19	38	30	87	0.44
14 Oct. 1966	exp	16.8	42.9	27.3		
3. Risnes, Masfjorden	obs	10	44	30	84	0.38
4 June 1961	exp	12.1	39.6	32.3		
4. Skorpo, Hardangerfjorden.	obs	29	31	8	68	0.65
6 June 1967	exp	28.7	30.9	8.3		
5. Gjermundshamn, Hardangerfjorden	obs	22	21	6	49	0.66
6 June 1967	exp	21.3	22.0	5.7		



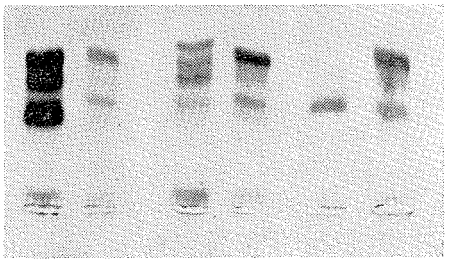


Fig. 2. Outline of serum esterase phenotypes in sprat by combined starch and agar gel electrophoresis at pH 9.0, together with a photograph of patterns obtained by routine analyses. Legend: Fig. 1.

(slow). A considerable part of the specimens showed diffuse electrophoretograms, and only the two slowest moving components, named Es S_1 and Es S_2 (which sometimes appeared double), were clear enough to form the basis for classification. One or both of these components were present in all specimens. When not taking into account the weak bands which often were present at position of lacking strong bands (Fig. 2), the specimens could be classified into three phenotypes on basis of the variations in Es S_1 and Es S_2 bands. These phenotypes were called Es S_1S_1, Es S_1S_2, and Es S_2S_2 according to which of the bands they posessed. The distributions of the phenotypes in five samples are shown in Table 2.

When a hypothesis of genetical control involving two allellomorphic genes, named Es^{S_1} and Es^{S_2}, is introduced, it appears that there are fairly good accordance between observed distributions of phenotypes and expected distributions of genotypes (Table 2). The hypothesis may accordingly explain the present variation in the zones Es S_1 and Es S_2. However, the variations in the other zones are still unexplained, and it is impossible to have any idea of the control of these variations as long as the specimens can not be classified with a reasonable degree of reliability.

It appears from Table 2 that there were considerable differences among samples in distributions of the phenotypes, and thus in frequencies of the hypothetical genes. Although the type determinations may be somewhat unreliable, the variations among samples were greater than may be explained by incorrect type determination or by errors of sampling. Thus the differences probably represent real differences between the populations from which the samples were drawn. This coincides with results from analyses of hemoglobins and transferrins (NÆVDAL 1968 and unpublished) which show significant frequency variations among samples of sprat from Norwegian waters. But because the type determination are somewhat unprecise, variations in esterase patterns in sprat appear at present to be of little value in segregation studies.

SUMMARY

1. Herring and sprat serum esterase has been studied by combined starch and agar gel electrophoresis at pH 9.0. Both strong and weak bands which represented esterase activity occurred in both species.
2. Most herring specimens contained one strong component of intermediate anodic mobility. Two strong components of higher and two of lower anodic mobility occurred at low frequencies. A hypothesis of genetical control by one gene controlling each of the components is proposed.

3. Maximum six weak bands of herring serum esterase were found. Considerable variations among specimens occurred in these bands. No theory of genetic control of the total variations can be given at present, but two codominant alleles may be responsible for the variation in two of the weak bands.
4. The intraspecific variations in sprat serum esterase were complicated, and it was difficult to classify the specimens into well defined groups on basis of these variations. A hypothesis of control by two allelic genes of the variations in two of the components is introduced.
5. Frequency variations among some of the samples of both species were indicated.

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STUDIES ON HEMOGLOBINS OF SOME GADOID FISHES

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INTRODUCTION

During the last few years it has been shown that in fish hemoglobins there excist intraspecific variations of at least two types, namely ontogenetic as in salmon (KOCK, EVANS, and BERGSTRØM 1964, VANSTONE, ROBERTS, and TSUYUKI 1964) and herring (WILKINS and ILES 1966), and genetically controlled polymorphism as first found in whiting and cod (SICK 1961). In sprat (WILKINS and ILES 1966, NÆVDAL 1968) and some other clupeoid fishes (SIMPSON and SIMON SCHLOTHFELDT 1966) intraspecific hemoglobin variations have been described, but these variations were neither found to be assosiated with age or length, nor has the genetic basis of the variations been worked out completely.

The present work is part of a search program to find polymorphic characteristics for use in segregation studies of fish populations. Most interest have been paid to gadoid fishes of commercial value, but bloods of minor economic important species have also been analysed for comparison.

MATERIAL AND METHODS

Blood samples have been obtained by cardiac puncture. Heparin or citrate was used as anticoagulant. The blood specimens were stored cold (0—4°C), and analyses were carried out within a few days after sampling.

Agar gel electrophoresis, described by (SICK 1965) was applied. Each run lasted for 60 minutes with about 50 volts between ends of gel. To control the results obtained by this method, part of the material was also analysed by combined starch and agar gel electrophoresis (MØLLER 1966) with 65 volts between ends of gel for 90 minutes.

Blood samples were collected from gadoid fishes from localities along the Norwegian coast and in the North Sea. Species, localities, date of

sampling and numbers are listed in Table 1 where the results also are presented. Scientific names and the order of the species are after SVETOVIDOV (1962).

RESULTS AND DISCUSSION

The hemoglobin components of all the species concerned here, moved towards the cathode in agar gel at pH 7.3. Fig. 1 shows the relative mobilities of the hemoglobin components and the hemoglobin pattern found for each species except forked hake. For comparison the cod hemoglobin type HbI–1–2 is shown. The hemoglobin of the forked hake moved only insignificantly by this method.

In all species, except forked hake, one or two strong and at least two weak or moderately strong components were observed. The electrophoretic mobility of the strong components did not differ very much from the mobility of the strong hemoglobin components of cod. The highest cathodic mobility of strong components was found in coalfish, the lowest in blue ling. The mobilities of the strong components of the other species were found within this range.

Intraspecific variation occurred in most species. In the following the same designations are used for corresponding patterns (phenotypes) of different species, although the mobilities of the components were not identical (Fig. 1).

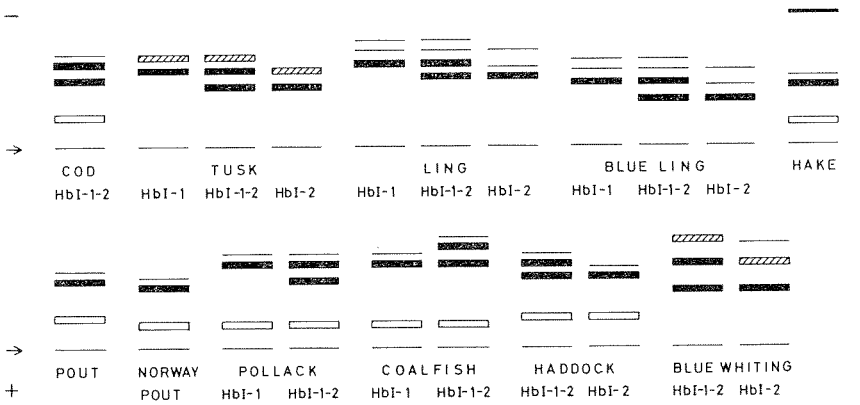

Fig. 1. Hemoglobin patterns of gadoid fishes obtained by agar-gel electrophoresis at pH 7,2. Filled in bars) strong bands, open bars) Hb II-components [moderately strong bands], cross hatched bars) other moderately strong bands, single lines) weak bands. Arrows indicate the points of application.

In tusk, ling and blue ling hemoglobin patterns with either one or both of two strong hemoglobin components were found. These patterns were similar to the hemoglobin patterns of whiting and cod (SICK 1961), and a similar nomenclature was chosen. Thus the components were named HbI–1 and HbI–2 in order of decreasing cathodic mobility, and the hemoglobin types were called HbI–1, HbI–1–2, and HbI–2, according to which of the components they possessed.

No evidence of ontogenetic variation in the hemoglobin of these species was found. The variations may be explained, however, by assuming that two allelomorphic genes, named HbI^1 and HbI^2, control the synthesis of the components HbI–1 and HbI–2 respectively. This corresponds to the genetical control of whiting and cod hemoglobin types (SICK 1961). The accordance between observed distributions of hemoglobin types (phenotypes) and calculated Hardy–Weinberg distribution of genotypes greatly supports this hypothesis (Table 1).

Two strong hemoglobin components, named HbI–1 and HbI–2, also occurred in pollack, coalfish, haddock and blue whiting, but only one of the single banded phenotypes was found in each species. However, the distribution and the calculated gene frequencies show that one of the hypothetical genes is too rare to be expected in a homozygotous state in the present material (Table 1). Therefore a corresponding mode of inheritance of hemoglobin types may exist also in these species.

In coalfish variations were very rare as only one specimen of 288 differed from the normal hemoglobin pattern of this species. In hake, pout and Norway pout no individual variations in the strong hemoglobin components were found.

In all species the strong components were accompanied on their cathodic side by weaker components named HbI–1' and HbI–2'. SICK (1961) found that corresponding components in whiting and cod increased in strength upon storing. This was evidently also the case in the species concerned here.

In ling and blue ling other weak components, named HbI–1'' and HbI–2'', of still higher cathodic mobility were present (Fig. 1). Also these components varied among specimens, but they often had a rather diffuse appearance, and therefore further studies have not been undertaken. In hake a moderately strong component with about twice as great cathodic mobility as the major hemoglobin component, was present in some of the specimens.

Components similar to the HbII components of whiting and cod (SICK 1961) were found in hake, pout, Norway pout, pollack, coalfish and haddock at positions between the point of application and the major components. The relative mobilities of these components differed among

species, and also intraspecific variations were indicated although not clear enough for classification of specimens into well defined groups. Except for some very faint bands, no components comparable to HbII components could be detected in tusk, ling, blue ling and blue whiting.

The intraspecific variations described here could also be found by combined starch and agar gel electrophoresis at pH. 9.0 (anodal movement). This confirms that the variations are real molecular differences and not methodical artifacts. By this method also the hemoglobins of forked hake moved towards the anode, but no intraspecific variation were found in this species.

Although the material was limited, the present observations clearly showed that intraspecific variations of the hemoglobin molecules, probably genetically controlled, are present in several gadoid species.

The different distribution of the hemoglobin types in the samples of ling (Table 1) indicate that different random mating populations excist in this species. However, the numbers of specimens are too low for reliable deductions.

The studies of protein polymorphism in fishes are increasing. Although yet insufficient to give a total survey, and despite different methods and lack of common reference, polymorph systems of one protein type often seem to be characteristic for one taxonomic group (family etc.), while systems of another protein are characteristc for others, for instance polymorphism in hemoglobins for *Gadidae* (Sick 1961) and in esterase for *Scombridae* (SPRAGUE 1967, NÆVDAL unpublished.).

SUMMARY

1. Hemoglobin of tusk, forked hake, ling, blue ling, hake, pout, Norway pout, pollach, coalfish, haddock and blue whiting were studied by agargel electrophoresis.
2. Both inter- and intraspecific variations in hemoglobin patterns occurred.
3. Intraspecific variations were found in tusk, ling, blue ling, pollack, coalfish (only one specimen differed from the «normal» pattern), haddock and blue whiting.
4. A hypothesis of genetical control involving two allelomorphic genes is proposed to explain the variations within each species. The population data coincided with this hypothesis.
5. No indication of ontogenetic variation of hemoglobin patterns have been found.
6. Frequncy variations of the hemoglobin types in ling indicate segregetion in the population structure.

Table 1. Material analysed for hemoglobin polymorphism. Observed distributions of types compared with the expected distributions of genotypes according to Hardy-Weinberg law.

Species, locality, and date of sampling	Distribution of hemoglobin types						No.	Frequency of the *HbI*[1] allele
	HbI-1		HbI-1-2		HbI-2			
	obs.	exp.	obs.	exp.	obs.	exp.		
Tusk, *Brosme brosme* (Müll.)								
N. 60°20', E. 4°20' ..... 24/ 5—67	5		9		4		18	
N. 62°56', E. 6°07' ..... 6/ 9—67	1		4		2		7	
N. 61°52', E. 1°23' ..... 8/ 9—67	6		19		8		33	
Total	12	13.4	32	28.9	14	15.7	58	0.48
Forked hake, *Phycis blennoides* (Brünn.)								
N. 61°52', E. 1°23' ..... 8/ 9—67			monomorphic				38	
Ling, *Molva molva* (L).								
Tennholmen, Nordland ..... 6/10—66	—		3		4		7	
Myking, Hordaland ..... 4—67	—		5		9		14	
N. 61°52', E. 1°23' ..... 8/ 9—67	1		7		9		17	
Total	1	1.8	15	13.0	22	23.1	38	0.22
N. 60°51', E. 3°02' ..... 27/ 2—68	—		1		56		57	0.08
Blue ling, *M. dipterygia* (Penn.)								
N. 60°20', E. 4°20' ..... 24/ 5—67	1	1.0	12	12.3	38	37.7	51	0.14
N. 61°52', E. 1°23' ..... 8/ 9—67	2	1.7	24	24.3	89	89.1	115	0.12
Hake, *Merluccius merluccius* (L).								
N. 60°20', E. 4°20' ..... 24/ 5—67			monomorphic				15	
N. 61°52', E. 1°23' ..... 8/ 9—67			monomorphic				37	
N. 60°51', E. 3°02' ..... 27/ 2—68			monomorphic				9	

Pout, *Trisopterus luscus* (L.).									
N. 53°35', E. 2°56'	16/ 9—67			monomorphic				27	
Norway pout, *T. esmarkii* (Nilss.)									
N. 62°56', E. 6°07'	6/ 9—67			monomorphic				50	
Pollach, *Pollachius pollachius* (L.)									
Myking, Hordaland	4—67	76	76.2	5	4.7	—	0.01	81	0.97
Coalfish, *P. virens* (L.)									
Hordaland	16/12—65	—		—		114		114	
Veidholmen, Nordmøre	17/12—65	—		1		33		34	
Røstbanken, Lofoten	9/ 3—66	—		—		140		140	
Total		—		1		287		288	0.002
Haddock, *Melanogrammus eaglefinus* (L.)									
Hjelmsøy, Finnmark	28/ 5—65	—		1		115		116	
Malangen, Troms	28/10—65	—		1		97		98	
Total, Northern Norway		—		2		212		214	0.004
Myking, Hordaland	4—67	—	0.1	5	4.9	80	80.0	85	0.03
Blue whiting, *Micromesistius poutassou* (Risso)									
N. 60°20', E. 4°20'	24/ 5—67	—		—		50		50	
N. 59°15', E. 3°35'	19/ 8—67	—		—		87		87	
N. 57°32', E. 7°57'	22/ 8—67	—	0.1	4	4,3	70	69.9	74	0.03
N. 62°56', E. 6°07'	6/ 9—67	—		—		91		91	

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