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SHIFTS IN HERRING SPAWNING AREAS IN THE NORTHWESTERN NORTH SEA IN RELATION TO ENVIRONMENTAL CHANGES

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Abstract

Annual surveys of herring larvae in the northwestern North Sea have shown that the distribution of larvae between 1972-82 was restricted nearly entirely to the Orkney/Shetland area, and that from 1983 onwards a second important concentration was found in the Buchan area, some 150 miles farther south. The total abundance of herring larvae in the Orkney/Shetland area remained fairly constant between 1979-84, and the spawning at Buchan since 1983 does not necessarily have to be regarded as an "overflow" of the Orkney/Shetland population. Historical data show that the Buchan area was an important spawning ground for herring in the 1950's, and that these grounds were deserted in the late 1960's, following a northerly shift of spawning towards Orkney/Shetland. This northerly shift was ascribed by some authors to changes in plankton composition, possibly due to a reduction of Atlantic inflow into the North Sea. The southerly shift of spawning grounds in recent years seems to be a reversal of the trend that was observed in the 1960's, and an environmental cause is a distinct possibility.

1. Introduction

Annual surveys of herring larvae have been conducted on the various herring spawning grounds in the North Sea has since the late 1960's, in order to follow developments in spawning stock size. Apart from providing indirect stock estimates for the various components of North Sea herring, the larvae surveys also produce data of a more general biological interest.
For instance, the surveys may detect changes in spawning time and position, which may be indicative of long-term biological changes in the herring populations.

This paper considers a drastic change that occurred in the distribution of herring larvae in the northwestern North Sea in the early 1980's. For many years, spawning in this area had been restricted to the waters around Orkney and Shetland (Figure 1). From 1983 onwards large concentrations of newly hatched larvae appeared on the Aberdeen Bank and Turbot Bank, some 150 miles farther south. This so-called Buchan area had been a major herring spawning area in the 1950's, but the abundance of larve in this area had declined during the 1960's, and hardly any larvae had been found after 1967.

The question addressed in this paper is whether the return of spawning herring to the Buchan grounds was simply an "overflow" of the growing Orkney/Shetland population (the commonly accepted view), or whether this return was somehow related to a change in environmental conditions in the northwestern North Sea.

2. Changes in the distribution of herring larvae from 1972 to 1985.

Surveys for herring larvae have been conducted in the northern North Sea since the 1950's. However, it is only from 1972 onwards that data from ICES-coordinated surveys have been stored in a joint data base at the Aberdeen Marine Laboratory, and so are readily accessible for analysis. For the present study, a copy of this data base for the years 1972-85 was kindly made available by the Marine Laboratory.

Annual surveys were made in two sampling areas: the Orkney/Shetland area, and the Buchan area (Figure 2). Coverage in the earlier years of the surveys was rather irregular, both in area and in time. Since 1982 an attempt has been made to obtain a full coverage of each area both in the first and second half of September. Sampling stations were situated 10 miles apart, and were fished according to a standard routine. Details of the methodology used are given in Anon 1977. The larvae were grouped into 3 length categories: small (<10mm), medium (10-15mm) and large(>15mm).
For this study, mean values per station for 3-day periods were calculated, and then the average of all 3-day periods within the month of September.
To illustrate changes in the distribution of larvae in recent years, the results for the years 1972-85 have been grouped into three successive periods: 1972-77 (low abundance at Orkney/Shetland), 1978-82 (increased abundance at Orkney/Shetland) and 1983/85 (increased abundance also at Buchan). Figure 3 shows the mean distribution of the smallest length group (< 10 mm) for each of these periods. It is seen that the geographical distribution of larvae hardly changed between the first and second period;
the main concentration of larvae occurred in the Orkney/Shetland region, and only the abundance of the larvae increased. In the third period, however, the picture changed drastically, with an entirely new concentration of larvae appearing farther south on the offshore spawning grounds of Aberdeen Bank and Turbot Bank.

In order to see whether the appearance of larvae on the southern spawning grounds was due to an "overflow" of the existing population at Orkney/Shetland, the mean abundance of larvae in each year was considered in more detail. For each size group of larvae

(<10mm, 10-15mm, and >15mm) the annual abundance was calculated for the Orkney/Shetland area and the Buchan area. The annual abundance was calculated by multiplying the mean station values for September with the surface area each station represented, and then summing the products. The results of this procedure are shown in Figure 4.

At Orkney/Shetland the abundance of small larvae reached a minimum in 1975, and then recovered rapidly between 1977 and 1979. After 1979 the abundance of small larvae leveled off (ignoring the outlier for 1985). The abundance of medium and large larve more or less followed the pattern for small larvae.

At Buchan very low numbers of small larvae were seen until 1982. Then, after a first small revival in 1982 the abundance of small larvae in 1983 suddenly increased to a level comparable to that at Shetland. Medium and large larvae were present already in relatively high numbers since 1979, probably due to the drift of larvae hatched at Orkney/Shetland into the Buchan area.

Figure 4 shows that in the 4 years prior to 1983, there was no further build up of larval abundance at Orkney/Shetland. The sudden southward extension of spawning in 1983, therefore, does not seem to be due to an overflow of overcrowded Orkney/Shetland spawning grounds. Still, the possibility of a population density effect cannot be completely disregarded on the basis of the above observations.

3. Discussion

The data presented above indicate that the southward extension of spawning from 1983 onwards was not necessarily the effect of an increased population size. An alternative explanation for the observed change in spawning area is a change in environmental conditions in the northwestern North Sea. As the herring are rather selective in the choice of their spawning grounds, it is possible that subtle changes in hydrographic parameters could have changed the preference of the herring for certain spawning grounds.

To tackle the question of "overflow" versus environmental change, it is useful to look at changes in herring spawning areas in this region in earlier times. In the 1950's the Buchan area was the main spawning ground for herring in the northwestern North Sea. The decline of spawning activity in this area, which took place in the 1960's, has been well documented by Saville (1971). The decline apparently was not related to a decline of the total herring population (there was no decrease in abundance of larvae in the northern North Sea), but to a northward shift of the population towards Orkney/Shetland. Saville illustrated his findings by distribution charts for herring larvae over the periods 1951-54, 1955-60, and 1961-66. Because of their relevance for the present study, these charts have been reproduced here as Figure 5. It is seen that there was a gradual decrease in significance of the Buchan spawning area, and a concomitant increase in the more northern areas off Wick and Orkney. Saville considered that the northward shift of spawning could have been due either to a shift in spawning of the existing population, or to the replacement of the old Buchan population by a newly developed, independant population at Orkney/Shetland.

The question of the northerly shift of herring spawning grounds in the 1960's was also addressed by Bainbridge and Forsyth (1972). These authors related the northern displacement of herring spawning grounds to large scale changes in the composition and abundance of the zooplankton in the northwestern North Sea. Their data, based on the results of the Plankton Indicator Programme in 1950-67, showed a sharp decrease in the abundance of some important zooplankton species (Calanus and Spiratella) in the Buchan area around 1960, at the same time when herring spawning in this area declined. The decline of Calanus in the Buchan area seemed to be related to a northward shift of the

zooplankton towards the Shetland area. Bainbridge and Forsyth assumed that the herring during summer would be distributed farther north in search of their food, and that they would therefore also select a more northern spawning area at the end of the feeding season.

Bainbridge and Forsyth found that annual variations in the plankton were related both to the degree of vertical mixing in spring, and to the degree of Atlantic influence during summer. They used salinity anomalies in an area southeast of Buchan as an index for the Atlantic inflow into the northwestern North Sea. A strong oceanic inflow resulted in high numbers of zooplankton and vice versa. The conclusion of their findings (although not explicitely drawn by the authors themselves) is that the long-term decline in zooplankton in the Buchan area could have been caused by a long-term decrease in Atlantic influence. This factor could at the same time have been responsible for the northward retreat of herring spawning in this area.

Turning from historical data to the developments in more recent years, it seems that the southward extension of spawning after 1983 can be regarded as a reversal of the trend of the 1960's. The question then arises whether in recent years there are also plankton and hydrographic data that point to changes in environmental conditions.

Unfortunately, the detailed plankton investigations in the northwestern North Sea under the Plankton Indicator Programme came to an end around 1970, and there are no data of comparable accuracy available for later years. However, the plankton in the area has been monitored up till the present by the Continuous Plankton Recorder Programme, which works a coarser grid throughout the year and over a much wider area (including all the seas around Great Brittain).

The CPR data have shown a declining trend in a large number of zooplankton and phytoplankton species during the period 1950-80, and a reversal of this trend after 1980 (Colebrook et. al. 1984, Colebrook 1986). This trend occurred not only in the northwestern North Sea but also in most other parts of the North Sea, and even in the waters west of Scotland and Ireland.

Comparing the data of Bainbridge and Forsyth with those of the CPR programme, it seems that the decline of Calanus and Spiratella in the Buchan area around 1960 may have been just one aspect of a more general decline in zooplankton over the entire North Sea and waters west of Scotland; a decline that started already in the 1950's, and that continued until about 1980. This decline in plankton was probably related to a large-scale, long-term environmental process, the nature of which is still unclear. It is tempting to speculate that the northerly shift of herring spawning between 1951 and 1967 was also related to this environmental change.

It is interesting to note that the southerly extension of herring spawning in the early 1980's roughly coincided with a reversal of the long-term trend in CPR-data. This observation strengthens the impression that the shifs in herring spawning area were somehow related to the changes in the environment.

Indications for an environmental change in the northwestern North Sea in the late 1970's and early 1980's were found by Robinson and co-workers (Robinson, 1976, 1977, 1978, 1979, Robinson and Budd 1980, Robinson and Jonas, 1982,1983, Robinson and Hunt, 1984, 1985, 1986) when studying the the occurrence of plankton indicator species in CPR-samples from the west coast of Scotland and the northwestern North Sea. They found a low abundance of Atlantic indicator species in the northwestern North Sea in 1974-78, which they considered as an indication of a low inflow of Atlantic water. From 1980 onwards, they reported a more northward distribution of warm-water Atlantic species to the west of the British Isles, and a stronger penetration into the North Sea These observations do suggest a low Atlantic influence in the northwestern North Sea in the 1970's, and an increase after 1980.

The conclusion from the above observations is that the shifts in herring spawning area both in the 1960's and early 1980's were paralleled by large scale changes in plankton abundance and distribution. It is likely, therefore, that both plankton and herring reacted to a long-term environmental change. This change was not restricted to the northwestern North Sea, but according to the results of the CPR programme, it occurred over the whole shelf area of the N.E. Atlantic. A long-term change in the current system of the North Atlantic seems to have been the ultimate cause of the observed changes.

A possible mechanisme for the shifts in herring spawning grounds in the northwestern North Sea would be a change in Atlantic influence in this area. An increase in Atlantic inflow, or an inflow of water with increased Atlantic properties, would probably result in a southward extension of the area where optimum conditions for herring spawning prevail. Conversely, a decrease in Atlantic influence in the northwestern North Sea would tend to contract the region of optimum spawning conditions to the Orkney/Shetland region.

Acknowledgements

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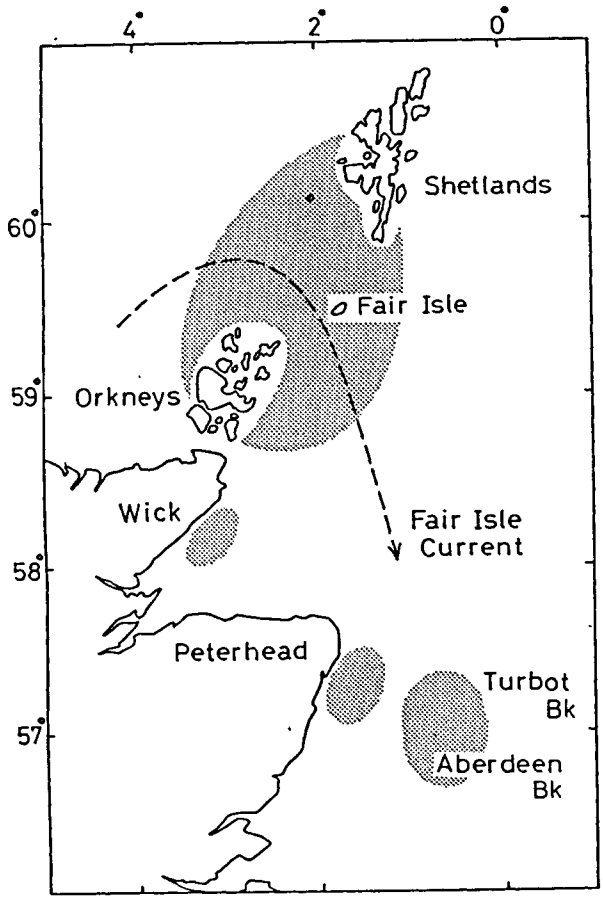

Figure 1. Herring spawning areas and main residual current in northwestern North Sea.

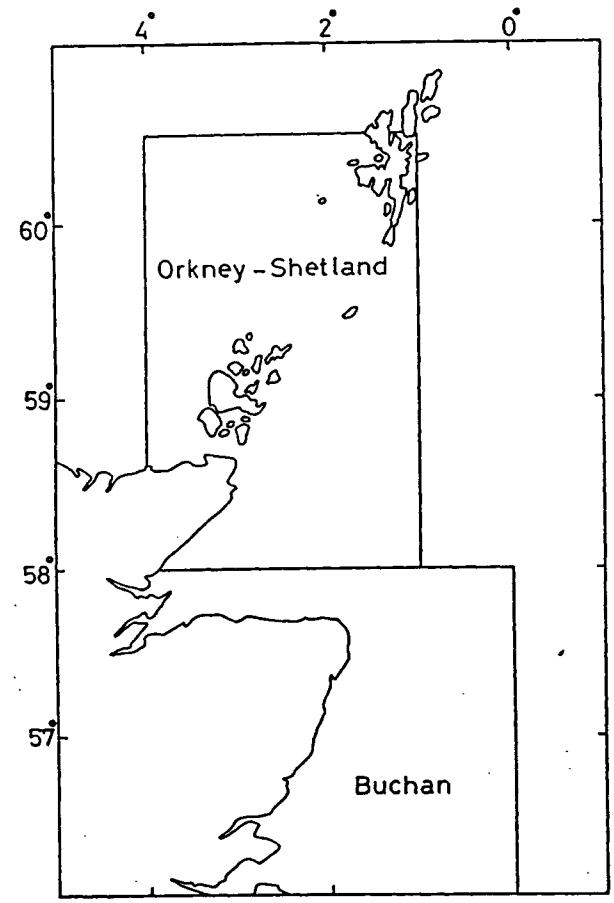

Figure 2. Standard sampling areas for herring larvae in the northwestern North Sea.

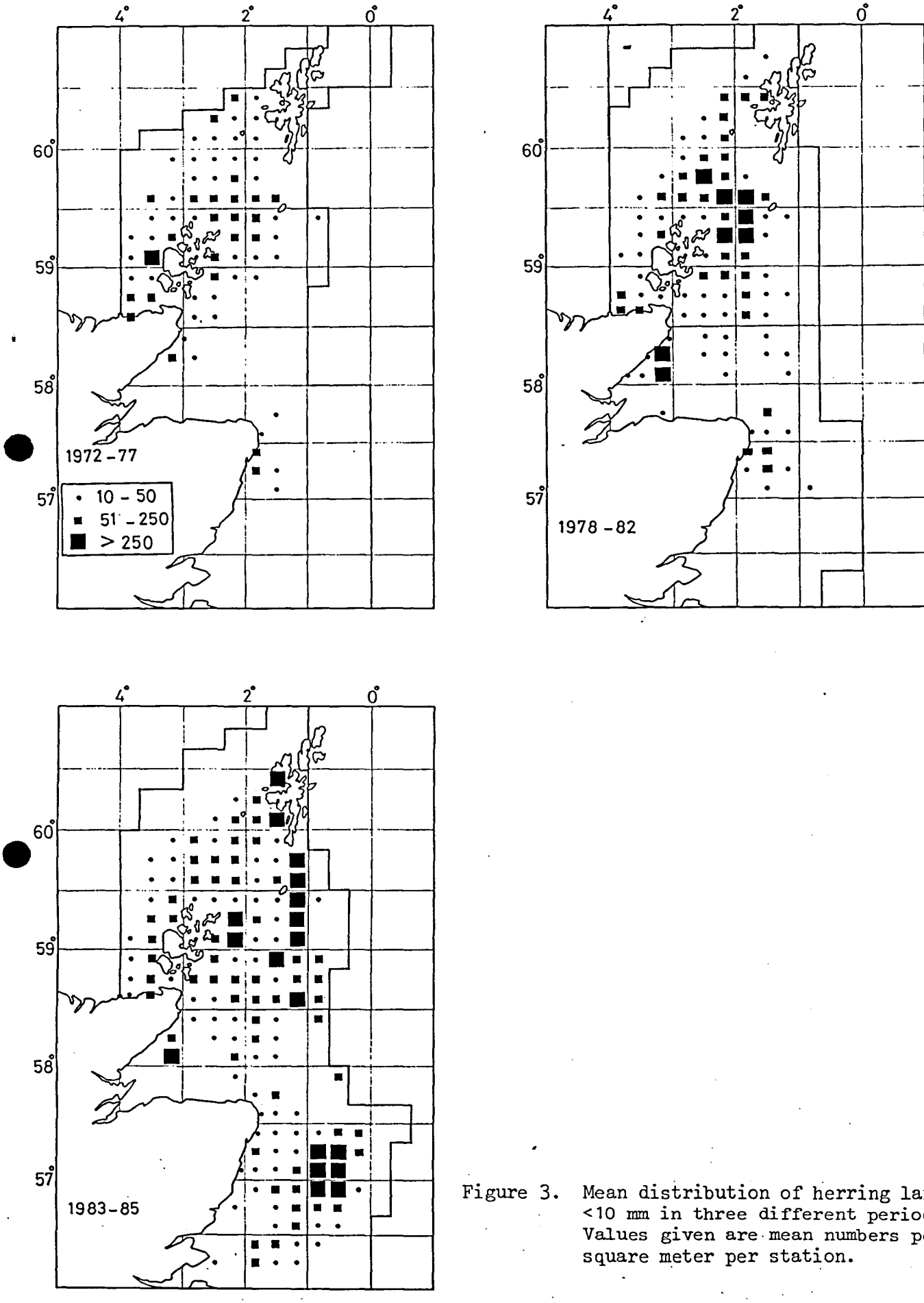

Figure 3. Mean distribution of herring larvae <10 mm in three different periods. Values given are mean numbers per square meter per station.

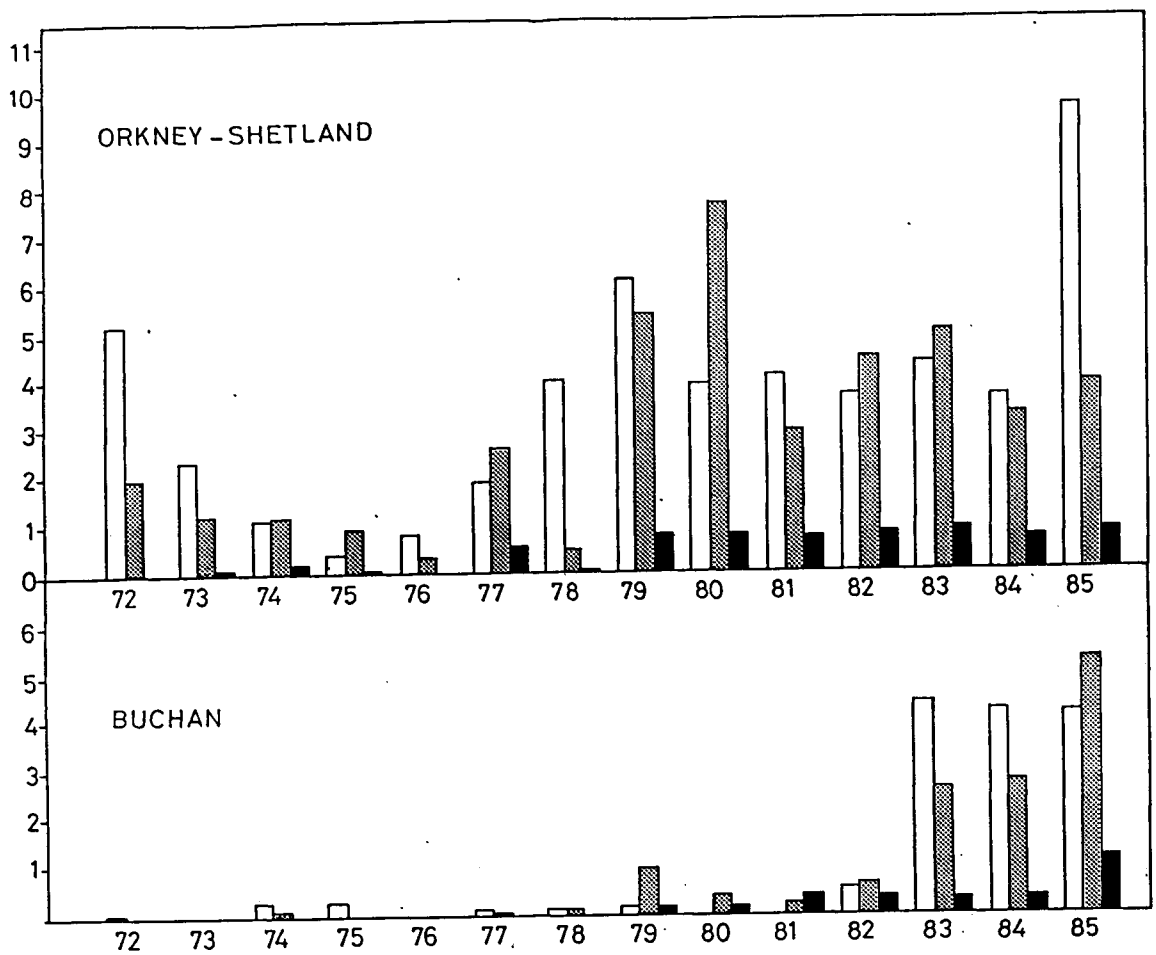

Figure 4. Abundance of herring larvae in two different areas of the north-western North Sea. Three size categories of larvae are distinguished: <10 mm (white bars), 10-15 mm (shaded), and >15 mm (black).

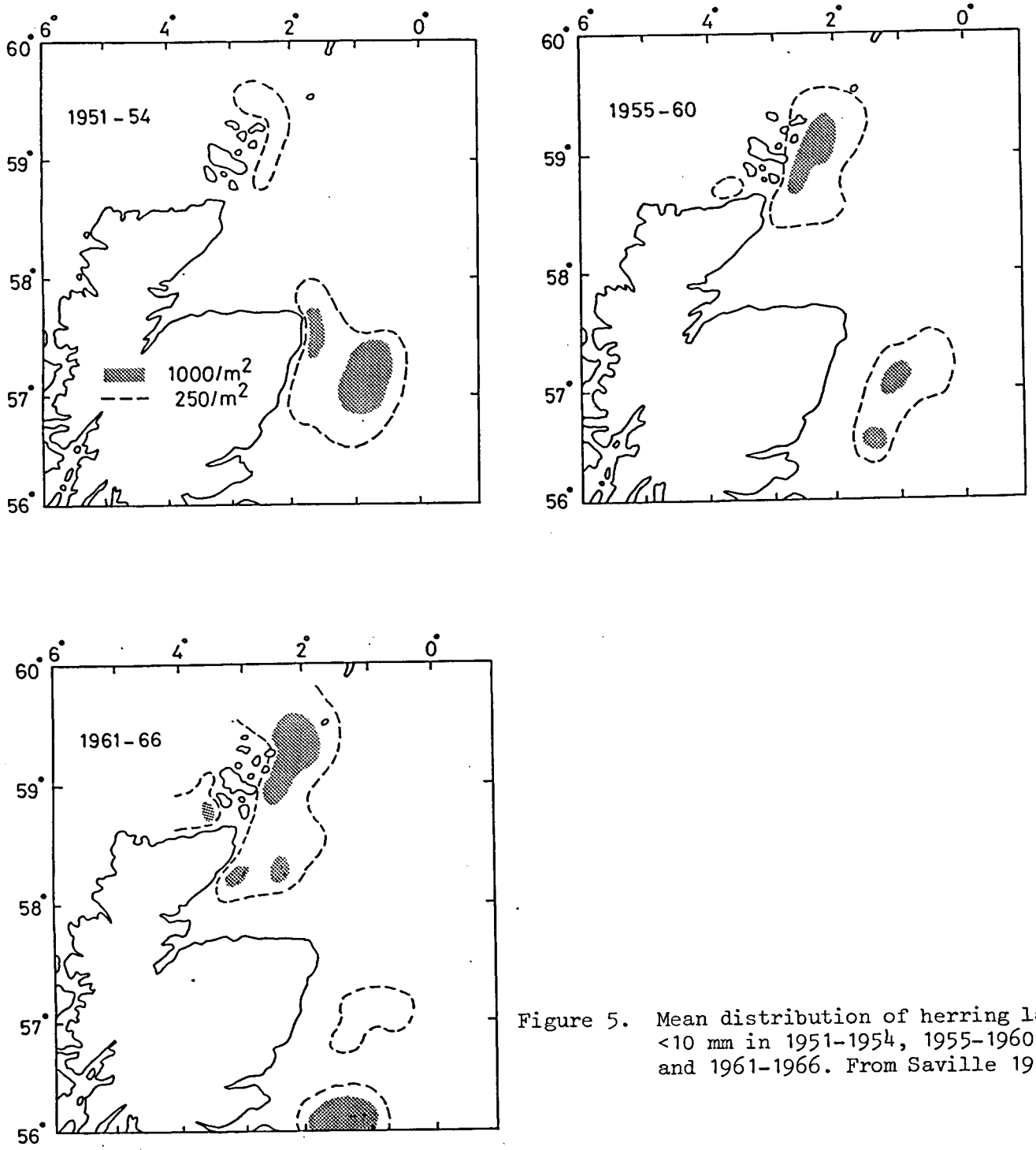

Figure 5. Mean distribution of herring larvae <10 mm in 1951-1954, 1955-1960, and 1961-1966. From Saville 1971.