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SURVEYS OF HERRING LARVAE IN THE NORTH SEA
AND ADJACENT WATERS 1973/74

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I. REPORT ON THE INTERNATIONAL SURVEYS OF HERRING LARVAE
IN THE NORTH SEA AND ADJACENT WATERS 1973/74

by

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INTRODUCTION

This report describes the results of the seventh international survey of herring larvae in the North Sea and adjacent waters. These surveys have been carried out annually since 1967 and they are intended to provide measures of changes in the North Sea herring spawning stocks which are independent of catch per unit effort data.

Results of the previous surveys are published in Saville (1970), Boëtius and McKay (1970), Wood (1971), Zijlstra (1972), Schnack (1973) and Saville and McKay (1974).

MATERIAL AND METHODS

During the autumn and winter of 1973/74 five countries participated in the surveys, with the following research vessels: England, RV "Corella"; Federal Republic of Germany, RV "Anton Dohrn II"; Netherlands, RV "Willem Beukelsz" and RV "Tridens"; Scotland, RV "Clupea" and RV "Scotia"; and Sweden, RV "Thetis".

This represented a substantial reduction in effort compared with the previous year, when nine research vessels of seven countries took part. As a consequence, the coverage was not so good, particularly in the northern North Sea during the autumn. In addition, in the southern North Sea and eastern English Channel the winter surveys were seriously curtailed by exceptionally bad weather, which in fact caused the January 1974 survey of RV "Willem Beukelsz" to be abandoned.

The timing of each survey which was carried out in each area is given in Table 1. Sampling on all the ships was carried out using a modified Gulf III sampler towed in a double oblique haul, sampling the whole water column down to 5 m or less from the sea bed. A more detailed description of the gear and sampling technique is given by Saville (1970). From August 1973 until February 1974 a total of 1 182 stations were sampled. The results, recorded as numbers of herring larvae beneath one square metre (m²) of sea surface at each station, are shown in Figures 1-30 for each size group of larvae and survey period, and for each of the sub-areas as defined by the Working Group on North Sea Herring Larval Surveys (Anon., 1971).

The size groups are, as in earlier reports, <11, 11-16 and >16 mm for larvae caught in the Southern Bight and eastern Channel but <10, 10-15 and >15 mm for larvae caught in all other areas. Yolk-sac larvae have again been omitted in calculating the abundance estimates (Anon., 1971). Charts have not been included for size groups on individual surveys during which few or none of that size group of larvae were caught.

Abundance estimates were calculated in a similar manner to that of Schnack (1973), viz. each station value was multiplied by a 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 more than once during a survey, the greatest number of larvae caught were always used in the calculations. This method of calculating abundance estimates gives results which are very similar to those based on density-contoured and planimeted charts, and it has a number of distinct advantages, the chief one being that it can be easily written into a computer program, of which increasing use is being made for working up all plankton surveys. Even without a computer the saving in time achieved by using this method is very considerable.

RESULTS - DISTRIBUTIONS

Shetland-Orkney

Sampling in this area was carried out during three periods in the autumn of 1973. The first survey (28 August - 3 September) was of limited extent and covered only the areas immediately to the north and east of Orkney and the Moray Firth (Figures 1 and 2). Recently-hatched larvae <10 mm in length were found to the north and east of Orkney, with densities of up to 1 442/m². Larvae 10-15 mm long were distributed in the same localities, with a maximum density of 30/m². No larvae were caught in the >15 mm category.

During the second survey period (7 - 14 September) almost the whole of the specified ICES grid of stations covering the areas to the east and west of both Orkney and Shetland was effectively sampled by English and Scottish research vessels (Figures 3-7), although a few stations of importance to the southeast of Orkney and in the Moray Firth were omitted. Small larvae <10 mm in length were taken at the majority of stations but there were two distinct concentrations, one to the north of Orkney, with a maximum density of 655/m², and the other southwest of Orkney, where the maximum was 720/m². Larvae 10-15 mm in length were widely distributed over most of the surveyed area, the highest concentration being 284/m² to the north of Orkney. Small numbers of larvae >15 mm in length were recorded at only a few stations and densities did not exceed 5/m².

On the third survey (18 - 25 September) the coverage was again unfortunately of only limited extent, although a total of 76 stations were sampled around Orkney and in the Moray Firth (Figures 8-10). Small larvae <10 mm were obtained at most of the stations which were sampled and two centres of distribution were distinguishable. One centre to the southwest of Orkney had a maximum density of 852/m², and the other off Clythness had a maximum of 336/m². Larvae 10-15 mm in length were taken at almost every station but with a highest concentration of 174/m² to the southwest of Orkney. Small numbers of larvae in the >15 mm size category were also found at most stations, the maximum density being 20/m² off the northwest coast of Orkney.

Cape Wrath-Butt of Lewis

In 1972 and 1973, after completion of the standard ICES Orkney-Shetland survey to the east of longitude 4° west during early September, RV "Corella" carried out additional surveys over the more westerly spawning areas off Cape Wrath and the Butt of Lewis. The results of the survey made in 1972 are included in the present report because they were omitted from the report for that year (Saville and McKay, 1974).

In 1972 (5 - 8 September) substantial numbers of recently-hatched larvae <10 mm in length were taken at a number of stations, with a very high maximum density of 5 523/m² to the northeast of Cape Wrath (Figure 11). Larvae in the 10-15 mm category were widely distributed in small numbers

over most of the area which was surveyed, but northeast of Cape Wrath a density of $237/\text{m}^2$ was recorded (Figure 12). Only a single larva >15 mm in length was caught during this survey.

The sampling in 1973 (12 - 16 September) revealed a distribution rather different from that of the previous year. There was a more extensive patch of small <10 mm larvae to the northeast of Cape Wrath but with a very much lower maximum concentration of $812/\text{m}^2$ (Figure 3). On the other hand, densities were very much higher than in the previous year at a number of stations further westwards, with a maximum of $832/\text{m}^2$ near to the Flannan Isles. Larvae 10-15 mm long were distributed over the major portion of the area surveyed, but in lower concentrations, the maximum density being $209/\text{m}^2$ to the southeast of Stornoway in the North Minch. Only two larvae >15 mm in length were caught.

Buchan

The Buchan area was surveyed four times during the period 27 August - 6 October. The first survey (27 August - 6 September) was extensive and the whole area was effectively sampled. However, herring larvae were caught only at two stations, both off Peterhead with densities of 1 and $2/\text{m}^2$ and both containing only recently-hatched larvae <10 mm in length (Figure 1).

During the second survey (10 - 11 September) 16 stations were sampled off Peterhead and small numbers of larvae were obtained at five of these, with a maximum density of $5/\text{m}^2$ for larvae <10 mm in length (Figures 5-6). No larvae >15 mm in length were caught.

The third survey (26 - 27 September) was again restricted in extent to the area off Peterhead and Aberdeen (Figures 8-10). Recently-hatched larvae <10 mm were taken at only four stations, the maximum density being $5/\text{m}^2$. Small numbers of the larger sizes of larvae were also taken at a few stations but most appeared to have been carried into the area defined as Buchan (i.e. south of latitude 58° north) from further to the north.

The final survey (3 - 6 October) covered only the area to the south of latitude $57^\circ 15'$ north (Figures 23-25). The numbers of larvae which were obtained were again very low and confined to a few stations, the maximum density being $4/\text{m}^2$ in the 10-15 mm size category at a station off the Firth of Forth.

Central North Sea

The central North Sea spawning grounds situated in the Longstone-Whitby-Dogger and Dowsing areas were surveyed four times during September-October 1973. The first survey (4-12 September) revealed two patches of recently-hatched larvae <10 mm in length (Figure 13). The more northerly patch off the Longstone had station densities up to $493/\text{m}^2$ but in the other patch off Whitby the densities were much lower, with a maximum of only $35/\text{m}^2$. Small numbers of larvae in the 10-15 mm category were also taken in both areas (Figure 14). No larvae >15 mm in length were obtained from this survey.

The areas were again surveyed during the period 18 - 26 September (Figures 15-19). Although the main survey was carried out by RV "Willem Beukelsz", 21 of the stations were also sampled by RV "Corella", whilst on passage southwards. Three separate patches of recently-hatched <10 mm larvae were located. A northerly patch lying to the south of the Longstone had station densities up to $1805/\text{m}^2$, a central patch off Whitby had densities up to $201/\text{m}^2$ and a southerly patch extending over the Westernmost Rough to the Outer Dowsing had densities up to $194/\text{m}^2$. Larvae

in the 10-15 mm size group were much more abundant than during the first survey and their distribution extended from north of the Longstone to the south of Flamborough Head, with a maximum density of 268/m² to the south of the Longstone. Of especial interest was a small patch of larvae in low concentrations in the Well Bank-Sole Pit area. A few larvae >15 mm in length were obtained off Flamborough Head, with a maximum station density of 17/m².

The results of the third survey (27 September - 6 October) were fairly similar to those obtained during the previous period insofar as distribution was concerned (Figures 23-25). Patches of small <10 mm larvae were located south of the Longstone with densities up to 247/m², off Whitby with densities up to 517/m² and in the region of the Outer Dowsing where the maximum was 27/m². (A small number of stations were resampled in the Dowsing area on 8 October, when a maximum density of 54/m² was obtained). Larvae 10-15 mm in length were again distributed over the whole of the area surveyed, extending from north of the Longstone to the Outer Dowsing with station densities up to 115/m². Only small numbers of larvae >15 mm in length were caught and these again were mainly off Flamborough Head.

On the final survey in the central North Sea (16-24 October) small patches of recently-hatched larvae <10 mm were again taken in a number of localities (Figure 20). Three stations near the Longstone had densities of larvae up to 10/m², and two at the Northeast Bank had a maximum of 15/m². A more extensive patch off Flamborough Head had a maximum concentration of 312/m², and in addition one station to the northeast of Spurn Point had a density of larvae of 4/m² and another near Well Hole 1/m². Herring larvae in the 10-15 mm length category (Figure 21) were distributed over an extensive area adjacent to the English coast, with densities up to 108/m², and larvae >15 mm were also found over much the same area, with densities up to 82/m² (Figure 22).

Southern Bight-English Channel

These areas were surveyed during two periods, firstly in December 1973 and again during January/February 1974, with good coverage, in both periods of all the important spawning localities. On the first survey (10-20 December) recently-hatched larvae <11 mm in length were only obtained at stations sampled in the eastern Channel (Figure 26) and densities were low, with a maximum of 19/m² off Point d'Ailly. Larvae in the 11-16 mm size category (Figure 27) were more abundant, with a maximum concentration of 99/m², also off Point d'Ailly; in addition, they were somewhat more widely distributed, with small numbers occurring at stations both in the Bay of the Seine and at Sandettié.

During the second period (23 January - 4 February) very similar surveys were carried out at almost the same time by both German and English research vessels. Only a few larvae <11 mm in length were caught (Figures 28 and 31). They were found at six stations in the Southern Bight, with a maximum density of 3/m², and at eight stations in the eastern Channel, where the maximum density was also 3/m². Larvae in the 11-16 mm category (Figures 29 and 32) were a little more abundant and there was a patch in the Southern Bight where densities up to 9/m² were obtained. Larvae of this size group were also taken at four stations in the eastern Channel, with a maximum density of 4/m². Larvae >16 mm were found at a few stations in the Southern Bight and at two in the eastern Channel, with a maximum concentration of 6/m² (Figures 30 and 33).

Kobbergrund

One survey of this area was carried out in October 1973 and a total of only five herring larvae were taken. At no station did the density exceed $1/m^2$.

QUANTITATIVE ESTIMATES

As mentioned earlier, the chief object of these conjoint international surveys is to provide measures of changes in the herring spawning stock sizes, by monitoring the changes which occur in larval production from year to year. Given in Table 2 are estimates of larval abundance in 1973/74 for the three size groups of herring larvae in each area and survey period.

The results again demonstrate, as have all the previous ones since the surveys began in 1967, that the stock of herring spawning in the Orkney-Shetland area is much larger than any of the other North Sea stocks at the present time. Because of the reduced coverage in 1973 it is not possible to make a very precise comparison of larval abundance for the Orkney-Shetland area with that of the previous year.

Production in 1973 would appear, however, to have been substantially lower if the total abundance estimate of $2\,558 \times 10^9$ larvae for the period 7-14 September (when the major part of the area of distribution was effectively covered) is compared with the total of $7\,697 \times 10^9$ larvae estimated for the period 12-21 September 1972. A reduction in abundance in 1973, although to a much lesser extent, is also to be seen if the estimates for both the earlier and later survey periods are compared with those of the previous year. It must therefore be concluded that the spawning stock of herring in the Orkney-Shetland area in 1973 was smaller than in 1972, but the magnitude of the reduction in stock size is not very clear from the larval data available.

Further to the west the abundance of herring larvae off Cape Wrath in September 1973 also appeared to be lower than in the previous year, although the distribution was more extensive. However, the survey in 1973 was timed a week later, which makes an exact comparison between the two years impossible, and the difference in timing could also account for the much higher larval densities near to the Flannan Isles in 1973. The total abundance estimate for larvae in the Cape Wrath-Butt of Lewis-Flannan Isles area in September 1973 was $3\,293 \times 10^9$ and in 1972 $2\,728 \times 10^9$. Both are very substantial figures and serve to illustrate once again the importance of the herring larval production which occurs immediately to the west of longitude 4° west during early September. The importance of the larval production in this area and its relevance in the interpretation of the results of the international surveys have been discussed in the past by Wood (1971 and 1973), Zijlstra (1972) and Schnack (1973). Recoveries of both surface and sea bed drifters released during these larval surveys off Cape Wrath have moreover demonstrated that, at least in some years, the mechanism exists for a rapid easterly movement of larvae to take place (Ramster *et al.*, 1973). That substantial numbers of herring larvae are transported into the North Sea from the spawning grounds to the west of longitude 4° west has also been indicated by the subsequent movements of herring tagged in the ICES Bløden Tagging Experiment, which was carried out from July 1969 to March 1970 (Anon., 1973). However, possibly because of the incomplete coverage of the area west of Orkney and Shetland during the final survey, there was no direct evidence of any large-scale transport of herring larvae eastwards from Cape Wrath during the 1973 conjoint surveys. One third of the sea bed drifters released off Cape Wrath during the larval survey in September

1973 were however subsequently recovered in the North Sea from the Moray Firth.

For the Buchan area in 1973 the results given in Table 2 show that the production of herring larvae was at a very low level. The situation was in fact much the same as it was in 1970, and it must therefore be concluded that the Buchan spawning stock has once again declined to a very small size.

There was a dramatic increase in larval production in the central North Sea in the autumn of 1973, particularly in both the Longstone and Whitby areas. Recently-hatched larvae <10 mm in length were widely distributed in the area adjacent to the English coast, and this suggested rather widespread spawning; the occurrence of yolk-sac larvae was confined, however, to three stations in the vicinity of the Farne Islands, four stations off Whitby and Scarborough and one station at the Outer Dowsing. In spite of this, some spawning also appeared to have taken place, although on a very small scale, both on the Northeast Bank and in the Well Bank-Sole Pit area. Overall, the abundances of larvae estimated for the central North Sea in 1973 were the highest to have been recorded since these surveys were inaugurated in 1967. It follows that the spawning stock of herring must have been substantially larger than during the most recent years, when it has been much reduced in size. From age distributions of spawning herring in the Longstone and Whitby areas (Wood and Boon, 1975) it must be concluded that recruitment of the 1970/71 year class, particularly to these components of the Bank stock, was exceptionally good in 1973.

In the Southern Bight and eastern English Channel, spawning during the winter of 1973/74 seems to have been confined mostly to the grounds off Point d'Ailly. Although only surveyed during two periods the abundance estimates from these suggest that production was at a somewhat lower level than in the previous winter. Moreover, these estimates indicate, when they are compared with the moderately good ones of 1970/71, that the size of the Downs stock in 1973/74 was very small.

No larval abundance estimates were possible for the Kattegat (Kobbergrund). The one survey which was carried out in October 1973 produced a total of only five herring larvae. The abundances of larvae in recent years have indicated a steady decline since 1969 in the size of the autumn-spawning stock, which seems now to have almost reached the point of extinction.

DISCUSSION

In the previous report (Saville and McKay, 1974) the authors discussed the possibility of the herring larval production cycle being defined by a normal curve. They concluded, from an examination of the abundance estimates for herring larvae in the smallest (<10 mm) size category by area, that the production cycle could not in fact be defined in this way, other than perhaps in the Orkney-Shetland area. However, the possibility was not excluded that the production cycle might be definable in this way within each discrete spawning area, such as those which occur within the central North Sea.

The production of herring larvae within the central North Sea has therefore been examined separately for the three main spawning grounds of recent years, i.e. the Longstone, Whitby and Dowsing areas. This has been done for each year during which sufficient surveys were carried out for the production cycles to be defined with reasonable accuracy. For the Longstone and Whitby areas this was possible for the three most recent years (1971, 1972 and 1973), but for the Dowsing area only for the last two years (1972 and 1973). The results are shown in Figure 34.

A number of conclusions may be drawn, the chief one being that larval production in the central North Sea can probably be defined by a normal curve when each discrete spawning area is considered separately on its own. The slight bimodality of the production curve for the Dowsing area in 1973 is due either to the fact that at least two discrete spawning grounds lie within the area termed here as Dowsing, or to differences in the abundance estimates caused by differences in the actual catches of larvae obtained in this area by research vessels of England and the Netherlands. (This point will be discussed later in more detail).

It is also clear from Figure 34 that peak hatching occurs in the Longstone area about three weeks earlier than is the case further south off Whitby. The maximum yearly variation in peak hatching time indicated for each area is no more than 7-8 days, the latest time occurring in 1973, the year of highest production. In the Dowsing area the situation is more complex. In some years, such as in 1972, two quite separate hatchings of herring larvae appear to take place and the production cycle may then be defined by two quite separate normal curves (the spawning pattern may also have been similar to this in 1968, when a late hatching of some magnitude occurred in mid-October). However, in some other years, as in 1973, the evidence points to only one main hatching in this area. Defining the production cycle accurately for the Dowsing area may also sometimes be made rather difficult by the rapid transport which can occur into this area, of larvae hatched on the spawning grounds a little further to the north.

As mentioned above, differences were found between 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 two days, by both countries. The comparable data are given in Table 3a. It can be seen that although larvae 5 and 6 mm in length were obtained in the English catches none were recorded by the Netherlands, who in addition recorded fewer larvae 7-11 mm long. A number of yolk-sac stages were also identified in the English catches amongst the larvae between 5 and 8 mm in length, but none were recorded by the Netherlands. On the other hand, somewhat lower numbers of the larger larvae (>12 mm) were obtained in the English catches.

In view of these discrepancies the catches at a number of stations in the northwestern North Sea, which were sampled at much the same time by both English and Scottish research vessels, were also examined. The results were very similar to those from the central North Sea. No larvae 5 and 6 mm in length were recorded by Scotland, nor any yolk-sac stages, although these were present in the English catches in some quantity; 7 and 8 mm larvae were also more abundant in the English catches, but larvae from 9 to 14 mm in length were recorded in substantially higher numbers by Scotland.

The results from these two comparisons suggest that the English modified version of the Gulf III sampler catches lower numbers of the larger sizes of herring larvae than either of the versions used by the Netherlands and Scotland. On the other hand, and of much greater significance considering the importance attached to the abundance estimates for larvae <10 mm, is the fact that either the English sampler is much more efficient at catching the smaller sizes of herring larvae, or the English sorting technique is better suited to the picking out and identification of the smaller herring larvae contained in the plankton samples.

At the Lowestoft Laboratory all larvae are stained, before sorting, with Aqueous Carmine Borax (5 ml per sample of approximately 300 ml). Sorting is carried out with transmitted light in conjunction with an illuminated low-power magnifier. Subsequent identification is made with a Zeiss Zoom Stereomicroscope, using polarized light. The use of polarized light

greatly facilitates the counting of myotomes and enables positive identification to be made of the very small larvae and also damaged specimens, which cannot in general be identified without this aid.

It is of considerable importance that the reasons for the observed differences discussed above should be determined as rapidly as possible and it is suggested that the staining of larvae before sorting and the use of polarized light to aid identification should be adopted as standard procedure by countries participating in these surveys.

In concluding this report the continuing need for additional countries to take part in these conjoint surveys must once again be stressed. Although the coverage of the herring spawning areas both in the central and southern North Sea and in the eastern English Channel during recent years has been adequate, this report again underlines the need for increased effort in the very important Orkney-Shetland area during September and October. In addition there is clearly a need for regular surveys also to be conducted to the west of longitude 4° west.

However, none of the above criticisms should be allowed to detract from an appreciation of the value of the surveys which have been carried out to date. The coverage is now much better than in the first years, and at a time when so many factors such as closures and restrictions on fishing affect the commercial catches of herring, the independent evidence as to the state of the spawning stocks which is derived from these larval surveys is quite invaluable.

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Table 1. Surveys carried out in 1973/74.

Country	Area	Period	Number of Stations Sampled
England	Cape Wrath (Butt of Lewis)	12-16 Sep 1973	69
Scotland	Shetland-Orkney	28 Aug- 3 Sep 1973	52
England	" "	7-12 Sep 1973	68
Scotland	" "	11-14 Sep 1973	70
Scotland	" "	18-25 Sep 1973	76
Scotland	Buchan	27 Aug- 6 Sep 1973	77
Scotland	"	10-11 Sep 1973	16
Scotland	"	26-27 Sep 1973	27
England	"	3- 6 Oct 1973	32
Netherlands	Central North Sea	4-12 Sep 1973	78
England	" " "	19-19 Sep 1973	21
Netherlands	" " "	18-26 Sep 1973	73
England	" " "	27 Sep- 8 Oct 1973	94
Netherlands	" " "	16-24 Oct 1973	118
Netherlands	Southern Bight-English Channel	10-20 Dec 1973	119
Germany (F.R.)	" " " "	23-28 Jan 1974	88
England	" " " "	24 Jan- 4 Feb 1974	86
Sweden	Kattegat	22-31 Oct 1973	18

Table 2. Estimates of herring larval abundance.

Area	Period	Abundance of Herring Larvae x 10 ⁻⁹			
		<10 mm	10-15 mm	>15 mm	Total
<u>Cape Wrath (Butt of Lewis)</u> (West of 4°W)	5- 8 Sep 1972	2 099	628	1	2 728
	12-16 Sep 1973	2 664	628	1	3 293
<u>Shetland-Orkney</u> (North of 58°N)	28 Aug- 3 Sep 1973	1 055	52	-	1 107
	7-14 Sep 1973	1 977	577	4	2 558
	18-25 Sep 1973	755	737	68	1 560
<u>Buchan</u> (Between 56-58°N)	27 Aug- 6 Sep 1973	1	-	-	1
	10-11 Sep 1973	4	-	-	4
	26-27 Sep 1973	4	5	7	16
	3- 6 Oct 1973	1	7	4	12
<u>Central North Sea</u> (Between 53-56°N)	4-12 Sep 1973	516	41	-	557
	18-26 Sep 1973	1 008	486	19	1 513
	27 Sep- 6 Oct 1973	1 220	438	14	1 672
	16-24 Oct 1973	158	200	194	552
		<11 mm	11-16 mm	>16 mm	Total
<u>Southern Bight-English Channel</u> (South of 53°N)	10-20 Dec 1973	15	58	-	73
	23-28 Jan 1974	5	13	9	27
	24 Jan- 4 Feb 1974	3	17	4	24

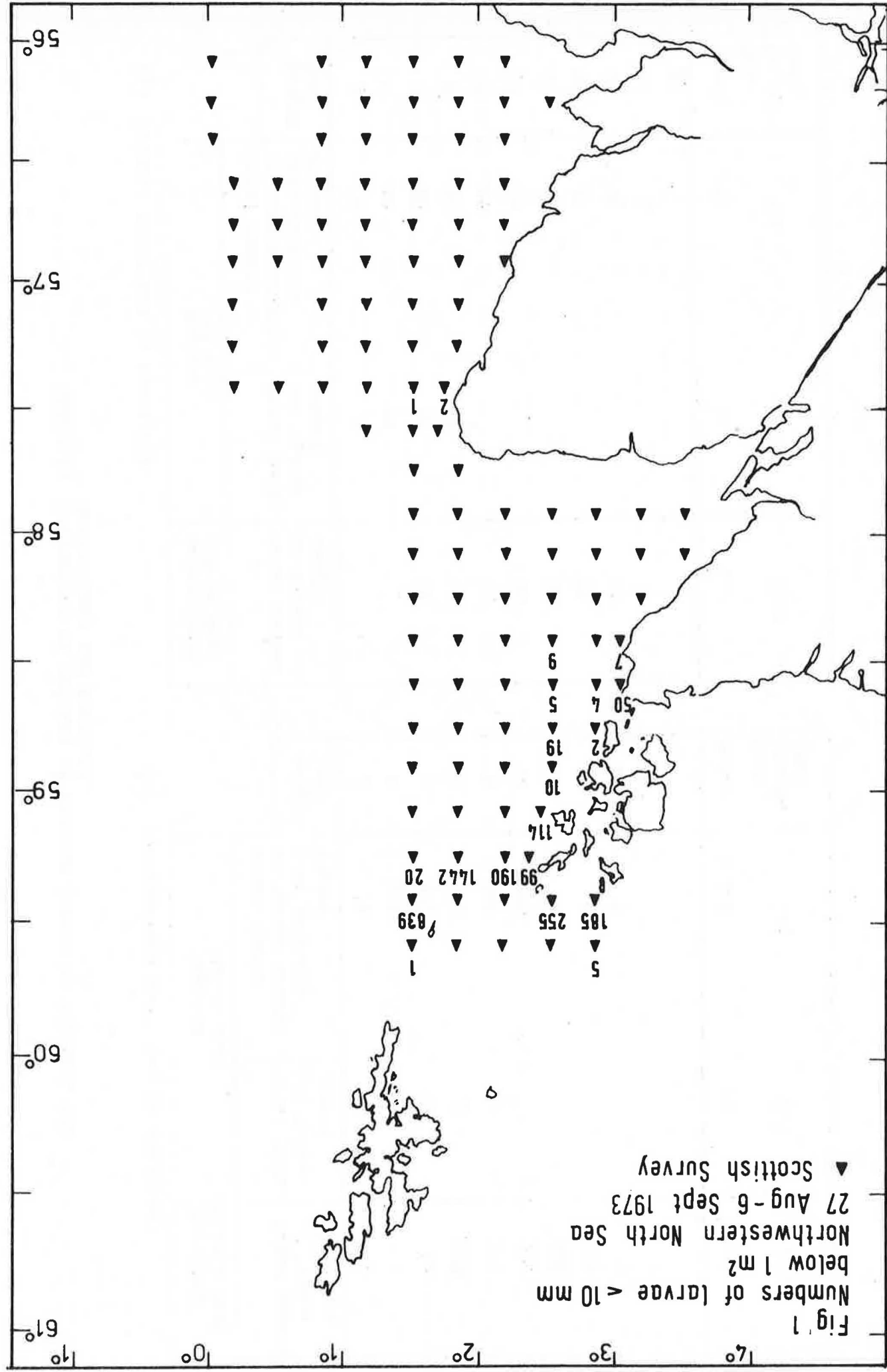
Table 3. Comparison of catches of herring larvae by England, the Netherlands and Scotland.

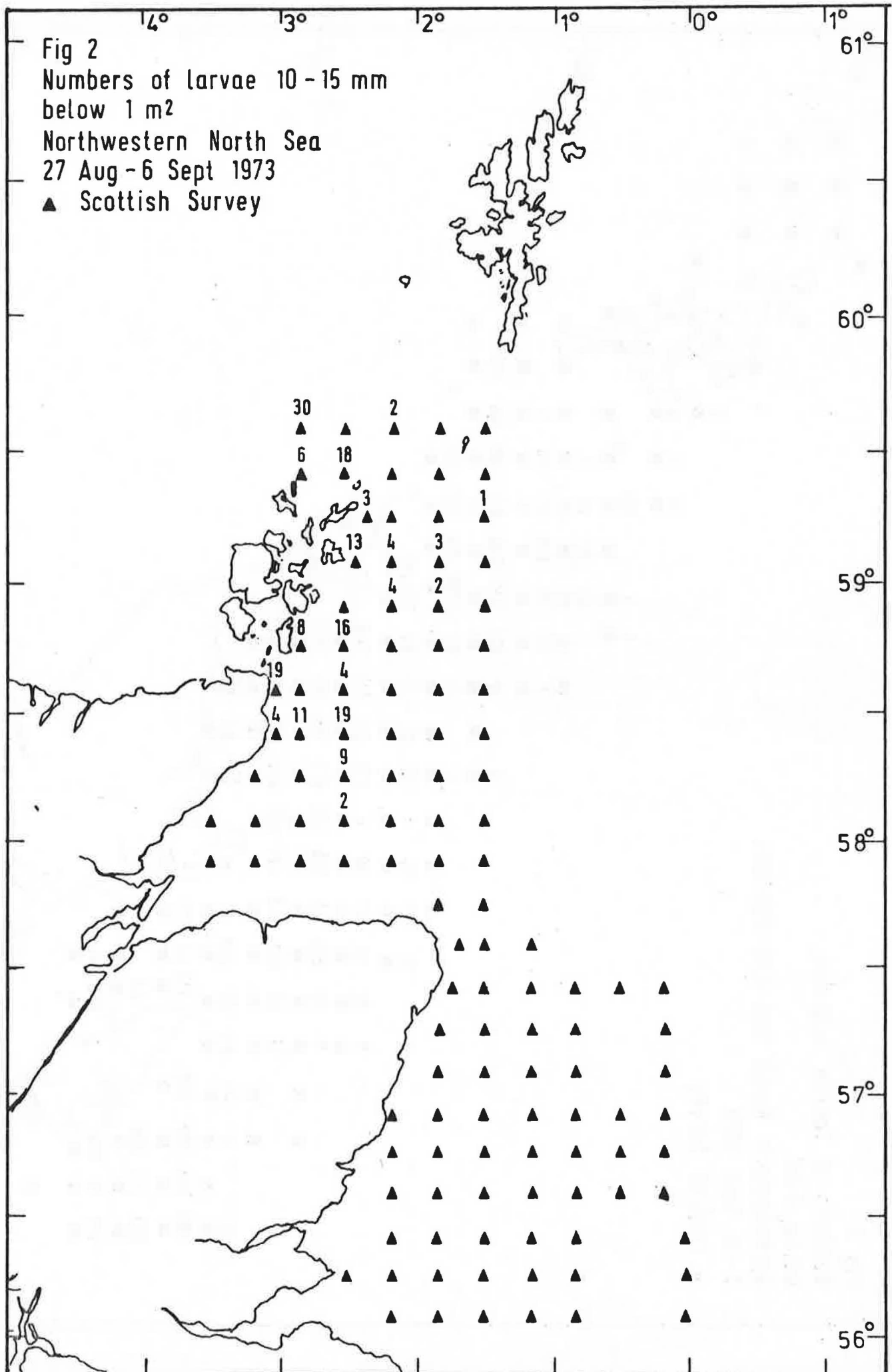
(a) Central North Sea (5 stations)

Length (mm)	England (18 Sep)		Netherlands (18-20 Sep)
	Total number of larvae caught - less yolk-sac stages	Total yolk- sac larvae caught	Total number of larvae caught
5	3	5	
6	27	30	
7	42	32	15
8	50	4	5
9	27		13
10	25		16
11	17		14
12	21		21
13	15		17
14	4		7
15			7
Total	231	71	115
Mean Length (mm)	9.4	7.0	11.4

(b) Northwestern North Sea (8 stations)

Length (mm)	England (10-11 Sep)		Scotland (11-12 Sep)
	Total number of larvae caught - less yolk-sac stages	Total yolk- sac larvae caught	Total number of larvae caught
5	4	5	
6	112	28	
7	541	10	31
8	804	2	229
9	346	1	381
10	55		339
11	28		194
12	9		25
13	3		7
14			2
Total	1 902	46	1 208
Mean length (mm)	7.9	6.8	10.0

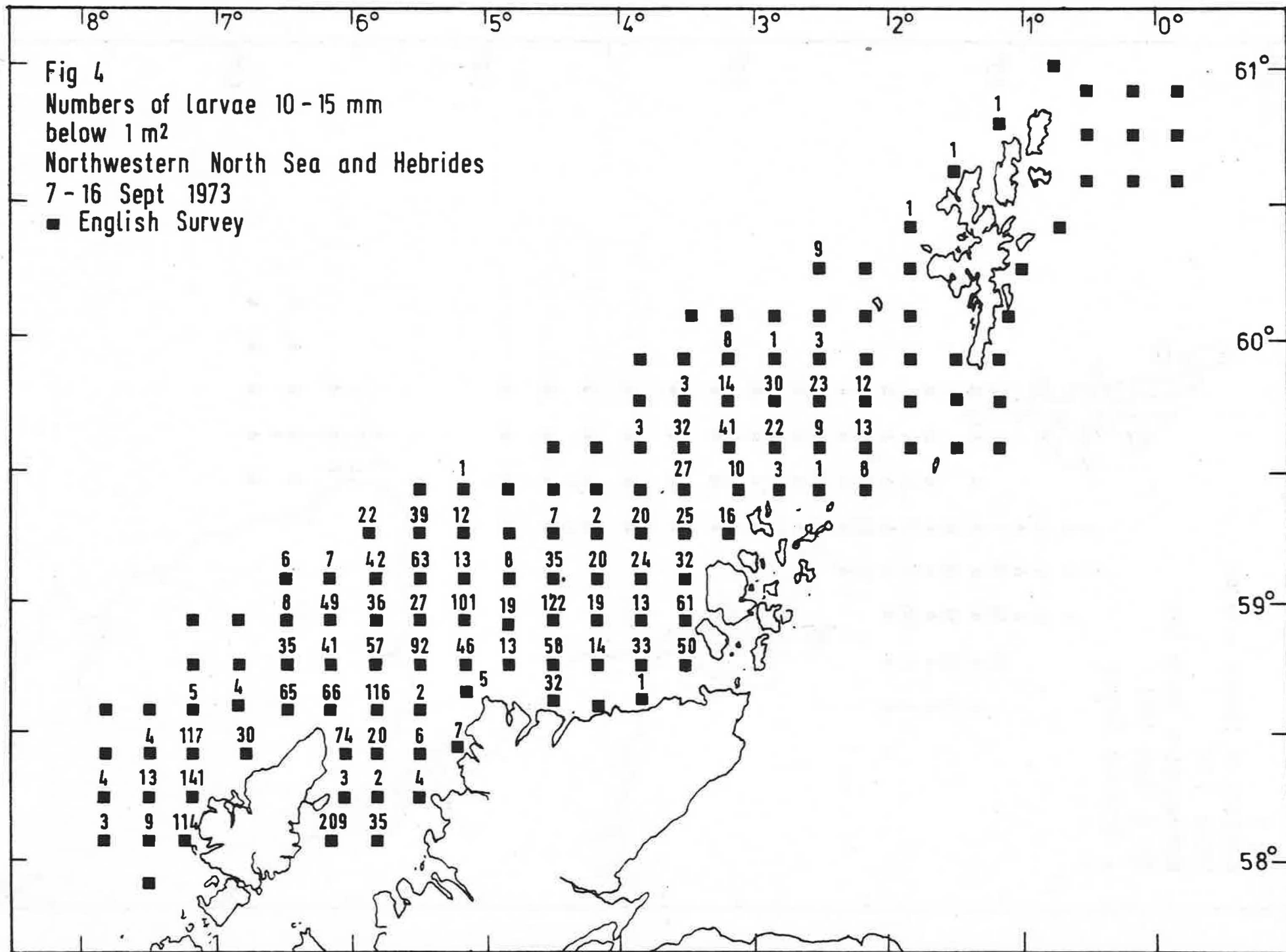


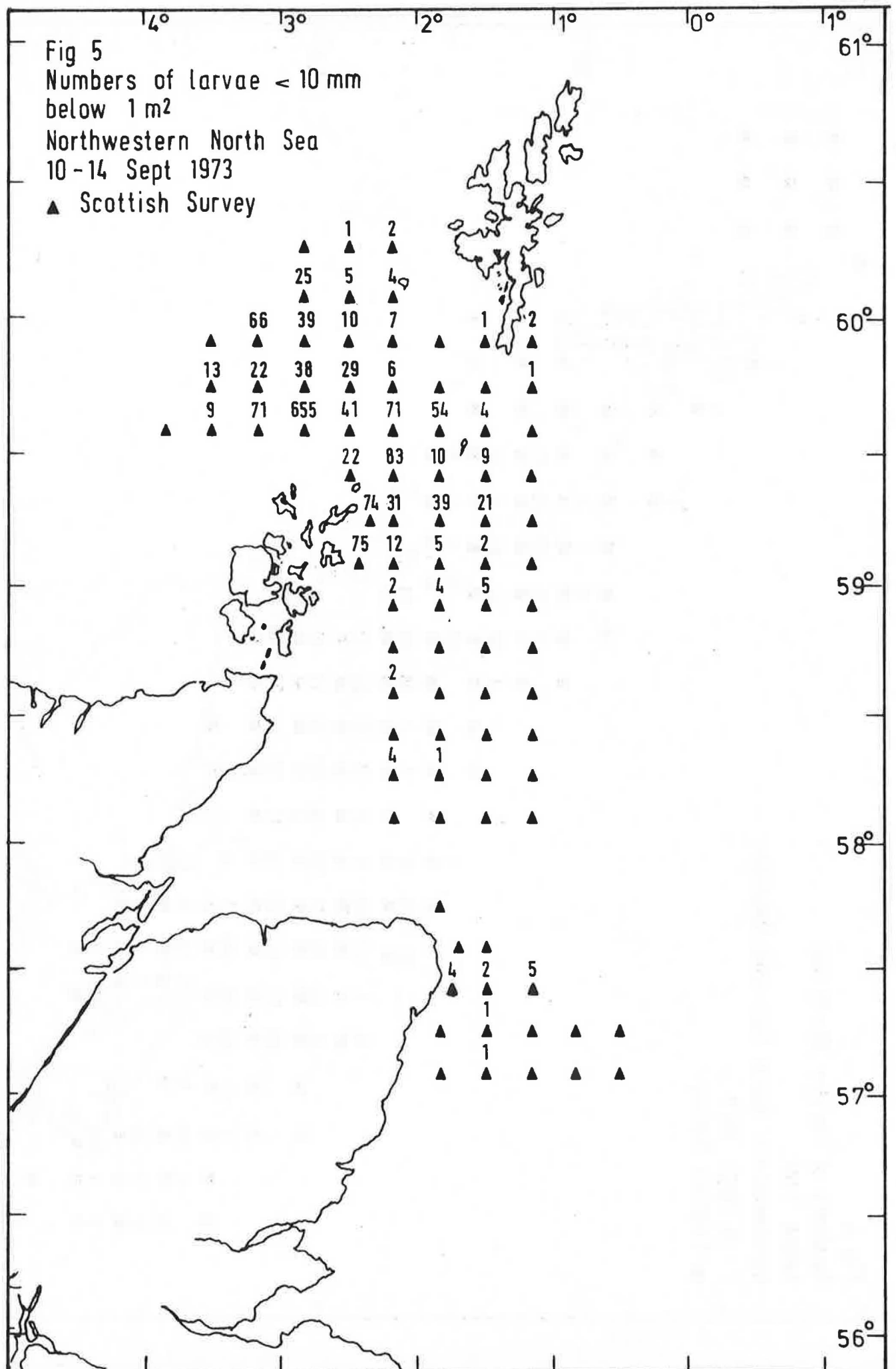


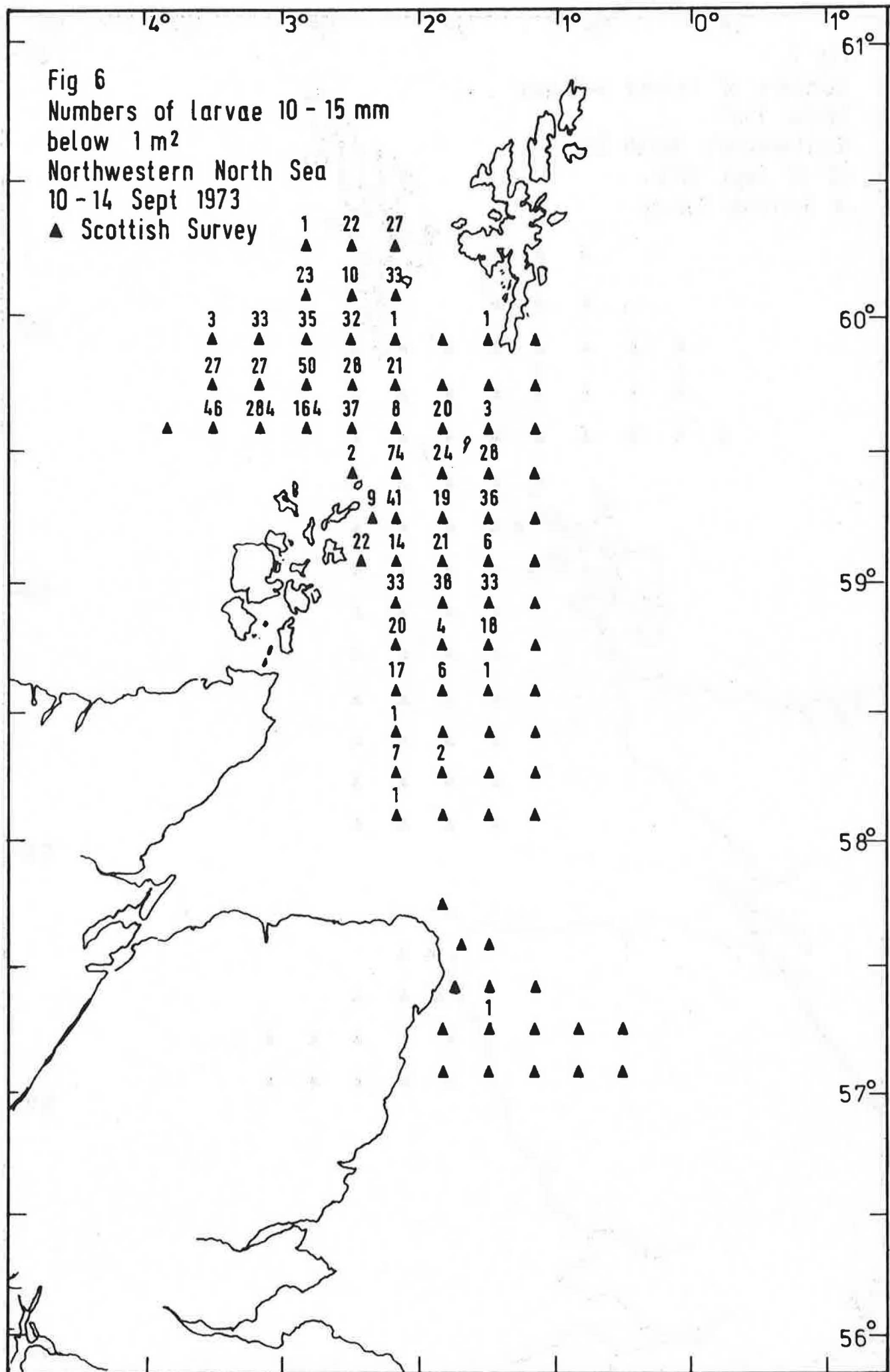
Numbers of larvae 10 - 15 mm
below 1 m²

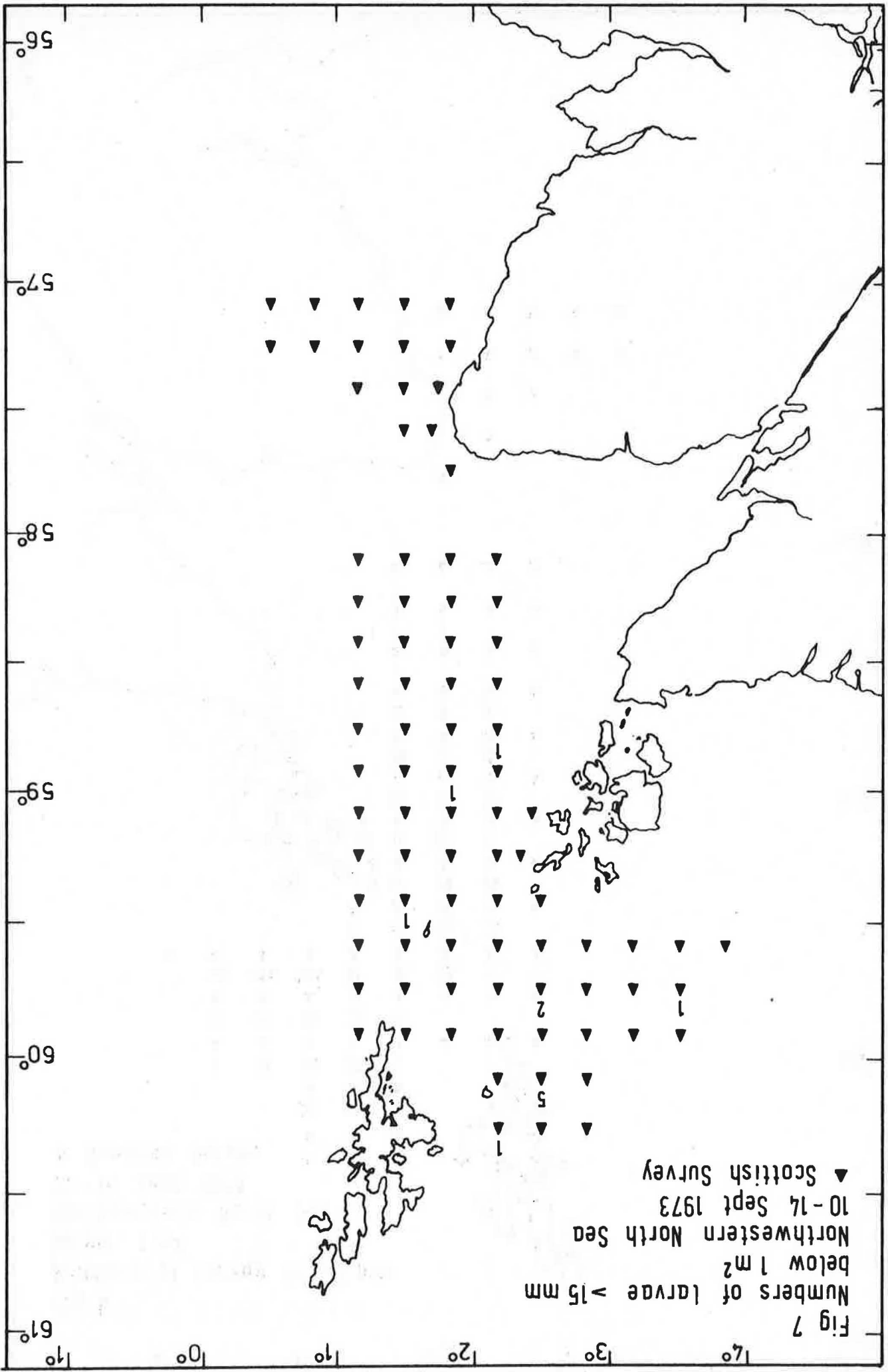
7 - 16 Sept 1973

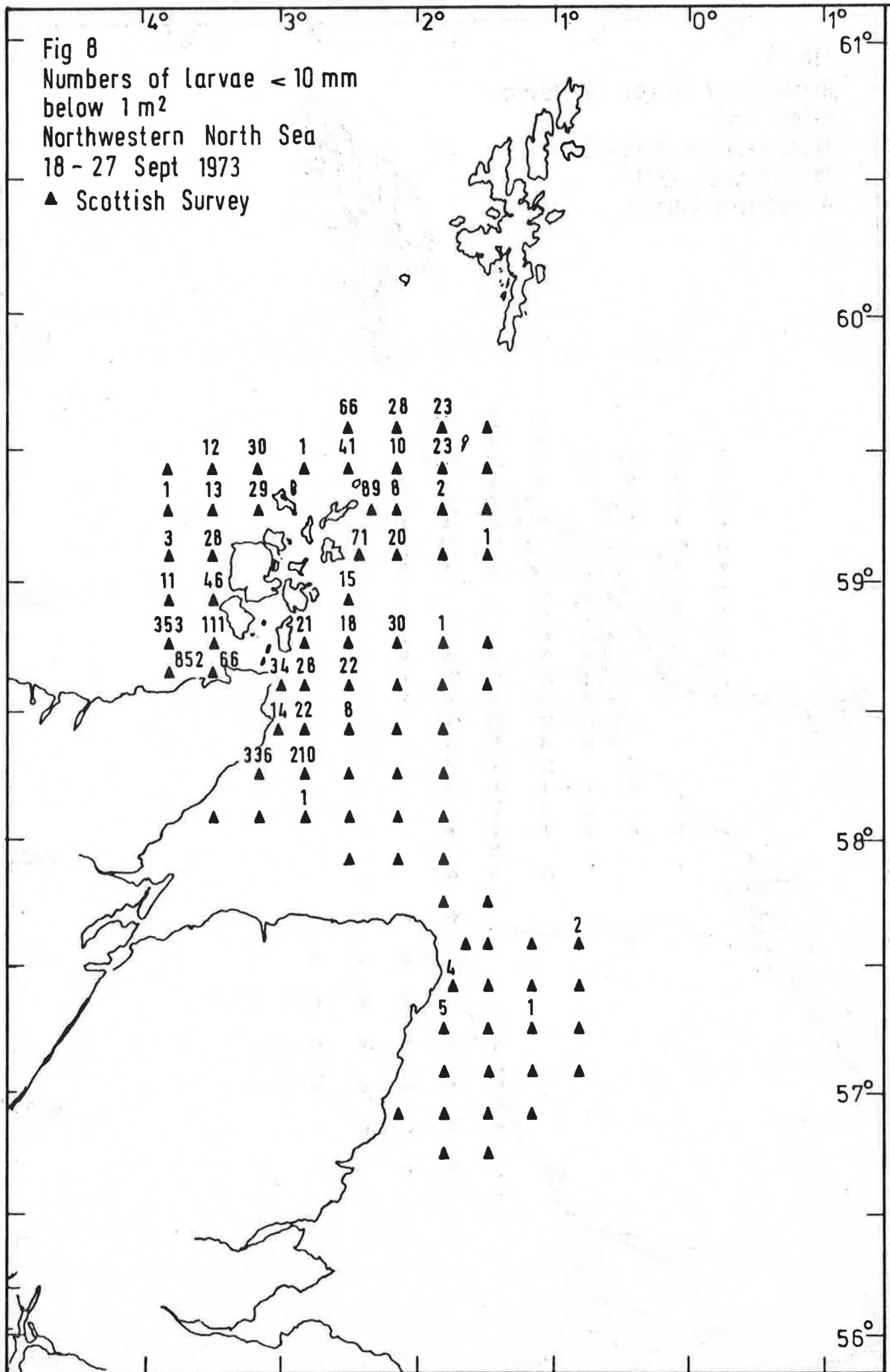
■ English Survey

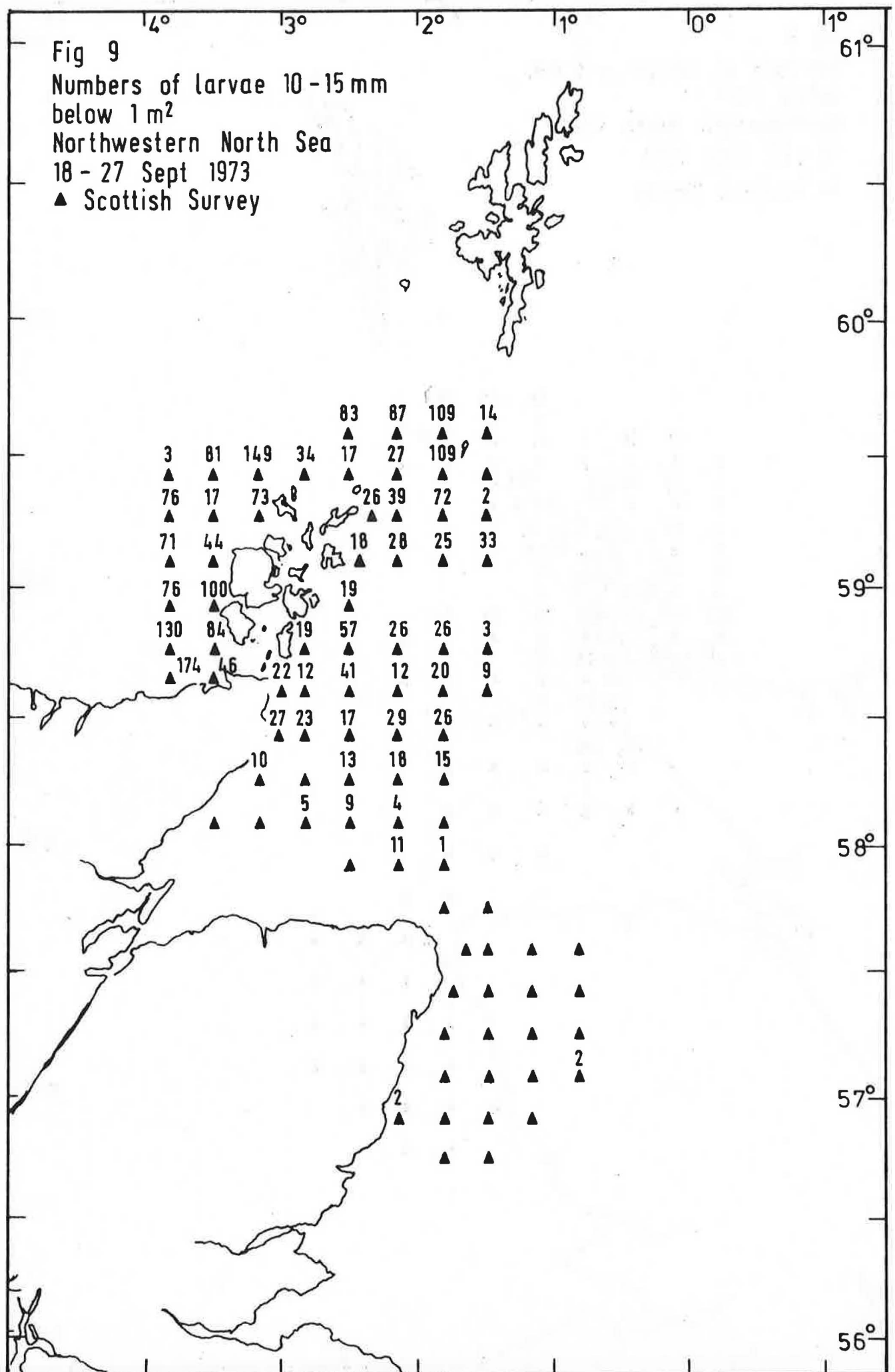


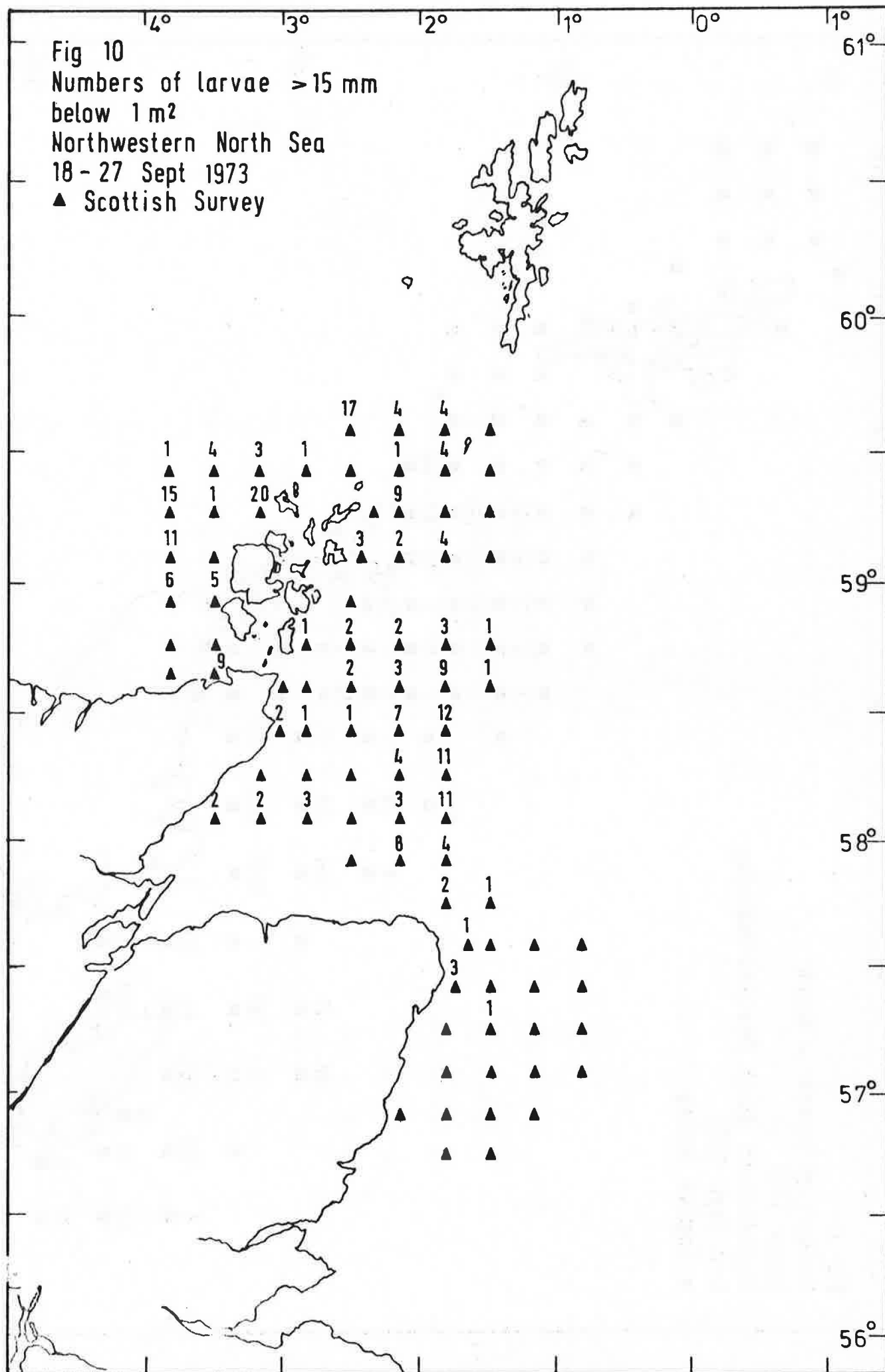


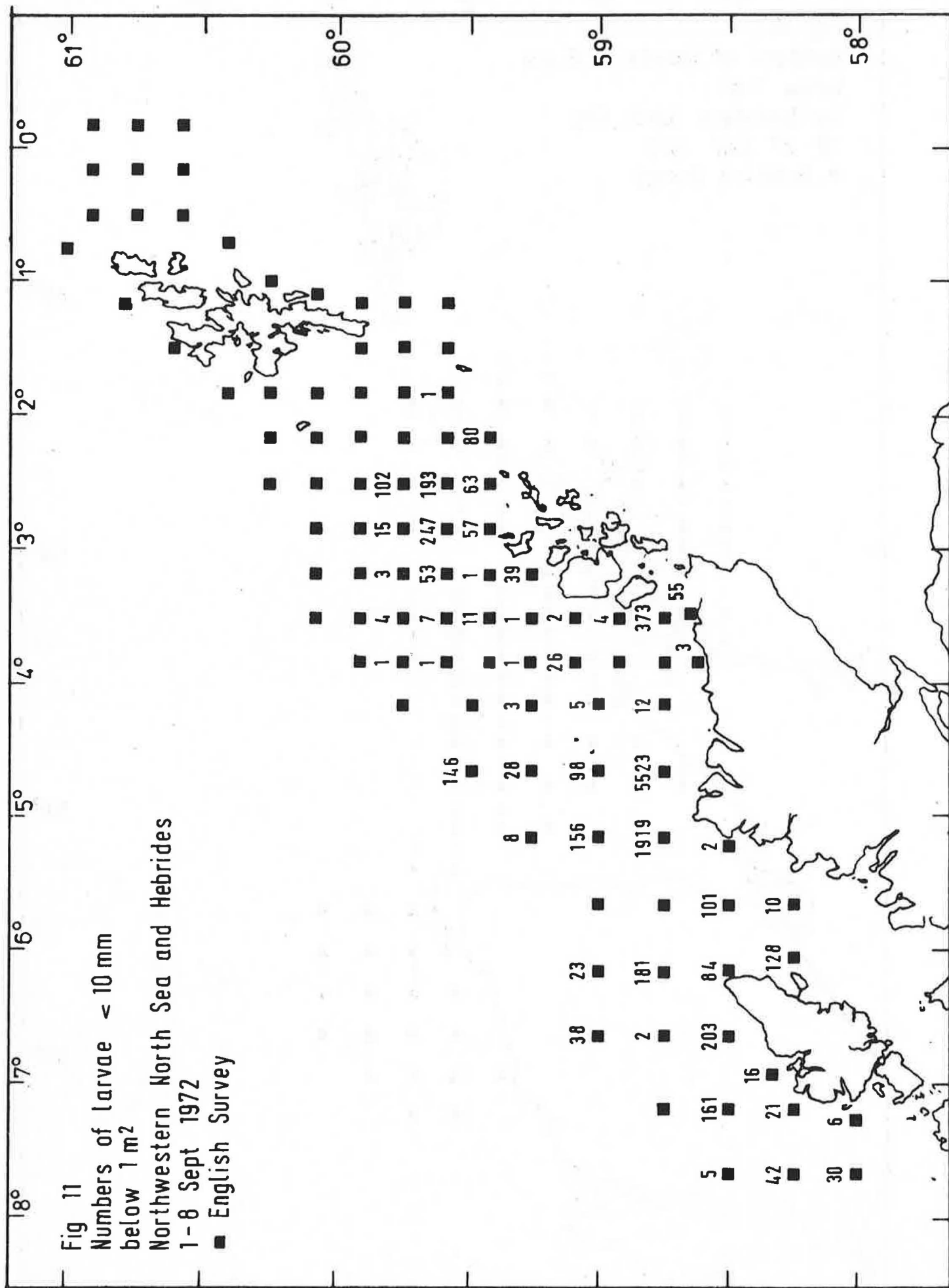


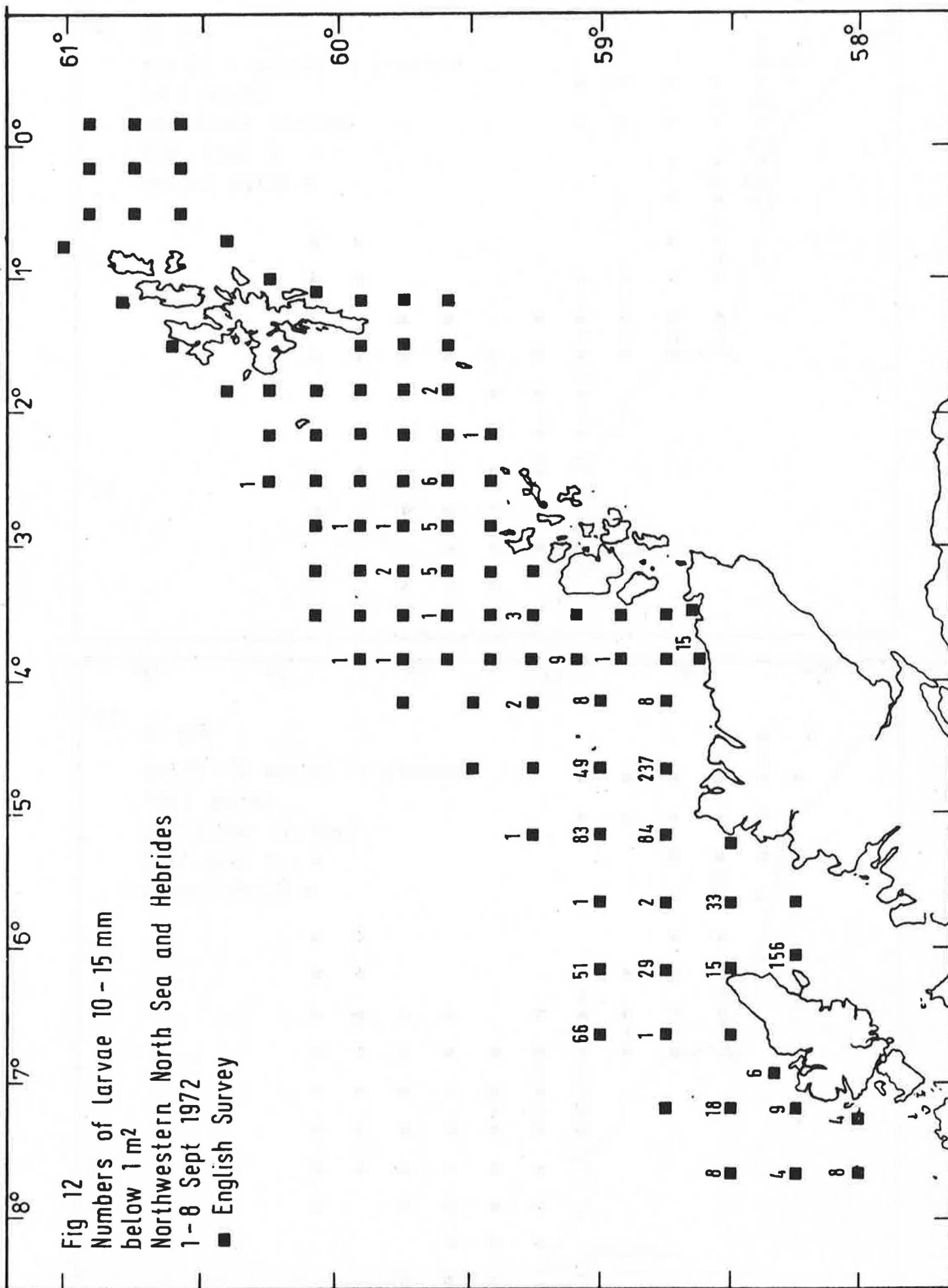
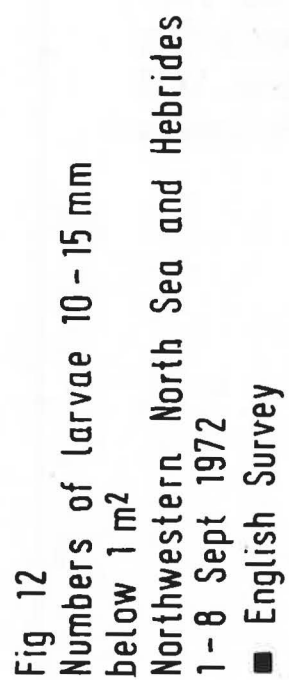


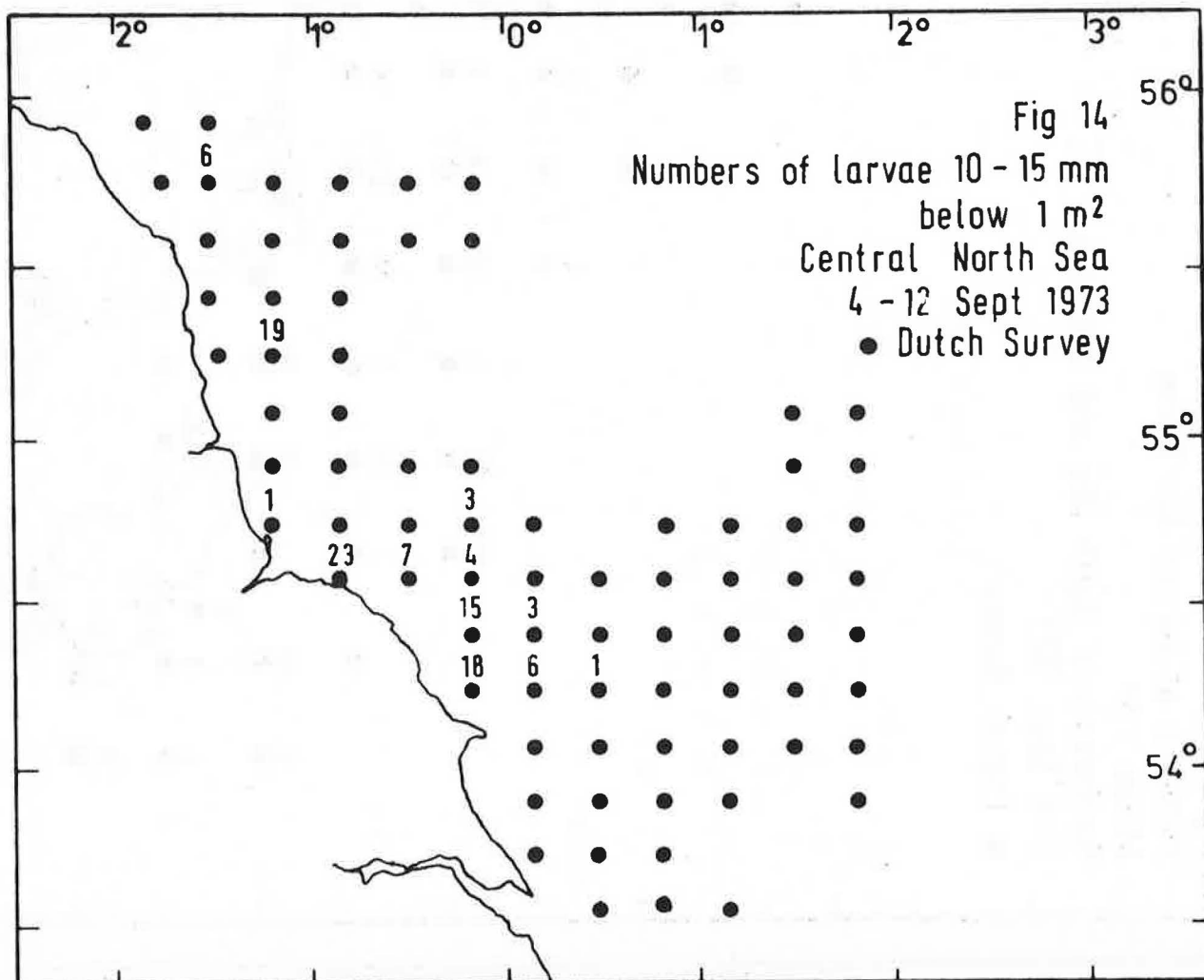
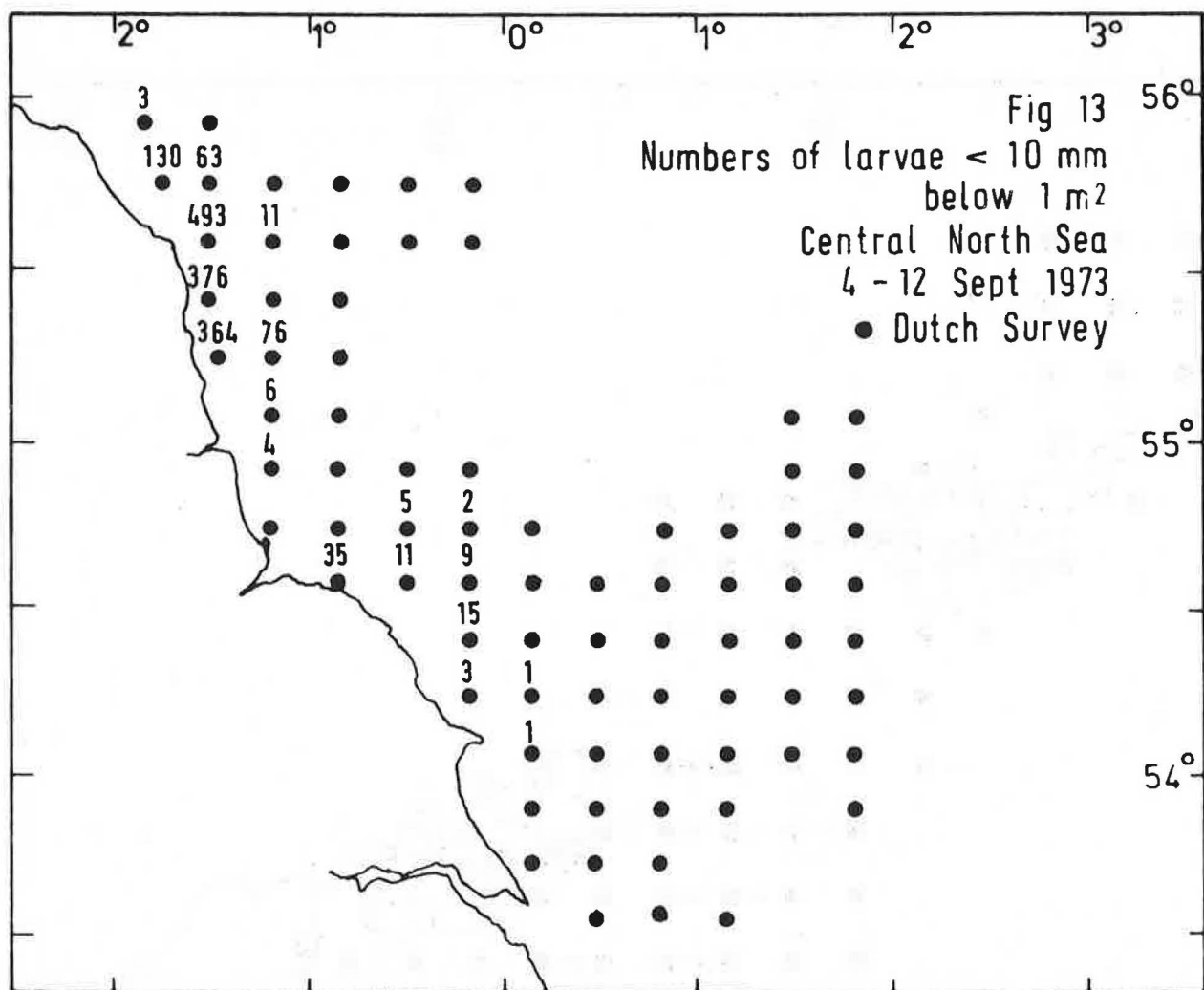


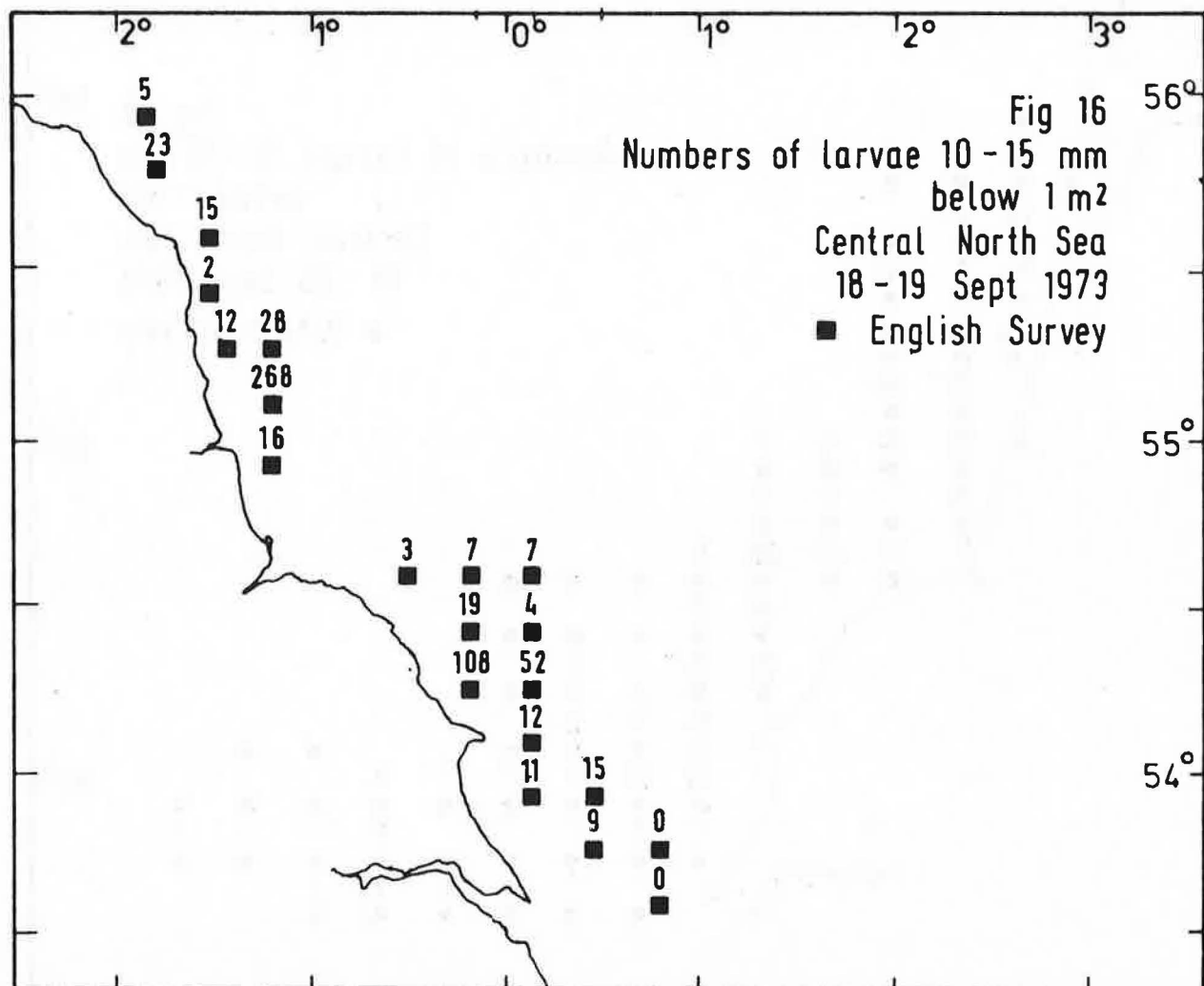
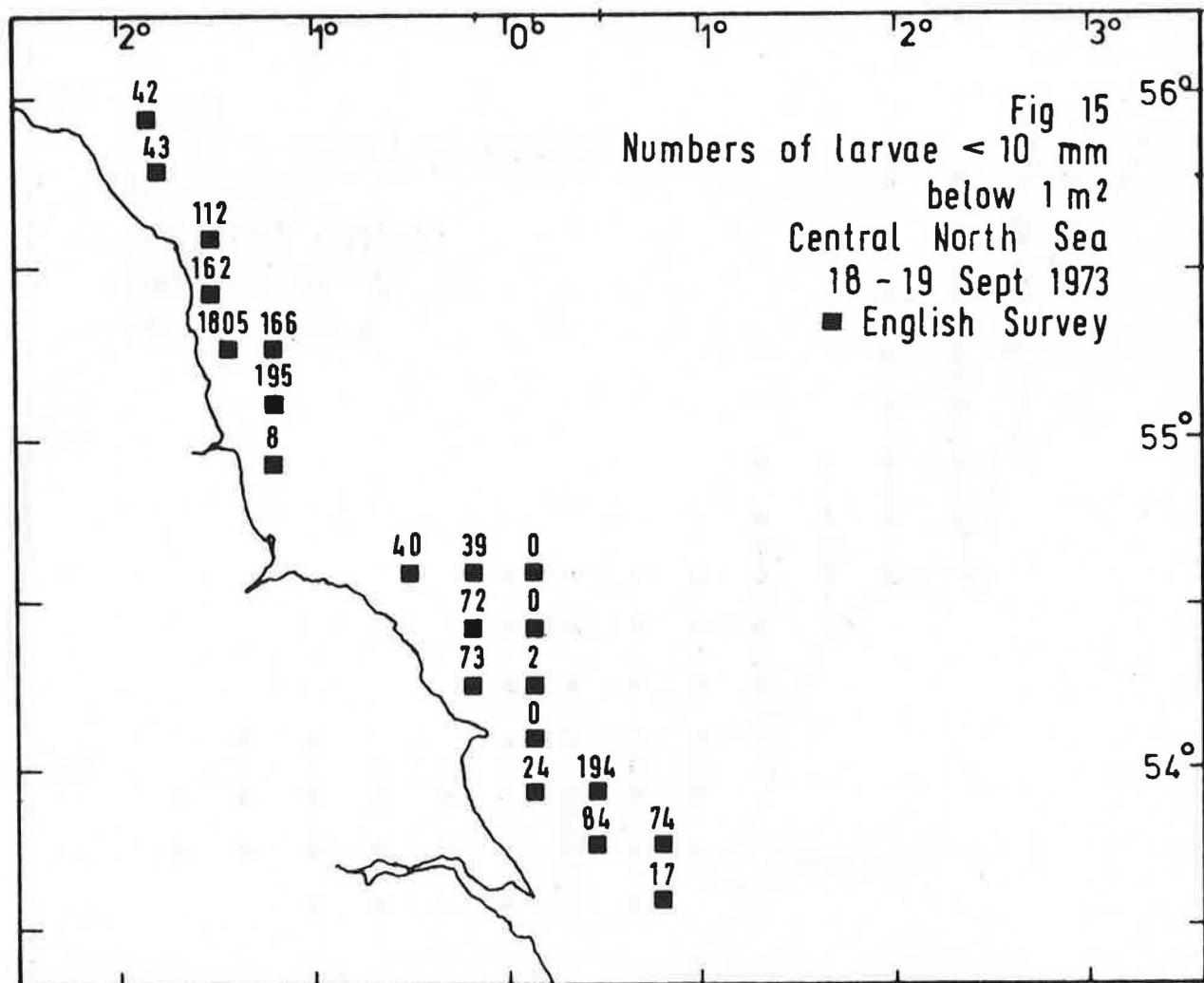


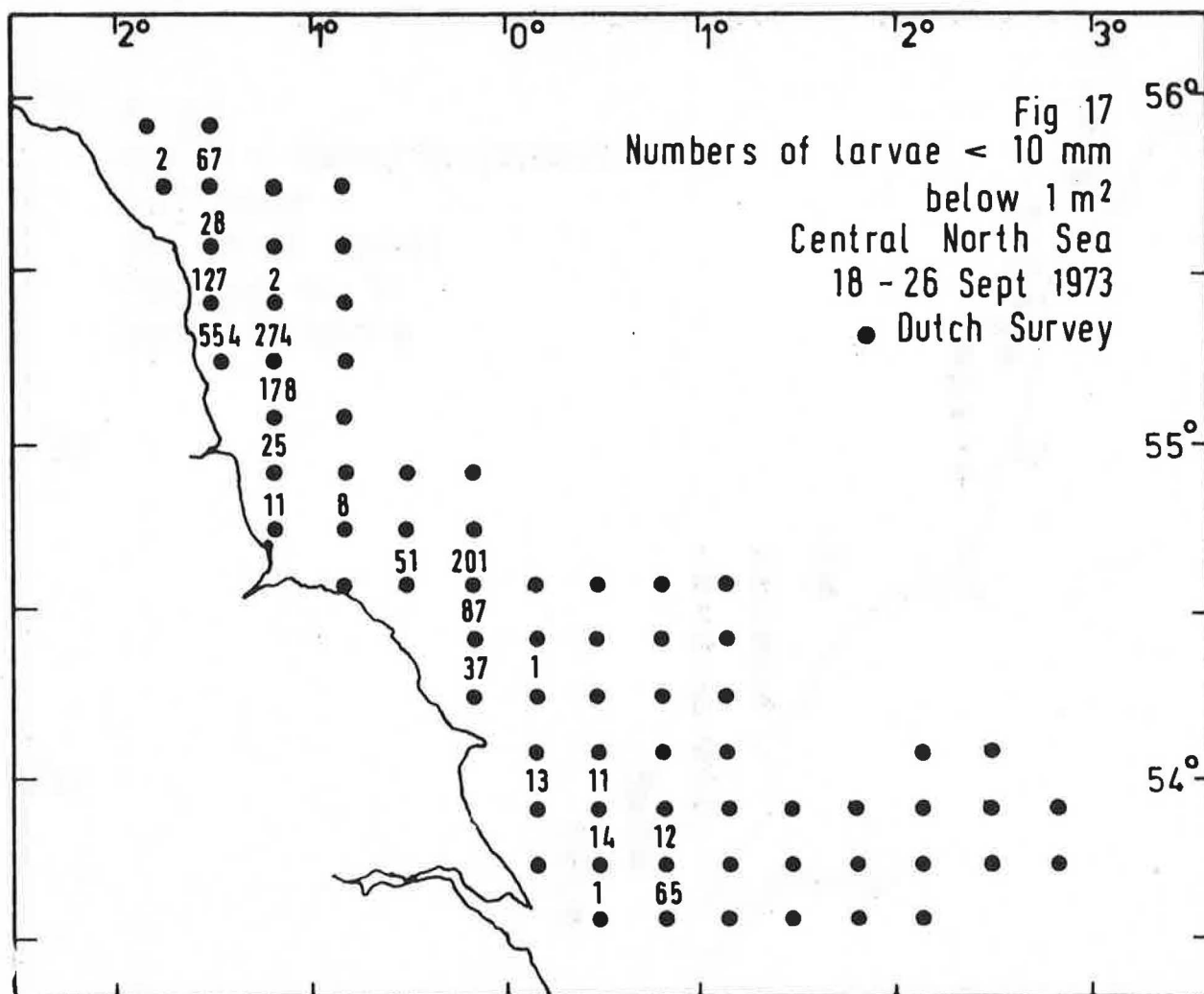


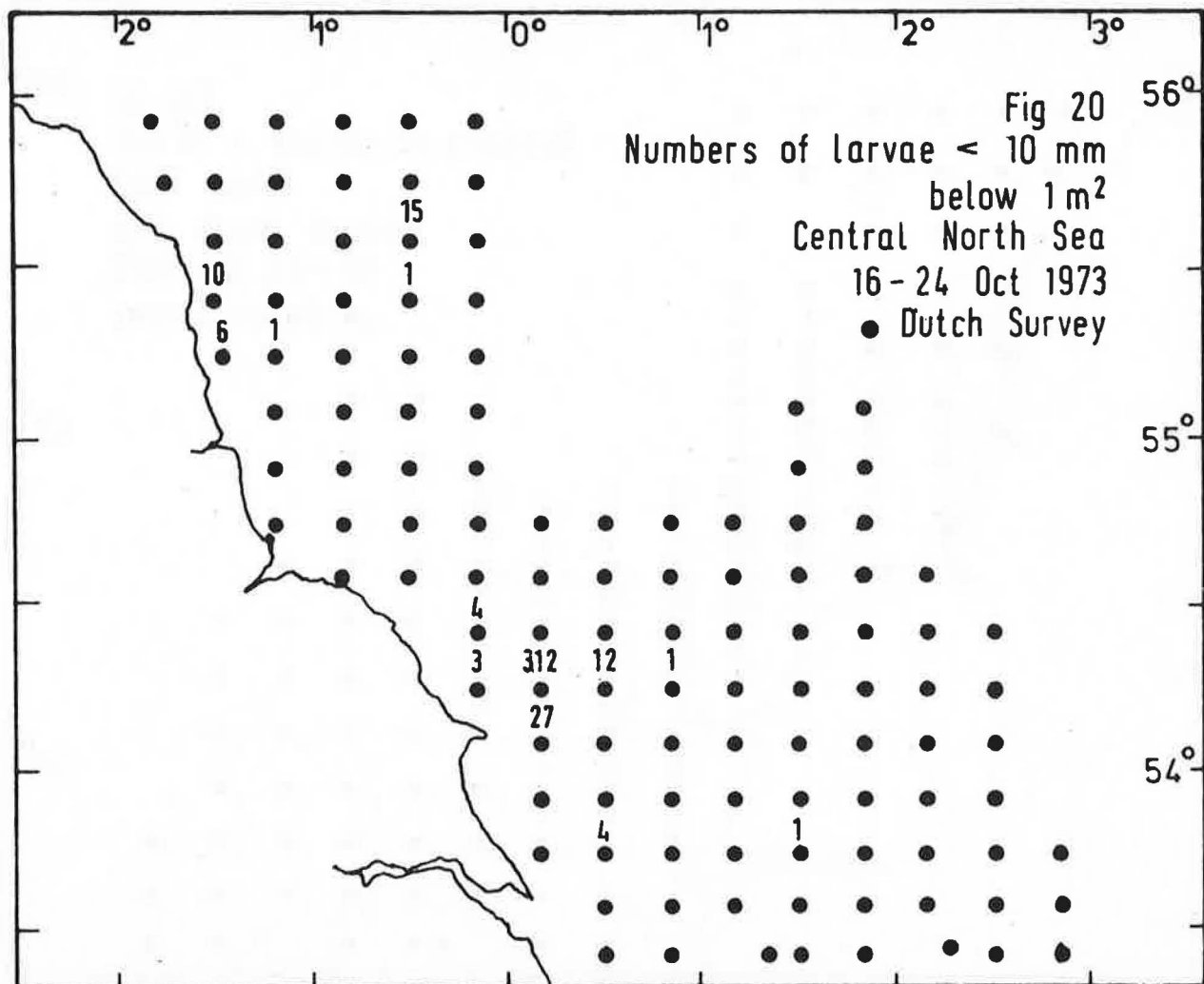
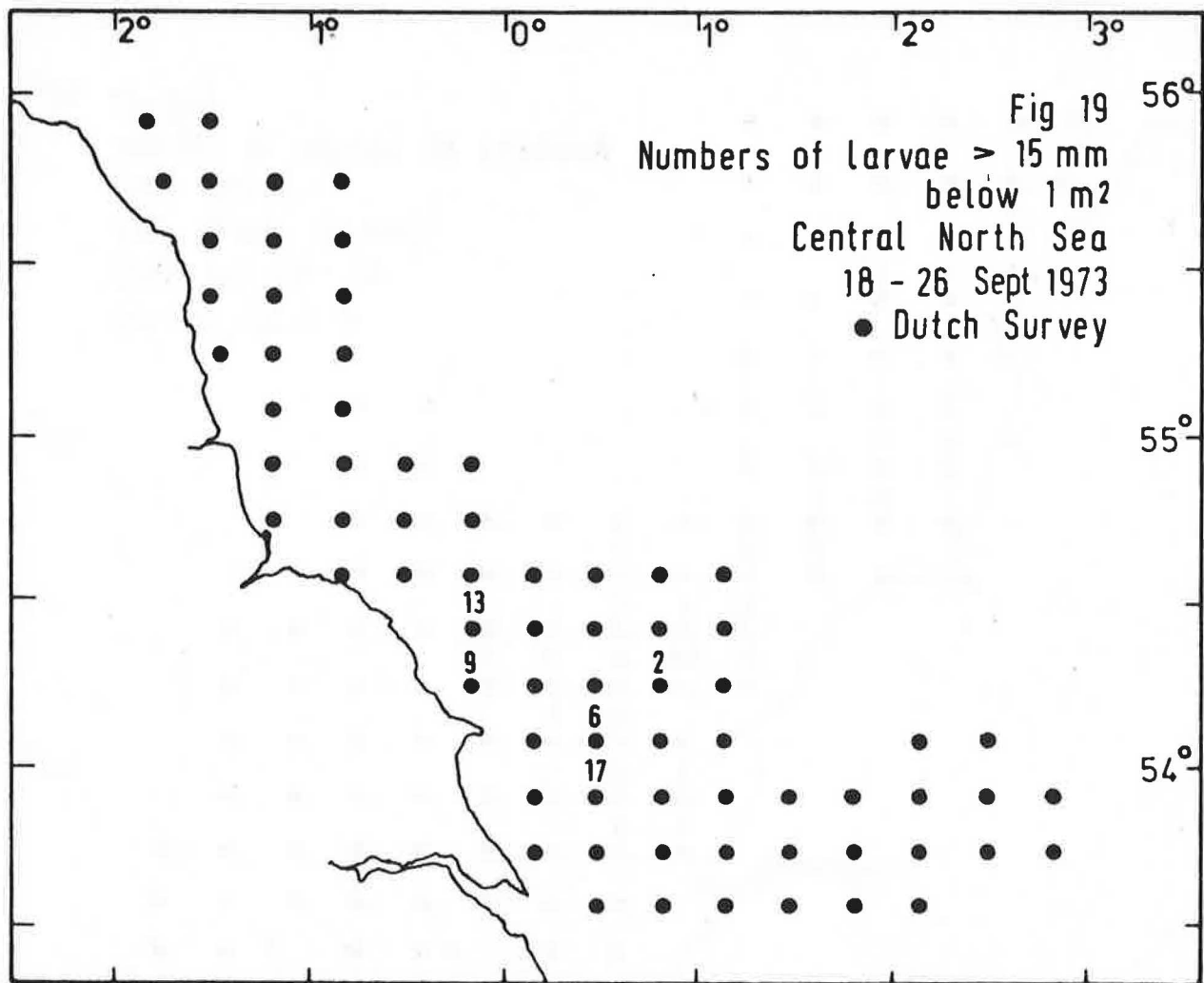


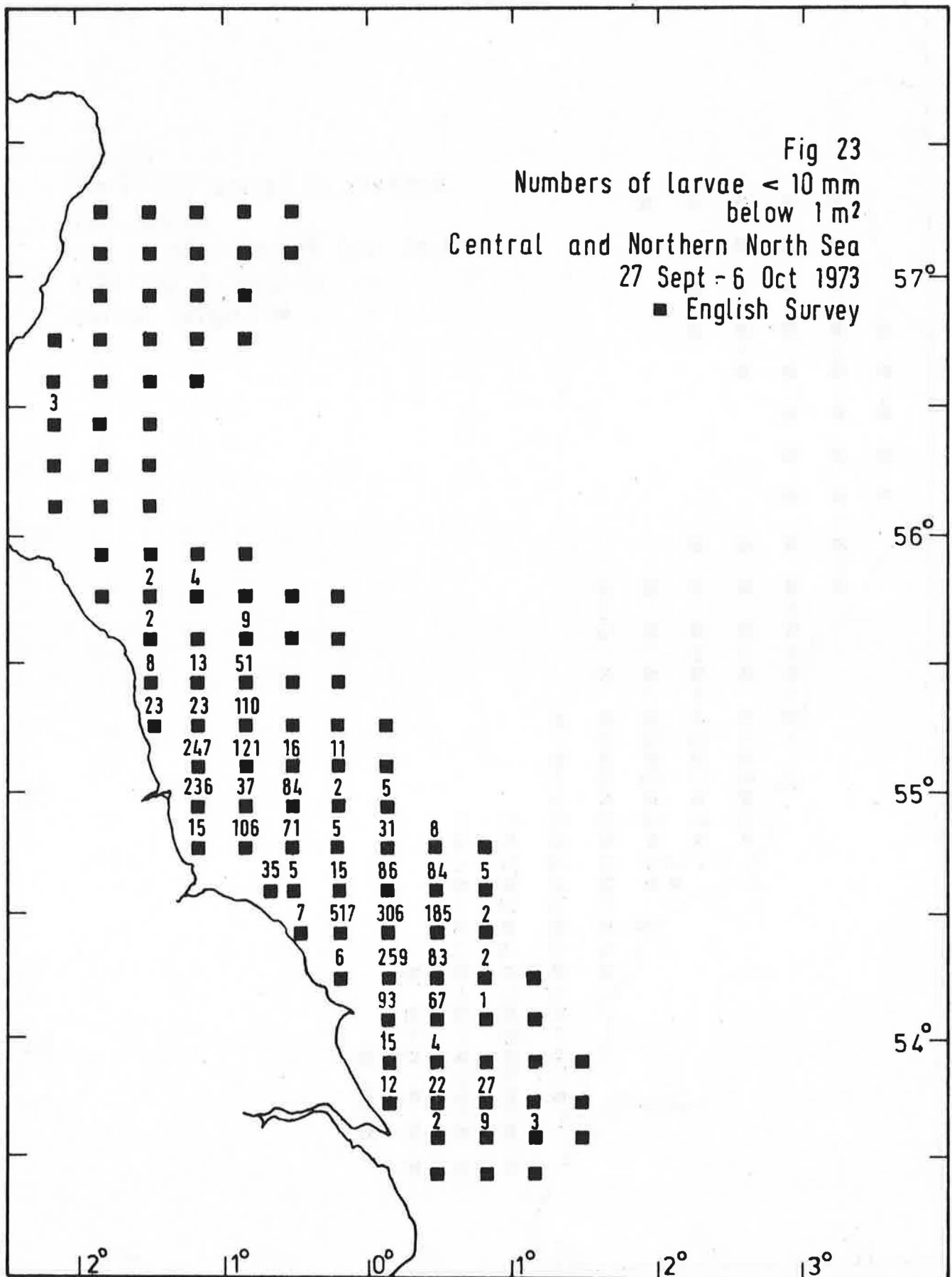


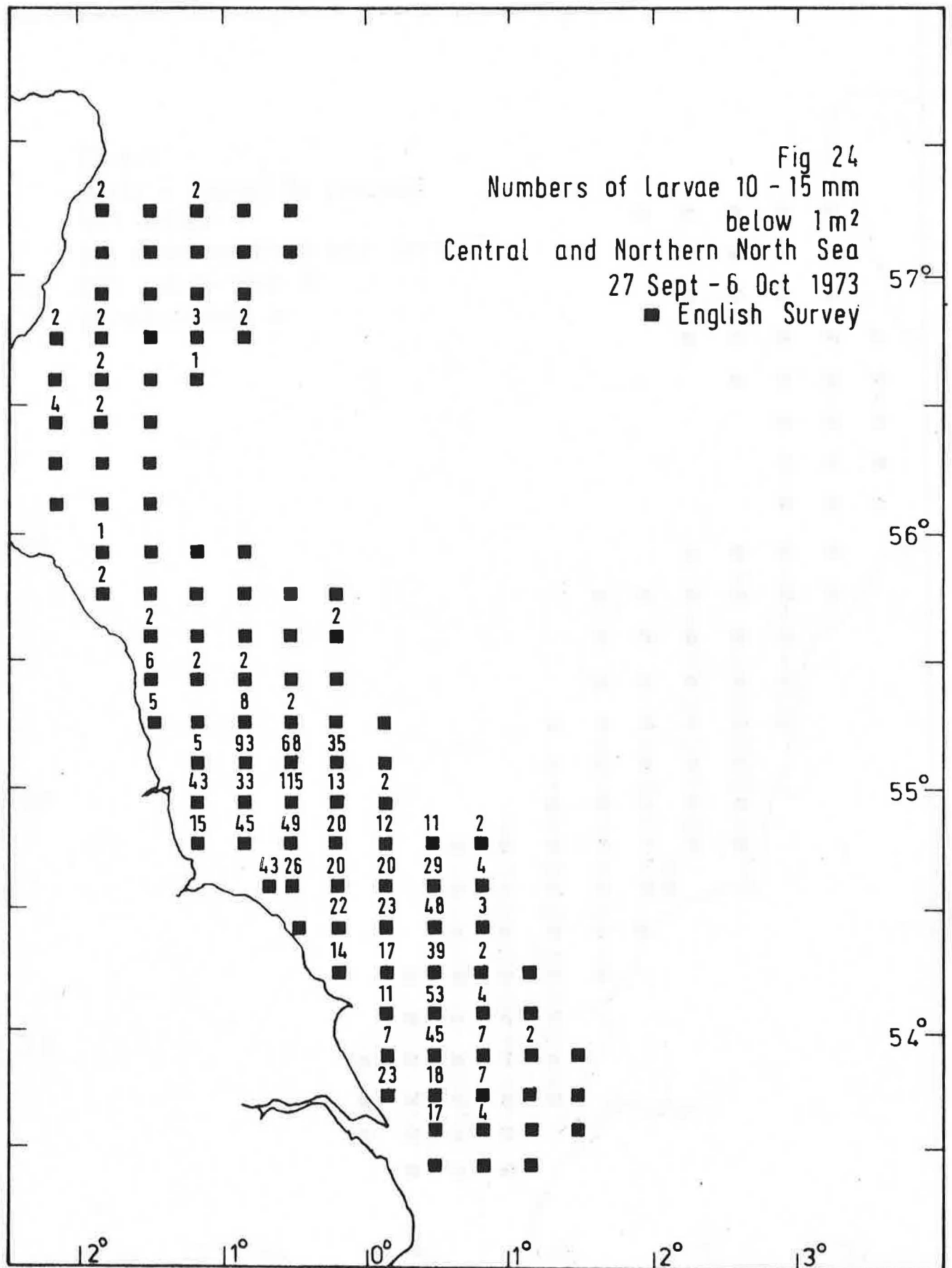


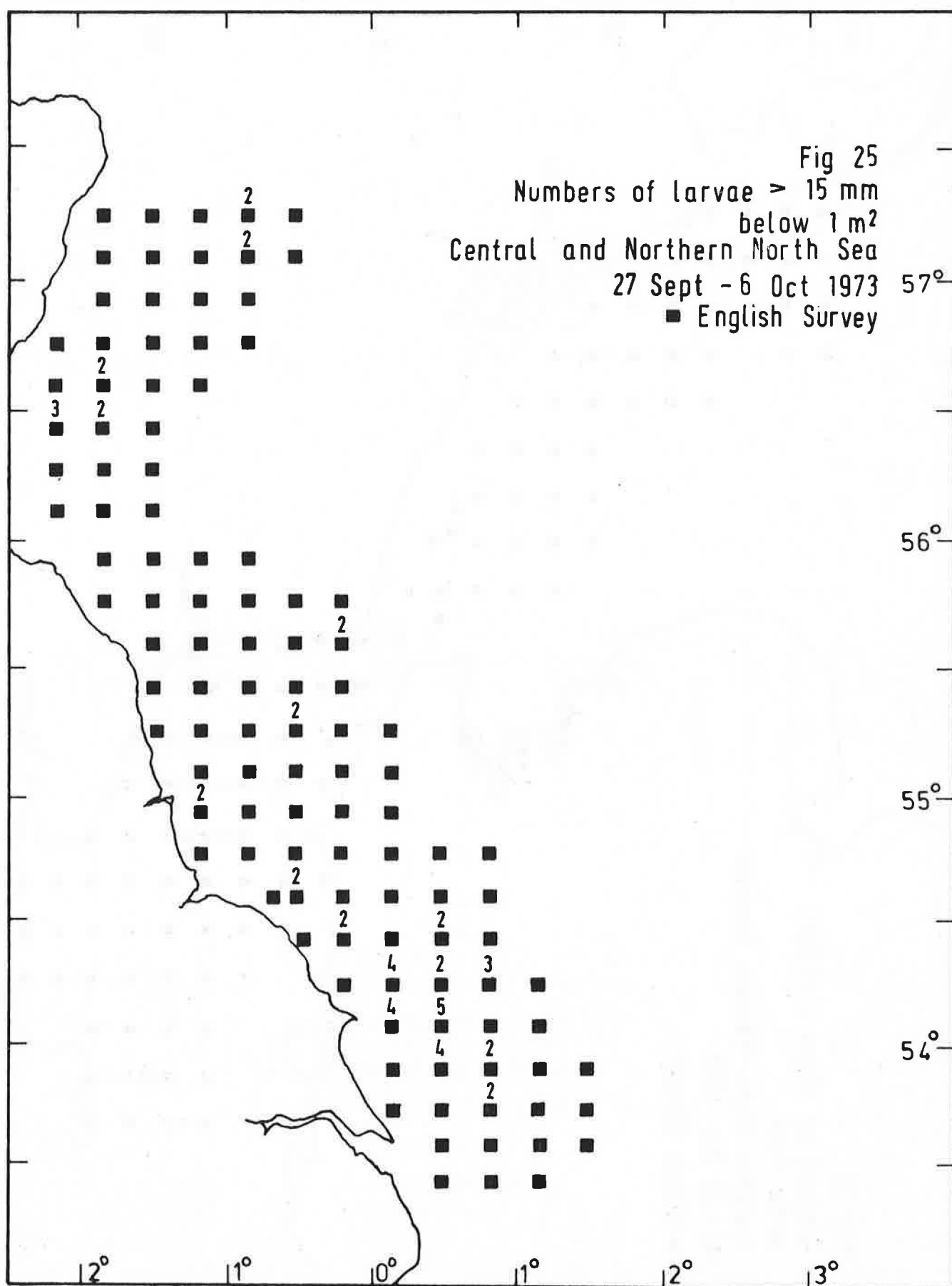












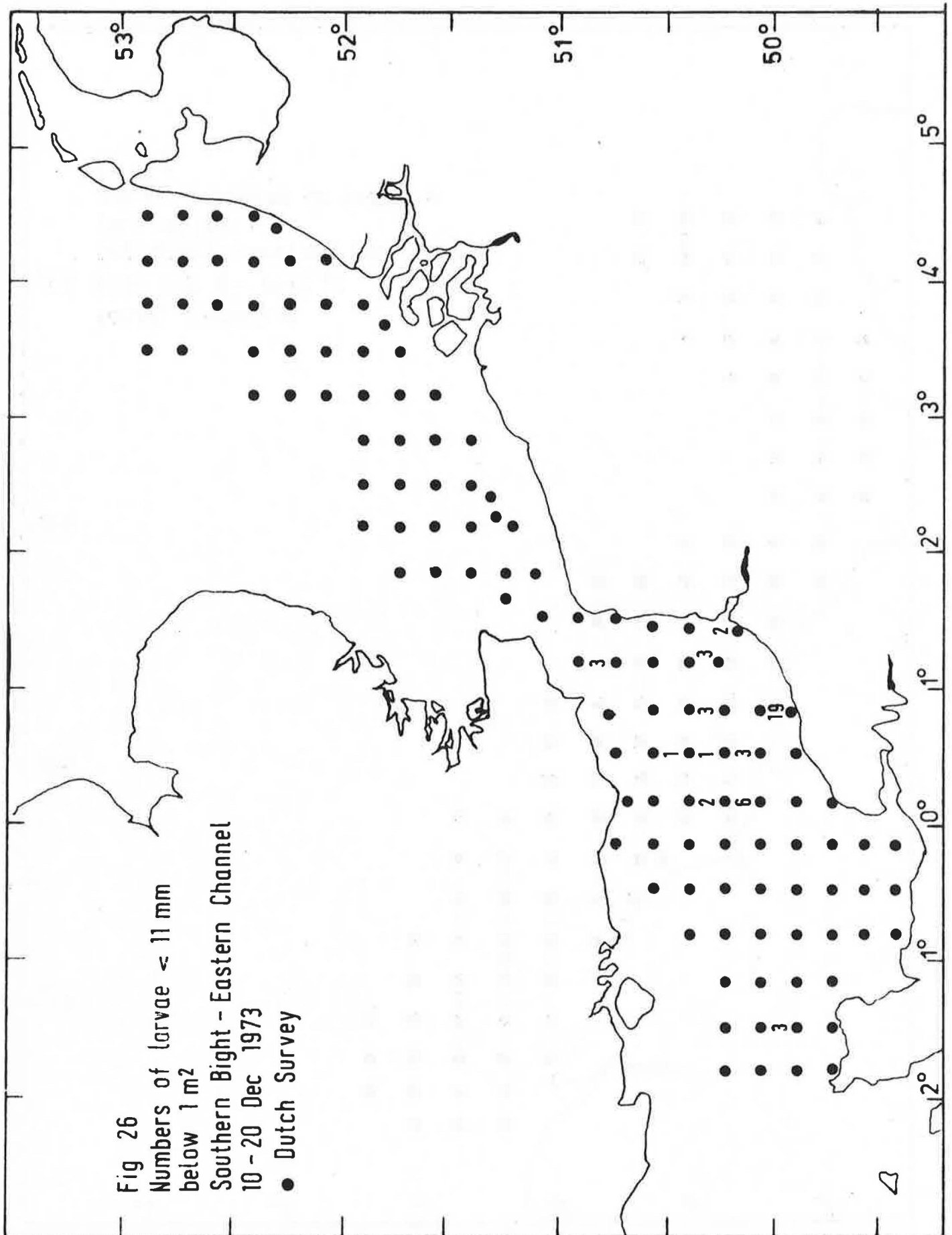


Fig 27
Numbers of larvae 11 - 16 mm
below 1 m²
Southern Bight - Eastern Channel
10 - 20 Dec 1973
● Dutch Survey

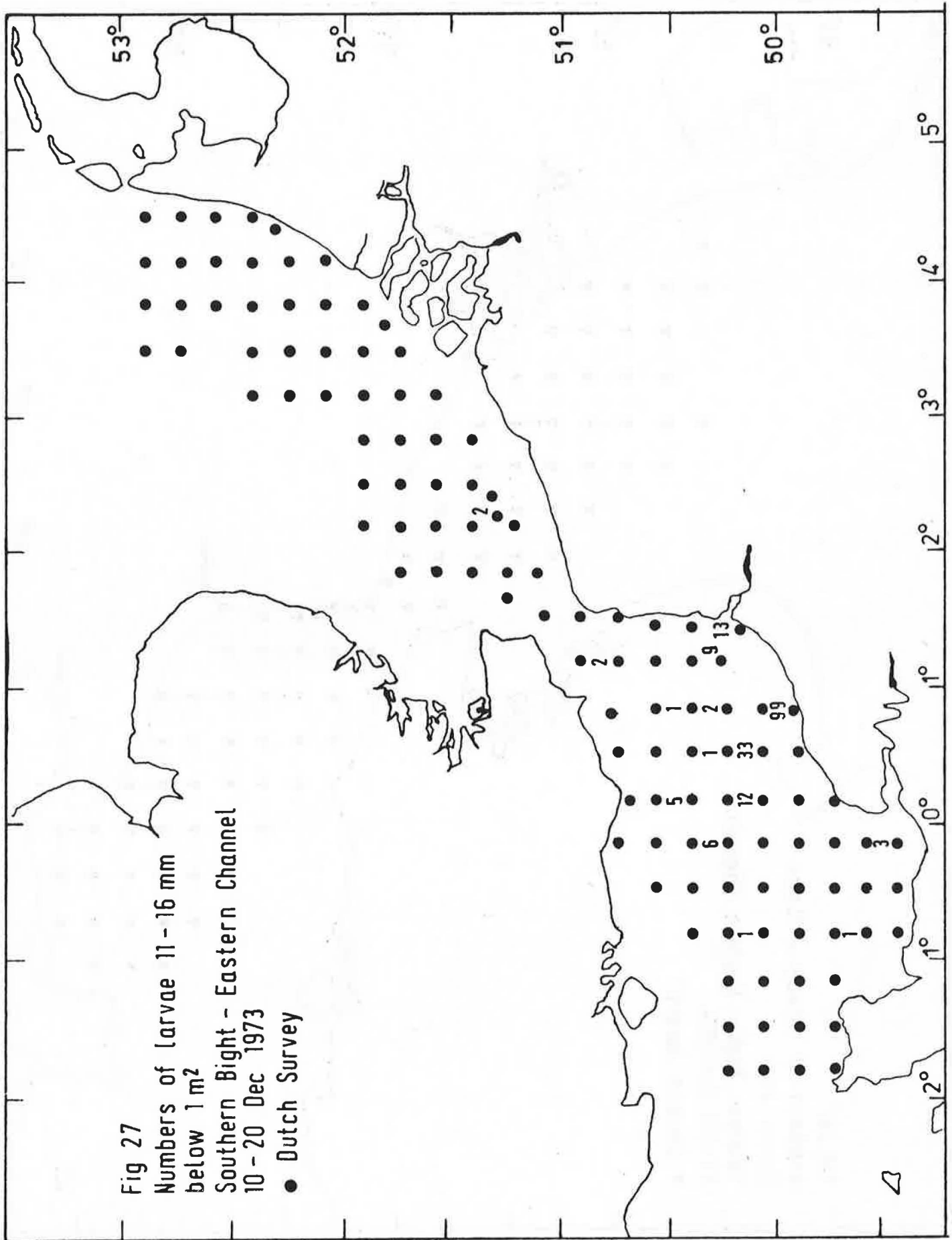


Fig 28

Numbers of larvae < 11 mm
below 1 m²

Southern Bight - Eastern Channel
23-28 Jan 1974

▼ German Survey

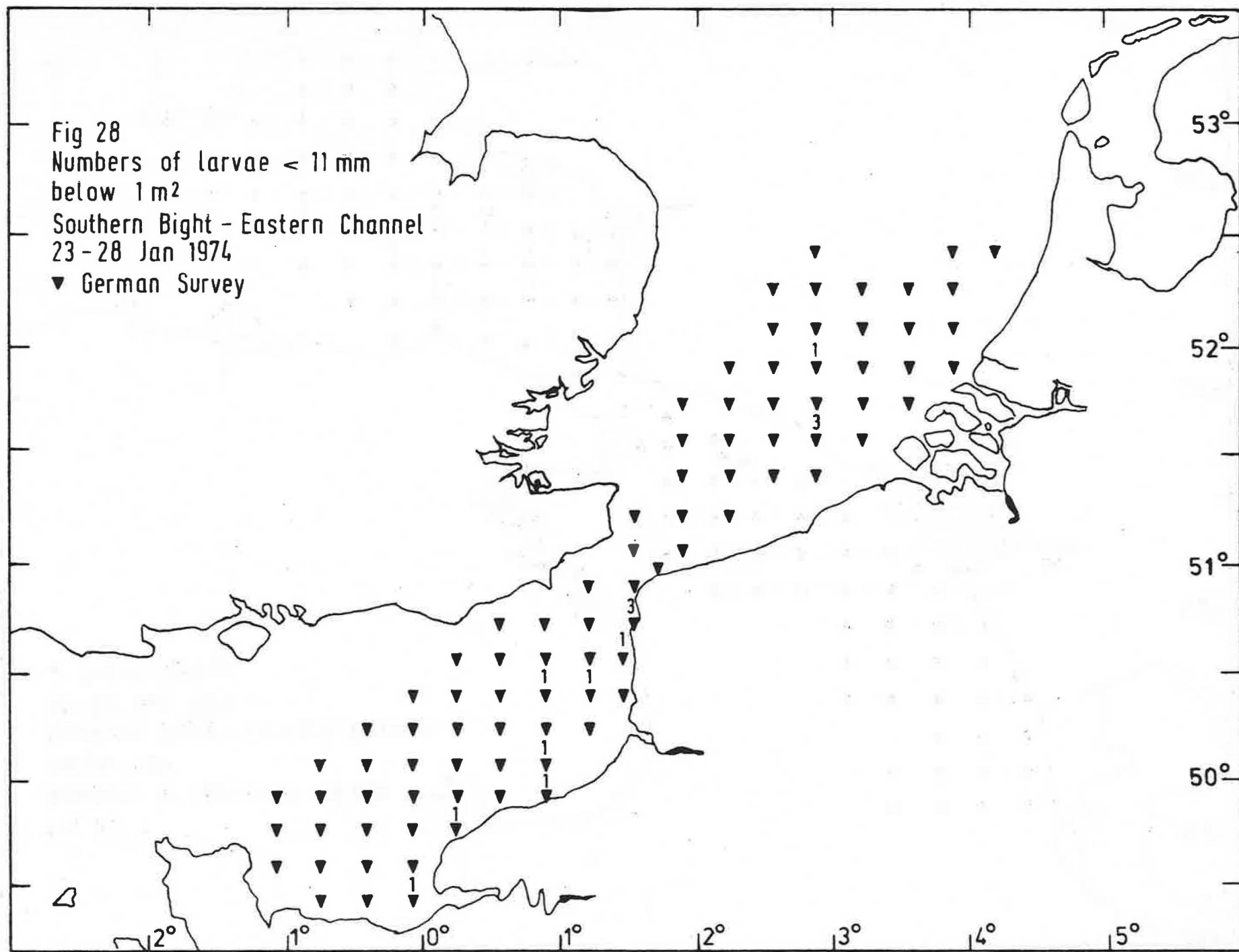


Fig 29
Numbers of larvae 11 - 16 mm
below 1 m²
Southern Bight - Eastern Channel
23 - 28 Jan 1974
▼ German Survey

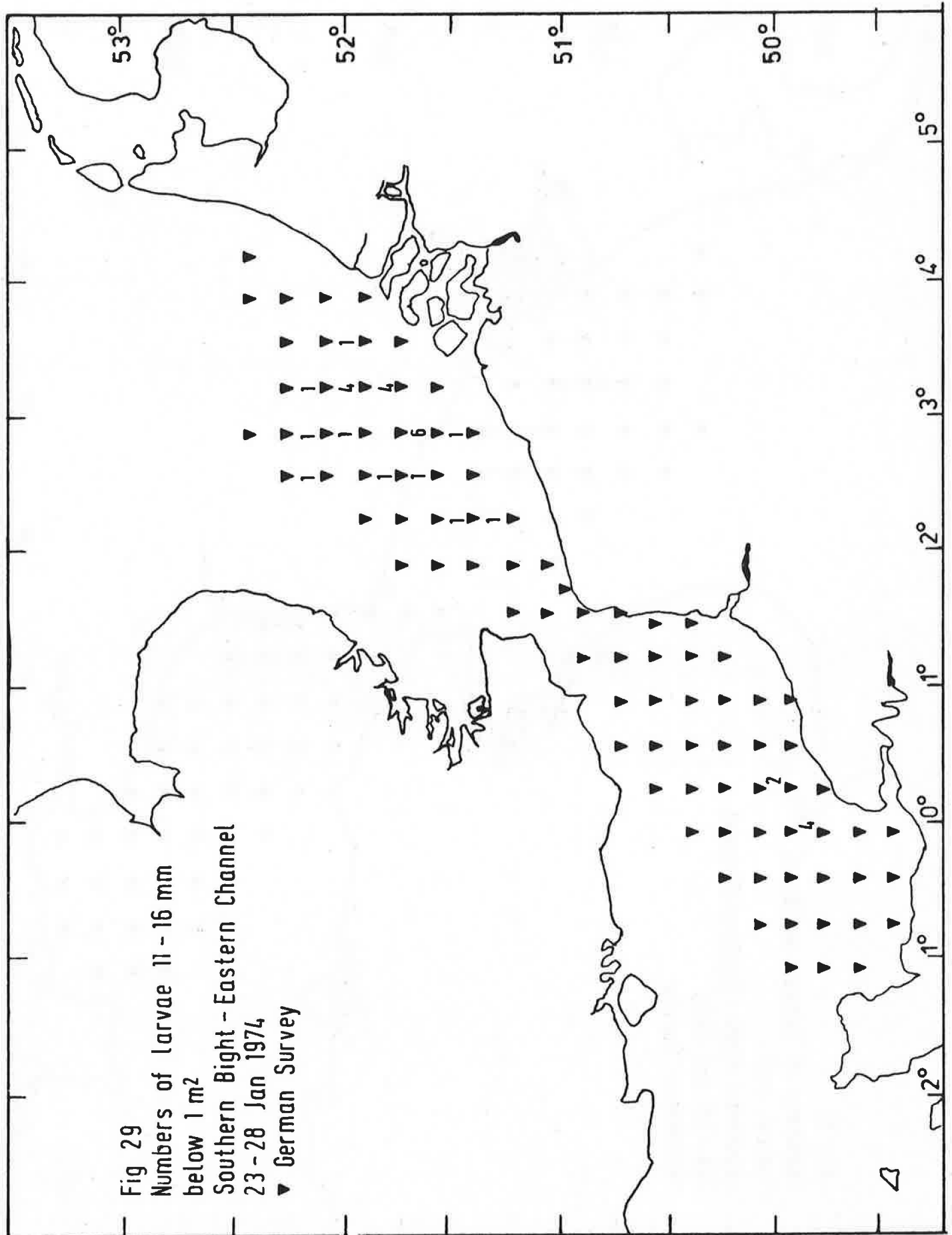


Fig 30

Numbers of larvae > 16 mm
below 1 m²

Southern Bight - Eastern Channel

23 - 28 Jan 1974

▼ German Survey

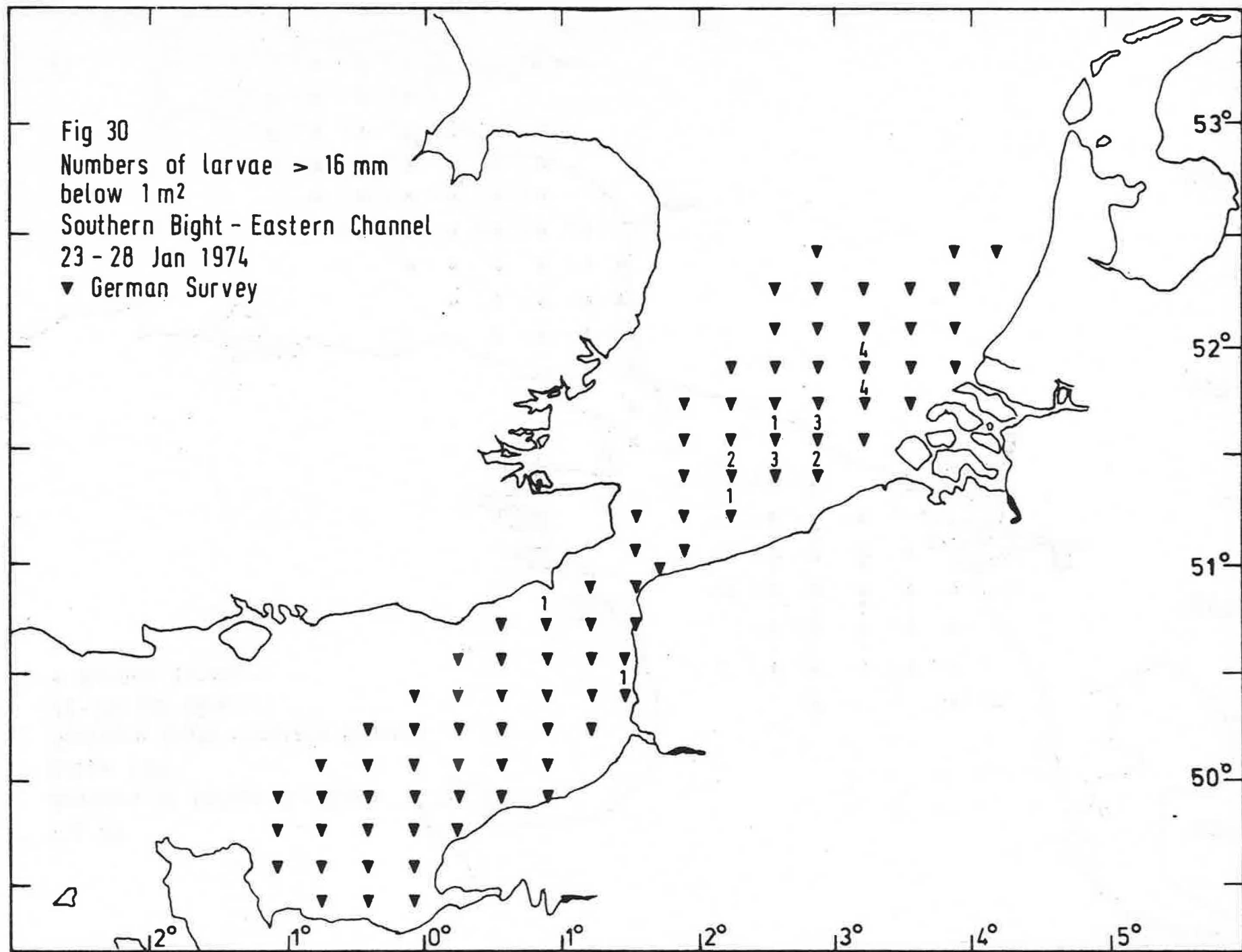
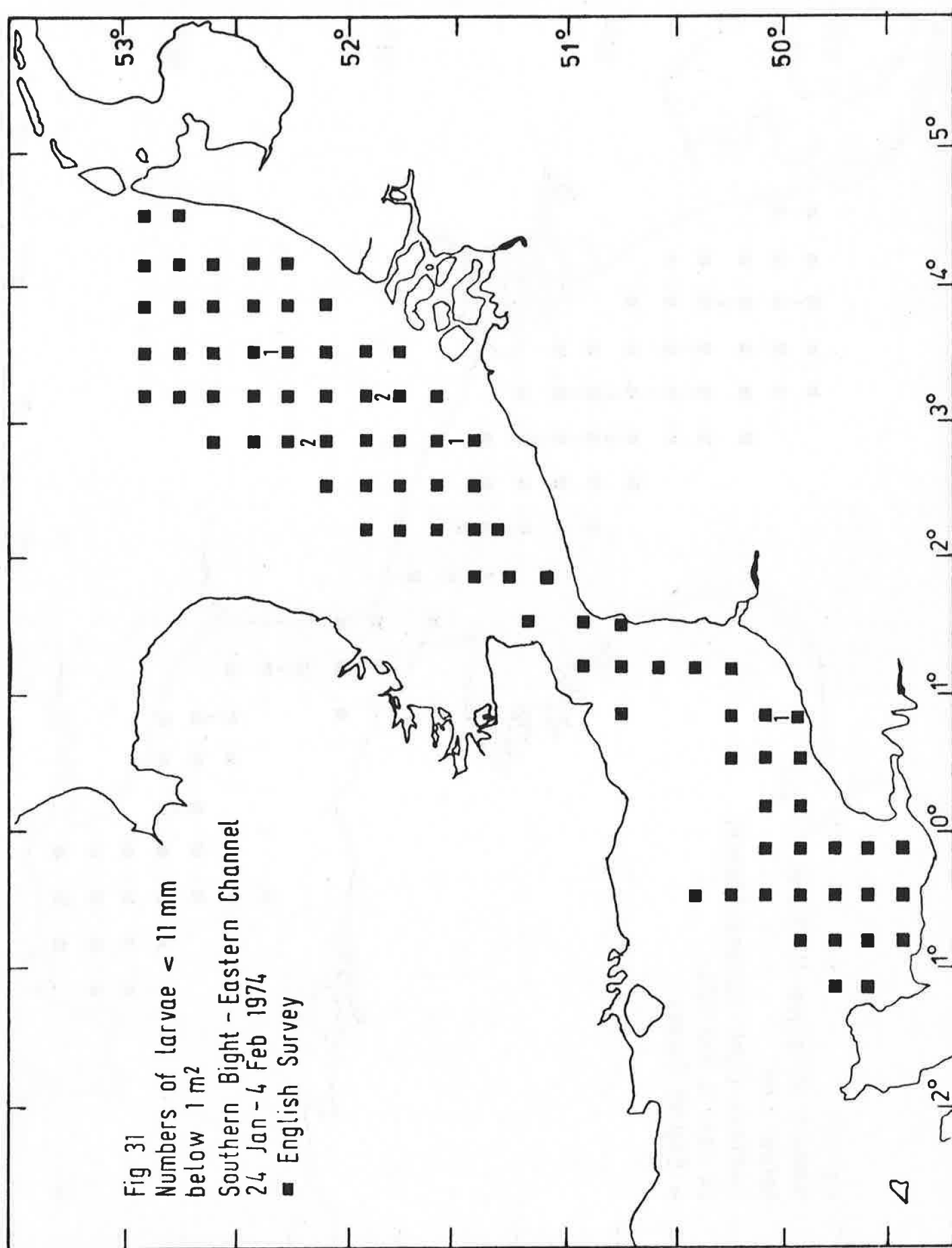
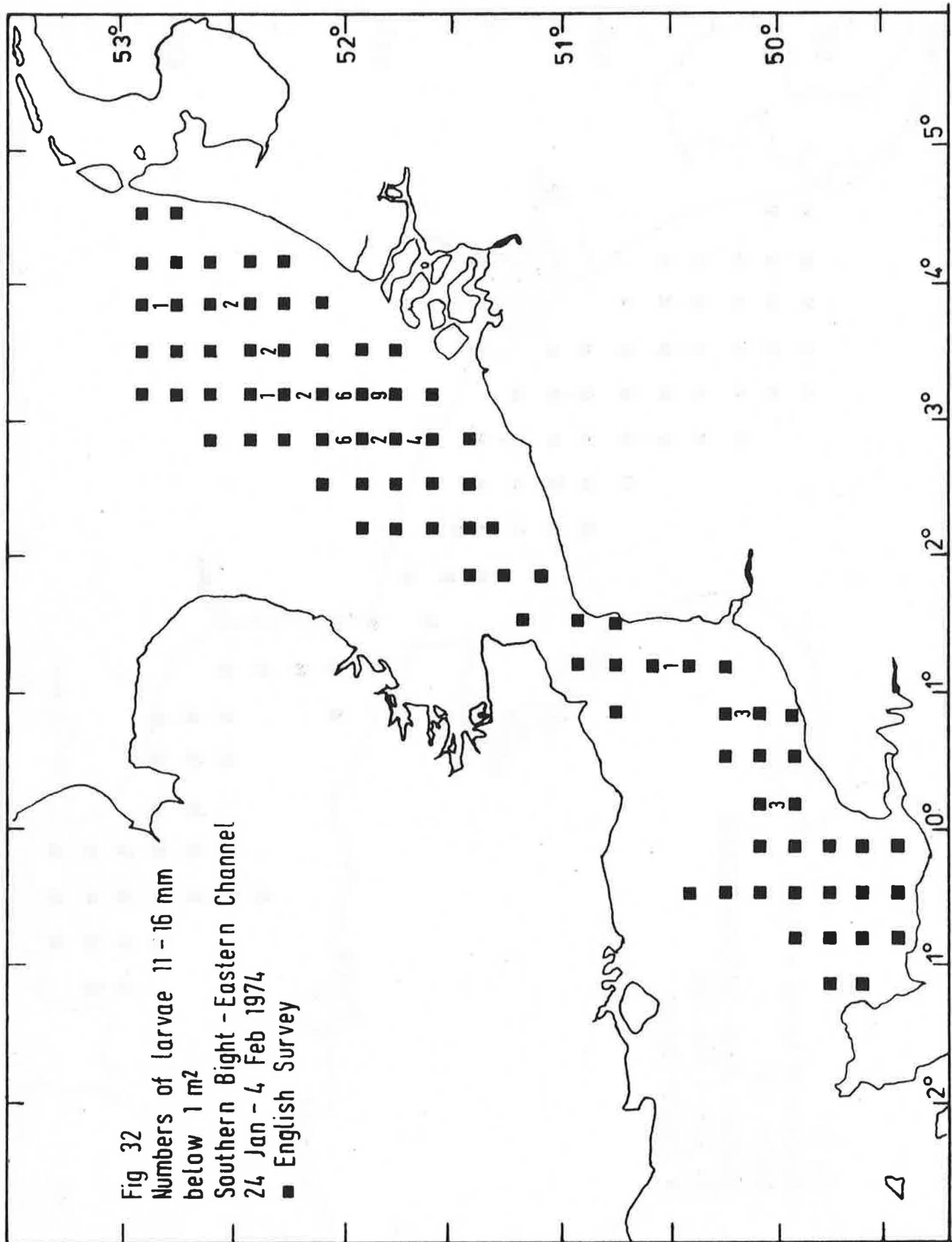


Fig 31
Numbers of larvae < 11 mm
below 1 m²
Southern Bight - Eastern Channel
24 Jan - 4 Feb 1974
■ English Survey





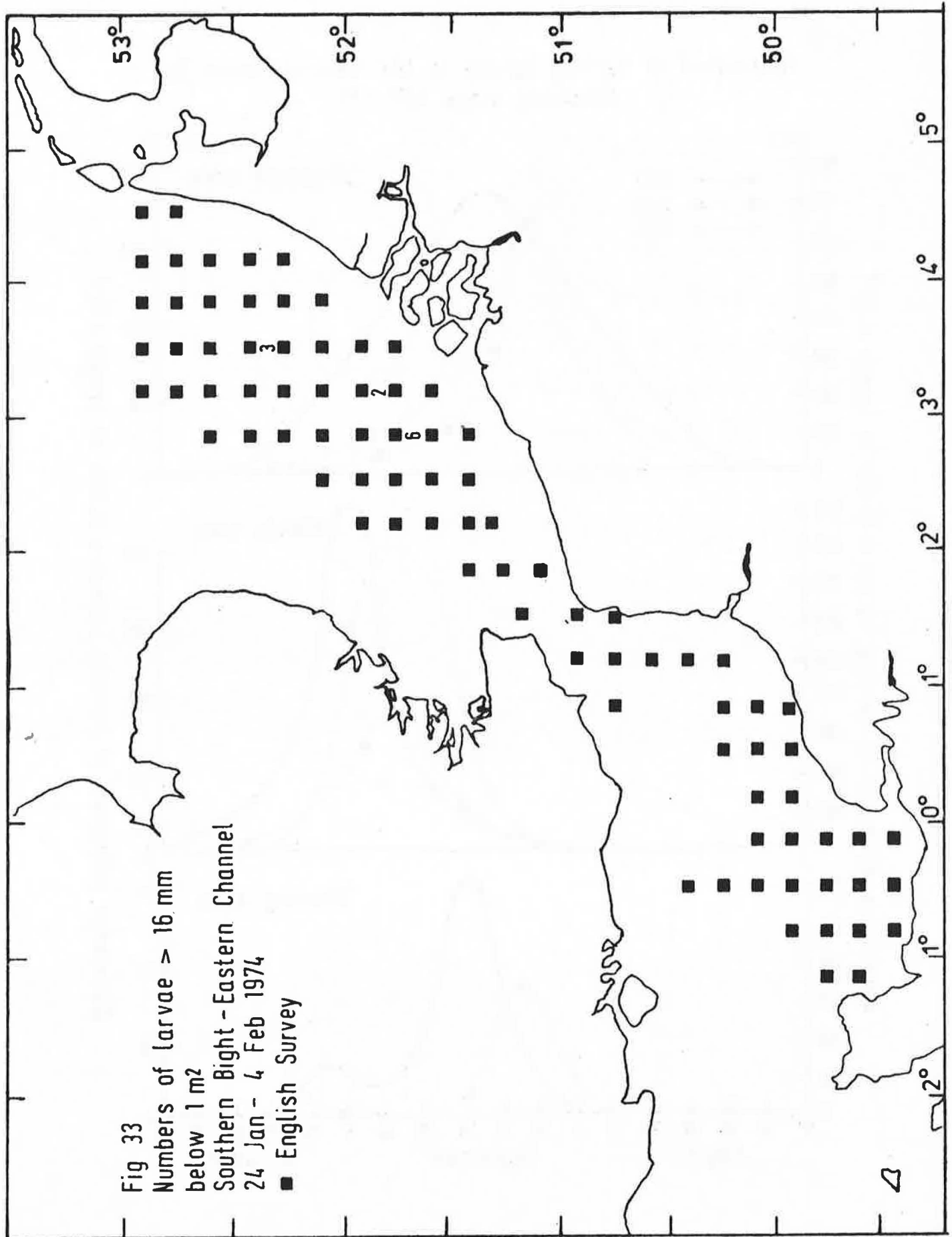
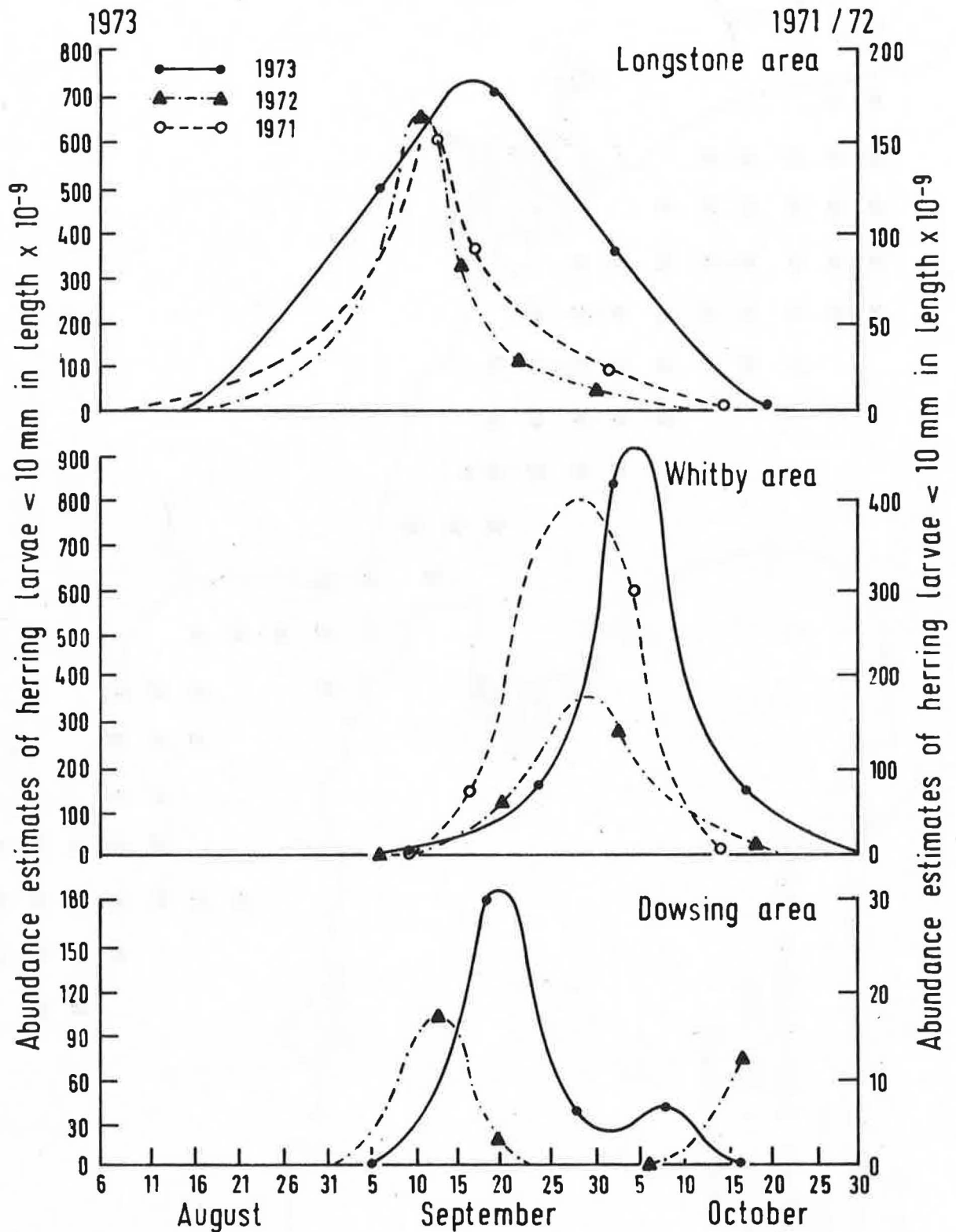


Fig 34
Production of herring larvae in the Central North Sea
Spawning areas 1971-73



II. THE DISTRIBUTION AND ABUNDANCE OF HERRING LARVAE TO THE WEST OF SCOTLAND IN 1973

by

D. W. McKay

Marine Laboratory, Aberdeen

SUMMARY

The results of herring larval surveys carried out to the west of Scotland in the autumn of 1973 are described. Larval densities were similar to those of corresponding surveys in 1972. The results are discussed in terms of numbers of larvae and in relation to the adult stock size in the area.

Comparisons have also been made between surveys carried out in early September by the RV "Corella" and RV "Scotia" and possible reasons for the differences are discussed.

INTRODUCTION

This report gives the results of the fourth survey 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 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) and Saville and McKay (1974 b).

MATERIAL AND METHODS

The spawning area of autumn-spawning herring in Area VIa as delineated by Wood (1971, 1973) was surveyed completely on two occasions. The surveys were carried out by the RV "Scotia" of the Marine Laboratory, Aberdeen, the first survey taking place during the period 11 to 20 September 1973 and the second during the period 27 September to 8 October 1973. On 9 October, nine stations were sampled to the north of Ireland as the beginning of a third survey. During the period 12 to 16 September 1973 the area north of 58°N was surveyed independently by the RV "Corella" of the Fisheries Laboratory, Lowestoft.

Samples were collected and analysed in the same ways as in the North Sea herring larval survey (Saville, 1970). Densities 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 of the two complete surveys carried out by RV "Scotia" are given in Figures 1-5. On the first survey larvae < 10 mm long were located in a broad belt extending from St. Kilda north and east to 4°W the eastern boundary of the survey area, with an area of high density, up to 715 larvae/m² surface, being found to the southwest of the Flannan Isles and extending north towards the Butt of Lewis. Secondary patches of newly hatched larvae were found north of Malin Head and west of Aran Island with maximum densities of 70 and 247 larvae/m² surface respectively.

The estimated numbers of larvae <10 mm long in the whole survey area was $2\,210 \times 10^9$ with $2\,016 \times 10^9$ (Table 1) being located north of $56^\circ 30'N$. Larvae in the 10-15 mm length range were found in two major patches, one to the west of the Isle of Lewis and the other larger patch extending north and east from the Butt of Lewis to the survey boundary at $4^\circ W$. The number of larvae in the 10-15 mm length range was estimated to be $2\,962 \times 10^9$. Larvae >15 mm long were only found in very small numbers at one or two stations and no estimate has been made of their abundance.

On the second survey high density patches of larvae <10 mm long were located in two areas, to the west of the Outer Hebrides and to the north and west of Ireland. To the west of the Outer Hebrides these patches were located from the Flannan Isles to the Butt of Lewis with a maximum density of 314 larvae/m² surface and to the west of North and South Uist with a maximum density of 226 larvae/m² surface. In the area to the north and west of Ireland patches of newly hatched larvae were located to the north of Malin Head with a maximum density of 389 larvae/m² surface and west of Aran Island, with a maximum density of 130 larvae/m² surface. Both of these patches were incompletely defined with the Aran Island patch being open to both the south and west and the Malin Head patch to the east. The total number of larvae <10 mm long in the surveyed area was estimated to be $2\,189 \times 10^9$, with $1\,665 \times 10^9$ being north of $56^\circ 30'N$. Larvae in the 10-15 mm length range were also widely distributed with the major concentrations being located west of the Outer Hebrides. Maximum densities of 363 larvae/m² surface and 296 larvae/m² surface, respectively, were obtained from patches to the east and west of the Flannan Isles. The estimated number of larvae in the 10-15 mm length range for the whole survey area was $2\,010 \times 10^9$. Larvae >15 mm long were rather scarce, being found mainly north and east of the Butt of Lewis, with an estimated total number of 145×10^9 (Table 1).

From the nine stations sampled on 9 October by the RV "Scotia" (Figures 6 and 7) very high densities, up to 1 882 larvae/m² surface, were obtained north of Malin Head. Due to the very limited coverage of the area no estimate of total larval abundance for this survey has been made.

The results from the RV "Corella" survey are given in Figures 8 and 9. A broad belt of larvae <10 mm long was located, extending from the Flannan Isles north and east to the eastern boundary of the survey at $4^\circ W$, with areas with a density of 832 larvae/m² being found in the vicinity of the Flannan Isles, and of 812 larvae/m² north of Cape Wrath. A patch of newly hatched larvae was also located in the North Minch, with a maximum density of 308 larvae/m² surface. The estimated number of larvae <10 mm long was high at $3\,584 \times 10^9$. Larvae in the 10-15 mm length range were present at lower densities over a similar area to the <10 mm long larvae with concentrations being found to the west of the Isle of Lewis and in the North Minch. The estimated number of larvae in the 10-15 mm length range was 813×10^9 (Table 2). No larvae >15 mm long were found.

DISCUSSION

(a) Annual variations in larval abundance and estimates of spawning stock size

In making comparisons between larval abundance in 1973 and those of previous surveys (Wood, 1971, 1973 and Saville and McKay, 1974b) it is necessary to group the estimates into comparable time periods and survey areas. These data are given in Tables 3 and 4 for areas north and south of $56^\circ 30'N$; they show that the larval abundance estimates for the northern part of VIa in late September/early October 1973 were very similar to those in 1972. If, however, the mean number of newly hatched larvae for all surveys is calculated for both years the 1972 figure, $3\,822 \times 10^9$,

is almost twice that of 1973, $2\,200 \times 10^9$. This is largely due to the survey in the first week of September 1972, which gave very high larval abundances and for which there was no comparable survey in 1973. Every effort should be made in the future to obtain a measure of larval production in the northern part of VIa in early September.

The most marked difference between the 1973 surveys and those of previous years occurred in the southern part of VIa (Table 4). In this area abundances of newly hatched larvae in both the 1973 surveys were of an order of magnitude higher than those of corresponding surveys in 1972. The September abundance estimates in 1973 were of the same order as the October ones in 1965 and 1971 (Wood, 1971, 1973). There were indications from the limited sampling carried out on 9 October that production of herring larvae in this area in 1973 may have been greater than in 1965 and 1971 as the larval densities obtained in some of these samples were considerably higher than those obtained in this area on any previous survey.

By comparing larval abundance data in VIa with similar data and spawning potential of stocks in the North Sea, Saville and McKay (1974b) estimated the spawning stock size in VIa in 1965 and 1971. Using the data on larval production and spawning potential for North Sea stocks given by Saville and McKay (1974b) estimates of stock sizes in VIa have been produced for those years for which there are larval abundance data (Table 5). For comparison estimates are given of the biomass of the spawning stock in each of these years, derived from the virtual population analysis of Saville and Morrison (1973 and personal communication) by calculating the number of survivors of the stock at 1 January to the time of spawning, and multiplying by the mean weight per age group at spawning.

The estimates from the virtual population analysis and those from the comparison of larval abundances in VIa and in the Northern/Central North Sea are as close as could be expected from the nature of the data. Both sets of data show an increase in the spawning stock size from 1965 to 1972 with a decrease in 1973. The size of the decrease in the estimates from larval abundance data may be greater than actually occurred because of the lack of an early September survey in 1973. If this early 1972 survey is omitted from the calculation of mean larval abundance the stock size estimates obtained for the 1972 stock by both comparisons are 630 000 and 417 800 tonnes, indicating that the stock in VIa in 1973 was slightly higher than that of 1972.

(b) Inter-ship variability

As stated earlier the area north of 58°N was surveyed during the period 11-16 September 1973, independently by the RV "Corella" and RV "Scotia". These surveys gave rather different estimates of larval abundance (Table 2). It is apparent from these data that although the two surveys gave similar estimates of total larval abundance the estimates for the component size groups show considerable differences. The RV "Corella" caught much larger numbers of <10 mm larvae than the RV "Scotia", while the RV "Scotia" caught more 10-15 mm long larvae than the RV "Corella", with the difference largely originating from sampling in the Cape Wrath area.

This could have been due simply to a time difference in sampling of the same area of the survey by the two ships but examination of the order of sampling the stations within the survey area has shown that the ships had a very similar pattern of operation. Further examination of the data has shown that the size distributions of the larvae caught by the two ships were markedly different with the RV "Corella" catching considerable numbers of larvae in the 5-7 mm length range while the RV "Scotia" caught very few larvae at 7 mm long and none ≤ 6 mm long. This could be associated with slight differences in the towing speeds. The RV "Scotia"

towing one knot faster, at 6 knots, than the RV "Corella" could have resulted in the smallest larvae being extruded through the meshes of the sampler used by RV "Scotia".

To test this the smallest categories of larvae were omitted from the RV "Corella" catches and the larval densities were plotted in Figure 10. Comparison of this with Figure 1 shows that the amended larval densities obtained by the RV "Corella" have even less similarity with those of the RV "Scotia" than those data given in Figure 8. It would therefore appear that although extrusion may occur it is not at a high enough level to explain the differences in the data.

It would therefore appear that the differences in larval abundances and size distributions were due to differences in sampling techniques or in the methods used to measure the larval lengths. To explain the discrepancies in larval size distributions fairly major differences in sampling techniques and larval distributions would be necessary whereas only small errors in the larval length measurements might cause such a difference.

In view of the differences and the fact that these ships and gears are widely used for herring larval surveys it would appear that comparative tests of the various sampling gears and the length measuring techniques should be carried out as soon as possible.

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Table 1. Estimated abundances of herring larvae on each complete survey in VIa in 1973. (Total for N and S of 56°30'N given separately).

Date	Survey area	Number of larvae x 10 ⁻⁹			
		<10 mm	10-15 mm	>15 mm	Total
11-20/9/73	N of 56°30'N	2 016	2 553	-	4 569
	S of 56°30'N	194	47	-	241
	55°N - 59°30'N	2 210	2 600	-	4 810
27/9 - 8/10/73	N of 56°30'N	1 665	1 779	142	3 586
	S of 56°30'N	524	231	3	758
	55°N - 59°30'N	2 189	2 010	145	4 344

Table 2. Estimated abundances of herring larvae N of 58°N during the period 11-16/9/1973 by RV "Scotia" and RV "Corella".

Date	Survey ship	Number of larvae x 10 ⁻⁹		
		<10 mm	10-15 mm	Total
11-16/9/73	"Scotia"	1 917	2 503	4 420
12-16/9/73	"Corella"	3 584	813	4 397

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

Time periods	Estimated abundances x 10 ⁻⁹											
	<10 mm				10-15 mm				Total			
	1965	1971	1972	1973	1965	1971	1972	1973	1965	1971	1972	1973
1-10/9	NS	ND	7 691	NS	NS	ND	669	NS	NS	3 267 ¹⁾	8 360	NS
11-25/9	NS	NS	1 334	2 016	NS	NS	1 350	2 553	NS	NS	2 773	4 569
26/9-10/10	NS	NS	2 388	1 665	NS	NS	2 122	1 779	NS	NS	4 586	3 586
10-25/10	415 ²⁾	319	NS	NS	ND	ND	NS	NS	1 330 ²⁾	1 037	NS	NS

NS = no survey

ND = no data

1) incomplete survey including yolk-sac larvae

2) including Minches

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

Time periods	Estimated abundances x 10 ⁻⁹											
	<10 mm				10-15 mm				Total			
	1965	1971	1972	1973	1965	1971	1972	1973	1965	1971	1972	1973
11-25/9	NS	NS	21	194	NS	NS	29	47	NS	NS	51	241
26/9 - 10/10	NS	NS	31	524	NS	NS	21	231	NS	NS	57	758
10-25/10	504	677	NS	NS	ND	ND	NS	NS	807	940	NS	NS

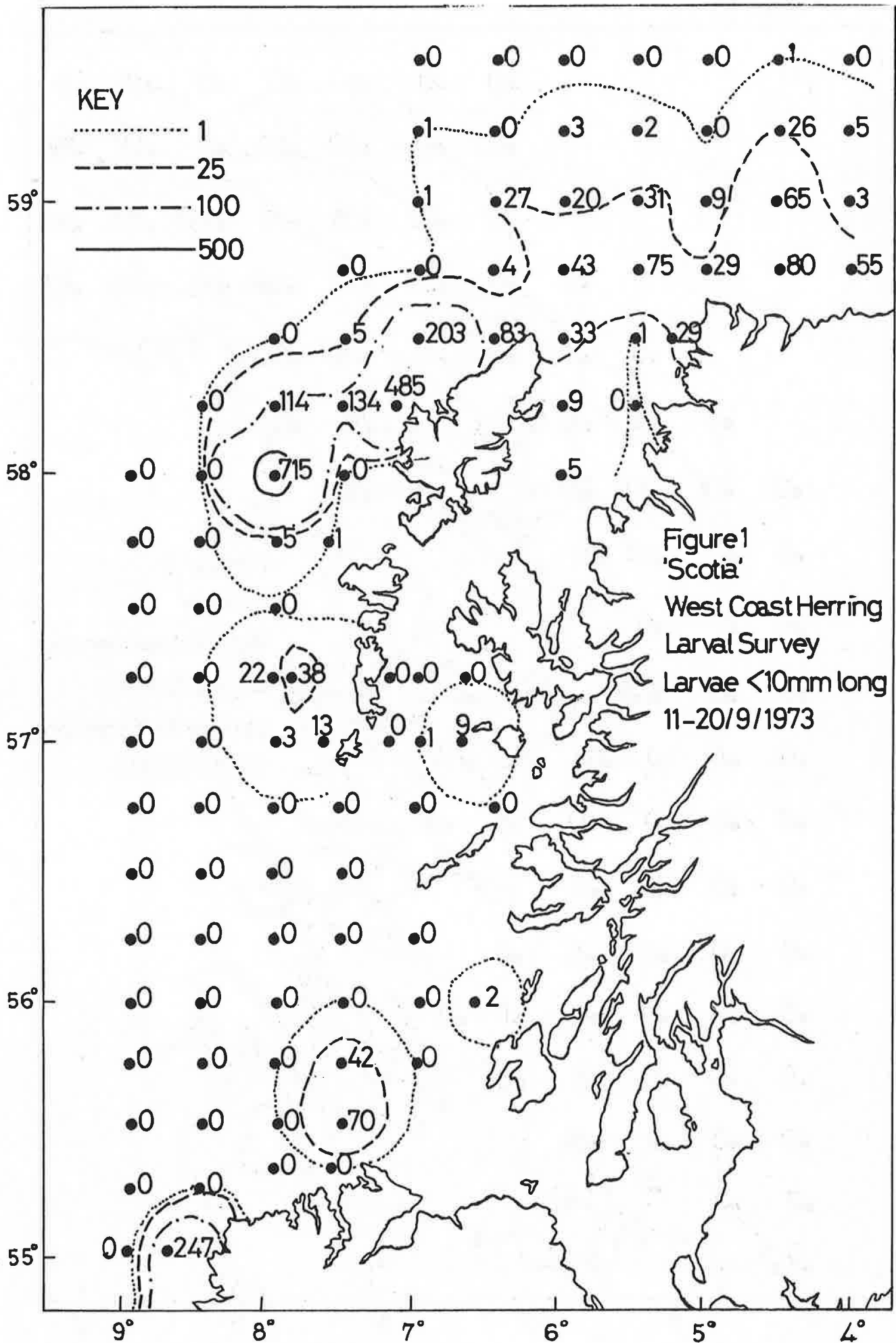
NS = no survey

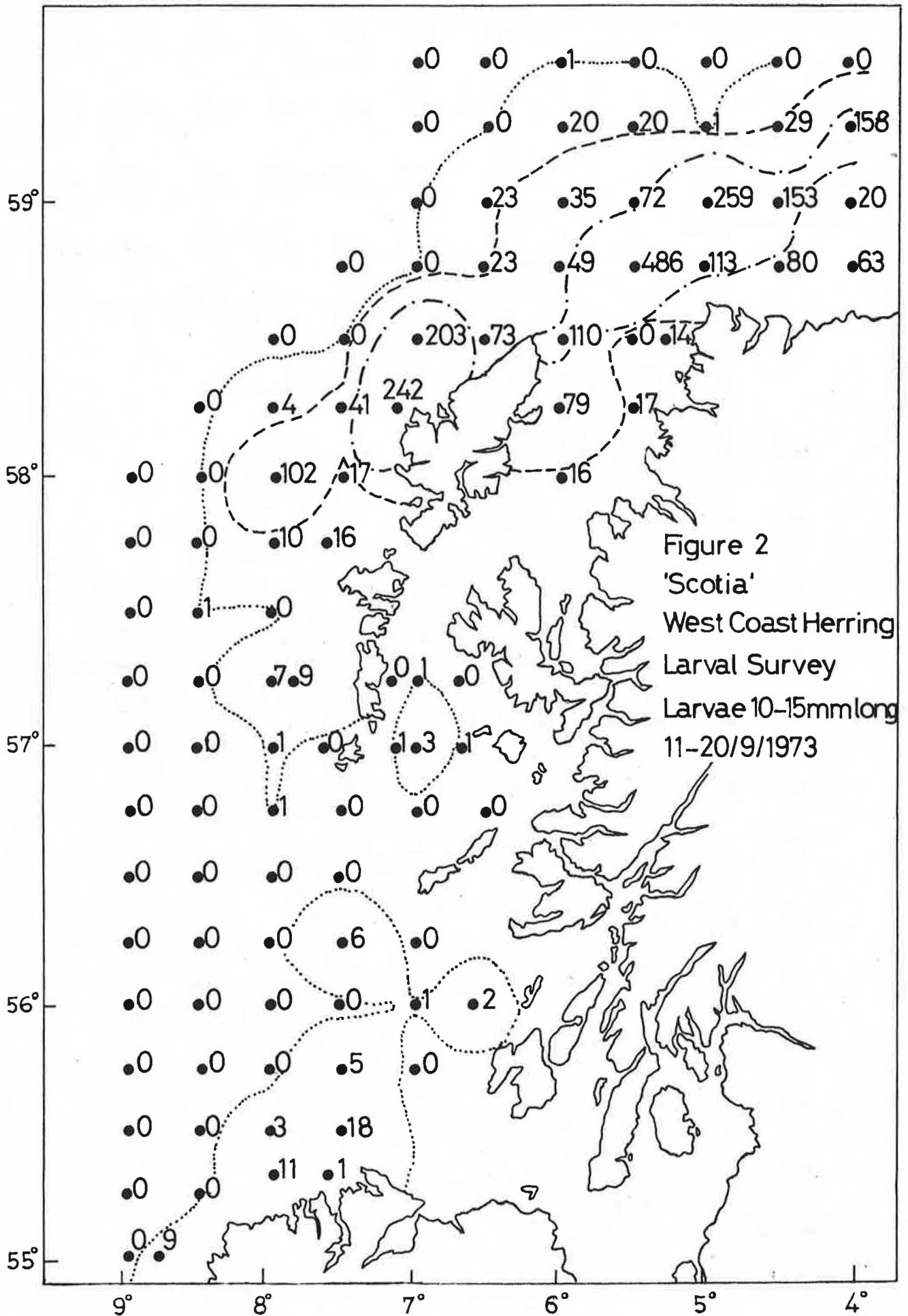
ND = no data

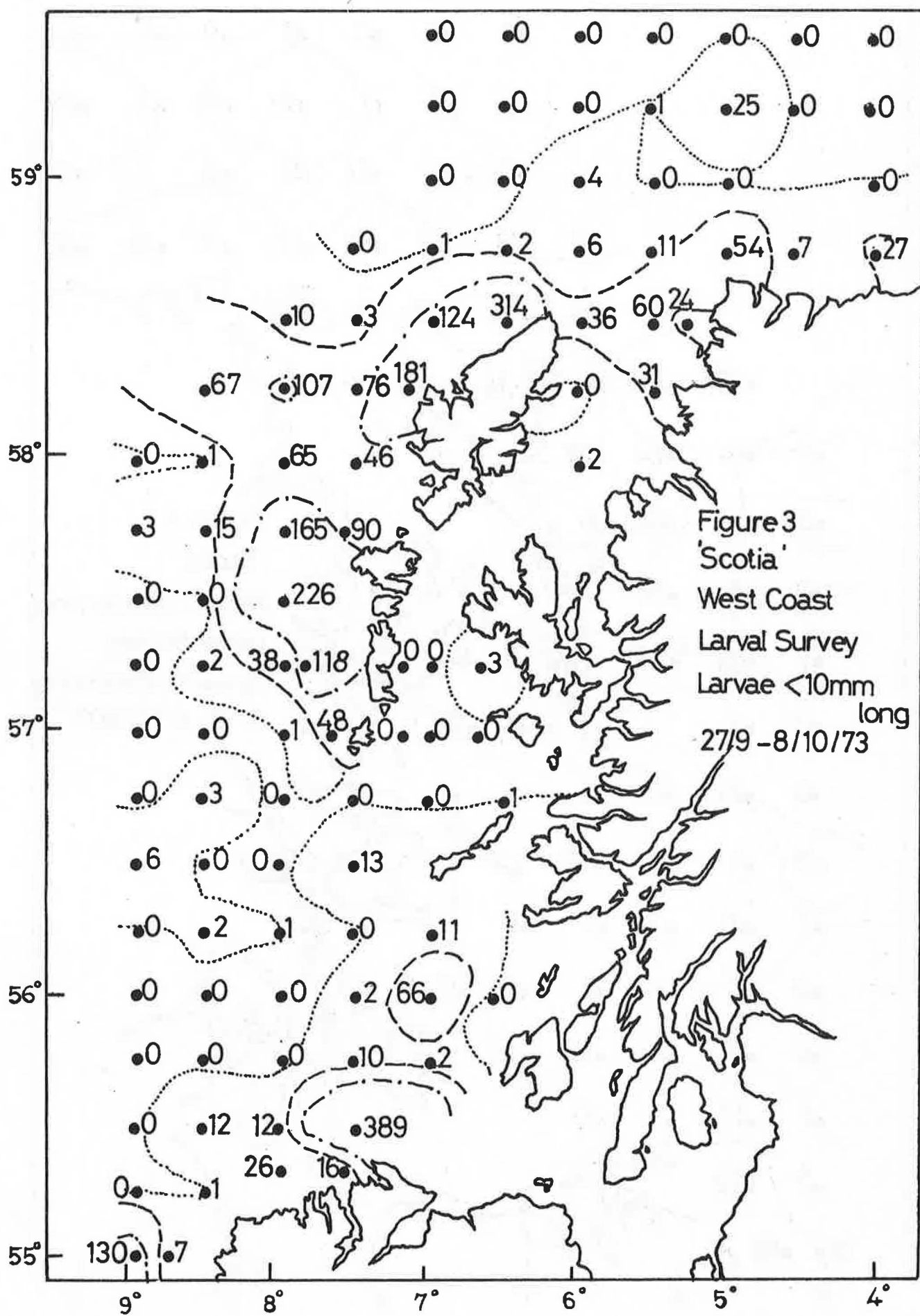
Table 5. Estimated spawning stock size in tonnes in VIa in 1965, 1971, 1972 and 1973.

Year	Period/Area comparison	Estimated spawning stock size in VIa (tonnes)	
		From larval abundances	From VPA
1965	Central/Northern North Sea 1957-60	227 500*	231 700
1965	Central/Northern North Sea 1961-64	150 800*	
1971	Central/Northern North Sea 1957-60	371 000*	330 200
1971	Central/Northern North Sea 1961-64	220 500*	
1972	Central/Northern North Sea 1957-60	1 276 300	825 000
1972	Central/Northern North Sea 1961-64	846 100	
1973	Central/Northern North Sea 1957-60	734 600	583 000
1973	Central/Northern North Sea 1961-64	487 100	

* Estimates from Saville and McKay (1974b).







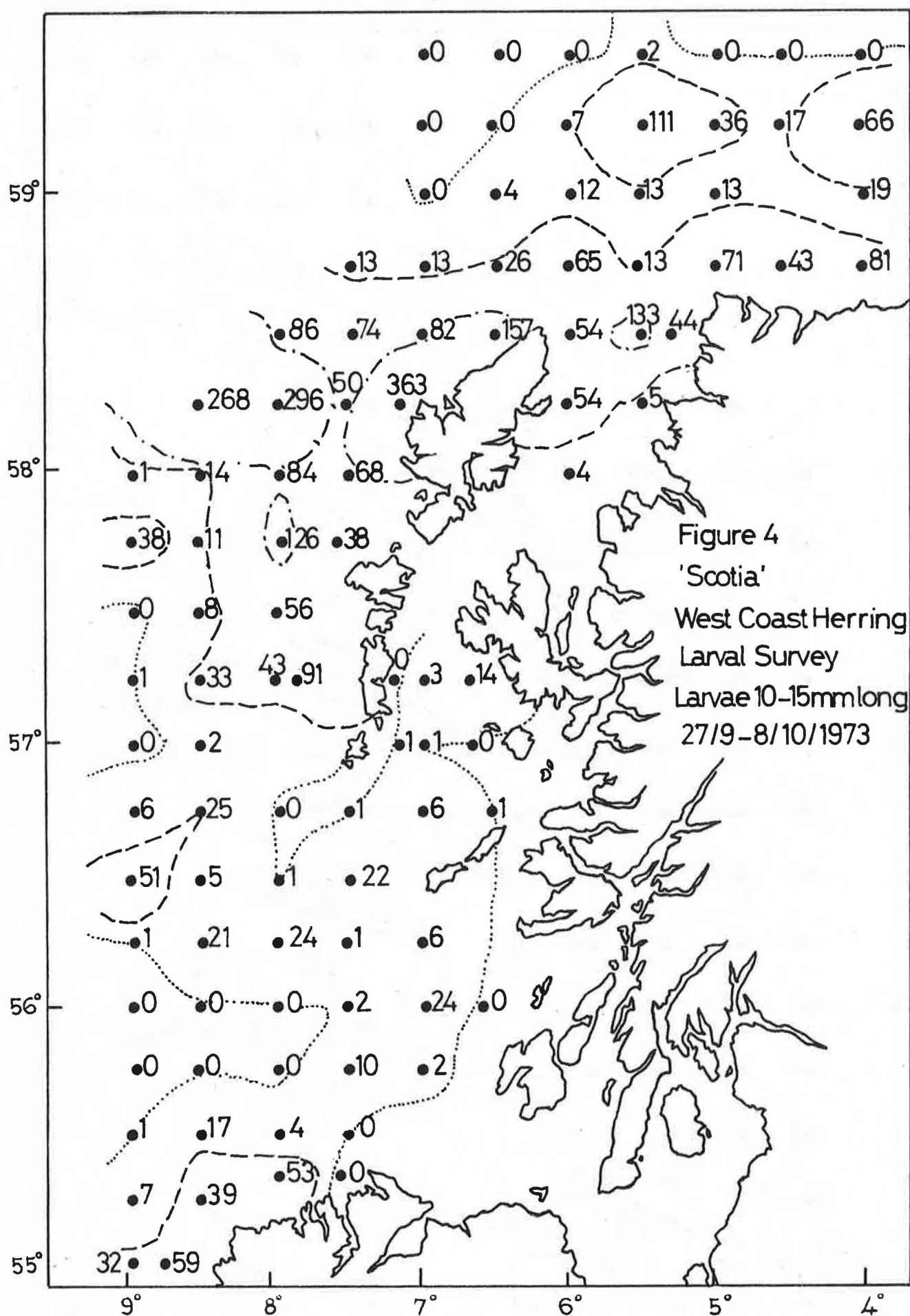
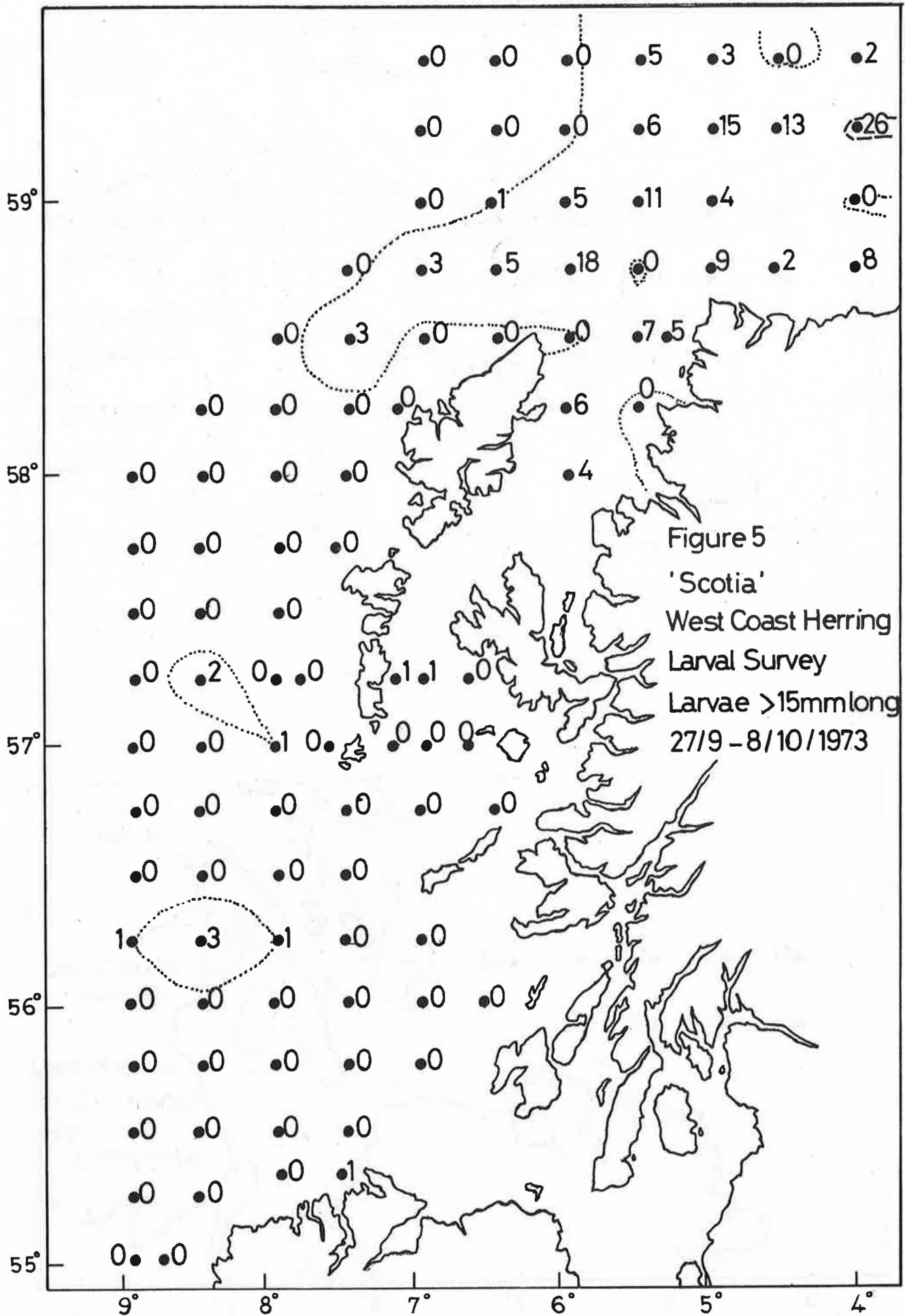
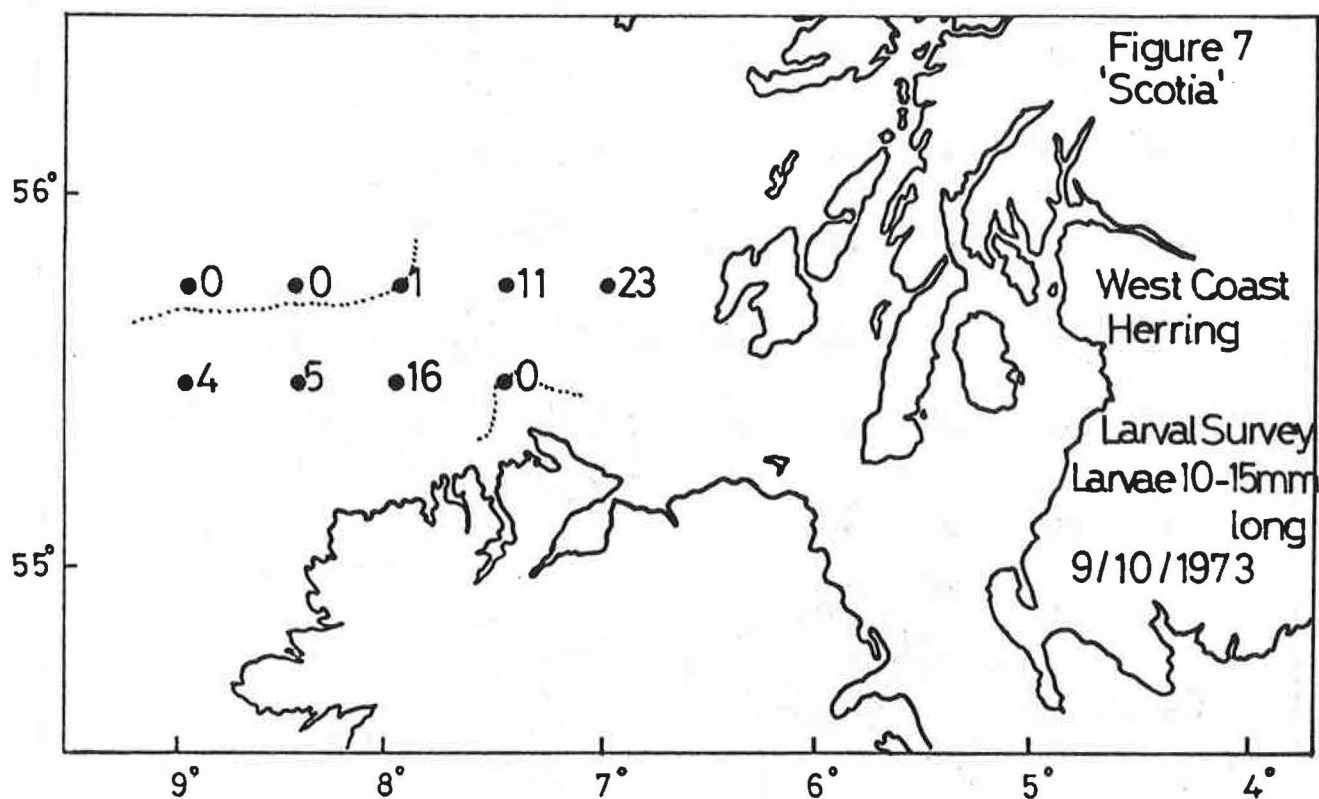
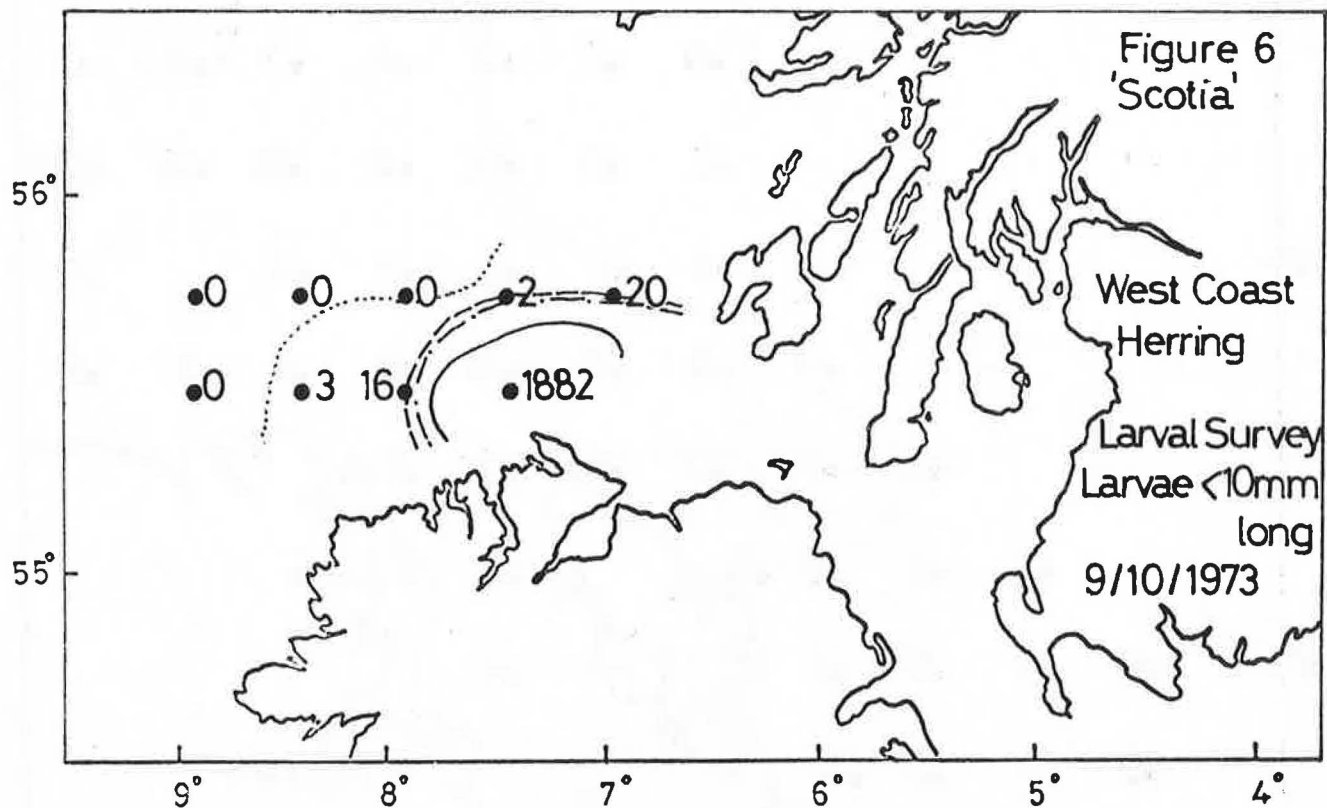
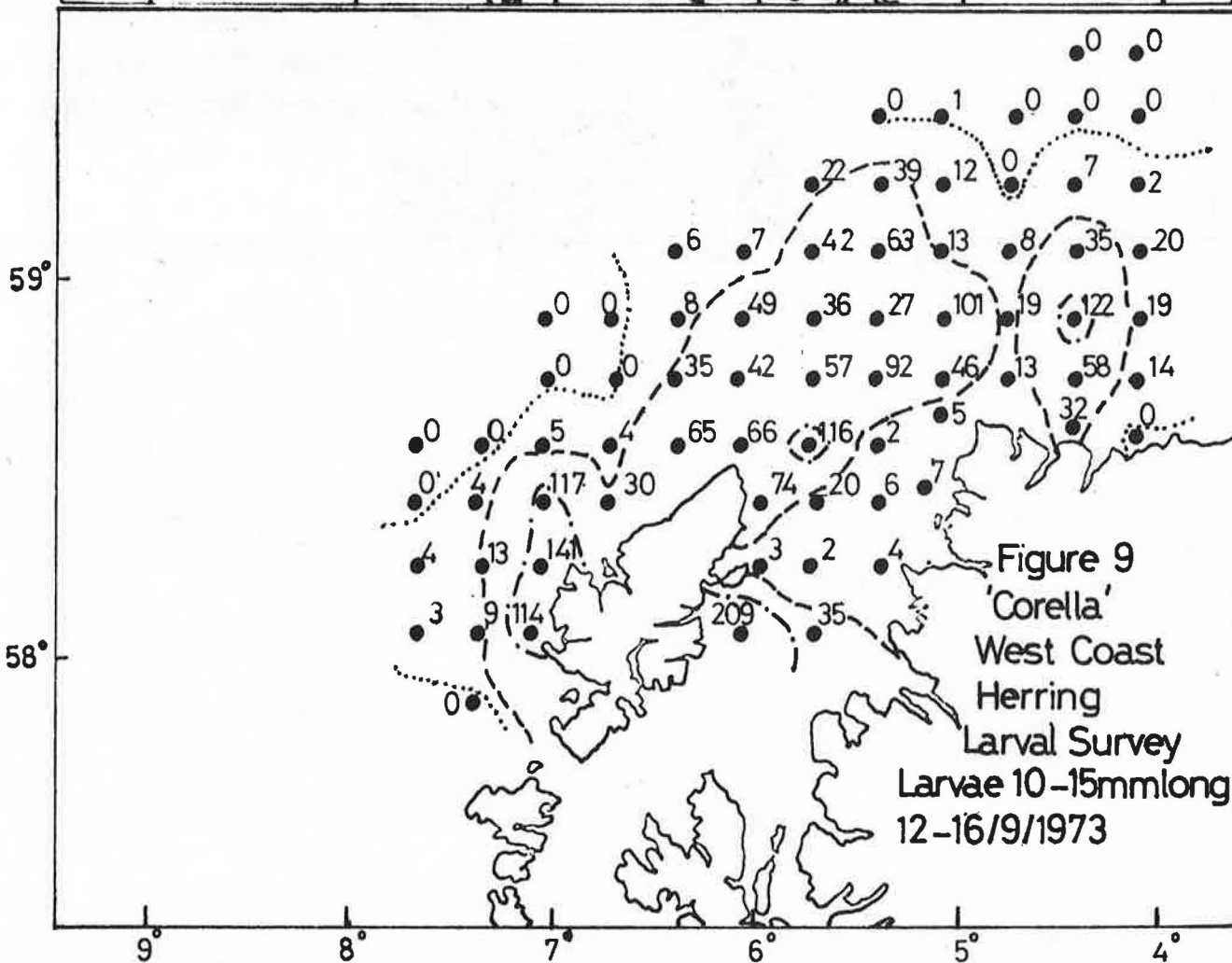
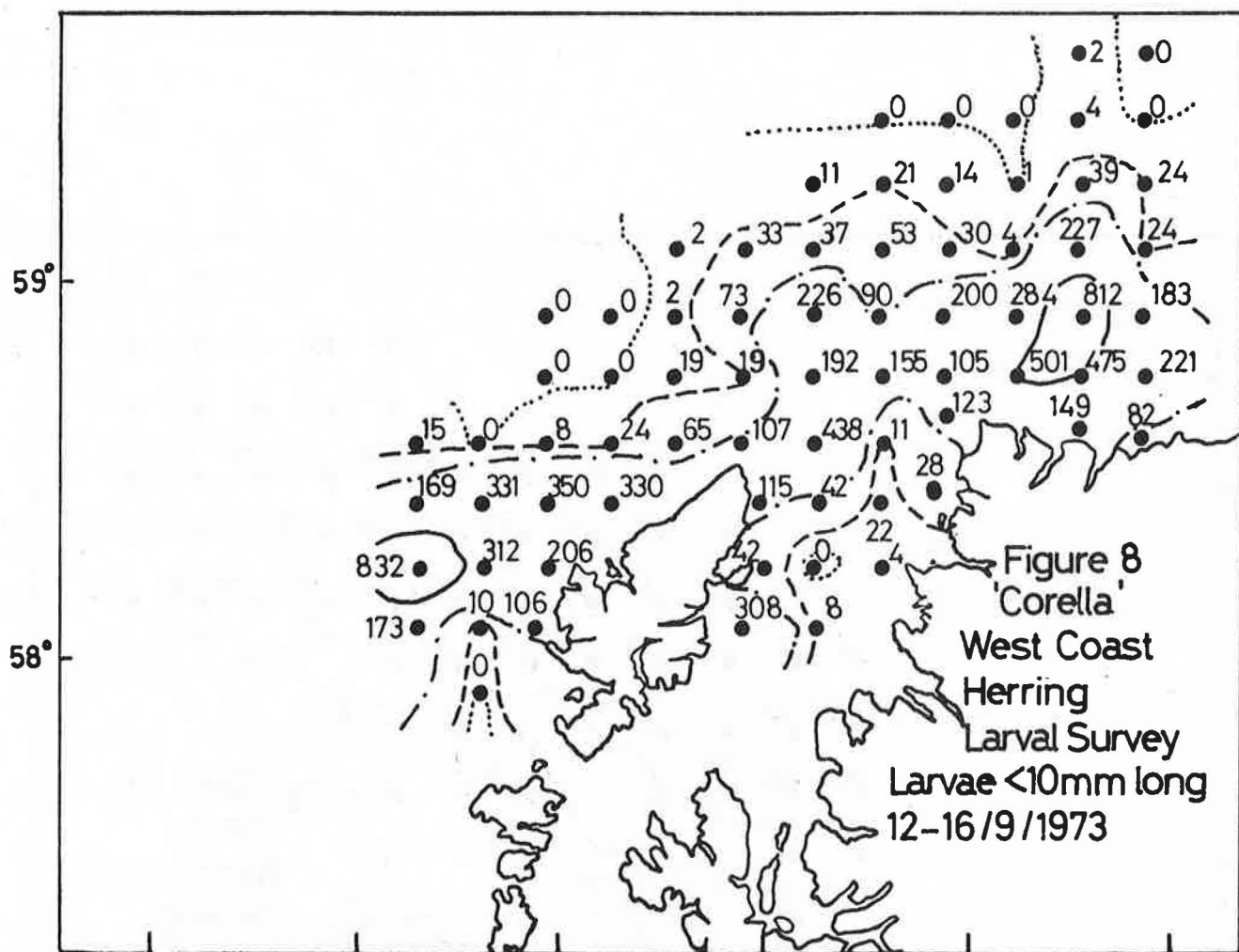
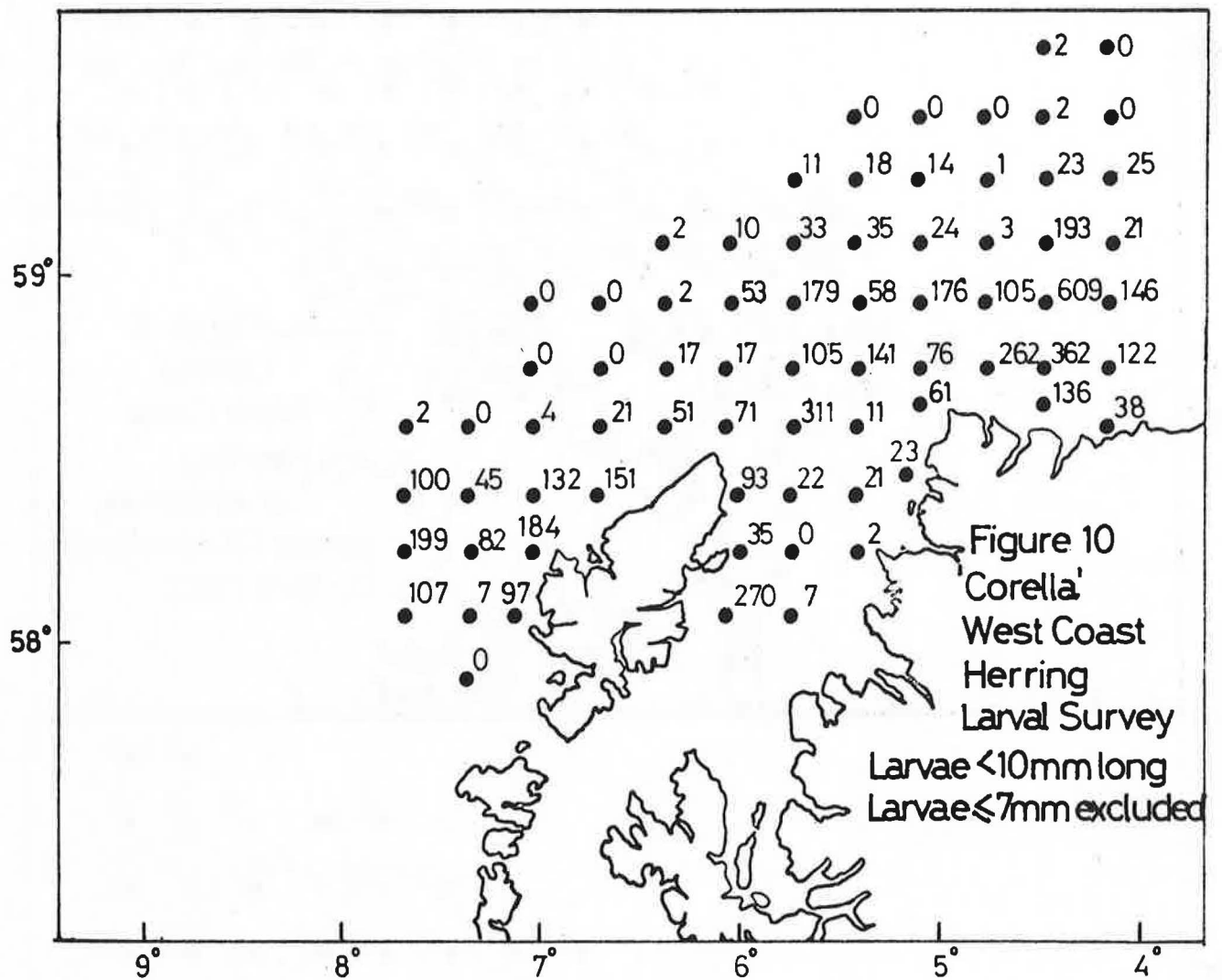


Figure 4
'Scotia'
West Coast Herring
Larval Survey
Larvae 10-15mm long
27/9-8/10/1973









III. ABUNDANCE AND DISTRIBUTION OF HERRING LARVAE IN THE NORTHERN
NORTH SEA AND ADJACENT WATERS IN 1973

by

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INTRODUCTION

The investigations on herring larvae abundance which have been performed since 1962 were continued in 1973 during a cruise of FRV "Eisbär".

A research programme agreed upon with the Peoples Republic of Poland and the Soviet Union for investigation of the herring larvae abundance in the most important spawning areas along the east coasts of Scotland and England started in 1963 and has been continued with only a single interruption (we were unable to investigate the herring larvae abundance in 1972) until the present time.

The results of our work from 1962 to 1967 were published by Hyronimus in 1971, those for 1969 by Schultz and Hahlbeck in 1970 and those for 1970 and 1971 by Hahlbeck in 1973. These publications and the present paper deal exclusively with the results of our contribution to the joint programme.

The aim of the investigations is to clarify the problem of recruitment and to contribute towards assessment of the future year classes.

This paper deals with the abundance and distribution of herring larvae in 1973.

MATERIAL AND METHODS

During a cruise in the northwestern North Sea and west of the Orkneys and Shetland Isles (ICES Divisions IVa and partly VIa), ichthyoplankton stations were sampled during the period 13 to 24 September by the "Hai" plankton sampler, and, for comparison, also by a ring trawl at 13 stations. Only the catches obtained with the "Hai" are shown in the Tables and the Figures.

Table 1. Date of investigations and number of stations.

Date	Area	No. of Stations	Mean number of herring larvae/m ² and station
18-20 Sep	Eastern Orkneys (South of Fair Isle)	39	5
21-24 Sep	Northwest Orkneys	34	53
13-17 Sep	Aberdeen Bank	24	0

The "Hai" stations were sampled day and night (Gulf III plankton sampler from Messrs. Hydrobios, Kiel, with Monodur net, mesh size: 315 μ between filament centres; yarn thickness: 120 μ ; metal net used only on Aberdeen Bank, mesh size: 355 μ ; wire thickness: 224 μ).

The herring larvae investigations were performed by the usual oblique hauls using the "Hai". The speed of the ship was 5 nm. The "Hai" was towed mainly by means of a wire rope with a diameter of 10 mm and the mean hauling and lowering speed was 0.66 m/s.

The depth of the "Hai" was recorded at all stations. On the Aberdeen Bank, the sampler was equipped with a transducer from a net sounder which was connected to the ship by a cable in order to check the depth. The simultaneous use of a wire rope and a net sounder cable reduced the stability of the "Hai". Steady sampling at all depths was not possible at all times owing to the different hauling speeds of the cable and trawl winches.

In the other working areas with the majority of the stations sampled during the cruise, the Japanese cableless depth meter (FURUNO) was used. The speed of the ship and the duration of the haul were used as a basis for calculating the quantity of water fished.

The unknown filtration rate of the "Hai" has, in the past, hindered sufficiently good quantitative analyses.

The installation of a flow meter (200 mm in diameter) in the inlet opening of the "Hai" in 1974 will introduce a new quality in the future evaluation of catches obtained by this sampler. The flow meter is calibrated by a fluid flow calibration device.

The area of the "Hai" opening, and thus the cross section of the water body fished, is 0.027 m^2 . Provided that no pressure wave is formed before the net opening, 50.0 cbm of water are filtered while towing over one nautical mile.

The areas of the regions with abundances of 1-9, 10-19, 20-29, 30-39, 40-49, 50-59, 60-69, larvae were measured by planimetry. The abundances are shown in the Figures in the categories 1-9, 10-49, 50-250 and above 250 for reasons of clarity. The total number of larvae was calculated by multiplying the measured area by the mean number of larvae in the region concerned.

The numbers of larvae were calculated and drawn separately for the three size groups $<10 \text{ mm}$, $10-15 \text{ mm}$ and $>15 \text{ mm}$ and were summed to obtain the total number of larvae caught.

RESULTS

Figure 2 shows the position of the stations in the investigated area together with the total number of larvae per m^2 .

The highest larvae abundances were found, as for the last several years, to the west and northwest of the Orkneys. The larvae were concentrated mainly to the west of the Orkneys where they formed a single continuous area with a single concentration. They were found further to the west than in 1970 and 1971.

This was augmented in 1973 by a conspicuously dense distribution northwards of the Orkneys. The proportion of larvae $>15 \text{ mm}$ was conspicuously larger there than in the area to the west of the Orkneys.

Less herring larvae were found in the region of Moray Firth than in 1971. The larvae there generally exceeded 15 mm in length. On the Aberdeen Bank, where numbers worth mentioning were found in 1971 for the first time, no herring larvae were caught in 1973.

Figure 1 gives an impression of the length distribution of the herring larvae. The mean length differs only significantly in the sub-areas to the south of Fair Isle and to the northwest of the Orkney Isles. Most larvae in the area with the highest abundance (northwest Orkneys)

reached a length of 11-13 mm; this also applied to the area south of Fair Isle (mean length: 12.4 mm) where the abundance was not so high.

Larvae of all size classes (Figures 2b-2d) were found in the West Orkneys-Shetlands areas. Small larvae were found primarily in the northern part of the area investigated.

The majority of the larvae belonged to the medium-sized group which formed the largest size group throughout the area investigated except in the Moray Firth region.

Small quantities of large larvae in noteworthy concentrations were found north of the Orkneys and in the Moray Firth. More larvae were found south of Fair Isle than in 1971. The assumed drift can be seen in Figures 2a-2d.

DISCUSSION

Table 2 shows the estimates of the herring larvae occurrence in the three size groups and sub-areas for 1973 together with the estimates from 1969 and 1971 for comparison.

Compared with 1971, a noteworthy improvement in the larvae abundance can be seen, particularly as a result of the additional area with a high abundance north of the Orkneys. The numerical values for the abundance in the northwest Orkneys area (see Table 2) differed considerably from those for 1971. Our investigations in 1973 found the highest abundances since 1969, although it should be noted that we were unable to investigate the larvae during 1972. Despite this improvement, the abundance should not be assessed as above average. It should also be remembered that, according to Nellen and Hempel (1969), the nylon net used in the "Hai" for the first time in 1973, has better fishing properties than the metal net. Compared with the results of the ICES 1972 programme (Saville and McKay, 1974), the abundances in 1973 were lower than in 1972.

Wood (1971) suggested that the larvae occurring in the ICES Division VIa west of the Orkneys and Shetlands should be separated from the larvae in the northwestern North Sea (Division IVa).

It has not been possible to solve this problem by means of our investigations which in 1971 and 1973 went beyond 4°W.

In 1971, the distribution of the larvae west of the Orkneys covered a continuous area with a pronounced concentration region. The small and medium-sized larvae forming the larger part of the larvae were more numerous in the eastern part of this concentration area.

The concentration west of the Orkneys was also strongly pronounced in 1973, but it was located further to the west than in 1970 and 1971 and, at the boundary of the region, merged with the conspicuously dense occurrence north of the Orkneys. The proportion of larvae >15 mm is also conspicuously larger in this area than to the west of the Orkneys. The small and medium-sized larvae forming the major part of the abundance indicate that a spawning ground exists in the western part of this area of concentration.

Table 2. Total number ($\times 10^{-9}$) of herring larvae in the investigated area of the North Sea and adjacent waters.

	Period	Number of Stations	<10 mm	10-15 mm	>15 mm	Total
Total	14.9 - 5.10.69	105	34	365	149	548
East Orkneys	17.9 - 20.9.69	38	6	39	4	49
Aberdeen Bank	14.9 - 16.9.69	24	-	-	0.4	0.4
NW Orkneys	27.9 - 3.10.69	21	27	324	121	472
E.Shetlands/ E. Fair Isle	3.10 - 5.10.69	22	0.6	2	24	26.6
Total	16.9 - 28.9.71	102	163	521	92	776
East Orkneys	16.9 - 23.9.71	44	32	58	51	160
Aberdeen Bank	21.9 - 23.9.71	18	6	69	-	74
NW Orkneys	25.9 - 28.9.71	40	125	394	41	542
Total	13.9 - 24.9.73	97	193	1 474	144	1 734
East Orkneys (S.Fair Isle)	18.9 - 20.9.73	39	7	262	44	299
Aberdeen Bank	13.9 - 17.9.73	24	-	-	-	-
NW Orkneys	21.9 - 24.9.73	34	186	1 212	100	1 435

It may be concluded that larvae populations of different origin can merge in the ICES Division IVa in some years, but that they do not merge regularly. This problem will receive further attention in future investigations.

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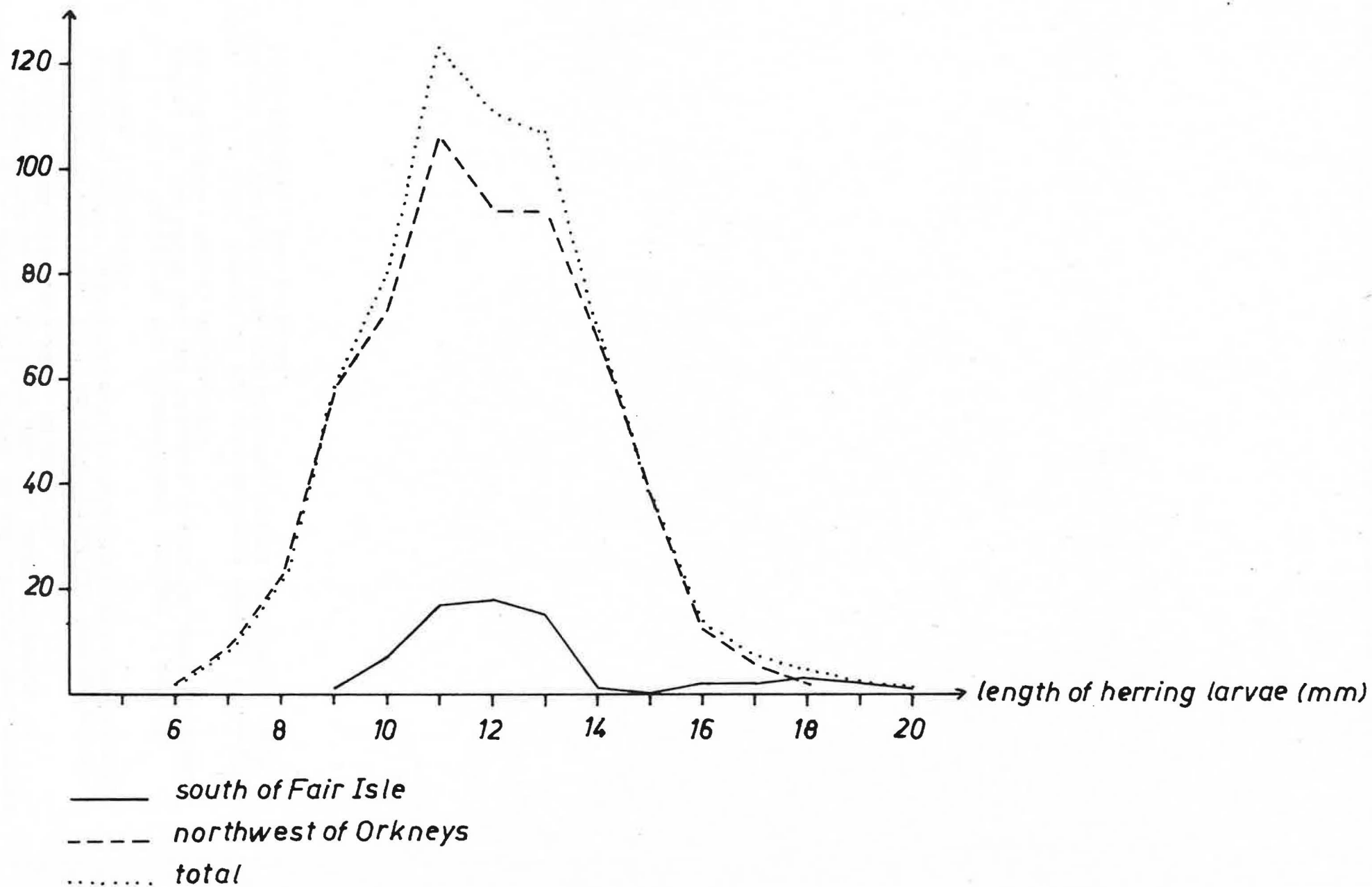
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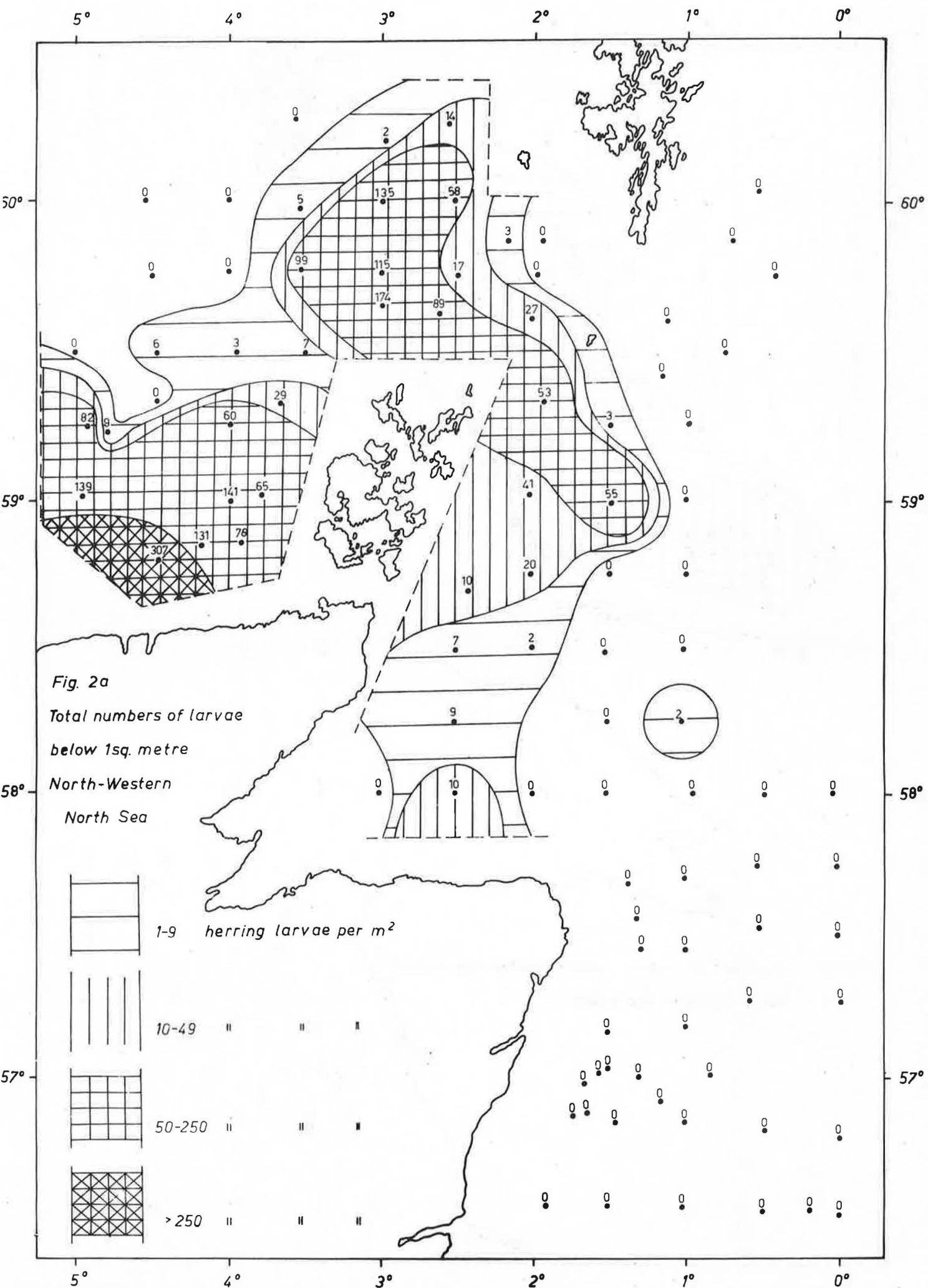
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*herring larvae
numbers*

Fig.1: Length distribution of herring larvae 1973

- 60 -





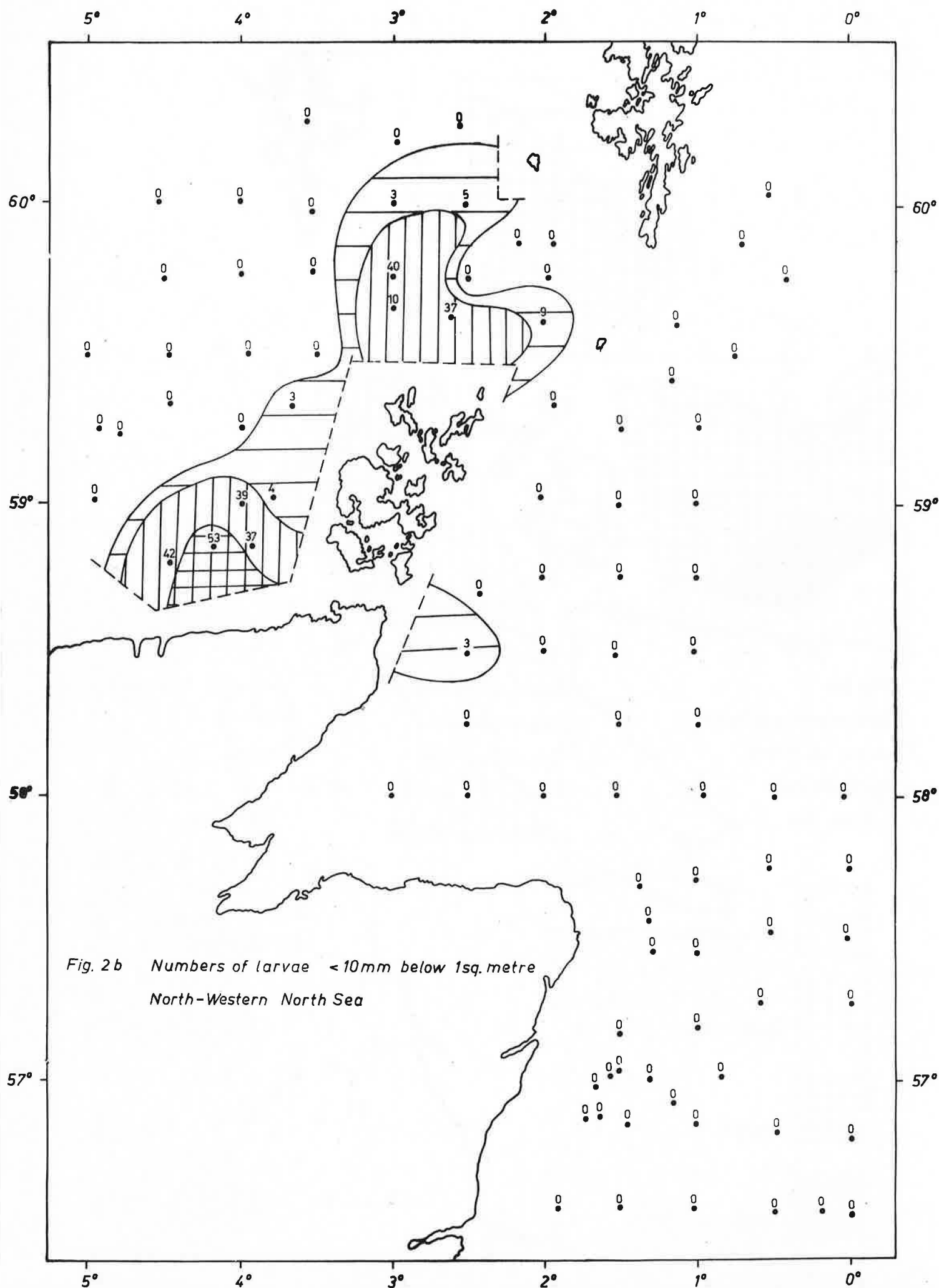


Fig. 2 b Numbers of larvae <10mm below 1sq. metre
North-Western North Sea

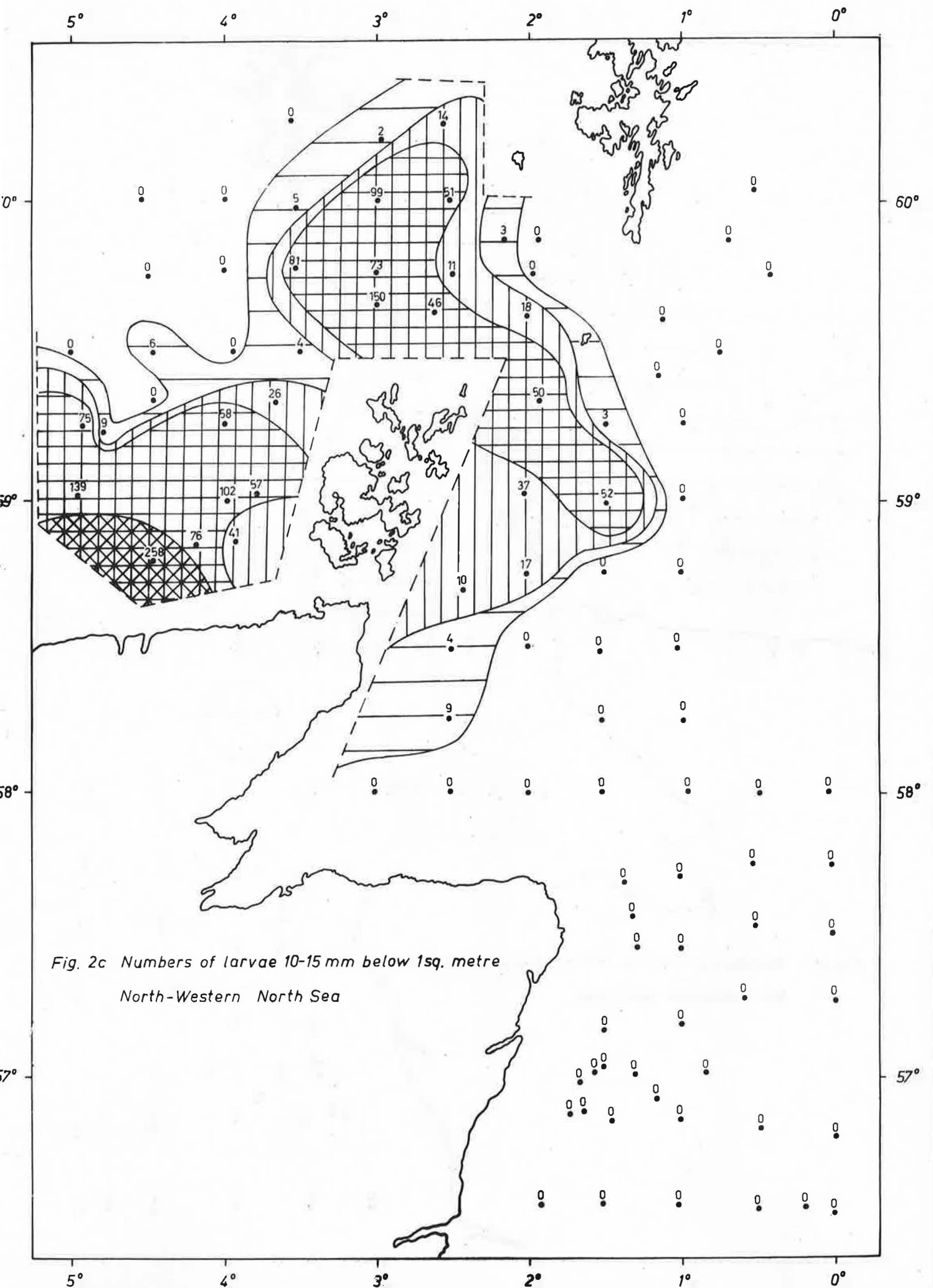


Fig. 2c Numbers of larvae 10-15 mm below 1sq. metre
North-Western North Sea

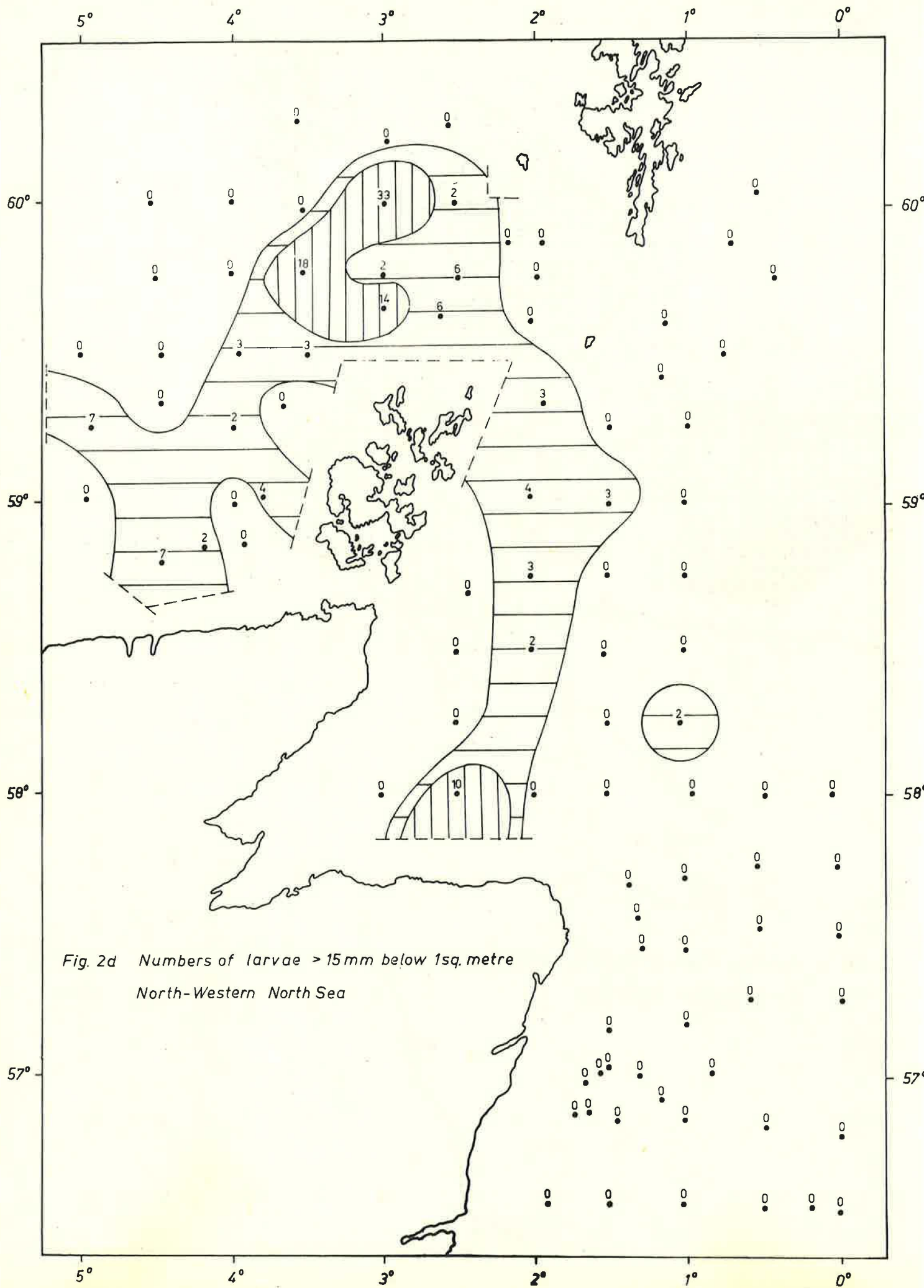


Fig. 2d Numbers of larvae > 15mm below 1sq. metre
North-Western North Sea

