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

by
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Introduction

The Norwegian herring fishery in the North Sea started in 1898 (Iversen 1904). In the years up to the Second World War only small quantities were landed from the North Sea, particularly because of the good profitability of other herring fisheries, i.e. those based upon the Norwegian spring spawning stock. However, the decline in the Norwegian winter herring fishery at the end of the fifties induced the fishermen to a heavier exploitation of the herring stocks in the North Sea.

The total catches and number of vessels participating in this fishery in the period 1945-63 are shown in Figure 1. The main gear used during this period was trawl, both bottom trawl and pelagic pair-trawl. A few drifters have occasionally participated in this fishery, and during autumn 1963 some catches were also made by purse seiners equipped with power-blocks and ring-nets.

At the beginning of this century the major part of the catches was taken during summer (June - August) east of Shetland and during autumn (August-October) in the Viking Bank area. From the end of the fifties the fishery has been concentrated to the north-eastern North Sea, particularly along the western slopes of the Norwegian Channel. Except for the months June, July, when the trawlers switched over to fish Sand Eel, the herring fishery went on throughout the year.

The distribution of the main areas of fishing in 1962 are summarized in Figure 2. The landings from the various areas have been grouped into two-monthly periods. A regular pattern of movement emerges. In January and February the majority of the catches came from the area west of Utsira. During March and April the greatest catches were taken further north, between Utsira and Bergen about 20-40 nautical miles off the coast. In July and August the main area of capture shifted seaward and to south-west, 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 and December the main center of activity was in the Egersund Bank - Coral Bank area.

The north-eastern North Sea is supposed to be a mixing area of autumn and spring spawning stocks. Spring spawners are recorded to spawn on the Viking Bank in February and March (Clark 1933, Wood 1936, Marty 1956), but otherwise there are no observations of spawning in the north-eastern North Sea.

To get information about the composition of spring and autumn spawning groups, both in space and time, and further, by analysis of biological characters to determine or indicate which stocks within the autumn spawning group that are most frequent in the north-eastern North Sea, collecting of samples from the catches commenced in autumn 1961. The investigations of the spring spawning group in these samples are presented in another report at this meeting (Haraldsvik 1966).

Material

The present report is based on 23 samples, comprising 3.825 individuals, collected from September 1961 to May 1963. The majority of the samples are from commercial catches, only 6 samples were taken onboard research vessels. Sampling locality is shown in Figure 3.

The samples have been taken by drift-net, trawl and purse seine (Table 1). There was no trend in length composition of the herring taken by different gears, and the samples therefore are presumed to give a fairly correct picture of the exploited stocks in the north-eastern North Sea.

The herring have been examined as to age, Vert.S., maturity stage, otolith type, otolith measurements and growth. For practical reasons the observational data are not included in this report, but may be obtained on request to the library of the Institute of Marine Research, Bergen.

The quality of the herring varied from sample to sample. Except the samples taken onboard research vessels, the samples were 2-10 days old before examination. These samples had either been on ice or been frozen. According to German investigations onboard R/V "Anton Dohrn" herring shrink up to 4.8% at 25 cm of length when kept in -20°C (K. Schubert, verbal communication). The present samples had been frozen in different number of days, some had been frozen before rigor mortis, some after. Due to all these uncertain factors the effect of shrinkage of the fish has not been considered in the length measurements.

Frozen material may also give some inaccuracy in the maturity determination. Especially for the females the eggs will tend to get hyaline after being frozen. The amount of hyaline eggs is one of the main characters to distinguish between the maturity stages IV and V and between V and VI, but owing to lack of sharp limits between the different stages it is impossible to adjust these data.

The otoliths were mounted whole and without clearing, into a transparent resin "Eukitt" on black coloured slides. This resin, manufactured by O. Kindler, Deckglaszuschneiderei, Freiburg, Germany, was found more suitable than Canada balsam regarding drying time and optical properties. The otoliths were examined under a binocular microscope in strong, concentrated reflected light and with a magnification of 25 xx.

Composition of spring and autumn spawning group of herring in the north-eastern North Sea

The spring and autumn spawners were separated on otolith characters (Parrish and Sharman 1958). It is likely that most of these characters are phenotypic and reflect differences in general physiology and growth of herring inhabiting different nursery grounds during their adolescent phase. The difference in spawning time between the two groups (e.g. autumn spawners spawn between August and December and spring spawners between February and May) may also give evidence for the low frequency of intermediate structures.

The composition of spring and autumn spawners in the samples are given in Table 1. It appears that there is a general increase of the spring spawning component from September 1961 to March 1962. Whether this is a result of an immigration of spring spawners or an emigration of autumn spawners is unknown. However, the remarkable low percentage of spring spawners in the samples number 9 and 22, which both are from end of March, may indicate an emigration of this group to the spawning grounds.

In summer, from the end of July to the beginning of September, the spring spawning group was dominating, which together with low landing figures during the same period, was associated with an emigration of the autumn spawning group from the north-eastern part of the North Sea to the spawning grounds.

During autumn and winter 1962/63 the spring spawning component in the samples was less abundant than the year before. The increase of the autumn spawning group during autumn and winter 1962/63 was due to an extensive inflow of two year-old herring (1960 year-class) to the north-eastern North Sea (see page 4.).

From the data available the autumn spawning group constituted 69%. The percentage of this spawning group in the total yield from the North Sea was probably somewhat higher, due to low landing figures during summer, when the spring spawning component predominated.

According to earlier investigations there has been a change in the relative abundance of spring and autumn spawners in the north-eastern North Sea. Broch (1909), Bjerkan (1917), Krefft (1954), Schubert (1954) found that the spring spawning component was predominating in this area from February to November, and further, that this spawning group mainly consisted of the Norwegian spring spawning stock.

During the last two decades the Norwegian spring spawning stock has changed spawning grounds (Devold 1963), and the simplest way of explaining this change in abundance of the two spawning groups, is therefore to suppose that the Norwegian spring spawning stock before 1960 had a migration route between the feeding area in the Norwegian Sea and the spawning grounds on the south western coast of Norway along the Norwegian Channel and north-eastern part of the North Sea, while afterwards, the spawning grounds have changed to north of Stad, and consequently the migration route will be north of the North Sea.

Support for this hypothesis is an observed negligible admixture of the Norwegian winter herring stock in the samples from the north-eastern North Sea during 1961, 1962 and 1963 (Haraldsvik 1966).

The autumn spawning group

The north-eastern North Sea is supposed to be a feeding and overwintering area for some of the autumn spawning stocks which have their spawning grounds in the western and southern North Sea and in the northern Kattegat. These stocks are as follows:

a) The Bank herring stock, spawning grounds from the Shetlands in the north to the Dogger Bank in the south, spawning time from August to October.

b) The Downs herring stock, spawning grounds in the southern North Sea (Sandettié) and eastern English Channel, spawning time in November and December.

c) Northern Kattegat herring stock (Kolbergrund), spawning grounds along the Swedish Kattegat coast, spawning time in September and October.

The non-spawning distribution of these stocks are to some extent known thanks to investigations on similarities of meristic data and tagging experiments. A review of the migration pattern of these stocks is given by Parrish and Saville (1965).

The differences in meristic characters may be a result of differences in genotype, or of differences in environmental factors operating on one genotype, or of both these effects acting together. The plasticity of these characters, under the influence of environmental factors, the large degree of overlap of values, presents the greatest difficulties in distinguishing the individual fish in samples taken from a region of mixing of stocks. However, using many characters, comparing data collected in the same year, this method can undoubtedly provide some success in determining the different stocks within the autumn spawning group.

Unfortunately, information from recent years for the Kattegat autumn spawning stock is not available, and this comparison will therefore be concentrated to the Bank and Downs herring stocks.

Age composition

Both scales and otoliths were used for age determination. According to Dahl (1907), Clark (1933), Hodgson (1934) and Wood (1951) the formation of the scales of the herring does not begin until the young herring is about 4-5 cm in length, and that is approximately the size increment of the autumn spawners 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 their first ring at an age of three to four months, thus giving a group of herring whose age was normally overestimated by one year. The scales of these herring had a small size of the central area. No such scales were observed in the material available, and from information about the growth rate of larval and post-larval herring it seems unlikely that substantial numbers of herring will lay down their first 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 therefore lay down their otoliths in winter condition, and will get a hyaline nucleus.

The number of winter-rings on the scales was always in accordance with that on the otoliths (outside the nucleus), which also demonstrate that the first winter-ring on the scales is formed during the second winter.

Not all scales and otoliths did fit for age determination, mainly due to secondary rings in the summer growth zones, regenerated scales and transparent otoliths. An attempt was made to obtain an idea of which otoliths or scales were most suitable for age determination. In this connection the following scale for readability has been used:

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

In Table 2 are summarized the results of the observations on readability of scales and otoliths. The trawl and drift-net herring were frequently lacking scales, or the scales remaining were small and did not fit for age determination, which may explain the great discrepancy of the readability 0 for these gears. The precentage of readability 0 of the otoliths was high regardless of the gears. 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 on readability 0 for either scales or otoliths, i.e. about 80% of the material. One must assume that the remaining 20% is dominated by older herring, and this infers that the age composition, as illustrated in Figure 4, is slightly biased.

From this figure it appears that the age composition in the samples from September 1961 to April 1962 is characterized by a strong 1956 year-class (50-70%) and comparatively strong 1954 and 1957 year-classes. During summer some of the samples from 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 north-eastern part (samples No. 12, 13, 16) remained unchanged. From the end of September 1962 the age composition changed considerably, due to a heavy inflow of two year-old immature herring. It should be noted that this 1960 year-class did not increase in abundance north of the 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 (September to April) may indicate that the area is visited by a single stock. The change of age composition in the southern region (south of latitude 59°N) during spring and summer (April to September) is probably due to a segregation or an immigration of herring. Members of a year-class first recruit the southern part of the region in autumn at two years of age, and their range will during winter mainly be concentrated to the areas south of latitude the 59°N.

In Figure 5 is given the age composition of herring from the western, central and southern part of the North Sea. This figure is based upon German data in ICES, Statistical News Letters No. 18. The material from the Bressay shoal and the Fladen Ground is supposed to illustrate the age composition of the Bank herring stock, and that from Sandettié and Channel the Downs herring stock. The Dogger Bank area is during autumn supposed to be a mixing area of spawning Bank herring and mature Downs herring (Burd 1962).

This comparison shows a striking resemblance between the age composition of the autumn spawners in the north-eastern North Sea during autumn and winter 1961/62 and during winter 1963 (north of latitude 59°N) and the Bank herring stock. It will also be seen that the 1958 year-class, which was comparatively strong in some of the samples from spring and summer 1962 in the southern part of the area was the dominant one amongst the Downs herring stock.

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. According to Scottish and Belgian data in ICES, Statistical News Letters No. 23, the 1960 year-class this year constituted about 80% and 70% of the Bank and Downs herring stocks respectively. There is no information of age composition of the Kattegat autumn spawners in 1962, but in autumn 1963 the 1960 year-class constituted about 90% of this stock (Höglund 1965).

Due to the strength of the 1960 year-class in all these stocks, it is therefore impossible by means of the age composition to identify the different stocks in north-eastern North Sea south of the latitude 59°N during autumn and winter 1962/63.

Vertebrae

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

In a mixing area of different herring stocks it is therefore reasonable to assume that the mean vertebral number will fluctuate in proportion to the abundance of the different stocks.

In Table 3 is given the frequency distribution, the mean and the variance of Vert. S in the different samples. The means vary between 56.35 and 56.66, but no trend in time and space is observed. To test if there were significant differences in vertebral number an analysis of variance has been applied. The result of the analysis of variance, Table 4, shows that the differences within samples are insignificant compared with the differences between means of samples. 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 vertebral number between the autumn spawning stocks. Earlier investigations have shown that the mean vertebral number had an increasing trend from north to south, with low values on the Buchan spawning grounds and higher values on the Sandettié and English Channel spawning grounds.

According to Anon (1961) no large differences in mean vertebral number could be detected between pre- and postwar investigations on the Downs stock, and for the period 1952-59 their means ranged from 56.53 to 56.59.

The mean vertebral number of herring from the Dogger area varied in the same period between 56.51 and 56.56, with an overall mean of 56.55 (Anon, loc. cit.). This figure is significantly higher than pre-war observations (Wood 1936). For the spawning shoals of the Buchan area in the pre-war years Wood (loc. cit.) gave a mean vertebral number of 56.42. In the years 1952-55 the mean number was slightly different from pre-war data, but after 1955 there has been a marked rise in the mean number and up to 1960 the range was from 56.54 to 56.58 (Anon 1961).

The Kattegat autumn spawners have a mean vertebral number of 56.35 (Johansen 1924). The low means in some of the samples from summer 1962 can therefore indicate an admixture of this stock.

The total mean vertebral number (56.52) in the available material was in good agreement with those of the Bank and Downs herring stocks, and it may be concluded that these stocks, without intimate anything about the mutual abundance, inhabit the north-eastern North Sea and constitute the dominant part of the autumn spawning group.

Maturity.

For the routine assessment of sexual maturity a modified form of the maturity scale given by Johansen (1919) has been applied. This scale is in accordance with the one recommanded by the Herring Committee of ICES in 1962.

Transistional cases between two stages have been included under the higher stage. It frequently occured difficulties in distinguishing between stage VIII and an advanced stage II. Especially for herring that have spawned only once the criteria such as striation of gonad walls, 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 intestinal fat have been decisive; e.g. herring with moderate or large quantities of fat were put into stage II and herring with practically no, or a little fat, were put into stage VIII.

Figure 6 shows the percentage frequency distribution of the maturity stages in the material. The herring were sampled throughout the year and it is therefore suggested that this figure will give a fairly coherent picture of the maturity cycle of the autumn spawning group.

Virgin herring, stages I and II, were hardly represented in the material up to October 1962. During autumn and winter 1962/63 these stages constituted a dominant part of the samples due to the immigration of the 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 north-eastern North Sea to the spawning grounds during summer and early autumn these stages will probably cover a longer period than indicated in Figure 6.

Spent herring, stage VII, were distributed during December and January 1961/62, and during September and October 1962. This fact points to an immigration of late and early autumn spawning components. From Figure 6 it is also noted that stage VII was present during spring both in 1961 and 1962, which may indicate an alteration 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 North Minch areas. There is also observations on spawning herring in August in an inlet on the west coast of Norway with distinct and definite "winter-spring" otoliths. Racial characters such as scale pattern, l_1, vertebral number of these herring were in accordance 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 spawners in the north-eastern North Sea have changed their spawning season, this should be reflected in a two-peaked curve of the various maturity stages.

These spring samples, containing stage VII, had all been frozen and were in bad condition when examined, and it seems most likely therefore that there might be some error in the maturity determination.

The maturity cycle of the autumn spawning group in the north-eastern North Sea is characterized by a long duration of the recovering stage VIII, almost 8 months, and a rapid process of the 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 spent herring in September and first half of October belong probably to the Bank herring stock, but otherwise it seems impossible to distinguish between the various autumn spawning stocks by means of this character.

Age at first spawning

The autumn spawners had no typical spawning rings neither on the scales nor on the otoliths. The maturity composition during autumn and winter by each age-group can, however, provide useful information on the age of the onset of spawning.

Herring in stage III are classified as uncertain, i.e. they may be immature and probably do not spawn before the next autumn, or they may be early autumn spawners that have already recovered their gonads. The composition of virgin (stage I and II), uncertain (stage III) and spent herring (stages VII and VIII) in each agegroup is illustrated in Figure 7. It will be seen that first time spawners occurred amongst two to six year-old herring, but the majority, about 70% were spawning at an age of three. This feature is common to the North Sea and the Kattegat autumn spawning stocks (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 year-olds, and the major recruitment to the spawning shoals took place as four year-old herring. This marked change in the age at first spawning occurred widely over the North Sea in the 1952 season and was associated with an increase in growth rate during the adolescent and pre-recruit phases, which resulted in an earlier movement from the nursery areas, and earlier maturation of members of the year-classes recruiting both the Bank and Downs spawning shoals.

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 amongst the autumn spawning group

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 between the forms of the first winter zone and the sizes of the first growth zone amongst members of the North Sea autumn spawning group. These features are probably phenotypic, and they may provide some important pointers to the 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-sharp first winter zone and a relatively large first growth zone.

According to Das, Postuma and Zijlstra (1959) the "narrow" type was dominating amongst spawning herring in the Dogger Bank area, while the "wide" type was the prominent one on the spawning grounds in the southern North Sea and 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 b), and it seems therefore to be a decreasing trend of the "narrow" otolith type from north to south.

The occurrence of the two otolith types in the samples from north-eastern North Sea is given in Table 5. In this table are also included the otoliths which could not be categorized under either of these major types. These doubtful cases contributed about 7% of all the otoliths examined.

From Table 5 it is seen that the "narrow" type dominated in all the samples, and no trend in the composition of the two types is observed neither in time nor in space. It is interesting to note that there is neither an increasing tendency of the "wide" otolith type during the summer feeding season nor a decreasing tendency of this type in the samples during the spawning season for the Downs herring stock, which may give evidence for that this stock do not immigrate into the north-eastern North Sea.

In Table 6 is given the percentage distribution of otolith types amongst the age-groups in each of the years 1961-63. The most important features of these data are as follows:

1) No "wide" zoned otoliths were identified amongst the 2 year-old herring in any of the years.
2) The proportion of the two otolith types differed between year-classes. The 1958 year-class contained a relatively high proportion of the "wide" zone type as three to six year-olds.

There was no evidence from the data of an increase in the proportion of "wide" with age amongst the year-classes. This is in contrast to the result of studies in the north-western North Sea in the years 1953-1956 (Parrish and Sharman 1959 a), where the proportion of the "wide" type increased between ages three to five. The high proportion of "narrow" typed otoliths in the samples could count for a connection between the Bank herring stock and the autumn spawners in north-eastern North Sea, but as long as the otolith type composition amongst the Kattegat autumn spawning stock is unknown, it is impossible to verify this statement.

First growth zone measurement on otoliths

The distribution of first growth zone measurements for the two otolith types exhibited marked differences. The otoliths were measured from centre of the nucleus to the distal edge of the first winter zone, along an axis to the post-rostrum, and the ranges and means for the "wide" and "narrow" types are presented in Table 7. The percentage frequency distributions for the two types in each of the years 1961-1963 are illustrated in Figure 8.

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 all the years. 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 was dominating in these samples, while the 1956 year-class was the dominant one in the others.

The ranges and means for the "narrow" and "wide" otoliths from north-eastern North Sea were somewhat lower than the values obtained for the Bank herring stock in the years 1953-1956 (Parrish and Sharman 1959 a).

These differences were, however, small and probably well inside the range of what can be expected when dealing with material consisting different year-classes.

In Table 8 is compared the means of the first growth zone measurements for the two otolith types amongst herring from the Dogger area (two ringers, 1956 year-class, from Bohl 1960) and present data from north-eastern North Sea (total material, 1956 year-class dominating).

The good conformity can indicate a connection between 2 year-old pre-recruits in the Dogger area and mature herring in the north-eastern North Sea.

While the result of this investigation provide some important pointers to the supply and composition of the autumn spawners in the north-eastern North Sea, it must, however, be stressed that at present it is not possible to assess the full biological significanse between the two otolith types and to what extent this character can be used in herring "racial" studies. It is suggested that the differences between the growth zones of the "wide" and "narrow" types is due to a slow or fast first year growth, resulting from either an early or late time of hatching or a difference in growth-rate. The differences between the size of the first winter zone in the two 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 between the vertebral number for the two types. The frequency distributions of Vert.S. of the "narrow" and "wide" 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 further informations of the otolith types amongst the spawners from the Dogger, Southern Bight and northern Kattegat areas and extensive studies of herring in different nursery areas are needed, and the effect of food and temperature on ring formation should be investigated in aquarium experiments.

Growth

Lea (1910, 1938) has shown that the relation between the scale length and the total length of the herring was 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 for identifying the herring from each spawning ground. In the North Sea are the differences of the l_1-distributions between the Bank and Downs herring stocks 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 either the differences between year broods or those within the observations of 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 used.

$$l_1 = \frac{s_1}{S_n} L + (1 - \frac{s_1}{S_n})$$

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 measured total length, l_1 is the calculated length at the formation of the first winter-ring. The resulting data are illustrated in Figure 9, and for comparison is shown the l_1 distribution of four year-olds (1954 year-class) Bank (Anon 1962) and Downs herring (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. Minor differences in l_1 distribution between year-classes may occur. Burd (loc. cit.) has, however, shown that there is a close relationship between the l_1 values and the amount of Calanus available in the first year.

The mean number of Calanus per metre^3 in the Flamborough Line (between Flamborough Head and Dogger) Hensen net catches were in 1955 = 203 Calanus per m^3 and in 1957 = 172 Calanus per m^3, i.e. the food available in the first year of feeding for the 1954 and 1956 year-classes were approximately at the same level. The l_1 data of the Bank and Downs herring in Figure 9 are calculated by Lea's first formula, i.e. these l_1

data are in average $(1 - \frac{s_1}{S_n})$ cm lower than the l_1 data presented for the autumn spawners in north-eastern North Sea. The differences in the two growth formulas are for 6 year-old herring estimated to be 0.5 cm. Notwithstanding this disadvantage, it must be concluded that there is good agreement between the l_1 data for the autumn spawners in the north-eastern North Sea and the Bank herring stock.

The differences found in first growth zone measurements in the "narrow" and "wide" types suggest that similar differences would be found in the l_1 data of these two groups of fish. In Figure 9 is also the l_1 distribution separated on otolith types and compared with the l_1 data for the Bank and Downs stocks. The good correspondance between the l_1 distributions for the "wide" and the Downs herring and for the "narrow" and the Bank herring indicate that the types originate from these stocks. Raitt (1961) found good correlation between l_1 and otolith types, and estimated a critical length at 11.5 cm for formation of "narrow" and "wide" types, i.e. herring $>$ 11.5 cm in the second winter would lay down a "narrow" ring and herring $<$ 11.5 cm a "wide" ring. 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.

If the l_1 is related to the time of year when the fish is hatched, then one can expect that the proportion of herring $\gtrless$ 11.5 cm in the Bank and Downs stocks will differ by virtue of the 3-6 months differences in spawning time, and consequently also the otolith type compositions. On this basis a comparison between l_1 of "wide" type and Downs herring (where "wide" type is dominating) and "narrow" type and Bank herring (where "narrow" type is dominating) therefore will give good conformity.

A difference of nearly 4 cm between modal length at formation of the first winter-ring 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 back-calculation for "narrow" and "wide" types 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. The mean l_1, l_2 values etc. of the 1956 year-class in this table have been used to obtain the growth constants for the "narrow" and "wide" typed herring, and the von Bertalanfly (1938) growth equation was used in the form

$$L_t = L_{\infty} \, (1 - e^{-kt}),$$

where L_t is length at time t (yearly intervals), L_{∞} is the assumptotic length of the herring and k is the growth constant. The L_{∞} was obtained by Walford's (1946) graphical method. The values of the constants for the two types of herring are shown in Table 11, and for comparison are also the values of the growth constants for the 1943/44 brood of the Bank and Downs herring included in this table.

It is seen that there is great differences between the "narrow" and "wide" herring in both L_{∞} and k. In comparing the "wide" type and the 1943/44 brood of the Downs stock the values of L_{∞} and k are showing good conformity. The values of L_{∞} for the "narrow" typed herring and the Bank stock are also of the same order, while the values of k are different. The difference in k may be linked to differences in food supply for the two year-classes considered.

It is clear from the above that the "narrow" and "wide" typed herring differ in their growth rates. The l_1 distribution of the "narrow" type have many more higher l_1 values than those of the "wide" type, and the differences in the values of L_{∞} between the two types may well be attributable to the original difference in the l_1.

As suggested in the previous section both the "wide" and "narrow" types belong to the Bank herring stock, but according to the good conformity in l_1 and growth constants between the "wide" type and the Downs herring it is reasonable to assume that this component of the Bank stock have some similarities with the Downs stock, such as nursery areas, feeding localities or feeding time.

Concluding remarks

In an attempt to determine which stock or stocks within the autumn spawning group that the Norwegian herring fishery is based upon in the north-eastern North Sea, some of the biological characters presented in the preceding have been compared with similar characters for the Bank, Downs and Kattegat autumn spawning stocks as far as these were available.

The plasticity of these characters and the large degree of overlap of values between the stocks make it difficult to attain a complete identification of the stocks by this method. Some of the characters such as age composition, otolith type composition and l_1 distribution may, however, provide valuable informations in this identification work.

The age composition of the samples from September 1961 to May 1962 showed a striking conformity with the Bank herring stock (Figure 4). According to otolith type composition (Table 5) and the Vert. S. (Table 3) in the same samples it seems obvious that the intermingle of other stocks was nil or negligible amongst the autumn spawning group in that period.

In the samples from May to September 1962 it became more complicated to identify the stock composition. In these samples a low first growth zone measurement was found in the "narrow" otoliths (Table 7) and low values of Vert. S. (Table 3). These changes in characters could be a consequence of segregation, i.e. the older year-classes have emigrated from the area so that the 1958 and 1959 year-classes became more abundant (Figure 4), or could be caused by an immigration of other stocks. An analysis of variance of Vert. S. showed that the differences within year-classes was insignificant compared with the differences between year-classes, but it should be noted that the 1958 and 1959 year-classes had the lowest values of Vert.S., 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, however, suggested that the immigration of Downs herring 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). 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 spawners present in the north-eastern North Sea in the period May to September are a mixture of Bank and Kattegat autumn spawners.

During autumn 1962 a new strong year-class immigrated the areas south of latitude 59°N. This 1960 year-class was strong amongst the Bank, Downs and Kattegat autumn spawners, but the high vertebral count (Table 3), the high proportion of "narrow" typed otoliths (Table 5), the high values of first growth zone measurement (Table 7) in these samples should argue for that this year-class mainly did derive from the Bank herring stock. North of latitude 59°N, during winter 1963, we again got a striking conformity as to age composition, vertebral number, composition of "narrow" and "wide" typed otoliths between the sampled herring and the Bank herring stock.

From this investigation, therefore, it is concluded that the Norwegian herring fishery in the north-eastern North Sea along the western slope of the Norwegian Channel is mainly based upon the Bank herring stock. This stock is prevailing amongst the autumn spawning group during autumn, winter and spring, but is in summer probably mixed up with Kattegat autumn spawners in the southern areas.

Summary

The present paper deals with the composition of spring and autumn spawned herring in the north-eastern North Sea and an analysis of some biological characters such as age composition, maturity cycle, otolith type composition, first growth zone measurement made on the otoliths

and growth for the autumn spawned group.

The material consists of 23 samples, collected during the period September 1961 to May 1963.

The autumn spawned group dominated in the samples during autumn, winter and spring and constituted 69% of the sampled herring. The dominance of the spring spawning group in the samples from end of July to the beginning of September (69%) was probably caused by an emigration of the autumn spawners in north-eastern North Sea.

The otoliths were more suitable than scales for age determination. The 1956 year-class was predominating in the samples up to autumn 1962 in the whole area and also in the samples taken north of latitude 59°N during winter 1963. In autumn 1962 the 1960 year-class immigrated the southern area and made up between 65-85% of the autumn spawners.

An analysis of the vertebral number showed that the differences of the variance within samples was insignificant compared with the differences between means of samples. The mean vertebral number of the total was 56.524 ($\pm$ 0.025).

The maturity cycle of the autumn spawners has been considered. The maturity stage VIII had a duration of about 8 months, and dominated in 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 second half of August. No spawning of herring was recorded in the area.

An analysis of the occurence of "narrow" and "wide" first winter zones in the otoliths showed that the proportion of "narrow" typed herring was in majority in all the samples and constituted 87% of the autumn spawning group.

Measurements of first growth zone of "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).

The l_1 distribution showed a significant difference between the "narrow" and "wide" typed herring. Bertalanffy's growth equation was fitted to data obtained by projection and back calculation, and great differences were found in the growth constants, L_∞ and k, between "narrow" and "wide" typed herring.

The relationship between the autumn spawners in north-eastern North Sea and the Bank, Downs and Kattegat autumn spawning stocks was examined. The evidence suggests that the Bank herring stock was predominating during autumn, winter and spring, while in summer this stock was probably mixed up with Kattegat autumn spawners in the southern areas.

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

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

Table 2. Percentage distribution of readability 0-4 of scales and otoliths of autumn spawners from north-eastern North Sea, 1961-63.

Gear	Character	Readability					n
		0	1	2	3	4	
Trawl	Scale	36.2	9.1	4.6	26.8	23.3	1953
	Otolith	69.8	9.2	9.6	11.4	0.1	1953
	Total	77.7	9.1	6.7	6.6	-	1953
Drift-net	Scale	60.8	11.8	7.9	18.2	1.3	595
	Otolith	73.8	11.4	8.4	6.4	-	595
	Total	85.2	8.1	4.0	2.7	-	595
Purse-seine	Scale	59.8	11.0	12.2	17.1	-	82
	Otolith	65.9	13.4	8.5	12.2	-	82
	Total	78.0	11.0	6.1	4.9	-	82
Total	Scale	45.2	9.8	5.6	24.6	17.6	2630
	Otolith	70.6	9.8	9.3	10.3	+[1]	2630
	Total	79.4	8.9	6.1	5.6	-	2630

+[1]) < 0.05

Table 3. Vertebrae frequency distributions of autumn spawners from north-eastern North Sea, 1961-63.

Sample number	Date	Vertebral number							n	$\bar{x}$	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	1180	1246	100	3	2611	0.5243	0.4028

$\bar{x}$ = average excess above the "working mean", 56 vertebrae.

Table 4. Analysis of variance of vertebral 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	2588	0.4017	P $<$ 0.05
Total	1051.2333	2610		

Table 5. Percentage distribution of otolith types amongst autumn spawners from north-eastern 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	2630

Table 6. Percentage distribution of otolith types by age amongst autumn spawners in north-eastern North Sea, 1961-63. (N= "Narrow" type, W= "Wide" type, U= unclassified)

Age	2			3			4			5			6			7			7+			n
Year / Type	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	1101
1963...	-	-	-	98	1	1	86	14	-	80	20	-	79	9	12	81	12	7	75	19	6	473

Table 7. Ranges and means of first growth zone measurements of "narrow" and "wide" otolith types amongst autumn spawners from north-eastern North Sea, 1961-63. (1 unit= 0.0409 mm).

Sample number	Date	"Narrow" Range	Mean	n	"Wide" Range	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	1203	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	2209	18 - 30	24.6	168

Table 8. Mean first growth zone measurements (mm) of "narrow" and "wide" otolith types amongst herring from Dogger Bank and north-eastern North Sea.

Type	Dogger Bank	n	NE North Sea	n
"Narrow"	1.23	928	1.22	2309
"Wide"	1.02	332	1.01	168

Table 9. Vertebrae frequency distributions of "wide" and "narrow" typed herring amongst autumn spawners from north-eastern North Sea.

Type	Vertebral number 54	55	56	57	58	59	n	$\bar{x}$	σ^2
"Wide"	-	5	75	85	1	-	166	0.4940	0.3242
"Narrow"	2	63	1023	1082	93	3	2266	0.5340	0.3999

$\bar{x}$ = average excess above the "working mean", 56 vertebrae.

Table 10. The lengths (1) of 1, 2,..5 year-old "narrow" and "wide" typed herring amongst autumn spawners from north-eastern North Sea (calculated from scale measurements)

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

Table 11. Growth constants for "narrow" and "wide" typed herring (1956 year-class) amongst autumn spawners in north-eastern North Sea compared with the constants for Bank and Downs stocks (1943/44 year-class).

	L_∞ (cm)	k
"Narrow"	28.33	0.829
"Wide"	27.67	0.685
Bank	28.64	0.635
Downs	27.58	0.654

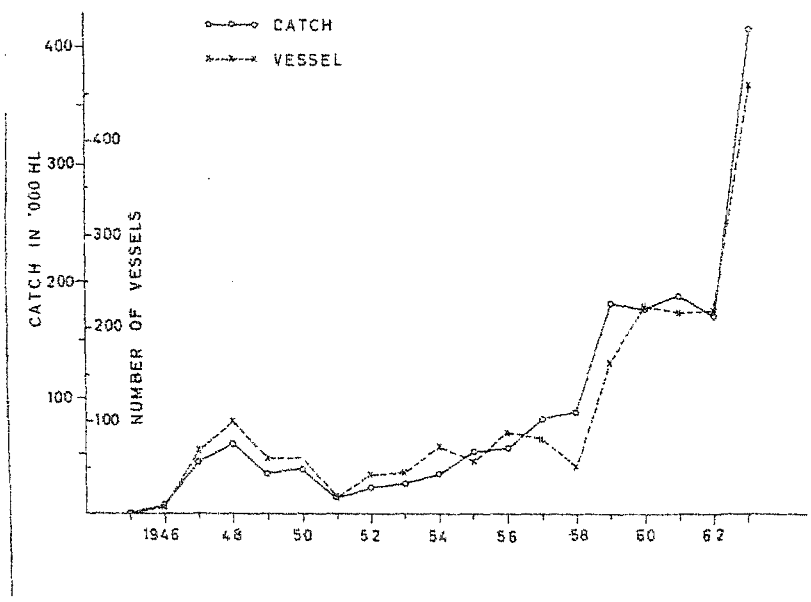

Fig. 1. Total catches of herring from the North Sea and Skagerak, taken by Norwegian vessels, 1946-63.

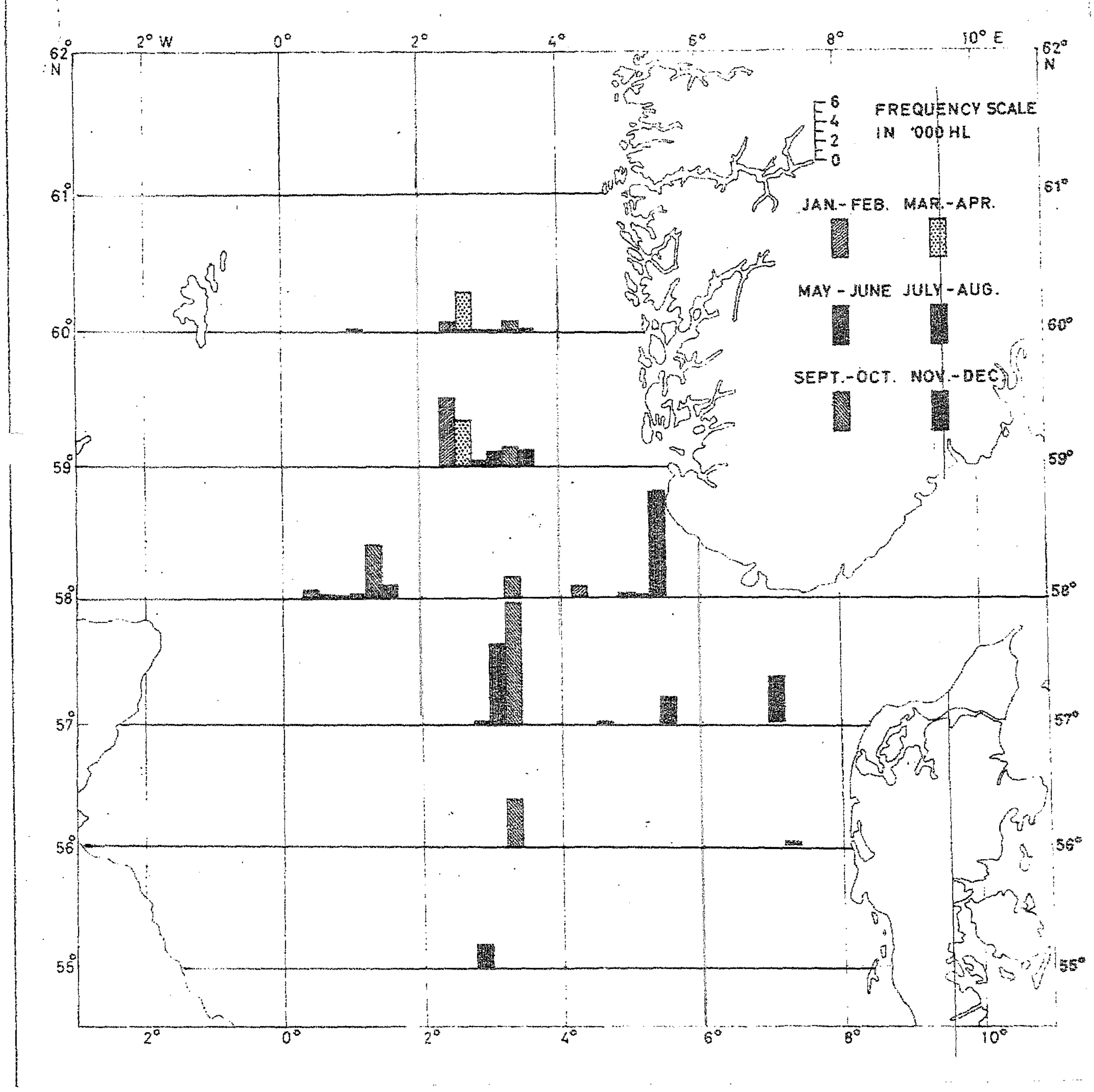

Fig. 2. Distribution of the Norwegian North Sea herring catch (two-monthly periods) ón 1962.

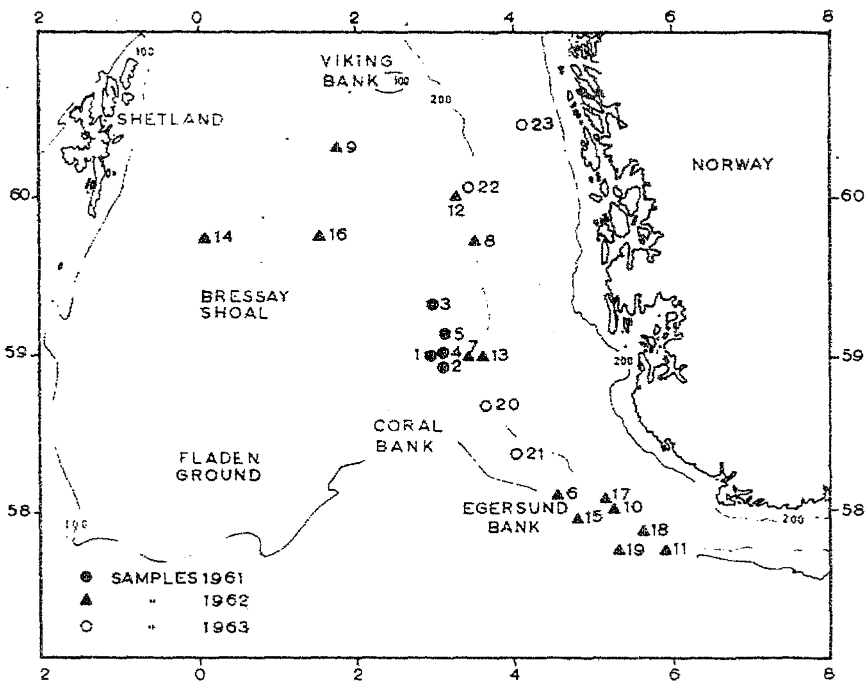

Fig. 3. Sampling locality.

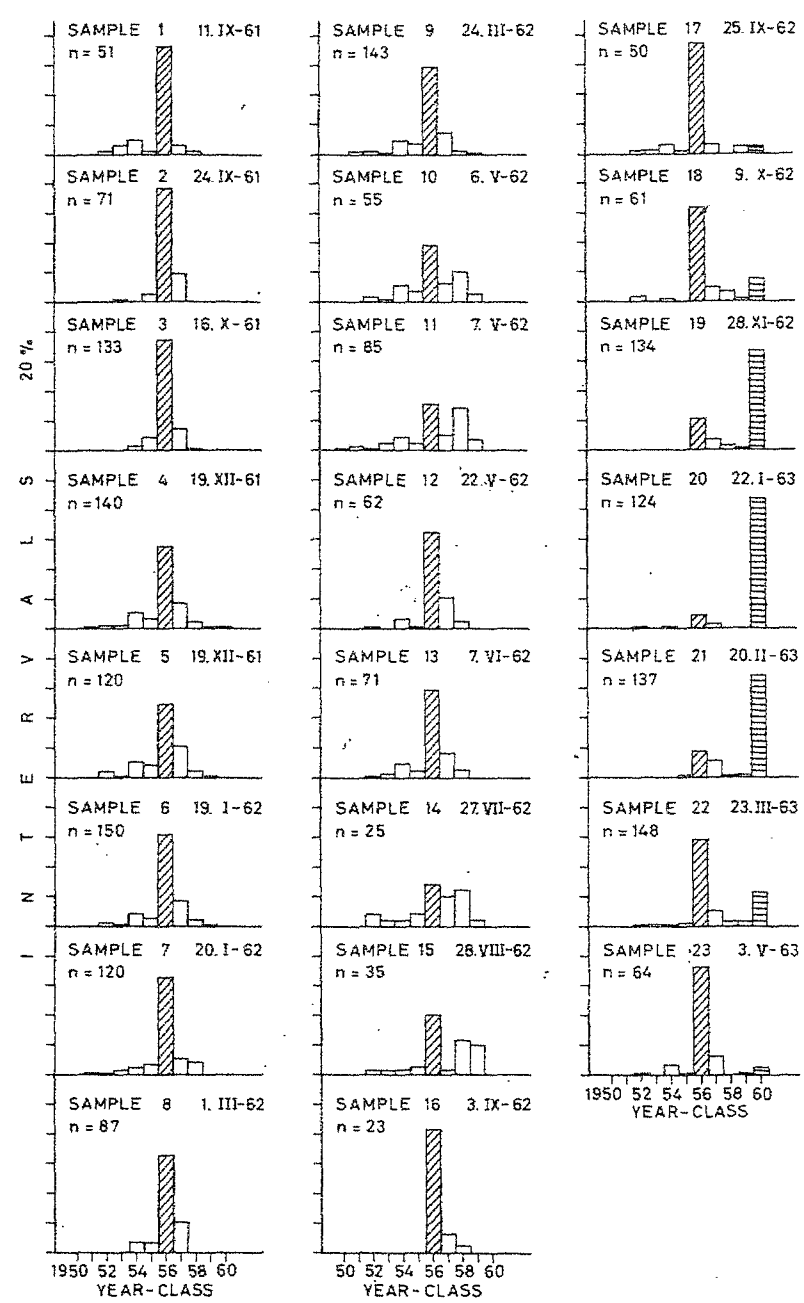

Fig. 4. Age composition of autumn spawning herring from north-eastern North Sea, 1961-63.

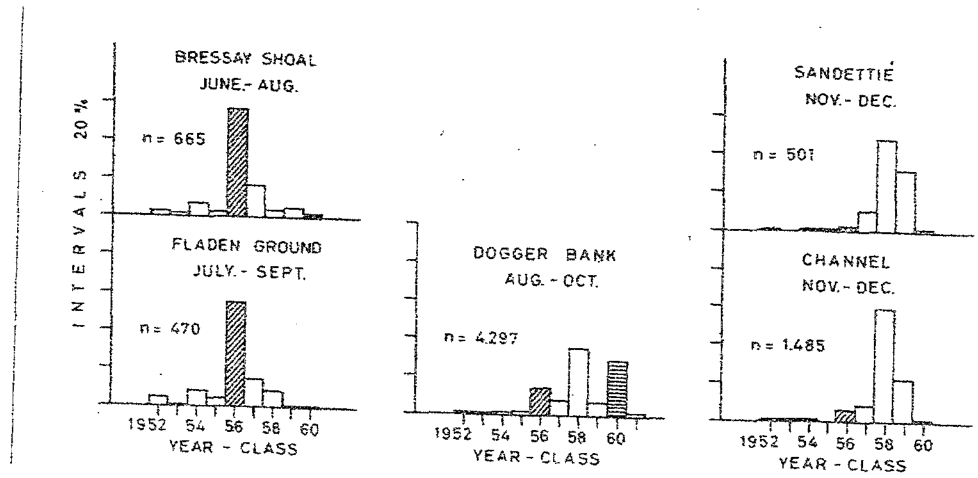

Fig. 5. Age composition of herring from western central and southern part of the North Sea, 1962.

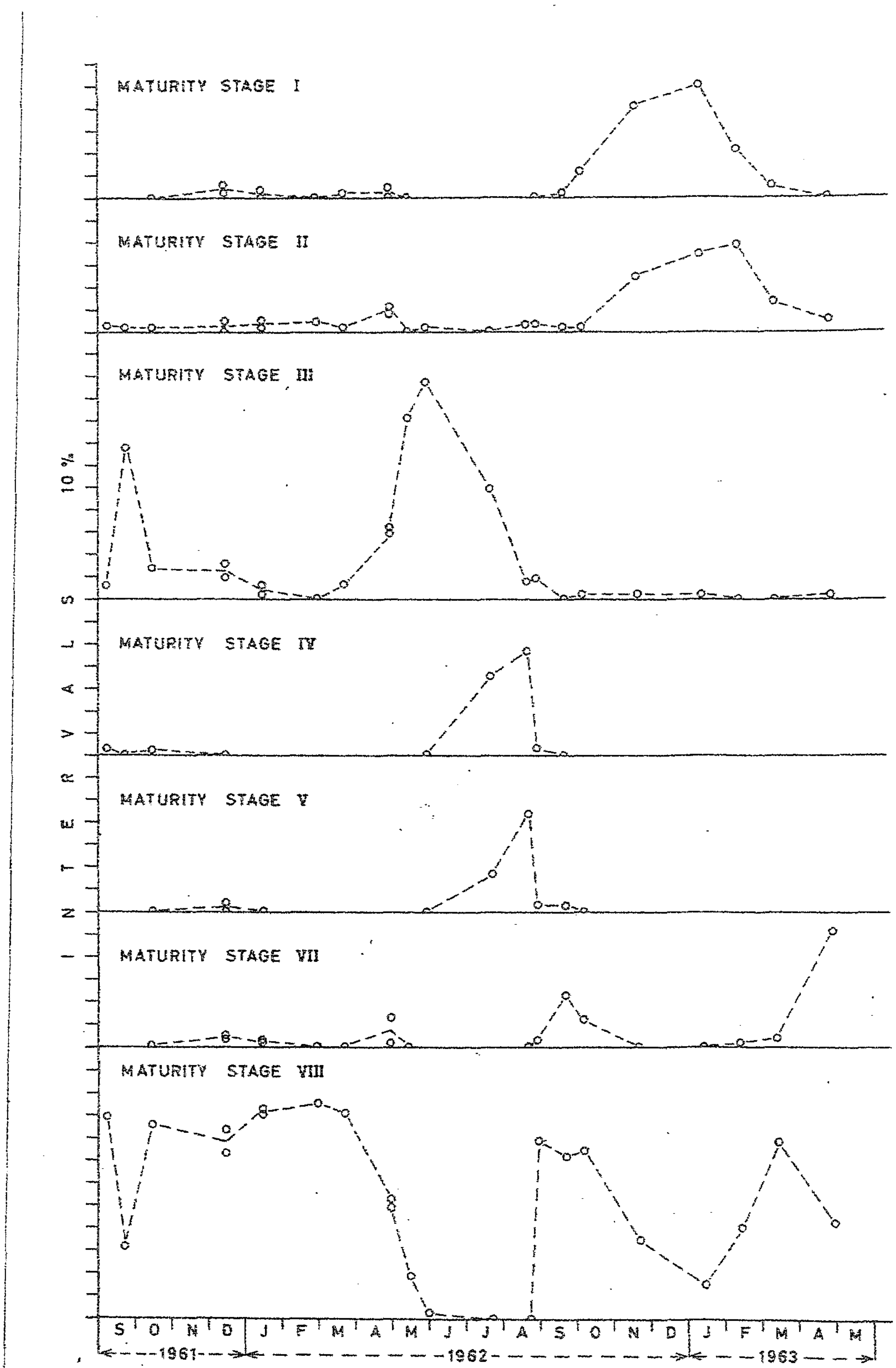

Fig. 6. Maturity stages of autumn spawning herring from north-eastern North Sea 1961-63.

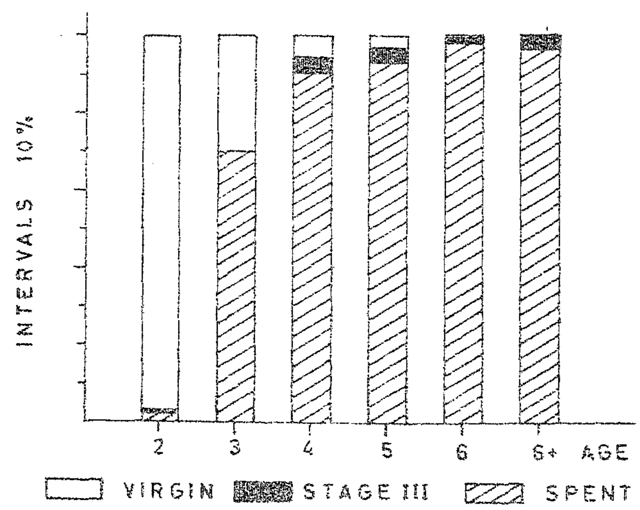

Fig. 7. Compositions of virgin herring, herring in maturity stage III and spent herring during autumn and winter amongst 2-6 + year-old autumn spawning herring in north-eastern North Sea.

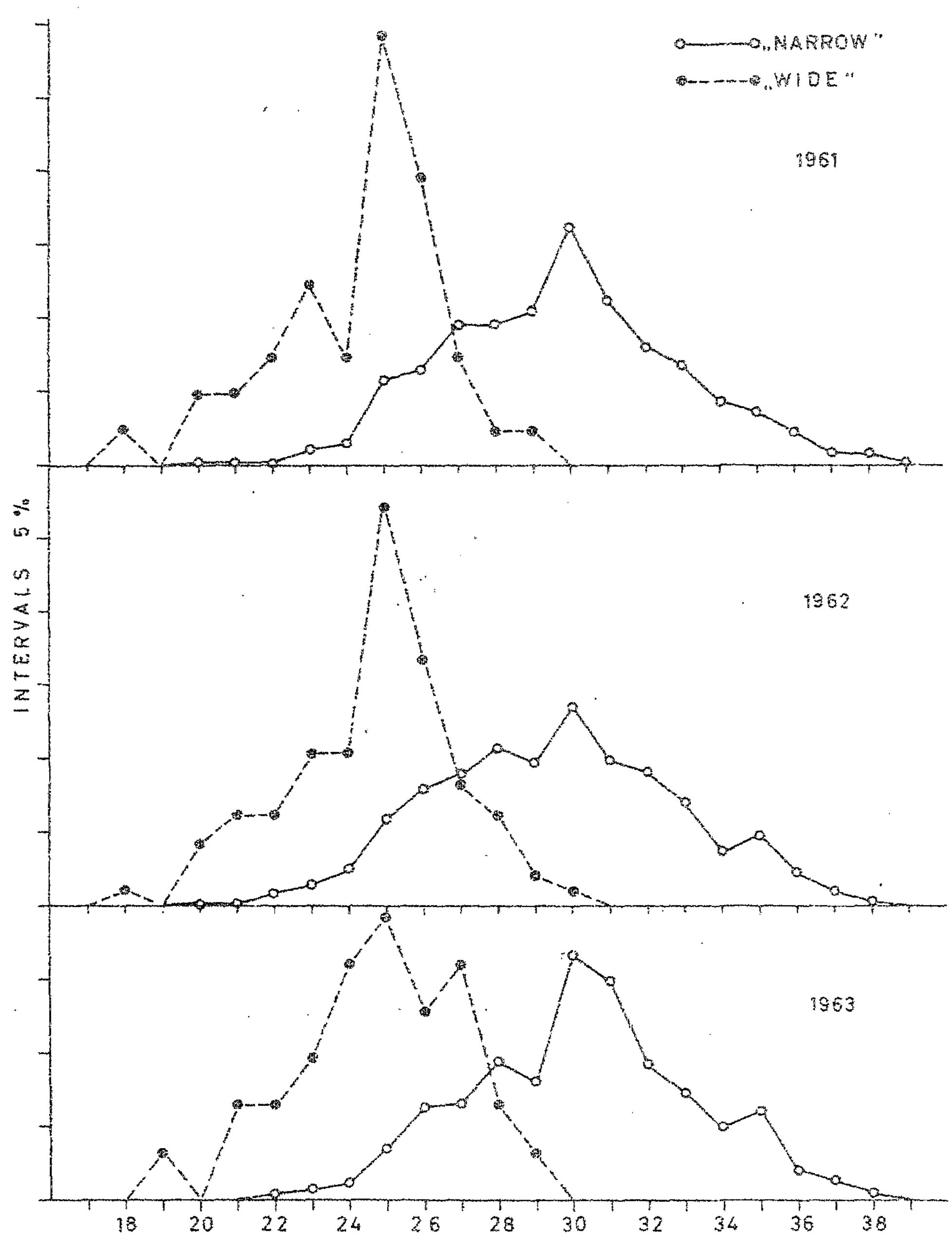

Fig. 8. Frequency distributions of otolith zone measurements in "wide" (●---●) and "narrow" (○—○) types of autumn spawning herring in north-eastern North Sea, 1961-63.

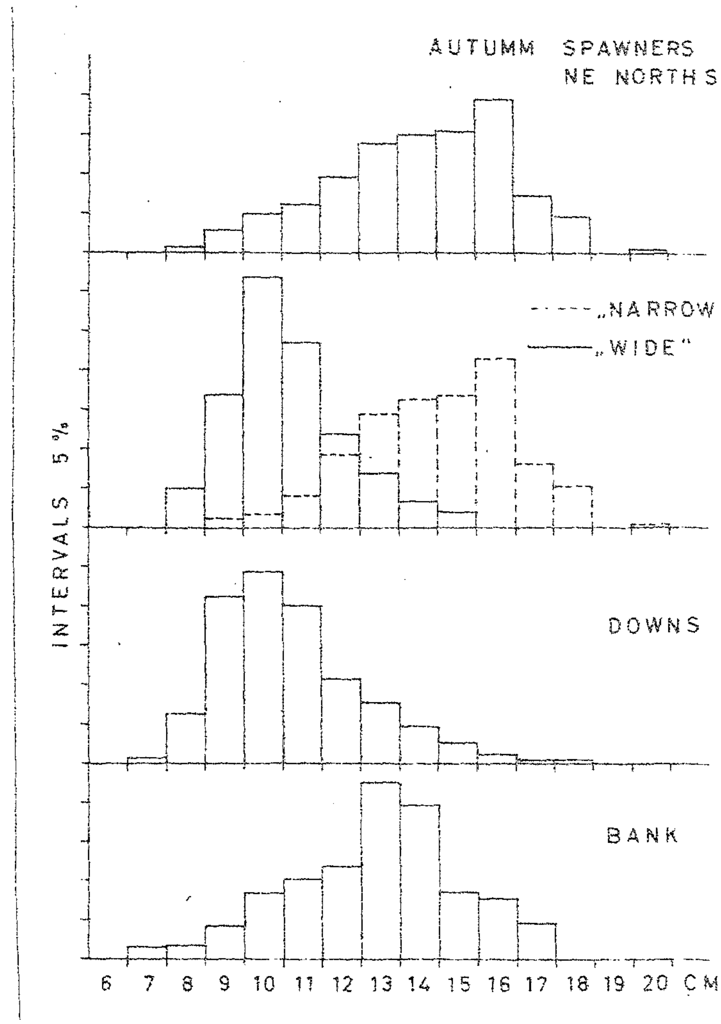

Fig. 9. Frequency distribution of l_1 for the autumn spawning group of herring (total and separated in "wide" and "narrow" types) in north-eastern North Sea, compared with the l_1 distribution for the Bank and Downs herring stocks.