On the Immature Herring of the North Sea

By

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Introduction

Since 1950, the size of the adult North Sea herring showed an increase and a change took place in the pattern of recruitment to the adult stocks (ANCELLIN, 1953; ANDERSEN, 1954; KREFFT *et al.*, 1955; CUSHING and BURD, 1957).

The interpretation of these facts led to a discussion between HODGSON (1956a, b) and CUSHING (1962) which concerned the immature herring.

Pre-war investigations indicated as the main nursery areas of North Sea herring:

1. The area to the north-west of the Dogger (BJERKAN 1918; HODGSON, 1925b; WOOD, 1937).
2. The area to the east of the Dogger (HODGSON, 1925).
3. Skagerak (BJERKAN, 1918).
4. Scottish Firths (WOOD, 1937; BJERKAN, 1918).

HODGSON showed the immatures to the east of the Dogger to be smaller than those to the north-west (HODGSON, 1925b). This fact led him to ascribe the observed growth phenomena in the adult herring to a selective removal of the small immature fish by an industrial fishery in the area east of the Dogger, developed in the years around 1950 whereas CUSHING decided on a true change in the growth rate of the herring. As both authors comprised the immature herring in their views, a greater knowledge of the juvenile stock in the North Sea might be of considerable assistance in the efforts to explain the causes of the changes in the adult herring.

In this paper an attempt will be made to detect from analysis of length and age data, whether the apparent changes in growth and in recruitment pattern in the adult herring can be traced back in the immature stock. A second aim of this paper is to provide a better insight in the distribution and recruitment pattern of the young herring, both before and after 1950.

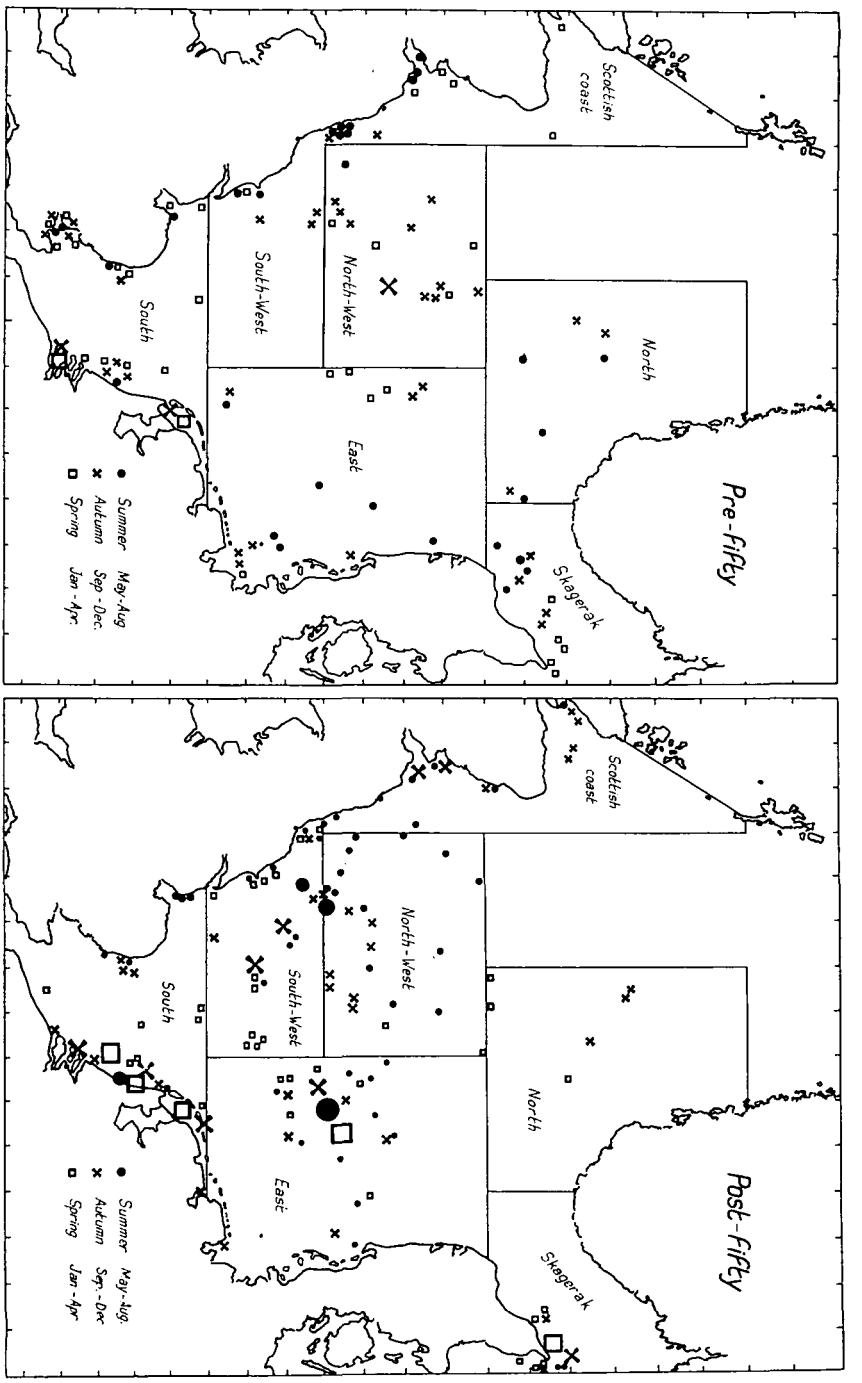

Figure 1. Distribution of samples of immature herring, in the pre- and post-fifty period, described in this paper.

Table 1

Account of the material used in this paper, shown by area, season and period (see References). bers unknown, usually rather large; (400*) = over 400. N.D. signifies

Pre-fifty

Area	Summer	Autumn	Spring
NORTH	BJERKAN, 1918 pp. 20, 21; Table 1 (37)	BJERKAN, 1918 pp. 20, 21; Table 1 (13)	—
SKAGERAK	BJERKAN, 1918 pp. 20, 21; Table 1 HEINCKE, 1898 p. 73; Table 55 JOHANSEN, 1924 pp. 104; Table D (80)	BJERKAN, 1918 pp. 20, 21; Table 1 (67)	JOHANSEN, 1924 pp. 100, 107; Tables C, G 63, 65, 67 (921)
SCOTTISH COAST	BJERKAN, 1918 pp. 20, 21; Table 1 HODGSON, 1929 p. 38; Table 15 (2,670)	HODGSON, 1929 p. 38; Table 15 WOOD, 1937 pp. 19, 48, 49; Table 12, appendix (?)	WOOD, 1937 pp. 19, 48, 49; Table 12, appendix (400*)
NORTH-WEST	—	BJERKAN, 1918 pp. 20, 21; Table 1 LISSNER, 1926 p. 499; Table 5 WOOD, 1937 pp. 48, 49; appendix (1800)	HODGSON, 1925b p. 5; Table 1 WOOD, 1937 pp. 48, 49; appendix (240)
SOUTH-WEST	—	HODGSON, 1925b p. 7; Table 4	HODGSON, 1929 p. 40; Table 16
EAST	BJERKAN, 1918 pp. 20, 21; Table 1 HEINCKE, 1898 p. 114; Table 96 (640)	BJERKAN, 1918 pp. 20, 21; Table 1 HEINCKE, 1898 pp. 115, 116, 119, 121; Tables 97, 98, 99, 103, 105 HODGSON, 1925b p. 7; Table 3 JOHANSEN, 1924 p. 99; Table B (680)	HEINCKE, 1898 pp. 117, 118; Tables 51, 52 HODGSON, 1925b p. 5; Table 1 (790)
SOUTH	SAVAGE, 1919 p. 19; Table 6 (3,050)	HODGSON, 1929 pp. 32, 40; Tables 8, 16 SAVAGE, 1919 p. 18; Table 3 N.D. (4,660)	HODGSON, 1929 pp. 32, 40; Tables 8, 16 HODGSON, 1925b p. 6, Table 2 SAVAGE, 1919 pp. 18, 19; Tables 3, 4 N.D. (7,640)

Figures refer to the numbers of immature herring, found in all samples together.(?) = num-data found in the records of the Netherlands Fisheries Institute

	Post-fifty	
Summer	Autumn	Spring
	N. D.	N. D.
—		
	(150)	(150)
	JENSEN, 1956 p. 154; Table 45 JENSEN, 1957 p. 213; Table 76 JENSEN, 1958 p. 210; Table 50	JENSEN, 1956 p. 154; Table 45 JENSEN, 1957 p. 213; Table 76 JENSEN, 1958 p. 210; Table 50
—	(?)	(?)
McPHERSON, 1952 p. 142; Table 5 N. D.	McPHERSON, 1951 p. 128; Table 4 McPHERSON, 1952 p. 142; Table 5 McPHERSON, 1953 p. 179; Table 6 McPHERSON, 1954 p. 153; Table 8 McPHERSON, 1956 p. 123; Table 5 McPHERSON, 1957 p. 174; Table 13	McPHERSON, 1951 p. 128; Table 4 McPHERSON, 1952 p. 142; Table 5 McPHERSON, 1953 p. 179; Table 6 McPHERSON, 1954 p. 153; Table 8 McPHERSON, 1956 p. 123; Table 5 McPHERSON, 1957 p. 174; Table 13
(2,500)	(?)	(?)
N. D.	N. D.	N. D.
(1,000)	(810)	(100)
N.D. (930)	N.D. (1,129)	N.D. (200)
BAHR, 1954 p. 221; Table 4 KÜHL, 1957 p. 182; Table 1 KÜHL *et al.*, 1957 p. 62; Figure 1 TIEWS, 1956 p. 51; Figure 1 N. D.	BAHR, 1954 p. 221; Table 4 TIEWS, 1956 p. 51; Figure 1 KÜHL *et al.*, 1957 p. 62; Figure 1 N. D.	POPP MADSEN, 1956 p. 4; Figure 1
(1,200*)	(2,000*)	(?)
WOOD, 1954 p. 154; Table 9 WOOD, 1956 pp. 124, 125; Tables 7, 8 N. D.	WOOD, 1954 p. 154; Table 9 WOOD, 1956 pp. 124, 125; Tables 7, 8 N. D.	WOOD, 1954 p. 154; Table 9 N. D.
(1,300*)	(5,000*)	(4,100*)

Material

Part of the material used was found in unpublished records of the Netherlands Fishery Institute, including both samples collected in recent years, and material collected by REDEKE, DELSMAN, TESCH and HAVINGA in pre-war years. Most of the evidence used is, however, derived from literature. Part of this latter material was collected and published with a special view to study the distribution of the immature herring (BJERKAN, 1918; HODGSON, 1925b; WOOD, 1937), but a considerable quantity was collected for a variety of other reasons, e.g. to estimate the removal of immature herring by the herring trawl (FULTON, 1922; BORLEY and RUSSELL, 1922; LISSNER, 1926) or to study the commercial catches of immature herring (KÜHL, 1957; KÜHL and TIEWS, 1957; POPP MADSEN, 1956; TIEWS, 1956).

To facilitate an analysis of the material derived from the various sources indicated, it has been compiled as follows:

1. Two periods were distinguished, a pre-fifty period (prior to 1950) and a post-fifty period (1950-1959), related to the change in the size of the adult herring. Material for the period 1939–1950 proved to be extremely scarce.
2. The year was subdivided in three seasons called: *summer* (May–August), *autumn* (September–December) and *spring* (January–April).
3. The North Sea has been split up into a number of areas, indicated in Figure 1. This chart gives also the distribution of the samples used in the pre- and post-fifty periods with a reference to the season in which the samples were collected.

A full account of the origin of the material utilized has been given in Table 1, which refers to the list of references.

4. Samples from the same period, season and area, but often different as to author and year of catch, have been condensed into one length distribution, in which all samples had an equal weight.
5. For the sake of convenience the first of May was adopted as the nominal birthday of the herring.

Results

(a) Growth changes

If HODGSON's explanation of the observed changes in the adult herring were correct and these changes had to be ascribed to the industrial fishery on the grounds where the small-sized I-group herring are found, the size distribution of the immature herring could be expected to have been similar in the various areas in both the pre- and post-fifty period. CUSHING's interpretation might, on the other hand, imply an increased size of the immature herring in all areas in the post-fifty period.

In Figure 2 the length distributions of immature herring of all age-groups are shown for each area, season and period. Although the presence of various age-groups, appearing from the polymodality of the length curves, complicates the picture, the material does suggest in most cases that compared with the pre-fifty period an increase in size really took place in the post-fifty years. A better comparison, which moreover enables us to evaluate the magnitude of the lenth increase, is obtained when the length curves are separated according to age-groups.

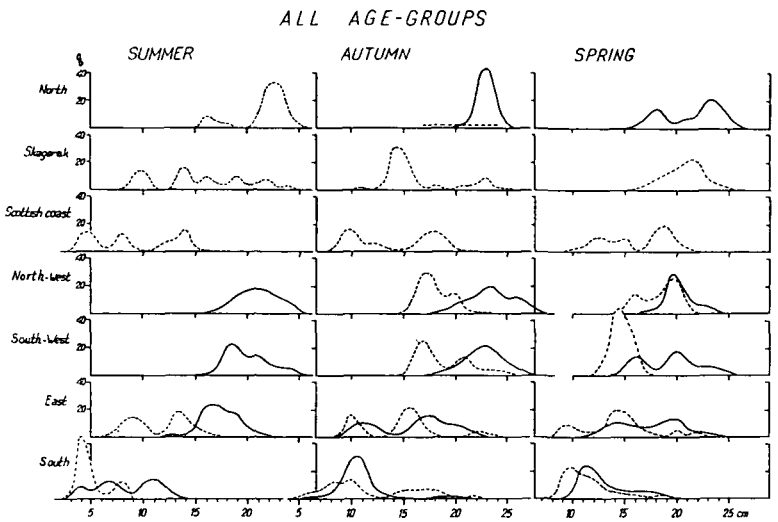

Figure 2. Length composition of immature herring in various areas and seasons, in the pre- and post-fifty period.
– – – – – – = pre-fifty; ———— = post-fifty.

This appeared to be possible by the application of length-age information, available for part of the samples, to all the samples from the same season and area, within each of the two periods. Such a procedure may be open to objection, but the fact that in general the age-groups coincided with the modes in the length curves suggests that no serious errors will have been made.

The length distributions of the 0-group herring in the pre- and post-fifty period are shown in Figure 3. The question whether there are signs of an increase in length among the immature herring is especially important for this age-group, because it is hardly touched by the industrial fishery. Judging from L_1 measurements in adult III-group herring from the Southern Bight, an increase in size in the 0-group herring of some 2·5 cm might be expected in the case of a true growth change (BURD, 1962: 1929–1934 year-classes, average L_1 = 9·2 cm; 1950–1954 year-classes, average L_1 = 11·4 cm).

Though the length data for areas east and south, shown in Figure 3, do, indeed, suggest an increase in the size of 0-group herring in post-war years, it is extremely difficult to estimate the actual magnitude of the increase. Furthermore, there are reasons to question the reliability of the material due to difficulties in sampling the 0-group herring in a representative way. Samples of I-group herring, collected in the same area and season, tend to be very similar. Samples of 0-group herring sometimes showed great differences in length composition, even when collected at short distances, especially in coastal areas. It seems therefore quite possible that unrepresentative sampling could have affected the length data in Figure 3, and it was therefore decided to investigate some better known situations.

An opportunity to check this difference was offered by the availability of length measurements of 0-group herring from commercial catches along the Dutch coast. Fishing for whitebait takes place in the inlets in the south and north of Holland, and further in the open sea off the coast. The 0-group

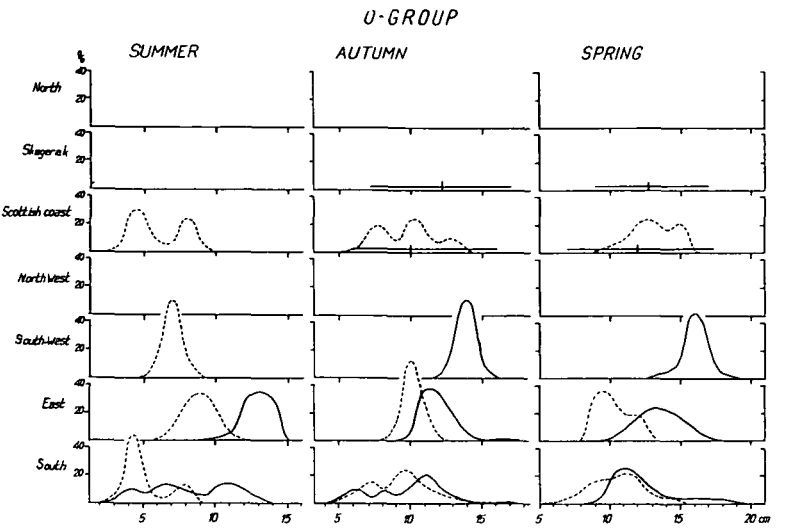

Figure 3. Length composition of 0-group herring.
– – – – – – = pre-fifty; ———— = post-fifty.
——|—— = only length range is known; – – – –|– – – – = only mean length is known.

herring caught in this fishery differs in length, as is demonstrated by the following figures obtained in the period 1955–1959: inlets (south) 10·6 cm, inlets (north) 10·8 cm, open sea 12·5 cm. The fact that the larger individuals are found in the open sea is a common feature in 0-group herring and is presumably brought about by an offshore migration of the larger individuals.

Comparison of pre- and post-fifty data gave us three arguments in favour of a larger size of the 0-group herring along the Dutch coast in the latter period.

1. With few exceptions the mean lengths of whitebait in the inlets fluctuated around 9·2 cm in pre-fifty years, but around 10·5 cm in post-fifty years (see Figure 6).

2. Fishing in the inlets commenced in late autumn and went on until spring in the pre-fifty period, whereas it started already in summer in post-fifty years, and was of little importance late in winter, which suggests that the fish will nowadays reach a commercial size at an earlier date and will subsequently leave the inlets earlier than under pre-fifty conditions.

3. In a winter fishery on sprats in the open sea, 0- and I-group herring are regularly found as by-catch in post-fifty years, but for the pre-fifty period records on 0-group herring are missing, though the presence of I-group herring was reported.

Because the larger sized open sea fraction of the 0-group herring was absent in the pre-fifty period, a length increase of 1·3 cm as found for the whitebait in the inlets is without doubt an underestimate, considering the Dutch coastal area as a whole. The true magnitude of the increase is, however, very hard to estimate with this pattern of distribution.

Another situation was found in the German Bight (area east) where both in the pre- and post-fifty period samples were collected in the open sea in July, probably close to the seaward limit of the 0-group concentration. BJERKAN

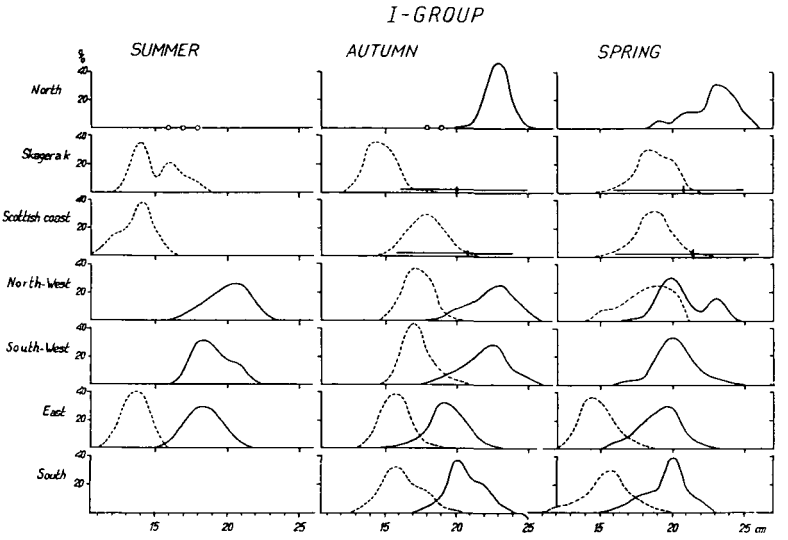

Figure 4. Length composition of I-group herring.
Symbols as in Figure 3.

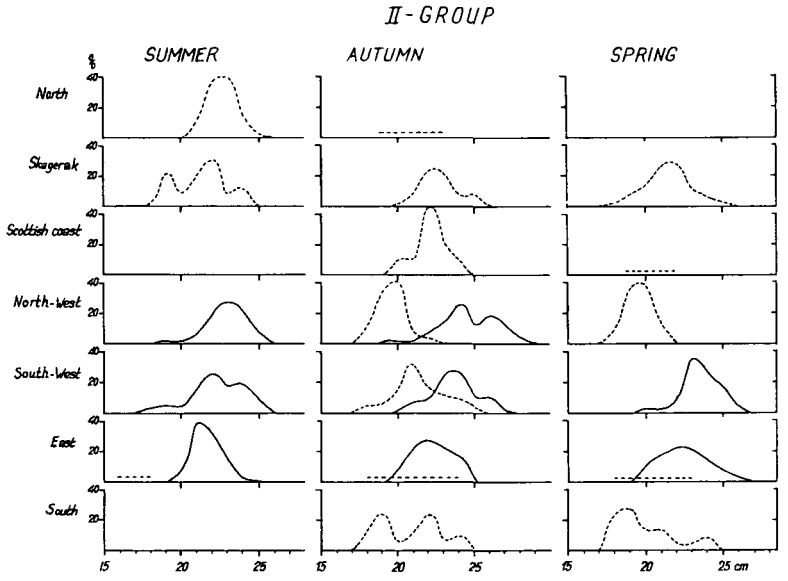

Figure 5. Length composition of II-group herring.
Symbols as in Figure 3.

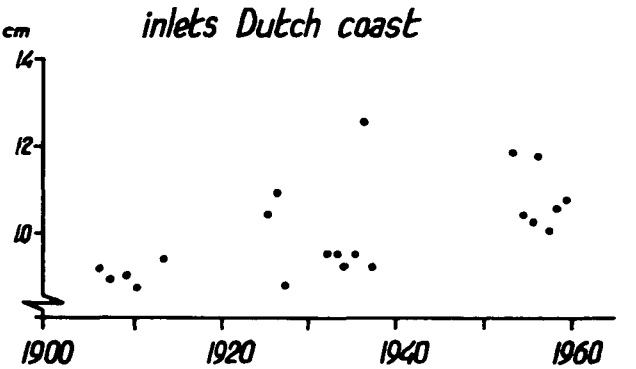

Figure 6. Mean length of 0-group herring during autumn and spring in the inlets along the Dutch coast in some years in the period 1900–1960.

(1918) describes 0-group herring caught off the Danish and German coasts in 1912 with a mean length of 9·2 cm, whereas we caught in 1959 in the vicinity of the White Bank 0-group herring with a mean length of 12·7 cm: a difference of 3·5 cm.

I-group herring predominates in the samples and these will probably show the most reliable length data. In this group the increase in size was observed in all areas, as shown in Figure 4, and varies from 2·5 cm to 5·5 cm with an average of about 4 cm. In all areas together the length compositions ranged in the pre-fifty period from 13–20 cm, in post-fifty years from 16–25 cm, which also indicates an increase in size of some 4 cm. This value of 4 cm is in good agreement with the differences between the pre- and post-fifty estimates of L_2 averages from adult III-group herring in the Southern Bight (pre-fifty:

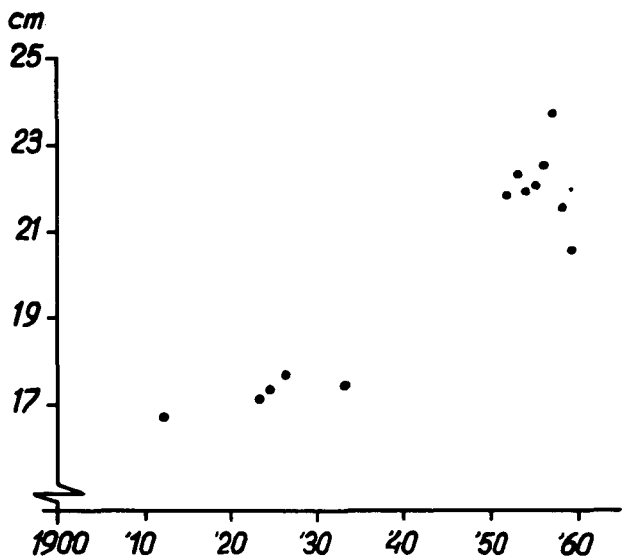

Figure 7. Mean length of I-group herring in the areas south-west and north-west in the autumn of some years in the period 1910–1960.

1924, $L_2 = 16{\cdot}8$ cm (HODGSON, 1925a); post-fifty: 1953–55, $L_2 = 20{\cdot}9$ cm (Netherlands data)).

Though Figure 5 indicates a length increase in II-group herring, the data shown may be complicated by an admixture of adolescent and adult herring, especially in post-fifty years. For this reason no attempt has been made to evaluate the growth increase in the immature II-group. Besides, at this age the selective action of the industrial fishery, assumed by HODGSON, would have worked already and the data on the II-group are therefore not decisive.

The material on 0- and I-group herring thus shows that the increase in size which occurred in the adult herring in the years around 1950, was accompanied by a similar change in the immature herring. This indicates a true growth change, as advocated by CUSHING, rather than an effect of the industrial fisheries.

In the material there is little evidence pointing to a gradual change in the growth rate of the immature herring prior to 1950, as mentioned for the adult herring by CUSHING (1957). The data shown in Figure 6 for 0-group and Figure 7 for I-group fish do not clearly indicate such a gradual change.

(b) Distribution of immature herring

From the preceding section it appears that along with an increased size of the immature herring went an increased size of the juvenile fish. The question arises now how this size increase affected the distribution and movements of the immature herring and the recruitment to the adult stock.

From Figure 1 it appears that immature herring occur in the whole southern and central North Sea, including the Skagerak and the Scottish firths. Judging by the sampling locations of immature herring no major changes can be found in the general distribution of the immature herring in the pre- and post-fifty years, with the exception of changes in sampling intensity.

The distribution of juvenile herring according to length (irrespective of age) can be seen in Figure 2 and appears to be as follows: smaller herring, mixed with some larger individuals are found in the regions south, east, Scottish coast and Skagerak, whereas in the areas south-west, north-west and north only the larger sized herring occur. Within an age-group the length distribution of the herring in the areas shows a similar pattern as may be seen in Figure 4 for the I-group, for which the more reliable data are available: the smaller sized specimens are found in the areas south and east, the larger sized ones in the areas south-west, north-west and north. Although the overall length of immature herring in the Skagerak and Scottish coast areas is rather small, the I-group herring in these areas do not always belong to the small sized category.

Taking the geography of the North Sea into account, the pattern indicates that the smaller sized herring occur predominantly in the shallower parts, the larger sized in the deeper areas, which confirms HODGSON's hypothesis (1925b) concerning a relationship between the length of the immature herring and the depth. It is possible, because of the great differences in depth over short distances that the samples from the Skagerak and Scottish coast do show some irregularities.

In view of the apparent relationship between the length of the herring and the depth, an increase in size in the immature herring might result in an

accelerated migration towards the deeper water in a western and northern direction. This would affect the relative numbers in the various areas rather than the size in each area. The fact, mentioned above, that an increase in length took place in all areas and especially that in the I-group this increase was everywhere of approximately the same magnitude, conflicts with a strong migration towards the deeper water, following the increase in size.

There are, however, some arguments indicating that a shift to the deeper water did take place, if on a limited scale.

The first argument concerns BJERKAN's "northwest patch" (area north-west). Herring trawlers have been working this area more or less continuously since 1910. Their catches consisted mainly of adult herring, with a small by-catch of immatures. The relative importance of the immature herring in the catches could give an indication about possible changes in their abundance, provided that no great changes had occurred in the size of the adult stock. Expressing the I-group herring as percentages of the total catch (in numbers), the following summary can be given:

Period	Author	% I-group of total catch	Remarks
Pre-fifty			
1911–1915	STORROW (1920)	0·7	Landings at North Shields
1913	FULTON (1922)	3·0	Research vessel catches*
1913	BORLEY and RUSSELL (1922)	2·0	Trawl catches on "Outer Grounds"*
1913	BORLEY and RUSSELL (1922)	0·9	Trawl catches on "Inner Grounds"*
1922–1934	EHRENBAUM (1934)	0–7, av. 1·8	German trawl catches
Post-fifty			
1955–1958	SCHUBERT (1957, 1958, 1959, 1960)	1–52, av. 21	German trawl catches
1952–1954	Netherlands data	1–20, av. 8	Research vessel catches
1955–1958	Netherlands data	1– 6, av. 3	Landings in IJmuiden

The low post-fifty figure for the Dutch commercial landings is probably due to the fact that the Dutch trawlers have mainly been exploiting the spawning concentrations in the Dogger region, rather than the maturing and spent fish caught in the pre-fifty fisheries and by the German post-war fishery, as appears from maturity data.

Considering all facts, the pre-fifty level of I-group herring can be estimated at approximately 2%, the post-fifty level at roughly 10%, which indicates an increase in abundance of I-group fish in the "northwest patch", unless the adult stock was reduced by 5 times or more, which does not seem very likely.

A second argument indicating an increased abundance of I-group herring in the deeper areas is provided by some summer fisheries in the western and northern North Sea, where I-group herring occur more frequently in the catches since the growth increase. In the Shields fishery I-group fish made up 0·7% of the catches in 1912–1919 (STORROW, 1920) against 17% in 1957–1962 (Fish Stock Record, 1958–1962).

On the Buchan grounds I-group herring were found in the catches in only

* Number of I-group herring estimated from length distributions with length-age key from BJERKAN (1918). Obtained length distributions for I-group point to overestimate.

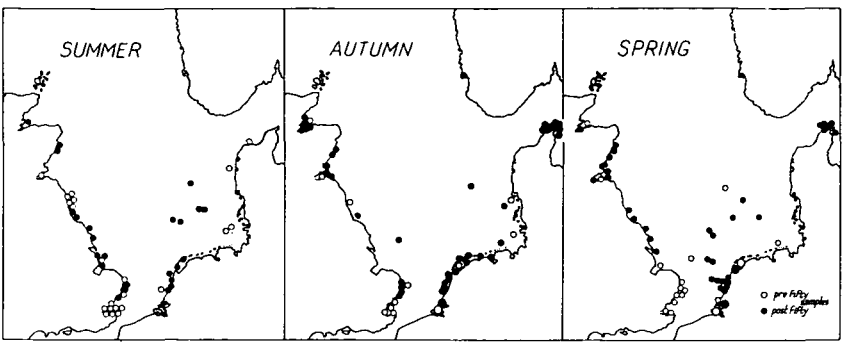

Figure 8. Distribution of samples, containing 0-group herring, in the pre- and post-fifty period.

4 out of a total of 10 seasons during the pre-fifty period, whereas they occurred in 5 out of 6 seasons in post-fifty years. The average abundance, however, expressed in crans per landing hardly increased, from 0·026 crans to 0·032 crans (PARRISH and CRAIG, 1957).

The data on the Shields and the Buchan fisheries concern drift-net catches and mesh selection may have affected them, a factor probably not operating in the trawl fishery on the Fladen Ground, where I-group fish were absent in the pre-fifty period (EHRENBAUM, 1934) but were found in small quantities in the post-fifty catches (SCHUBERT, 1957–1960; PARRISH *et al.*, 1954–1958).

(c) Movements of immature herring

0-group (Figures 3 and 8)

Both in pre- and post-fifty years, in summer and autumn, the distribution of 0-group herring seems to be restricted to the shallow waters and inlets along the coasts, though in some of the samples collected in the open sea in areas east and south 0-group herring were already present in summer.

An offshore migration seems to take place in early spring, leading to a larger quantity of 0-group herring to be found in the open sea, dispersed over a wider area. For the post-fifty period, this view is supported by evidence from the industrial fishery in the Bløden area (area east) where this age-group is virtually absent in the autumn catches whereas the spring catches are made up for a large part by 0-group herring (POPP MADSEN, 1956). Besides, in spring, 0-group herring seem to invade area south-west (Silver Pit, Fig. 8) and possibly also area north-west, as was observed during the young herring trawling survey in 1960.

For the pre-fifty period, there are two samples taken by HODGSON (1925b) in March 1924 on the Tail End of the Dogger and in the Silver Pit area, and made up for a large part of 0-group herring which together with the presence of a few 0-group herring in the samples described by WOOD (1937) from the area north-west, indicate at least a wide dispersal of the fish.

Although the material available suggests in general a similar distribution of the 0-group herring in the two periods, there are some indications which point to a greater importance and a wider area of distribution of the open sea fraction in post-fifty years:

1. The presence of larger sized fish off the Dutch coast in recent years (see the section on growth changes).
2. Samples collected on the eastern edge of the Dogger in spring containing proportionally more 0-group herring in the post-fifty years (44% against 24%).
3. Only those of BJERKAN's summer catches in area east taken close to the coast contain 0-group herring, whereas in recent years 0-group herring were found much further offshore (see Figure 8).

I-group (Figure 4)

In summer and autumn the distributions of I-group herring show both in the pre-fifty and post-fifty period the pattern already mentioned in a preceding section: the larger sized fish are found in the regions with a greater depth (areas south-west, north-west and north), the smaller sized ones in the shallower areas. The only exception is formed by the fish in area south-west in summer (post-fifty), which are similar to those in area east, this in contrast to the situation in autumn when the herring in the area south-west closely resembles those of area north-west. This could be explained by an eastward migration of small herring from the English north-east coast through area south-west in summer.

In spring, however, there are marked differences between the pre- and post-fifty periods. In the pre-fifty period the length compositions in the various areas (south, east, south-west, north-west) were similar to those in the previous autumn. In the post-fifty period, however, the length of the fish in areas south-west and north-west is notably smaller than in the previous autumn, suggesting admixture with fish of the length of areas south and east. In the latter areas no change in length took place. These phenomena are most easily explained by assuming a north-west migration of I-group fish from areas south and east in the post-fifty period, during winter.

In the next section we will try to demonstrate that the distribution of II-group herring supports the idea, that the spring migrations of I-group fish were different before and after the growth change.

II-group (Figures 5 and 9)

To facilitate comparison with the length data of the I-group herring the L_2 distribution of II-group fish (obtained from back calculation on the scales) will be used rather than the actual length data.

In Figure 9 the length composition of I-group herring in the main nurseries has been set against the L_2 frequencies of II-group fish from some areas. A comparison of the graphs lead to the following, tentative conclusions:

(i) In the pre-fifty period, the L_2 values of the II-group herring in the Shields area in summer were large compared with the length of I-group fish in the nurseries and it seems therefore likely that the II-group herring represented a selection of the largest fish from the north-west nursery (or from the Scottish coast).

In the post-fifty period, however, the L_2 values are only medium and the II-group fish could well have originated from both the nurseries east and north-west of the Dogger (or were a selection of smaller fish from area north-west). This change in recruitment pattern of the II-group herring counter-balanced the change in growth rate so that the L_2 values in the Shields area are rather similar in the pre- and post-fifty period.

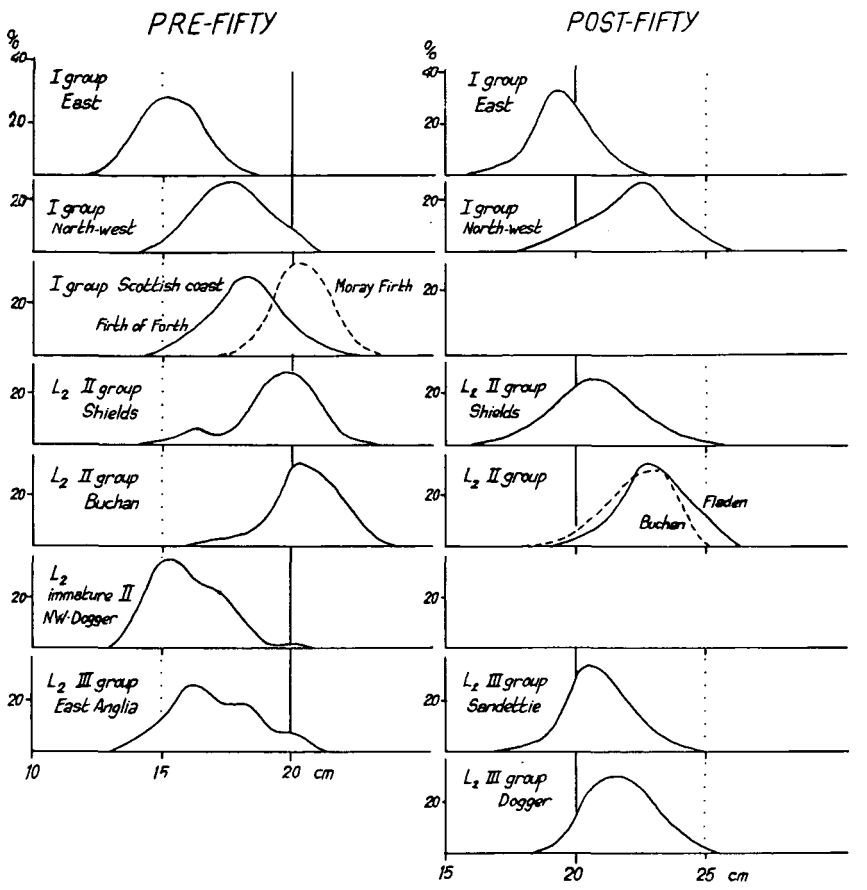

Figure 9. Length compositions of I-group herring in areas east, north-west and Scottish coast, compared with L_2 frequencies of II- and III-group immature, pre-spawning and spawning herring of some North Sea areas, in pre- and post-fifty years (see text).

(ii) In the Buchan area the L_2 values of II-group herring were extremely large in pre-fifty years, compared with the length of I-group fish in the nurseries. It seems probable that the II-group fish in that period, recruited mainly from the Scottish coast, as WOOD (1937) suggested, with a possible addition of a selection of very large herring from the north-west nursery.

In the post-fifty period, there is a close resemblance between the L_2 distribution of the II-group herring in the Buchan (Fladen) area and the length composition of the I-group in the north-west nursery. This suggests that a large part of the Buchan (Fladen) II-group herring came from area north-west; although it seems likely that some of the Buchan fish originated from the Scottish coast nurseries, for which detailed information is lacking.

(iii) The II-group herring in the Shields and Buchan areas were mainly adolescent and maturing fish, in both the pre- and post-fifty period. In post-fifty years most of the herring matured in their third year of life (II-group),

leaving very few fish in the nurseries. Under pre-fifty conditions, however, only part of the herring became mature in their third year and immature II-group herring were found in area north-west, in autumn. The L_2 distribution of these immature 2-ringers, shown in Figure 9, suggests that they originated from the eastern nursery and to a lesser extent from those present in the north-west nursery in spring.

In the section on the migration of I-group fish, it was shown that in the pre-fifty period there were no signs that fish from the eastern nursery had migrated to area north-west in spring. The appearance of immatures from area east in the north-west nursery as 2-ringers in autumn suggests that a migration from area east to area north-west took place between spring (I-group) and autumn (II-group).

A number of samples, not shown in Figure 9, indicated that immature II-group herring, originating from the north-west nursery were also present in the following areas:

1. An area 80–125 miles east of the Tyne, in September–October, (trawl samples described by STORROW, 1914).
2. The Inner Trawling Ground in autumn 1924 (HODGSON, 1925b).
3. The Firth of Forth, autumn samples, described by WOOD (1936).

These samples suggest a somewhat wider distribution of the herring from the north-west nursery than discussed under headings i–iii.

The fate of the large residue of immature herring, not recruiting to the adult stock in their third year in the pre-fifty period, is indicated by L_2 data given by STORROW (1914) for the Shields area. These show, for II–V group herring, a gradual decrease in L_1 with increasing age, to values of 15–16 cm, i.e. to the length of the I-group herring in area east. The decreasing L_2 values can be explained by assuming a recruitment from the north-west nursery at higher ages, in which the small herring, originally coming from area east, came last.

The relation between the I-group nursery and the adult herring in some spawning concentrations is indicated by the L_2 distributions of the spawning fish, shown in Figure 9 (pre-fifty: III-group East Anglia; post-fifty: III-group Sandettié and Dogger). For both periods, the fact that the length distributions of the spawners are intermediate between those of the two main nurseries points to the presence of fish from both nurseries among the spawners; Downs spawners containing more fish from the eastern nursery, Dogger herring more from the north-west nursery.

Discussion and Conclusions

Although we are quite aware that the heterogeneous material used may be of limited value, we feel convinced that it does allow some tentative conclusions.

The main problem considered in this paper, is the question whether the changes in size and recruitment pattern observed in the adult North Sea herring since about 1950, were accompanied by similar changes in the immature stock. It was anticipated that this might provide new evidence on the subject discussed by HODGSON and CUSHING.

The fact that an increase in the size of I-group herring occurred in all the main nurseries is difficult to reconcile with HODGSON's hypothesis to account

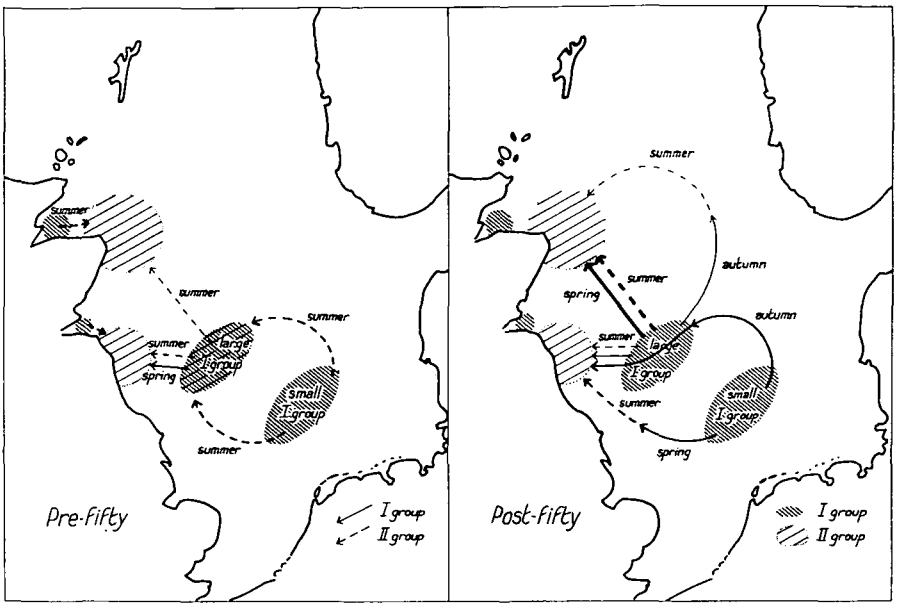

Figure 10. Schematic presentation of the migration pattern of immature I- and II-group herring, before and after the growth change.

for the increase in the size of the adult herring and can more easily be explained in terms of CUSHING's hypothesis of a true change in the growth rate. This applies even more strongly in the case of an increased size of 0-group herring, for which evidence was brought forward.

The effect of the increased size on distribution and migrations of the immature herring was, in the case of 0-group herring, probably restricted to a somewhat increased importance of the open sea fraction of this age-group, and to a greater extension of its distributions in the open sea.

Our conclusions on the migration pattern of I- and II-group herring for the periods preceding and following the change in the size are shown in Figure 10, and may be summarized as follows.

Pre-fifty. The small I-group herring were found in the eastern nursery, the larger ones in the north-west nursery. The herring from the eastern nursery moved to the north-west patch, between spring (I-group) and autumn (II-group). As III- and IV-group fish they turned up in the Shields area as adolescents. From the north-west nursery the largest herring migrated into the Shields area as I- and II-group, in spring and summer, and to the Buchan area in summer (II-group; WOOD, 1936). These fish represented the maturing part of the II-group herring. Most of the north-west nursery herring, however, remained in the area, recruiting at a higher age to both the Shields and Buchan fisheries.

Post-fifty. As in the pre-fifty period, the small I-group herring were to be found in the eastern nursery, the larger sized ones in the north-west patch. Already in late autumn and early spring, part of the I-group herring from the eastern nursery migrated into the north-west patch, and possibly moved from

there into the Shields area in summer (II-group fish). The other part moved more directly into the Shields area, in spring (I-group) and summer (II-group). The migration route to the north-west patch may have led along the north-eastern edge of the Dogger, whereas the "direct" migration to the Shields area led them probably along the southern edge of the Dogger, as indicated by the presence of such herring in the Silver Pit in April (BERTELSEN and POPP MADSEN, 1954; BURD, 1958). In the Shields area the II-group herring were maturing.

The herring from the north-west nursery moved predominantly northwards into the Buchan and Fladen areas, but a small fraction went into the Shields fisheries. Those migrations occurred probably in spring (I-group) and early summer (II-group), the herring being on the verge of maturing.

A small body of herring from the north-west nursery may have moved in a north-easterly direction as early as autumn, appearing in the commercial catches in the north-eastern North Sea in late autumn and spring (German trawl catches (SCHUBERT, 1957–1960) and Scottish drift-net catches (PARRISH *et al.*, 1954–1958)) and then migrated in spring and summer westwards into the Buchan and Fladen fisheries.

In the post-fifty period recruitment to the adult stocks in the Shields and Buchan areas was almost completed in the third year, leaving only few fish in the nurseries, this in contrast to the pre-fifty situation, when the major part of the II-group herring remained in the nurseries, probably mainly in the north-west one.

Evidence, indicating a somewhat greater abundance of I-group herring in the north-west nursery in the post-fifty period, suggests a certain shifting in the main concentration of such herring towards the north-west and agrees with the pattern obtained from the migrations which points to an accelerated migration in north-westerly direction after the growth change.

Our views concerning the migration pattern are not in full agreement with those of CUSHING (1962). CUSHING assumes an "easterly retreat" of the nursery after the size change in 1950, the main nursery being the north-west patch in pre-war years, the area east of the Dogger in post-war years.

Now we agree with CUSHING that after the change in the length-for-age, the importance of the north-west patch as nursery for immature herring of all ages must have diminished, because of the earlier maturation of the herring and the resultant disappearance of immature II- and III-group fish from that area. We doubt, however, that the distribution of the immature I-group has fundamentally changed, comparing the pre- and post-fifty situations. The increased proportion of I-group fish in the catches in area north-west contradicts a reduced importance of this nursery. The frequent reports about small herring found east and south of the Dogger by English trawlers in the years around 1924, as mentioned by HODGSON (1925b), together with information on I-group herring from this area in other published data used in this report, proves the existence of the east nursery under pre-fifty conditions.

CUSHING postulates that before the growth change recruitment to the adult stocks, both of small and large immature herring (his Downs and Bank recruits) came from the north-west patch. We arrived at the same conclusion, because we could show that small fish of the eastern nursery moved into the north-west patch as immature II-group herring and recruited from there to the Shields and Buchan grounds as III- and IV-group fish.

For the period after the growth change (post-fifty), CUSHING thinks that all recruitment to the adult stocks occurred from our area east (Bløden Ground). The small fish (his Downs component) would travel westwards along the southern edge of the Dogger and move into the Shields area, whereas the large fish (Bank component) from area east would travel northwards, probably in autumn, and join the schools of adult Bank herring along the Norwegian Deep, in February and March. From here they would invade the Fladen and Buchan fisheries in summer.

Our views agree with those of CUSHING on the point that fish from the eastern nursery are travelling along the southern edge of the Dogger into the Shields area, either direct or via the north-west patch. This is based on the same argument, i.e. the presence of small I-group herring in the Silver Pit in spring (BERTELSEN and POPP MADSEN, 1954).

The only other place where we could trace small I-group herring from the eastern nursery, in spring, was in the north-west nursery and we could show that these fish must have moved into that area during winter.

We have serious doubts concerning the northwards movement of large I-group herring from the Bløden Ground (area east) into the Norwegian Deep area, as postulated by CUSHING. The I-group fish in the north-eastern North Sea (area north) in spring were too large (20–26 cm (Fig. 4) or over 22 cm (Scottish drift-net data)) to have come *en masse* from the eastern nursery, where the length of the fish ranged up to 22 cm (see Figure 4). According to our views the 1-ringers, found in autumn and spring in the north-eastern North Sea (our area north) came probably from the north-western nursery, where the length range of I-group fish in autumn (18–26 cm, Fig. 4) shows a close resemblance to the 1-ringers in the north-eastern North Sea.

CUSHING's hypothesis that under post-fifty conditions the major recruitment of large adolescent fish (his Bank recruits) to the Fladen and Buchan fisheries came from the north-eastern North Sea seems to us also unlikely, because the relative abundance of I-group herring in the north-eastern North Sea in spring was low (7% of the autumn spawners in the Scottish drift-net catches (PARRISH *et al.*, 1954–1958)), compared with the proportion of the II-group recruits in the Fladen and Buchan fisheries (respectively 20% and 70%). In our opinion recruitment to the two areas came predominantly from the north-west nursery, as in the pre-fifty period.

In a nutshell, our disagreement with CUSHING is this: where CUSHING is of the opinion that the main nursery has moved eastwards after the growth increase, so that recruitment to the adult stocks takes place from a more easterly starting point, we think that fundamentally very little has changed, the nurseries and the starting points of the recruitment being roughly the same and that the only differences are found in the age at which the herring start maturing and leave the nurseries.

We do agree with CUSHING that the possibilities of a Bløden fishery would most probably have been less profitable under pre-fifty conditions than at present, not because the nursery was found more westwards than in present days, as CUSHING thinks, but because of the smaller size of the herring, probably resulting in a reduced weight of the stock, even taking the slightly higher abundance of the herring in the Bløden area, indicated in this paper, into account.

Summary

The change in growth rate, which apparently took place in adult herring in about 1950, has been accompanied by a similar length-for-age increase in immature herring. This is particularly clear from I-group herring, but it is also suggested by data related to 0-group herring.

The increase in size of the immature herring had the following consequences for their distribution in the North Sea and their migration pattern:

(i) The 0-group herring were mainly found in the coastal areas, both before and after the growth change, with a possibly somewhat wider distribution to the seaward in the post-fifty period. The 0-group herring moved out of the coast in spring.

(ii) I-group herring were found in two main nurseries, with the smaller fish to the east of the Dogger Bank and the larger ones to the north-west, in both periods. Both before and after the growth change the fish from the eastern nursery migrated into the north-west patch, although at a different age. Before the growth change the migration took place in the II-group in summer. After the growth change migration took place in the spring when the fish belonged to group I.

(iii) Before the growth change, recruitment to the western and north-western North Sea (Shields and Buchan areas) occurred from the north-west nursery. A few herring recruited as II-group fish and these represented a selection of the largest fish from that area. Most herring recruited at a higher age (as III–V group fish).

After the growth change most of the recruitment probably still came from the north-west nursery, the fish recruiting mainly as II-group. An important part of the large I-group fish, originally inhabiting the north-west nursery, moved to the Buchan and Fladen areas. The smaller I-group herring, from the eastern nursery moved into the Shields area, either through the north-west nursery or more directly along the southern edge of the Dogger.

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