With the authors compliments

E X T R A I T

Rapp. et Proc.-Verb. Vol. 143, I. 1957
Cons. Internat. Explor. de la Mer

1983

Recents changes in the North Sea Herringfisheries

by B. B. Parrish and R. C. Craig.

2.

Recent Changes in the North Sea Herring Fisheries

By B. B. Parrish and R. E. Craig
Marine Laboratory, Aberdeen.

In the working paper circulated to members of the Herring Committee, Cushing and Burd drew attention to some important changes in recent years in the yields from and the composition of the catches of the East Anglian herring fishery. They ascribed these events partly to changes in the biology, and partly to an increase in fishing mortality of the "Downs" stock of herring. These events together pose a Southern Bight problem, which it was the task of this Committee to examine in the light of collective statistical and biological data.

Of importance to this enquiry are the results of herring investigations in other parts of the North Sea, many of which are published in recent volumes of *Annales Biologiques*, which show clearly that striking changes have also taken place in other North Sea herring fisheries. Amongst these are the Scottish drift-net fisheries in the northern North Sea, in which changes in both productivity and catch composition have taken place since the second world war. It is felt therefore than an analysis of the changes in these fisheries and a comparison of their nature with those at East Anglia may be of direct relevance—not only to the Southern Bight problem, but also to a better understanding of the North Sea herring fisheries as a whole.

The Scottish North Sea Drift-Net Herring Fisheries

The Scottish drift-net fisheries, which are conducted between April and September over a wide area in the northern North Sea, can be divided into three main components. They are:—

(i) The "Shetland" fishery, which is conducted between May and August mostly on grounds within 60 miles of the port of Lerwick, to the east and south of the Shetlands.

(ii) The "Buchan" fishery which extends from late April or early May to early September on grounds off the Scottish east coast and the Moray Firth, mostly within a range of 70 miles from the major fishing ports Fraserburgh and Peterhead.

(iii) The much smaller and more recent north-eastern North Sea "boxing" fishery, which is conducted on grounds mostly to the east of longitude 1° E. and north of latitude 58° N. in April and May. The vessels fishing in this area subsequently join in the "Buchan" fishery in the period June to early September.

The general biology of the herring stocks in the Scottish area was elucidated during the inter-war period, notably by Wood (1936, 1937, 1946), and is described in much greater detail in the appropriate publications. The disposition of these fisheries is shown in Figure 1, and the main features of the herring stocks on which they are based may be briefly summarized as follows:—

1. The stock fished between April and September in the Scottish fisheries is composed of two distinct biological groups of herring; a main group, which we will term "summer-autumn" spawners[1]) which spawns between August and January or February on grounds ranging from the Scottish east coast to the Eastern English Channel, and a smaller, "winter-spring" spawning group, which is confined principally to the eastern and northern parts of the Scottish area, and which is represented chiefly by fish between 2 to 5 years of age. Most of the members of this group are adolescents of the major "Atlanto-Scandian" group of herring which spawn off the west coast of Norway and along the edge of the continental shelf and to the north and west of Scotland.
2. The "summer-autumn" group can, for the present purpose, be divided into two components; an "adult" component comprising all age-groups which have been part of the open-sea stock for

[1]) This group comprises the main body of herring in the North Sea spawning between the Scottish east coast in the north and the Eastern Channel grounds in the south. It thus includes the groups known widely as the "Banks" and "Downs" stocks. In view of the uncertainty about the "racial" distribution of these groups, no attempt is made here to distinguish between them.

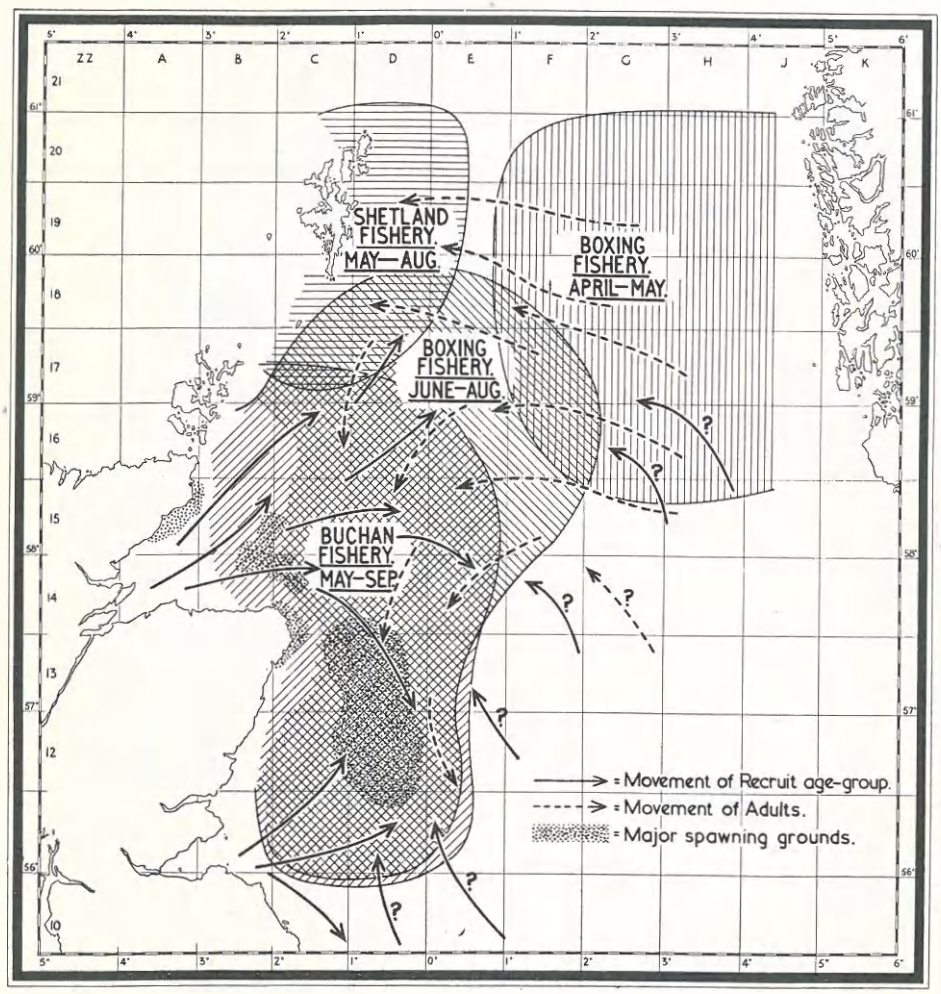

Figure 1. General scheme of fishing operations and of movements of autumn-spawning herring in the northern North Sea between April and September.

one or more years, and most of which have spawned at least once, and an "adolescent" component consisting principally of 3-year-olds (2 winter-rings on the scales) which have migrated in the spring and early summer from the nursery areas on to the main open-sea fishing grounds.

The main concentrations of the "adolescent" component first appear in the western parts of the "Buchan" fishing grounds in April. These subsequently spread over these grounds and in June and July constitute part of the stock exploited by the "Buchan" fishery. The centres of distribution do not extend to the Shetland fishing grounds during this period nor generally to the more easterly areas exploited by the "boxing" fishery. In late July and early August, there is a general movement of these young herring southwards, and only a small part of the original concentrations remain on the "Buchan" grounds and join the members of the "adult" component on the spawning grounds off the Scottish east coast.

Major concentrations of the "adult" component are found in the north-eastern regions of the North Sea in March, April and early May, where they are exploited by the "boxing" fishery. This body of fish then gradually spreads westwards during late May and early June and invades the "Shetland" and "Buchan" fishing areas. They remain on these grounds during the pre-spawning months and extend their range southwards. After spawning members of both components appear to spread eastwards and northwards into deeper water, where they are fished by trawlers in several parts of the North Sea. However, their subsequent movements prior to their reappearance in the north-eastern North Sea in the following spring are not clearly known.

Thus, the herring concentrations fished by the three Scottish fisheries differ in two important re-

spects. The "boxing" and "Shetland" fisheries are centred chiefly on the "adult" component of the "summer-autumn" group and smaller concentrations of the younger members of the "winter-spring" group. On the other hand the "Buchan" fishery in the pre-spawning months May-July is centred almost exclusively on feeding concentrations of the "adolescent" and "adult" components of the "summer-autumn" group, and in August and September on spawning fish of each component.

3. Not all of the members of the "summer-autumn" group of herring fished in the northern North Sea in summer spawn on the Scottish spawning grounds. Results of tagging experiments (Wood, Parrish, and McPherson, 1955) have confirmed the results of earlier investigations (Wood, 1946), indicating a movement of fish from the north-western North Sea feeding grounds to spawning grounds in the central and southern regions of the North Sea. Thus, the stock exploited in the Scottish fisheries during the summer constitutes a pre-spawning reservoir from which many, if not all, of the concentrations of "adult" spawners on central and southern North Sea spawning grounds are derived.
4. The localities in which the main concentrations of both the "adolescent" and "adult" components of the northern North Sea stocks are found change from year to year, due undoubtedly to changes in migrations in response to fluctuations in environmental factors. This often has an important bearing on the success of the Buchan and Shetland drift-net fisheries, which are centred on traditional grounds within daily landing distance from the major fishing ports. Thus, the extent to which the "adult" component penetrates westwards in spring will determine the success with which the Shetland and Buchan drifter fleets contact these shoals, or a shift in the concentrations of the "adults" northwards or southwards in the north-western North Sea will govern the relative concentrations on the Shetland and Buchan grounds. Similarly, the movements of the "adolescent" component will determine the extent of their penetration on to the Buchan grounds and beyond.

Changes in the Buchan and Shetland Drift-Net Fisheries

Statistics of annual catch are available for the Buchan and Shetland fisheries from the beginning of the present century. Crude measures of total effort are available for the Buchan fishery since 1906, and for the Shetland fishery since 1923. These data are given in Table 1.

While these statistics, particularly those of effort, are subject to limitations as measures of the quantities of herring caught and the effort expended, they do nevertheless reflect the main fluctuations and trends

Table 1. Catch and effort statistics for Buchan and Shetland drift-net fisheries [1]) 1900—1955

Year	Total catch (1000's of crans)		Total effort (1000's of landings)		Catch per landing (crans)	
	Buchan	Shetland	Buchan	Shetland	Buchan	Shetland
1900	132·4	321·2	—	—	—	—
1	344·2	430·1	—	—	—	—
2	527·2	294·7	—	—	—	—
3	449·7	299·3	—	—	—	—
4	558·9	543·3	—	—	—	—
5	452·6	645·8	—	—	—	—
6	496·0	458·9	28·4	—	17·5	—
7	730·3	468·4	29·2	—	25·0	—
8	611·3	516·8	38·3	—	16·0	—
9	490·4	362·9	33·3	—	14·7	—
1910	678·1	468·9	37·4	—	18·1	—
11	539·9	392·2	39·3	—	13·7	—
12	554·3	398·2	38·5	—	14·4	—
13	529·4	202·7	39·9	—	13·3	—
14	493·3	273·5	31·8	—	15·5	—
15	10·4	26·3	1·5	—	6·9	—
16	185·9	134·5	12·9	—	14·4	—
17	170·3	34·4	15·8	—	10·8	—
18	186·5	27·9	17·3	—	10·8	—
19	496·8	145·1	26·1	—	19·0	—
1920	401·6	88·8	31·7	—	12·4	—
21	259·7	168·7	19·2	—	13·5	—
22	243·4	256·4	18·7	—	13·0	—
23	372·5	254·5	20·7	14·3	18·0	17·8
24	500·6	341·7	28·5	15·2	17·6	22·5
25	248·1	191·6	20·6	14·6	12·0	13·1
26	391·9	226·5	26·3	14·6	14·9	15·5
27	396·0	180·2	29·1	13·4	13·6	13·4
28	389·9	240·3	30·6	12·4	12·7	19·5
29	442·2	304·2	29·1	14·3	15·2	21·2
1930	349·2	232·1	31·7	12·0	11·0	10·7
31	177·9	108·9	21·1	9·6	8·4	11·4
32	221·6	132·0	22·3	8·7	9·9	16·7
33	210·3	67·3	25·9	6·4	8·1	10·5
34	238·5	153·5	21·6	8·4	11·0	18·4
35	297·8	204·0	24·5	10·1	12·1	20·3
36	253·1	171·5	26·4	11·5	9·6	14·9
37	189·5	144·2	20·3	8·9	9·3	16·2
38	242·7	171·4	17·9	8·7	13·6	19·9
39	190·6	56·2	22·9	6·7	8·3	8·4
1940	17·1	0·3	4·6	0·2	3·7	1·5
41	20·1	5·1	1·3	0·6	15·5	8·5
42	57·4	6·8	2·8	0·9	20·5	7·7
43	94·5	10·1	5·9	0·7	16·0	15·1
44	195·6	9·9	9·8	0·8	20·0	12·4
45	259·2	12·2	11·0	0·9	22·6	12·9
1946	365·0	63·0	17·1	1·8	21·3	34·8
47	292·6	119·6	22·1	3·4	13·3	32·2
48	284·5	143·5	19·9	5·2	14·3	27·9
49	137·9	74·3	13·2	4·6	10·4	16·2
1950	106·2	53·1	7·6	3·4	13·9	15·6
51	159·8	31·5	11·9	1·9	13·4	16·6
52	300·6	49·2	12·7	2·4	23·7	20·5
53	343·4	15·7	15·1	1·3	22·7	12·1
54	239·9	23·4	10·4	1·7	23·1	13·8
1955	263·5	43·2	8·8	1·7	29·9	25·4

[1]) The statistics for the Buchan fishery are the combined totals for the three ports Fraserburgh, Peterhead and Wick, and for the Shetland fishery, the landings at Lerwick.

in these fisheries; also the estimated catches per unit effort give a general indication of the more important changes in the abundance of herring available to capture on the grounds.

A number of important features of these fisheries, of particular relevance to the present enquiry, emerge from these data. They show:—

1. Fairly large short-term fluctuations in the catches of herring on both the Buchan and Shetland grounds during the inter-war period.
2. A large increase in average catch on the Shetland grounds immediately after the second world war, followed by a steady decline up to 1951 and thereafter marked short-term fluctuations.
3. No significant increase in average catch on the Buchan grounds immediately after the first world war, and only a relatively small increase during and after the second world war.
4. A marked increase in average catch on the Buchan grounds after 1951, to give in 1955 the highest average catch since these records were begun in 1906.

These features reveal some similarities and some striking contrasts with the changes in the East Anglian fishery, as described in Part III of CUSHING and BURD's paper. The statistics for the Shetland fishery show the same marked increase in abundance of herring immediately after the second world war as in the East Anglian fishery. On the other hand the post-war increases are much less marked in the statistics of the Buchan fishery and, in the years following the first world war, the catch per unit effort was no greater than in the years before 1914.

In most striking contrast to the East Anglian fishery is the increase in the catch per unit of effort in the Buchan fishery in the years after 1951. Whereas at East Anglia there was a general decline in the catch per unit of effort after 1950, in the Buchan fishery it increased sharply in 1952 and has remained at a relatively high level since then. A trend in catch per unit effort, somewhat similar to that at East Anglia, is however shown by the post-war Shetland statistics up to 1951; these show a steady decline in catch per unit effort from a high immediate post-war value. It is striking however that the catches at Shetland did not increase over the pre-war level during the war years, so that it is difficult to attribute the subsequent increase to the effect of a reduced fishing mortality and an accumulation of older fish. The inference is similar from catch per unit of effort and average age data for the German trawl fisheries for herring on the Fladen, Gut and Dogger grounds (KREFFT, SCHUBERT, and SAHRHAGE, 1955). Only in the Fladen fishery do these data show a post-war increase in catch per unit effort over the late pre-war years. Furthermore, the Fladen and Dogger data show no significant increase in the average age of the catch, and the catch per unit effort values were higher in each of these fisheries in 1946 and 1947 than in 1945 when fishing commenced after the wartime respite.

It is not possible, therefore, from the raw statistics of the Scottish and other northern and central North Sea fisheries to detect any significant effect of reduced wartime fishing intensity, nor do they provide clues to changes in the composition of the catches during the post-war period. These can, however, be gauged from abundance indices of the age-groups making up the commercial catch. No completely satisfactory indices of abundance are available (see Part III, CUSHING & BURD, 1956) but rough assessment can be made from the catch per landing data and the age compositions determined from sampling surveys of the commercial catch each year.

Indices of abundance for the Buchan and Shetland fisheries have been determined from these data for the period 1930—1955. For the Shetland data, presented in Table 2, average indices for the whole season's fishing are given, but for the Buchan fishery, indices have been calculated separately for the pre-spawning period, May to July (Table 3), and for the spawning period August and September (Table 4). This division is made because, as explained earlier, of the general change in the composition of the stock in this area at the onset of the spawning season.

Shetland fishery

Representative age and length sampling of the Shetland fishery did not commence after the second world war until 1948, so that there are no data for the period immediately after the war-time respite from fishing, but a number of important features are revealed.

(i) The average abundance of the younger age-groups[1]) (3- to 5-year-olds), which are a mixed stock of North Sea "summer-autumn" herring and of "winter-spring" spawners, has not changed significantly between the pre-war and post-war periods. In both periods, except in 1955, recruitment to the fishery at three years of age was very small, and it was spread principally over age-groups IV and V.

(ii) The average abundance of fish older than five years of age has been higher in the post-war years than during the period 1930—1939. The average abundance indices for each of the age-groups older than five years in the two periods are as follows:—

	Crans per landing		
Age	Winter-rings	1930—1939	1948—1955
6	5	3·1	2·6
7	6	1·8	2·2
8	7	1·2	2·1
9	8	0·9	1·6
older than 9	> 8	0·4	2·9

[1]) The ages given in this paper refer to the number of summer growth-zones on the scales and otoliths and are always one more than the number of winter-rings. This brings the age reference in conformity with that used in the paper by CUSHING and BURD.

Table 2. Abundance indices (crans per landing) of age-groups in Shetland fishery in the period May—August 1930—1955 (exclusive of 1940—1947)

Age	3	4	5	6	7	8	9	Older than9
Winter-rings	2	3	4	5	6	7	8	>8
Year								
1930.....	3·3	3·3	3·9	4·6	0·9	1·4	0·9	0·2
1931.....	0·6	4·6	1·0	1·1	1·3	1·0	0·9	0·4
1932.....	0·1	5·2	3·7	1·3	1·1	1·2	1·2	1·0
1933.....	0·2	0·9	4·2	1·3	0·6	0·3	0·4	0·5
1934.....	0·1	5·4	2·6	5·6	1·5	0·5	0·3	0·3
1935.....	1·2	3·5	3·6	3·4	5·2	1·0	0·5	0·4
1936.....	0·03	2·4	3·7	2·0	1·7	3·3	0·6	0·5
1937.....	0·0	1·6	4·6	4·9	1·8	0·8	3·0	0·5
1938.....	0·04	1·3	2·2	6·1	2·9	1·9	1·1	3·5
1939.....	0·1	0·5	2·6	1·1	1·5	0·7	0·3	0·4
1948.....	0·1	4·5	2·9	6·0	4·8	4·2	2·8	2·0
1949.....	1·2	0·7	3·3	1·5	2·6	3·1	1·6	2·0
1950.....	0·1	2·5	2·5	3·4	2·3	2·4	1·6	1·0
1951.....	0·2	1·2	3·7	1·8	2·8	1·8	2·1	3·1
1952.....	0·6	2·2	1·5	2·6	1·5	2·5	1·9	6·1
1953.....	0·8	2·4	1·5	1·2	1·6	0·9	0·9	2·1
1954.....	0·4	2·1	2·3	1·4	1·0	1·3	0·9	4·6
1955.....	4·8	7·1	4·0	3·0	1·1	0·9	1·0	2·2

(iii) However, there has been a marked decline in the catches of these older age-groups during the post-war period, and in the years 1953—1955, their abundance was smaller than the pre-war average. This decline took place quite suddenly in 1953, as is shown by the following indices of abundance for these age-groups in each of the years 1948—1955:—

1948	13·8	1952	12·0
1949	9.3	1953	5·5
1950	7·3	1954	7·8
1951	9·8	1955	5·2

Table 2 shows that this decrease cannot be attributed to lower brood strength for these years; nor can it be associated with a marked reduction in the stock of "winter-spring" spawning herring on the Shetland grounds. It must be attributed in the main to a sudden fall off in the catchable stock of the adult component of the "summer-autumn" spawning group.

Buchan pre-spawning fishery

Again, age sampling of the catches did not commence immediately after the second world war, but the following important features are revealed:—

(i) Since 1951 there has been a striking increase in the abundance of 3-year-olds in the catches. Whereas in post-war years up to 1951 recruitment by this age-group was at about the same average level as in pre-war years, in 1952 it increased approximately fourfold over this average level, and has attained even higher levels since then.

Table 3. Abundance indices (crans per landing) of age-groups in Buchan fishery in pre-spawning period, May—July, 1930—1955, (exclusive of 1940—1946)

Age ..	2	3	4	5	6	7	8	9	Older than9
Winter-rings..	1	2	3	4	5	6	7	8	>8
Year									
1930..	0·1	3·3	4·8	1·7	2·5	0·7	0·6	0·3	—
1931..	—	1·0	4·5	2·1	1·1	1·1	0·8	0·6	0·3
1932..	0·03	1·3	7·4	2·1	0·6	0·2	0·2	0·1	0·1
1933..	—	1·4	3·6	1·5	0·5	0·1	0·1	—	—
1934..	—	1·7	2·9	4·2	1·3	0·5	0·2	0·1	0·1
1935..	—	2·7	7·1	1·3	1·7	0·5	0·2	0·1	—
1936..	0·03	0·8	3·9	2·3	0·5	0·8	0·8	0·1	0·1
1937..	—	1·8	2·3	3·7	1·6	0·2	0·3	0·2	0·1
1938..	0·1	1·1	8·4	2·0	2·4	0·7	0·2	0·2	0·1
1939..	—	3·2	3·0	3·0	0·4	0·3	0·1	—	—
1947..	—	4·2	3·0	2·9	1·7	1·0	0·4	0·1	0·2
1948..	0·1	2·0	3·6	1·5	2·3	1·3	0·8	0·4	0·4
1949..	0·04	3·0	2·1	1·1	0·6	0·7	0·5	0·3	0·2
1950..	0·02	1·7	5·7	2·5	1·4	0·9	0·9	0·6	0·4
1951..	0·03	1·4	3·1	4·3	1·8	1·0	0·7	0·6	0·6
1952..	—	8·4	4·6	4·4	4·2	1·9	1·1	0·7	1·1
1953..	0·03	8·8	6·5	2·2	1·7	1·6	0·8	0·4	0·5
1954..	0·1	13·8	4·2	1·8	0·8	0·7	0·5	0·2	0·3
1955..	0·01	22·5	5·1	1·1	0·6	0·3	0·3	0·1	0·2

(ii) During the period of increasing abundance of 3-year-olds, the abundance of 4-year-olds has remained at about the same or at a slightly higher level than previously.

Thus, as in the East Anglian fishery, there has been a major change in the relative proportions of 3- and 4-year-olds in the Buchan pre-spawning catches. This important change is similar and it took place in the same year, as in the East Anglian fishery. Only in 1955 do the two fisheries differ markedly in this feature. In the Buchan fishery the abundance of 3-year-olds reached its highest value in 1955 but it dropped sharply from the 1953—54 level in the East Anglian fishery. In the Buchan fishery the abundance of 4-year-olds increased slightly following the increase in recruitment of 3-year-olds, but in the East Anglian fishery, the abundance of 4-year-olds decreased.

(iii) As in the Shetland fishery, the average post-war abundance of the older age-groups has been greater than in the pre-war period. The averages for each of the age-groups above 5 are as follows:—

		Crans per landing	
Age	Winter-rings	1930—1939	1947—1955
6	5	1·3	1·7
7	6	0·5	1·0
8	7	0·4	0·7
9	8	0·2	0·4
older than 9	>8	0·1	0·4

Again this increase cannot be attributed to greater brood strength in post-war years. It is evident also from Table 3 that these high values cannot be as-

signed to high indices of older fish in the early post-war years since the total abundance of these age-groups was higher in the years 1951—1953 than in the years 1947—1950. In 1954 and 1955, however, the total abundance of these age-groups fell again, to reach in 1955 its lowest post-war value.

It is interesting to note that the year of high total abundance of these older age-groups in the Shetland catches, 1952, was also the year of their highest post-war abundance in the Buchan pre-spawning fishery, and in both fisheries there was the same sharp fall off in abundance in 1953 and subsequent years.

Buchan spawning fishery

The data for this fishery reveal some similar and some contrasting features with the pre-spawning fishery, of which it is a continuation. Most relevant of these are:—

(i) The abundance of 3-year-olds in the post-war years up to 1951 was at the same general level as in pre-war years. After 1951, as in the pre-spawning fishery, it increased and remained at a relatively high level in the succeeding years, but still at a much lower level than in the pre-spawning fishery.

(ii) Unlike the pre-spawning fishery, there was a marked increase in the abundance of 4-year-olds following the increase in recruitment of 3's, which is also reflected in the subsequent catches of 5's and 6's.

(iii) As in the Shetland and the Buchan pre-spawning fisheries, the average abundance of fish older than 5 years of age was greater in the post-war than in the pre-war periods. This is shown by the following average abundance indices for each age-group in the two periods.

		Crans per landing	
Age	Winter-rings	1930—1939	1948—1955
6	5	0·9	2·1
7	6	1·0	3·7
8	7	0·7	1·5
9	8	0·5	1·4
older than 9	>8	0·4	2·4

Again this cannot be explained as a direct consequence of an increase in brood strength in the post-war years, nor to the weighting given by high abundance of older fish in the immediate post-war years. No substantial decline in the abundance of these older age-groups can be detected during the post-war period; in fact there has been a marked increase in the abundance of the oldest broods.

There are therefore some striking similarities between the post-war changes in the composition of the catches in the Scottish and East Anglian drift-net fisheries and some differences. Thus, the Buchan pre-spawning and the Shetland fisheries together show a similar marked increase since 1951 in the catches of 3-year-olds and an accompanying change in the ratio of 3- and 4-year-olds, and also a reduction since 1952 in the catches of the older age-groups. Only in the Buchan spawning fishery are the changes not paralleled; here there has been no marked decline in the catches of the older age-groups, but instead a general increase.

Interpretation of Changes in Scottish and East Anglian Catches since 1950

It is evident from the above that several of the phenomena detailed in CUSHING and BURD's paper are not confined to the Southern Bight fisheries, but are common to drift-net fisheries in widely separated regions of the North Sea.

The two important widespread changes which require examination are:—

(i) The increase in the catches of 3-year-olds since 1951 and the associated change in the relative proportions of 3- and 4-year-olds.

(ii) The reduction in the catches of older age-groups in some fisheries since 1952.

Increase in catches of 3-year-olds

There are two possible alternative explanations for this change:—

(i) An increase in brood strength, giving a greater total abundance of herring of this age-group on the fishing grounds.

(ii) An increase in the "availability" of each year-class to capture at this age.

Data at our disposal indicate that the observed change in the north is probably the result of the combined effect of both of these factors. Evidence that there probably has been some increase in brood strength is given by:—

1. The increase in the catches of 4-year-old and older fish in the Buchan pre-spawning and spawning fisheries (Tables 3 and 4) the Aberdeen offshore "boxing" fishery, and to a lesser extent the Shetland fishery (Table 2).
2. The recent increase in the abundance (as measured by drift-net landings) of herring on the Moray Firth nursery grounds. This is shown by the following data for the Scottish "halflin" fishery carried out in the upper reaches of the Moray Firth between October and March.

Year	Total catch (crans)	Av. catch per landing (crans)
1945—46	3,215	4·2
1946—47	7,958	9·9
1947—48	356	4·5
1948—49	3,409	9·9
1949—50	3,790	13·4
1950—51	2,790	7·6
1951—52	19,066	24·4
1952—53	38,885	23·8
1953—54	61,773	23·3
1954—55	25,263	14·7
1955—56	34,644	22·0

The catches in this fishery are composed almost entirely of the single age-group which appears as 3-year-olds (2 winter-rings) in the open-sea fisheries in the following summer. The marked increase in the catches in this fishery coincided with the jump in the catches of 3-year-olds in the Buchan pre-spawning fishery in 1952 (Table 3). While a part of this increase may well be the result of a change in the "availability" of the halffin stock, it should be noted that there is no evidence that this is so, and it is considered that this increase in catch reflects an increase in brood strength of the respective year-classes. However, while the members of this local nursery stock undoubtedly contribute appreciably to the total stock of 3-year-old recruits to the Buchan fishery, they do not constitute the whole of it; a substantial part of the recruits to this fishery undoubtedly come from other nursery grounds. Therefore, the above figures cannot be taken as measures of the increase in abundance of the total recruit year-classes entering the Buchan fishery after 1951.

That the increase in the catches of 3-year-olds cannot be attributed entirely to increased brood strength is indicated by the general failure of the catches of the 4-year-olds and subsequent age-groups to increase to the extent which would be expected from an increase in brood survival alone. There is, therefore, an indication of a similar change in the recruitment pattern in the Scottish fishery as proposed by Cushing and Burd for the East Anglian fishery. Whereas in both fisheries prior to 1952 a substantial component of each year-class was not recruited to the fishery until 4 years of age, after this time a greater part of the total recruitment took place at 3 years of age.

Such a change could be brought about in one or other of two ways.

(i) A general change in the distribution, behaviour and/or catchability (which we will collectively term "availability") of the 3-year-old fish, resulting in their being present in greater abundance and/or their being more vulnerable to capture over the traditional fishing grounds.

(ii) A change in the policy and method of fishing, resulting in a greater concentration of fishing effort on the grounds inhabited by the smaller, younger fish.

While there have in recent years been changes in the general distribution of fishing effort by the Buchan drifter fleet (Glover, 1955), and the shift has been towards the younger herring areas, it has not been of sufficient magnitude to account for this major change in catch composition; it is probably due more to biological changes affecting the availability of 3-year-olds to the commercial fleets.

As in the Southern Bight, there has been an increase in recent years in length of the constituent age-groups in the Buchan stock. This is shown by the average lengths presented in Table 5, of age-groups III to VI in the Fraserburgh and Peterhead catches in the pre-war years 1935 to 1938 and in the post-war period 1947 to 1955. It is considered that this increase in length has resulted in a greater proportion of the total stock of 3-year-olds becoming available to capture by the commercial fishery than hitherto. This is probably due, partly to a greater proportion of the age-group being retained by the meshes of the drift-nets, and partly to an increase in the proportion of the total stock of 3-year-olds being recruited to the fishing area.

From the data available, therefore, the increase in the catches of 3-year-olds in the Scottish fishery can be attributed at least in part to the same general causes as in the Southern Bight fisheries. In the light of these and other published data (Ancellin, 1953—54; Gilis, 1950—1955; Krefft, Schubert, and Sahrhage, 1955; and Andersson, 1954), the growth increase, probably together with an associated change in the incidence of first maturity, can be traced in the catches from all of the major North Sea herring fisheries. It appears therefore to be a general biological feature of the whole North Sea stock of "summer-autumn" herring, and has resulted in a change in the whole recruitment pattern to the respective fisheries. A direct consequence of such a change in the pattern of recruitment to the fisheries would be an increase in fishing mortality amongst the 3-year-olds, which for any given brood strength will result in some decrease in the abundance of 4-year-olds and older fish and will explain in part at least the fall off in abundance between the 3- and 4-year-olds in the drifter catches.

Table 4. Abundance indices (crans per landing) of age-groups in Buchan fishery in spawning period, August—September, 1930—1955 (exclusive of 1940—1946 and 1948).

Age ..	2	3	4	5	6	7	8	9	Older than 9
Winter-rings..	1	2	3	4	5	6	7	8	>8
Year									
1930..	—	0·6	1·6	1·2	0·8	0·7	0·8	0·4	0·3
1931..	—	1·0	1·3	0·8	0·7	0·5	0·5	0·4	0·3
1932..	—	0·03	0·6	3·3	0·8	0·4	0·2	0·1	0·2
1933..	—	1·1	2·4	4·5	0·7	0·8	0·6	0·3	0·5
1934..	—	0·3	1·0	2·0	6·3	1·2	1·0	0·6	0·5
1935..	—	0·9	3·8	1·2	1·8	3·2	0·4	0·5	0·5
1936..	—	0·1	1·4	1·8	0·9	1·6	2·2	0·7	0·6
1937..	—	0·2	0·3	1·8	1·4	0·2	0·4	1·2	0·3
1938..	—	1·7	3·2	0·8	1·0	0·7	0·3	0·2	0·6
1939..	—	1·4	1·1	0·8	0·2	0·3	0·2	0·1	0·2
1947..	—	0·4	0·9	1·9	2·8	1·1	1·8	1·1	1·2
1949..	—	0·3	0·9	3·3	2·3	3·3	2·6	1·2	1·4
1950..	—	1·4	1·0	1·0	1·2	1·1	1·5	2·9	1·4
1951..	0·2	1·2	2·8	2·0	0·8	1·6	1·4	1·9	2·1
1952..	—	2·7	1·4	2·5	1·4	0·5	1·0	0·9	3·4
1953..	0·1	5·7	6·6	1·7	2·9	1·6	0·6	1·3	3·9
1954..	—	4·4	4·1	5·2	1·3	2·2	1·2	0·6	3·5
1955..	—	9·6	5·3	3·6	4·0	1·2	1·5	1·0	2·6

No sampling took place in 1948

Table 5. Average lengths (cm.) of 3-6-year-old herring in Buchan fishery in May—September, 1935—39; and 1947—1955

Age	3	4	5	6
Winter-rings	2	3	4	5
Year				
1935	24·0	24·3	25·8	25·9
1936	24·2	25·0	26·2	27·4
1937	24·2	25·0	26·4	27·3
1938	23·6	24·9	26·1	27·1
1939	23·9	24·7	25·9	27·2
1947	24·7	25·4	26·5	27·7
1948 omitted due to incomplete sampling.				
1949	23·3	24·9	26·5	27·1
1950	24·5	24·9	26·1	27·7
1951	24·7	**25·8**	25·9	26·5
1952	24·9	26·3	**26·8**	27·3
1953	24·5	26·4	27·0	**28·1**
1954	24·7	26·9	28·1	28·7
1955	24·2	26·8	28·7	29·3

Table 6. Estimated annual percentage mortality rates for the Buchan pre-spawning fishery, 1930—1955

Years/Age-groups	III-IV	IV-V	V-VI	VI-VII	VII-VIII	VIII-IX
1930–31	*	56·1	35·3	56·0	*	0·0
1931–32	*	53·1	71·2	81·9	81·9	87·3
1932–33	*	79·8	76·1	83·1	50·0	100·0
1933–34	*	*	13·3	0·0	*	0·0
1934–35	*	55·0	59·2	61·4	60·0	50·0
1935–36	*	67·6	61·4	53·0	*	50·0
1936–37	*	5·1	30·4	60·0	62·3	75·0
1937–38	*	13·0	35·1	56·1	0·0	33·3
1938–39	*	64·1	80·0	87·4	85·9	100·0
1947–48	14·3	50·0	20·6	23·5	20·0	0·0
1948–49	*	69·4	60·0	69·5	61·5	62·5
1949–50	*	*	*	*	*	*
1950–51	*	24·5	28·0	28·6	22·2	33·3
1951–52	*	*	2·3	*	*	0·0
1952–53	22·6	52·0	61·2	62·0	58·0	63·7
1953–54	52·1	72·2	63·7	58·9	68·7	75·0
1954–55	63·0	73·9	66·7	62·6	57·0	80·0

* Second year frequencies greater than first year frequencies.

Changes in abundance of the older age-groups

It has been shown already that, as in the East Anglian fishery, the catches of fish older than 5 years have undergone marked changes in the Scottish fisheries since the war. Most striking of these has been a general increase since the war, followed in 1953 by a sharp decline, in both the Buchan pre-spawning and the Shetland fisheries. Can this be attributed to an increase in the fishing mortality rate as proposed for the East Anglian fishery by CUSHING and BURD?

In Table 6 are given the apparent total mortality rates estimated from the data in Table 3 for each year-class in successive years of life in the Buchan pre-spawning fishery between 1930 and 1939, and between 1947 and 1955.

The most striking feature shown by these data is the large variation from year to year in the values of the mortality rates for the different age-groups. Thus, in the pre-war period, mortality rates were high for all year-classes between 1931 and 1933, between 1934 and 1936, and between 1938 and 1939; between 1936 and 1938 they were intermediate, and between 1933 and 1934 they were very small or were negative in value. Similar changes are evident in the post-war period; high mortality rates characterize the years 1948—1949 and 1952—1955; intermediate values the years 1947—48 and 1950—51, and very small or negative values the years 1949—50 and 1951—52.

The data strongly indicate wide fluctuations in "availability" of these age-groups in the fishery. Thus, in the post-war period it appears that the years 1950—52 were years of high "availability" in the Buchan fishery, relative to the preceding and succeeding years; and, similarly, 1934 was a year of high "availability" in the pre-war period, and 1932, 1933, and 1939 were years of low "availability". "Availability" therefore appears to be an important factor in determining the short-term fluctuations in the catches of the older age-groups in the Buchan fishery and it is important to consider whether the striking decline in the abundance of the older age-groups since 1952, and the increase in the apparent mortality rates, can be largely attributed to this factor. That this is so is suggested by the following:—

(i) The catches by the Aberdeen "boxing" fishery in the north-eastern North Sea in April and May, a major component of which are the older age-groups of the "summer-autumn" group of herring, have not decreased in recent years but have remained at a relatively high level since 1952. The statistics of catch and effort, and a rough measure of catch per unit of effort for this fishery in April and May between 1949 and 1955 are as follow:—

	Total catch (crans)	Number of landings	Av. catch per landing
1949	17,233	230	74·9
1950	17,995	246	73·2
1951	10,754	248	43·4
1952	24,167	324	74·6
1953	30,975	420	73·7
1954	20,812	272	76·5
1955	25,341	338	75·0

(ii) The abundance indices of the older age-groups in the Buchan spawning fishery have not declined during the period of the decline in the pre-spawning fishery. It appears in fact, that there has been an increase in the numbers of the oldest age-groups on these spawning grounds in recent years.

(iii) No measures of effective total effort are available for the major adult herring fisheries in the North Sea over the period, but only in the Channel trawl fishery is there evidence of a marked increase in the total effort after 1950. (Part III of CUSHING and BURD's paper). Thus it appears that there has been no increase in fishing effort

in the period 1953—55, sufficient to account for the increase in total mortality rate in the northern North Sea fisheries. However, effort data for the whole North Sea herring fisheries are urgently required.

(iv) The age compositions of the catches in the northern and central North Sea trawl fisheries, which are known to exploit part if not the whole of the same body of herring as the Scottish drifters are not characteristic of a heavily fished stock. This is evident from the data presented in Figure 10, of Part II of CUSHING and BURD's paper. These indicate average mortality rates between successive age-groups over 5 years of age in the period 1952—1954 of not more than 25 % per annum, which were in fact no greater than the mortality rates in the periods 1946—49 and 1950—51. Similar indications are given by the age compositions of Fladen trawl catches landed in Aberdeen (Ann. Biol., 8—11).

This information, which it must be emphasized is not proof, strongly suggests that there has been a major change in the "availability" of the older groups in the Buchan pre-spawning and the Shetland fisheries since 1952 rather than a marked increase in the fishing mortality rate. It is probable that this is mainly the result of a change in herring distribution in the northern North Sea, resulting in the main centres of density of the shoals being nearer to the fringes of the grounds fished by the Buchan and Shetland fleets. (It must be remembered that the area of activity of the drifter fleets is restricted mainly to within 60-70 miles of the ports.)

While we are not able to provide a full explanation of this "availability" change, it is significant that it has coincided with some marked changes in features of the environment in the North Sea and that it may therefore be a response of the herring to environmental factors. The years since 1951 have been characterized by strong oceanic influence in the northern North Sea, along with some striking changes in the composition, abundance, and time of appearance of some plankton organisms (RAE, 1956; GLOVER, 1955 and 1957). A brief account of the physical and planktonological changes are given in the Appendices to this report and will be reported more fully elsewhere. Hydrographic and planktonic changes have in fact been reported by a number of authors for many North Sea regions and some adjacent waters, and associated changes in the distribution and/or biology of some fish species have been recorded. For example, GILIS (1954) and HODGSON (1954) draw attention to unusually large concentrations of pilchards (*Clupea pilchardus*) in the Southern Bight after 1950, which HODGSON associates with changes in the water temperatures in the period October-December. AURICH (1953) also records marked increases in the spawning of pilchard (*C. pilchardus*), anchovy (*Engraulis encrasicholus*), sole (*Solea vulgaris*), horse mackerel (*Caranx trachurus*) and mackerel (*Scomber scombrus*) in the southern North Sea since 1948, which he relates to increased penetration of Atlantic water into the North Sea. The increase in growth of the herring all over the North Sea is also probably a direct consequence of planktonic and perhaps hydrographic changes.

Table 7. Estimated annual percentage mortality rates for the East Anglian fishery, 1935—1955

(estimated, using data from CUSHING and BURD, 1956).

Years/Age-groups	III-IV	IV-V	V-VI	VI-VII	VII-VIII	VIII-IX	IX-X
1935–36..	*	52·2	*	27·9	52·0	29·4	45·4
1936–37..	*	21·1	44·0	55·4	62·1	41·6	75·0
1937–38..	*	31·5	49·2	57·0	*	42·8	42·8
1946–47..	*	27·8	46·6	16·7	59·0	58·9	57·8
1947–48..	*	31·8	12·4	*	37·1	10·4	60·8
1948–49..	*	24·3	36·4	44·6	80·9	77·1	84·3
1949–50..	*	44·9	38·3	39·2	50·0	27·8	50·0
1950–51..	*	26·5	41·0	43·6	38·1	46·1	61·6
1951–52..	2·1	36·8	27·3	40·6	50·0	42·9	62·0
1952–53..	43·2	56·4	65·5	67·1	64·9	55·0	58·2
1953–54..	34·0	32·0	30·4	6·9	36·3	16·6	66·8
1954–55..	67·2	74·9	66·2	68·0	70·1	76·0	80·0

* Second year frequencies greater than first year frequencies.

This association may be of importance not only to the understanding of the northern fisheries but also those of the south, and it may be useful to consider whether the decline in the catches of the older age-groups in the East Anglian fishery can be attributed, at least in part, to similar changes in "availability", in the wide sense used here.

In Table 7 are given the apparent total mortality rates between each successive year of life, calculated from the data in Table 6 of Part III of CUSHING and BURD's paper, for each year since 1935. As in the Scottish data, these show marked fluctuations in the mortality estimates from year to year, which seem very large to be reconciled with changes in the fishing mortality component alone. Thus, in the period since 1951, mortality rates were very high between 1952—53, and 1954—55, but they were relatively very low between 1953—54; in this year they were lower than in any year prior to 1951 except 1947—48; furthermore, in 1951—52, the rates were no greater than the average for the earlier post-war years, despite a major increase in trawl catches in that year. It is evident that the increase in mortality rate between 1950—55 over the earlier pre-war years is weighted heavily by the very high values for the years 1952—53 and 1954—55.

Therefore, during the period since the major increase took place in the Channel trawl fishery, the estimated apparent total mortality rates in the East Anglian stock have fluctuated widely. In two periods, 1952—53 and 1954—55, they have been relatively high, and in two periods, 1951—52 and 1953—54, they have been relatively low. In one of the high mortality years, 1955, the abundance indices of all age-groups were very low compared with previous years, which strongly suggests low "availability" of the whole stock on the traditional fishing grounds.

Conclusions and Summary

The data reviewed here on recent changes in the composition of the catches of many of the North Sea herring fisheries suggest that the phenomena are so widespread as to have been largely due to a change in the biology of the great population of North Sea "summer-autumn" herring in response to changes in their environment.

The authors consider that the main trends in the fisheries can be most simply explained in terms of faster development of the fish of this group. Thus we find all over the North Sea increased size for age, giving rise to earlier capture by drift-net, advancement of the age of first maturity, and of all stages in the migration pattern. These biological changes, with their implication of changed "availability", are the most important ones. It is also possible, indeed likely, that the older fish of this stock tend normally to migrate northwards to the deeper waters of the northern North Sea, and that this tendency like the other aspects of the life history has been increased in recent years.

In addition, there remains an impression that, while brood strengths have been well up to average in the northern areas, they may well have been somewhat below average in the southern regions, and perhaps particularly among those herring contributing to the eastern Channel fisheries. Although Le Gall (1935), for example, regarded these last as a separate race, Cushing and Burd give cogent reasons for regarding them as part of their "Downs" stock. Perhaps tagging experiments will provide a final answer. Meanwhile, it is part of their case that it is fish spawning in this area which have become most scarce in the East Anglian fishery. It is also fish of this group which spawn so late as not to differ greatly in spawning date from typical coastal spring spawners, such as those of the Moray Firth, Firth of Forth, and Firth of Clyde. All of these groups have provided poor fishings in recent years, probably as the result of extensive environmental changes. Herrings spawning so late as January/February, whether they constitute a separate stock or are late spawners of a larger stock with an extended spawning season, may not have been unaffected by such changes.

Finally, whatever may be the cause of the recent changes in the fisheries, whether due to increased fishing or to "natural causes", wholly or in part, there has undoubtedly been cause for concern recently about the results and prospects of the East Anglian fishery. Some other fisheries have produced more than average in recent years, but investigations show that we do not yet have enough understanding of them. Excessive fishing in relation to the available stock might be "round the corner" without our being able to anticipate it. In these circumstances it seems essential to make every effort to improve our national statistics, and our biological and environmental knowledge, and to pool them so as to be able to anticipate the probable effects of any changes, whether natural or man-made.

References

Angellin, J., 1953. "Hareng du sud de la Mer du Nord et de la Manche orientale, campagne de 1952—53." Ann. Biol., Copenhague, **9** (1952): 202—05.

— 1954. "Hareng du sud de la Mer du Nord et de la Manche orientale, campagne de 1953—54." Ibid., **10** (1953): 183—85.

Andersson, K. A., 1954. "Studies on the fluctuations in the rate of growth of the herring in the Kattegat and the Skagerak." Rep. Inst. Mar. Res. Lysekil, Ser. Biol., 3.

Aurich, H. J., 1953. "The spawning of anchovy and pilchard in the south-eastern North Sea, with reference to climatic changes." Ann. Biol., Copenhague, **9** (1952): 123.

Cushing, D. H., & Burd, A. C., 1956. "On the herring of the southern North Sea." Min. Agric. Fish. & Food, Fish. Invest., Ser. 2, **20** (2). In press.

Gilis, Ch., 1950—56. Ann. Biol., Copenhague, **6—11** (1949—54), Section: Herring.

— 1954. "Notes on the unusual presence of large quantities of pilchards (*Clupea pilchardus* Walb.) in the herring catches from the extreme southern area of the North Sea. I." Ann. Biol., Copenhague, **10** (1953): 185—86.

Glover, R. S., 1955. "Science and the herring fishery." Advanc. Sci., Lond., **11**: 426—34.

Hodgson, W. C., 1954. "Notes on the unusual presence of large quantities of pilchards (*Clupea pilchardus* Walb.) in the herring catches from the extreme southern area of the North Sea. II." Ann. Biol., Copenhague, **10** (1953): 186.

Krefft, G., Schubert, K., & Sahrhage, D., 1955. "Der augenblickliche Stand der Erforschung des Nordseeherings mit besonderem Hinblick auf die Frage seiner Überfischung." Arch. Fischereiwiss., **6**: 141—88.

Le Gall, J., 1935. "Le hareng *Clupea harengus* Linné. Les populations de l'Atlantique nord-est." Ann. Inst. Océanogr., **15**: 1—213.

Rae, K. M., 1956. "The continuous plankton recorder survey: plankton around the British Isles during 1954." Ann. Biol., Copenhague, **11** (1954): 54—58.

Wood, H., 1936. "Race investigations of the herring population of Scottish waters." Sci. Invest. Fish. Scot., 1936, 3, 52 pp.

— 1937. "Movements of herring in the northern North Sea." *Ibid.*, 1937, 3, 49 pp.

— 1947. "The herring of the north-western North Sea." Rapp. et Proc.-Verb., Copenhague, **118**: 9—23.

Wood, H., Parrish, B. B., & McPherson, G., 1955. "Review of Scottish herring tagging experiments 1948—1953." Rapp. et Proc.-Verb., Copenhague, **140** (2): 35—54.

APPENDIX I

The Environment: The Evidence of the Plankton

By R. S. GLOVER
Scottish Marine Biological Association, Edinburgh.

FLUCTUATIONS in herring fisheries have frequently been ascribed to environmental factors and, in particular, to the fluctuating inflow, into the North Sea, of water of oceanic origin. The plankton has often been used to provide biological indications of the presence of oceanic water. A notable example was the collapse of the Plymouth herring fishery, coinciding with environmental changes which were indicated by the replacement of *Sagitta elegans* by *S. setosa* (RUSSELL, 1936 and KEMP, 1938). STORROW (1930—1932) and STORROW and COWAN (1933 and 1939) attempted to relate the biology of the herring and the varying fortunes of the Scottish and English fisheries to changes in the inflow of mixed oceanic and western coastal water which enters the North Sea near the Shetlands. More recently RAE, at the meeting of the British Association in 1949, drew attention to the close parallel between the annual influx, into the North Sea, of planktonic indicators of mixed water and the temporal and spatial distribution of spawning grounds of the herring; this parallel has been illustrated by GLOVER (1955, Fig. 7). The collapse of the Shetland herring fishery since 1951 has been associated, tentatively, with the simultaneous invasion of oceanic plankton (GLOVER, 1955 and FRASER, 1956). Finally, CUSHING and BURD (1956) have suggested that the increased growth of East Anglian herrings since 1950 has followed an increase in the supply of *Calanus*, a most important food of the herring; the greater abundance of *Calanus* was also probably the result of an increased oceanic contribution to the North Sea (GLOVER, 1957).

In the preceding pages, PARRISH and CRAIG (p. 20) have referred briefly to the planktonic and hydrographic evidence for environmental change, coincident with recent changes in the character of the Scottish summer herring fishery.

The evidence for parallel changes in the planktonic environment of the herring is presented in some detail in a separate publication (GLOVER, 1957) but it may be useful to introduce here, a précis of the main conclusions.

The plankton samples were obtained with the small Plankton Indicator (GLOVER, 1953). Fishermen from Fraserburgh used the Indicator every night during the summer fishing seasons, from 1947 to 1955. The Indicator was towed at a depth of about eight metres and the samples have been used to estimate between- and within-season fluctuations in the abundance and composition of the plankton at this depth on the Buchan fishing grounds. Figure 1 shows the seasonal fluctuations in abundance of three groups of plankton.

The Cladocera were numerous until 1951; in 1952 they suddenly declined in abundance and thereafter their numbers remained at a very low level with signs of a slight recovery in 1955. *Calanus finmarchicus*, stages V and VI, showed a reverse succession; the early years were characterized by moderate numbers but after 1952 there was a considerable increase in abundance, very high numbers indeed being found in 1954. *Clione limacina* was absent from Indicator samples when the survey started in 1947 and 1948; subsequently it increased in abundance to a maximum in 1953, appearing progressively earlier in each season.

These three examples were chosen because they illustrate a trend which affected the whole plankton community; since 1947 there has been a marked decrease of abundance of typical North Sea species and an increase of organisms which characterize the mixed Atlantic coastal and oceanic water which flows into the northern North Sea. This is summarized in Figure 2 which shows the relative seasonal abundance of the different components of the plankton on the Buchan fishing grounds. The "nine-year mean" was calculated for each organism, that is, the mean number of individuals per cubic metre over the whole period 1947—1955. Those years in which this "nine-year mean" was exceeded for at least a third of the fishing season were classed as years when an organism was "abundant"; when the number per cubic metre exceeded twice the nine-year mean for a third of the season, the organism was said to be "most abundant". Alternative standards were tested and the resulting picture was much the same as that shown in Figure 2.

The organisms were arranged in order so that those species which were plentiful in the early years came first in the list and those which were abundant in the later years came last with a more or less orderly sequence in between (Figure 2). The resulting succession begins with ubiquitous or typical North Sea species such as *Pseudocalanus* and *Paracalanus*, Appendicularia, Cladocera, *Temora longicornis*, and *Centropages hamatus*.

The bottom half of the list, species abundant in the later years, contains organisms which are either

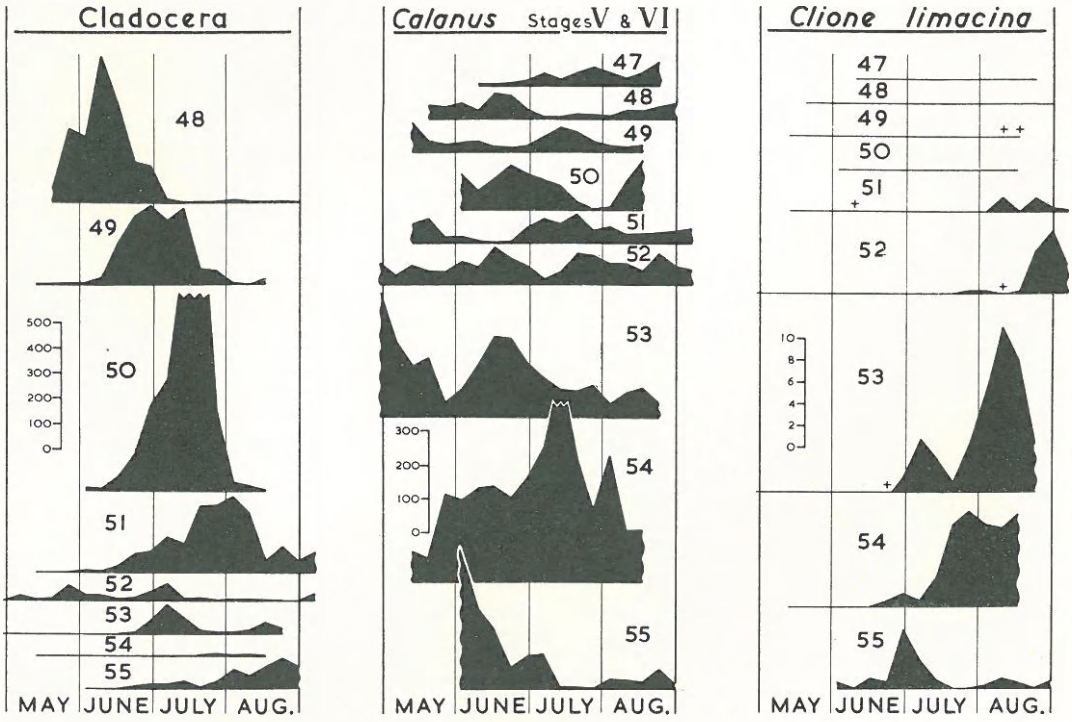

Figure 1. Week-by-week fluctuations in the abundance of Cladocera, *Calanus finmachicus* stages V and VI and *Clione limacina* in samples collected with the Plankton Indicator on the Buchan fishing grounds. The graphs show the mean number of each organism per cubic metre of water sampled. Cladocera were not counted in 1947.

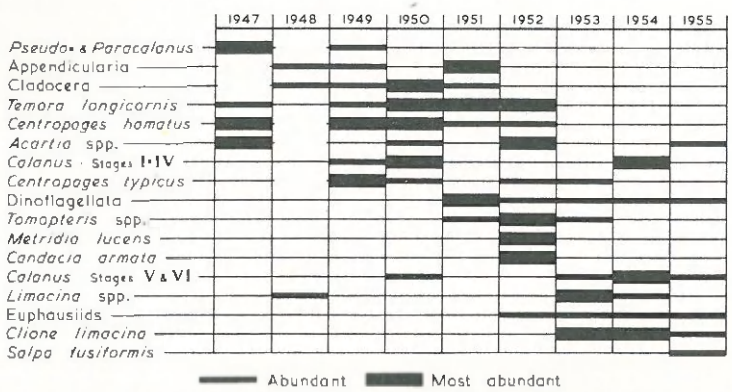

Figure 2. The relative seasonal abundance of the plankton of the Buchan fishing ground. See text for explanation of symbols; a blank space indicates that the organism was not counted in the analysis of the samples in that year (1947 and 1948, only).

accepted as indicators of the mixture of oceanic and coastal water entering the North Sea from the north or which are generally associated with this current, for example, *Tomopteris helgolandica, Metridia lucens, Candacia armata, Limacina* (mostly *retroversa*) euphausiids (mostly *T. inermis*), *Clione limacina,* and *Salpa fusiformis.* Although these organisms, individually, may not always be good indicators of the presence of inflowing water, together they provide strong evidence of its influence. They have been found distributed in a long tongue of plankton extending southwards from the Shetlands and roughly following the pattern of water inflow which TAIT (1937, Figure 48) has postulated.

From the plankton, therefore, one might suggest that the period 1947—1955 began with a typically neritic or North Sea type of environment and ended with a strong admixture of elements drawn from the water to the north of the Buchan fishing grounds. The increasing inflow of mixed water appeared to be most marked between 1951 and 1952, probably reached its maximum in 1953 and was maintained in 1954; but there may have been some slight reduction in 1955. The increase in the abundance and variety of planktonic indicators of inflowing water was, therefore, contemporary with some major changes in the herring fishery which are described in the preceding pages.

Some evidence of the connexion between the indicators of "mixed" water on the fishing ground and oceanic plankton proper is provided by RAE (1956) from the Continuous Plankton Recorder on the "W" route in the Atlantic west of Ireland. *Clione* and other indicator species appeared on the Records progressively earlier in each year from 1948 to 1954, but, each year, about three months before *Clione* appeared in the samples from the Buchan herring grounds (see Figure 1); RAE points out that the lag of three months is compatible with the expected rate of progression of the Atlantic drift.

At intervals of four to six weeks in 1954 and 1955, extensive surveys were made by the Scottish Home Department's research ships using the Plankton Indicator. These surveys have demonstrated that the direction of inflow may also vary; the evidence suggests that the apparent reduction of mixed water on the fishing grounds in 1955 may not have resulted so much from a diminution of the strength or intensity of the inflow as from its direction south-eastwards towards the central North Sea and away from the coastal fishing grounds. In 1954 the tongue of inflowing plankton stretched almost due south from the Shetlands, directly on to the Buchan fishing grounds.

It is notable that most of the organisms which became abundant after 1951 are important in the food of the herring and it may be significant that the increased rate of growth of the fish occurred when there was a large standing crop of their planktonic food. Nevertheless there are reasons for believing that the relation between the herring and the oceanic contribution to their environment may not be solely a direct feeding connexion (GLOVER, 1957).

References

CUSHING, D. H., & BURD, A. C., 1956. "Recruitment and maturity of the East Anglian herring." Nature, Lond., **178**: 86—87.

FRASER, J. H., 1956. "Plankton collections by the Scottish research vessels." Ann. Biol., Copenhague, **11**: 52—54.

GLOVER, R. S., 1953. "The Hardy plankton indicator and sampler: a description of the various models in use." Bull. Mar. Ecol., **4**: 7—20.

— 1955. "Science and the herring fishery." Advanc. Sci., Lond., **11**: 426—34.

— 1957. "An ecological survey of the drift-net herring fishery off the north-east coast of Shetland. Pt. II. The planktonic environment of the herring". Bull. Mar. Ecol., **5**. (In press).

KEMP, S., 1938. "Oceanography and the fluctuations in the abundance of marine animals." Rep. Brit. Ass., 1938, 85—101.

RAE, K. M., 1956. "The continuous plankton recorder survey: plankton around the British Isles during 1954." Ann. Biol., Copenhague, **11**: 54—58.

RUSSELL, F. S., 1936. "The importance of certain plankton animals as indicators of water movements in the western end of the English Channel." Rapp. et Proc.-Verb., Copenhague, **100** (3): 7—10.

STORROW, B., 1930. "Cullercoats herring investigations and their relation to other marine work: an essay on fluctuations." Proc. Univ. Durham Phil. Soc., **8**: 191—238.

— 1931 and 1932. "Herring investigations. 1. Herring shoals." Rep. Dove Mar. Lab., N. S., **19**: 9—30; **20**: 8—26; **21**: 11—30.

— & COWAN, D., 1933 and 1939. "Herring investigations." Rep. Dove Mar. Lab., Ser. 3, **1**: 7—25; **6**: 12—28.

TAIT, J. B., 1937. "The surface water drift in the northern and middle areas of the North Sea and in the Faroe-Shetland Channel." Sci. Invest. Fish. Scot., 1937, 1, 60 pp.

APPENDIX II

Recent Hydrographic Changes in the North-Western North Sea

By R. E. Craig
Marine Laboratory, Aberdeen.

From hydrographic surveys of the north-western North Sea (Craig and Lovegrove, 1952, Craig, 1953—57), carried out since 1951 between March and August each year in connexion with herring investigations, the conclusion has been reached that 1952 and 1953 were the most markedly oceanic in the north-western region. The year 1954 was slightly less so, 1951 significantly less so, and 1955 the least oceanic. Both 1954 and 1955 showed recoveries of the strength of inflowing water in the latter part of the season, which brought 1954 almost to the same oceanic level as 1953 (with salinities above 35·4 $^0/_{00}$ east of Shetland in June at both surface and bottom). In 1955, even as late as August, there was no water approaching this salinity and water of 35·3 $^0/_{00}$ extended only as far as a point a little east of Fair Isle.

In support of these salinity data it may be noted that the temperature distributions up to June in 1952, 1953, and 1954 were clearly dominated by the warmth of the inflowing water, but in 1955 temperatures in the usual path of inflowing water were relatively low.

The monthly charts of surface temperature and salinity, published since 1950 by the Fisheries Laboratory, Lowestoft, and latterly by ICES, provide additional data. The surface salinity distributions in the north-western approaches to the North Sea suggest that the peak of the recent phase of oceanic activity may have been reached about January, 1953.

Surface temperature anomalies have been calculated by Smed (1946—57) for the north-western North Sea (Area F). These show that the temperatures in 1953 were, taken over the whole year, the highest recorded since 1876. Data are not available during the two wars, but indirect (wind) data suggest that high values may also have occurred during the period 1943—1945.

Broad estimates of "oceanicity", based on somewhat arbitrary estimates of heat transport southward through the north-western North Sea, from 1920 to 1955, emphasize the outstandingly continental nature of conditions during the first half of 1947, from which recovery in 1948 led to the extremely oceanic year 1949, followed by a recession to 1951. From 1951 the cycle of heat transport grew steadily to a peak in 1953 and then declined again. On these arbitrary estimates, oceanicity during 1953 was greater than in any other year of the period examined.

References

Craig, R. E., & Lovegrove, T., 1952. Ann. Biol., Copenhague, **9**: 107.
Craig, R. E., 1953—1957. Ann. Biol., Copenhague, **10**—**12**, Section: North Sea (Near Northern Seas).
Smed, J., 1946—1957. Ann. Biol., Copenhague, **1**—**12**, Sections: North-Western Area and North Sea (Near Northern Seas).