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HERRING SPAWNING GROUNDS IN THE NORTH SEA

and

SURVEYS OF HERRING LARVAE IN THE NORTH SEA AND  
ADJACENT WATERS, 1974/75

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## HERRING SPAWNING GROUNDS IN THE NORTH SEA

by

K H Postuma, A Saville and R J Wood\*

### Introduction

At the 62nd Statutory Meeting of ICES the following resolution was passed (C.Res.1974/4:23):

"It was decided, that:

- (i) in the light of:
  - (a) the recent expansion of the marine aggregate industry and the shift of extraction activities to deeper water; and
  - (b) the need to protect herring spawning grounds, member countries of ICES should take immediate steps to delineate the herring spawning grounds;
- (ii) the Working Group on North Sea Herring Larval Surveys should assist in this by:
  - (a) making available data collected to date on the distribution of yolk-sac larvae; and
  - (b) by collecting and summarising all available information on delineation of spawning grounds;
- (iii) for this purpose the Group should meet, if necessary".

After discussion of this resolution with various members of the Working Group it was decided that a meeting was unnecessary for this purpose but that it could be most efficiently met by correspondence between the authors and the preparation of a joint paper utilising all the relevant data available in their laboratories and in the literature.

### Material and methods

For the delineation of herring spawning grounds four types of data are available:

- (a) Observation of spawn, either by dredging or grabbing techniques or by direct visual observations.
- (b) Records of the position of capture of herring which are, or are on the point of, spawning.

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- (c) Position of capture of other fish species which are feeding on herring spawn.
- (d) Position of capture of recently hatched herring larvae.

Of these (a) - the observation of spawn - is likely to give the most precise delineation of spawning grounds. Unfortunately, however, the number of records of this type in the North Sea is very limited. Parrish *et al.* (1959) delineated spawning grounds in the Firth of Clyde in considerable detail using dredges and grabs; Runnström (1941) used similar techniques for describing the spawning grounds of Atlanto-Scandian herring. But despite several surveys made using these techniques in the North Sea the only recorded success in locating herring spawn is that by Bolster and Bridger (1957) in the English Channel at a position 51°06'N 01°38'E.

Techniques (b), (c) and (d) are essentially less precise in that the fish or larvae may move, or may have moved, considerable distances before spawning, since having eaten the spawn, or since hatching. However, the consistency of these data both between methods, and within methods between years, gives considerable confidence that, although perhaps not fixing the precise location of spawning grounds, they do provide a useful first approximation.

The positions of capture of spawning herring have been obtained from the records of the English, Netherlands and Scottish laboratories from their routine sampling of the catches of the commercial herring fisheries. In the area north of 56°N the records of spawning fish are all derived from the Scottish fishery which has not consistently exploited the spawning concentrations in this area. The data on capture of spawning fish have not been quantified as any form of abundance index but are merely recorded as position of capture of catches consisting predominantly of fish in maturity stage VI.

To identify spawning grounds from the sampling of herring larvae the best index would be the centres of abundance and yolk-sac larvae. However, yolk-sac larvae are seldom caught in appreciable numbers - probably because they are distributed in a narrow depth zone close to the bottom which is rather inefficiently sampled by oblique tows of plankton samplers. The records of yolk-sac larvae which are available are largely obtained from the English laboratory and are shown simply as positions of capture because their quantification is very dubious. Also shown are the centres of abundance of larvae less than 10 mm long (less than 11 mm in the southern North Sea - Division IVc). Larvae of this size group are taken much more consistently but because they may be up to 15 days from hatching, during which they are subject to tidal and residual drift and to diffusion, they show a distribution pattern which is likely to be more widespread than the distribution of the spawning areas. In an attempt to minimise this only centres of high abundance, numbers  $>100/m^2$ , of this category of larvae have been used as indicative of spawning grounds.

No systematic collection of records of fish feeding on herring spawn have been collected in any of the laboratories since the second World War. Consequently very little recent information is available from this source, although there are some records in the literature, principally dating from the period between the wars. These data have not been given further treatment but will be commented on in the discussion.

#### Positions of capture of herring in spawning condition

The positions in which catches consisting predominantly of herring in maturity stage VI have been taken in the northwestern North Sea (north of 56°N) are shown in Figure 1. As mentioned earlier these are rather scattered observations both in space and time because of the nature of the Scottish fishery. In the Shetland area catches of ripe fish have been recorded from east of the islands at positions up to 6 miles east of Fetlar, in Sandwick

Bay, and 4-6 miles ESE of Sumburgh Head. From the west of Shetland the only recorded catch of ripe herring was taken 1 mile west of Ramna Stacks. There are several records from positions between northeast and southeast of Fair Isle within 6-12 miles from the Island. In the Orkney area spawning fish have been recorded from positions 3-5 miles east of Start Point and to the west of the islands at the entrance to Hoy Sound. The most consistent records of catches of ripe fish from the northwestern North Sea come from the Clythness area where a considerable Scottish fishery on spawning fish takes place in some years. These catches are distributed from Freswick Bay to Berriedale Ness at distances up to about 6 miles from the coast. On the south coast of the Moray Firth there are also a number of records of capture of ripe fish in an area up to 10 miles from the coast between Cullen in the west and Troup Head in the east. Further south off the east coast of Scotland records are rather sparse, but ripe fish have been captured at distances of 2-6' east of Kinnaird Head, 25 miles east of Todhead,  $\frac{1}{2}$  mile west of the Bell Rock and in a band extending from the Wee Bankie across Marr Bank to  $56^{\circ}25'N$   $1^{\circ}W$ .

In the central North Sea, between  $53^{\circ}N$  to  $56^{\circ}N$ , as shown in Figure 2, capture of spawning herring has been recorded over a wide area and with great frequency. However, although there are a few records from the intervening areas, it would appear that the data can be grouped into four major locii where spawning fish have been caught with great frequency:

- (a) off the Northumberland coast in the vicinity of the Longstone Rock, between 2 miles to 7 miles off the coast, in depths of from 12 to 40 fathoms;
- (b) to the east of this in the area of the North East Bank and of the Farn Deep between  $55^{\circ}22'N$  and  $55^{\circ}45'N$  and between  $0^{\circ}17'W$  and  $1^{\circ}00'W$ ;
- (c) an area off the Yorkshire coast between  $53^{\circ}55'N$  and  $54^{\circ}42'N$  largely outwith the 20 fm depth contour, and extending eastwards for about 23 miles;
- (d) a large area to the east of this extending as a band about 45 miles wide to the east of a line from  $54^{\circ}45'N$   $1^{\circ}00'E$  to  $53^{\circ}30'N$   $2^{\circ}00'E$  and enclosing the southwest corner of the Dogger Bank, the Well Bank, the Outer Silver Pit and Indefatigable Bank.

Outwith these four areas of concentration there are more scattered records, particularly on the northwest edge of the Dogger Bank and between the Outer Dowsing and Spurn Point.

In the southern North Sea and eastern Channel the positions of capture of spawning herring are also shown in Figure 2 and would suggest four areas of major concentration:

- (a) one in a band about 20' wide in its northern portion and narrowing to about 6' wide in its southern end lying between  $52^{\circ}07'N$  and  $51^{\circ}00'N$  and enclosing the Hinder Banks, Bligh Bank and Sandettié Bank;
- (b) a smaller area between  $50^{\circ}32'N$   $1^{\circ}E$ ,  $50^{\circ}55'N$   $1^{\circ}E$ ,  $50^{\circ}55'N$   $1^{\circ}23'E$  and  $50^{\circ}32'N$   $1^{\circ}30'E$  and enclosing the southern part of the Colbard, Bassurelle and Vergoyer;
- (c) a third area off Ailly between  $50^{\circ}N$   $1^{\circ}E$ ,  $50^{\circ}24'N$   $1^{\circ}E$ ,  $50^{\circ}24'N$   $0^{\circ}12'E$  and  $50^{\circ}N$   $0^{\circ}12'E$ ;
- (d) a fourth area in the Baie de la Seine between  $49^{\circ}25'N$   $0^{\circ}15'W$ ,  $49^{\circ}55'N$   $0^{\circ}15'W$ ,  $49^{\circ}55'N$   $0^{\circ}40'W$  and  $49^{\circ}25'N$   $0^{\circ}40'W$ .

These positions of capture of spawning fish shown in Figures 1 and 2 are composite ones from all the data available over the period 1955-73. In fact, they mask considerable changes in areas of capture, particularly

in the central North Sea, which took place during this period. In Figures 3 and 4 records of capture of stage VI herring by Dutch vessels are shown for the periods 1955-59 and 1965-69 separately. This illustrates clearly the change in the Dutch fishery for spawning herring from predominantly on the southwestern corner of the Dogger Bank to predominantly off the north-east English coast between these two periods, as a consequence of the decline of the stock spawning on the Dogger Bank. This shift has been intensified in recent years. These figures also show a decline between the two periods in the records of capture of spawning herring in the eastern Channel and its approaches but a decline particularly marked in the fishery on spawning fish in the Bay of Seine. This latter fishery, however, showed some signs of revival in the years subsequent to 1969.

#### Positions of capture of small herring larvae

The positions of capture of herring larvae less than 10 mm long in the north-western North Sea are shown in Figure 5. The contour lines enclose all positions at which larvae of this size group have been taken at concentrations of more than 100 per square metre over the period for which records are available. The spawning areas delineated in this way in the northwestern North Sea are:

- (a) an extensive area around Orkney extending roughly from  $4^{\circ}\text{W}$  to  $1^{\circ}\text{W}$  and from  $60^{\circ}\text{N}$  to  $58^{\circ}15'\text{N}$  and
- (b) another large area to the east of the Scottish mainland extending from  $58^{\circ}\text{N}$  to  $56^{\circ}\text{N}$  eastwards to the prime meridian.

In the northwestern North Sea these larval data would suggest much more extensive spawning areas than are shown in Figure 1 from the positions of capture of spawning herring. As has already been mentioned in discussing the latter data fish in spawning condition are probably not very intensively exploited by the Scottish fishing in this area. On the other hand, due to drift and diffusion, the larval data, even at this rather high level of concentration, probably give an exaggerated impression of the extent of the spawning grounds although the positions of capture of yolk-sac larvae, within the area sampled by the Lowestoft Laboratory, are largely coincident with the area demarcated by the  $100/\text{m}^2$  larval contour.

In the central North Sea the spawning areas derived in the same way are shown in Figure 6. In this area there are two major spawning areas, off the northeast English coast, one extending from north of Holy Island to south of the mouth of the River Tyne and extending seawards to about  $0^{\circ}30'\text{W}$  and a second from off Whitby to Flamborough Head and extending eastwards to about  $0^{\circ}50'\text{E}$ . Off the northeast coast of England there are also five smaller areas where early larval concentrations have been located; one on Berwick East Bank and four smaller ones between Flamborough Head and Spurn Point extending seawards to about  $1^{\circ}\text{E}$ .

In addition, three spawning areas are delineated further offshore around the Dogger Bank, a large area covering the North West Rough and the western edge of the bank, a somewhat smaller area in the vicinity of the southwest patch and a third very small one between the Outer Silver Pit and Markhams Hole. These areas agree well with those shown in Figure 2 as the locations of capture of ripe herring, and with the positions where yolk-sac larvae have been taken.

In the southern North Sea and eastern Channel larval abundances, particularly in recent years when larval surveys have been conducted most extensively, have been so low that a level of more than 100 small larvae per square metre is quite inappropriate as indicative of spawning sites. In this area the level shown in Figure 7 is of more than 10 larvae per square metre. On this basis three major and two smaller areas are demarcated. One at the eastern entrance to the Channel between  $51^{\circ}$  and  $51^{\circ}30'\text{N}$  covers Sandettié Bank, the North, East and West Hinder Banks and Bligh Bank. A second fairly extensive area north of Pt Ailly includes the southwestern part of Vergoyer Bank while



a third fairly large area lies within the Baie de la Seine. Two small areas are also indicated south of Beachy Head in depths of about 25 fathoms.

As in the central North Sea there is a reasonably good correspondence between the areas delineated by capture of ripe fish (Figure 2) and those shown in Figure 6 from areas of concentration of small larvae. The areas where yolk-sac larvae have been taken, also shown in Figure 6 also accord fairly well with those defined by the other two sources of data, bearing in mind the limitations of the yolk-sac data discussed previously. In the northwestern and central sub-divisions of the North Sea there have been major changes in the areas of high concentration of early larvae during the period when the data used in preparing Figures 5-7 were collected. These changes have been reported by Saville (1971) and Zijlstra (1970). In brief, they correspond closely with the changes already discussed in relation to the positions of capture of ripe fish - in the northwestern North Sea, a shift from spawning grounds predominantly in the Aberdeen Bank-Turbot Bank area to predominantly around Orkney; and in the central North Sea from predominantly on the Dogger-Well Bank area to predominantly off the northeast English coast.

### Discussion

It is unfortunate that in the North Sea the only two adequate sources of data, the capture of herring in spawning condition and the distribution of early larvae, do not allow very great precision in delimiting herring spawning grounds. The duration of Stage VI in herring is not known with any accuracy but Iles (1964) suggests that in the northwestern North Sea fish are in this stage for about 5 days. If the fish are still actively migrating towards the spawning sites during this maturity stage, therefore, it is possible for ripe fish to be caught a considerable distance away from the spawning grounds.

The data provided by the capture of early larvae are subject to imprecision of a similar nature. The only data on the duration of the yolk-sac stage in herring, and of early growth rates, are derived from aquarium experiments and may not accurately reflect these parameters under natural conditions. Blaxter and Hempel (1963) give the duration of the yolk-sac stage in northwestern and central North Sea autumn spawning herring as 4 days, for southern North Sea herring as 12 days. Using growth rates during the early larval stage from these authors one can calculate that larvae less than 10 mm could be up to 16 days old measured from the time of hatching. Thus the larval data used to delimit the spawning grounds in this paper are subject to a considerable degree of imprecision due to the effects of diffusion and residual drift during these time periods.

However, the degree of correspondence between the two methods of determining spawning sites engenders considerable confidence that these methods give reasonably reliable indications of where herring deposit their eggs. This is further supported by the agreement between the spawning areas demarcated here and those defined by earlier authors from the capture of other fish species which had been feeding on herring spawn (Bowman, 1922; Hodgson, 1928; Russell, 1914).

Within these broad areas outlined by these methods as those within which spawning takes place the actual sites utilised can, to some extent, be further refined by the knowledge that herring only deposit their eggs on a substrate of small stones, gravel, or on flints overlying gravel (Parrish *et al.*, 1959; Runnström, 1941; Bolster and Bridger, 1957). It is unfortunate that this is also the type of substrate that is likely to be of particular interest to dredging operations. However, any dredging of such a substrate in the areas defined above as being within the localities utilised by herring for spawning is likely to have serious repercussions on the future of the herring fisheries. Utilising all the available data these areas, as regards the major North Sea autumn spawning stocks can be defined as:

- (1) The whole of the east coast of Shetland within the 40 fathom contour from Fetlar to Sumburgh Head.

- (2) The sea around Orkney and the northeast coast of Scotland, bounded by a line at 4°W from Strathy Point to 60°10'N, thence east to 2°40'W, thence south to 59°45'N, thence east to 1°W, south to 59°N, then SW x S to Berridale Ness.
- (3) To the east of the Scottish mainland bounded by a line from Buckie to 58°N 3°W, then east to 58°N 1°W, south to 57°35'N 1°W, then east to 57°35'N 0°, then south along the prime meridian to 56°N, then east along 56°N to Barns Ness.
- (4) Off the northeast coast of England from Berwick eastwards along 55°50'N to 0°40'W, then to 54°30'N 0°30'E, then south to 53°40'W 0°30'E, then east to 53°40'N 1°40'E, then south to 53°08'N 1°40'E, then west to Skegness.
- (5) A more offshore area in the Dogger Bank vicinity bounded by 54°45'N 1°00'E, 54°45'N 2°20'E, 54°N 1°E, 54°N 1°45'E, 53°32'N 1°45'E, 53°32'N 3°E.
- (6) An area at the eastern entrance to the Channel bounded by 52°06'N 3°00'E, and 52°N 2°00'E, 51°N 1°24'E, 51°N 1°50'E.
- (7) An area off Dieppe impinging on the French coast at 0°12'W and at 1°W, northwards to 50°30'N, then NE to 50°45'N 1°17'E, and 50°36'N 1°24'E.
- (8) An area in the Baie de la Seine bounded by 49°35'N and 49°54'N and between 0°00' and 0°53'W. These areas are shown in Figure 8.

In discussing both the larval data and the data on the capture of ripe herring it has been pointed out that, particularly in the northwestern and central North Sea, during the period over which these data were collected there have been major changes in the importance of some spawning locations. Some of the areas demarcated above have been of only minor importance in recent years but this should not be taken as a justification for removing the substrate there. To do so would ensure that the fisheries which formerly took place on them could never recover. In the main body of this paper the emphasis has been entirely on autumn spawning localities as these are by far the major component of the North Sea fisheries, and the stock on which research work has largely been concentrated. In addition, however, there are a number of small spring spawning herring stocks which can be of considerable importance to local inshore fisheries. Known spawning areas of such stocks can be listed as:

- (a) 2-3 miles off the Lincolnshire coast of England between Saltfleet and Mablethorpe;
- (b) in the Thames estuary, on Eagle Bank, and further up to the River Blackwater opposite the village of Stone, and 100 metres off the end of Herne Bay Pier, and on Studhill Bank a little further seawards;
- (c) in the eastern Channel 2-5 miles off Littlehampton.

### Summary

All the available data for defining the spawning grounds of autumn spawning herring in the North Sea are reviewed and discussed.

The spawning areas as defined by positions of capture of ripe herring, and of recently hatched larvae, are described. From the composite data areas where dredging of gravel and small stone substrates should not be permitted are specified.

Attention is also drawn to known spawning grounds of local spring spawning herring where the same restrictions should be applied.

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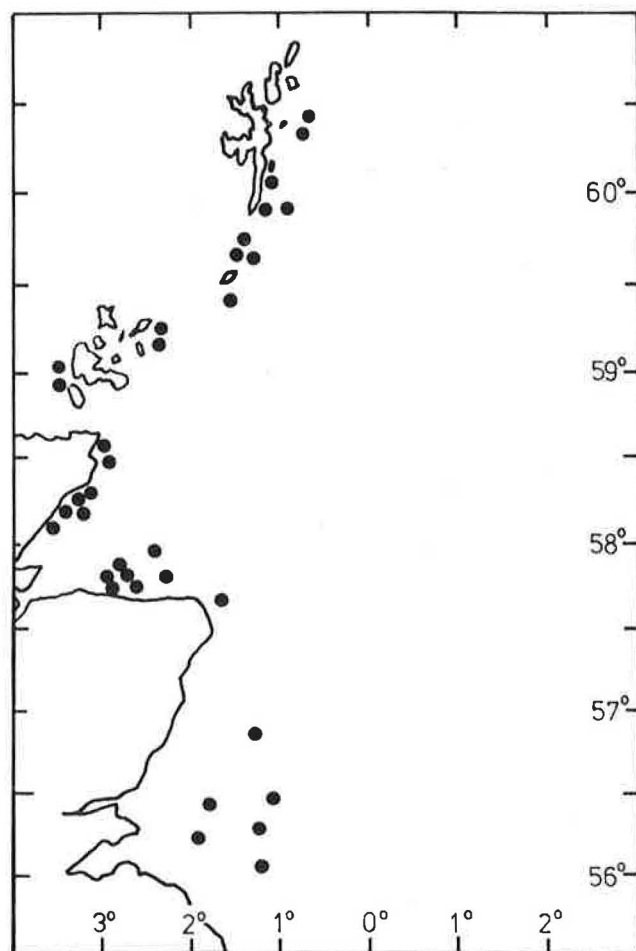
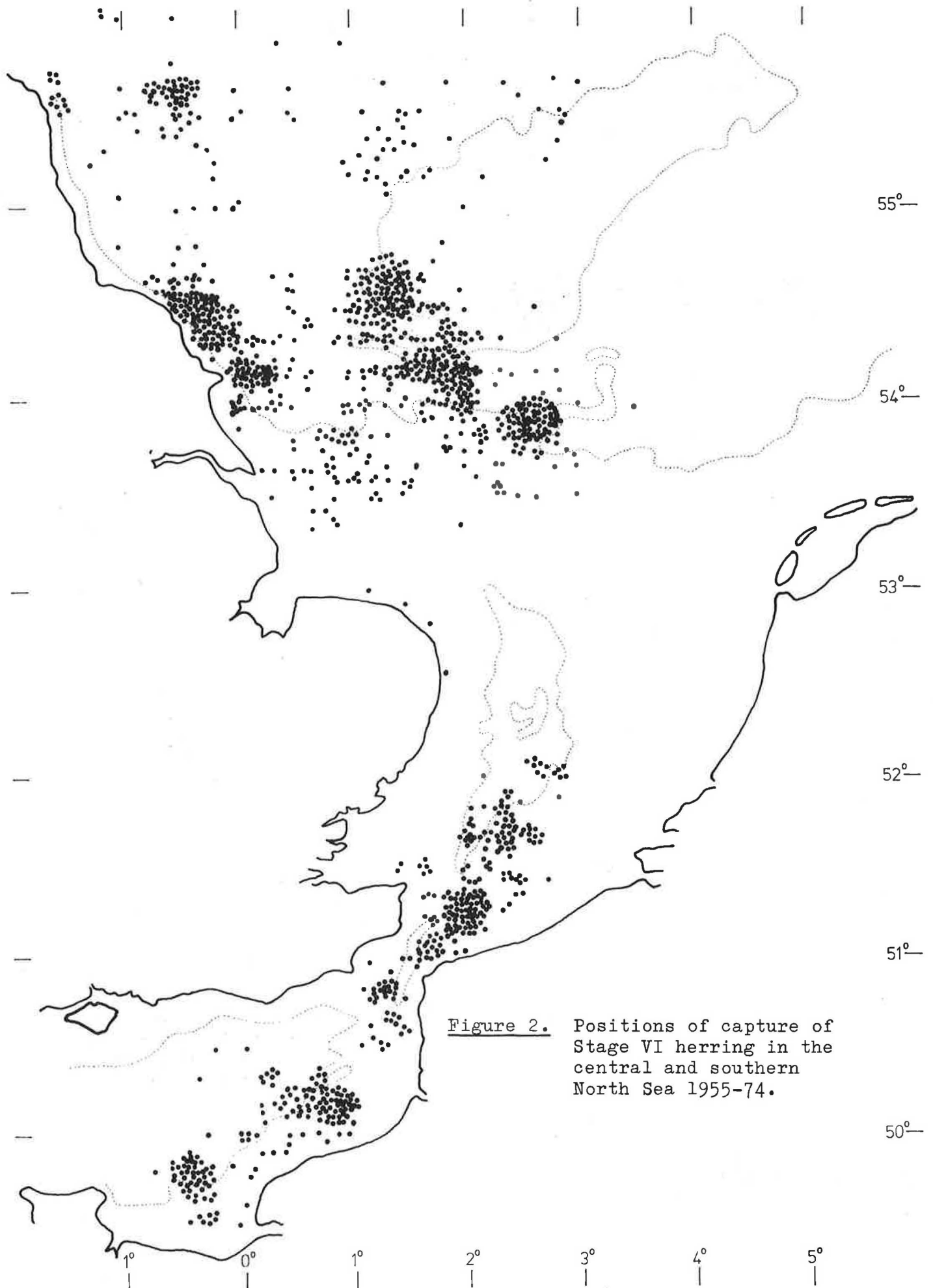
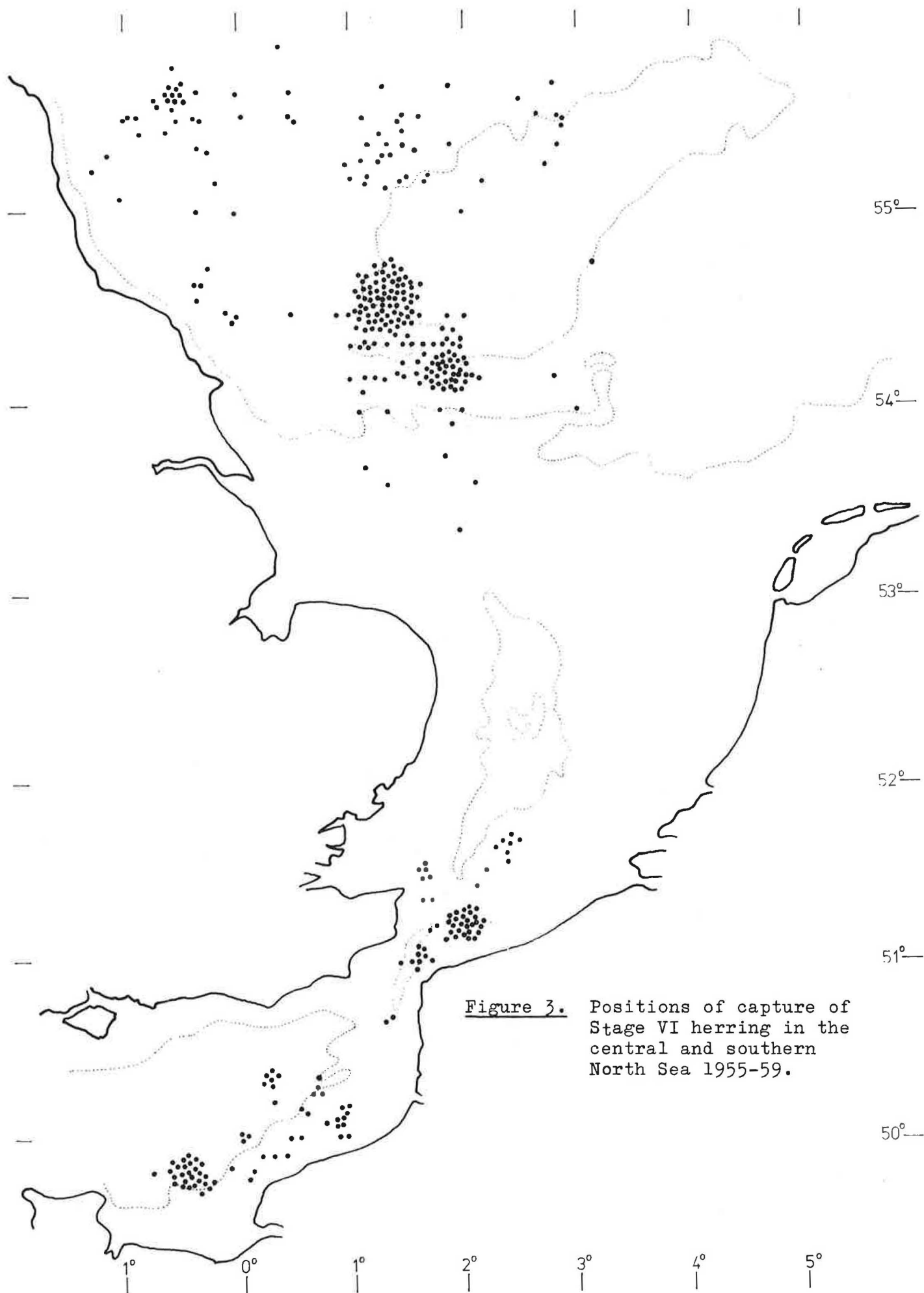


Figure 1. Positions of capture of Stage VI herring in the northwestern North Sea 1962-74.







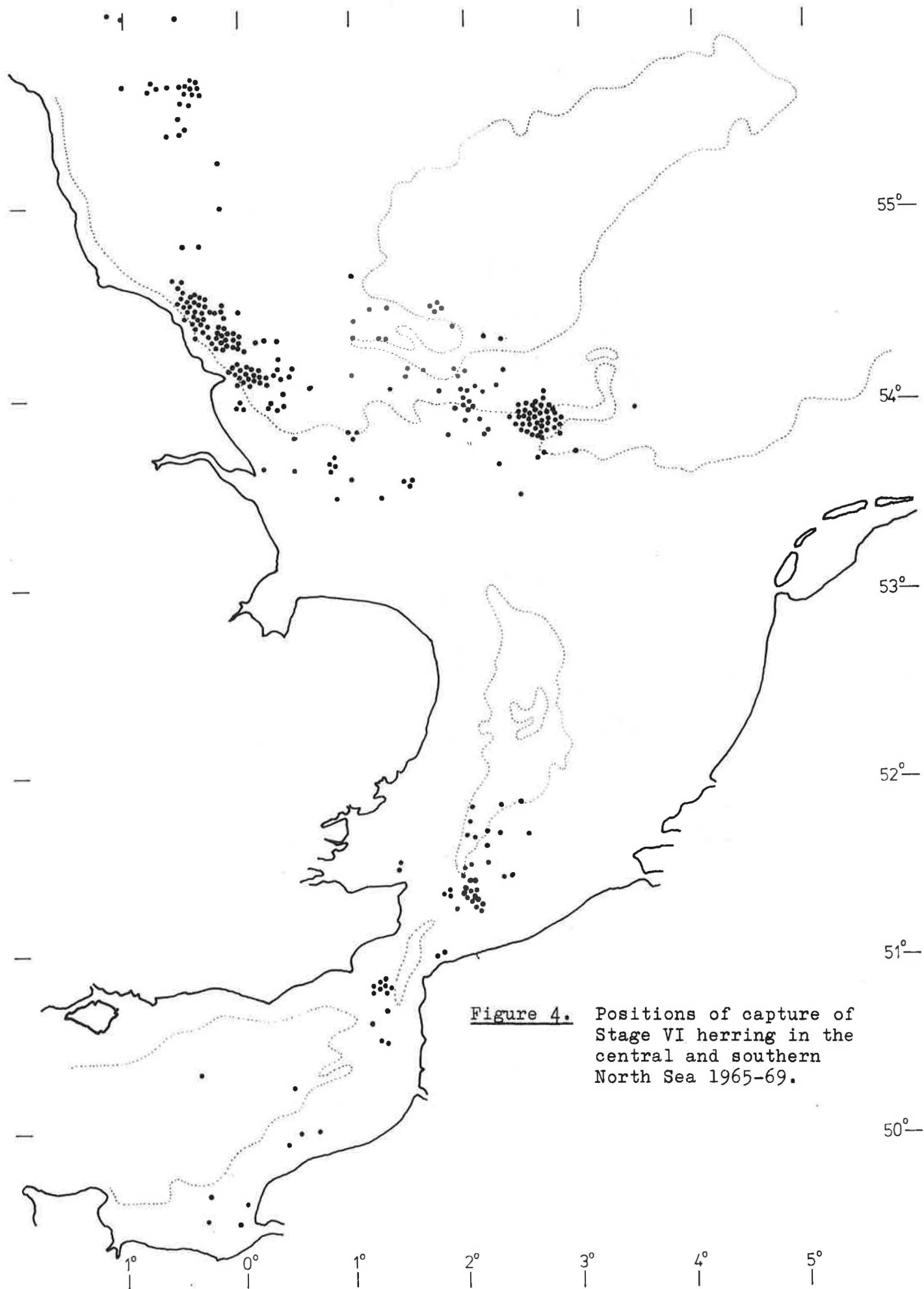


Figure 4. Positions of capture of Stage VI herring in the central and southern North Sea 1965-69.

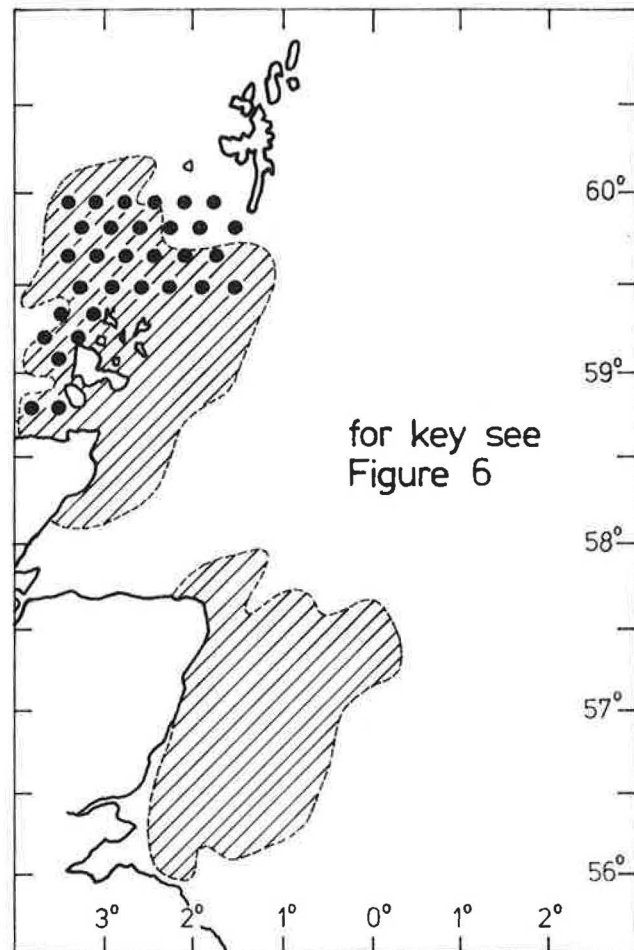


Figure 5. Areas of capture of small herring larvae in the northwestern North Sea.

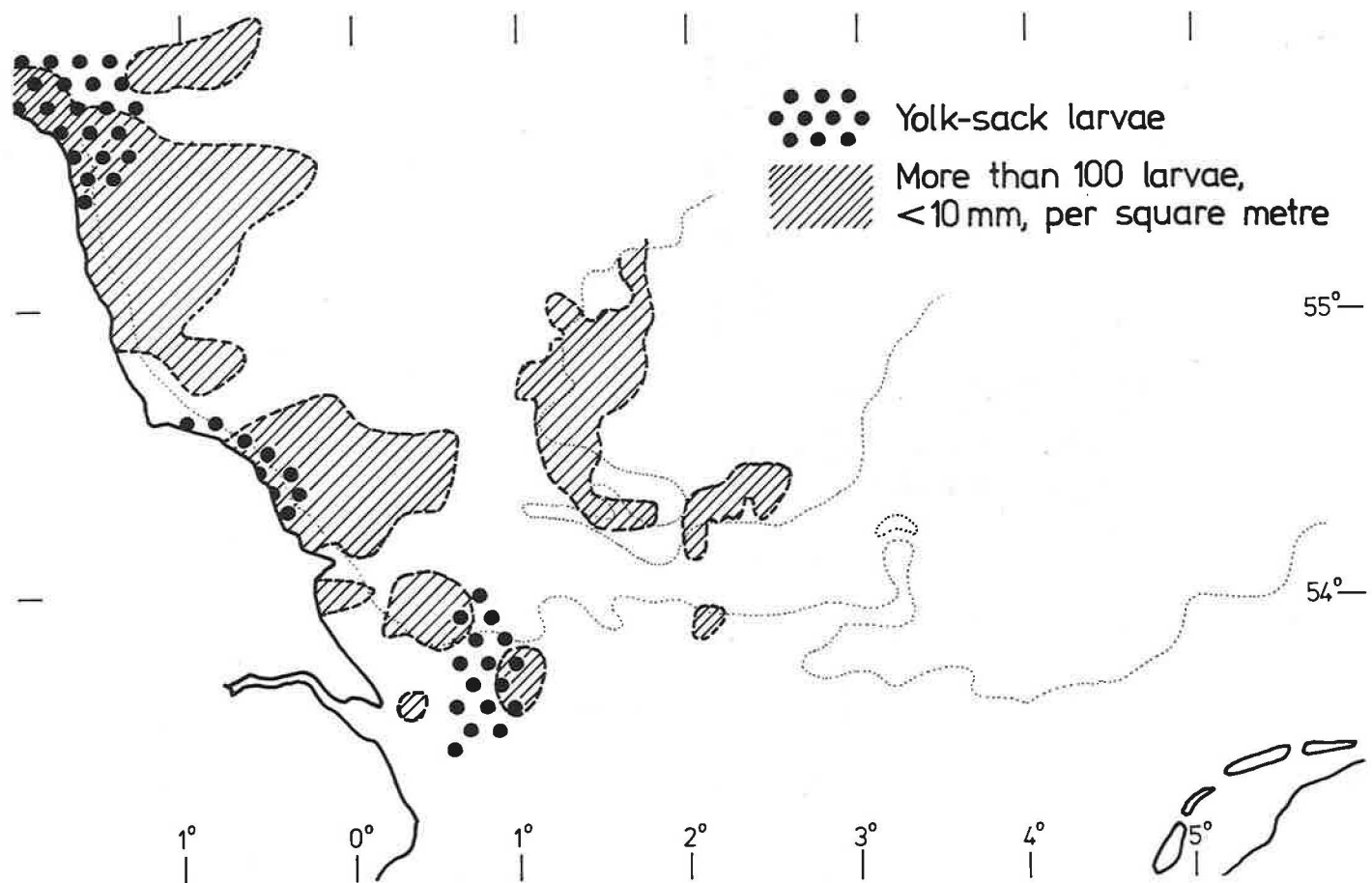


Figure 6. Areas of capture of small herring larvae in the central North Sea.

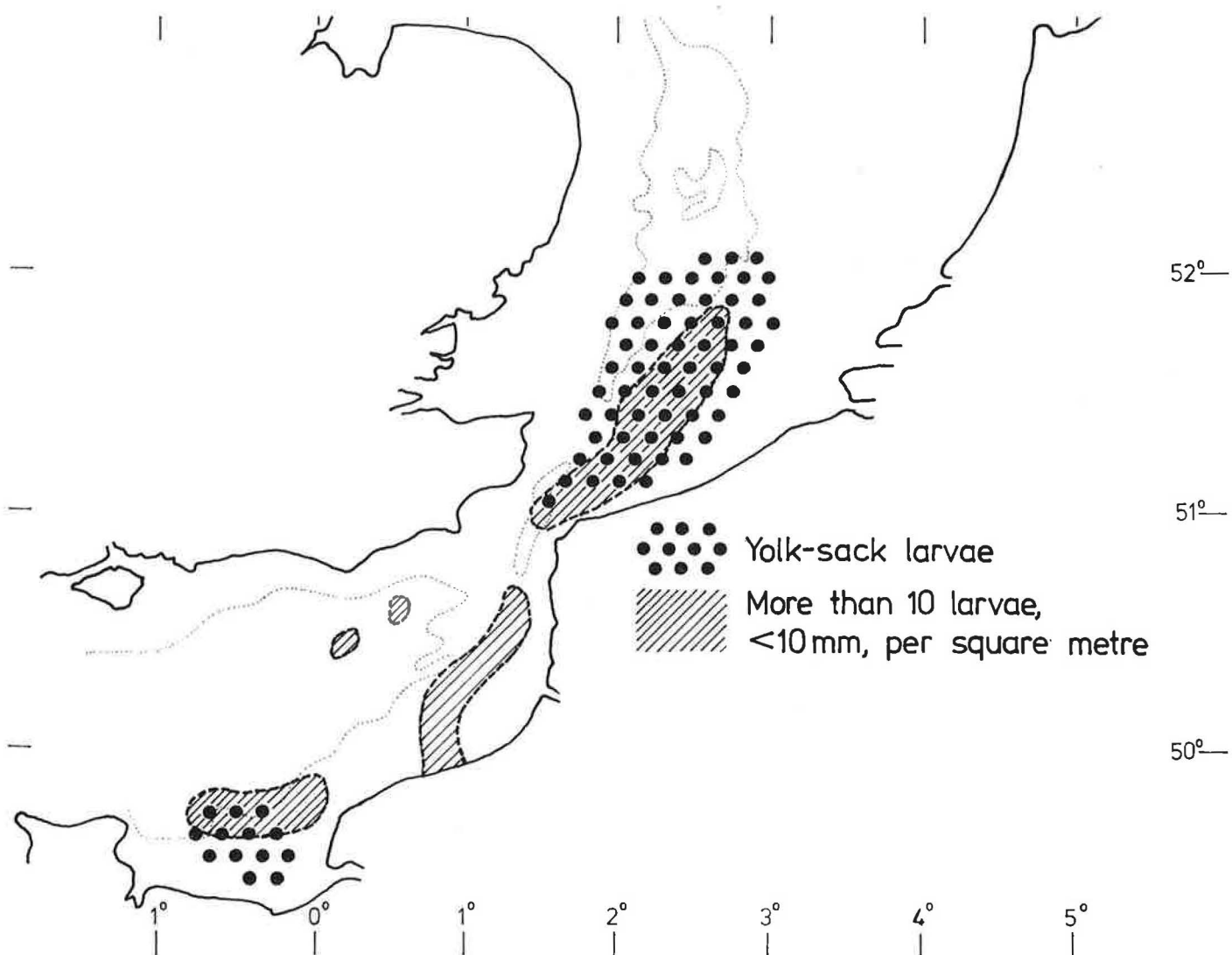
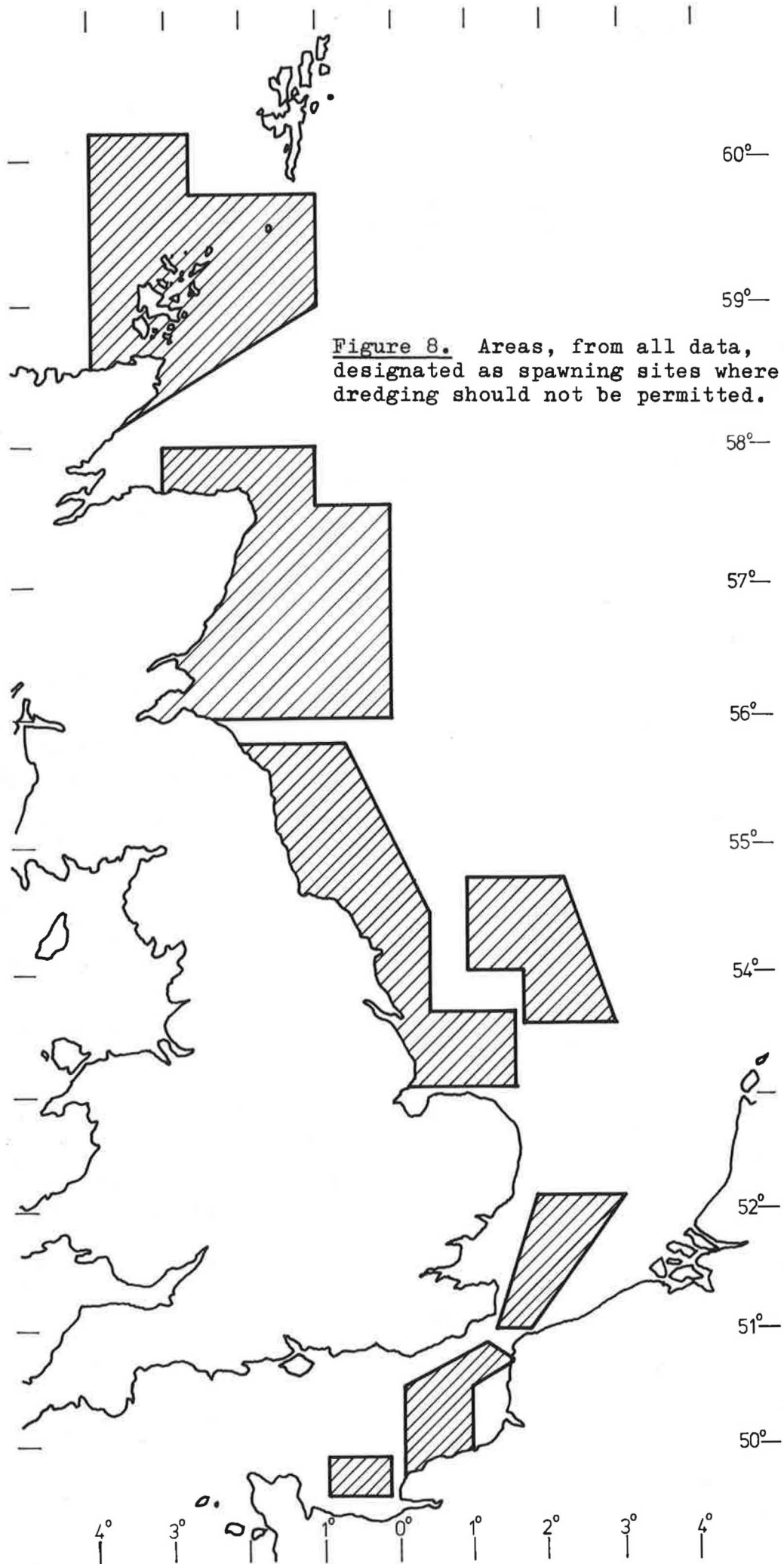


Figure 7. Areas of capture of small herring larvae in the southern North Sea and English Channel.



REPORT ON THE INTERNATIONAL SURVEYS OF HERRING LARVAE IN  
THE NORTH SEA AND ADJACENT WATERS 1974/75

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Introduction

This report gives the results of the eighth international survey of herring larvae in the North Sea and adjacent waters. These surveys were started in 1967 in order to monitor changes in the North Sea herring spawning stocks independently of catch per unit effort data.

Results of the previous surveys are published in Saville (1970), Boëtius and McKay (1970), Wood (1971), Zijlstra (1972), Saville and McKay (1974), and Wood (1975).

Material and methods

During the autumn and winter of 1974/75 five countries participated in the surveys, with the following research vessels: Denmark: RV "Dana"; England: RV "Cirolana", RV "Clione", and RV "Scotia"; Federal Republic of Germany: RV "Anton Dohrn" and RV "Walther Herwig"; Netherlands: RV "Tridens" and RV "Willem Beukelsz"; and Scotland: RV "Clupea" and RV "Explorer". On all ships a modified Gulf plankton sampler was used which was towed in a double oblique haul down to 5 metres or less above the bottom. The sampling technique is described in detail by Saville (1970).

The surveyed area is broken down into sub-areas. The timing of the surveys in the sub-areas is given in Table 1. From September until January 1975 a total of 1 080 stations was sampled. Compared to the previous year this represented a slight decrease of the overall effort but a considerable increase of effort in the Shetland-Orkney and in the Buchan areas. Sampling effort was substantially reduced in the Whitby-Dogger area whereas in the Southern Bight-English Channel area it was only slightly less than in the preceding year.

The results of the surveys, recorded as numbers per  $m^2$  at each station, are shown in Figures 1-34 for each size group of larvae. Charts of surveys on which no or very few larvae of a size group were caught have been omitted from this report but were presented at the 1975 Statutory Meeting of ICES (Pommeranz, 1975). For all areas except the Southern Bight-English Channel, the size groups (total length) of herring larvae are <10 mm, 10-15 mm, and >15 mm. For the Downs larvae, which hatch at a greater length, the size groups are <11 mm, 11-16 mm, and >16 mm.

Abundance estimates were calculated in a similar manner to that of Schnack (1973) and Wood (1974). The value for abundance per  $m^2$  at each station was multiplied by the sea surface area in square metres appropriate to that station, and the individual numbers were then summed for each survey and size group of larvae. In cases where a station was sampled several times during a survey period, the greatest number of larvae caught was used in the calculations.



## Results - distributions

### Shetland-Orkney

The Shetland-Orkney area was sampled during three periods (I-III), viz. 7-19 September, 24 September - 2 October, and 8-17 October. During the first period the area was covered effectively by three surveys overlapping in time.

During the first survey of period I (7-15 September) newly hatched larvae <10 mm in length were found nearly all around Orkney with a wide distribution north of Orkney. The highest concentration there was 142/m<sup>2</sup> (Figure 1). Larvae of the 10-15 mm size group were taken at the majority of the stations with a maximum density of 120/m<sup>2</sup> (Figure 2). Small numbers of larvae >15 mm long were recorded fairly regularly at the stations southeast of Orkney but the maximum of 15/m<sup>2</sup> was found further north (Figure 3).

During the second survey (11-15 September) of period I only the area west and north of Orkney was covered. The number of larvae <10 mm and of 10-15 mm larvae in the northern part of the area had increased (Figures 4 and 5). The maximum density of the small larvae was 352/m<sup>2</sup> and of the medium size group it was 100/m<sup>2</sup> west of Orkney. Larvae >15 mm were recorded with the highest concentration of 22/m<sup>2</sup> (Figure 6) north of Orkney.

At the time of the last survey of the first period (14-19 September) the main distribution of small larvae might have shifted slightly to the east (Figure 7). Larvae of the 10-15 mm category were again found at the majority of stations (Figure 8). Their maximum density of 203/m<sup>2</sup> was east of Orkney. Larvae >15 mm long were recorded all around Orkney, with a maximum of 53/m<sup>2</sup> in the east (Figure 9).

During period II almost the whole of the recommended station grid was covered by one survey (24 September - 2 October). At that time the small larvae <10 mm mostly occurred east of Orkney (Figure 10). The maximum of 339/m<sup>2</sup> was found in the northern part of the Moray Firth. High numbers with a maximum of 107/m<sup>2</sup> of larvae 10-15 mm long were regularly recorded east of Orkney (Figure 11). Larvae >15 mm were widely distributed over most of the surveyed area (Figure 12). The highest density of 48/m<sup>2</sup> occurred also east of Orkney.

In the final survey (period III) of the Shetland-Orkney area (8-17 October) only very few recently hatched larvae were taken east and north of Orkney (Figure 13). The larvae 10-15 mm long were regularly found in the eastern part of the surveyed area (Figure 14). There was a maximum of 68/m<sup>2</sup> south-west of Orkney. The larger larvae were again widely distributed with the highest density of 27/m<sup>2</sup> east of Orkney (Figure 15).

### Buchan

The Buchan area was surveyed seven times during four periods. Some of the surveys covered only small but important parts of the area. They supplement the surveys of a larger extent. The first survey lasted from 1-10 September. During this period another survey was also carried out and a second one was started (see Table 1).

The first survey revealed only one patch of recently hatched larvae off Newburgh, with a maximum density of 59/m<sup>2</sup> (Figure 16). Only very few larvae of the 10-15 mm size group were caught off Buchan Ness and Girdle Ness, and larvae >15 mm long were not taken at all.

The second survey (4-7 September) confirmed the patch of small larvae <10 mm off Newburgh (Figure 17), and a little more larvae of the 10-15 mm size group were found (Figure 18). Only few larvae >15 mm in length were taken (Figure 19). During the third survey (9-12 September) the number of

<10 mm and of 10-15 mm long larvae had increased with a maximum of 61/m<sup>2</sup> (Figure 20) and 60/m<sup>2</sup> respectively (Figure 21). Only few larvae of the size group >15 mm were taken along the coastline.

During the second period two surveys were made. The first of these (16-17 September) was of a limited extent. Recently hatched larvae were abundant (235/m<sup>2</sup>) off Buchan Ness (Figure 22), and the larger size groups were only scarcely found. During the next survey (17-24 September) the maximum density of small larvae <10 mm long was revealed again off Buchan Ness with a remarkable value of 1 492/m<sup>2</sup> (Figure 23). Larvae 10-15 mm long were dispersed over most of the surveyed area with a maximum density of 75/m<sup>2</sup> (Figure 24), and larvae >15 mm were slightly more abundant than during the previous survey (Figure 25).

During the survey period of 7-8 October only a few stations were sampled in the Buchan area, which showed, that there were larvae 10-15 mm (Figure 26) and >15 mm (Figure 27) in length near the southern limit of the Shetland-Orkney area and larvae of all size groups off Todhead Point. On two of five stations on 17 October 15 respectively 3 larvae >15 mm long were found north of Kinnairds Head (no figure).

#### Whitby-Dogger

The Whitby-Dogger area was surveyed twice. The first survey (27 August - 1 September) revealed three separate patches of recently hatched larvae at low densities, one in the Longstone area, one off Whitby and one off the Humber (Figure 28). Few larvae of the middle size group were caught along the middle part of the coastline. There were no larvae >15 mm in the whole area.

During the period 2-9 October two patches of recently hatched larvae were located, one in the Longstone area and another one with high densities up to 775/m<sup>2</sup> off Flamborough Head (Figure 29). Larvae of the 10-15 mm category were found all over the area with a maximum density of 120/m<sup>2</sup> (Figure 30). Larvae >15 mm long were widely spread in small numbers (Figure 31).

#### Southern Bight-English Channel

These areas were surveyed during three periods. During the first (9-16 December 1974) only a few small <11 mm larvae were found in the eastern Channel (Figure 32). Low numbers of larvae 11-16 mm also occurred, but no larger larvae.

Two surveys took place during the second period. During the first of these (7-12 January 1975), recently hatched larvae were caught in the Bay of the Seine, in the eastern Channel, and in the Sandettié area (Figure 33). The numbers of larger larvae were extremely low. The second survey (8-16 January) of that period had a poorer coverage. It revealed a patch of recently hatched larvae off Boulogne (Figure 34), with a maximum density of 10/m<sup>2</sup>. Larger larvae were totally absent.

During the third survey period (24-27 January) the coverage was incomplete due to bad weather. The abundance of herring larvae in the English Channel was very low. Only one larva of the middle size group was taken in the Bay of the Seine and two larvae >16 mm in length were caught off Dieppe.

#### Quantitative estimates

The major aim of these surveys is to monitor changes in larval production as a measure of spawning stock sizes. In Table 2 the estimates of larval abundance in 1974/75 for the three size groups of herring larvae in each area and survey period are given.

The results demonstrate again clearly the dominance of the spawning stock in the Shetland-Orkney area in the total herring population of the North Sea. The total abundance estimate of  $2\,206 \cdot 10^9$  for the period 7-19 September 1974 can be compared with the total of  $2\,558 \cdot 10^9$  for the period 7-14 September of the previous year. The production in 1974 therefore appears to be slightly poorer. At the end of September the total abundance was also lower in 1974 than in 1973.

The abundance of newly hatched larvae in the Shetland-Orkney area was smaller in 1974 than in the year before. However, larger larvae were considerably more abundant than in the previous year. This indicates earlier spawning and presumably higher overall larval production in 1974.

For the Buchan area the results given in Table 2 indicate higher larval production in 1974 when compared with the maximum value of  $16 \cdot 10^9$  herring larvae for the period 26-27 September 1973. In the Whitby-Dogger area the total abundance of early October 1974 was  $1\,704 \cdot 10^9$  larvae. The comparable figure for 27 September - 6 October was nearly the same, viz.  $1\,672 \cdot 10^9$ . Also the size composition was very similar for those two years. In the Southern Bight-English Channel area spawning was negligible in 1974/75, while in 1973/74 still a few larvae had been found.

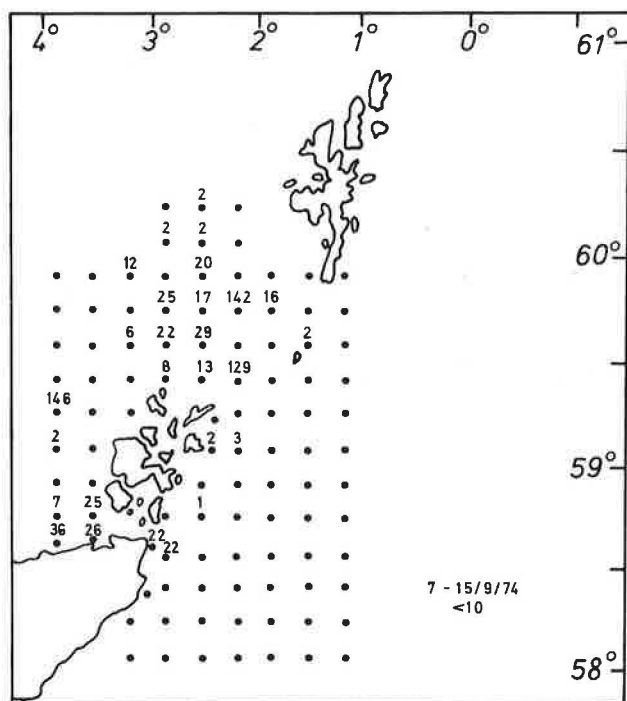
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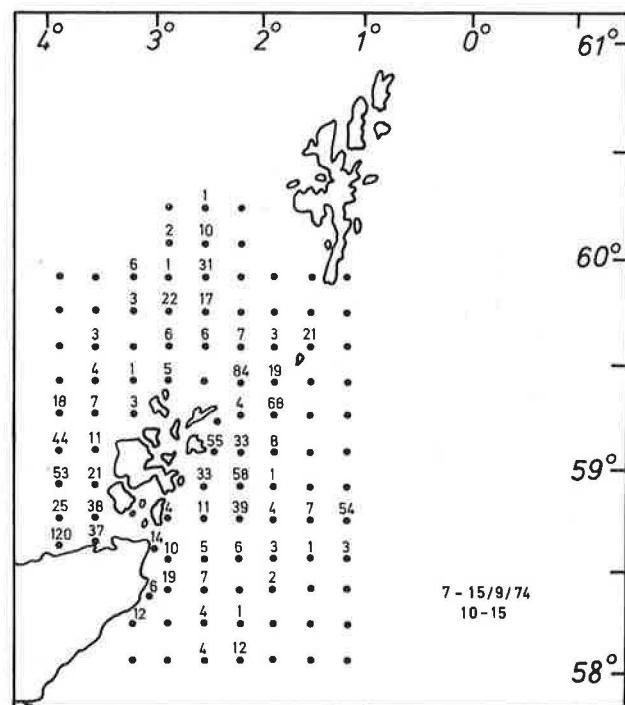
| Table 1: Surveys carried out in 1974/75 |                        |              |                 |       |
|---|------------------------|--------------|-----------------|-------|
| Country                                 | Area                   | Period       | No. of Stations | Total |
| Scotland                                | Shetland-Orkney        | 7-15/9/74    | 103             | 425   |
| England                                 | " "                    | 11-15/9/74   | 68              |       |
| Germany (F.R.)                          | " "                    | 14-19/9/74   | 72              |       |
| Scotland                                | " "                    | 24/9-2/10/74 | 94              |       |
| Scotland                                | " "                    | 8-17/10/74   | 88              |       |
| Denmark                                 | Buchan                 | 1-10/9/74    | 71              | 257   |
| Scotland                                | "                      | 4-7/9/74     | 66              |       |
| Scotland                                | "                      | 9-12/9/74    | 54              |       |
| Scotland                                | "                      | 16-17/9/74   | 21              |       |
| Scotland                                | "                      | 17-24/9/74   | 28              |       |
| Scotland                                | "                      | 7-8/10/74    | 12              |       |
| Scotland                                | "                      | 17/10/74     | 5               |       |
| Denmark                                 | Whitby-Dogger          | 27/8-1/9/74  | 74              | 160   |
| England                                 | " "                    | 2-9/10/74    | 86              |       |
| Netherlands                             | S. Bight-Engl. Channel | 9-16/12/74   | 83              | 238   |
| Germany (F.R.)                          | " "                    | 7-12/1/75    | 87              |       |
| Netherlands                             | " "                    | 8-16/1/75    | 38              |       |
| England                                 | " "                    | 24-27/1/75   | 30              |       |

| Table 2: Estimates of herring larval abundance |              |  |         |       |       |
|--|--------------|--|---------|-------|-------|
| Area   | Period       | Abundance of herring larvae 10 <sup>-9</sup> |         |       |       |
|  |              | <10mm  | 10-15mm | >15mm | Total |
| Shetland-Orkney                                | 7-19/9/74    | 1223   | 794     | 189   | 2206  |
| " "  | 23/9-2/10/74 | 224  | 545     | 231   | 1000  |
| " "  | 8-17/10/74   | 8  | 104     | 173   | 285   |
| Buchan   | 1-12/9/74    | 97   | 91      | 6     | 194   |
| " +  | 16-24/9/74   | 480  | 86      | 34    | 600   |
| " +  | 7-8/10/74    | 3  | 19      | 18    | 40    |
| " +  | 17/10/74     | 0  | 0       | 6     | 6     |
| Whitby-Dogger                                  | 27/8-1/9/74  | 16   | 2       | 0     | 18    |
| " "  | 2-9/10/74    | 1271   | 407     | 26    | 1704  |
|  |              | <11mm  | 11-16mm | >15mm | Total |
| S. Bight-Engl. Channel                         | 9-16/12/74   | 1  | 10      | 0     | 11    |
| " "  | 7-16/1/75    | 15   | 5       | 3     | 23    |
| " " +  | 24-27/1/75   | 0  | 0,2     | 0,2   | 0,4   |

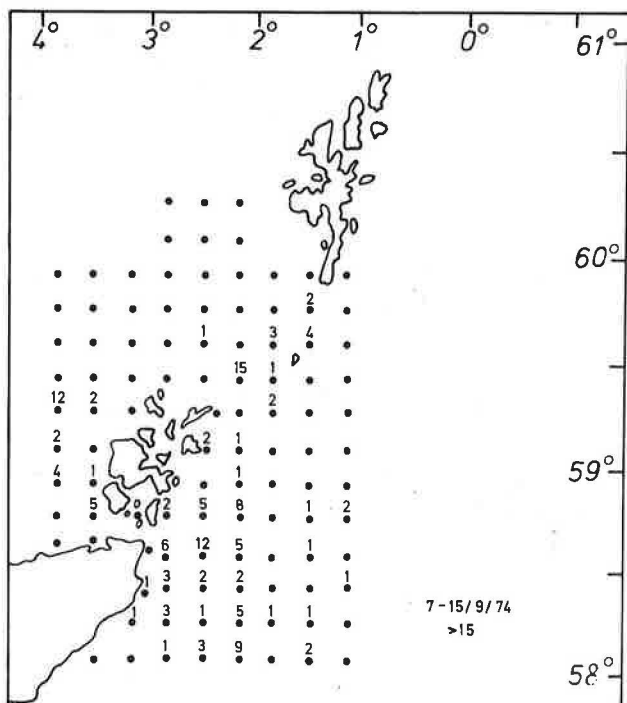
+ Survey incomplete



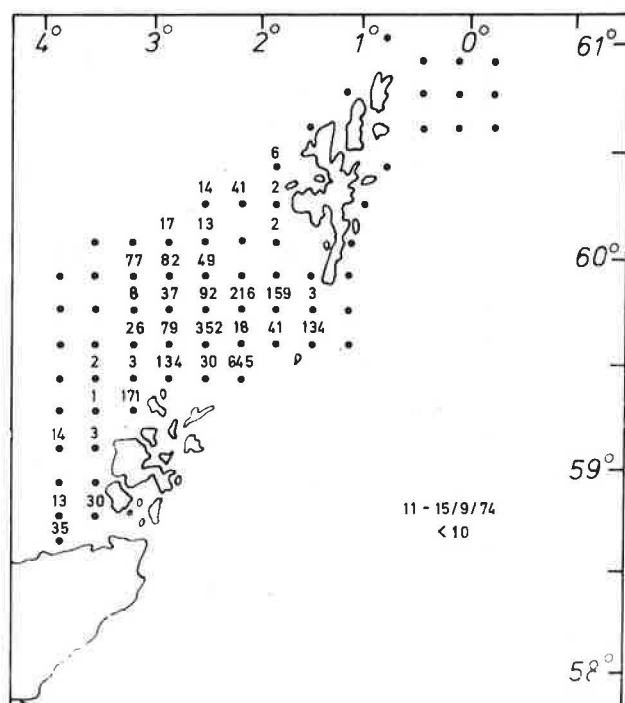
**Fig.1** Numbers of larvae <10mm below 1 m<sup>2</sup>, Shetland-Orkney area, Scottish survey 7-15/9/74.



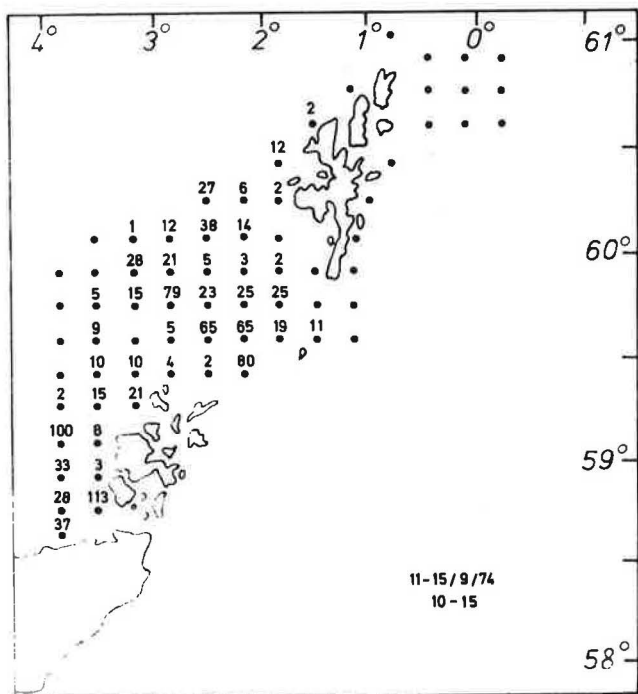
**Fig.2** Numbers of larvae 10-15mm below 1 m<sup>2</sup>, Shetland-Orkney area, Scottish survey 7-15/9/74.



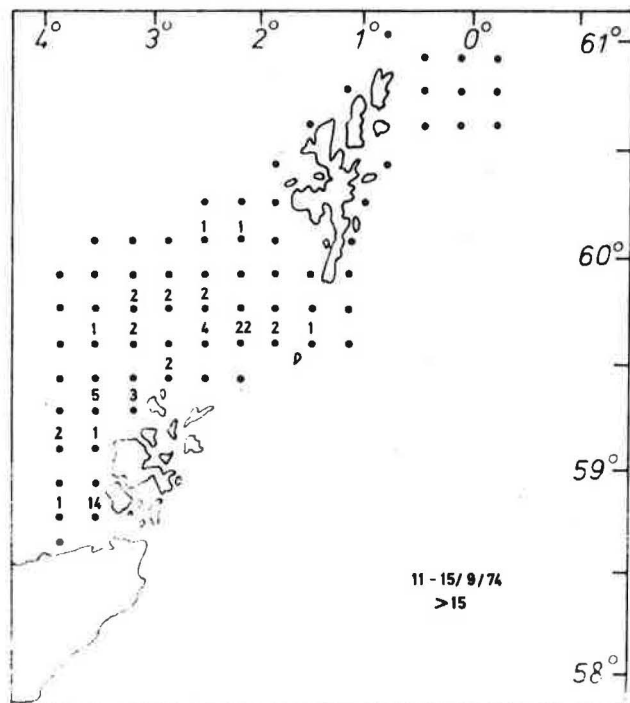
**Fig.3** Numbers of larvae >15mm below 1 m<sup>2</sup>, Shetland-Orkney area, Scottish survey 7-15/9/74.



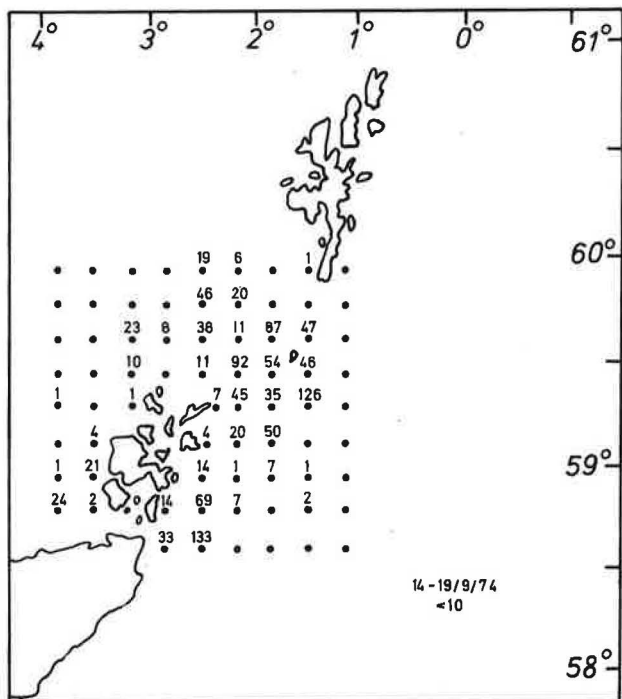
**Fig.4** Numbers of larvae <10mm below 1 m<sup>2</sup>, Shetland-Orkney area, English survey 11-15/9/74



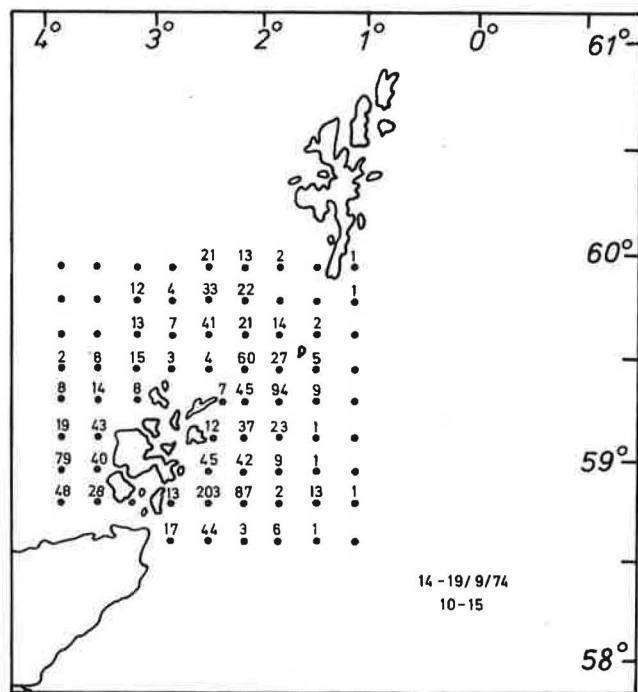
**Fig.5** Numbers of larvae 10-15mm below 1 m<sup>2</sup>, Shetland-Orkney area, English survey 11-15/9/74.



**Fig.6** Numbers of larvae >15mm below 1 m<sup>2</sup>, Shetland-Orkney area, English survey 11-15/9/74.

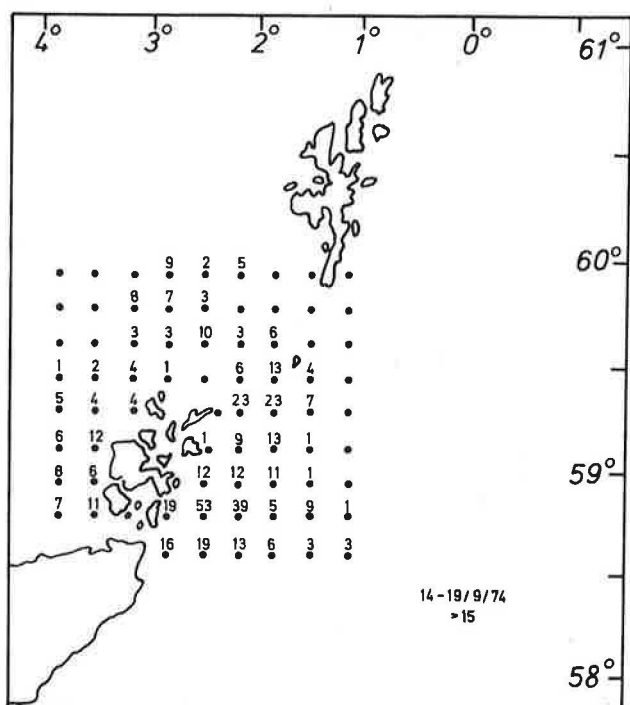


**Fig.7** Numbers of larvae <10mm below 1 m<sup>2</sup>, Shetland-Orkney area, German survey 14-19/9/74.

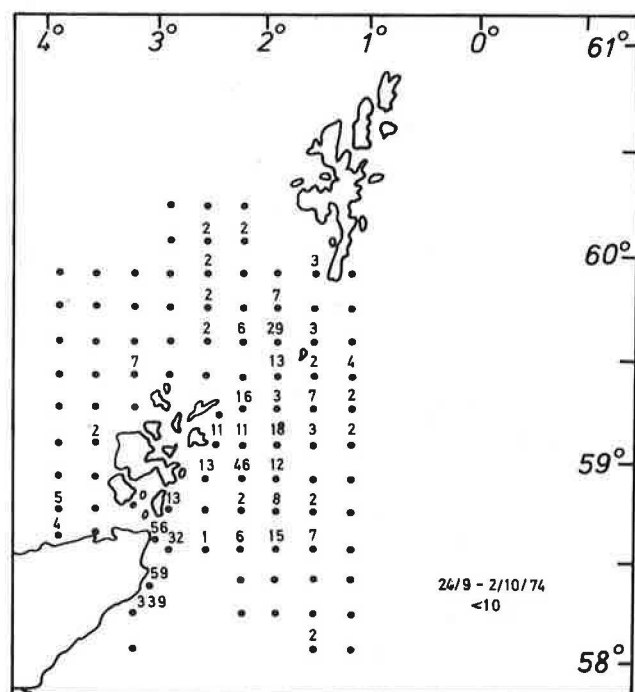


**Fig.8** Numbers of larvae 10-15mm below 1 m<sup>2</sup>, Shetland-Orkney area, German survey 14-19/9/74.

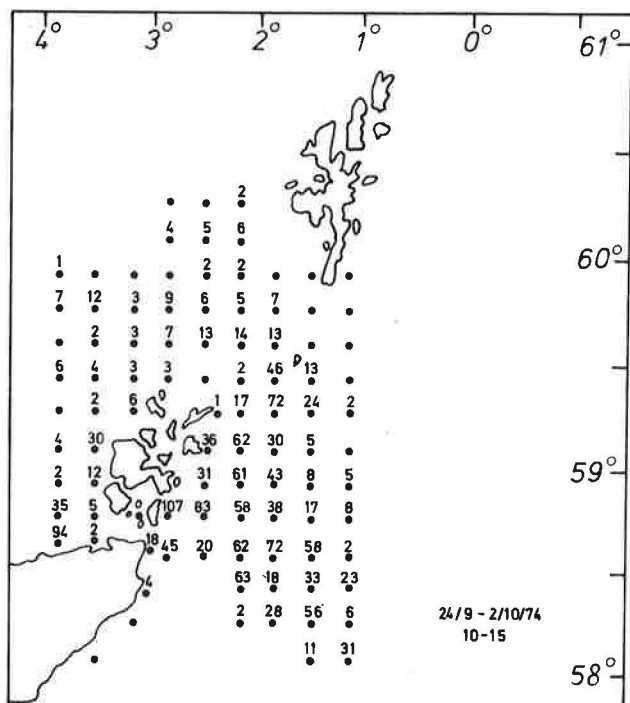




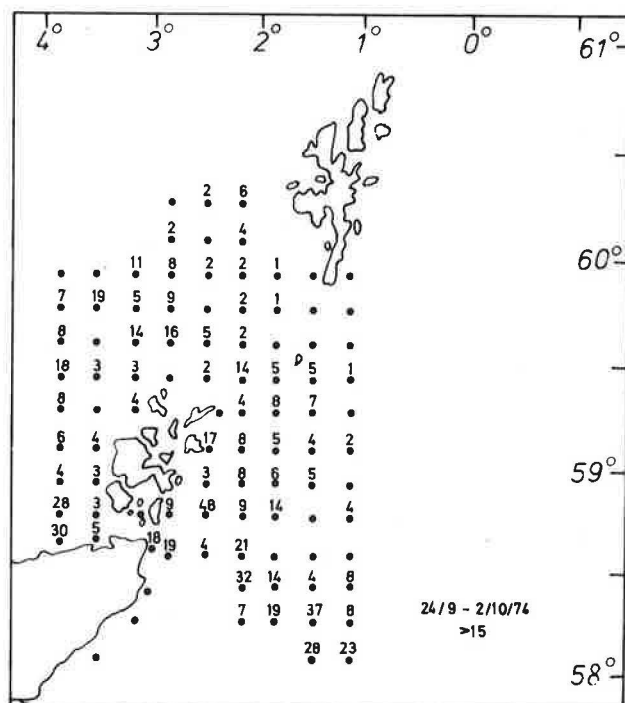
**Fig.9** Numbers of larvae >15mm below 1 m<sup>2</sup>, Shetland-Orkney area, German survey 14-19/9/74.



**Fig.10** Numbers of larvae <10mm below 1 m<sup>2</sup>, Shetland-Orkney area, Scottish survey 24/9-2/10/74.



**Fig.11** Numbers of larvae 10-15mm below 1 m<sup>2</sup>, Shetland-Orkney area, Scottish survey 24/9-2/10/74.



**Fig.12** Numbers of larvae >15mm below 1 m<sup>2</sup>, Shetland-Orkney area, Scottish survey 24/9-2/10/74.

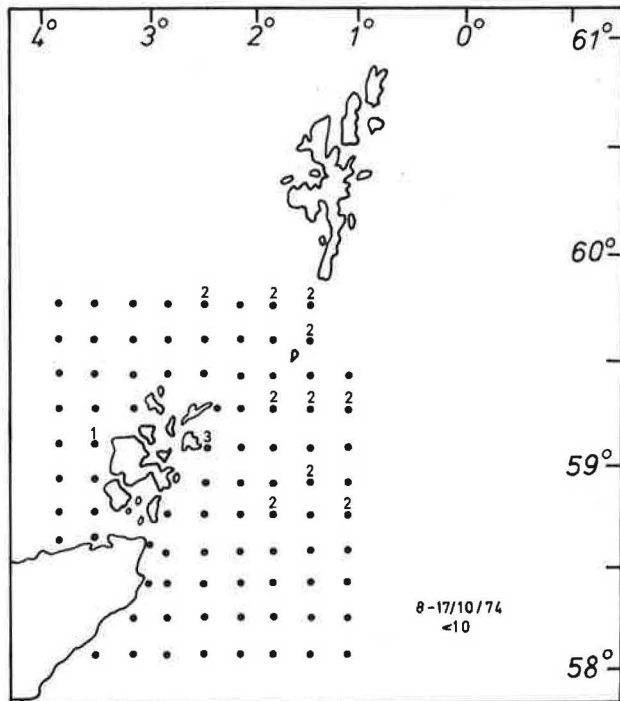


Fig.13 Numbers of larvae <10mm below 1 m<sup>2</sup>, Shetland-Orkney area, Scottish survey 8-17/10/74.

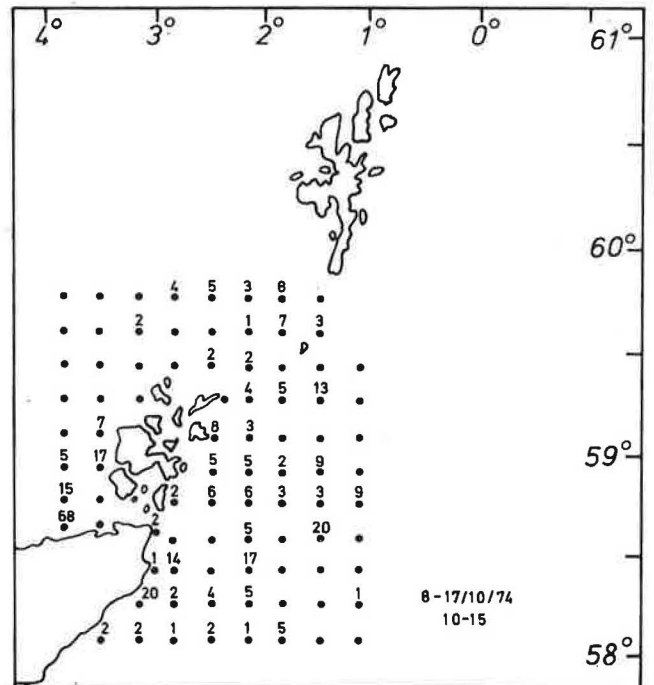


Fig.14 Numbers of larvae 10-15mm below 1 m<sup>2</sup>, Shetland-Orkney area, Scottish survey 8-17/10/74.

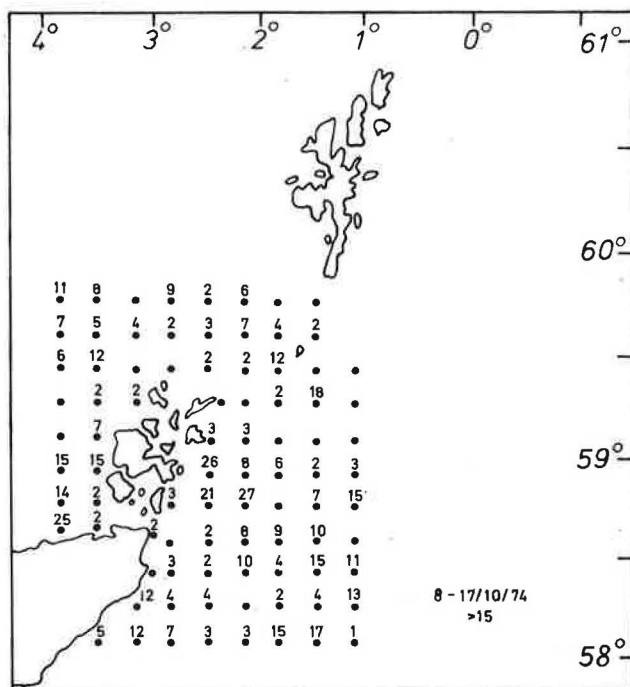


Fig.15 Numbers of larvae >15mm below 1 m<sup>2</sup>, Shetland-Orkney area, Scottish survey 8-17/10/74.

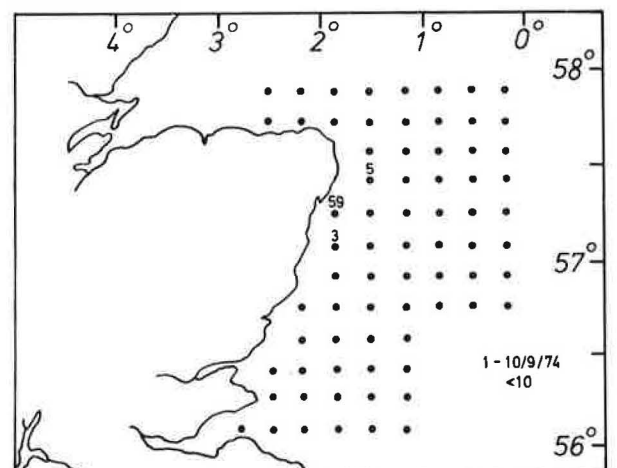
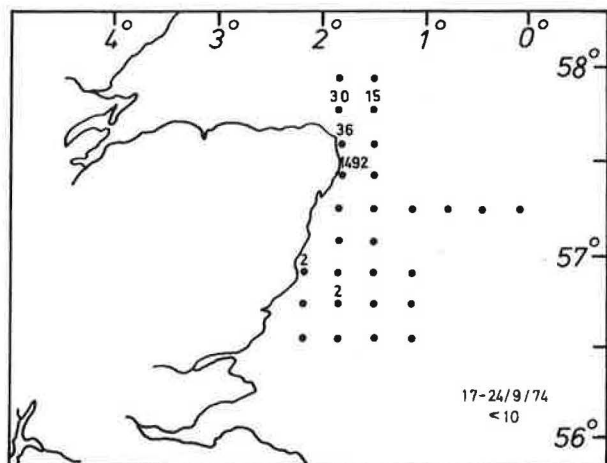


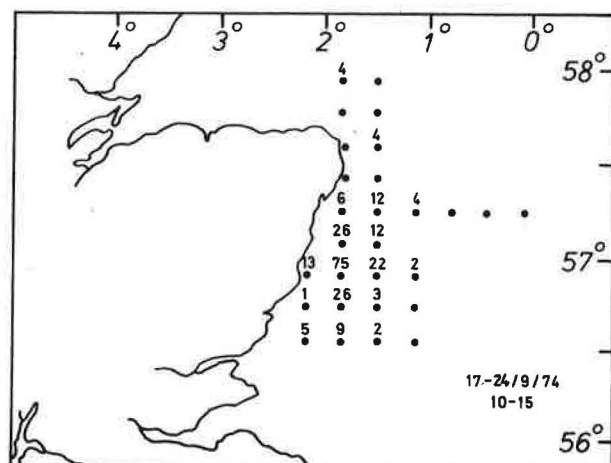
Fig.16 Numbers of larvae <10mm below 1 m<sup>2</sup>, Buchan area, Danish survey 1-10/9/74.



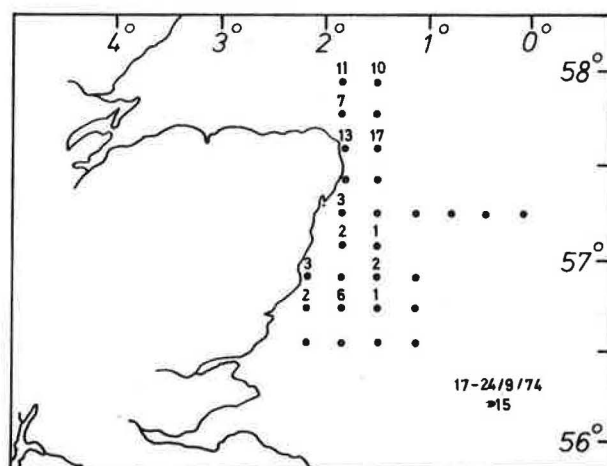




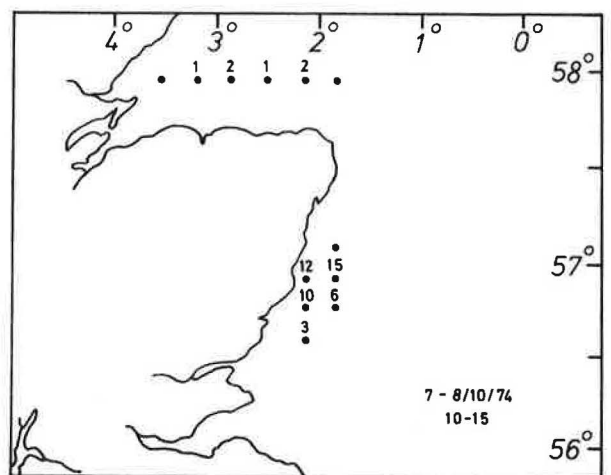
**Fig.23** Numbers of larvae <10mm below 1 m<sup>2</sup>, Buchan area, Scottish survey 17-24/9/74.



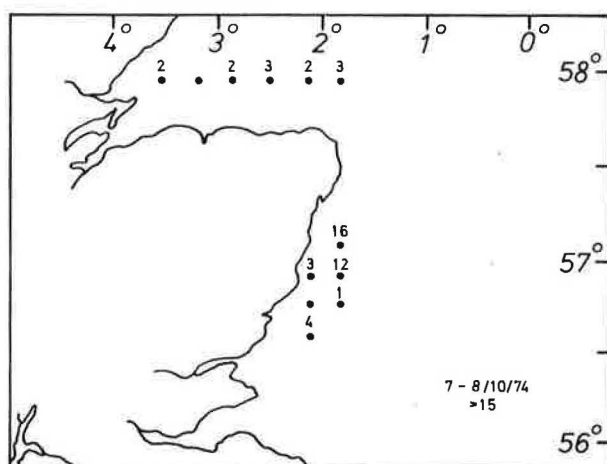
**Fig.24** Numbers of larvae 10-15mm below 1 m<sup>2</sup>, Buchan area, Scottish survey 17-24/9/74.



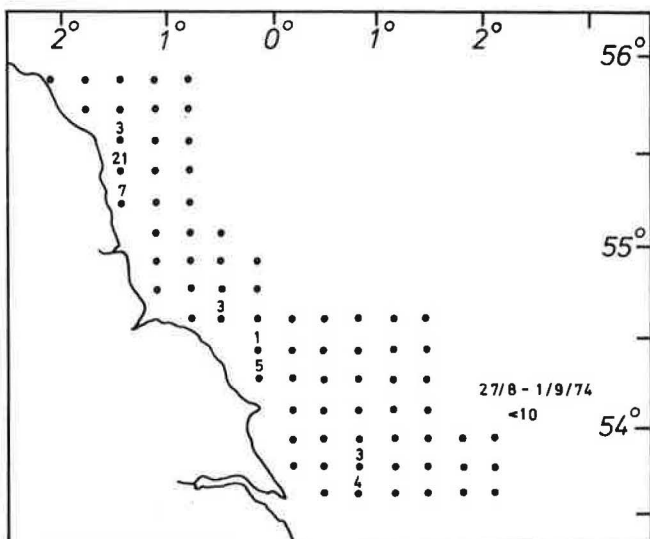
**Fig.25** Numbers of larvae >15mm below 1 m<sup>2</sup>, Buchan area, Scottish survey 17-24/9/74.



**Fig.26** Numbers of larvae 10-15mm below 1 m<sup>2</sup>, Buchan area, Scottish survey 7-8/10/74.



**Fig.27** Numbers of larvae >15mm below 1 m<sup>2</sup>, Buchan area, Scottish survey 7-8/10/74.



**Fig.28** Numbers of larvae <10mm below 1 m<sup>2</sup>, Whitby-Dogger area, Danish survey, 27/8-1/9/74.

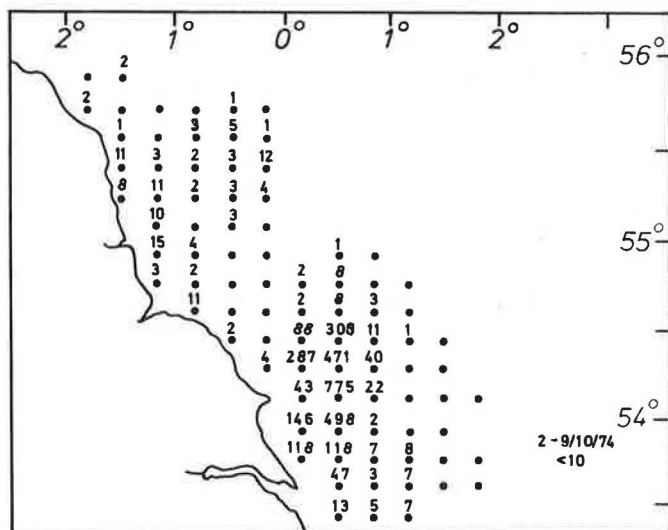


Fig.29 Numbers of larvae <10mm below 1 m<sup>2</sup>, Whitby-Dogger area, English survey 2-9/10/74.

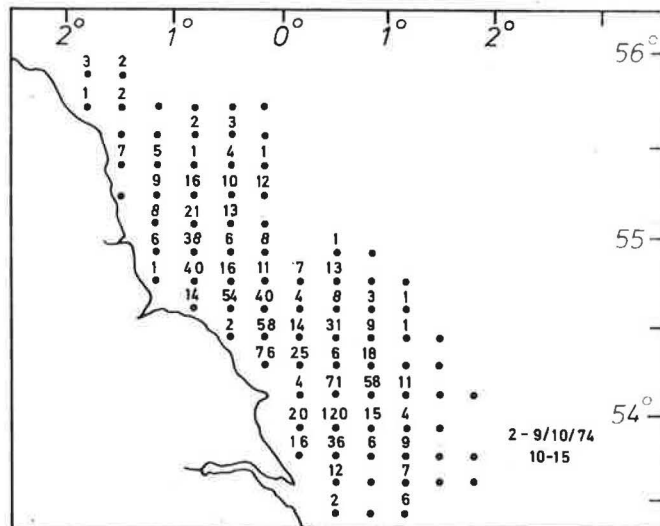


Fig.30 Numbers of larvae 10-15mm below 1 m<sup>2</sup>, Whitby-Dogger area, English survey 2-9/10/74.

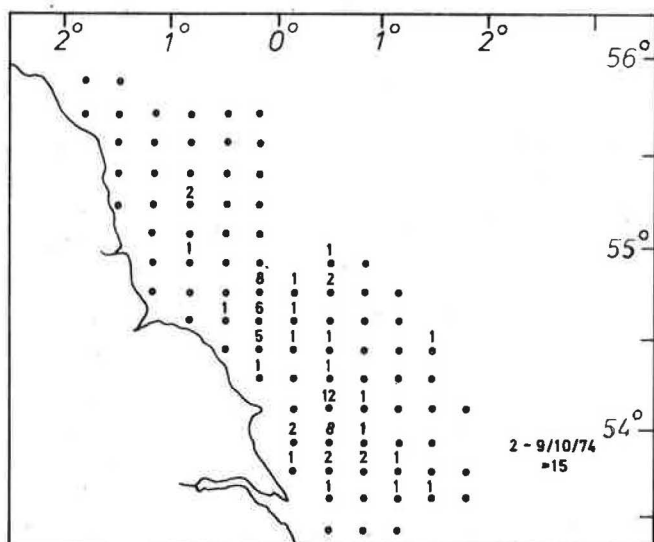


Fig.31 Numbers of larvae >15mm below 1 m<sup>2</sup>, Whitby-Dogger area, English survey 2-9/10/74.

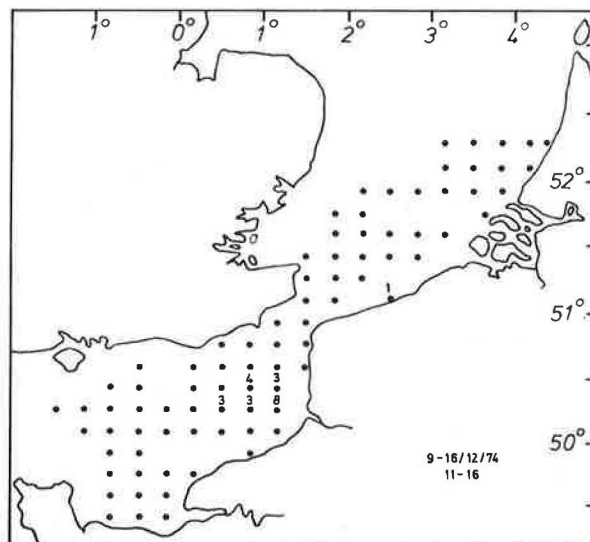


Fig.32 Numbers of larvae 11-16mm below 1 m<sup>2</sup>, S.Bight-Engl.Channel, Dutch survey 9-16/12/74.

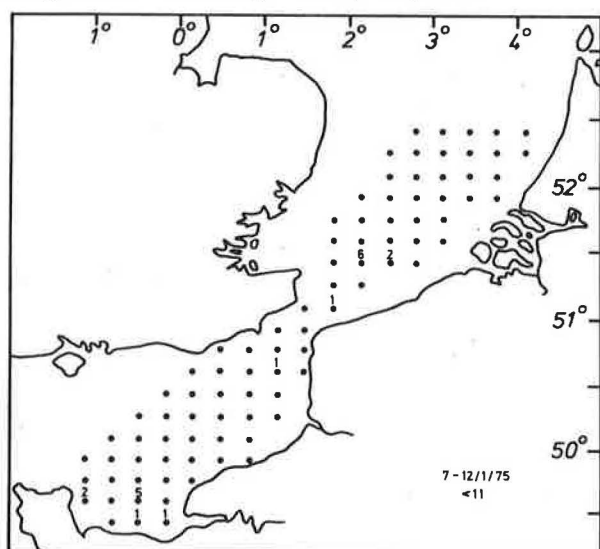


Fig.33 Numbers of larvae <11mm below 1 m<sup>2</sup>, S.Bight-Engl.Channel, German survey 7-12/1/75.

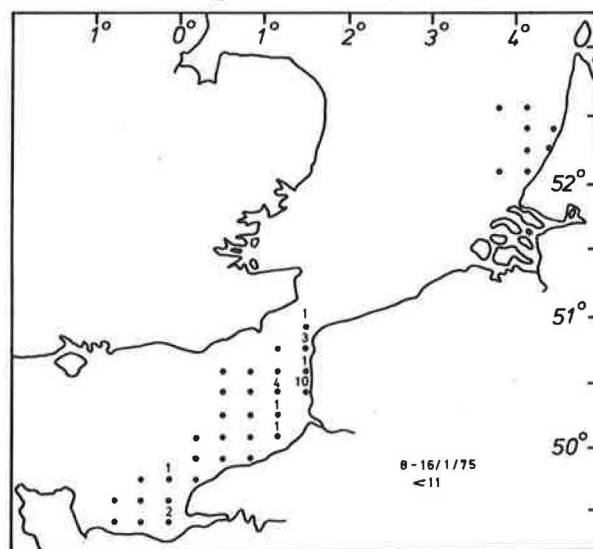


Fig.34 Numbers of larvae <11mm below 1 m<sup>2</sup>, S.Bight-Engl.Channel, Dutch survey 8-16/1/75

# QUANTITATIVE DISTRIBUTION OF HERRING LARVAE IN THE NORTH SEA IN 1974

by

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## Introduction

Investigations on the quantitative distribution of herring larvae in the North Sea have been made since 1963 with the aim of observing differences between herring year classes. Together with investigations on mature herring they permit the determination of the dynamics of the herring stock population in the North Sea.

## Material and method

Ichthyoplankton samples were collected during a cruise of RV "Birkut" from 12 September to 29 October 1974. Samples were taken at 65 stations in the usual research area limited by parallels 53°30' and 57°20'N and meridians 02°00'E and 02°00'W. This includes Aberdeen Bank, Berwick Bank, Farne Deep, off Whitby, Flamborough Ground and Little Pit.

The area investigated, the cruise track and the stations are shown in Figure 1.

Herring larvae were caught with a "Hai" sampler using the standard method; the speed of the hauling device and lift was 5 knots and 0.5 m/sec respectively. The material collected was preserved in 4% formalin and sorted. The numbers of herring larvae were calculated for the water column under 1 m<sup>2</sup> of sea surface. The length of the larvae was measured with an accuracy of 0.5 mm.

## Results

It was found that under 1 m<sup>2</sup> of sea surface, both the total number of herring larvae and the numbers in particular length classes (<10 mm; 10-15 mm; >15 mm) differed considerably from region to region (Figure 2). North of 55°00'N only specimens >15 mm were found, except at Station 903, where all three length categories were represented, the 10-15 mm class being the most numerous. South of 55°00'N, at Stations 918 to 923, length classes 10-15 mm and >15 mm were observed, the former being more numerous. At Stations 929 to 934 there was a marked increase in abundance in all length classes.

A comparison of quantitative distribution of herring larvae and temperature (Figures 3 to 4) shows that herring larvae are most numerous where surface temperatures amount to 11°C and bottom temperatures to 10-11°C, i.e. within the range 10-11°C. This observation should be controlled in the future, and data from previous years should be analysed since a comparison of hydrographical and biological data from this area for the period 1963-73 has not so far been made.

The area investigated is divided into the following three regions:

- I. Aberdeen Bank - Berwick Bank
- II. Farne Deep - off Whitby
- III. Flamborough Ground, the Little Pit.

It appears that the quantitative distribution of herring larvae becomes more clearly differentiated, and the hydrographical background seems to support such a division.

#### Aberdeen Bank and Berwick Bank

This region includes 18 stations. Herring larvae were found at 12 of these stations, the largest amounts along  $57^{\circ}00'N$ , with a maximum occurrence of 13.07 specimens/ $m^2$ . In this region, only larvae  $> 15$  mm in length were recorded (Table 1) at surface temperature  $12^{\circ}C$  and at bottom temperatures of  $10-12^{\circ}C$ .

#### Farne Deep - off Whitby

Material from 23 stations in this region was examined. Larvae were present at 8 stations. The relatively lowest bottom temperatures ( $8-10^{\circ}C$ ) were observed here. There was a maximum of larvae at Station 914 (14.00 spec./ $m^2$ ), and 13.12 spec./ $m^2$  at Station 903. At the latter station only, all length classes were represented, while at all other stations where larvae occurred their length exceeded 15 mm. Both these stations were in the area where the surface temperature was  $11^{\circ}C$  and the bottom temperature  $10^{\circ}C$ .

#### Flamborough Ground - Little Pit

No larvae were found at 2 of the 10 stations investigated in this region. The overall maximum occurrence of herring larvae was recorded here - 85.12 spec./ $m^2$  at Station 819. At 4 stations the numbers were as high as 43.25 to 52.75 spec./ $m^2$ . At Stations 918-923 two length classes (10-15 mm and  $>15$  mm) were represented, and at Stations 929-935 all three length categories were found. Generally, the highest numbers were found at stations nearer to the coast, but in relation to hydrographical data, stations with a temperature of  $11^{\circ}C$  were most abundant in herring larvae.

#### Discussion

An analysis of the results of the Polish investigations from 1963 to 1973 on the quantitative distribution of herring larvae in the area considered shows, that after 1963 (the year with the maximum abundance of 261 spec./ $m^2$ ) there was a significant decrease in larval quantity. In 1964 the maximum was 37 spec./ $m^2$ . At other stations only 1-4 spec./ $m^2$  were noted. In 1965 a further decrease was observed, with a maximum of 16 spec./ $m^2$  (Kijowski, 1966). In 1968 no larvae were taken, at least not with the "Hai" sampler within the area, though a few specimens were taken sporadically with a Ring trawl at one of the stations outside the area of the Polish investigation, i.e. north of  $58^{\circ}50'N$ . In 1969 it was evident that the number of larvae increased steadily though slowly, but only in the Flamborough Ground area. The same tendency was noted in 1970 (14 spec./ $m^2$ ) (Ciszewski, 1968, 1969 and 1970). In 1971 a transgression of herring larvae in the North Sea took place. The numbers of larvae increased to 181 spec./ $m^2$  in 1971 and to 242 spec./ $m^2$  in 1972. A slight drop was seen in 1973 (Szlachcikowska, 1971, 1972 and 1973). The results from 1974 indicate a slight increase over the whole area in question.

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Table 1. Quantitative distribution of herring larvae in the North Sea in 1974.

(n = number of specimens)

| Station No. | Date 1974 | Depth of tow | Water filtered (m <sup>3</sup> ) | Herring larvae |                  |  |       |       |
|-------------|-----------|--------------|----------------------------------|----------------|------------------|--|-------|-------|
|             |           |              |                                  | No. in sample  | n/m <sup>2</sup> | n/m <sup>2</sup> - length groups (in mm) |       |       |
|             |           |              |                                  |                |                  | <10                                      | 10-15 | >15   |
| 875         | 18 Sep    | 70           | 115                              | 3              | 1.87             | -  | -     | 1.87  |
| 876         | 18 Sep    | 65           | 75                               | 4              | 3.56             | -  | -     | 3.56  |
| 877         | 18 Sep    | 62           | 70                               | 3              | 2.68             | -  | -     | 2.68  |
| 878         | 18 Sep    | 72           | 90                               | 6              | 4.68             | -  | -     | 4.68  |
| 879         | 20 Sep    | 50           | 50                               | 2              | 2.02             | -  | -     | 2.02  |
| 880         | 20 Sep    | 60           | 65                               | 2              | 1.84             | -  | -     | 1.84  |
| 881         | 20 Sep    | 65           | 75                               | 6              | 5.32             | -  | -     | 5.32  |
| 882         | 20 Sep    | 75           | 105                              | 2              | 1.46             | -  | -     | 1.46  |
| 886         | 26 Sep    | 65           | 65                               | 14             | 13.97            | -  | -     | 13.97 |
| 888         | 26 Sep    | 60           | 65                               | 1              | 0.90             | -  | -     | 0.90  |
| 889         | 26 Sep    | 43           | 40                               | 1              | 1.08             | -  | -     | 1.08  |
| 892         | 27 Sep    | 70           | 80                               | 2              | 1.76             | -  | -     | 1.76  |
| 893         | 27 Sep    | 80           | 100                              | 1              | 0.69             | -  | -     | 0.69  |
| 894         | 29 Sep    | 82           | 100                              | 1              | 0.70             | -  | -     | 0.70  |
| 903         | 30 Sep    | 90           | 165                              | 24             | 13.12            | 3.28                                     | 8.19  | 1.64  |
| 904         | 30 Sep    | 60           | 60                               | 8              | 7.82             | -  | 5.87  | 1.96  |
| 905         | 1 Oct     | 65           | 75                               | 1              | 0.89             | -  | -     | 0.89  |
| 911         | 2 Oct     | 75           | 85                               | 1              | 0.86             | -  | -     | 0.86  |
| 914         | 10 Oct    | 65           | 70                               | 15             | 14.00            | -  | -     | 14.00 |
| 915         | 10 Oct    | 55           | 50                               | 7              | 7.73             | -  | -     | 7.73  |
| 916         | 10 Oct    | 65           | 70                               | 3              | 2.70             | -  | -     | 2.70  |
| 917         | 10 Oct    | 60           | 60                               | 17             | 16.50            | -  | -     | 16.50 |
| 918         | 10 Oct    | 55           | 50                               | 76             | 85.12            | -  | 81.76 | 3.36  |
| 919         | 12 Oct    | 48           | 46                               | 11             | 11.53            | -  | 8.38  | 3.14  |
| 920         | 12 Oct    | 42           | 40                               | 1              | 1.08             | -  | -     | 1.08  |
| 921         | 13 Oct    | 40           | 35                               | 4              | 4.86             | -  | 4.86  | -     |
| 922         | 13 Oct    | 42           | 40                               | 10             | 10.78            | -  | 8.62  | 2.16  |
| 923         | 13 Oct    | 25           | 20                               | 2              | 2.51             | -  | 2.51  | -     |
| 924         | 13 Oct    | 30           | 25                               | 1              | 1.15             | -  | -     | 1.15  |
| 926         | 14 Oct    | 24           | 15                               | 2              | 4.19             | -  | -     | 4.19  |
| 927         | 14 Oct    | 20           | 15                               | 2              | 2.77             | -  | 1.38  | 1.38  |
| 929         | 14 Oct    | 30           | 25                               | 22             | 26.49            | 4.81                                     | 21.67 | -     |
| 930         | 14 Oct    | 25           | 20                               | 42             | 52.75            | 37.68                                    | 7.54  | 7.54  |
| 931         | 15 Oct    | 45           | 40                               | 30             | 44.11            | 5.65                                     | 33.93 | 4.52  |
| 932         | 15 Oct    | 45           | 40                               | 27             | 30.54            | 6.79                                     | 18.10 | 5.65  |
| 933         | 15 Oct    | 55           | 55                               | 44             | 43.25            | 28.51                                    | 3.93  | 10.81 |
| 934         | 15 Oct    | 55           | 55                               | 52             | 51.12            | 5.90                                     | 36.37 | 8.85  |
| 935         | 15 Oct    | 45           | 40                               | 7              | 7.92             | -  | -     | 7.92  |



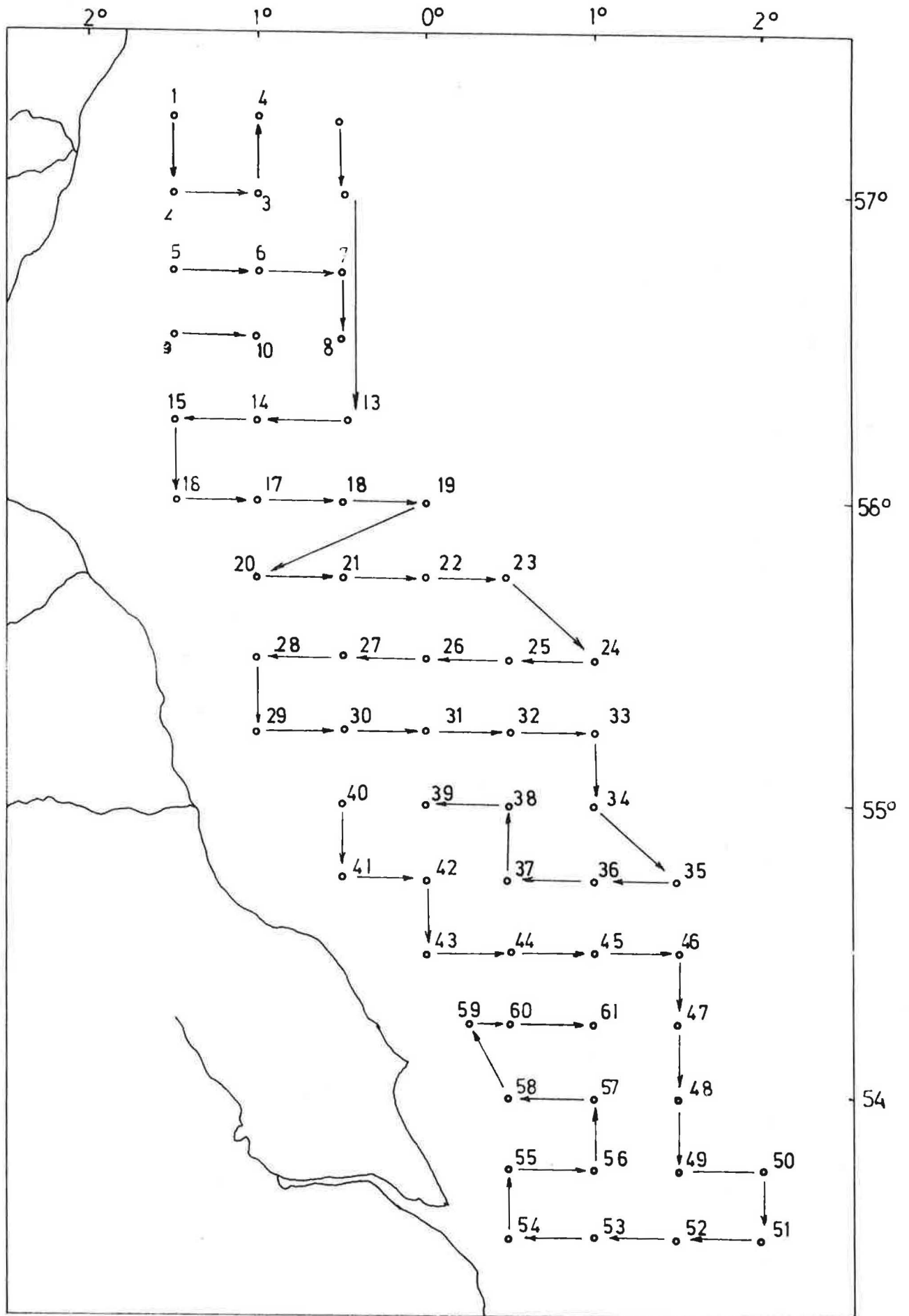


Figure 1. Track chart of the research cruise in the North Sea in September-October 1974.



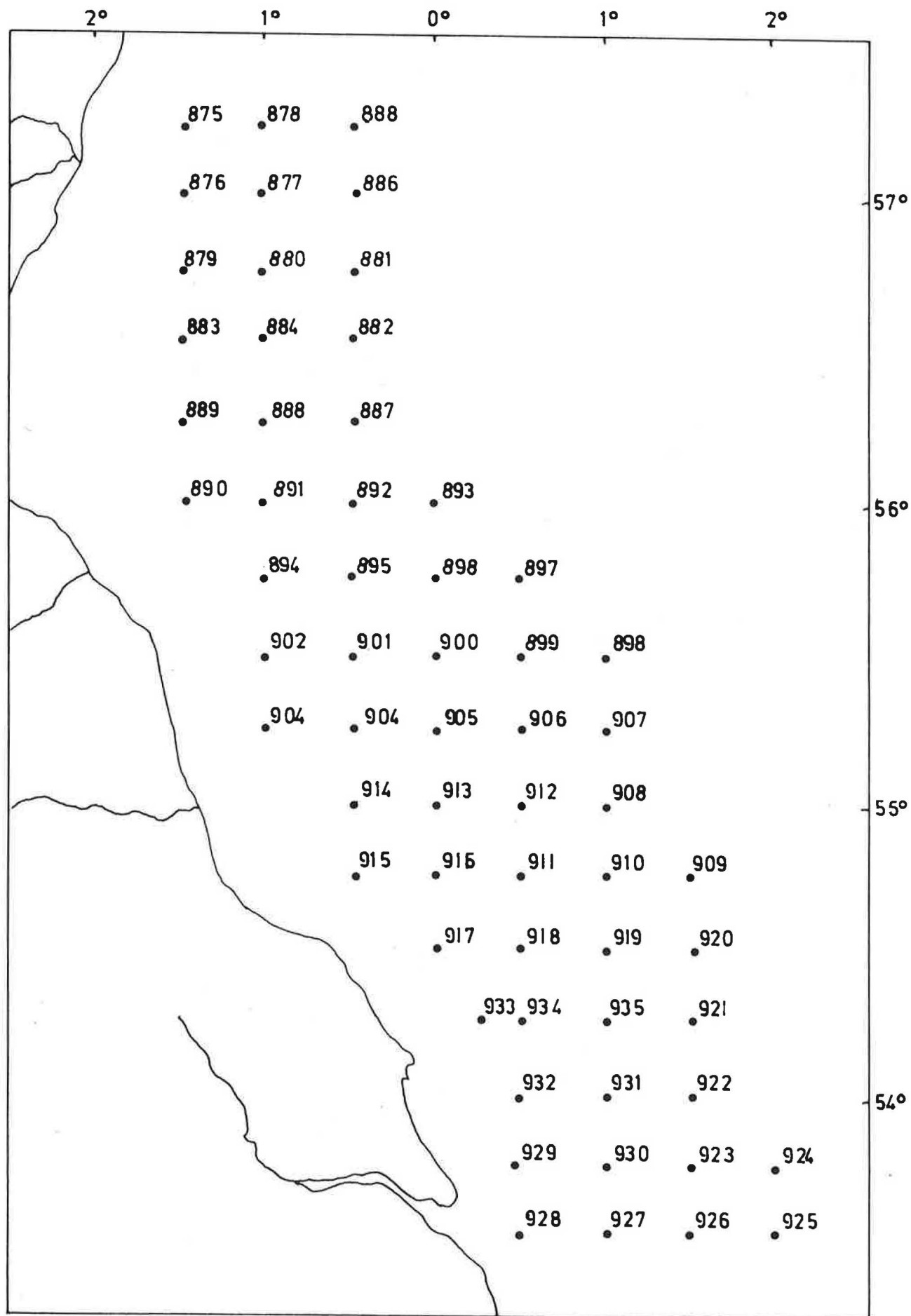
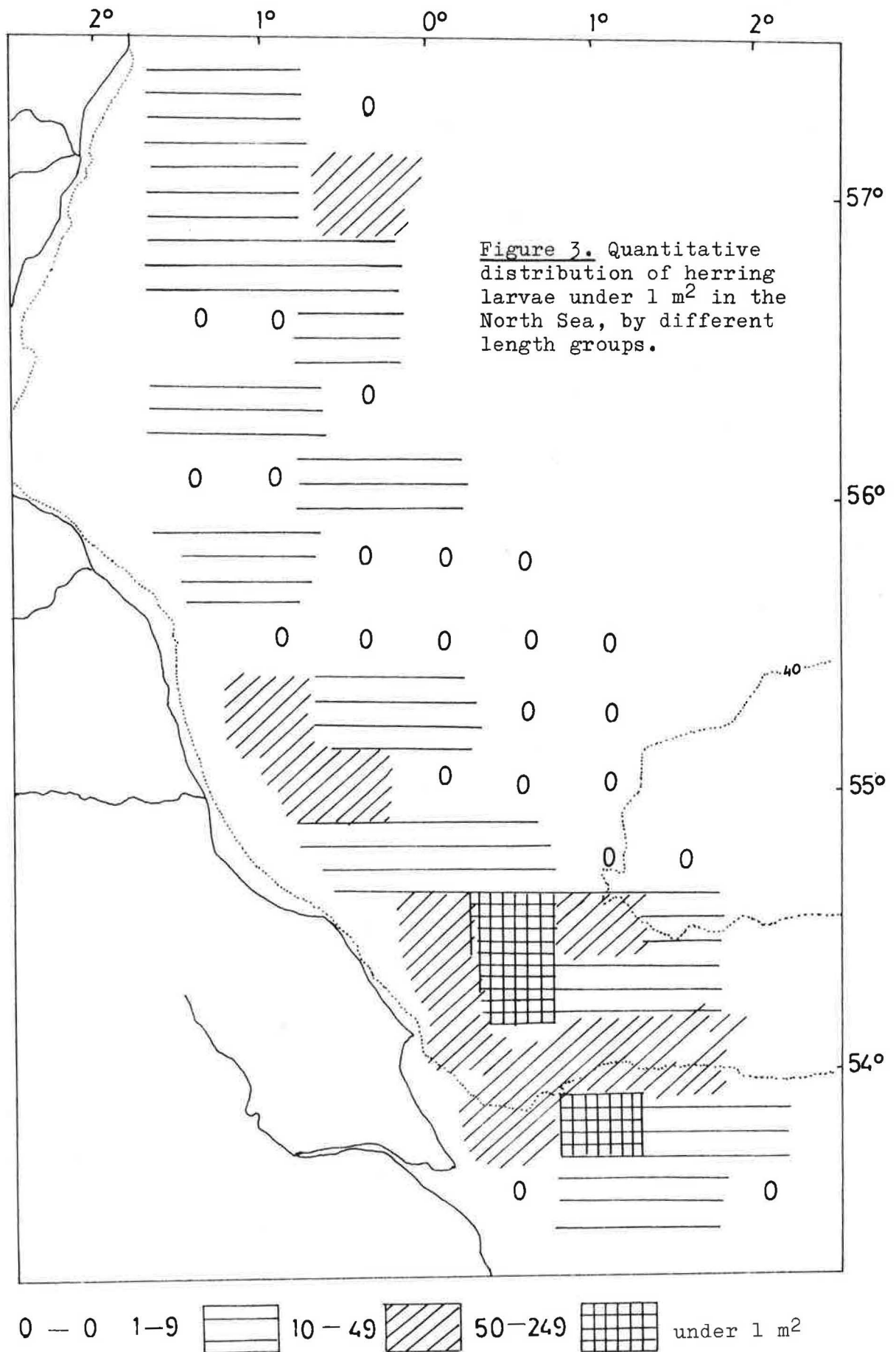


Figure 2. Location of stations where biological and hydrographical samples were taken during the cruise.



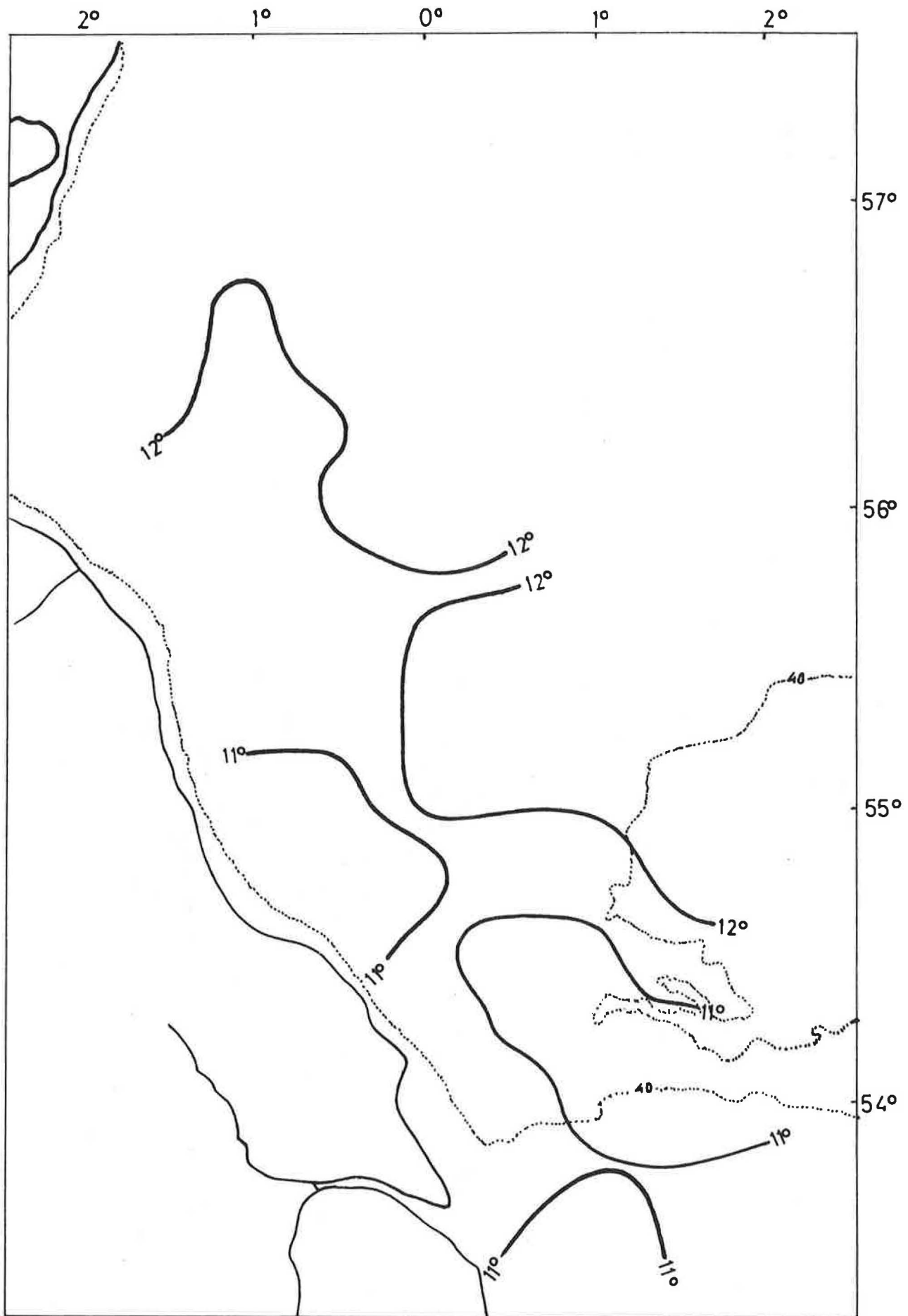


Figure 4. Surface temperatures in September and October 1974 (after W Kijowski).

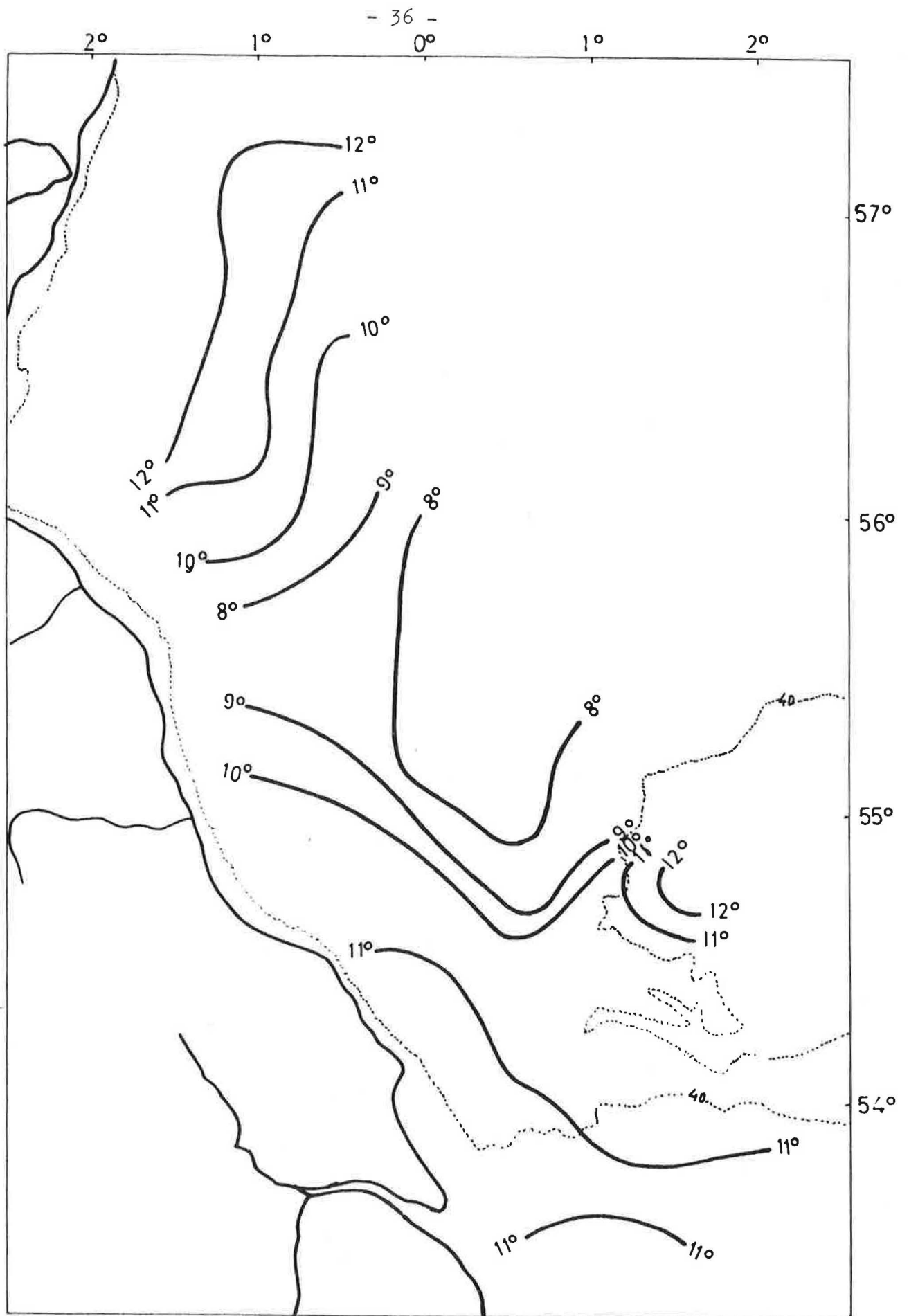


Figure 5. Bottom temperatures in September and October 1974 (after W Kijowski).

THE DISTRIBUTION AND ABUNDANCE OF HERRING LARVAE TO THE WEST OF SCOTLAND  
IN 1974

by

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Summary

The results of the herring larval surveys carried out to the west of Scotland in the autumn of 1974 are described. For the September and early October surveys larval densities in 1974 were similar to those of the corresponding surveys in 1973. Larval densities in the late October surveys were considerably higher than those in 1965 and 1971, when comparable surveys were last carried out.

The results are discussed in terms of numbers of larvae in relation to the adult stock size in the area.

Introduction

This report gives the results of the fifth of a series of annual surveys of herring larvae to the west of Scotland. Following an initial survey in 1965, a regular series began in 1971, following a recommendation by the ICES Herring Assessment Working Group (Anon., 1971). They are intended to provide measures of the changes in herring spawning stock size which are independent of catch per unit effort data.

The results of previous surveys have been reported by Wood (1971, 1973), Saville and McKay (1974b) and McKay (1975).

Material and methods

During the autumn of 1974 three countries participated in the surveys, with the following research vessels: England, RV "Scotia", Netherlands, RV "Tridens", Scotland, RV "Explorer" and RV "Scotia". Two complete and three partial surveys of the spawning area of herring in Division VIa were carried out, the timing of each survey being given in Table 1.

Table 1. Surveys carried out in 1974.

| Country     | Area            | Period          | No. of stations sampled |
|-------------|-----------------|-----------------|-------------------------|
| Scotland    | N of 58°N       | 30 Aug - 2 Sep  | 56                      |
| Netherlands | N of 56°30'N    | 11 Sep - 18 Sep | 80                      |
| England     | Cape Wrath Area | 15 Sep - 18 Sep | 35                      |
| Scotland    | 55° - 59°N      | 2 Oct - 9 Oct   | 104                     |
| Scotland    | 55° - 59°N      | 17 Oct - 24 Oct | 105                     |

Sampling was carried out using a modified Gulf III sampler towed in a double oblique haul fishing the whole water column to within 5 m of the sea bed. A more detailed description of the gear and sampling techniques is given by Saville (1970). From August to October a total of 390 stations were sampled.

Abundances of larvae, as numbers beneath one square metre of surface were plotted and planimetered and total abundances estimated as described by Saville and McKay (1974a).

### Results

The results from the various surveys in 1974 are given in Figures 1-13. On the first survey covering only the area north of 58°N larvae < 10 mm long were located in a patch extending from north of the Butt of Lewis to north of Cape Wrath with a maximum density of 294 larvae/m<sup>2</sup> surface being found north of Cape Wrath. The estimated number of larvae < 10 mm long in the surveyed area was 364 x 10<sup>9</sup> (Table 2). Larvae in the 10-15 mm length range were found in much the same area as the < 10 mm long larvae but at generally lower densities. The number of larvae in the 10-15 mm length range was estimated to be 205 x 10<sup>9</sup> (Table 2). No larvae >15 mm were taken during this survey.

Table 2. Estimated abundance of herring larvae on each survey in Division VIa in 1974 (Total for N and S of 56°30'N given separately).

| Dates          | Survey area        | Number of larvae x 10 <sup>-9</sup> |         |        |       |
|----------------|--------------------|-------------------------------------|---------|--------|-------|
|                |                    | <10mm                               | 10-15mm | >15 mm | Total |
| 30 Aug - 2 Sep | North of 58°N      | 364                                 | 205     | -      | 569   |
| 11 - 18 Sep    | North of 56°30'N   | 1 051                               | 832     | 23     | 1 906 |
| 2 - 9 Oct      | { North of 56°30'N | 1 376                               | 1 234   | 222    | 2 832 |
|                | { South of 56°30'N | 1 013                               | 149     | 10     | 1 172 |
|                | { 55°N - 59°N      | 2 389                               | 1 383   | 232    | 4 004 |
| 17 - 24 Oct    | { North of 56°30'N | 788                                 | 1 321   | 257    | 2 366 |
|                | { South of 56°30'N | 727                                 | 740     | 94     | 1 561 |
|                | { 55°N - 59°N      | 1 515                               | 2 061   | 351    | 3 927 |

The second survey sampled the area north of 56°30'N, but that part of it to the west of the Outer Hebrides was poorly sampled except for small areas northeast of the Flannan Islands and west of Barra Head. Larvae <10 mm long were found in several patches; the major one being located to the northeast of the Flannan Islands with a maximum density of 744 larvae/m<sup>2</sup> surface. Secondary patches of <10 mm long larvae were found to the west of Barra Head, density up to 331/m<sup>2</sup> surface, north of Butt of Lewis density up to 198/m<sup>2</sup> surface, west of Cape Wrath, density up to 125/m<sup>2</sup> surface, west of Skye, density up to 143/m<sup>2</sup> surface and north of Coll Island, density up to 98/m<sup>2</sup> surface. Such concentrations of larvae have not been observed in either of the latter two areas on any of the previous September surveys. The total number of larvae <10 mm long was estimated to be 1051 x 10<sup>9</sup> (Table 2). Larvae in the 10-15 mm length range were also widely distributed with the main concentrations being located in an almost continuous belt from the Flannan Islands north and east to the eastern limit of the survey at 4°W. Highest densities of 226 larvae/m<sup>2</sup> surface and 131 larvae/m<sup>2</sup> surface respectively were obtained to the north of Butt of Lewis and to the east of the Flannan Islands. The estimated number of larvae in the 10-15 mm length range for the whole survey area was 832 x 10<sup>9</sup> (Table 2). Larvae >15 mm long were rather scarce being located in scattered patches in the northern part of the survey area with an estimated total number of 23 x 10<sup>9</sup> (Table 2).

The third survey was of rather limited extent being confined to the area north and east of Cape Wrath with a few additional stations in the North Minch. On this survey a major patch of <10mm long larvae was located inshore between Cape Wrath and Strathy Point with the maximum density of 482 larvae/m<sup>2</sup> surface being located immediately west of Strathy Point. Because of its limited extent no estimates of abundances have been made for this survey. Larvae in the 10-15 mm length range were found in a similar area to the <10mm long larvae with the maximum density of 119 larvae/m<sup>2</sup> surface being located north of Cape Wrath. Densities of larvae in the 10-15 mm length range in the Minch were much higher than those for the <10 mm long larvae, with a maximum density of 65 larvae/m<sup>2</sup> surface being encountered off Tiumpnan Head.

On the first complete survey of the spawning area <10 mm long larvae were located in two main areas, to the west of the Outer Hebrides and to the north and west of Ireland. To the west of the Outer Hebrides the major concentration was located west of North and South Uist with a maximum density of 623 larvae/m<sup>2</sup> surface. In the area north and west of Ireland the major concentration, maximum density of 1331 larvae/m<sup>2</sup> surface was located to the west of Aran Island with a subsidiary patch, maximum density 154 larvae/m<sup>2</sup> surface to the northwest of Malin Head. The total number of larvae <10 mm long was estimated to be  $2389 \times 10^9$  (Table 2). Larvae in the 10-15 mm length range were also widely distributed but at lower densities than the <10 mm long larvae. The major concentration of larvae in the 10-15 mm length range was in the area west of the Outer Hebrides with a maximum density of 98 larvae/m<sup>2</sup> surface being observed in the area of St. Kilda. The total number of larvae in the 10-15 mm length range was estimated to be  $1383 \times 10^9$  (Table 2).

The final survey covered the whole spawning area and larvae <10 mm long were again found to the west of the Outer Hebrides and off the northwest coast of Ireland. In the former area the maximum concentration was located west of Lewis with a maximum density of 196 larvae/m<sup>2</sup> surface. In the area north and west of Ireland the major concentration was off Malin Head with a maximum density of 625 larvae/m<sup>2</sup> surface with a second patch to the west and north of Aran Island with a maximum density of 193 larvae/m<sup>2</sup> surface. The total number of larvae <10 mm long was estimated to be  $1515 \times 10^9$  (Table 2). Larvae in the 10-15 mm length range were generally distributed throughout the survey area with the major concentrations in the same areas as the <10 mm long larvae. The total number of larvae in the 10-15 mm length range was  $2061 \times 10^9$  (Table 2). Larvae >15 mm long were generally distributed at low densities over the whole survey area giving an estimated total abundance of  $351 \times 10^9$  larvae (Table 2).

### Discussion

In making comparisons between larval abundances in 1974 and those of previous surveys (Wood, 1971 and 1973; Saville and McKay, 1974b and McKay, 1975) it is necessary to group the estimates into comparable time periods and survey areas. These data are given in Tables 3 and 4 for the areas north and south of 56°30'N. This grouping of data is necessary in Division VIa as it would appear that hatching of the larvae in the north of the area is completed significantly earlier than in the south. In 1974 the hatching of larvae in the Cape Wrath/Butt of Lewis area was almost totally finished by the beginning of October whereas significant numbers of larvae were still being produced on the more southerly spawning grounds during the last survey in late October.

### September surveys

Because of the incomplete nature of the September surveys in 1974 direct comparison of the larval abundances in these surveys with those of previous years is rather misleading as these would indicate that the larval production in 1974 was considerably lower than in previous years. Much of this difference may however be due to the smaller area of the surveys. The survey lasting from 11-18 September gives total larval abundances approximately half



Table 3. Estimated abundances of herring larvae N of 56°30'N in Division VIa in 1965, 1971, 1972, 1973 and 1974 in standard time periods. (After Wood (1971, 1973), Saville and McKay (1974b) and McKay (1975)).

| Time periods       | Estimated abundances x 10 <sup>-9</sup> |     |                     |       |                   |          |    |                   |       |                   |                     |                     |       |       |                     |
|--------------------|---|-----|---------------------|-------|-------------------|----------|----|-------------------|-------|-------------------|---------------------|---------------------|-------|-------|---------------------|
|                    | <10 mm                                  |     |                     |       |                   | 10-15 mm |    |                   |       |                   | Total               |                     |       |       |                     |
|                    | 65                                      | 71  | 72                  | 73    | 74                | 65       | 71 | 72                | 73    | 74                | 65                  | 71                  | 72    | 73    | 74                  |
| 1-10 Sep           | NS                                      | ND  | 7 691 <sup>1)</sup> | NS    | 364 <sup>1)</sup> | NS       | ND | 669 <sup>1)</sup> | NS    | 205 <sup>1)</sup> | NS                  | 3 267 <sup>2)</sup> | 8 360 | NS    | 569 <sup>1)</sup>   |
| 11-25 Sep          | NS                                      | NS  | 1 334               | 2 016 | 1 051             | NS       | NS | 1 350             | 2 553 | 832 <sup>1)</sup> | NS                  | NS                  | 2 773 | 4 569 | 1 906 <sup>1)</sup> |
| 26 Sep -<br>10 Oct | NS                                      | NS  | 2 388               | 1 665 | 1 376             | NS       | NS | 2 122             | 1 779 | 1 234             | NS                  | NS                  | 4 586 | 3 586 | 2 832               |
| 10-25 Oct          | 415 <sup>3)</sup>                       | 319 | NS                  | NS    | 788               | ND       | ND | NS                | NS    | 1 321             | 1 330 <sup>3)</sup> | 1 037               | NS    | NS    | 2 366               |

NS - No survey

ND - No data given

1) incomplete survey

2) incomplete survey including yolk-sac larvae

3) including Minches

Table 4. Estimated abundances of herring larvae S of 56°30'N in Division VIa in 1965, 1971, 1972, 1973, and 1974 in standard time periods. (After Wood (1971, 1973), Saville and McKay (1974b) and McKay (1975)).

| Time periods      | Estimated abundances x 10 <sup>-9</sup> |     |    |     |       |          |    |    |     |     |         |     |    |     |       |
|-------------------|---|-----|----|-----|-------|----------|----|----|-----|-----|---------|-----|----|-----|-------|
|                   | < 10 mm                                 |     |    |     |       | 10-15 mm |    |    |     |     | > 15 mm |     |    |     |       |
|                   | 65                                      | 71  | 72 | 73  | 74    | 65       | 71 | 72 | 73  | 74  | 65      | 71  | 72 | 73  | 74    |
| 11-25 Sep         | NS                                      | NS  | 21 | 194 | NS    | NS       | NS | 29 | 47  | NS  | NS      | NS  | 51 | 241 | NS    |
| 26 Sep-<br>10 Oct | NS                                      | NS  | 31 | 524 | 1 013 | NS       | NS | 21 | 231 | 149 | NS      | NS  | 57 | 758 | 1 172 |
| 10-25 Oct         | 504                                     | 677 | NS | NS  | 727   | ND       | ND | NS | NS  | 740 | 807     | 940 | NS | NS  | 1 561 |

NS - No survey

ND - No data given



of those for the corresponding survey in 1973 (McKay, 1975), but the 1974 survey did not adequately cover the spawning areas to the west of the Outer Hebrides. If the larval distributions for the two surveys are compared, Figures 3 and 14, it is apparent that for the area surveyed in the two years the larval distributions and densities are very similar. It is therefore reasonable to assume that the larval abundance over the whole area during mid-September in 1974 is likely to be similar to that in 1973.

Because of their limited extent and the lack of comparable surveys in previous years the remaining surveys carried out in September 1974 are of little value when considering changes in spawning population size. They do, however, provide data which may be extremely valuable in the future design of these surveys. Comparison of the limited survey carried out in the Cape Wrath area during the period 11-18 September shows considerably different larval densities. During the 11-18 September survey the stations in the Cape Wrath area were sampled on 11-13 September and therefore there was a gap of five days between the sampling on the two surveys. During these five days the maximum density of  $<10$  mm long larvae to the east of Cape Wrath had increased from 25 larvae/m<sup>2</sup> surface to 482 larvae/m<sup>2</sup> surface whereas that to the west of Cape Wrath had fallen from 125 larvae/m<sup>2</sup> surface to seven larvae/m<sup>2</sup> surface. This would indicate that in this area rapid changes in larval densities are likely and therefore the timing of surveys in the area could cause considerable changes in total larval abundances, which could easily mask long-term variations in spawning intensity. An example of slight differences in timing giving apparently large changes in larval abundances are the early September surveys in 1972 (Saville and McKay, 1974b) and 1974. In 1972 when the survey of the area was carried out in the period 5-8 September very high larval abundances,  $7691 \times 10^9$  for larvae  $<10$  mm long, were observed whereas the abundance of larvae on the survey during the period 30 August-2 September 1974 was an order of magnitude less at  $364 \times 10^9$  larvae. There was a gap between the timing of the surveys of approximately 7 days and as this is at the beginning of the hatching period such a "build up" of small larvae could easily occur in such a time period.

#### October surveys

Although the abundance of larvae  $<10$  mm long in Division VIa during the early part of October 1974 ( $2389 \times 10^9$ ) was similar to that in 1972 and 1973 ( $2419 \times 10^9$  and  $2189 \times 10^9$  respectively) (Saville and McKay 1974b, and McKay 1975) the larval distributions were rather different. Whereas in previous years the area to the west of the Outer Hebrides, i.e. north of  $56^{\circ}30'N$  had contributed the majority of the larvae, almost all in 1972 and 75% in 1973, in 1974 the larval production in this area was only slightly higher than that in the southern part of VIa. The period from 1972 to 1974 would appear to have been marked by a gradual decline in the early October larval abundances in the northern part of VIa and a substantial increase in the southern part of VIa (Tables 3 and 4).

In late October the abundances of larvae were rather higher than those observed by Wood (1971 and 1973) in 1965 and 1971. This increased larval abundance was observed over the whole of VIa but was most marked in the northern area where abundances of larvae in all size groups were about twice that in 1965 and 1971 (Table 3). In the southern part of VIa the total larval abundance in 1974 was about 40% higher than that for 1965 and 1971 with the biggest increase being in size group  $<10$  mm long. As the survey in 1974 covered a smaller area with no sampling being carried out in Donegal Bay area it is probable that the increase in larval abundances between 1965 and 1971 and 1974 is even greater than shown in Table 4.

#### Stock size estimates

Saville and McKay (1974b) and McKay (1975) have attempted to estimate the size of the spawning stock in VIa by comparing the abundance estimates for

<10 mm long larvae for VIa with those of other stocks for which both larval abundance and stock size data are available. The relationship used is

$$S_{VIa} = \frac{S_{N.S.} \times F_{N.S.} \times L_{VIa}}{F_{VIa} \times L_{N.S.}}$$

where S = spawning stock size in tonnes, F = fecundity per tonne, L = larval abundance, and the subscripts VIa and N.S. (North Sea) refer to the areas. The various stock size and larval abundance data for the North Sea are given by Saville and McKay (1974b). Using this method the size of the spawning stock in VIa in 1974 was estimated to be of the order of 400 000 - 600 000 tonnes (Table 5). Whereas in previous years the estimates obtained by this method have been in reasonable agreement with that from the virtual population analysis (Saville and Morrison, 1973), in 1974 it would appear that this method of estimation gives a spawning stock size about twice that from virtual population analysis (Anon., 1975).

Table 5. Estimated spawning stock size in tonnes in VIa from comparison with Central/Northern North Sea in 1957-60, and 1961-64 and from VPA.

| Year | Estimated spawning stock size in VIa (tonnes) |                                    |                       |
|------|---|------------------------------------|-----------------------|
|      | by comparison with larval surveys:            |                                    | from VPA:             |
|      | Central/Northern North Sea 1957-60            | Central/Northern North Sea 1961-64 |                       |
| 1965 | 227 500 <sup>1)</sup>                         | 150 800 <sup>1)</sup>              | 231 700 <sup>3)</sup> |
| 1971 | 371 000 <sup>1)</sup>                         | 220 500 <sup>1)</sup>              | 330 200 <sup>3)</sup> |
| 1972 | 1 276 300 <sup>2)</sup>                       | 846 100 <sup>2)</sup>              | 825 000 <sup>3)</sup> |
| 1973 | 734 600 <sup>2)</sup>                         | 487 100 <sup>2)</sup>              | 583 000 <sup>3)</sup> |
| 1974 | 651 800                                       | 432 200                            | 220 000 <sup>4)</sup> |

- 1) Figures from Saville and McKay (1974b)
- 2) Figures from McKay (1975)
- 3) Figures from Saville and Morrison (1973)
- 4) Figures from Anon. (1975).

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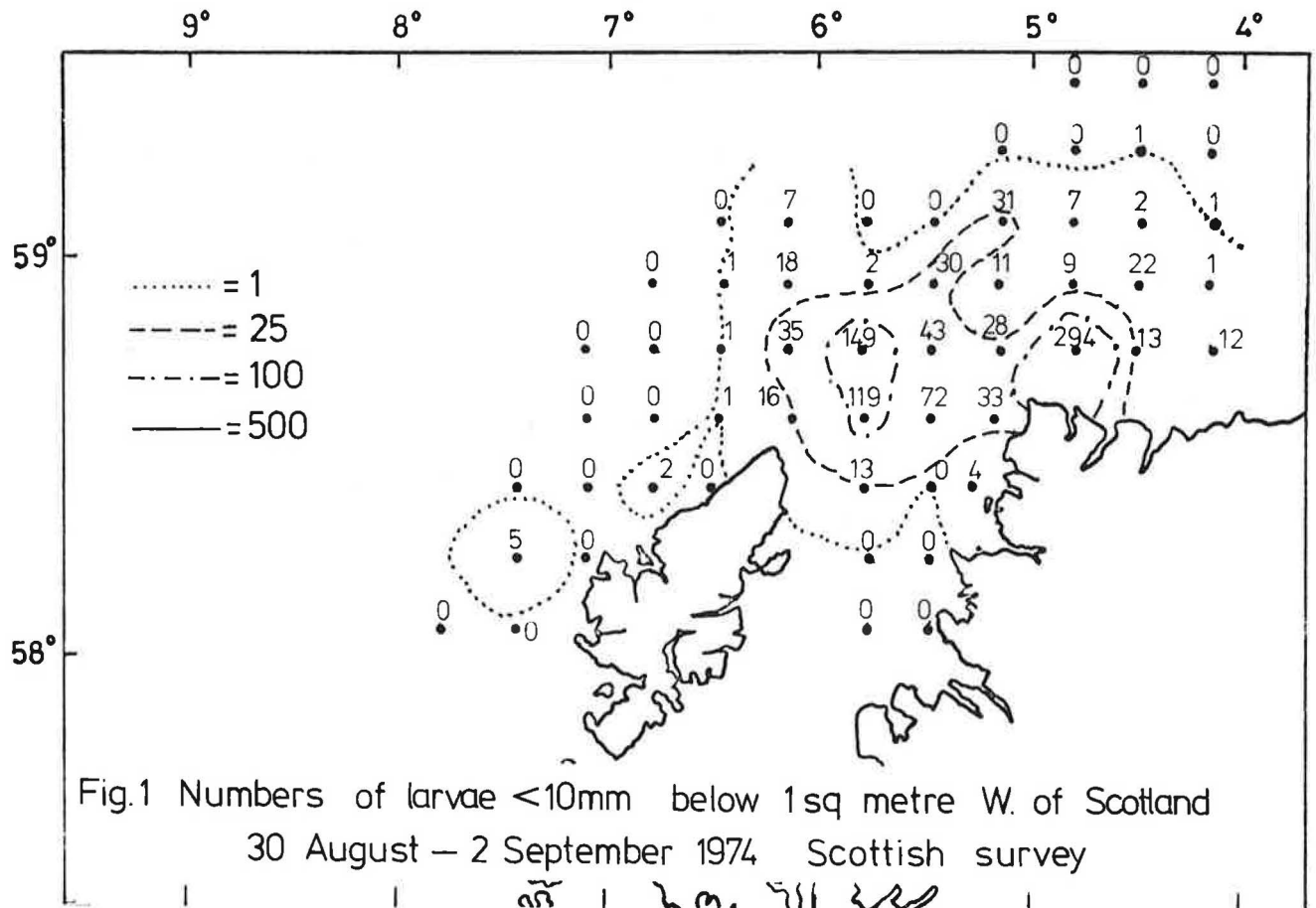


Fig.1 Numbers of larvae <10mm below 1sq metre W. of Scotland  
30 August – 2 September 1974 Scottish survey

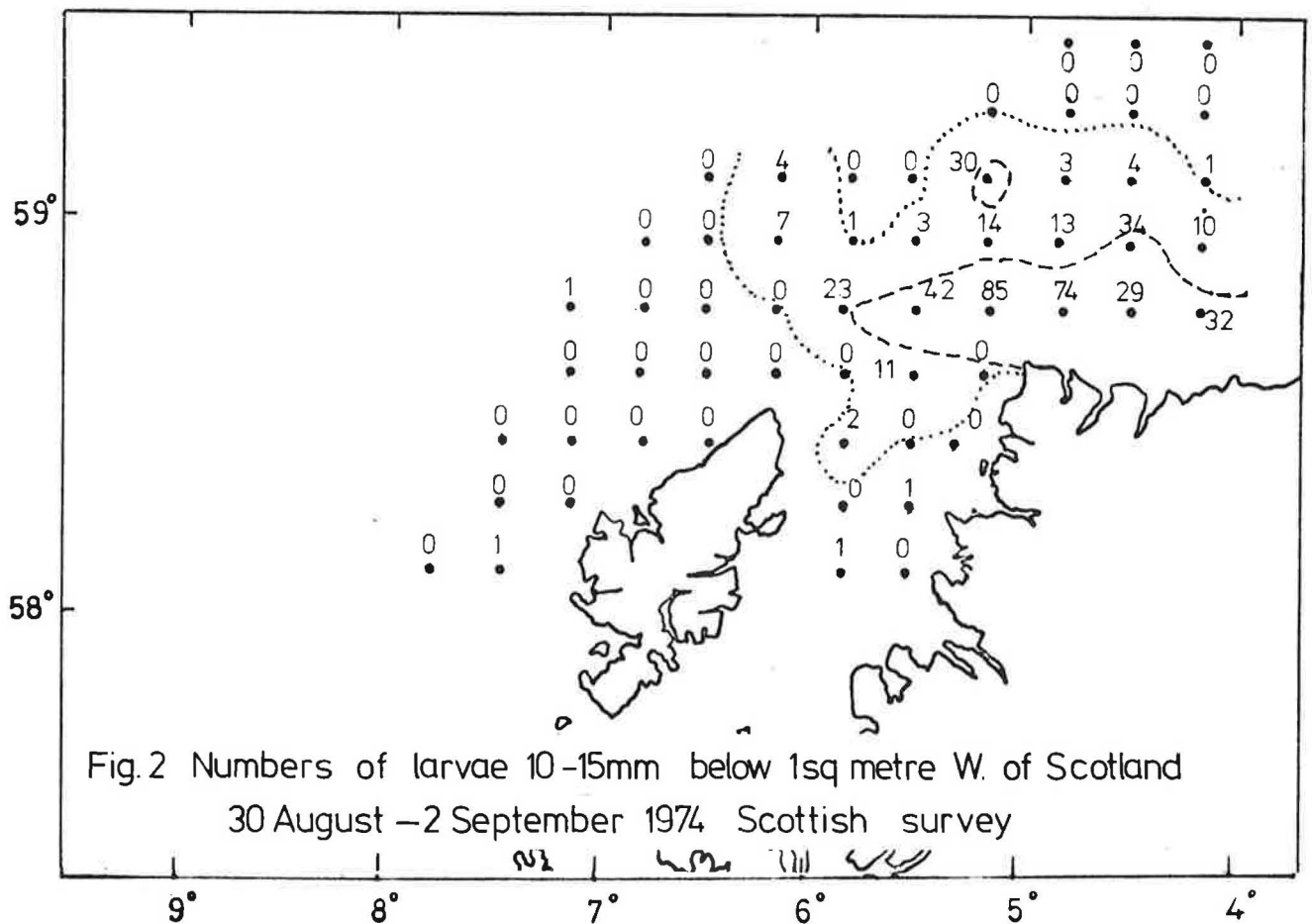


Fig.2 Numbers of larvae 10-15mm below 1sq metre W. of Scotland  
30 August – 2 September 1974 Scottish survey

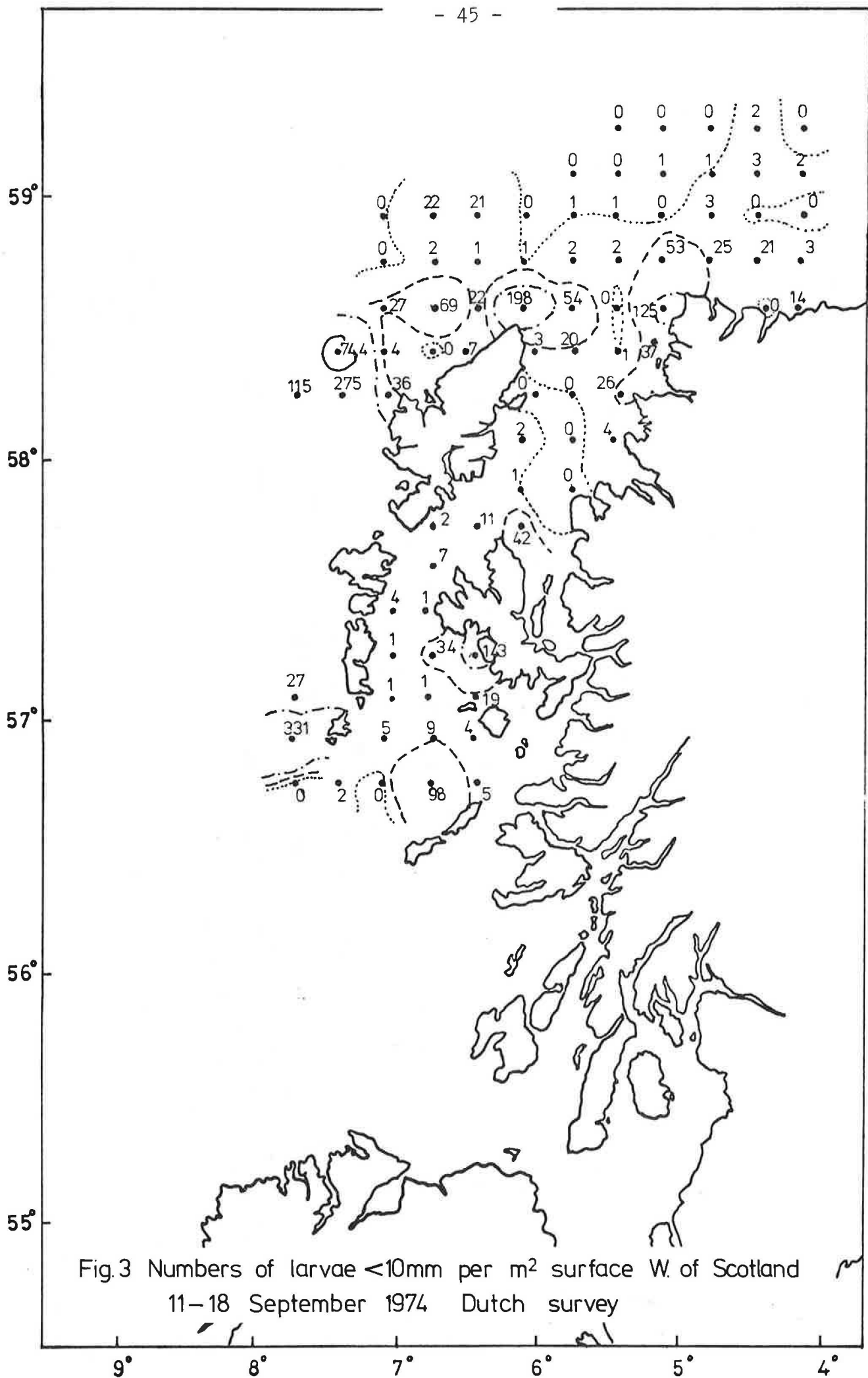
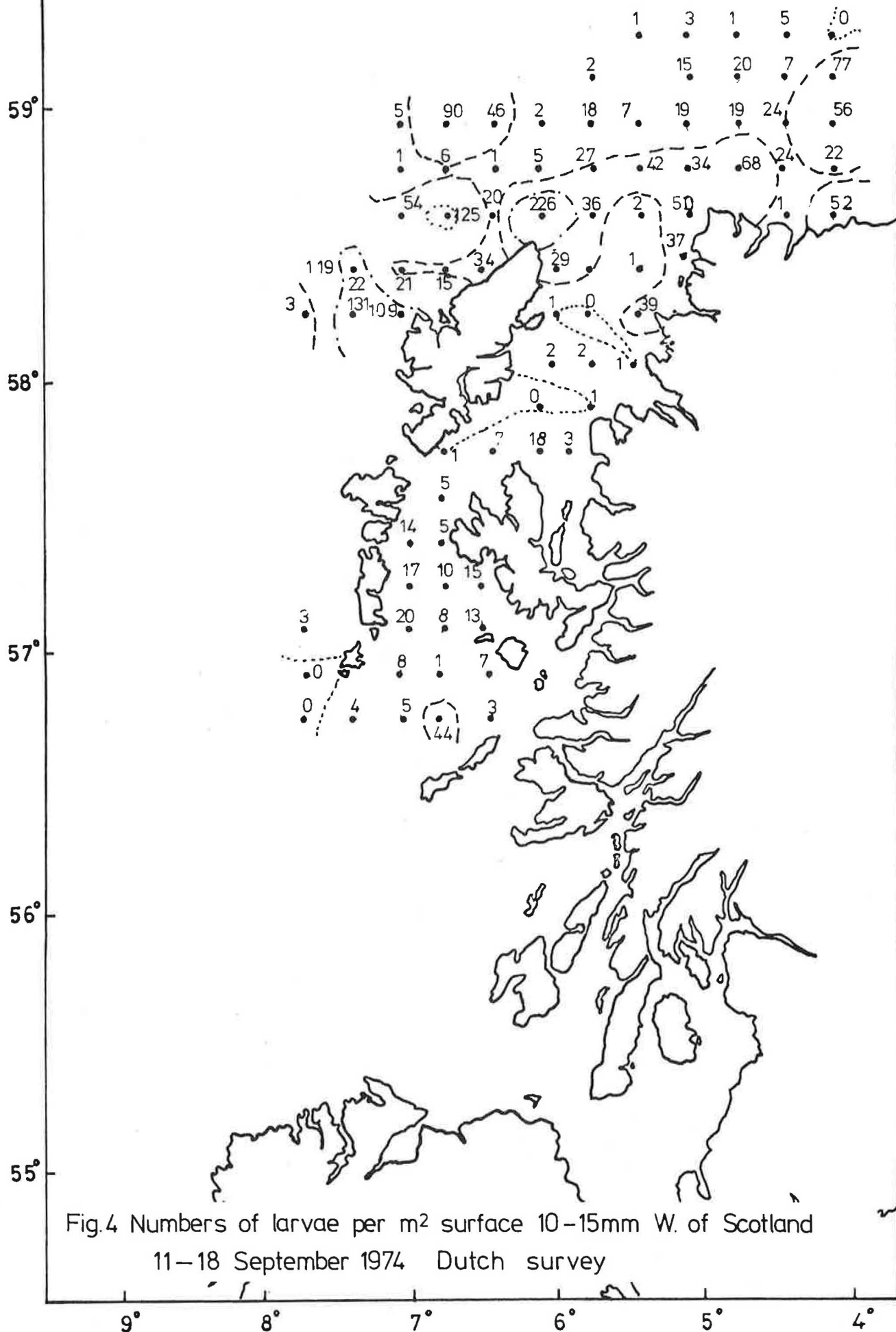


Fig.3 Numbers of larvae <10mm per m² surface W. of Scotland  
11-18 September 1974 Dutch survey



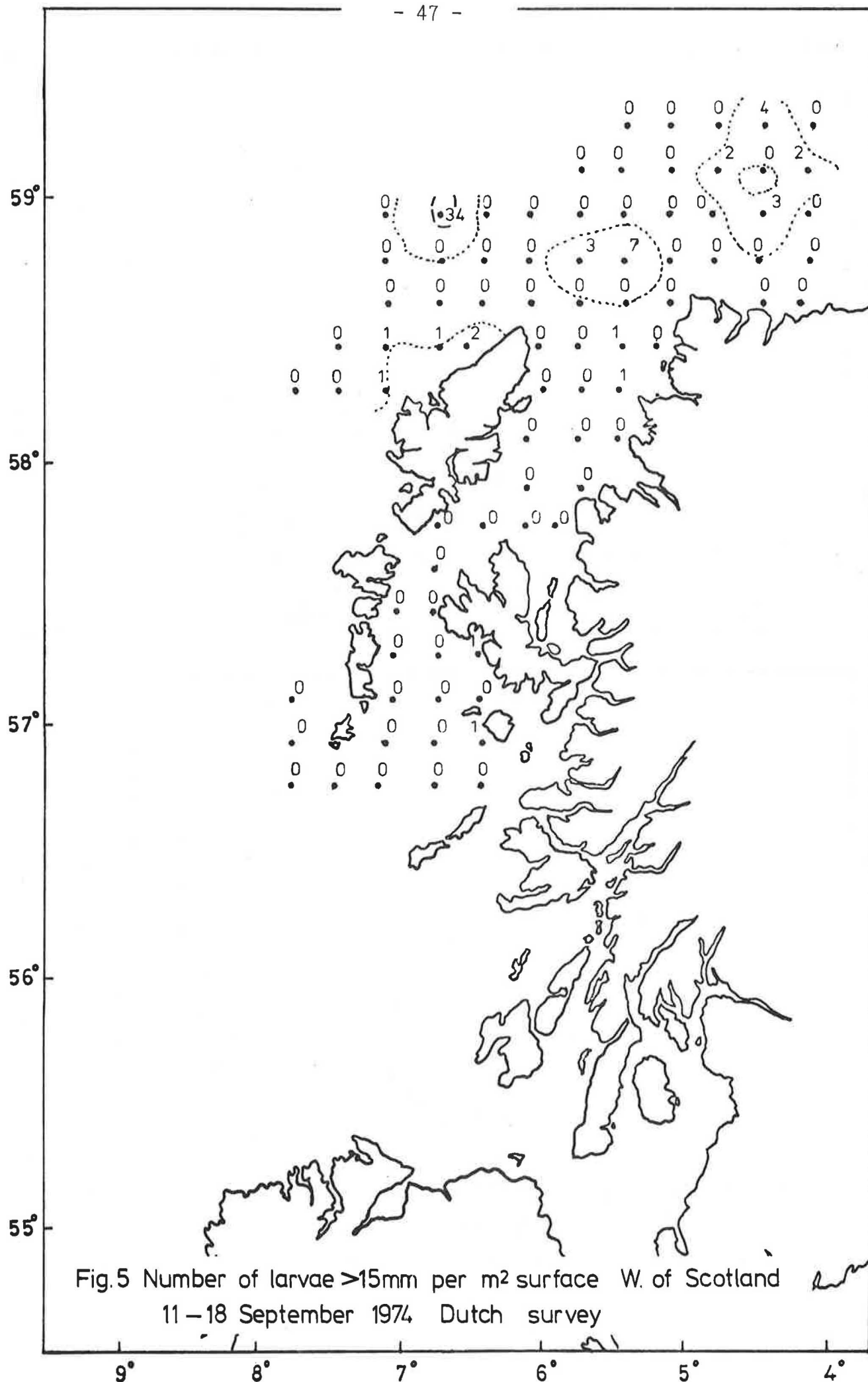
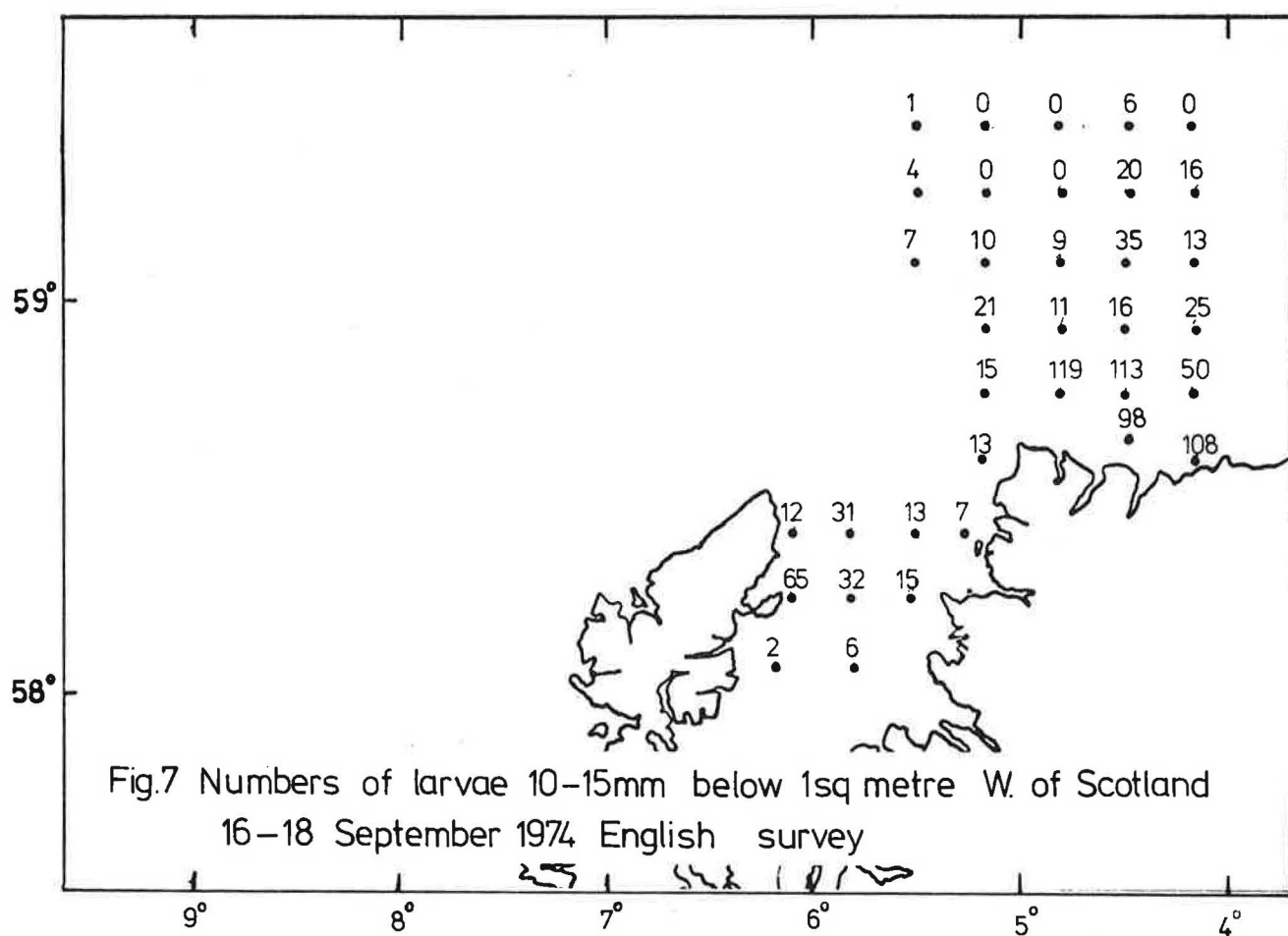
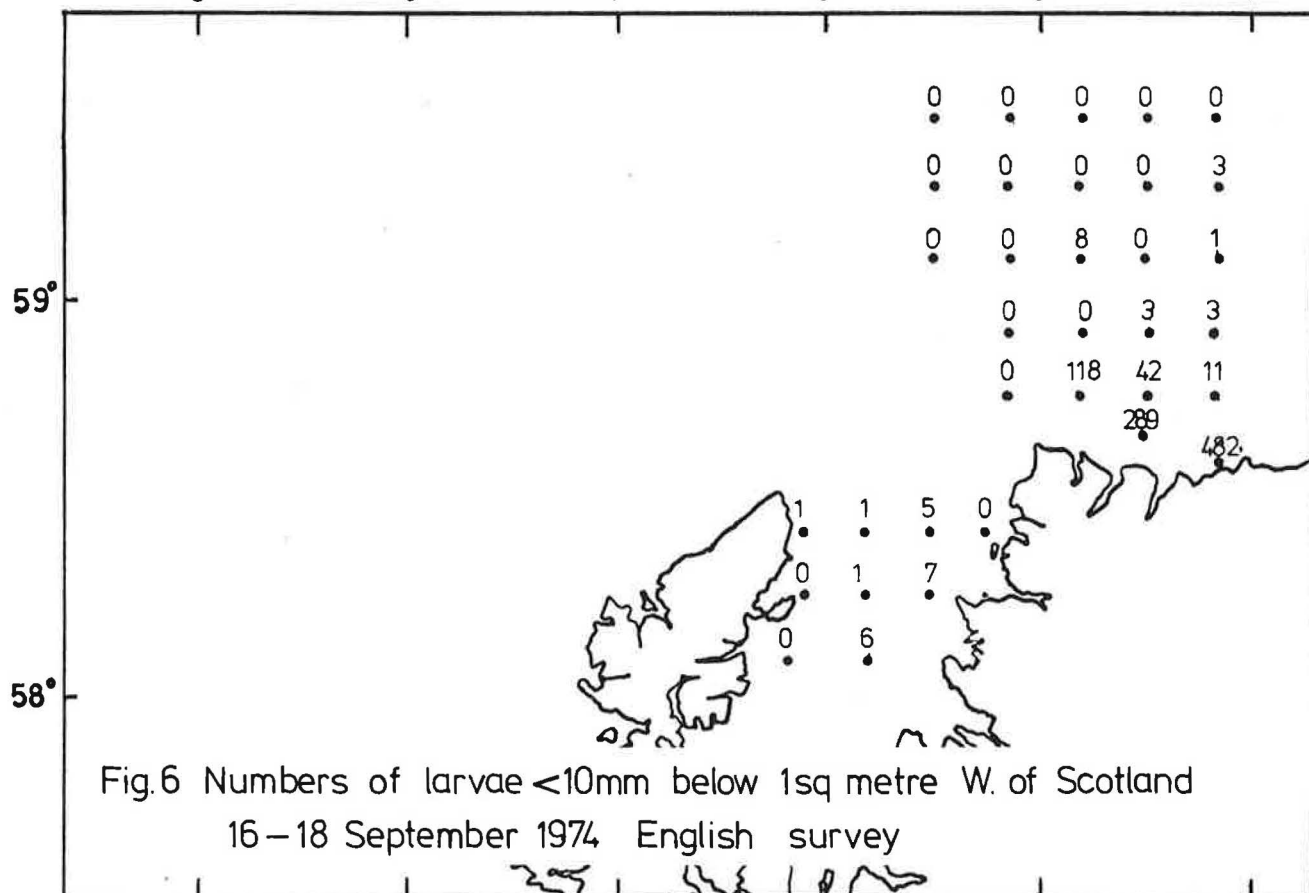


Fig.5 Number of larvae >15mm per m<sup>2</sup> surface W. of Scotland  
11 - 18 September 1974 Dutch survey





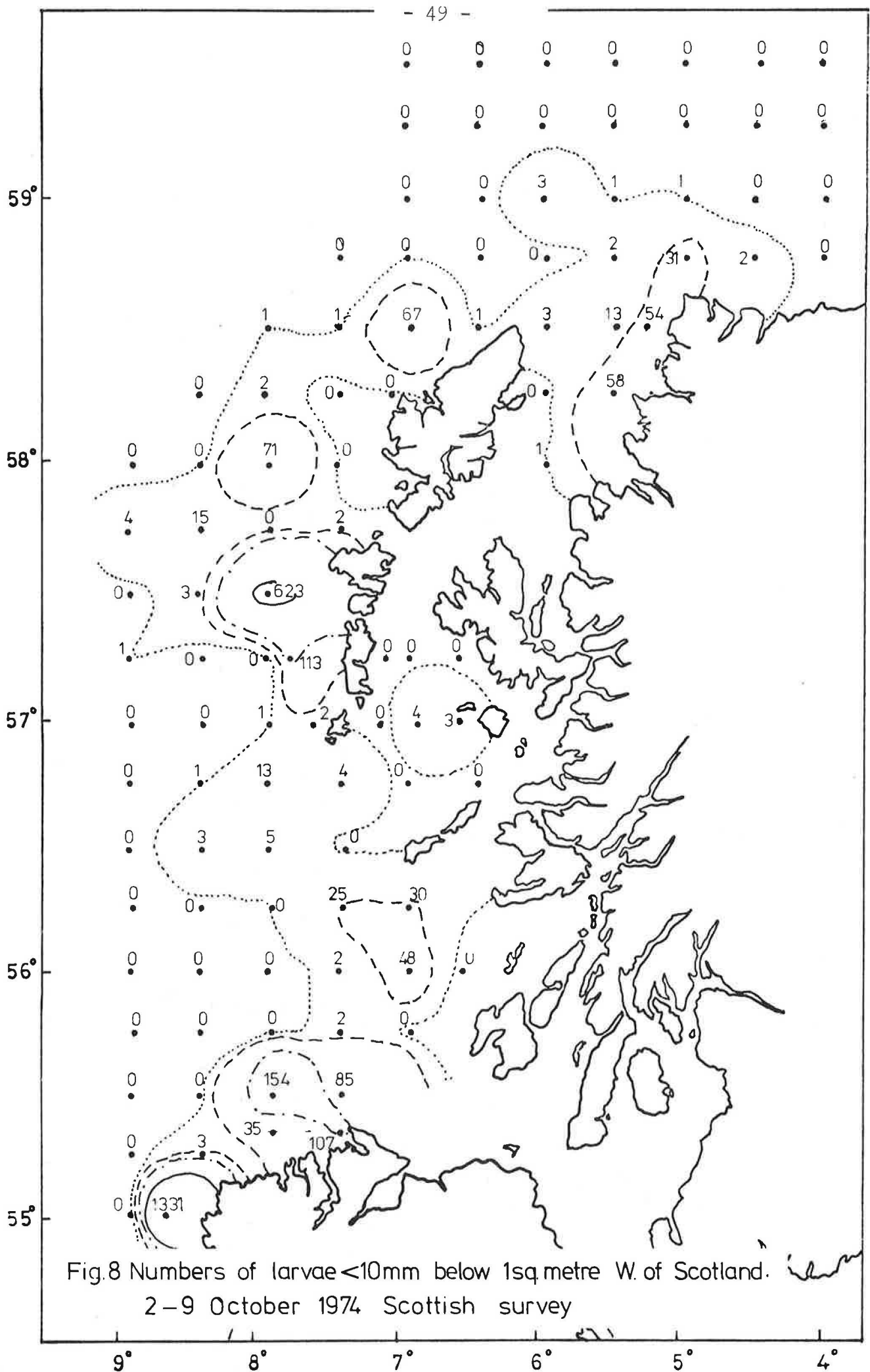
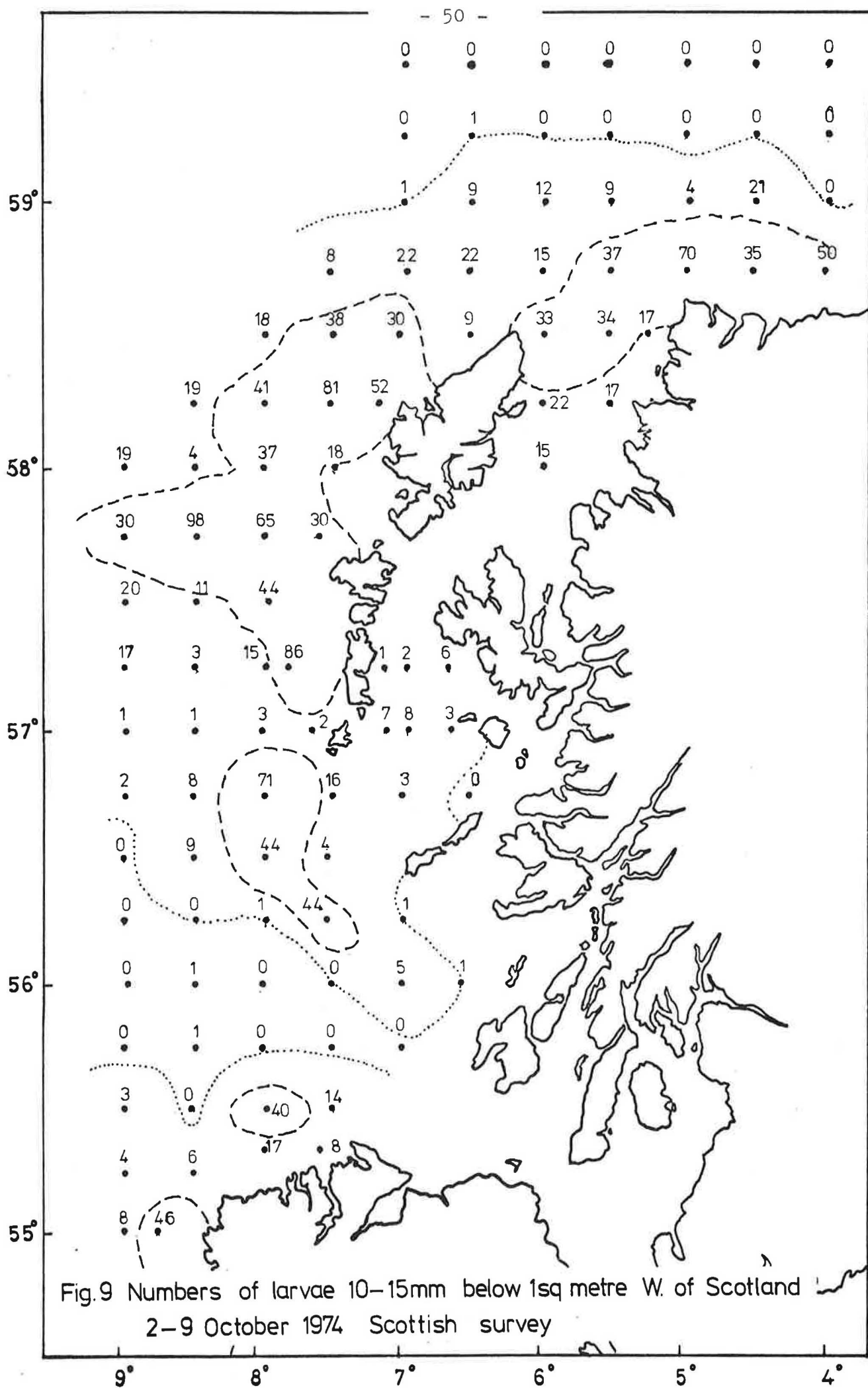


Fig.8 Numbers of larvae <10mm below 1sq metre W. of Scotland.  
2-9 October 1974 Scottish survey



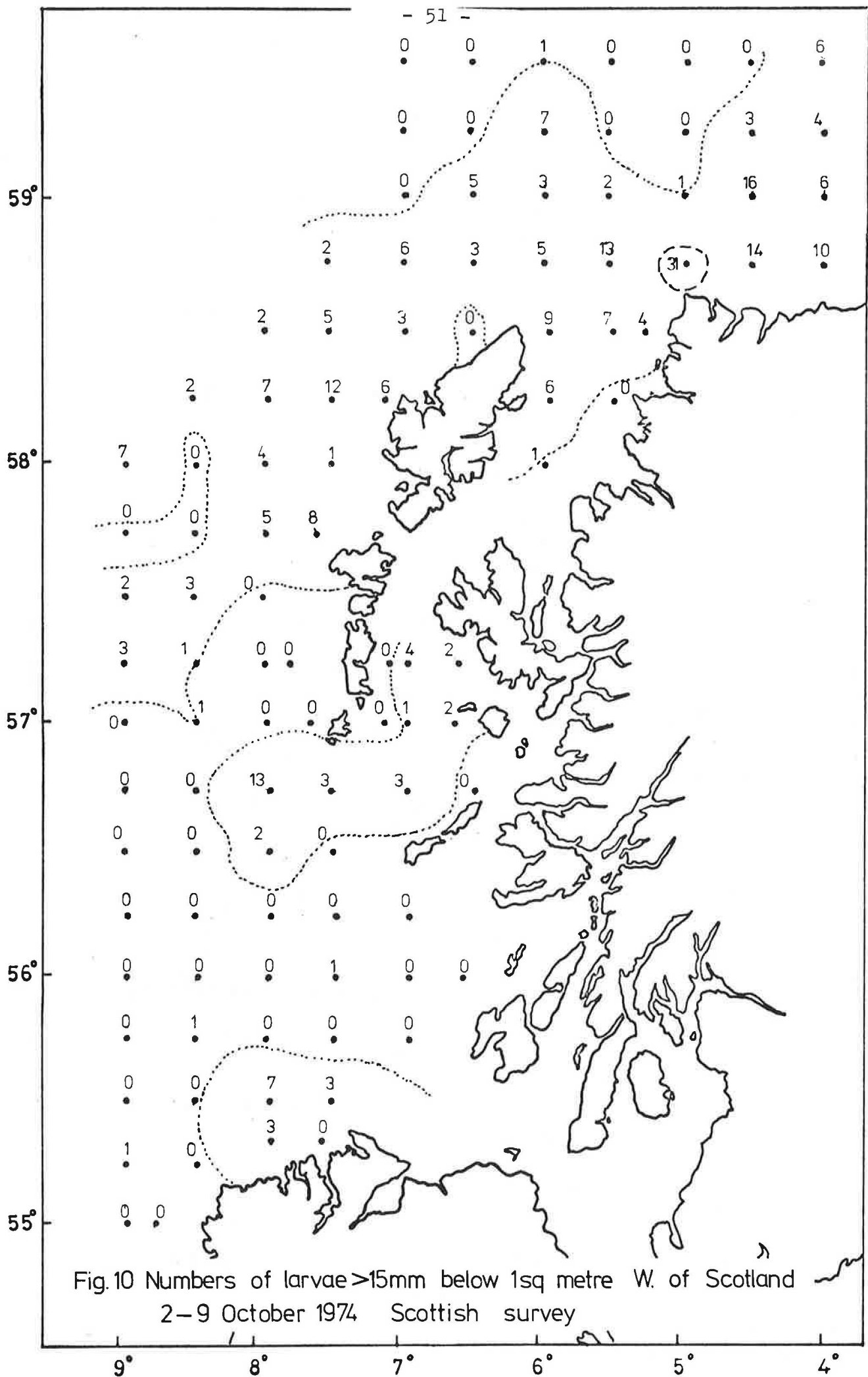
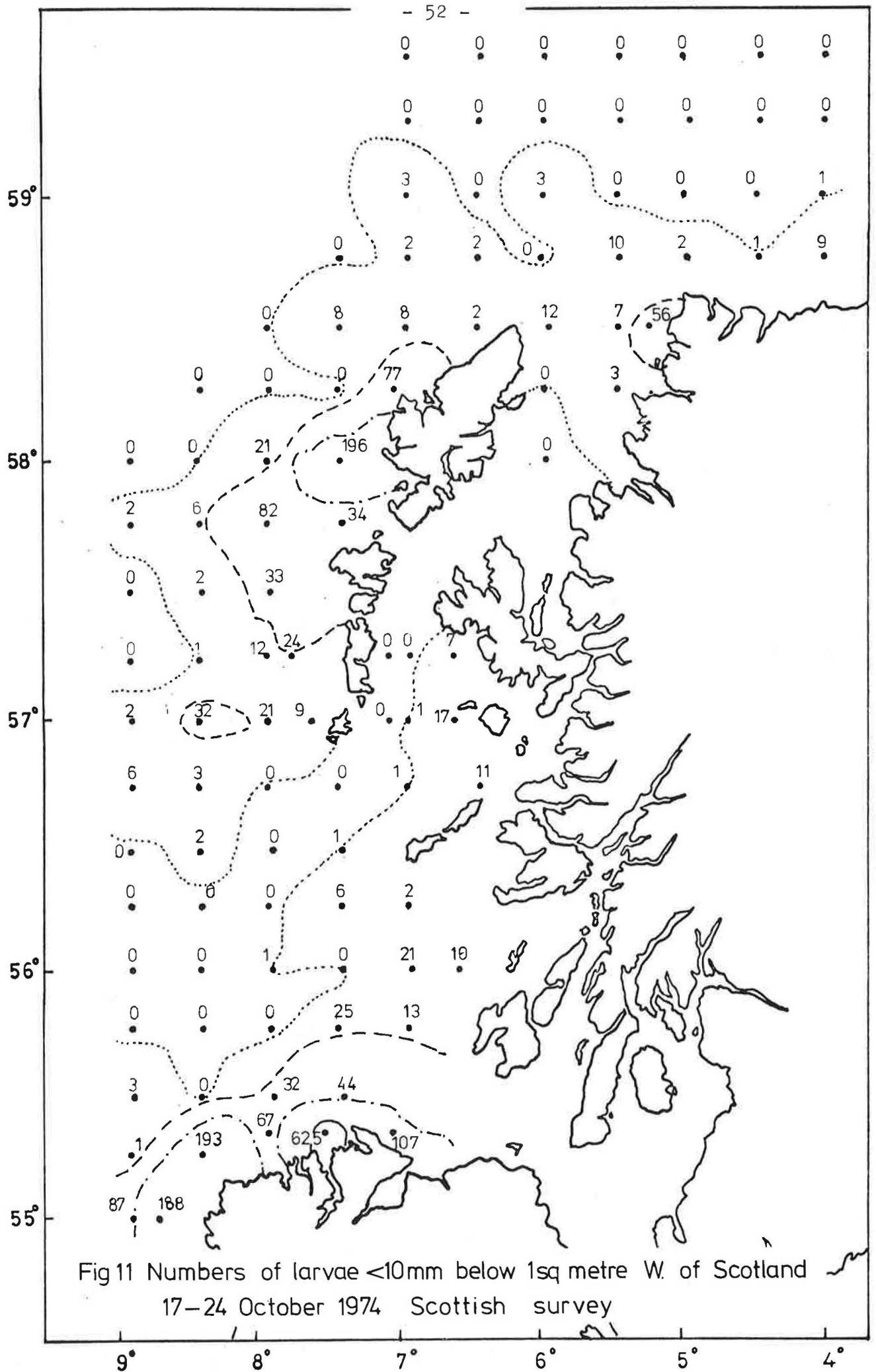


Fig.10 Numbers of larvae >15mm below 1sq metre W. of Scotland  
2-9 October 1974 Scottish survey



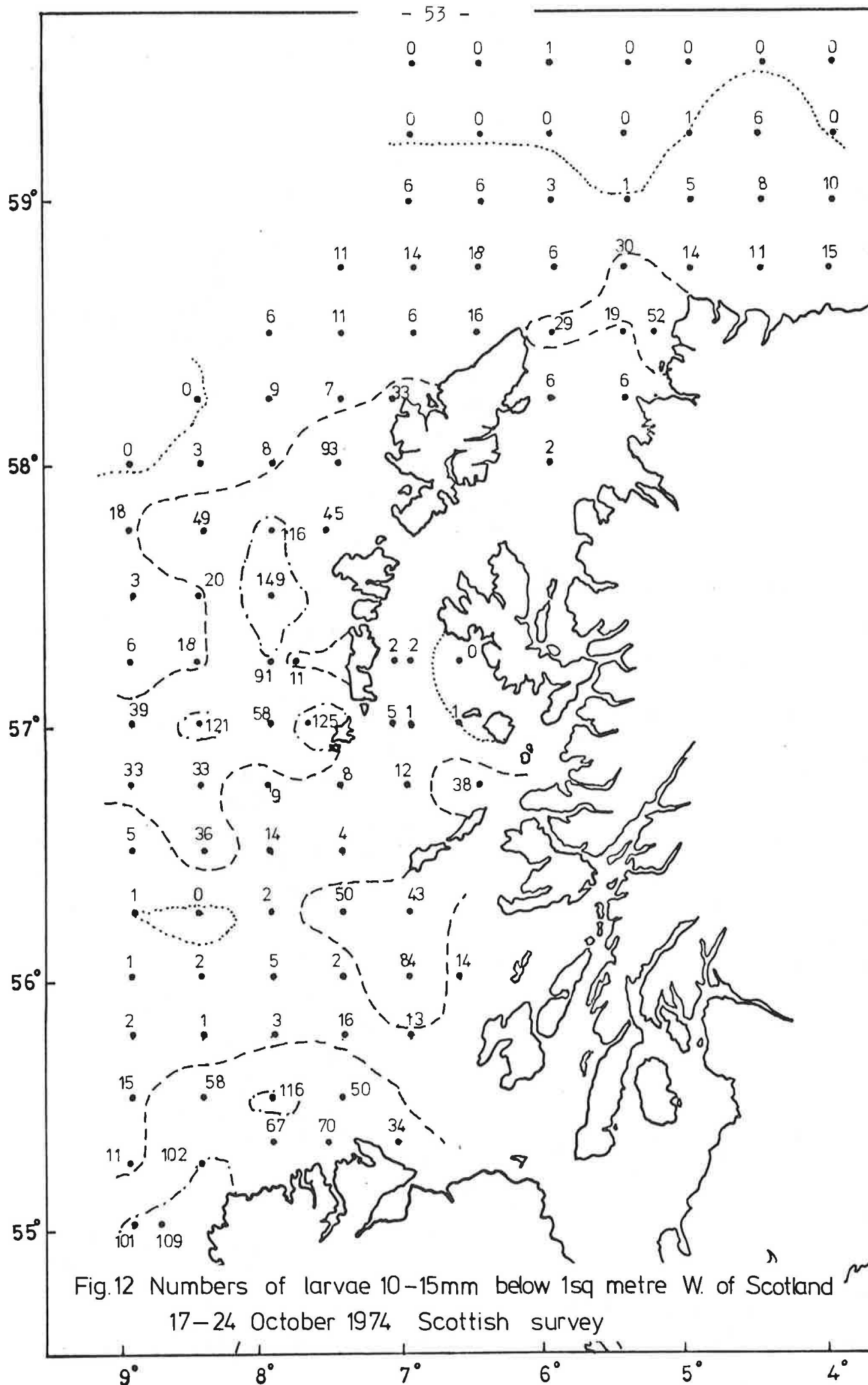
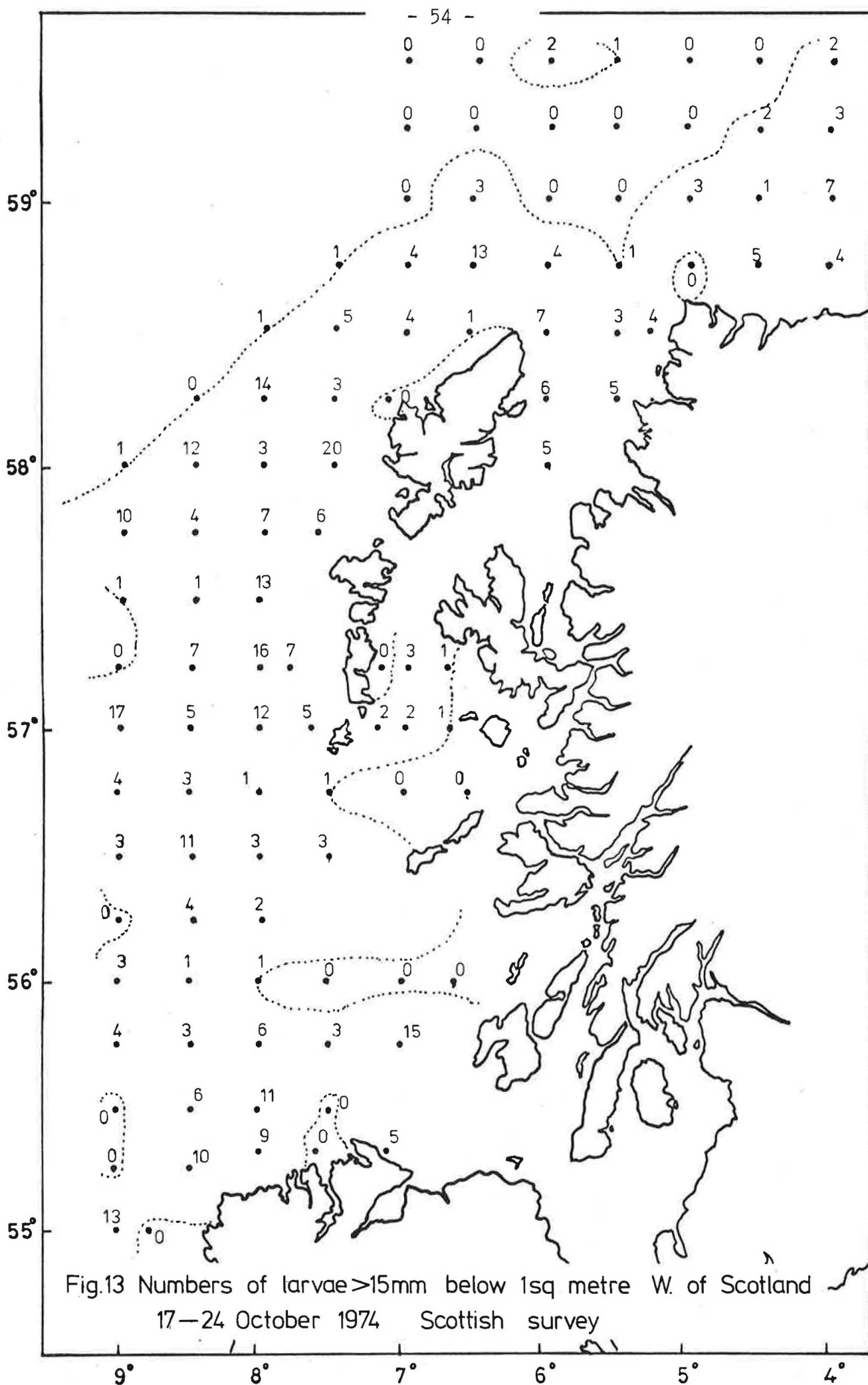


Fig.12 Numbers of larvae 10-15mm below 1sq metre W. of Scotland  
17-24 October 1974 Scottish survey



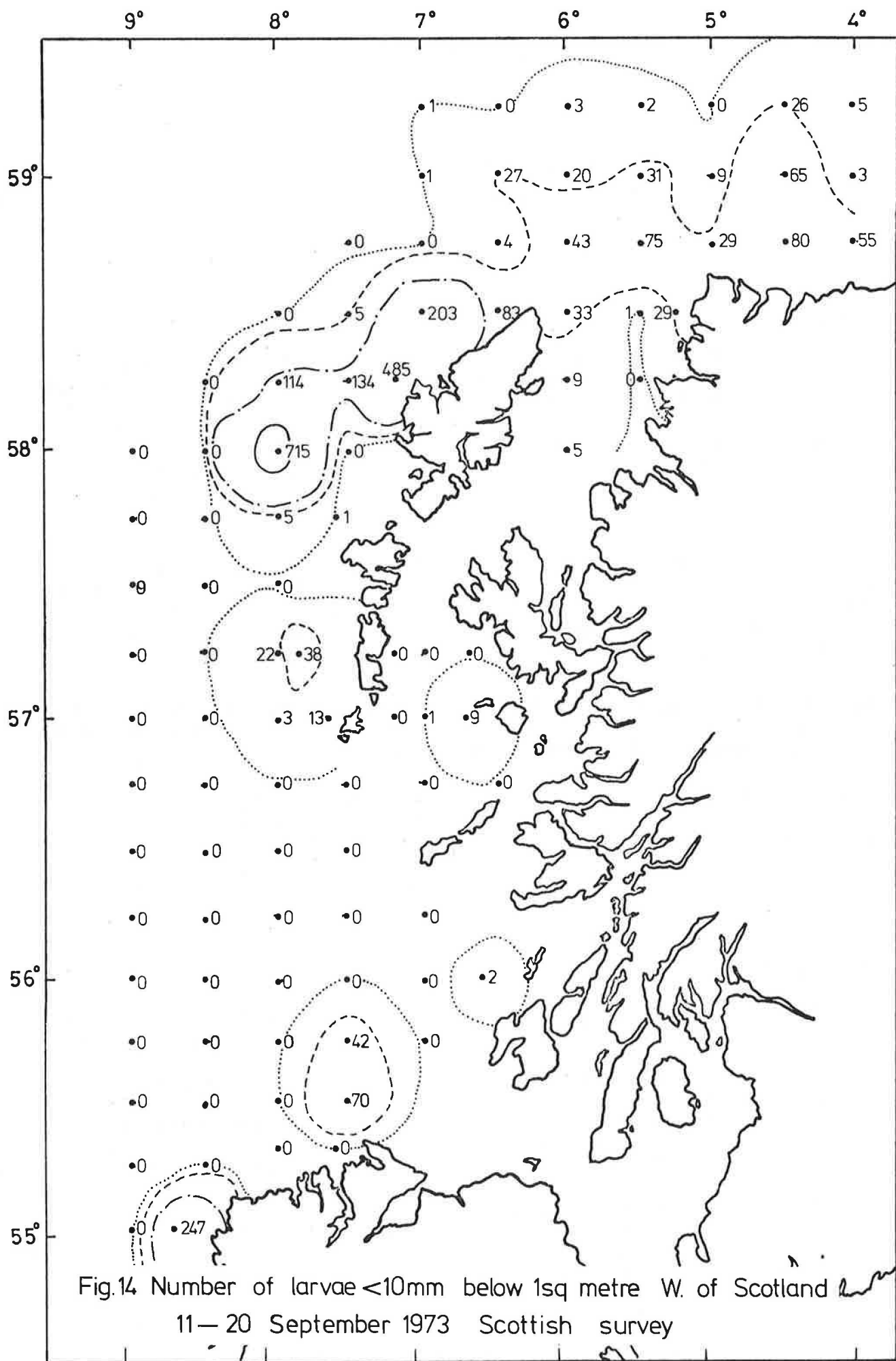


Fig.14 Number of larvae <10mm below 1sq metre W. of Scotland  
11—20 September 1973 Scottish survey

ON CATCHES OF SMALL HERRING LARVAE

by

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Introduction

Wood (1974) found considerable differences in the catches of herring larvae obtained by research vessels of England and the Netherlands when the same stations were sampled either on the same day or within one or 2 days by both countries. The English catches contained herring larvae 5 and 6 mm in length and yolk-sac stages, although none of these appeared in the Netherlands' catches. A similar discrepancy was also found between the catches of English and Scottish research vessels. No herring larvae 5 and 6 mm in length were recorded by Scotland, nor any yolk-sac stages, although these were all present in the English catches in some quantity.

In view of the importance placed by the ICES Working Group on North Sea Herring Larval Surveys on the abundance estimates of small herring larvae < 10 mm in length, and the fact that these are used to make deductions regarding changes in the size of the adult North Sea herring spawning stocks, it is of considerable importance to examine the reasons for the above discrepancies.

It was at first thought that differences in the sorting and identification techniques employed at the laboratories of the various countries might be an important factor, but it was later realized that:

- a. the speed of tow of the sampling gear was not the same for all countries, even though a speed of 5 knots had been specified for the internationally coordinated surveys;
- b. the depth to which sampling was carried out was variable.

These two factors have been investigated.

Speed of tow

During autumn 1974 a series of hauls was made at a single station in the North Minch with the standard English 50.8 cm high-speed sampler (fitted with the normal nylon net of 23.6 meshes per cm) being towed at a number of different speeds in order to ascertain whether the smallest herring larvae might be extruded through the meshes of the net at speeds higher than 5 knots. Details of the resulting catches of herring larvae are summarised in Table 1 and the percentage length distributions obtained at 3 different speeds are plotted in Figure 1. The work was conducted from RV "Scotia" and unfortunately at the time the ship's log was inoperative: the speed of tow in knots for each haul listed in Table 1 has therefore been calculated from a calibration of the sampler's external flowmeter revolutions against known speeds of tow. The calibration was obtained at a later date from RV "Cirolana".

It is clear from these data that the length distributions of the herring larvae which were caught in this experiment over a wide range of towing speeds were remarkably similar. More 5 mm larvae were caught at the lowest speeds and more 15 and 16 mm larvae at the higher speeds, but the



differences are certainly not significant, and there is no indication at all of 6 mm larvae, which were caught in some numbers, having been extruded from the net at the high towing speeds.

#### Depth of tow

An examination was made of data for those hauls with the standard English sampler, in the central and northern North Sea during the past 4 years in which substantial numbers of 5 and 6 mm herring larvae had been caught. The relevant details have been summarised in Table 2. The most interesting point that emerges is that most of the sizeable catches of small herring larvae have been obtained during tows in which the sampler reached to within 5 m of the sea-bed at the deepest point in the tow. There is no evidence from the data in Table 2 to suggest that these very small herring larvae perform any active upward migration away from the sea-bed during daylight, as has been demonstrated for larger herring larvae (Wood, 1971), since the hauls are evenly distributed between day and night. This suggests that newly hatched herring larvae in these areas of the North Sea remain close to the sea-bed, perhaps until a substantial part of the yolk-sac has been absorbed.

#### Conclusions

It seems unlikely that variations in towing speed could have led to the discrepancies in catches of small herring larvae described in the introduction to this paper. It appears more probable that these might have resulted from different countries sampling to different depths because of variations in sampling technique. This is suggested by the fact that sizeable English catches of very small herring larvae have usually only been obtained when the sampler has been towed close to the sea-bed. The English sampling technique aims, when the nature of the sea-bed allows, to obtain an oblique tow from the surface to within 5 metres of the sea-bed in accordance with the recommendations of the ICES Working Group on North Sea Herring Larval Surveys (Anon., 1971). This is achieved by using a pressure transducer on the sampler in conjunction with a shipboard depth gauge, as described by Harding et al. (1971). It has been demonstrated on many occasions that reliance on a warp/sampler depth relationship alone can lead to considerable errors in the depth of water actually sampled.

It is therefore recommended that in order to ensure that sampling is carried out to a uniform depth above the sea-bed and hence that small herring larvae are correctly sampled, countries participating in future internationally coordinated North Sea surveys should use an instrument similar to that described by Harding et al. (1971).

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Table 1. Catches of herring larvae at different towing speeds.

| Haul number           | Speed in knots | Length of larvae in mm |     |      |      |      |      |     |     |     |     |     |     | Total larvae |
|-----------------------|----------------|------------------------|-----|------|------|------|------|-----|-----|-----|-----|-----|-----|--------------|
|                       |                | 5                      | 6   | 7    | 8    | 9    | 10   | 11  | 12  | 13  | 14  | 15  | 16  |              |
| 1                     | 4.6            |                        | 1   | 20   | 5    | 9    | 4    | 4   | 7   | 2   |     |     |     | 52           |
| 2                     | 4.3            |                        | 1   | 27   | 14   | 8    | 3    | 4   | 1   | 1   |     |     |     | 59           |
| 6                     | 4.1            |                        | 2   | 21   | 18   | 4    | 3    | 6   | 4   |     | 1   |     |     | 59           |
| 10                    | 4.6            | 1                      | 7   | 62   | 32   | 22   | 6    | 6   | 2   | 2   | 1   |     |     | 141          |
| 14                    | 5.4            | 2                      | 6   | 35   | 34   | 26   | 10   | 8   | 3   | 2   | 1   |     |     | 127          |
| Mean speed            | 4.6            | 3                      | 17  | 165  | 103  | 69   | 26   | 28  | 17  | 7   | 3   |     |     | 438          |
| % Length distribution |                | 0.7                    | 3.9 | 37.7 | 23.5 | 15.8 | 5.9  | 6.4 | 3.9 | 1.6 | 0.7 |     |     |              |
| 3                     | 7.6            |                        | 2   | 36   | 43   | 7    | 5    | 12  | 4   | 1   | 2   | 1   |     | 113          |
| 5                     | 7.8            |                        | 6   | 21   | 39   | 12   | 6    | 10  | 8   | 4   | 3   | 1   |     | 110          |
| 7                     | 7.8            |                        | 1   | 32   | 39   | 13   | 8    | 11  | 3   | 4   |     |     |     | 111          |
| 9                     | 7.6            |                        | 2   | 37   | 52   | 29   | 15   | 9   | 7   | 4   | 1   | 2   | 1   | 159          |
| 11                    | 7.6            | 1                      | 8   | 129  | 88   | 29   | 18   | 16  | 5   | 3   | 1   |     |     | 298          |
| 13                    | 7.8            |                        | 18  | 102  | 78   | 36   | 30   | 16  | 3   | 1   |     |     |     | 284          |
| Mean speed            | 7.6            | 1                      | 37  | 357  | 339  | 126  | 82   | 74  | 30  | 17  | 7   | 4   | 1   | 1 075        |
| % Length distribution |                | 0.1                    | 3.4 | 33.2 | 31.5 | 11.7 | 7.6  | 6.9 | 2.8 | 1.6 | 0.7 | 0.4 | 0.1 |              |
| 4                     | 10.3           |                        | 8   | 67   | 28   | 15   | 17   | 17  | 9   | 2   | 1   |     |     | 164          |
| 8                     | 9.7            |                        | 13  | 60   | 54   | 25   | 10   | 18  | 4   | 2   | 1   | 1   | 2   | 190          |
| 12                    | 10.6           |                        | 35  | 175  | 85   | 60   | 70   | 30  | 12  | 4   | 1   |     |     | 472          |
| Mean speed            | 10.3           |                        | 56  | 302  | 167  | 100  | 97   | 65  | 25  | 8   | 3   | 1   | 2   | 826          |
| % Length distribution |                |                        | 6.8 | 36.6 | 20.2 | 12.1 | 11.7 | 7.9 | 3.0 | 1.0 | 0.4 | 0.1 | 0.2 |              |

Table 2. Summarised data for hauls containing substantial numbers of small herring larvae

| Date                      | Time<br>(GMT) | Sea-bed<br>depth<br>(m) | Sampled<br>depth<br>(m) | Minimum<br>sampler<br>height<br>above sea-<br>bed (m) | Numbers of herring larvae per length group |                |              |                |             |                |
|---------------------------|---------------|-------------------------|-------------------------|---|--|----------------|--------------|----------------|-------------|----------------|
|                           |               |                         |                         |   | <5mm                                       | <5 mm          | 5 mm         | 5 mm           | 6mm         | 6 mm           |
|                           |               |                         |                         |   | Yolk-<br>sac                               | No<br>yolk-sac | Yolk-<br>sac | No<br>yolk-sac | Yolk<br>sac | No<br>yolk-sac |
| <u>CENTRAL NORTH SEA</u>  |               |                         |                         |   |  |                |              |                |             |                |
| 5.10.71                   | 1757          | 47                      | 38                      | 9   |  |                | 223          | 25             | 167         | 29             |
| 2.10.72                   | 1357          | 55                      | 53                      | 2   |  |                | 61           | 45             | 150         | 214            |
| 18. 9.73                  | 0628          | 51                      | 45                      | 6   |  |                | 5            | 3              | 30          | 25             |
| "                         | 0723          | 40                      | 36                      | 4   |  |                | 1            | 10             | 14          | 26             |
| "                         | 0822          | 46                      | 45                      | 1   |  |                |              | 24             |             | 168            |
| "                         | 0917          | 88                      | 84                      | 4   |  |                |              | 15             |             | 56             |
| "                         | 1102          | 78                      | 76                      | 2   |  |                |              | 12             |             | 27             |
| "                         | 1515          | 50                      | 47                      | 3   |  |                | 4            | 2              | 69          | 11             |
| "                         | 2029          | 59                      | 55                      | 4   |  |                | 1            |                | 18          | 10             |
| "                         | 2136          | 52                      | 49                      | 3   |  |                | 1            | 7              | 2           | 12             |
| "                         | 0238          | 44                      | 44                      | 0   |  |                |              | 1              |             | 14             |
| "                         | 0516          | 25                      | 25                      | 0   | 1  | 10             | 1            | 19             |             | 9              |
| <u>NORTHERN NORTH SEA</u> |               |                         |                         |   |  |                |              |                |             |                |
| 7. 9.71                   | 0129          | 75                      | 71                      | 4   |  |                | 11           | 27             | 28          | 268            |
| "                         | 2114          | 75                      | 74                      | 1   |  |                | 4            |                | 5           | 11             |
| 8. 9.71                   | 0152          | 77                      | 72                      | 5   |  |                | 4            |                | 14          | 18             |
| "                         | 1027          | 89                      | 89                      | 0   |  |                | 62           | 21             | 137         | 58             |
| 8. 9.72                   | 1547          | 66                      | 62                      | 4   |  |                | 8            |                | 147         | 37             |
| 11. 9.73                  | 0852          | 76                      | 76                      | 0   |  |                | 5            | 2              | 27          | 29             |
| "                         | 1915          | 61                      | 56                      | 5   | 3  |                | 75           | 50             | 81          | 87             |
| "                         | 2103          | 70                      | 56                      | 14  | 2  | 3              | 5            | 68             | 10          | 59             |
| 12. 9.73                  | 0710          | 92                      | 90                      | 2   |  | 1              |              | 2              |             | 18             |
| 15. 9.73                  | 2256          | 94                      | 73                      | 21  |  |                | 6            | 25             | 162         | 130            |
| 16. 9.73                  | 0018          | 60                      | 56                      | 4   |  |                |              | 75             |             | 63             |
| "                         | 0146          | 95                      | 90                      | 5   |  |                |              | 3              | 2           | 30             |
| "                         | 0246          | 99                      | 94                      | 5   |  |                |              | 48             | 7           | 78             |
| "                         | 1854          | 54                      | 46                      | 8   |  |                |              | 1              | 7           | 9              |

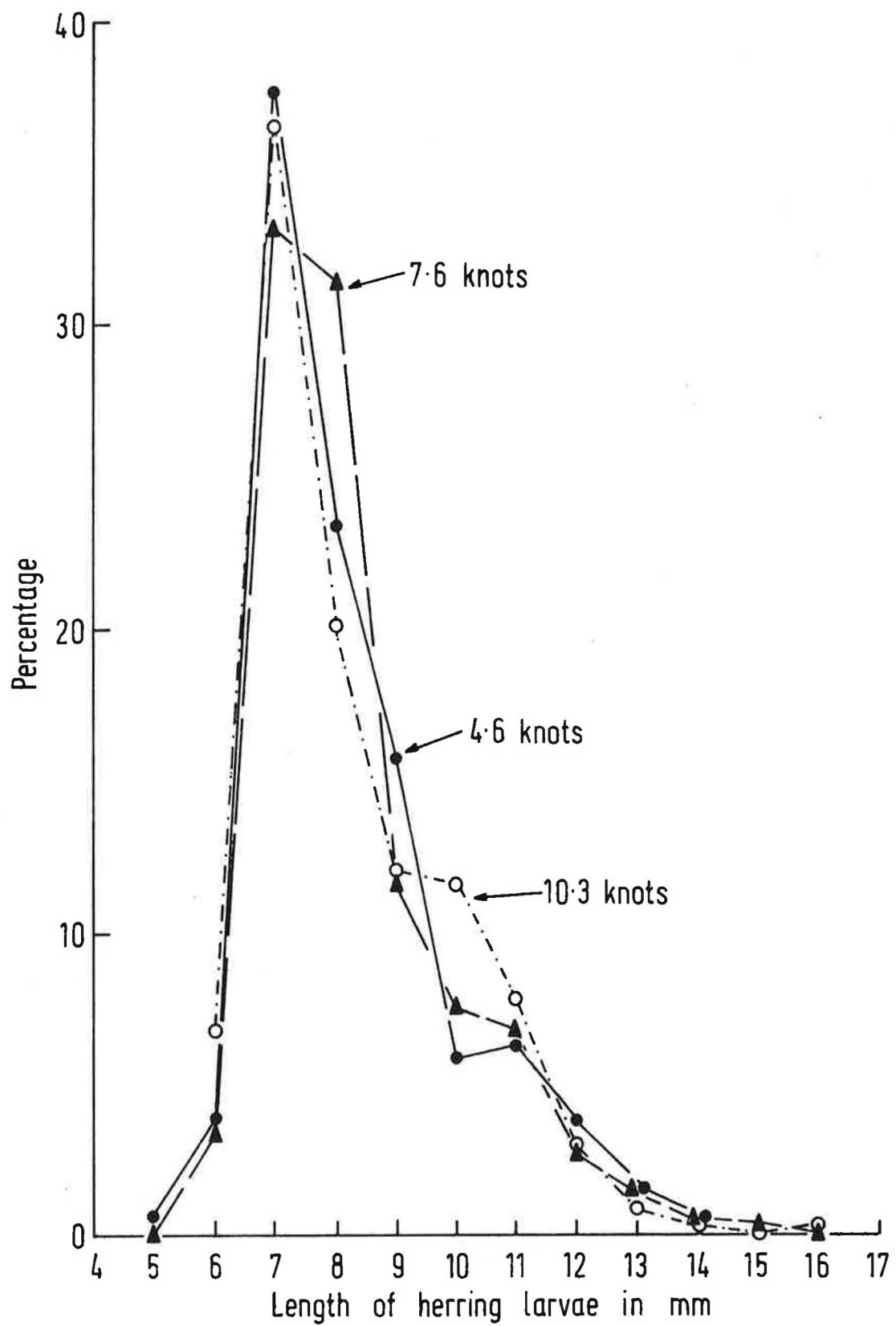


Figure 1. Percentage length distribution of herring larvae caught at three different speeds.



