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HERRING LARVAE SURVEYS IN THE NORTH SEA AND ADJACENT WATERS, 1977/78

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REPORT ON THE INTERNATIONAL SURVEYS OF HERRING LARVAE IN THE NORTH SEA AND ADJACENT WATERS, 1977/78

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Summary

The results of the 11th International Survey of Herring Larvae in the North Sea and Adjacent Waters, which was carried out during 1977/78, are presented.

They indicate a marked increase in larval production in both the northwestern and central North Sea compared with the previous two years. Some increase was also apparent in the Buchan area and in the southern North Sea/eastern Channel, although overall in these latter areas production was still at a relatively very low level.

The spawning stock size of herring in the northwestern and central North Sea, as estimated from sub-area regressions of larval abundance on spawning stock size is 136 733 tons. It is likely that in addition a further 25 000 tons of herring spawned in the southern North Sea/eastern Channel.

The catches of herring larvae taken by different countries were compared. It was found that there was no evidence of a significant difference in the catches of the critical < 10 mm size category.

Résumé

Les résultats du onzième inventaire international des larves de hareng en Mer du Nord et dans les eaux voisinantes, qui fut effectué en 1977/78, sont présentés.

Ils indiquent une nette augmentation de la production larvaire aussi bien dans le nordouest que dans le centre de la Mer du Nord par rapport aux deux années précédentes. On enregistre également un certain accroissement dans le secteur de Buchan et en Mer du Nord méridionale/Manche orientale, bien que globalement la production larvaire dans ces dernières régions soit relativement restée à un niveau très bas.

La taille du stock de harengs géniteurs dans le nordouest et le centre de la Mer du Nord estimée d'après les regressions par sous-secteur de l'abondance larvaire sur la taille du stock de géniteurs est de 136 733 tonnes pour ces deux régions combinées. Il est probable qu'en complément environ 25 000 tonnes de hareng se sont reproduites dans le sud de la Mer du Nord et en Manche orientale.

Les captures de larves de hareng réalisées par plusieurs pays ont été comparées aux données obtenues quand deux navires de recherches ou plus travaillerent dans un secteur à la même période. Il en ressort qu'aucune différence significative dans les captures de la catégorie critique de taille < 10 mm n'a pu être établie.

Introduction

This report describes the results of the 11th international survey of herring larvae carried out in the North Sea and adjacent waters in 1977/78. These surveys have been carried out annually since 1967 and are intended to provide measures of changes in the North Sea herring spawning stocks - measures which are independent of fishery data.

Results of the previous surveys are published in Saville (1970), Boëtius and McKay (1970), Wood (1971), Zijlstra (1972), Schnack (1973), Saville and McKay (1974), Wood (1975), Pommeranz (1977), and Saville and McKay (1979).

Material and Methods

During the autumn and winter of 1977/78 seven countries participated in the surveys and contributed a total of nine research vessels. The timing of each survey which was carried out in each area is given in Table 1 together with the number of stations worked. 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 in Saville (1970) and Anon. (1977a). From August 1977 until January 1978 a total of 1 212 stations was sampled. The results, recorded as numbers of herring larvae beneath one square metre (m^2) of sea surface at each station, 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) are shown in Figures 1-39.

The size groups are, as in earlier reports, <11, 11-16, >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 been omitted in calculating abundance estimates (Anon., 1971). Abundance estimates were calculated in a similar manner to that of Schnack (1973) and Wood (1975) *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. Where the results of two or more individual surveys have been combined for a single time period the mean number of larvae has always been used in the calculations, in all cases where a station was sampled more than once during that period.

Results - Distributions

Orkney-Shetland

There was a very good coverage of this area in autumn 1977 with a total of six surveys between 31 August and 6 October. During the first half of September three surveys were carried out, all covering very similar areas (Figures 1-9). Although an extensive area of major herring larval production was surveyed very intensively, it is rather unfortunate that it was not possible to extend the coverage further to the north and west. Major concentrations of recently hatched larvae, <10 mm in length, were found between Orkney and Shetland, south of Fair Isle and to the west of Shetland, while smaller concentrations occurred to the north and west of Orkney (Figures 1, 4 and 7). The highest station density of herring larvae <10 mm in length at this time ($568/m^2$) was found some 15 miles southwest of Shetland (Figure 4), but several of the most northerly and westerly stations which were worked also contained appreciable numbers of larvae of this size

category. Thus the area of distribution was not completely covered in spite of the very considerable sampling effort deployed.

Larger larvae, 10-15 mm in length, were unusually abundant during early September (Figures 2, 5 and 8). The main concentrations extended in a band southwards from Shetland for some 90 miles, with the highest station density of 920/m^2 about 23 miles southwest of Shetland. Assuming a growth rate of some 0.25-0.35 mm/day (Wood and Burd, 1976), the lengths of these larvae indicate a substantial amount of hatching during the last two weeks of August 1977. The distribution of the largest larvae, >15 mm in length (Figures 3, 6 and 9), was fairly similar to that of the 10-15 mm category. Station densities were low, the maximum being 23/m^2.

Three further surveys were carried out in the Orkney/Shetland area during the period 18 September to 6 October 1977 (Figures 13-21). Abundances of recently hatched larvae <10 mm in length (Figures 13, 16 and 19) were very much lower than during the first half of September. The main concentration of larvae of this size occurred to the west of Scotland round the Island of Foula, although a few stations with relatively high larval densities were also found off Clythness in the Moray Firth. Between 3 and 6 October two concentrations of newly hatched larvae were located to both the east and southwest of Orkney (Figure 19) with a maximum density of 216/m^2. As in the first half of September, the area of distribution of the recently hatched <10 mm larvae was not completely covered. As was to be expected following the high herring larval production in the Orkney/Shetland area at the end of August and in early September, larvae in the larger 10-15 mm and >15 mm size categories were very widely distributed in considerable numbers over most of the area which was surveyed between 18 September and 6 October.

Buchan

The Buchan area was completely surveyed during the period 12-23 September when two research vessels were working in this sector of the North Sea (Figures 7-12). A small number of stations were also completed between 3 and 6 October (Figures 19-21). During September recently hatched larvae <10 mm in length were found in one concentration off Ratray Head (Figures 7 and 10) with a maximum density of 220/m^2. Larger larvae were more widely dispersed but in fairly low numbers (Figures 8, 9, 11 and 12). The few stations which were worked between 3 and 6 October contained virtually no larvae <10 mm (Figure 19), but larvae 10-15 mm in length (Figure 20) were more abundant with a maximum density of 49/m^2. Larvae >15 mm (Figure 21) were found at most stations with a maximum density of 16/m^2.

Central North Sea

The central North Sea spawning grounds situated in the Longstone-Whitby-Dogger and Dowsing areas were very adequately covered with four surveys during September-October (Figures 22-33). The first survey (11-16 September) revealed two patches of recently hatched larvae <10 mm in length (Figure 22). The more northerly patch, which extended southwards from the Longstone, had station densities up to 151/m^2 but in the other, more extensive patch, off Flamborough Head densities were higher with a maximum of 445/m^2. Larger larvae, 10-15 mm in length (Figure 24) were widely distributed off the English coast with the highest density of 81/m^2 to the southeast of Flamborough Head. Only very small numbers of larvae >15 mm in length (Figure 26) were taken during this survey.

The areas were again surveyed during the period 20-23 September. On this occasion densities of larvae <10 mm (Figure 23) were much higher in the Longstone area, the maximum being 322/m^2. On the other hand, densities were very much lower off Flamborough Head with 89/m^2 the highest. Larvae 10-15 mm in length (Figure 25) were again widely distributed off the English coast from the Longstone to the Dowsing, the maximum station density of 154/m^2 occurring off Flamborough Head. Larvae >15 mm in length (Figure 27) were somewhat more abundant than in the previous survey but the highest station density was only 11/m^2.

The third survey was carried out from 2 to 10 October. Larvae <10 mm in length (Figure 28) were much less abundant than during the previous survey. The highest station density of 171/m^2 was just north of Flamborough Head. Some hatching of larvae had by this time taken place in the Dowsing area but the maximum station density was only 20/m^2. Larvae 10-15 mm in length (Figure 30) had a fairly extensive distribution, the main concentration being off Flamborough Head. Larvae >15 mm were widely distributed over the survey area (Figure 32), the highest density of 18/m^2 being in the Dowsing area.

On the final survey in the central North Sea from 14 to 19 October the hatching of herring larvae appeared to be completed. Larvae <10 mm in length (Figure 29) were only taken at three stations and densities were low. Larvae 10-15 mm in length (Figure 31) were mainly confined to one patch off Flamborough Head with a maximum density of 27/m^2, and the distribution of larvae >15 mm (Figure 33) was much the same, the highest density being 45/m^2.

Southern Bight-Eastern Channel

These areas were surveyed on four occasions, twice during December 1977 (Figures 34-36) and twice during January 1978 (Figures 37-39). On the first survey, 13-16 December, a few larvae <11 mm in length (Figure 34) were taken at three stations off Pointe d'Ailly in the eastern Channel. On the second survey, 19-22 December, larvae <11 mm in length (Figure 35) were only found at one station off Cap Gris Nez, while only two larvae 11-16 mm in length (Figure 36) were caught, one off Cap Gris Nez and one off Pointe d'Ailly. The third survey, 2-6 January, produced only larvae in the 11-16 mm size category (Figure 37). Most of the larvae were found in the Southern Bight, in the Ruytingen-Hinder area, with a maximum station density of 13/m^2. Two larvae were caught off Pointe d'Ailly. The last survey yielded the highest numbers of herring larvae. Four stations at the end of the eastern Channel contained larvae <11 mm in length (Figure 38), and larvae 11-16 mm in length (Figure 39), more widely distributed in the same area, had a maximum station density of 27/m^2. Only one larva >16 mm was caught.

Quantitative Estimates and Spawning Stock Biomass

As mentioned earlier, the chief objective of these international surveys is to monitor changes in larval production from which changes in the size of the spawning stock can be derived. In Table 2 estimates of larval abundance in 1977/78 for the three size groups of herring larvae in each area and survey period are given, together with estimates for the combined surveys carried out during each half of September in both the Orkney-Shetland and Buchan areas.

The results again demonstrate that the component of the North Sea herring stock which spawns in the Orkney-Shetland area is much larger than any of the other components at the present time. The estimates of

abundance for this area were all substantially higher than those for any year since 1973, while in the Buchan area, although production of larvae was very much better than in 1973 and 1976, it was not so high as in 1974 and 1975. In the central North Sea the abundance estimates for 1977 were only about 50% of those derived from the survey which were carried out in 1973, but they were somewhat higher than those for 1974 and 1975 and substantially larger than the estimates for 1976. Because of reduced sampling effort in the Southern Bight-Eastern Channel in some recent years it is impossible to make any exact comparison of larval abundance in those areas in 1977/78 with the earlier years. However, the abundance estimates for the four surveys which were carried out show a progressive increase to a value of 28 x 10^9 for all sizes of larvae in the final survey. This is the highest estimate from any single survey since 1973. It would seem to be clear therefore that production of herring larvae over the North Sea as a whole in the autumn and winter of 1977/78 was higher than in any year since 1973/74, although not at quite the same high level as in 1973/74. The total spawning stock biomass for North Sea herring in recent years has been: 1973 - 220 000 tonnes, 1974 - 158 000 tonnes, 1975 - 96 000 tonnes and 1976 - 155 000 tonnes (Anon., 1979). The larval abundance estimates from the 1977/78 surveys would therefore point to a total North Sea spawning stock in 1977 of between 158 000 and 220 000 tonnes, with a probable level of about 190 000 tonnes if the spawning stock in the central North Sea in 1977 is taken as 40 000 tonnes, i.e. approximately 50% of the spawning stock size of 85 300 tonnes calculated for the central North Sea in 1973 (Anon., 1977a), and an addition of 10 000 tonnes is made to take account of the somewhat higher production overall in the Buchan/Orkney/Shetland area in 1977.

The Report of the Working Group on North Sea Herring Larval Surveys (Anon., 1977a) contains linear regressions of the estimated abundances of larvae <10 mm in length on spawning stock biomass derived from VPAs for the northern and central North Sea separately. The Herring Assessment Working Group (Anon., 1978) considered that a functional regression (Ricker, 1973) was more appropriate to these data. Functional regressions, incorporating the new data both on catch and larval abundance which have become available since the report of the Working Group on North Sea Herring Larval Surveys was written, were calculated by the Herring Assessment Working Group and have the following equations:

Northern North Sea	$y = 0.04171x + 49.393$
Central North Sea	$y = 0.07365x + 30.044$

where y is the estimated spawning stock from the regressions (x 10^{-3} tonnes) and x is the mean survey abundance of herring larvae <10 mm in length (x 10^{-9}). The size of the spawning stocks in both the northern and central North Sea in 1976 and 1977 calculated from these regressions are:

	1976 (tonnes)	1977 (tonnes)
Northern North Sea	66 014	89 768
Central North Sea	34 445	46 965
Combined	100 459	136 733

There was thus an increase in the spawning stock size of 36 274 tonnes in 1977 for these two areas compared with the previous year.

The abundance estimates for herring larvae in the remaining area, southern North Sea and eastern Channel, were not very different in 1977/78 from those in the previous three years. The average catch from the adult herring fisheries in this area from 1974-76 was 16 804 tonnes, and the age compositions in these years show that only part of the adult spawning stock was being removed annually by fishing. It can therefore be assumed that the average spawning stock size would have been at least of the order of 25 000 tonnes. If this figure is added to the 136 733 tonnes derived from the regressions for the northern and central North Sea a total North Sea spawning stock of about 160 000 tonnes is arrived at for 1977.

From catch data the Herring Assessement Working Group (Anon., 1978) estimated that the size of the total North Sea herring spawning stock in 1977 was of the order of 180 000 tonnes. There is no evidence from the larval data obtained during the 1977/78 surveys, using either of the approaches discussed above, to suggest that this estimate is not correct.

Comparability of Catches of Herring Larvae made by Different Vessels

One of the objectives of arranging that a number of the surveys which were conducted by different research vessels in the northern North Sea in September 1977 should overlap, was to obtain data with which a comparison could be made of "sampling efficiency". It was considered essential that some comparative data should be obtained between new participants in these surveys and some of the more regular members (Saville and McKay, 1977). As the station abundance estimate (i.e. number of larvae per m^2 x surface area) is the basic value used both in calculating the spawning stock size and for comparison of overall production from year to year, it was considered more appropriate to compare these values rather than just numbers of larvae caught. Abundance estimates were therefore compared for pairs of research vessels when they sampled at the same station positions either within three days of each other or on the same day. Details of each comparison which it was possible to make are given in Table 3.

It can be seen in Table 3(a) that the comparisons which were made over a three day period were all based on reasonable numbers of common stations. The abundance estimates derived from these stations for larvae <10 mm in length were fairly similar for "Clupea"/"KW34", "Birkut"/"Clupea" and "Tridens"/"Eisbär" but rather different for both "Anton Dohrn"/"KW34", although, on the other hand, the abundance estimates for the larger size categories of larvae were in reasonable agreement for these latter two pairs of vessels. It was concluded that a comparison over a time period extending up to three days was not valid, not only because of the possible effect of wind, tide and the currents during this time on the distribution of the larvae in localised areas around each station position, but also because, with considerable hatching taking place during September when these surveys were being carried out, the numbers of small recently hatched larvae could have altered substantially during three days at stations positioned either over, or in close proximity to, actual spawning sites. A second comparison was therefore made based on common stations worked on the same day, and the results are presented in Table 3(b). The most significant feature is the remarkable similarity to be seen in the abundance estimates for larvae 10-15 mm in length. Some sizeable differences, however, can still be seen in those for recently hatched larvae <10 mm in length, and these differences were investigated. In every case where a large difference occurred between two vessels it could be referred to a single high density station, and as far as could be ascertained (from the record of station positions and dates for each vessel) to the fact that these stations had been worked, in nearly every case, in opposed directions by the two vessels concerned, i.e. one vessel

worked the stations on either a north/south or south/north course while the other worked from east/west or west/east. Obviously in these circumstances because of the different relation to the tidal stream different volumes of water would have been sampled by each vessel and thus the comparisons must be considered invalid. There were unfortunately insufficient stations which had been worked on the same day and in the same direction for any sensible comparisons to be made on that basis. In any case, even when stations were worked on the same day by two vessels. The actual times of sampling could have differed by up to 24 hours and again wind, tide and currents could have had a significant effect on the distribution of the larvae. The same arguments would not apply to the larger 10-15 mm larvae to the same degree, as these older larvae would be more widely and evenly dispersed so that the direction of tow or time of day would probably be of far less importance.

It would appear from these data that all the vessels which were compared were sampling the 10-15 mm larvae with the same efficiency and could therefore be expected to have also sampled the <10 mm size category equally effectively under identical circumstances. There is certainly no valid evidence to suggest that there is any serious discrepancy involved in sampling the critical <10 mm size group on the part of any of the vessels at present participating in the surveys. This in turn would suggest that the minor variations which exist in the sampling instruments themselves and in handling methods, are not of much importance. If it is still considered important to demonstrate that this is so, it could only be achieved effectively by arranging for research vessels on future surveys to sample a number of stations side by side at the same time.

Discussion

The chief objective of the International Herring Larval Surveys is to provide measures of changes in larval production from year to year, from which changes in the size of the spawning stocks can be derived - measures which are independent of fishery data. The reliability of the basic larval abundance data has steadily improved since the early years as both the sampling instruments and the survey techniques have become standardised, and incorporated important improvements and also as the coverage of each area has increased with the participation of a larger number of research vessels. As both this report and the preceding one have shown, the annual estimates of stock size derived from the most recent surveys have been in reasonable agreement with the stock sizes estimated by the Herring Assessment Working Group from the fishery catch data. These surveys may now be considered to be successfully performing the main function for which they were set up.

With the present state of the North Sea herring stocks, the recommendation of the Herring Assessment Working Group that the North Sea spawning stock as a whole should be rebuilt as rapidly as possible to a size of 800 000 tonnes, and with catches restricted to the very low levels necessary to achieve that objective, the larval surveys will undoubtedly continue to play a vital role in stock assessment. It is therefore important to consider whether the sub-area regressions, at present being used to estimate the size of the spawning stock in the northern and central North Sea, will still be valid at the substantially increased stock levels which will then arise. A criticism of the present method is that the linear regressions currently in use are based only on the recent years during which the North Sea herring stock size has been relatively quite small, and that these regressions may not be valid once the stock really begins to recover. It has been suggested that, over a very wide range of stock size and larval abundance, a linear regression may not in fact give the best fit to the data.

It is possible to test this hypothesis to some extent with data from the southern North Sea and eastern Channel (ICES Divisions IVc and VIId and e), as larval survey data are available for these areas covering a considerable number of years from 1947 until the present time. The mean survey abundance of herring larvae of all size groups combined from surveys carried out during the months of December and January are given in Anon. (1977b) for the years 1946-72 (Table 13), while the data from surveys conducted during 1973-76 are to be found in the relevant annual reports which are listed in the Introduction to this report. Because of the unsuitable form in which larval data from the earliest years was recorded, it is only possible to consider total abundance estimates for all size categories of herring larvae in Divisions IVc and VIId and e. Using the catch at age data for these Divisions and the annual values of fishing mortality which have been published in various reports of the Herring Assessment Working Group (Anon., 1979; Anon., 1977b and Anon., 1978), it was possible to run a VPA to give stock sizes at 1 January for the southern North Sea/eastern Channel spawning component of the North Sea stock. 1 January was taken as the mid-point of the spawning season. The annual total stock biomass for ages 3-8 rings (2 ring fish being excluded as these would not spawn until the following season) was calculated using English weight-at-age data from the East Anglian fishery for the earlier years (1947-67) and from reports of the Herring Assessment Working Group (Anon., 1977b) for the later years (1968-76). No correction factor for partial recruitment was applied to the 3 ring fish in the earliest years because it was concluded that this refinement to the biomass data was not necessary in view of possible inaccuracies in the larval data in the early post-war period before high-speed samplers were in use. Data for years in which the larval survey coverage was considered to be inadequate (particularly during the month of January) were rejected. Those data which were considered to be satisfactory are presented in Table 4. A functional linear regression (Figure 40) was calculated from the values of stock biomass and larval abundance for the spawning seasons 1957/58-1975/76, i.e. years during which the spawning stock size was low. This regression line was then projected (Figure 41) to cover the whole range of larval abundance values up to the highest which was achieved during the 1946/47 spawning season. It can be seen in Figure 41 that the points referring to the three years 1947, 1948 and 1952 during which the stock biomass was at a very high level and larval production was most substantial, do not lie very close to this linear regression derived from low levels of spawning stock. However, it must be borne in mind that the correlation coefficient of this regression at 0.4642 is quite low and also that the larval abundance estimates for the years 1947, 1948 and 1952 are probably serious underestimates, as only some of the surveys in those years covered both the Southern Bight and eastern Channel spawning areas. While it would be unwise therefore to conclude from these data that a linear relationship would not provide the best fit or give the most reliable prediction of spawning stock biomass over all possible levels of stock, the possibility that some form of curve might provide a better relationship cannot entirely be ruled out.

It must be assumed that doubts regarding the accuracy of the predicted spawning stock biomass from the larval abundance estimates will continue to be expressed, particularly once the North Sea herring stock increases much beyond a level of about 350 000 tonnes. When this happens there will be a pressing need for some other type of independent assessment of stock size and acoustic surveys might well provide the only reasonable alternative. In fact, an ideal solution might be to carry out combined larval and acoustic surveys at the same

time, and this proposal should be given serious consideration by all the present participants in the International Herring Larval Surveys.

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Table 1. Surveys carried out in 1977/78.

Area	Period	Country	Vessel	No. of stations	
				Per survey	Total
Orkney/ Shetland	31 Aug-12 Sep 1977	Netherlands	"KW 34"	89	502
	5-10 Sep 1977	Germany(F.R)	"A Dohrn"	98	
	5-15 Sep 1977	Scotland	"Clupea"	63	
	18-24 Sep 1977	German Dem. Rep.	"Eisbär"	84	
	21-28 Sep 1977	Netherlands	"Tridens"	94	
	26 Sep- 6 Oct 1977	Scotland	"Clupea"	74	
Buchan	12-22 Sep 1977	Poland	"Birkut"	39	132
	19-23 Sep 1977	Scotland	"Clupea"	78	
	3- 6 Oct 1977	Poland	"Birkut"	15	
Central North Sea	11-16 Sep 1977	England	"Corella"	97	371
	20-23 Sep 1977	Netherlands	"KW 34"	61	
	2-10 Oct 1977	England	"Corella"	105	
	14-19 Oct 1977	Norway	"J Hjort"	108	
Southern Bight/ Eastern Channel	13-16 Dec 1977	Netherlands	"Tridens"	58	207
	19-22 Dec 1977	Netherlands	"Tridens"	55	
	2- 6 Jan 1978	Netherlands	"Tridens"	52	
	19-23 Jan 1978	England	"Clione"	42	

Table 2. Estimated abundances of herring larvae for each survey carried out in the North Sea and adjacent waters in 1977/78.*

Area	Period	Abundance of herring larvae x 10^{-9}			
		<10 mm	10-15 mm	>15 mm	Total
Orkney/ Shetland	31 Aug-12 Sep 1977	1 128	1 485	33	2 646
	5-10 Sep 1977	1 629	558	41	2 228
	5-15 Sep 1977	763	748	18	1 529
	18-24 Sep 1977	258	1 033	139	1 430
	21-28 Sep 1977	295	1 374	637	2 306
	26 Sep- 6 Oct 1977	373	491	491	1 355
	Combined surveys				
	31 Aug-15 Sep 1977	1 490	1 059	37	2 586
	18-29 Sep 1977	328	1 379	506	2 213
Buchan	12-22 Sep 1977	102	49	11	162
	19-23 Sep 1977	25	18	14	57
	3- 6 Oct 1977	+	37	26	63
	Combined surveys				
	12-16 Sep 1977	92	15	0	107
	19-23 Sep 1977	26	29	17	72
Central North Sea	11-16 Sep 1977	502	196	5	703
	20-22 Sep 1977	310	330	31	671
	2-10 Oct 1977	104	198	68	370
	14-19 Oct 1977	3	53	106	162
		<11mm	11-16mm	>16 mm	
Southern Bight/ Eastern Channel	13-16 Dec 1977	1	0	0	1
	19-22 Dec 1977	1	1	0	2
	2- 6 Jan 1978	0	8	0	8
	19-23 Jan 1978	3	25	+	28

* A limited survey carried out by RV "Cirolana" 1-3 February 1978 between latitudes 51°40'N-52°50'N and longitudes 2°10'E-3°50'E gave a total abundance estimate of 22 x 10^9 herring larvae (<11 mm 8 x 10^9 and 11-16 mm 14 x 10^9).

Table 3. Comparison of abundance estimates of herring larvae for pairs of research vessels sampling at the same station positions.

Research vessel	Country	Date	No. of common stations	Abundance of herring larvae x 10^{-9}			
				<10 mm	10-15 mm	>15 mm	Total
(A) Within 3 days							
"Anton Dohrn"	Germany (Fed.Rep.)	5-8 Sep	31	196	84	9	289
"Clupea"	Scotland			318	114	0	432
"Anton Dohrn"	Germany (Fed.Rep.)	5-9 Sep	35	868	205	5	1 078
"KW 34"	Netherlands			556	242	+	798
"Clupea"	Scotland	5-15 Sep	41	592	617	17	1 226
"KW 34"	Netherlands			570	1 360	32	1 962
"Birkut"	Poland	18-23 Sep	24	10	35	11	56
"Clupea"	Scotland			8	11	3	22
"Tridens"	Netherlands	18-27 Sep	49	177	600	232	1 009
"Eisbär"	German Dem.Rep.			140	339	45	524
(B) On the same day							
"Anton Dohrn"	Germany (Fed.Rep.)	5-7 Sep	22	190	56	6	252
"Clupea"	Scotland			312	95	0	407
"Anton Dohrn"	Germany (Fed.Rep.)	7 Sep	8	5	7	1	13
"KW 34"	Netherlands			16	7	0	23
"Clupea"	Scotland	7-12 Sep	7	191	152	0	343
"KW 34"	Netherlands			98	153	2	253
"Birkut"	Poland	20-22 Sep	5	0	2	3	5
"Clupea"	Scotland			+	1	1	2
"Tridens"	Netherlands	23 Sep	9	48	115	43	206
"Eisbär"	German Dem.Rep.			60	116	10	186

Table 4. Estimates of larval abundance and spawning stock biomass for the southern North Sea and eastern Channel.

Year		Mean survey abundance estimate for all larvae x 10^{-9}	Spawning stock biomass x 10^{-3} tonnes at 1 Jan.
Dec	Jan		
1946	1947	1193*	497
1947	1948	1134*	398
1951	1952	686*	382
1957	1958	36	61
1958	1959	139	26
1960	1961	147	25
1961	1962	187	51
1962	1963	30	9
1963	1964	22	22
1965	1966	13	5
1967	1968	26	10
1969	1970	108	27
1970	1971	126	20
1971	1972	7	22
1972	1973	67	38
1974	1975	3	10
1975	1976	8	10

* Larvae taken by Hensen net and Heligoland larvae net corrected for day/night catch variation (Bridger, 1961). Abundance estimates for these years are therefore directly comparable with those obtained in all later years with high-speed plankton samplers.

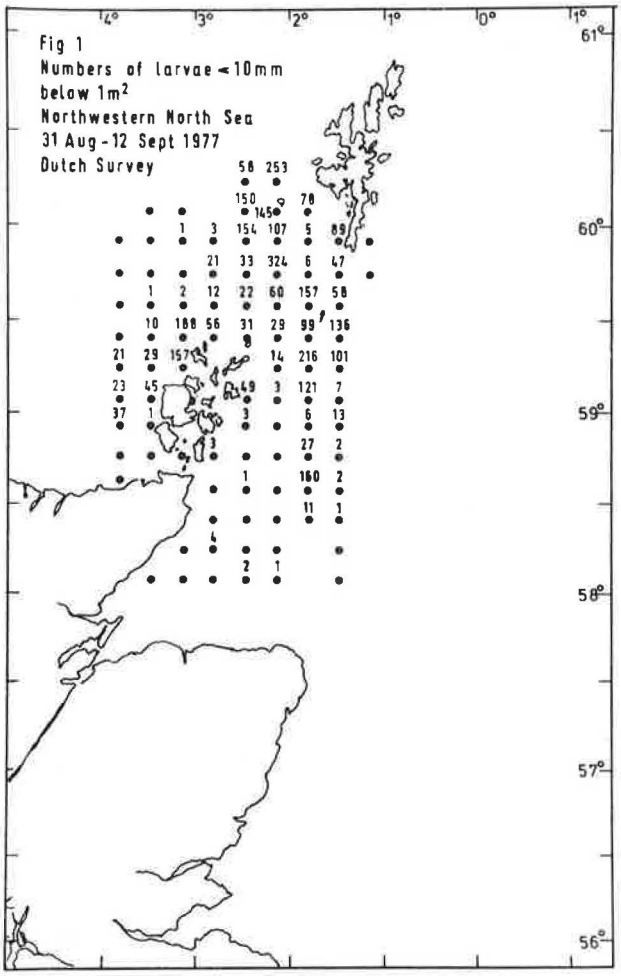
Fig 1
Numbers of larvae <10mm
below 1m²
Northwestern North Sea
31 Aug - 12 Sept 1977
Dutch Survey

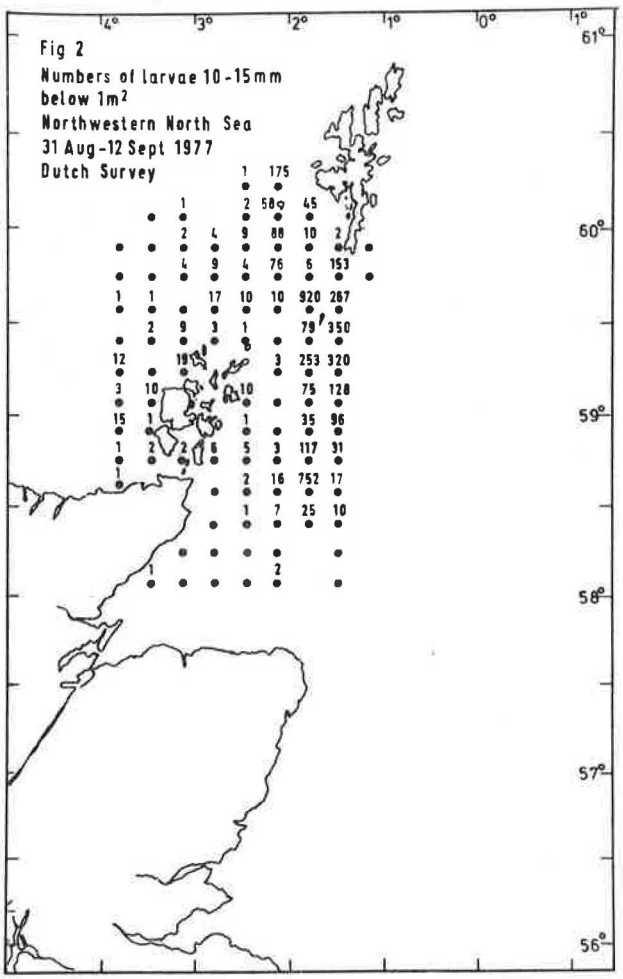
Fig 2
Numbers of larvae 10-15mm
below 1m²
Northwestern North Sea
31 Aug - 12 Sept 1977
Dutch Survey

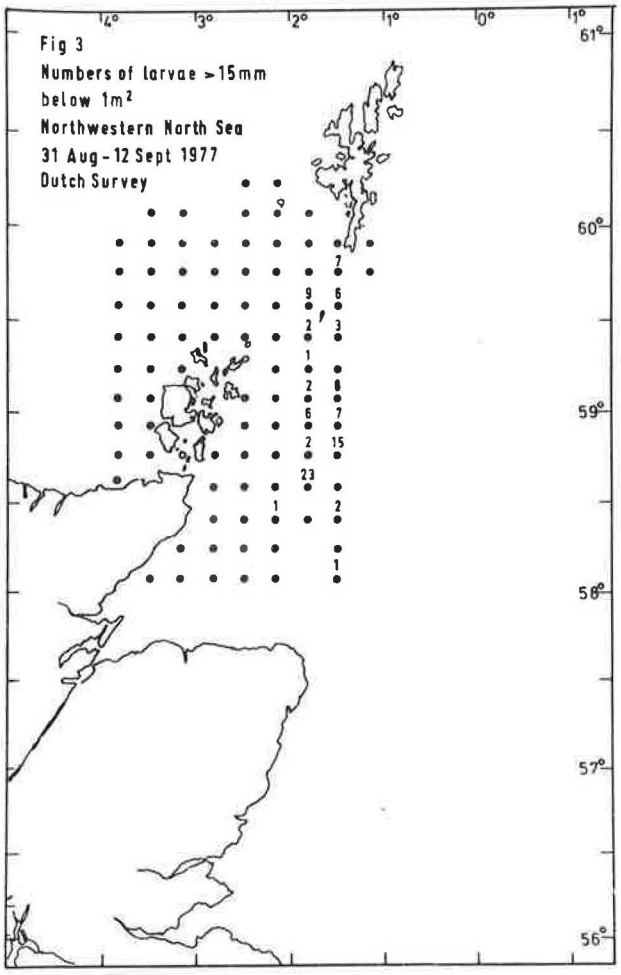
Fig 3
Numbers of larvae >15mm
below 1m²
Northwestern North Sea
31 Aug - 12 Sept 1977
Dutch Survey

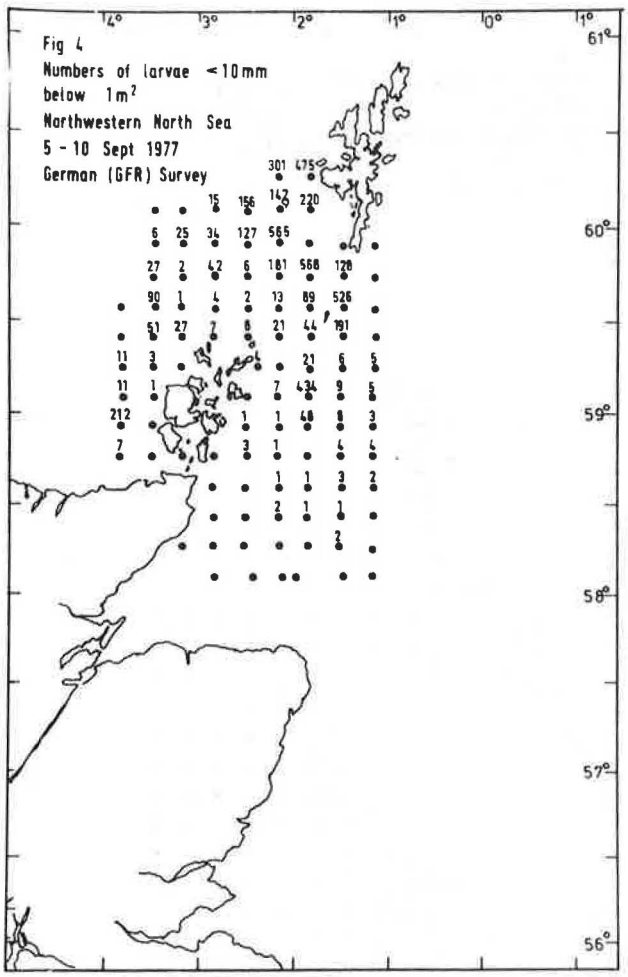
Fig 4
Numbers of larvae <10mm
below 1m²
Northwestern North Sea
5 - 10 Sept 1977
German (GFR) Survey

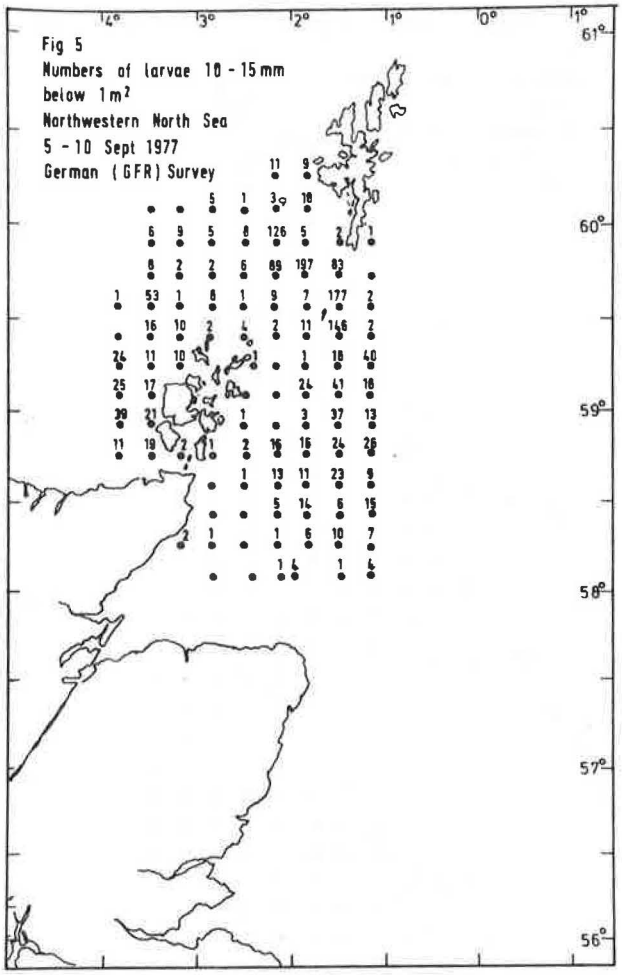
Fig 5
Numbers of larvae 10 - 15mm
below 1m²
Northwestern North Sea
5 - 10 Sept 1977
German (GFR) Survey

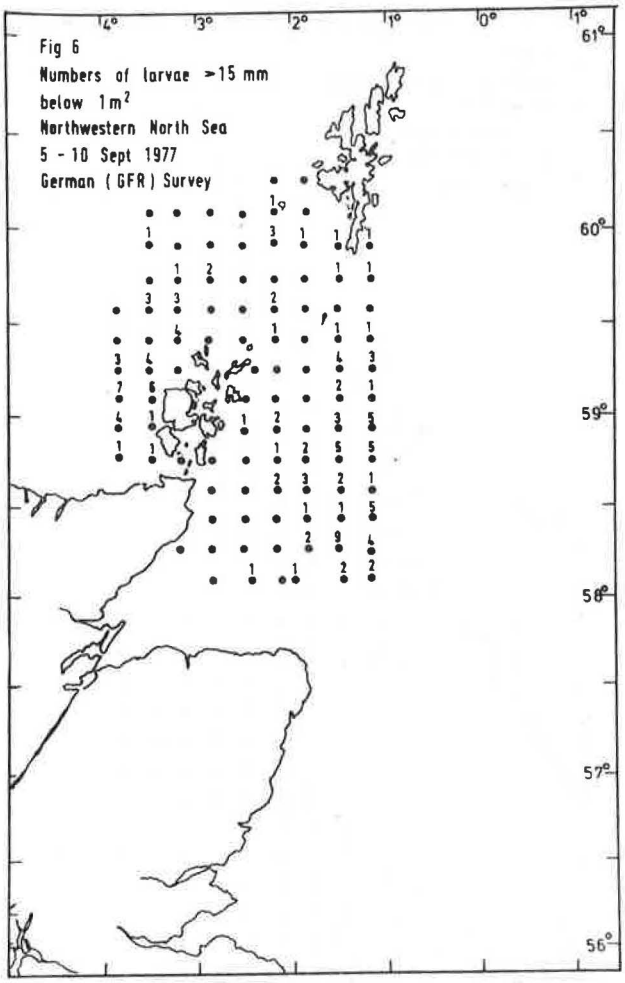
Fig 6
Numbers of larvae >15 mm
below 1m²
Northwestern North Sea
5 - 10 Sept 1977
German (GFR) Survey

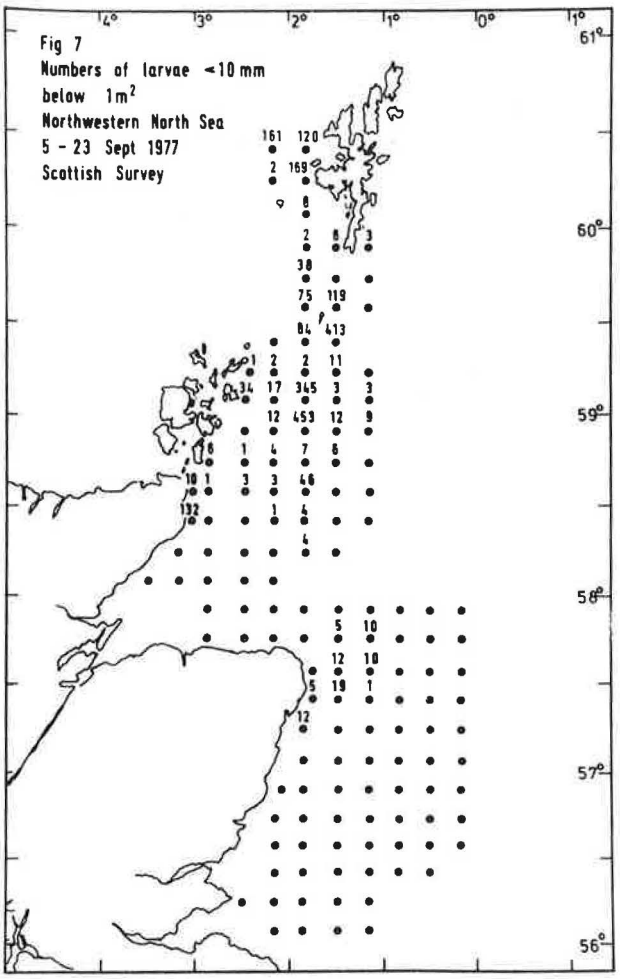
Fig 7
Numbers of larvae <10 mm
below 1m²
Northwestern North Sea
5 - 23 Sept 1977
Scottish Survey

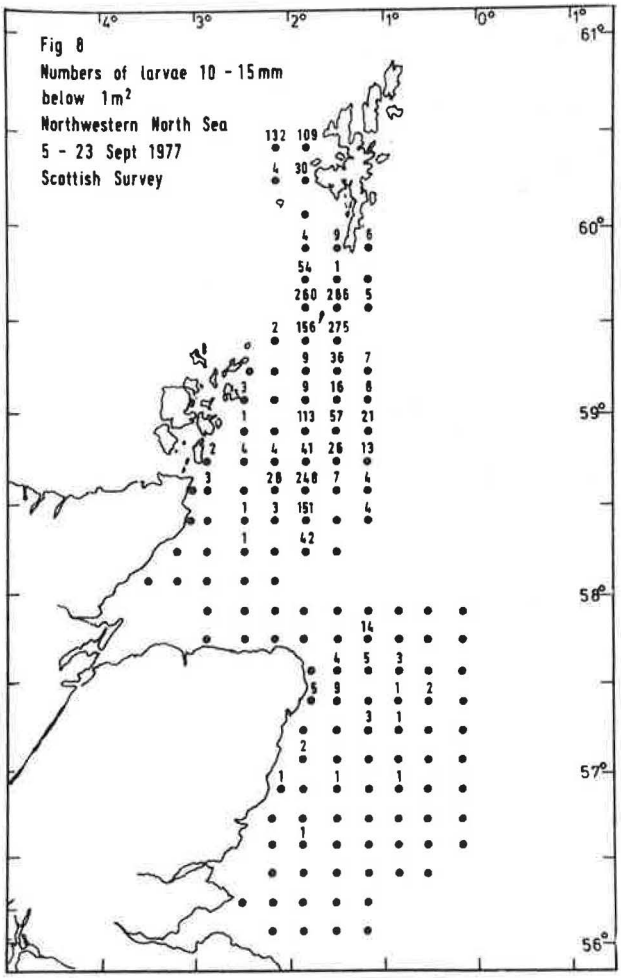
Fig 8
Numbers of larvae 10 - 15 mm
below 1m²
Northwestern North Sea
5 - 23 Sept 1977
Scottish Survey

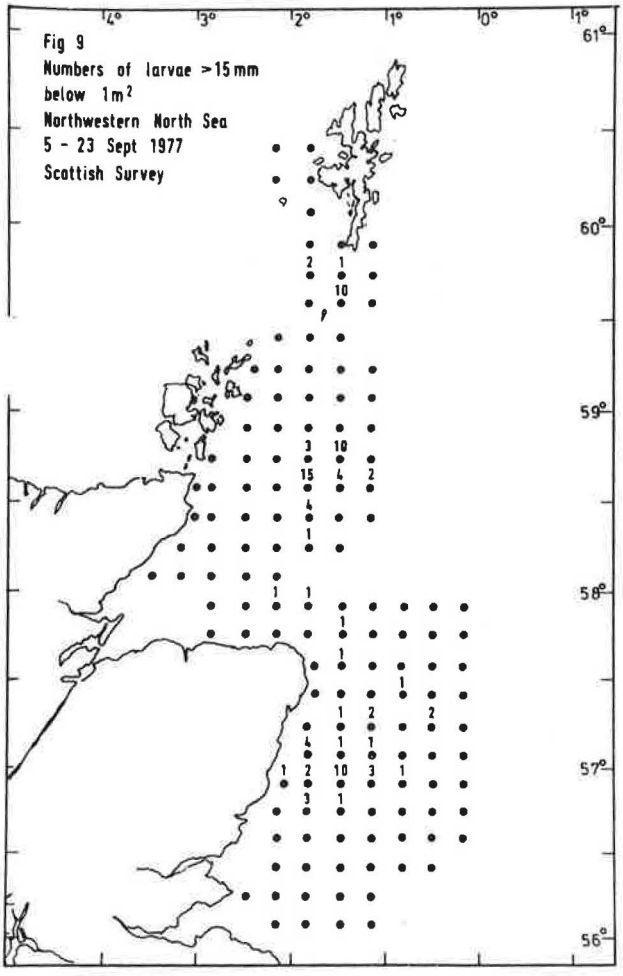
Fig 9
Numbers of larvae >15 mm
below 1m²
Northwestern North Sea
5 - 23 Sept 1977
Scottish Survey

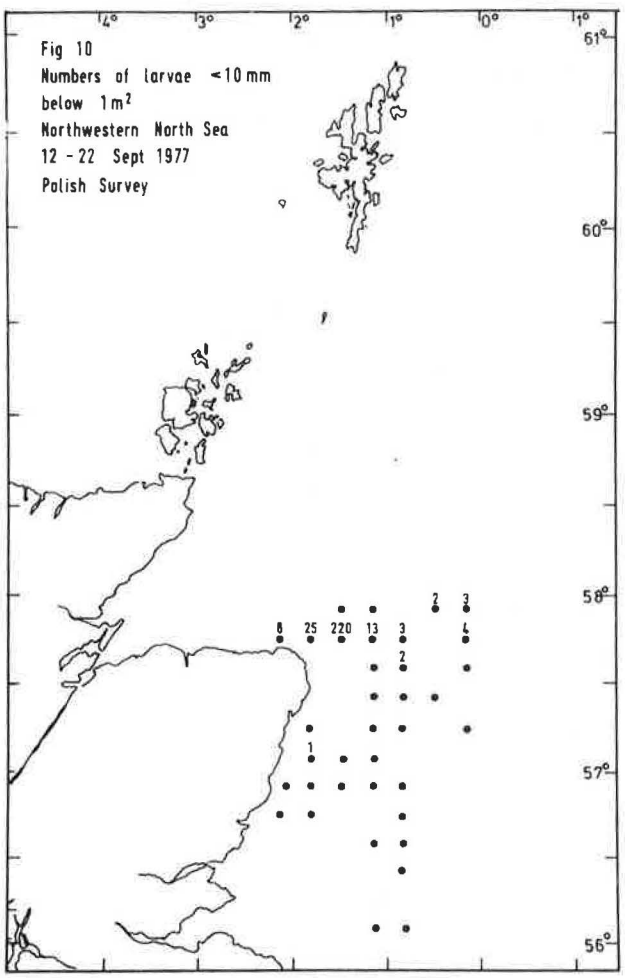
Fig 10
Numbers of larvae <10 mm
below 1m²
Northwestern North Sea
12 - 22 Sept 1977
Polish Survey
8 25 220 13 3 2 3 4
2
1
4°
3°
2°
1°
0°
1°
61°
60°
59°
58°
57°
56°

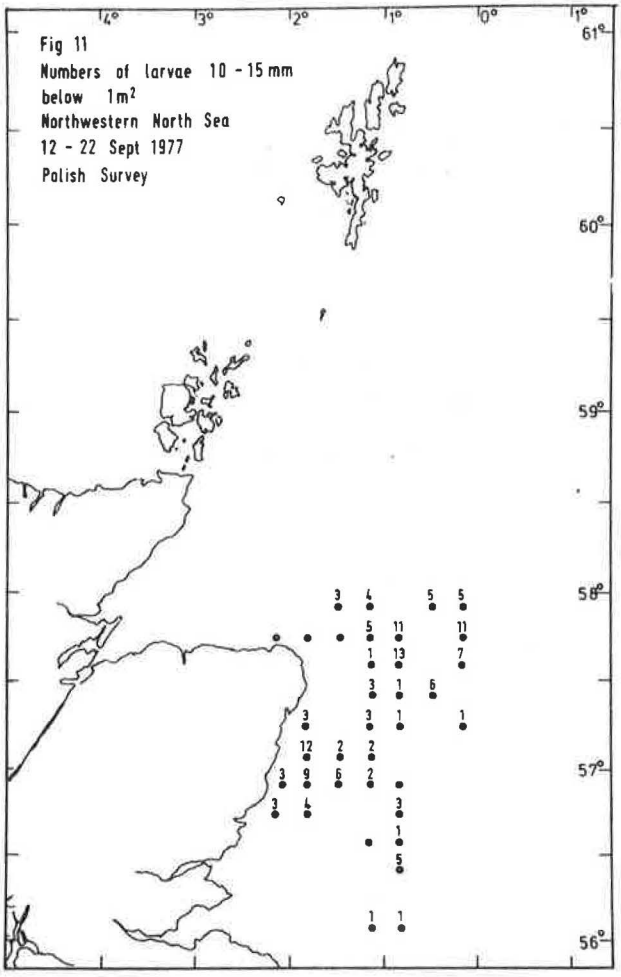
Fig 11
Numbers of larvae 10 - 15 mm
below 1m²
Northwestern North Sea
12 - 22 Sept 1977
Polish Survey
3 4 5 5
5 11 11
1 13 7
3 1 6
3 3 1 1
12 2 2
3 9 6 2
3 4 3
1
5
1 1
4°
3°
2°
1°
0°
1°
61°
60°
59°
58°
57°
56°

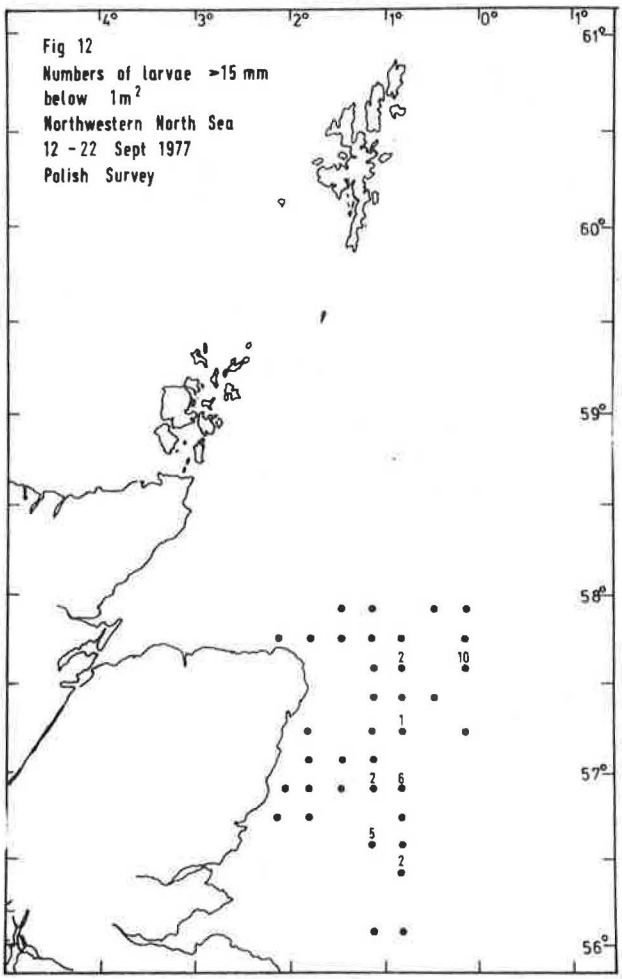
Fig 12
Numbers of larvae >15 mm
below 1m²
Northwestern North Sea
12 - 22 Sept 1977
Polish Survey
2 10
1
2 6
5
2
4°
3°
2°
1°
0°
1°
61°
60°
59°
58°
57°
56°

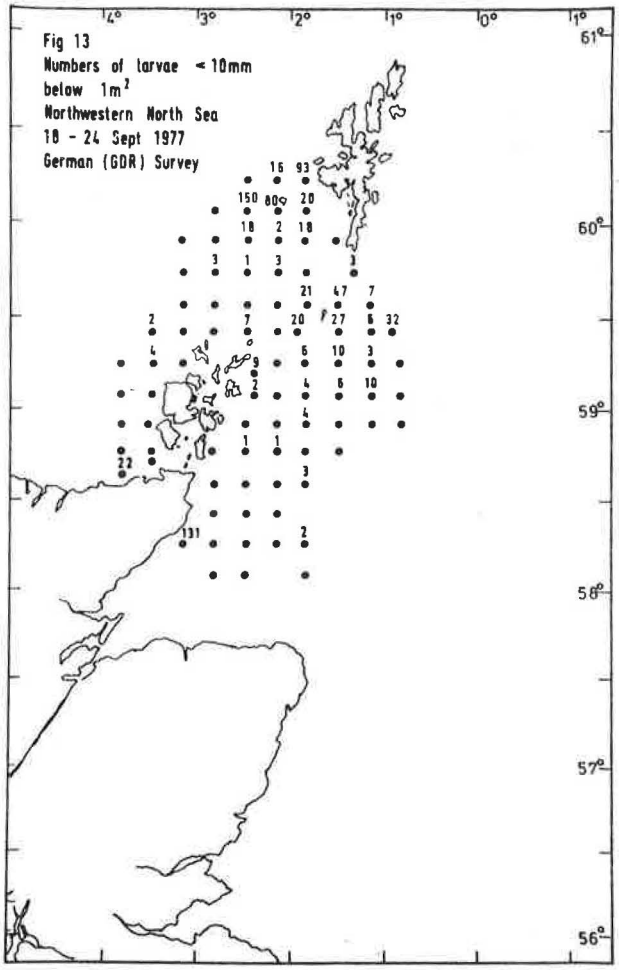
Fig 13
Numbers of larvae < 10mm
below 1m²
Northwestern North Sea
18 - 24 Sept 1977
German (GDR) Survey
4°
3°
2°
1°
0°
1°
61°
60°
59°
58°
57°
56°

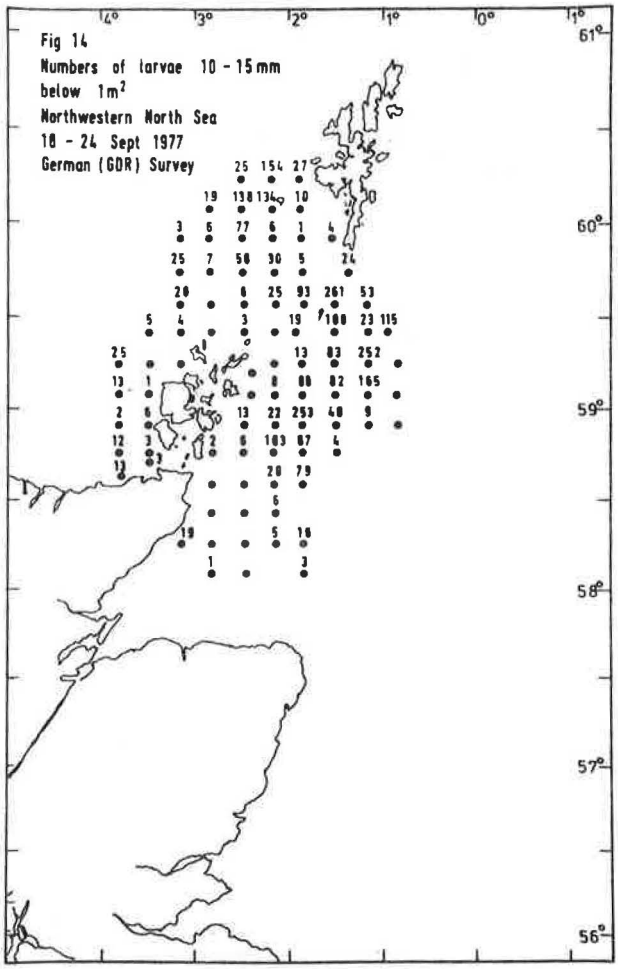
Fig 14
Numbers of larvae 10 - 15 mm
below 1m²
Northwestern North Sea
18 - 24 Sept 1977
German (GDR) Survey
4°
3°
2°
1°
0°
1°
61°
60°
59°
58°
57°
56°

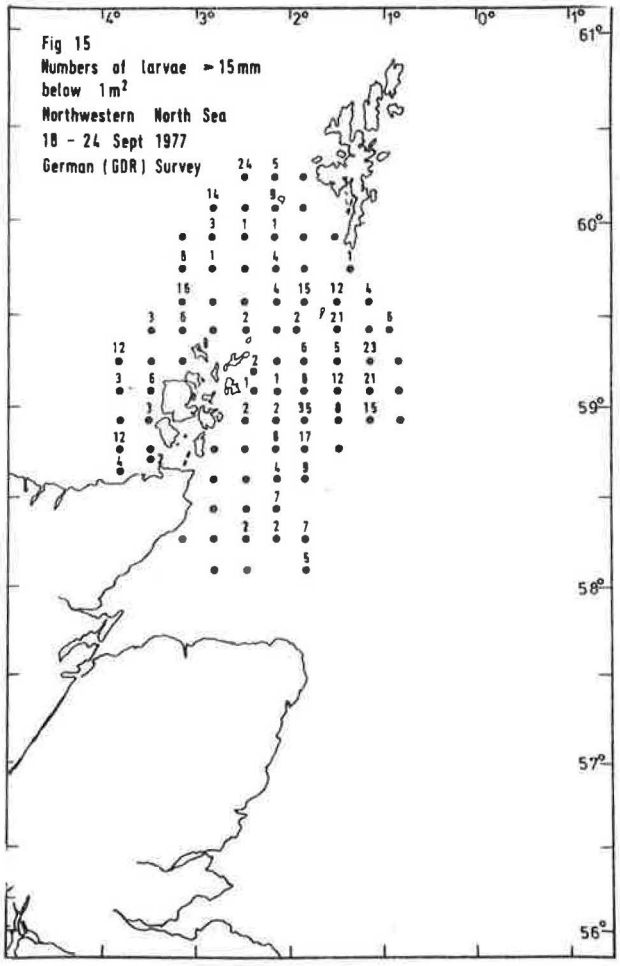
Fig 15
Numbers of larvae > 15 mm
below 1m²
Northwestern North Sea
18 - 24 Sept 1977
German (GDR) Survey
4°
3°
2°
1°
0°
1°
61°
60°
59°
58°
57°
56°

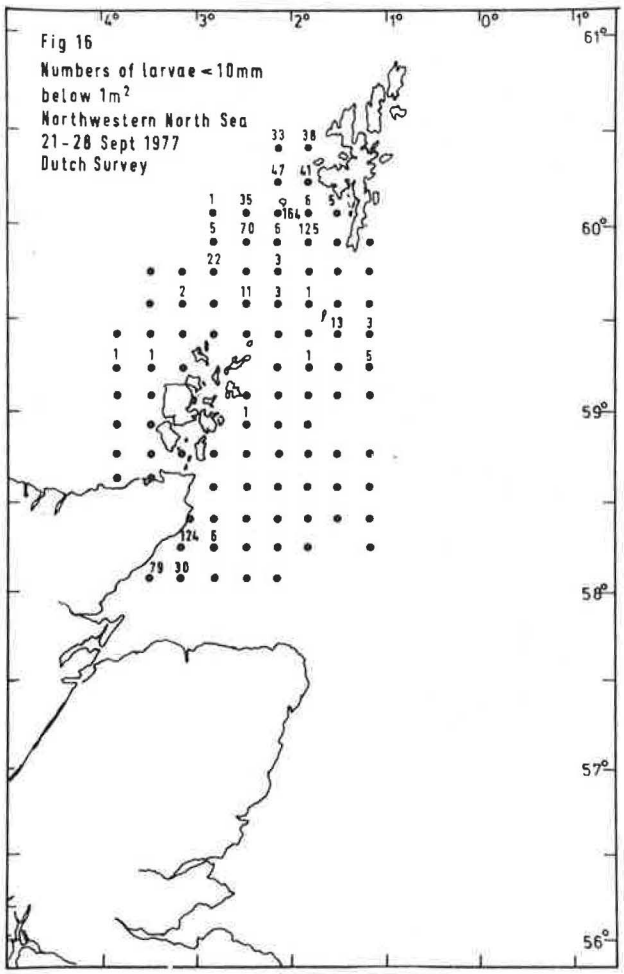
Fig 16
Numbers of larvae < 10mm
below 1m²
Northwestern North Sea
21-28 Sept 1977
Dutch Survey
4°
3°
2°
1°
0°
1°
61°
60°
59°
58°
57°
56°

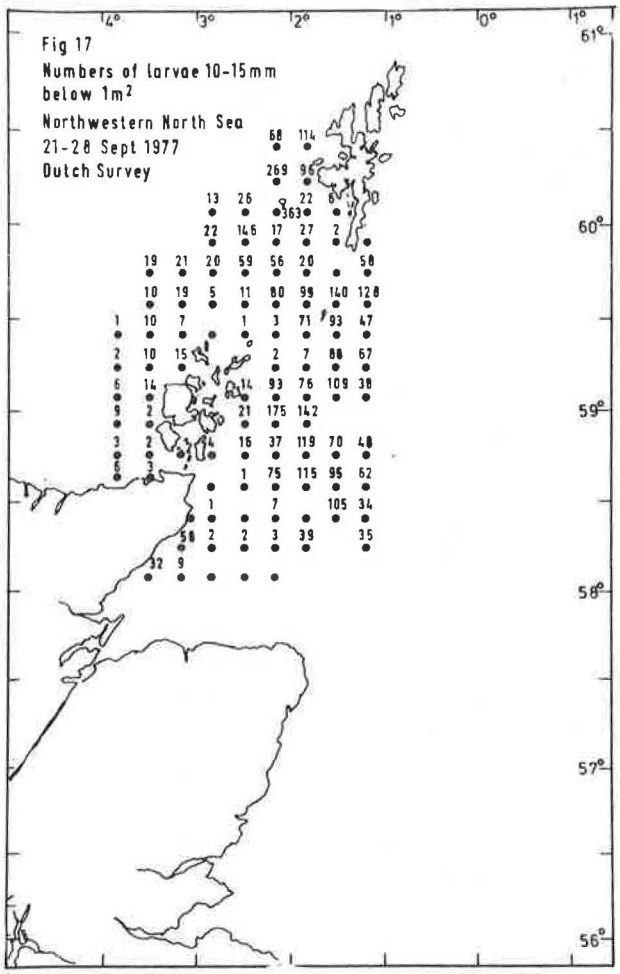
Fig 17
Numbers of larvae 10-15mm
below 1m²
Northwestern North Sea
21-28 Sept 1977
Dutch Survey
4°
3°
2°
1°
0°
1°
61°
60°
59°
58°
57°
56°

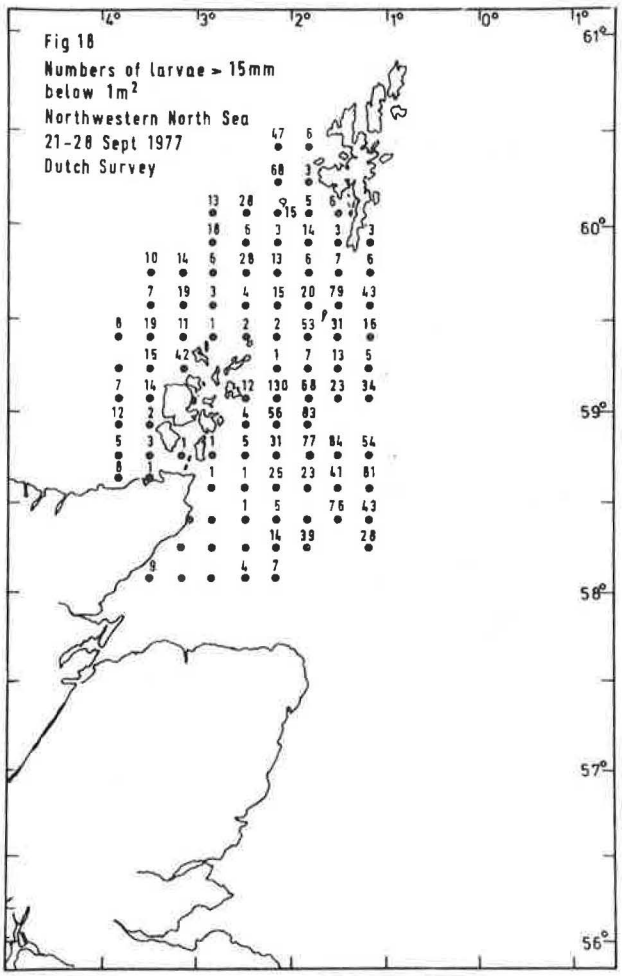
Fig 18
Numbers of larvae > 15mm
below 1m²
Northwestern North Sea
21-28 Sept 1977
Dutch Survey
4°
3°
2°
1°
0°
1°
61°
60°
59°
58°
57°
56°

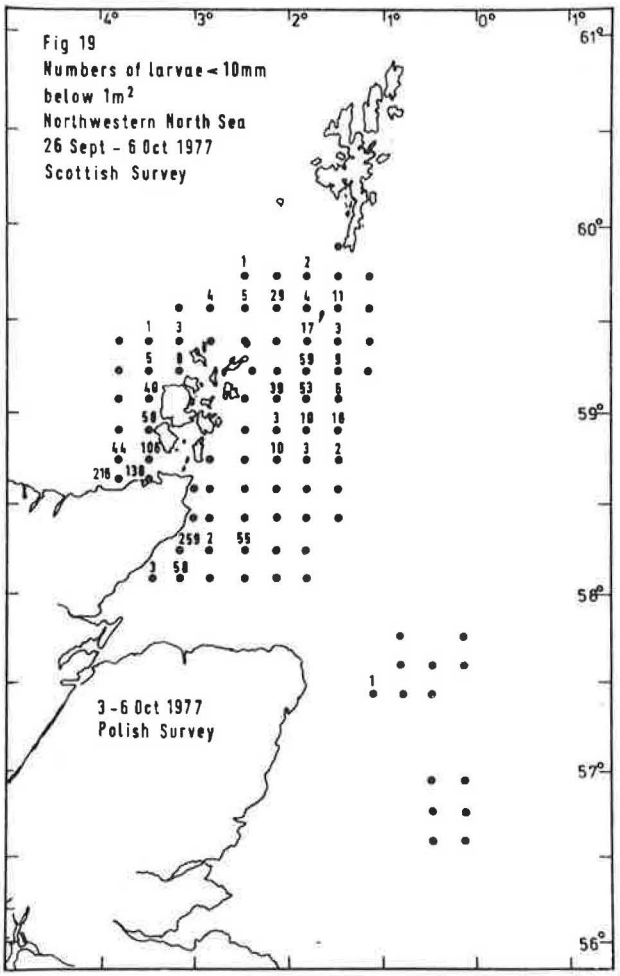
Fig 19
Numbers of larvae < 10mm
below 1m²
Northwestern North Sea
26 Sept - 6 Oct 1977
Scottish Survey
3-6 Oct 1977
Polish Survey

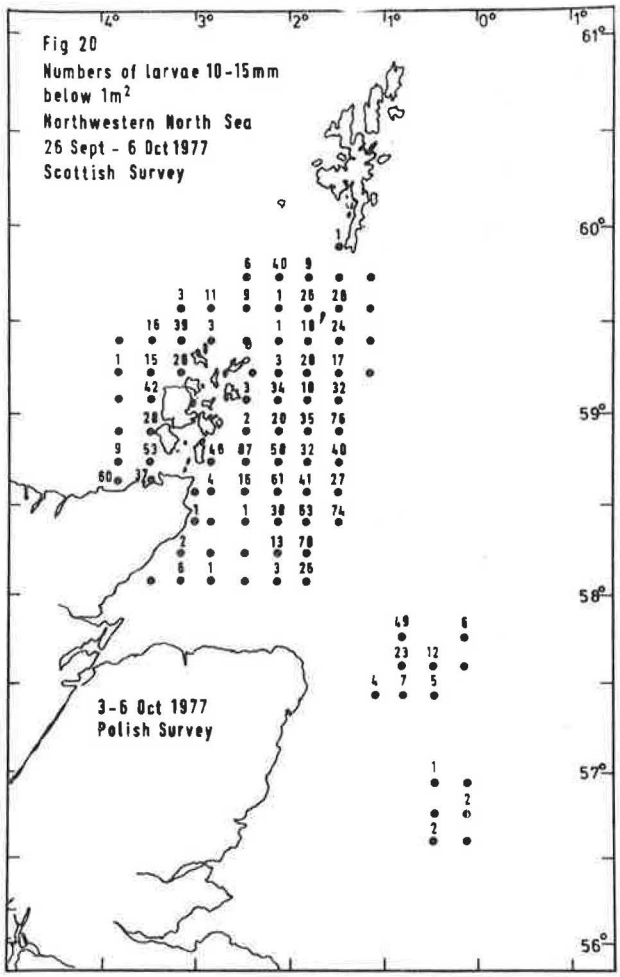
Fig 20
Numbers of larvae 10-15mm
below 1m²
Northwestern North Sea
26 Sept - 6 Oct 1977
Scottish Survey
3-6 Oct 1977
Polish Survey

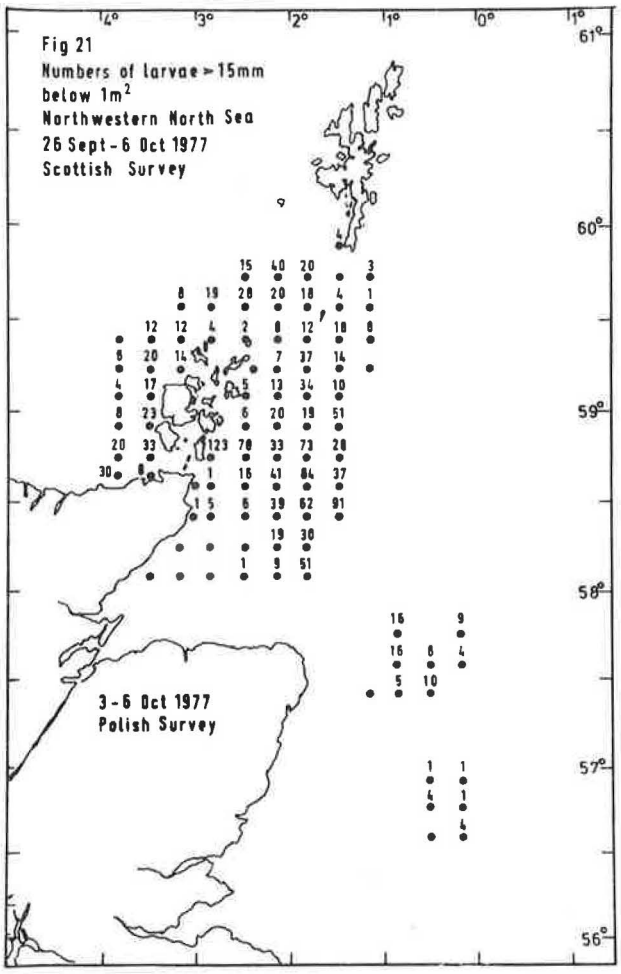
Fig 21
Numbers of larvae > 15mm
below 1m²
Northwestern North Sea
26 Sept - 6 Oct 1977
Scottish Survey
3-6 Oct 1977
Polish Survey

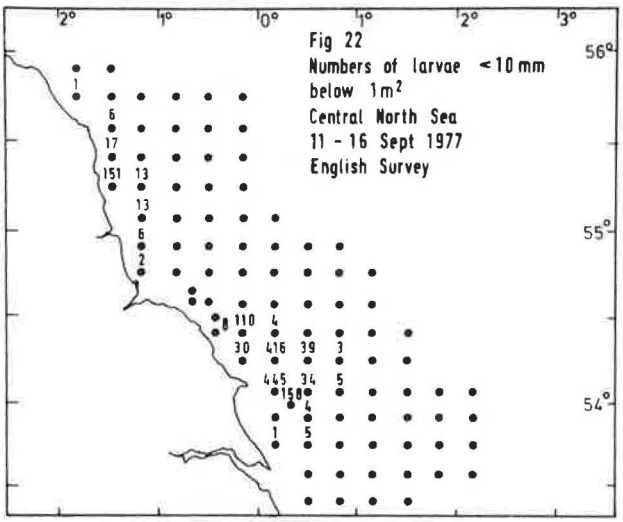
Fig 22
Numbers of larvae <10 mm
below 1m²
Central North Sea
11 - 16 Sept 1977
English Survey

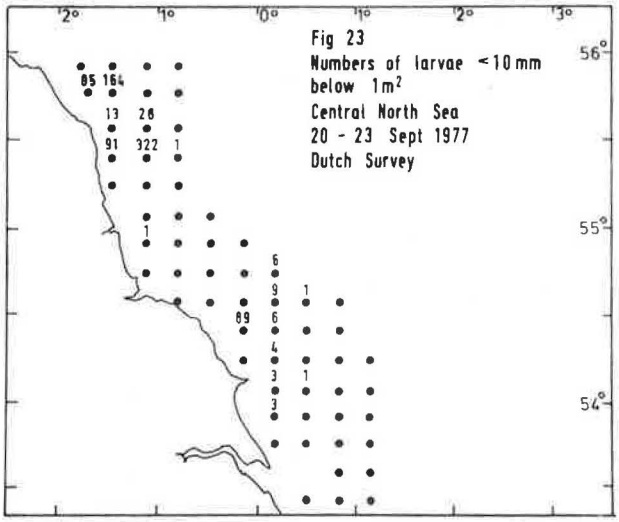
Fig 23
Numbers of larvae <10 mm
below 1m²
Central North Sea
20 - 23 Sept 1977
Dutch Survey

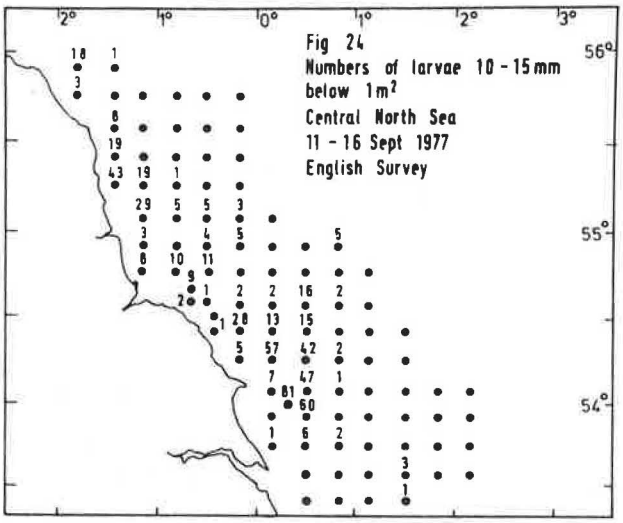
Fig 24
Numbers of larvae 10 - 15 mm
below 1m²
Central North Sea
11 - 16 Sept 1977
English Survey

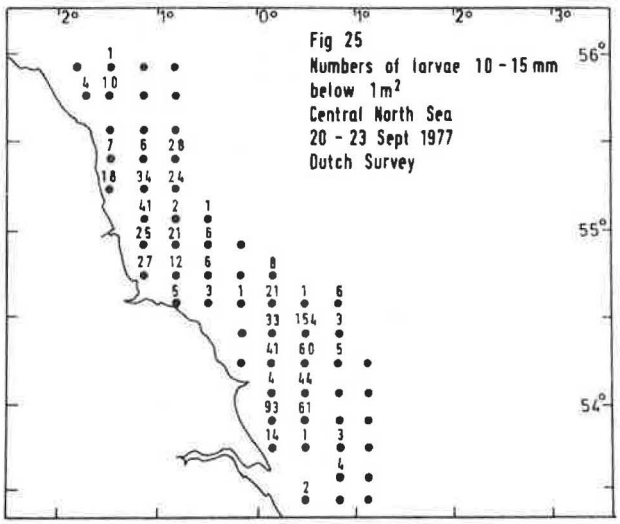
Fig 25
Numbers of larvae 10 - 15 mm
below 1m²
Central North Sea
20 - 23 Sept 1977
Dutch Survey

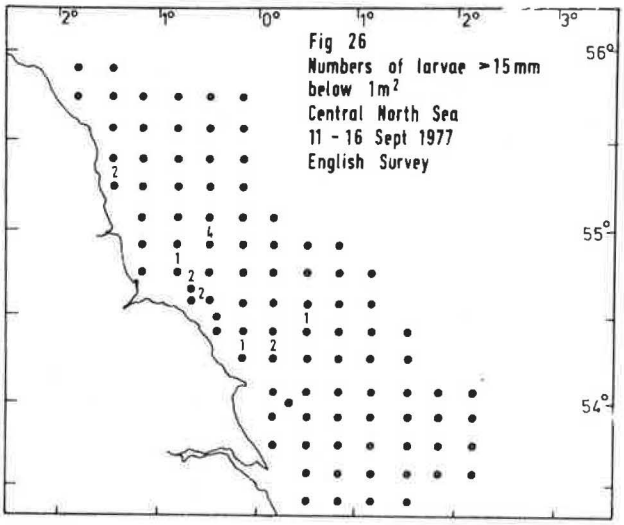
Fig 26
Numbers of larvae >15 mm
below 1m²
Central North Sea
11 - 16 Sept 1977
English Survey

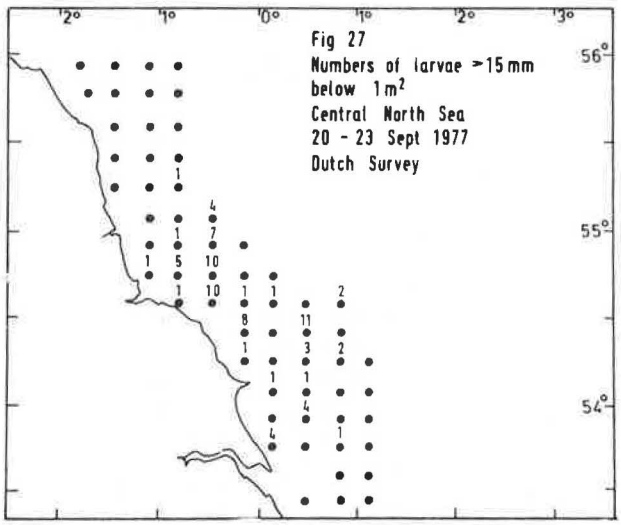
Fig 27
Numbers of larvae >15 mm
below 1m²
Central North Sea
20 - 23 Sept 1977
Dutch Survey

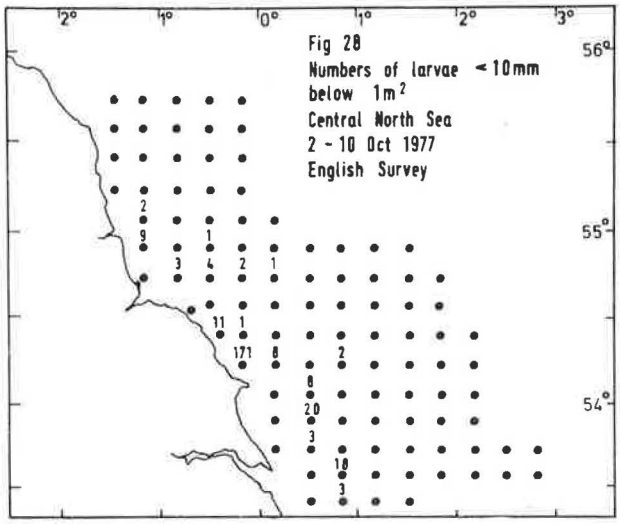
Fig 28
Numbers of larvae < 10mm
below 1m²
Central North Sea
2 - 10 Oct 1977
English Survey

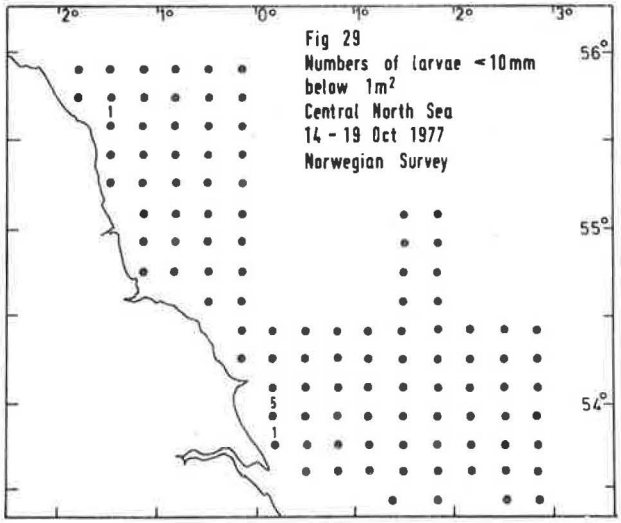
Fig 29
Numbers of larvae < 10mm
below 1m²
Central North Sea
14 - 19 Oct 1977
Norwegian Survey

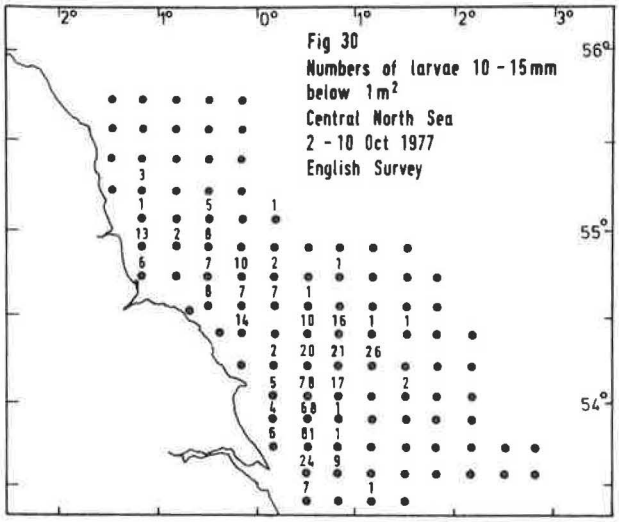
Fig 30
Numbers of larvae 10 - 15mm
below 1m²
Central North Sea
2 - 10 Oct 1977
English Survey

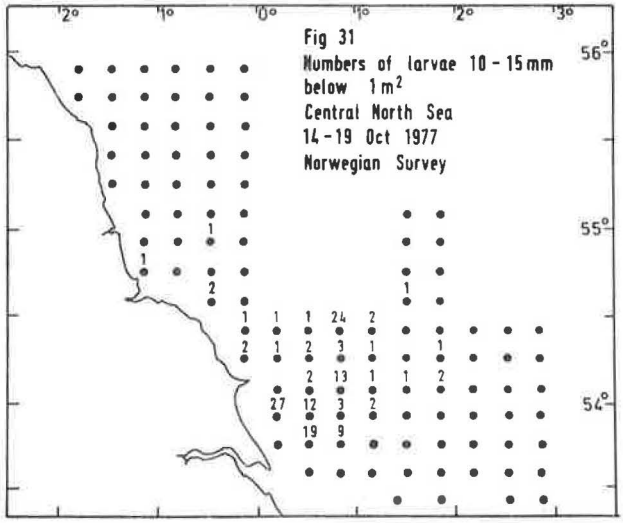
Fig 31
Numbers of larvae 10 - 15mm
below 1m²
Central North Sea
14 - 19 Oct 1977
Norwegian Survey

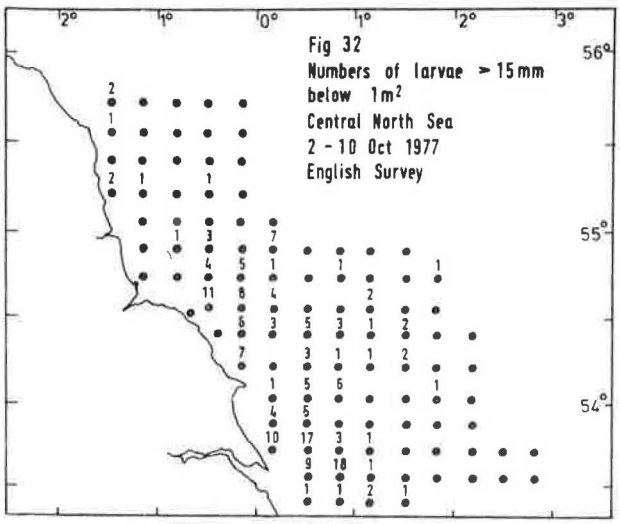
Fig 32
Numbers of larvae > 15mm
below 1m²
Central North Sea
2 - 10 Oct 1977
English Survey

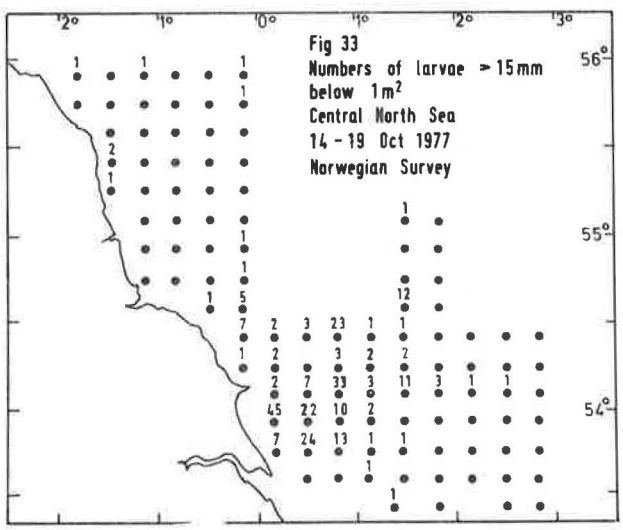
Fig 33
Numbers of larvae > 15mm
below 1m²
Central North Sea
14 - 19 Oct 1977
Norwegian Survey

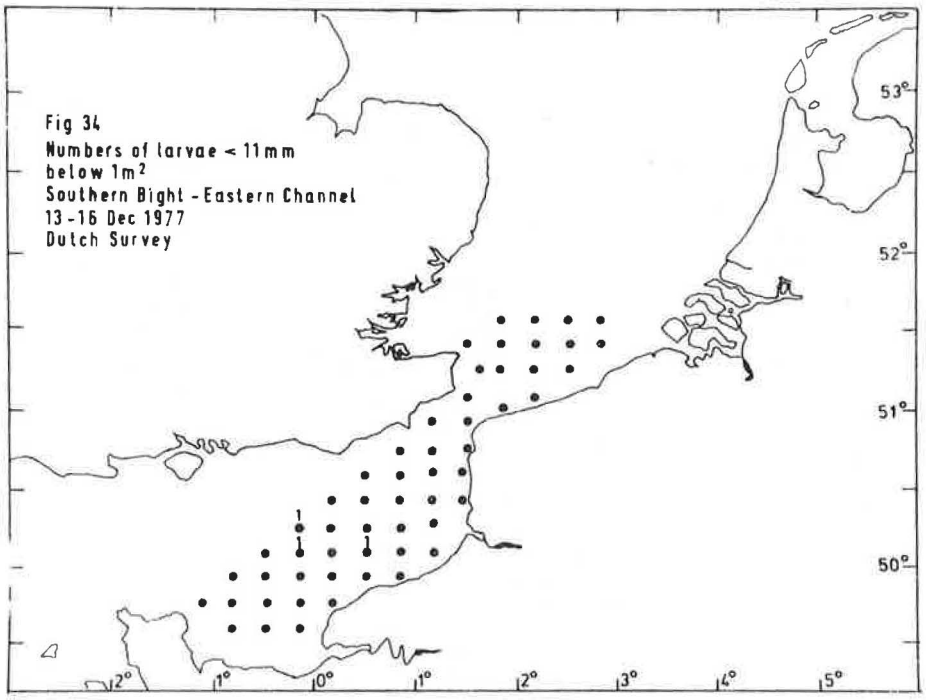

Fig 34
Numbers of larvae < 11mm
below 1m²
Southern Bight - Eastern Channel
13-16 Dec 1977
Dutch Survey

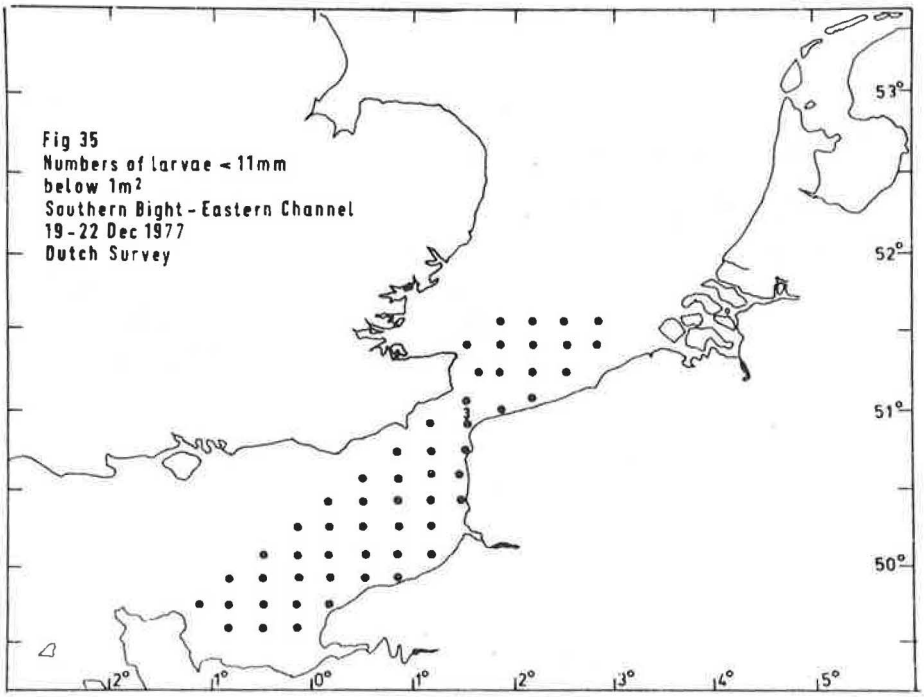

Fig 35
Numbers of larvae < 11mm
below 1m²
Southern Bight - Eastern Channel
19-22 Dec 1977
Dutch Survey

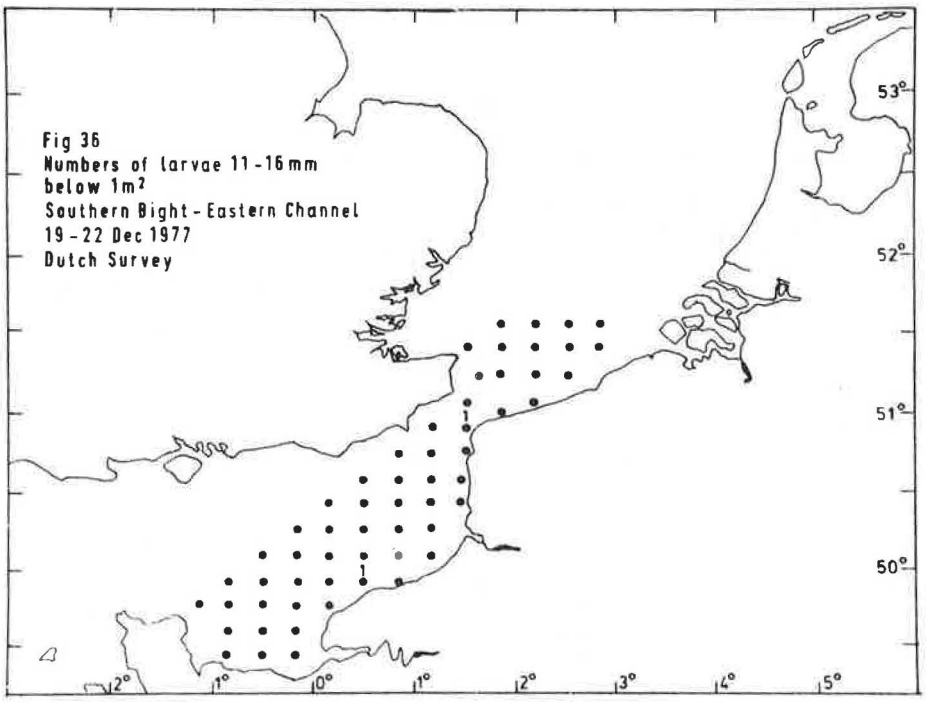

Fig 36
Numbers of larvae 11-16mm
below 1m²
Southern Bight - Eastern Channel
19-22 Dec 1977
Dutch Survey

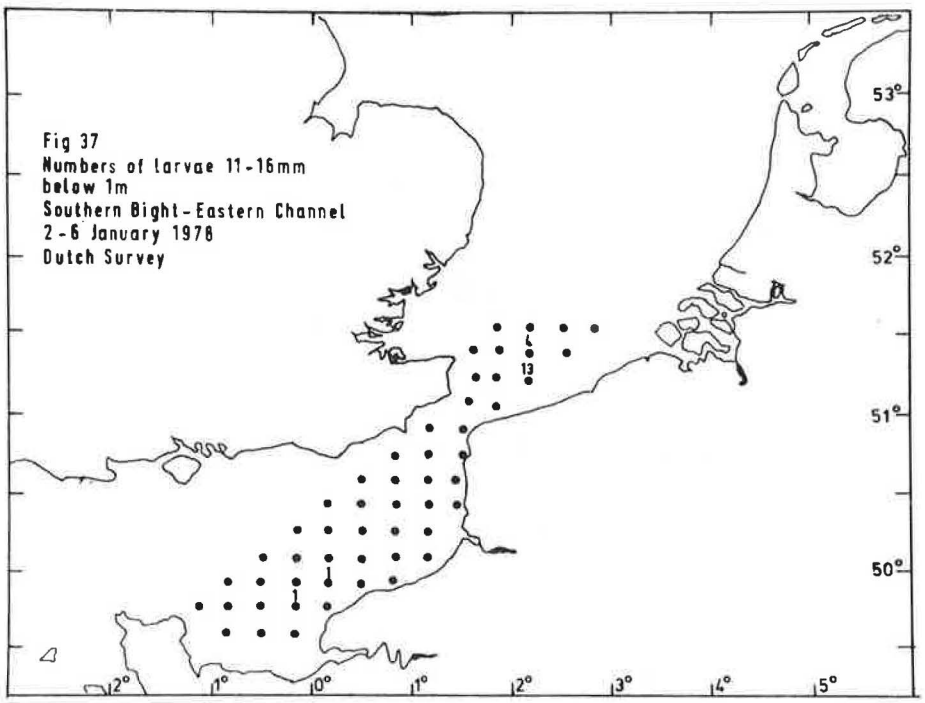

Fig 37
Numbers of larvae 11-16mm
below 1m
Southern Bight-Eastern Channel
2-6 January 1978
Dutch Survey

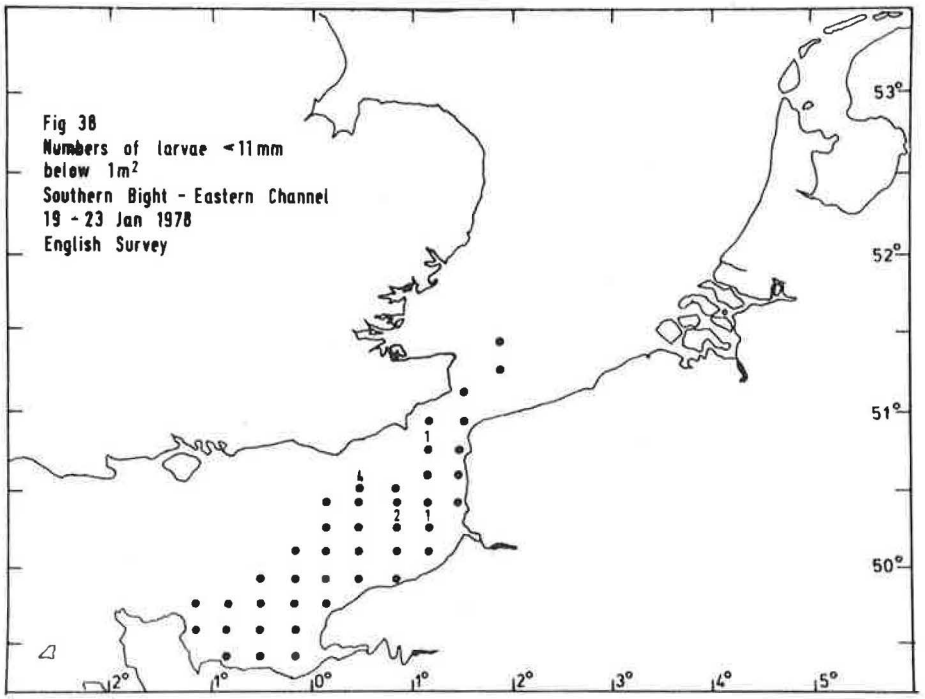

Fig 38
Numbers of larvae <11mm
below 1m²
Southern Bight - Eastern Channel
19 - 23 Jan 1978
English Survey

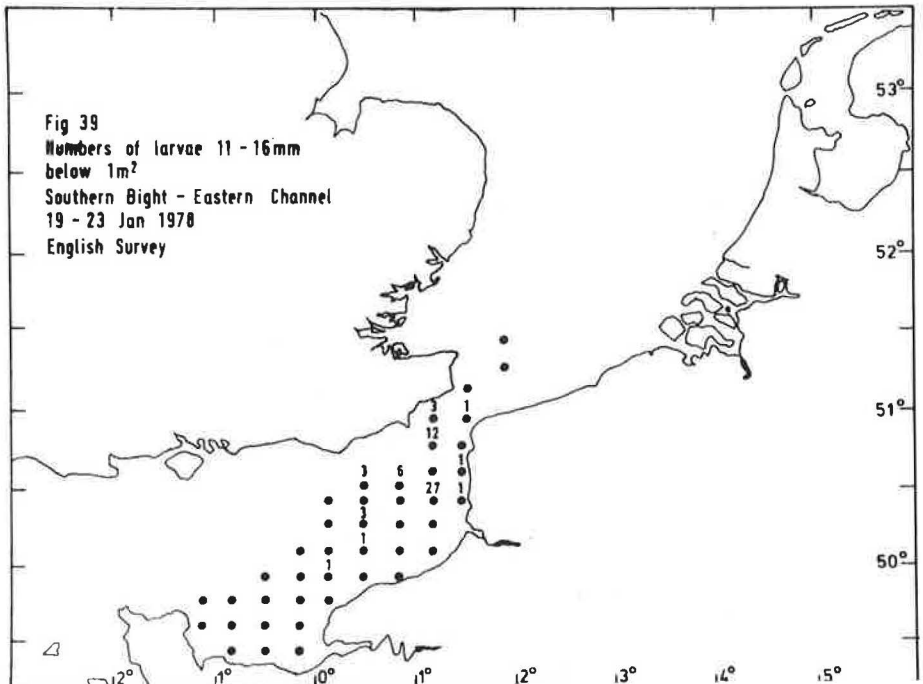

Fig 39
Numbers of larvae 11 - 16mm
below 1m²
Southern Bight - Eastern Channel
19 - 23 Jan 1978
English Survey

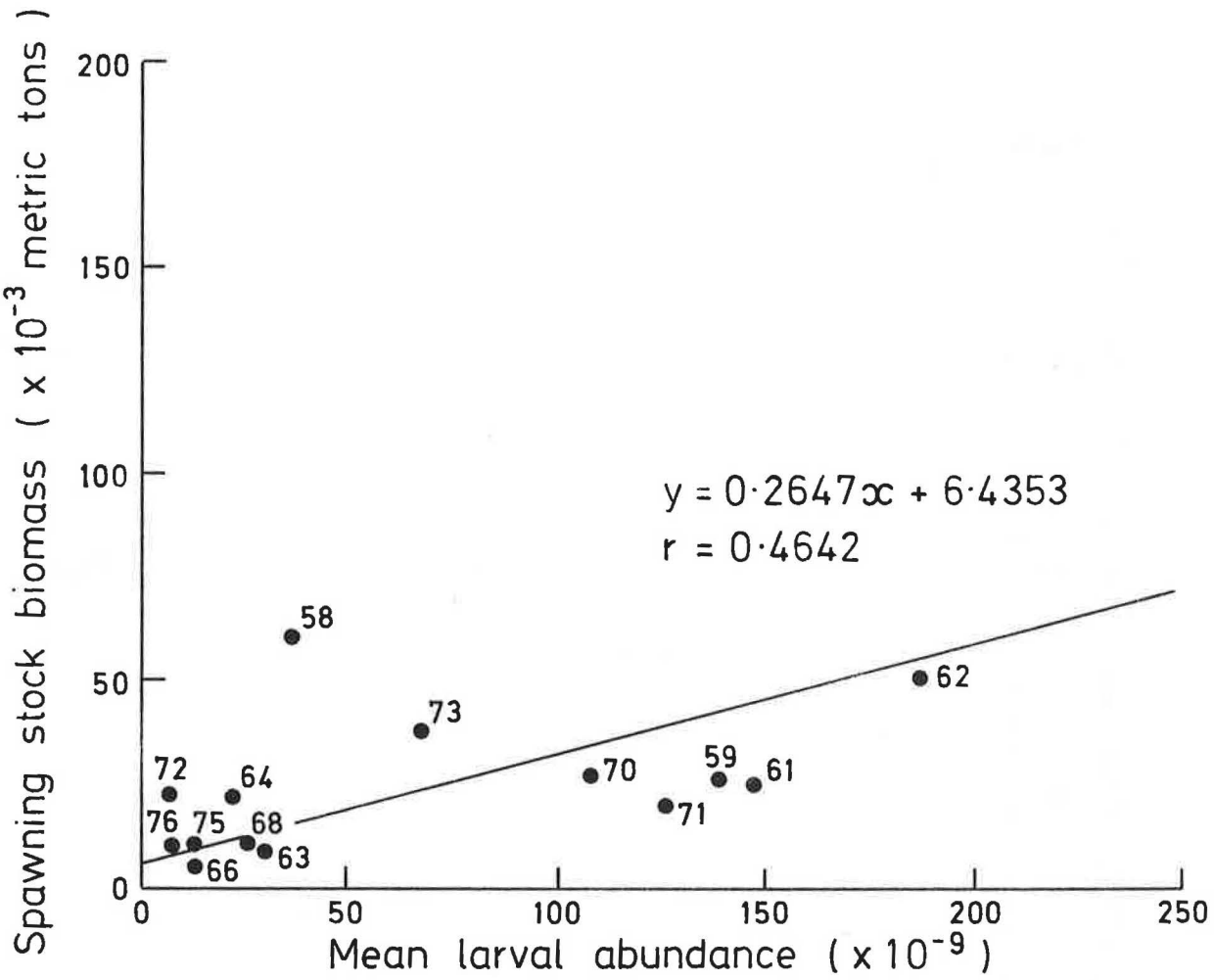

Fig 40 Estimated larval abundance and spawning stock biomass in the southern North Sea / Eastern Channel 1958 - 76

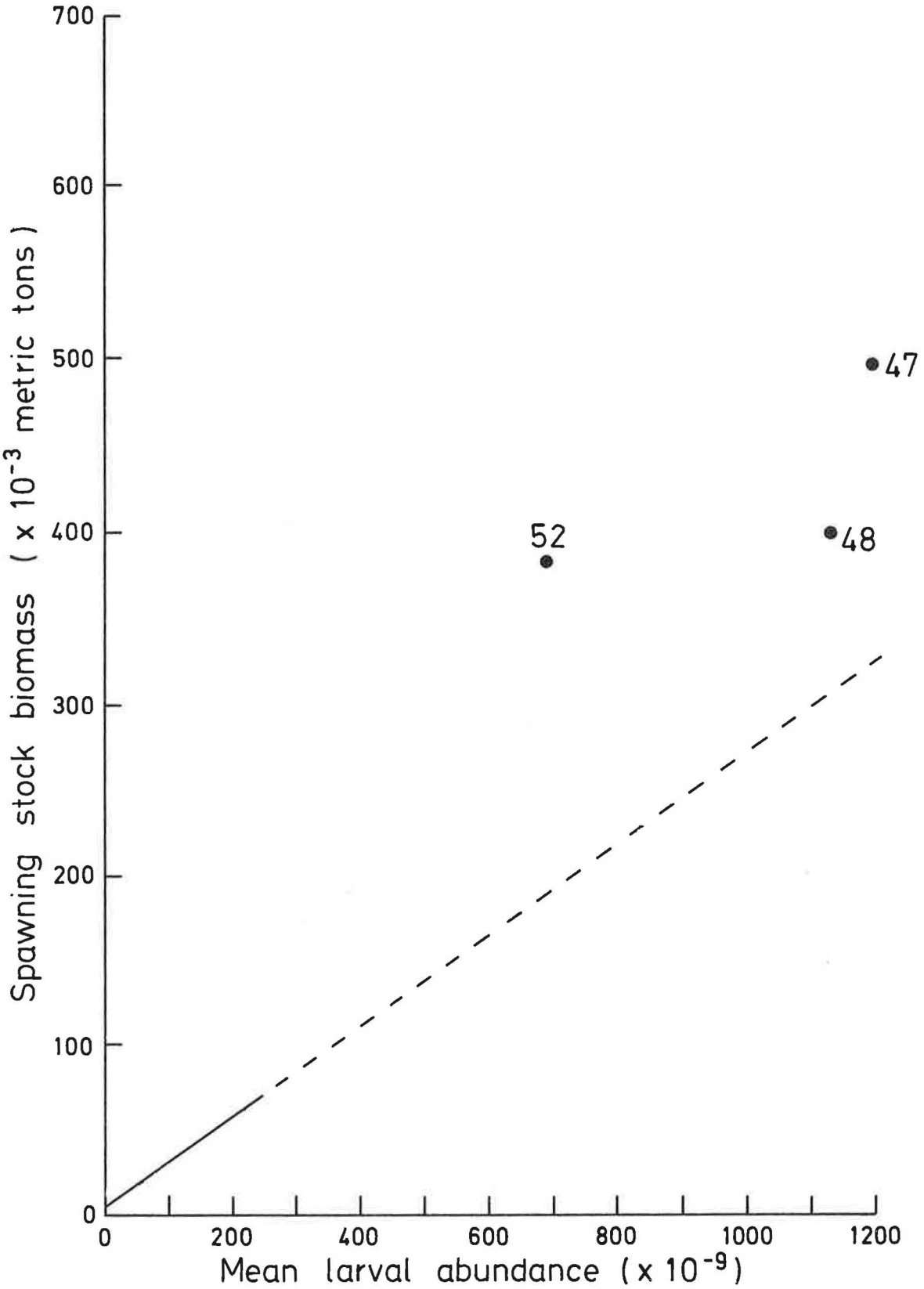

Fig 41. Estimated larval abundance and spawning stock biomass in the southern North Sea / Eastern Channel 1947 - 76

QUANTITATIVE DISTRIBUTION OF HERRING LARVAE IN THE NORTH SEA IN 1977

by

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Introduction

The research on quantitative distribution of herring larvae in the North Sea aims at determining the herring stocks' dynamics and the variations in their productivity. Such investigations in the area between 01°30'W and 04°00'E, and 57°15'N and 53°15'N have been carried out regularly by Polish research vessels for 20 years, in autumns from 1963 to 1979 (Kijowski, 1963-65, 1966, 1967; Ciszewski, 1968, 1969, 1970; Szlachcikowska, 1971, 1972. 1973; Siudziński, 1976, 1977, 1979).

From 1977 the area studied has been shifted to the east coast of Scotland (56°N and 58°N, and 00° and 03°00'W), as recommended by the ICES Working Group on North Sea Herring Larval Surveys. Other herring spawning areas in the North Sea were covered by research vessels of Denmark, German Democratic Republic, Federal Republic of Germany, Netherlands, Norway, Scotland and USSR.

Material and Methods

Samples of ichthyoplankton were collected during the cruise of MT "Birkut" from 1 September to 15 October 1977 at 89 stations. Sampling was repeated at 9 stations with a high number of herring larvae.

Sampling was made with the Gulf III High Speed Plankton Sampler according to recommendations of the meeting of the Working Group on North Sea Herring Larval Surveys, held at Lysekil, May 1976. The sampler was lowered to 5 m above the sea floor at the rate of 40 m/min and was then lifted at the same speed. The ship's speed was 5 knots. The larvae were sorted onboard and preserved in 4% formalin.

Results

The results are shown in Tables 1 and 2 and Figures 1 to 5. The amounts of herring larvae under 1 m^2 of the North Sea are shown in Figure 2.

Herring larvae occurred at 45 of the 89 stations, mainly in the area between 56°30'N and 58°00'N and 00° to 02°00'W. The highest abundance of herring larvae, 220 specimens under 1 m^2 at Station No.16, was found in the northern part of this area.

The detailed analysis of individual length groups showed that the most numerous group was larvae <10 mm with an average of 280.19 specimens/m^2 (Figure 3); they made up 60% of the total amount of larvae determined. Next came the group of 10 to 15 mm length, with 145.00 specimens/m^2 (Figure 4), and 31.1% of the total; and finally the group >15 mm, with 41.63 specimens/m^2 (Figure 5), and 8.9% of the total.

The larvae <10 mm (Figure 3) were concentrated in a small area, which may indicate a spawning region, especially at Station No.16, where 5-8 mm larvae were detected in amounts of 220 specimens/m^2.

The 10-15 mm larvae, on the other hand, were widely scattered over the whole area, with from 1 to 13 specimens under 1 m^2, and the larvae

>15 mm in length were observed only outside the coastal zone, in the open North Sea with 1-10 specimens/m^2. Concerning the distribution of herring larvae in relation to temperature, the observation made in preceding years was confirmed, i.e., that they were most abundant in waters with temperatures ranging from 10.5°C to 11.5°C (Siudziński, 1974, 1975, 1976).

Discussion

On the background of investigations on the occurrence of the herring larvae in the North Sea from 1963 to 1978 it was evident that there was an increase in number of larvae caught in 1977. It was highly significant, particularly if one compared with the values from 1976, the year with the lowest amount of larvae that have been detected since 1971.

Conclusions

- A significant increase in the number of herring larvae per 1 m^2 was noticed in 1977.
- Larvae 5-8 mm in length were the most abundant; they were concentrated in the coastal zone of the area investigated, indicating herring spawning areas (Station No.16).
- The larvae >10 mm, and particularly those >15 mm, showed a tendency of moving from the coastal zone into open North Sea waters.
- Optimal temperatures for herring larval development were in the range of 10-12°C.

ACKNOWLEDGEMENTS

The author wishes to express his gratitude to Marianna Pastuszak, Krystyna Maciejewska, Józef Wysocki and Maciej Sompoliński for their research efforts onboard.

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Table 1. Herring larvae, North Sea, caught with Gulf III sampler by MT "Birkut" from 12 September to 5 October 1977.

Station No.	Date	Position	Depth (m)	Water sampled (m^3)	No. caught	No. per m^2	Herring larvae (No./m^2)																	
							Standard length (mm)																	
							5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	<10	10-15	>15
16	12 Sep	57°45'N 01°30'W	68	43.28	140	219.98	51.85	117.85	48.71	1.57														219.98		
17	13 Sep	57°45' 01°50'	56	31.94	14	24.53	15.77	5.26		1.75	1.75													24.53		
18	13 Sep	57°45' 02°10'	44	28.76	5	7.66		4.60	3.06															7.66		
35	15 Sep	57°15' 01°50'	57	40.00	2	2.85							1.43		1.42										2.85	
46	16 Sep	57°05' 01°50'	78	67.26	11	12.79					1.16	1.16	3.49	3.49	3.49									1.16	11.63	
45	16 Sep	57°05' 01°30'	72	59.30	2	2.45									1.22		1.23								2.45	
49	16 Sep	56°55' 01°30'	72	63.58	5	5.69						2.28		1.13	2.28										5.69	
48	16 Sep	56°55' 01°50'	94	83.78	8	8.93						1.12		4.46	3.35										8.93	
47	16 Sep	56°55' 02°05'	50	32.74	2	3.05									3.05										3.05	
60	16 Sep	56°45' 02°10'	61	43.18	2	2.81										1.40	1.41								2.81	
59	16 Sep	56°45' 01°50'	63	49.95	3	3.78										3.78									3.78	
86	18 Sep	56°05' 01°10'	60	48.76	1	1.26											1.26								1.26	
85	19 Sep	56°05' 00°50'	63	44.78	1	1.39										1.39									1.39	
70	19 Sep	56°25' 00°50'	65	37.51	4	6.96								1.74	3.48			1.74							5.22	1.74
65	19 Sep	56°35' 00°50'	69	56.42	1	1.24											1.24								1.24	
64	19 Sep	56°35' 01°10'	65	47.56	4	5.46													1.37	2.73		1.36				5.46
56	20 Sep	56°45' 00°50'	58	40.60	2	2.84											2.84								2.84	
51	20 Sep	56°55' 00°50'	62	48.36	5	6.39												2.56	1.28	1.27			1.28			6.39
44	20 Sep	57°55' 01°10'	57	86.27	1	0.68									0.68										0.68	
50	20 Sep	56°55' 01°10'	62	37.61	2	3.29									1.64			1.65							1.64	1.65
43	20 Sep	57°05' 00°50'	62	37.71	1	1.67									1.67										1.67	
38	20 Sep	57°15' 00°50'	64	43.68	2	2.94										1.47		1.47							1.47	1.47

continued

TABLE 1 (ctd)

Station No.	Date	Position	Depth (m)	Water sampled (m^3)	No. caught	No. per m^2	Herring larvae (No./m^2)																		
							Standard length (mm)																		
							5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	<10	10-15	>15
37	20 Sep	57°15'N 01°10'W	76	51.44	2	2.96										1.48	1.48								2.96	
32	20 Sep	57°25' 01°10'	76	72.14	1	1.06											1.06								1.06	
31	20 Sep	57°25' 00°50'	74	60.70	1	1.18									1.18										1.18	
26	20 Sep	57°35' 00°50'	100	90.85	16	17.60					2.20		1.10	6.60	3.30	2.20		1.10		1.10				2.20	13.20	2.20
25	21 Sep	57°35' 01°10'	86	77.31	1	1.12						1.12													1.12	
14	21 Sep	57°45' 00°50'	88	82.89	13	13.82				1.06	2.13	2.13	1.06	2.13	4.25		1.06							3.19	10.63	
15	21 Sep	57°45' 01°10'	88	76.72	15	17.25		2.30	8.05		2.30	2.30	1.15		1.15									12.65	4.60	
8	21 Sep	57°55' 01°10'	93	65.57	3	4.28									2.85	1.43									4.28	
7	21 Sep	57°55' 01°30'	97	87.56	3	3.30								1.10		1.10	1.10								3.30	
9	21 Sep	57°35' 00°50'	89	98.11	1	0.89												0.89								0.89
10	21 Sep	57°55' 00°30'	96	93.93	7	7.20				1.03	1.03	1.03	2.05	1.03	1.03									2.05	5.15	
11	21 Sep	57°55' 00°10'	77	47.46	5	8.09				1.62	1.61	1.62	1.62				1.62							3.24	4.85	
12	21 Sep	57°45' 00°10'	96	81.69	12	14.11				2.35	1.18	3.53		2.35		3.53	1.17							3.53	10.58	
29	22 Sep	57°25' 01°10'	76	53.53	2	2.81						2.81													2.81	
28	22 Sep	57°35' 00°10'	91	78.51	15	17.38						1.16		3.48	1.16	1.16			1.16	5.78	2.32	1.16			6.95	10.43
40	22 Sep	57°15' 00°10'	77	63.88	1	1.23											1.23								1.23	
30	22 Sep	57°25' 00°30'	78	59.90	5	6.47										2.59	3.88								6.47	
55	3 Oct	56°45' 00°30'	68	54.13	3	3.74															2.49	1.25				3.74
66	3 Oct	56°35' 00°30'	70	58.11	2	2.38									1.19	1.19									2.38	
52	3 Oct	56°55' 00°30'	75	61.59	2	2.40											1.20				1.20				1.20	1.20
53	5 Oct	56°55' 00°10'	70	56.22	1	1.26												1.26								1.26
54	5 Oct	56°45' 00°10'	75	61.69	3	3.68										1.23	1.22		1.23						2.45	1.23
67	5 Oct	56°35' 00°10'	65	48.86	3	3.97														1.32	2.65					3.97

Table 2. Herring larvae, North Sea, caught with Gulf III sampler by MT "Birkut" from 5 October to 6 October 1977.

Station No.	Date	Position	Depth (m)	Water sampled (m^3)	No. caught	No. per m^2	Herring larvae (No./m^2) Standard length (mm)																				
							5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	<10	10-15	>15
29	5 Oct	57°25'N 01°10'W	75	59.10	4	5.10					1.30	1.30	1.20				1.30								1.30	3.80	
28	5 Oct	57°35' 00°10'	96	88.76	4	4.32															1.08	2.16	1.08				4.32
12	5 Oct	57°45' 00°10'	96	77.02	7	8.74												3.75	2.50	1.24	1.25						8.74
13	5 Oct	57°45' 00°10'	93	92.34	9	9.02										2.00	4.00	2.00			1.02					6.00	3.02
27	5 Oct	57°35' 00°30'	100	83.18	17	20.40										1.20	10.80	2.40	3.60	1.20		1.20				12.00	8.40
30	6 Oct	57°25' 00°30'	78	65.47	12	14.27									1.19		3.57	5.95	2.38		1.18					4.76	9.51
26	6 Oct	57°35' 00°50'	98	81.00	32	38.71							1.21			7.26	14.51	9.68	1.21	2.42	2.42					22.98	15.73
31	6 Oct	57°25' 00°50'	74	62.28	10	11.91								4.77		2.38		1.19		2.38				1.19		7.15	4.76
14	6 Oct	57°45' 00°50'	88	75.52	56	65.30							2.33	1.17	4.66	10.49	30.32	7.00	4.66	1.17	2.33	1.17				48.98	16.32

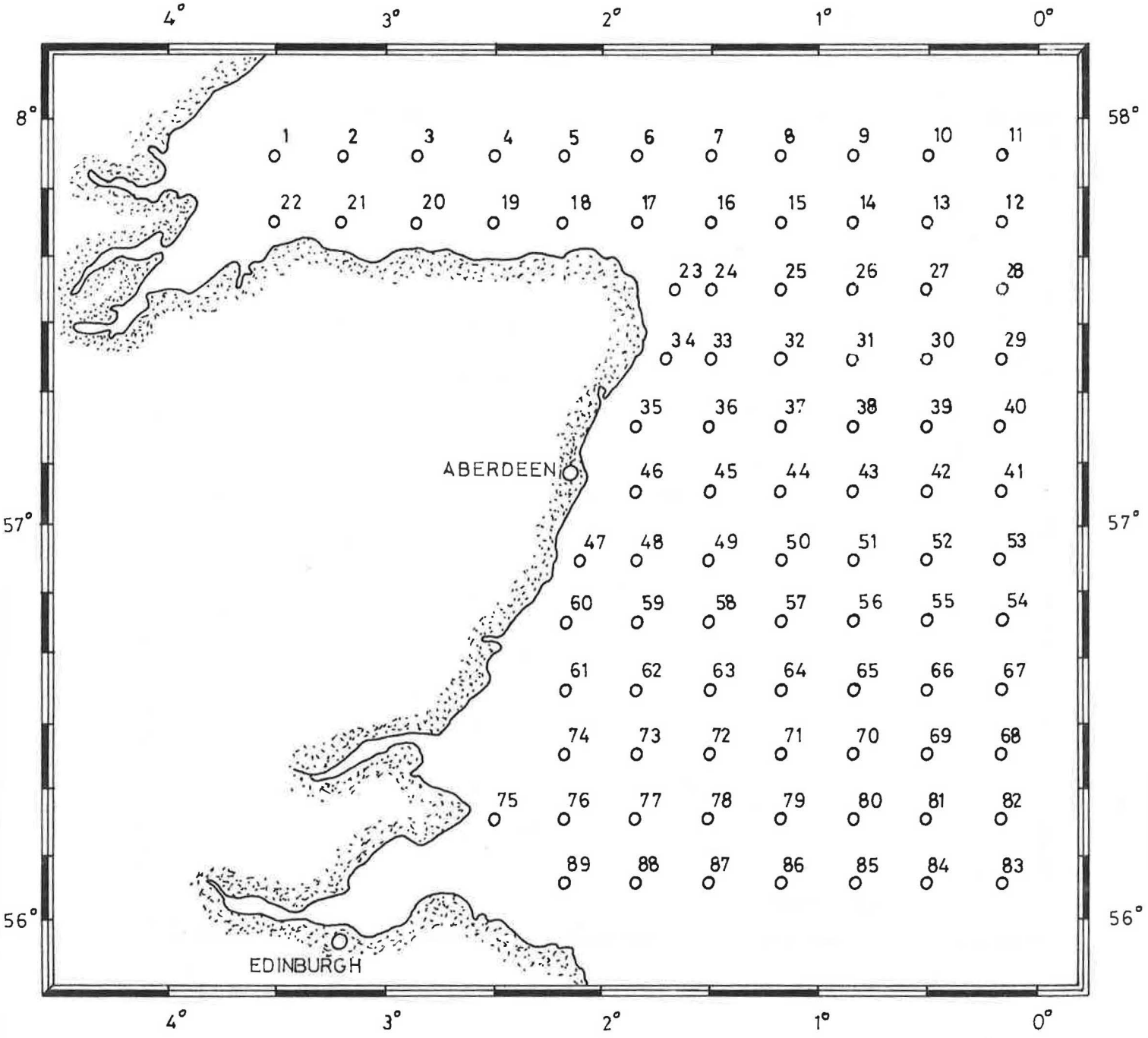

Figure 1. Location of sampling stations, 1 September to 15 October 1977.

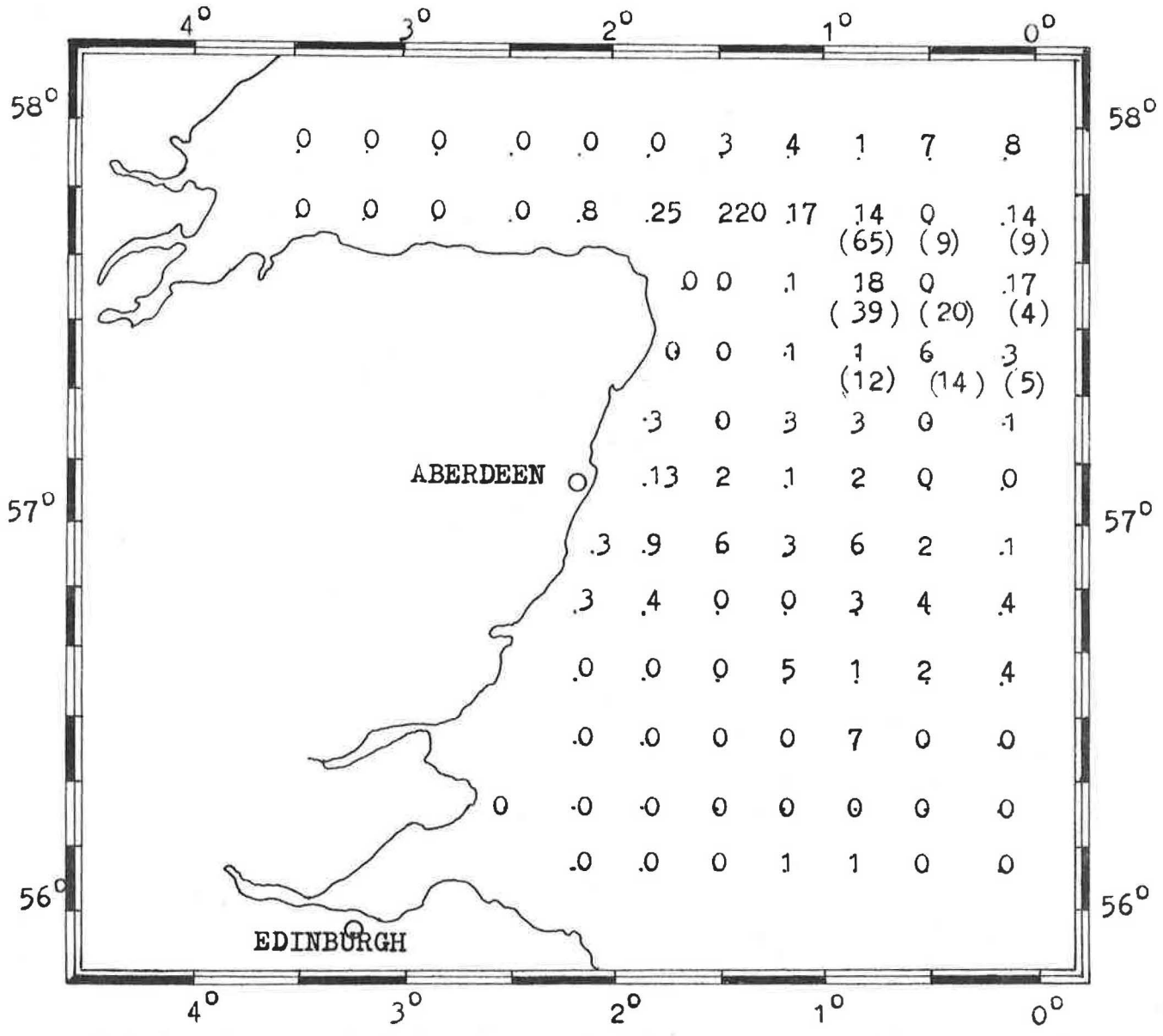

Figure 2. Number of herring larvae per 1 m^2 at the different stations.

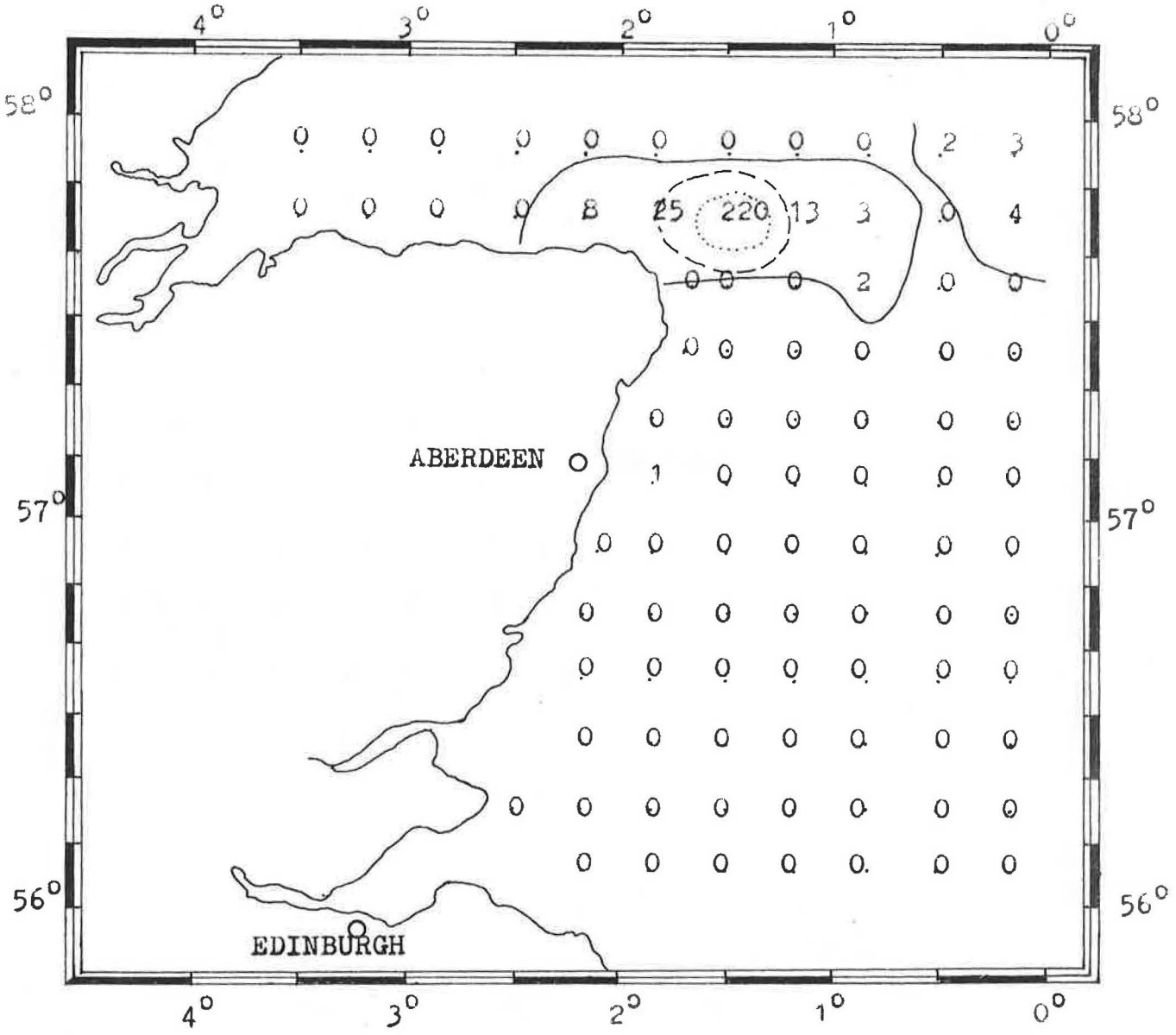

Figure 3. Number of herring larvae of <10 mm length/m^2, 1 September to 15 October 1977.

———— 1 specimen/m^2

-------- 25 specimens/m^2

····· 100 specimens/m^2

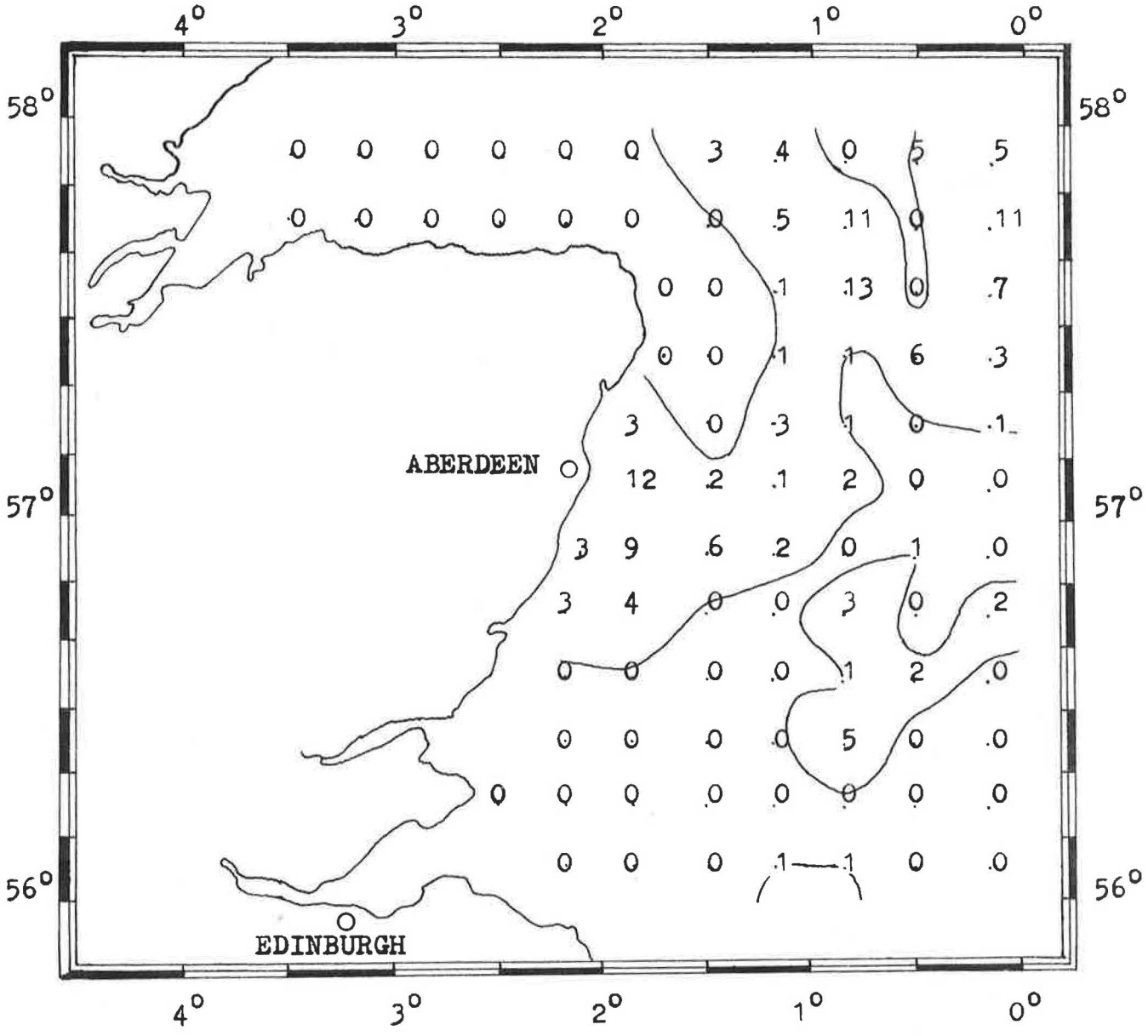

Figure 4. Number of herring larvae of 10-15 mm length/m^2, 1 September to 15 October 1977.

———— 1 specimen/m^2

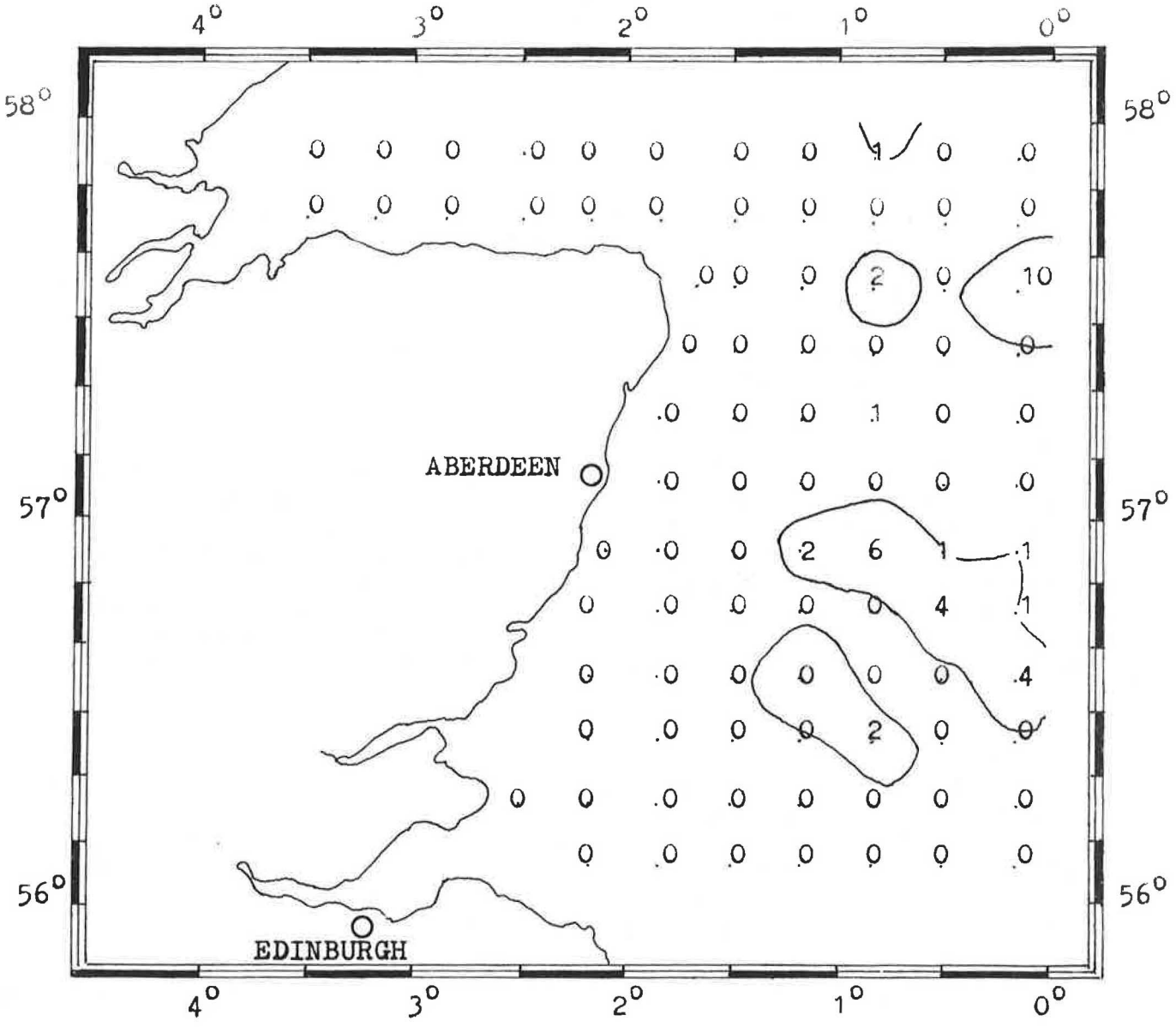

Figure 5. Number of herring larvae of >15 mm length/m^2, 1 September to 15 October 1977.

——— 1 specimen/m^2

THE DISTRIBUTION AND ABUNDANCE OF HERRING LARVAE TO THE WEST OF SCOTLAND IN 1977

by

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Summary

This paper describes the results of the herring larval surveys carried out to the west of Scotland in 1977. These gave larval abundances rather higher than in the 1976 surveys. The size of the spawning stock in Division VIa in 1977 has been estimated from the mean abundance of <10 mm long larvae. Data are presented on the pattern of spawning in the area to the west of South Uist and the size of the spawning stock in that area is estimated from the total larval production.

Résumé

Ce communiqué décrit les résultats des études portant sur les larves de harengs entreprises à l'ouest de l'Ecosse en 1977. Celles-ci ont donné des abondances larvaires un peu plus élevées que celles de 1976. L'importance de la population de poissons qui frayent dans Secteur VIa est estimée d'après l'abondance des larves. Le communiqué présente des données relatives à la conduite du frai dans la région à l'ouest de South Uist et l'importance de la population de poissons qui frayent dans la région est estimée d'après la production totale de larves.

Introduction

This report gives the results of the 8th annual survey of herring larvae to the west of Scotland. An initial survey in 1965 was followed by a regular series which began in 1971 as a result of a recommendation by the ICES Herring Assessment Working Group (Anon., 1971). These surveys are intended to provide a measure of the relative changes in the size of the herring spawning stock which are independent of those estimated from commercial fishery data. The results of the previous surveys have been reported by Wood (1971, 1973), Saville and McKay (1974) and McKay (1975, 1976, 1977a and b).

Materials and Methods

During the autumn of 1977 three surveys of the spawning area of herring in ICES Division VIa were carried out. In addition, three more detailed surveys were carried out on the spawning grounds to the west of South Uist in an attempt to describe the larval production curve in this small area. The timing of each survey is given in Table 1. On the surveys of the total spawning area sampling was carried out using a modified Gulf III sampler towed in a double oblique haul fishing the whole water column to within 5 metres of the sea bed. A more detailed description of the gear and sampling techniques is given by Saville (1970) and Anon. (1977). For the surveys to the west of South Uist a High Speed Loch Ewe Net was used. This net is bascially an unencased Gulf III sampler with two nets, one of 250 μ mesh aperture and an outer one of 65 μ mesh aperture. The nose cone geometry of the High Speed Loch Ewe Net is identical to that of the Gulf III sampler used on the other surveys. During September and October 1977 a total of 344 stations were sampled.

Abundance estimates were calculated in a similar manner to that of Schnack (1973). The estimated number of larvae below 1 m^2 at each station was multiplied by the sea surface area in square metres represented by that station, and the individual numbers were then summed for each survey and size group of larvae.

Results

Surveys of the whole spawning area

The results from the surveys carried out in 1977 are given in Figures 1-9. These have been contoured at the 1, 25, 100, 500 larvae/m^2 surface levels to illustrate the location and extent of larval concentrations. The first survey (8-16 September) covered the area from 56°15'N to 59°15'N and from St Kilda east to 4°W. On this survey the maximum density (350 larvae/m^2) of <10 mm long larvae was found north of Sule Skerry (Figure 1). The total number of larvae <10 mm long was estimated to be 404 x 10^9 (Table 2). Larvae in the 10-15 mm length range were widely distributed from Barra Head around the west and north of the Outer Hebrides and east to Strathy Point, as well as in the North Minch. The total number of larvae in the 10-15 mm length range was estimated to be 240 x 10^9. Larvae >15 mm long were largely confined to the North Minch and the area northwest of Cape Wrath (Figure 3). The total number of larvae >15 mm long was estimated to be 36 x 10^9 (Table 2).

On the second survey from 18 to 26 September <10 mm long larvae were found in five main areas west of the Outer Hebrides and off the north coast of Scotland, with the maximum density of 971 larvae/m^2 surface being located west of Barra (Figure 4). Off the Irish coast larvae were rather scarce, the maximum density of 11 larvae/m^2 being located off Malin Head. The total number of <10 mm long larvae was estimated to be 1 188 x 10^9 (Table 2). Larvae in the 10-15 mm length range were widely distributed over much of the northern part of the area surveyed, with the maximum density of 161 larvae/m^2 surface being located west of the Butt of Lewis (Figure 5). The total number of 10-15 mm long larvae was estimated to be 506 x 10^9 (Table 2). Larvae >15 mm long were found over a wide area from North Uist north and east to Strathy Point, the highest densities being found off the Butt of Lewis (Figure 6).

On the third survey from 15 to 24 October, <10 mm long larvae were found in two main areas, west of Harris (density up to 124 larvae/m^2 surface) and north of Malin Head (density up to 162 larvae/m^2 surface) (Figure 7). The total number of <10 mm long larvae was estimated to be 335 x 10^9 (Table 2). Larvae in the 10-15 mm length range were found at almost every station sampled but the highest densities were found in a broad belt west of the Hebrides from North Uist north to north of the Butt of Lewis (Figure 8). The total number of larvae in the 10-15 mm length range was estimated to be 838 x 10^9 (Table 2). Larvae >15 mm long were widely distributed to the west of the Outer Hebrides at generally low densities (Figure 9).

Comparisons with previous surveys

To obtain estimates comparable with those from earlier surveys it is necessary to compare surveys made over the same time periods and in the same areas. Because of the difference in the timing of larval production in area north and west of the Hebrides from that off the northwest coast of Ireland the surveys have been planned to be carried out at different times in the two above areas. It has therefore been necessary to consider the abundance data for the areas north and south of 56°30'N separately. Estimates of larval abundance for the past and present surveys of Division VIa divided in this way are given in Tables 3 and 4.

September surveys

Because of the timing of the surveys in 1977 no comparisons of the larval abundances in the early part of September 1977 can be made with those in previous years. For the area north of 56°30'N the estimate of larval abundance in the period 11 to 25 September was considerably higher than that obtained during the same period in 1976, and apparently about the same as that for the same period in 1975. It should, however, be pointed out that the 1975 survey was confined to the Cape Wrath/Butt of Lewis area. Comparing estimated numbers only at those stations sampled in both 1975 and 1977 (Figure 4 and McKay (1976, Figure 3)) the estimate of herring larval abundance in 1975 was twice as high as that in 1977. In the area south of 56°30'N only one survey was carried out in 1977. This indicated that the abundance of larvae was rather less than in the three preceding years and approximately the same as in 1972.

October surveys

The only survey carried out in October 1977 covered the period 15 to 24 October. The estimated abundance of herring larvae <10 mm long was rather higher than in 1976, and this difference was most marked in the area south of 56°30'N. The estimates of larval abundance, however, were well below those for the years prior to 1975.

Stock size estimates

McKay (1979) compared the mean abundance of <10 mm long larvae in years when more than one survey was carried out with the spawning stock size in that year. Because of the differences in the number of surveys carried out in the areas north and south of 56°30'N the mean abundance of larvae on all the surveys has been calculated separately for each area and summed to give the mean larval abundance in ICES Division VIa. The spawning stock size was assumed to consist of all herring 3 years old and older on 1 January estimated from virtual population analysis (VPA) corrected to the stock size at the end of August by applying two thirds of the Z in that year also estimated by VPA. From the data then available no significant relationship was found. Saville and Bailey (1978) have pointed out that there is considerable immigration of herring ≥3 years old into Division VIa from the North Sea so that the estimates of the abundance of all herring 3 years and older given by the Herring Assessment Working Group will not be a realistic estimate of the spawning stock size, even if the estimated abundances of these age groups at 1 January given in the Working Group report are correct. However, as no other detailed series of data are available for the years 1972-77, spawning stock sizes have again been calculated using the same method from the estimates of adult stock sizes given in the most recent Herring Assessment Working Group report (Anon., 1978). The relationship between spawning stock size and mean abundance of <10 mm long larvae has been re-examined (Table 5 and Figure 10) and the regression of spawning stock size on larval abundance is

$$S.S. = 12.66\ L.A. + 22.01$$

where L.A. = mean abundance of <10 mm larvae x 10^{-11}

and S.S. = spawning stock size in tonnes x 10^{-3}.

This regression is not significant at the 5% level. It should also be pointed out that the regression is based on the data from 1972-76 and that the values of the spawning stock size in 1975 and 1976 from VPA may be extremely unreliable. In the absence of other methods of relating larval abundance to spawning stock size the above regression has been used to estimate the size of the spawning stock in 1977. The estimated spawning stock size in Division VIa in 1977 was 107 000 tonnes.

In 1977 there was no larval survey between 26 September and 10 October, in previous years a period of high larval production. The absence of this survey in 1977 might therefore be expected to depress the mean larval abundance compared with that from other years, thereby underestimating the stock size. A corrected mean abundance of <10 mm larvae has been produced for 1977 by weighting the observed mean larval abundance by the ratio in previous years of the mean abundance from all surveys to the mean abundance from surveys in those periods in which surveys were carried out in 1977. This corrected mean indicates a spawning stock of 120 000 tonnes.

South Uist spawning

During 1977 an attempt was made to describe quantitatively the pattern of larval production on a small part of the spawning grounds, those west of South Uist. The area was surveyed six times during September and October 1977, three times on the surveys of the whole spawning area in Division VIa and three times on more detailed surveys carried out in the period 16 to 25 September. The abundance of <10 mm larvae in the area on each survey is given in Table 6 and the curve of larval abundance is plotted in Figure 11. From these data it is apparent that the abundance of small larvae on the spawning grounds west of South Uist changes very rapidly within a spawning season. Wood (1975) and Saville and McKay (1979) indicated that, as a first approximation, larval production within each of the discrete spawning areas in the central North Sea could be defined by a normal curve. A similar assumption was made with the present data in an attempt to describe more fully the pattern of change in larval abundance. A normal curve fitted to the data points (Figure 11) shows that the data are not adequately described by this model.

The data on which the larval abundance estimates are based, however, are derived from surveys with only a small number of stations. The variation in catches at the stations within the area is very high. On the second survey of the whole spawning area (Figure 4) in the area west of South Uist, for example, there were six stations sampled and the estimates of larval abundance at these varied from zero to 971 larvae/m^2 surface. In view of this variation within and between surveys the differences between the estimates were tested statistically. When consecutive surveys were compared the differences between the second and third and the fifth and sixth surveys were significant at the 10% and 0.1% level, respectively. No significant differences were found between the results of the other consecutive surveys, largely because estimates from the fourth survey had a very high variance.

As few of the differences between the estimates of larval abundance on consecutive surveys were significant, the running means of the estimated abundance of larvae have been plotted against the mid point of the period between the two surveys (Figure 12). These values are very close to those predicted from the normal curve fitted to the original data points.

Saville, Baxter and McKay (1974) estimated the total larval production on Ballantrae Bank during the spawning season by integrating from a curve of daily larval production. To use this approach with the data from the spawning grounds west of South Uist it is necessary to calculate the daily production rate of larvae during each survey. The abundance estimates given in Table 6 and Figures 11 and 12 are for larvae <9.5 mm long, excluding yolk sac larvae, which are not sampled quantitatively by the methods used on these surveys. The daily production of larvae would therefore be the abundance of larvae on the survey divided by the number of days production this represents i.e., the time taken for the larvae to grow from length at first sampling to 9.5 mm. Schnack (1972) and Wood and Burd (1976) estimate that the growth rate of herring larvae in the North Sea

varies from 0.17 to 0.35 mm/day so that larvae would spend between 7 and 15 days in this length group assuming that growth rates in Division VIa were the same as those in the North Sea. Integrating from the normal distribution curve given in Figures 11 and 12 the estimated larval production on the spawning grounds west of South Uist in 1977 was between 455 and 974 x 10^9. Allowing for a 10% per day mortality rate during the period between hatching and sampling the corrected larval production in the area west of South Uist would be between 1 151 and 1 532 x 10^9. These data would indicate that the spawning stock west of South Uist was between 7.8 and 10.5 x 10^3 tonnes, given that the fecundity per tonne of herring was 146 x 10^6 (Baxter, pers.comm.).

Discussion

From a regression of spawning stock size on larval abundance it has been estimated that the spawning stock size in Division VIa in 1977 was 120 x 10^3 tonnes. As the regression from which the estimate was made, is not significant at the 5% level the 95% confidence limits of the estimates are higher than the estimated spawning stock size. These estimates of confidence limits are based solely on the variance about the regression line, i.e. they assume that the input values of larval abundances are known with absolute precision. Present estimates of stock size in this area from larval abundance data can therefore not be used at present to confirm or reject estimates from other sources.

The estimates of larval abundance on the surveys carried out on the spawning grounds west of South Uist indicate that short-term variation in the estimated larval abundance is very high, e.g. in the six day period surrounding the second survey of the whole spawning area the estimated larval abundance on three separate surveys of the grounds west of South Uist varied between 62 and 462 x 10^9. The estimated abundance of <10 mm long larvae on the survey from 18 to 26 September was 1 188 x 10^9 (Table 2), of which 462 were contributed by the spawnings west of South Uist. It is therefore the case that minor (2 or 3 days) changes in the timing of sampling of this particular spawning ground could cause very large variations in the total estimate of larval abundance on the survey. It has been assumed that on wide ranging surveys, sampling errors on each individual spawning ground would balance out to give an estimate over the whole spawning area that was reasonably accurate. However, with only a few (five or six) areas of high larval densities in the whole survey area major errors in the sampling of one or two of these could have a major effect on the total estimate.

In the present situation, when information on adult stock size from fishery data is extremely limited, data from larval surveys may be the only indicator of changes in the adult stock. It is therefore important to assess whether the procedure adopted on surveys could be modified to produce an absolute rather than a comparative estimate of stock size. From the surveys carried out to the west of South Uist in 1977 it was shown that larval production approximately took the form of a normal curve. Using this curve the spawning stock in the area in 1977 was estimated to be between 7.8 and 10.5 x 10^3 tonnes. Extending this approach to cover all the spawning sites in Division VIa would necessitate a large increase in sampling effort.

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1) Will be published in Rapp.Proc.-Verb. Cons.int.Explor.Mer.

Table 1. Surveys carried out in 1977.

Period	Area	Sampling gear	No. of stations sampled
8-16 Sep 1977	N of 56°15'N	Dutch Gulf III	96
16-17 Sep 1977	W of S Uist	H.S. L Ewe	14
18-19 Sep 1977	W of S Uist	H.S. L Ewe	13
24-25 Sep 1977	W of S Uist	H.S. L Ewe	9
18-26 Sep 1977	55°N - 59°N	Dutch Gulf III	125
15-24 Oct 1977	55°N - 59°N	Dutch Gulf III	85
		Total	344

Table 2. Estimated abundances of herring larvae on the surveys of Div.VIa in 1977 (totals N and S of 56°30'N given separately).

Date	Survey area	Larval abundance x 10^{-9}			
		<10 mm	10-15mm	>15 mm	Total
8-16 Sep 1977	N of 56°30'N	404	240	36	680
18-26 Sep 1977	N of 56°30'N	1 171	487	94	1 752
	S of 56°30'N	17	19	1	37
	Complete survey	1 188	506	95	1 789
15-24 Oct 1977	N of 56°30'N	168	721	101	990
	S of 56°30'N	167	117	4	288
	Complete survey	335	838	105	1 278

Table 3. Estimated abundance of herring larvae in Division VIa, North of 56°30'N, in 1965, 1971, 1972, 1973, 1974, 1975, 1976 and 1977 in standard time periods. (After Wood (1971, 1973), Saville and McKay (1974) and McKay (1975, 1976, 1977a and 1977b).)

Size group of larvae	Time period	Estimated abundance x 10^{-9}							
		1965	1971	1972	1973	1974	1975	1976	1977
<10 mm	1-10 Sep	NS	NS	7 691[1]	NS	364[1]	515	NS	NS
	11-25 Sep	NS	NS	1 334	2 016	1 051[1]	1 132[1]	198	1 171
	26 Sep-10 Oct	NS	NS	2 388	1 665	1 376	663	231[1]	NS
	10-25 Oct	415	319	NS	NS	788	421[1]	145	168
10-15 mm	1-10 Sep	NS	ND	669[1]	NS	205[1]	83	NS	NS
	11-25 Sep	NS	NS	1 350	2 553	832[1]	976[1]	96	487
	26 Sep-10 Oct	NS	NS	2 122	1 779	1 234	949	51[1]	NS
	10-25 Oct	ND	ND	NS	NS	1 321	334[1]	367	721
Total	1-10 Sep	NS	3 267[2]	8 360[1]	NS	569[1]	598	NS	NS
	11-25 Sep	NS	NS	2 773	4 596	1 906[1]	108[1]	305	1 752
	26 Sep-10 Oct	NS	NS	4 586	3 586	2 832	1 661	284	NS
	10-25 Oct	1 330	1 037	NS	NS	2 366	795[1]	562	990

NS - No survey

ND - No data given

1) Incomplete survey

2) Including yolk sac larvae

Table 4. Estimated abundances of herring larvae in Division VIa, South of 56°30'N, in 1965, 1971, 1972, 1973, 1974, 1975, 1976 and 1977 in standard time periods. (After Wood (1971, 1973), Saville and McKay (1974) and McKay (1975, 1976, 1977a and 1977b).)

Size group of larvae	Time period	Estimated abundance x 10^{-9}							
		1965	1971	1972	1973	1974	1975	1976	1977
<10 mm	11-25 Sep	NS	NS	21	194	NS	153	71	17
	26 Sep-10 Oct	NS	NS	31	524	1 013	810	NS	NS
	10-25 Oct	504	677	NS	NS	727	NS	117	167
10-15 mm	11-25 Sep	NS	NS	29	47	NS	5	18	19
	26 Sep-10 Oct	NS	NS	21	231	149	151	NS	NS
	10-25 Oct	ND	ND	NS	NS	740	NS	240	117
Total	11-25 Sep	NS	NS	51	241	NS	158	92	37
	26 Sep-10 Oct	NS	NS	57	758	1 172	972	NS	NS
	10-25 Oct	807	940	NS	NS	1 561	NS	371	288

NS - No survey

ND - No data given

Table 5. Estimated mean abundance of <10 mm larvae and spawning stock size from VPA (Anon., 1978) during the period.

Year	Abundance of larvae <10 mm long x 10^{-9}	Spawning stock size x 10^{-3}
1972	3 830	494
1973	2 200	396
1974	1 942	218
1975	1 252	124
1976	285	82
1977	673	48

Table 6. Abundance of <10 mm long larvae in the spawning grounds west of South Uist

	Abundance of <10 mm long larvae x 10^{-9}
*10-11 Sep 1977	14
16-17 Sep 1977	26
18-19 Sep 1977	62
*22-23 Sep 1977	462
24-25 Sep 1977	219
*18 Oct 1977	3

* Data derived from wide ranging surveys

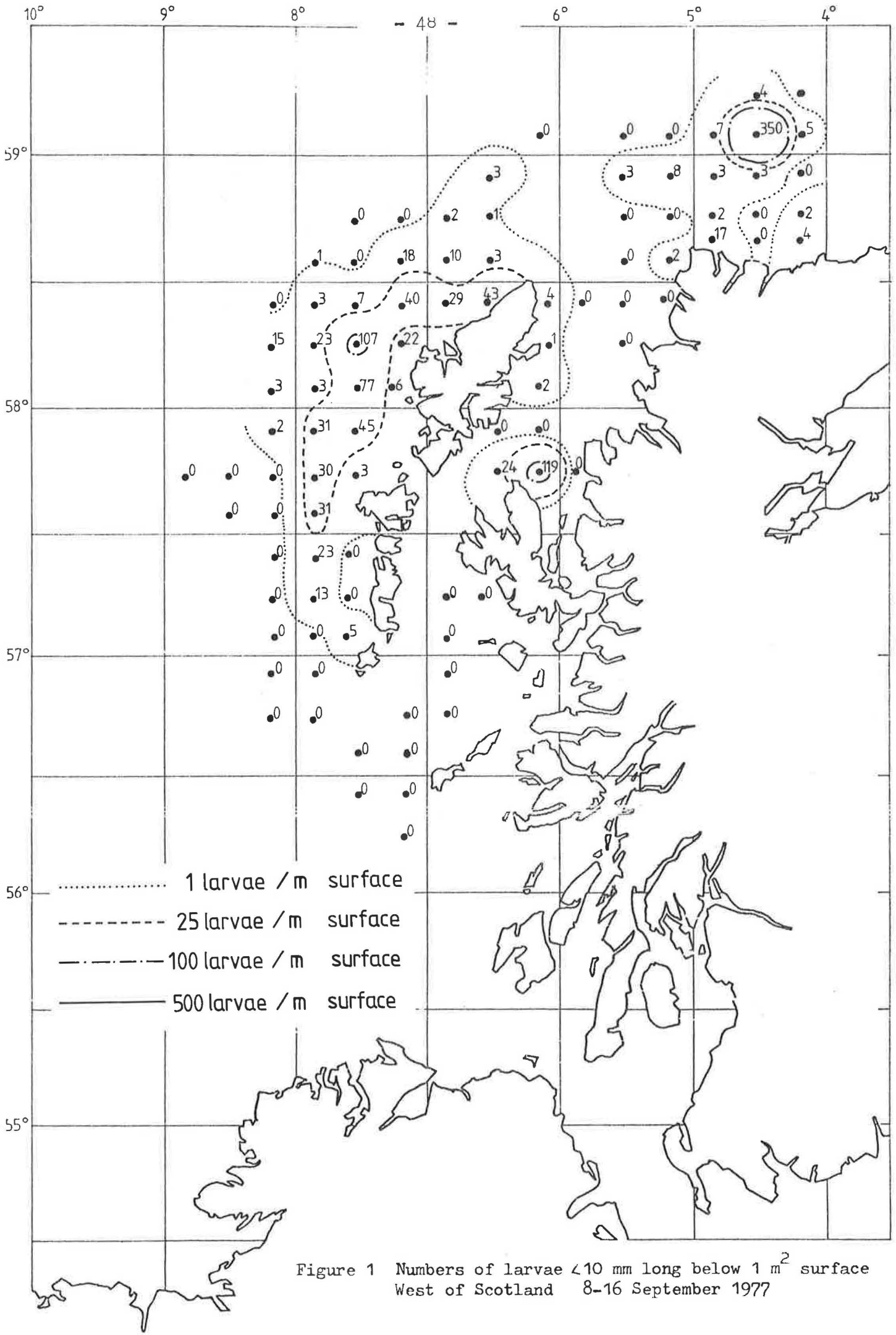

Figure 1 Numbers of larvae <10 mm long below 1 m^2 surface
West of Scotland 8-16 September 1977

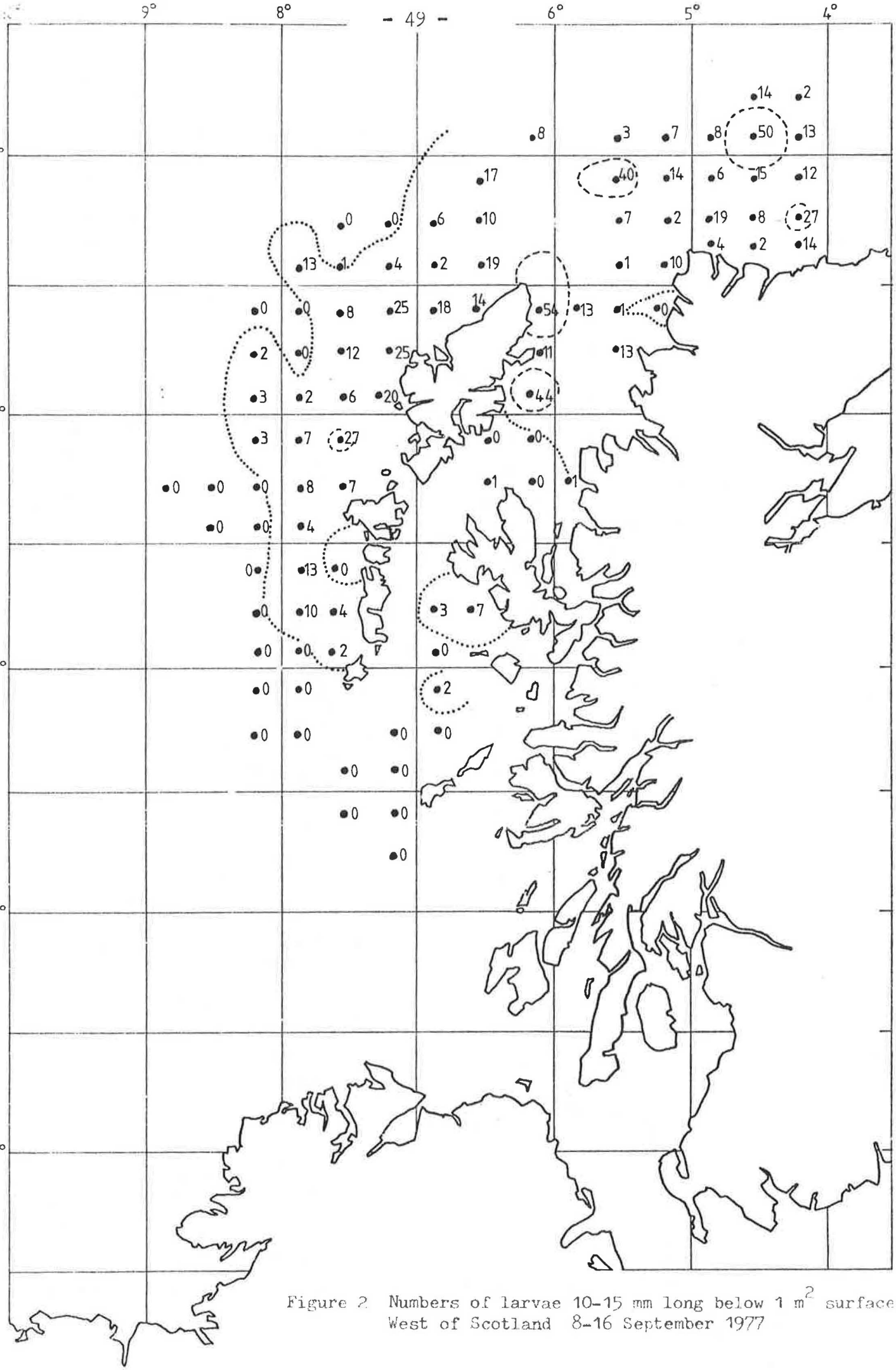

Figure 2 Numbers of larvae 10-15 mm long below 1 m^2 surface
West of Scotland 8-16 September 1977

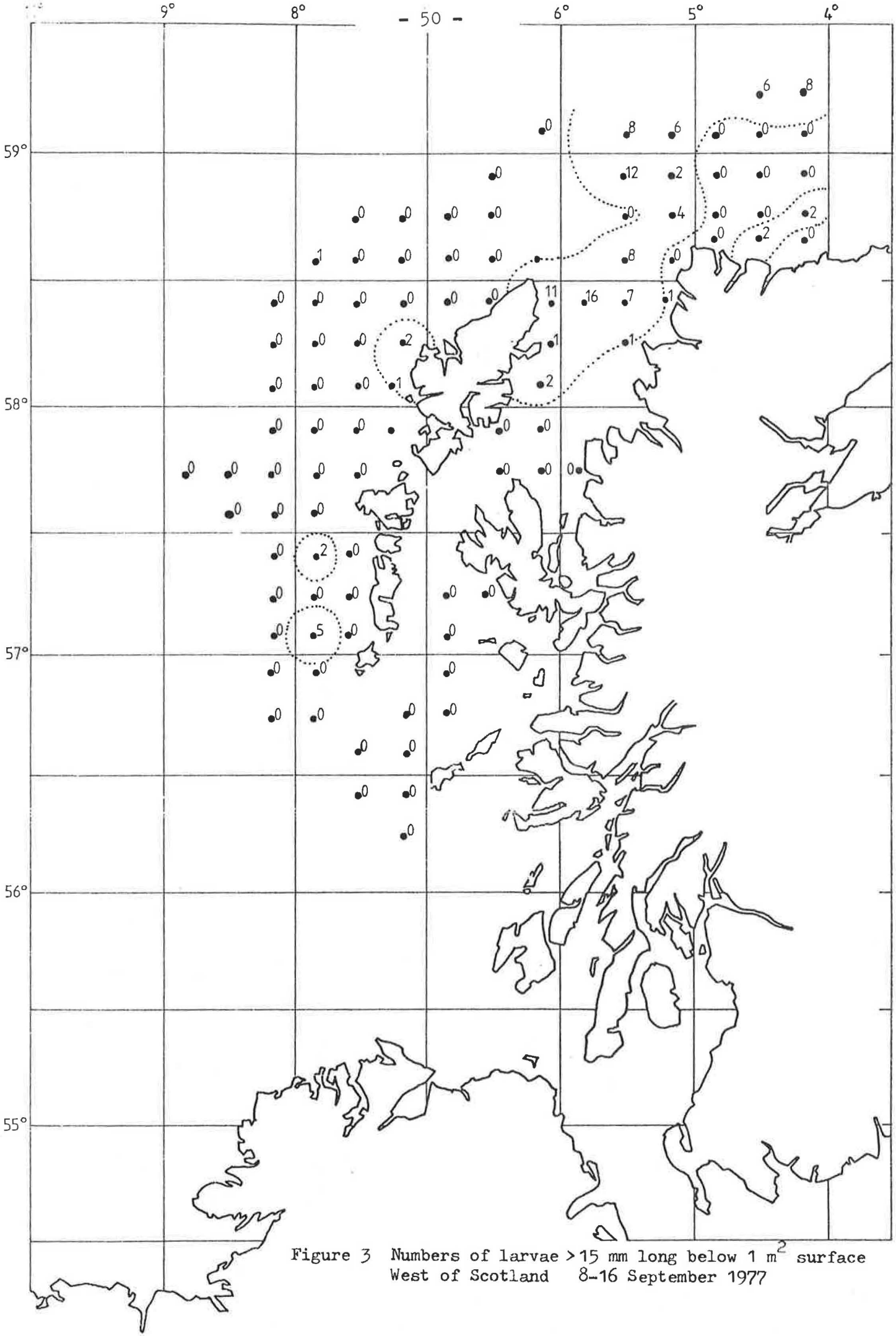

Figure 3 Numbers of larvae >15 mm long below 1 m^2 surface
West of Scotland 8-16 September 1977

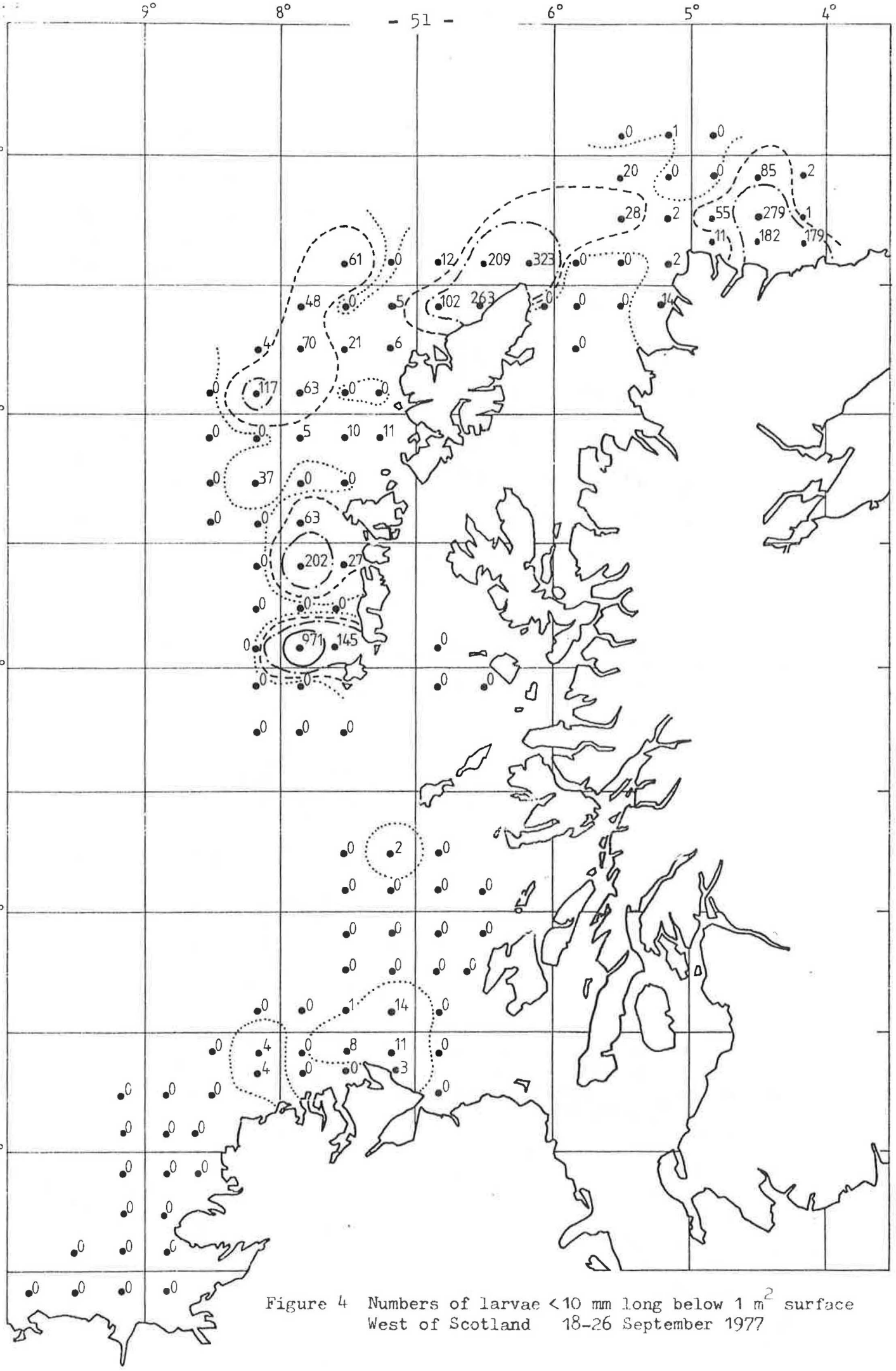

Figure 4 Numbers of larvae <10 mm long below 1 m^2 surface
West of Scotland 18-26 September 1977

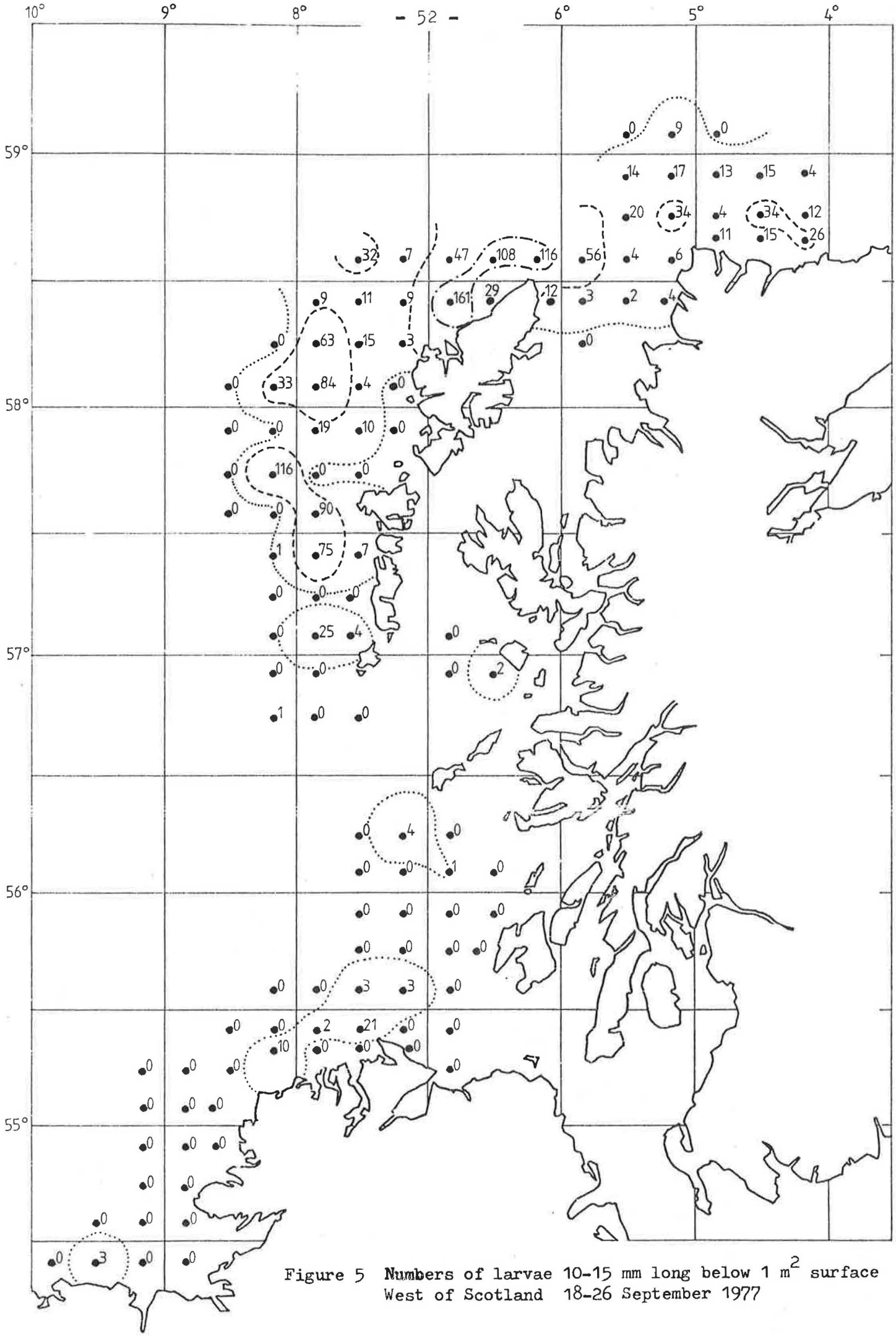

Figure 5 Numbers of larvae 10-15 mm long below 1 m^2 surface
West of Scotland 18-26 September 1977

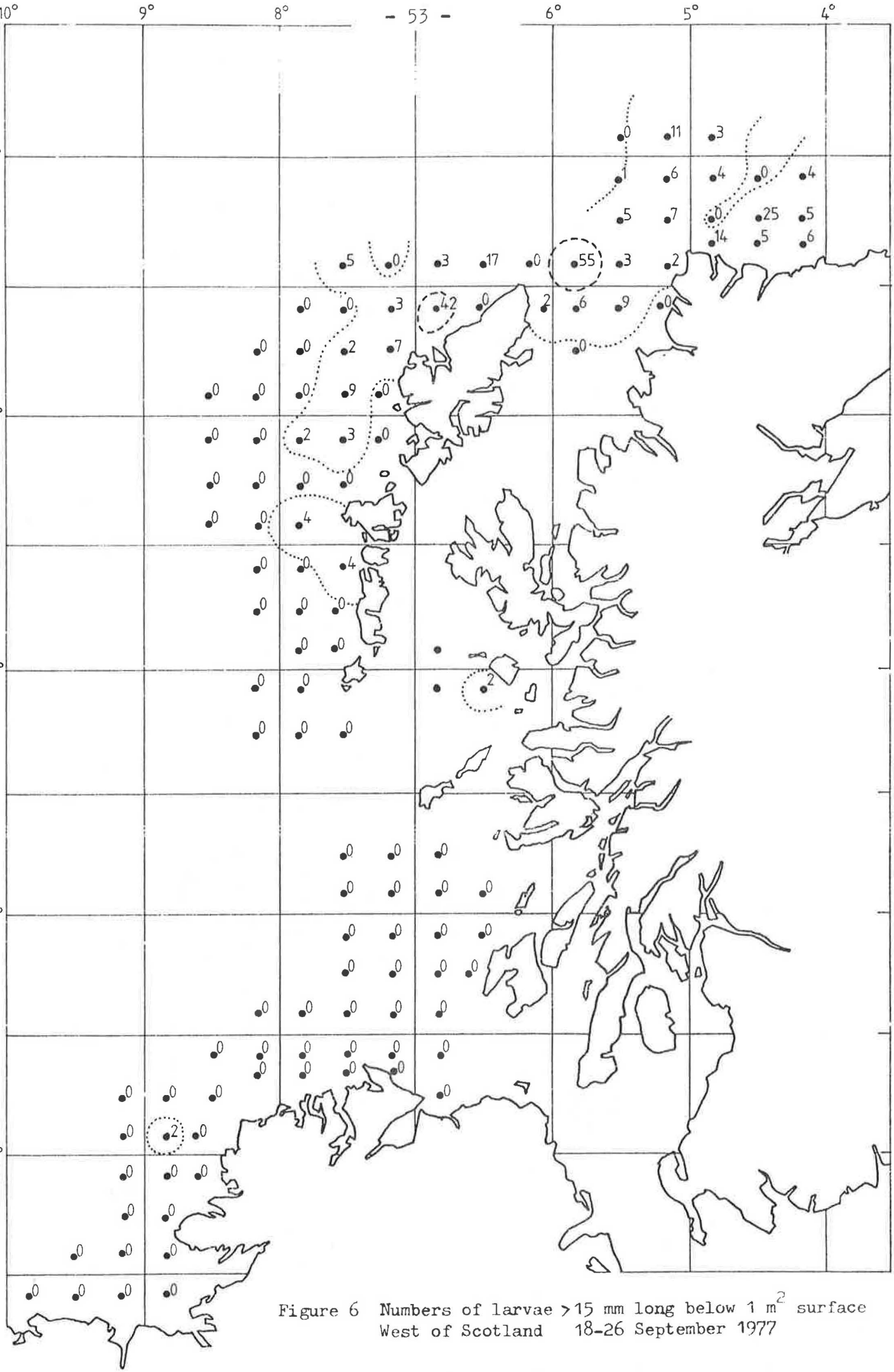

Figure 6 Numbers of larvae >15 mm long below 1 m^2 surface
West of Scotland 18-26 September 1977

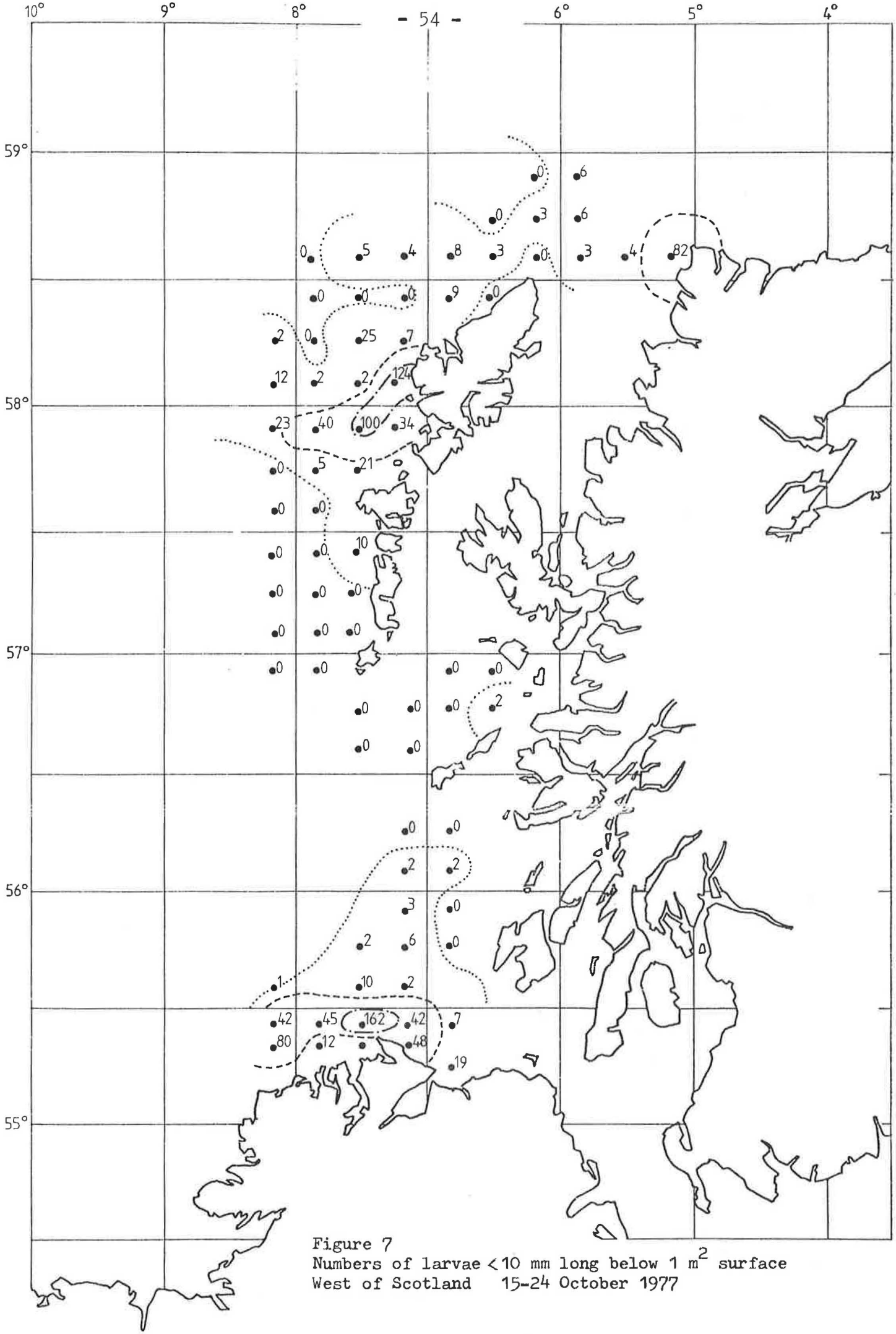

Figure 7
Numbers of larvae < 10 mm long below 1 m^2 surface
West of Scotland 15-24 October 1977

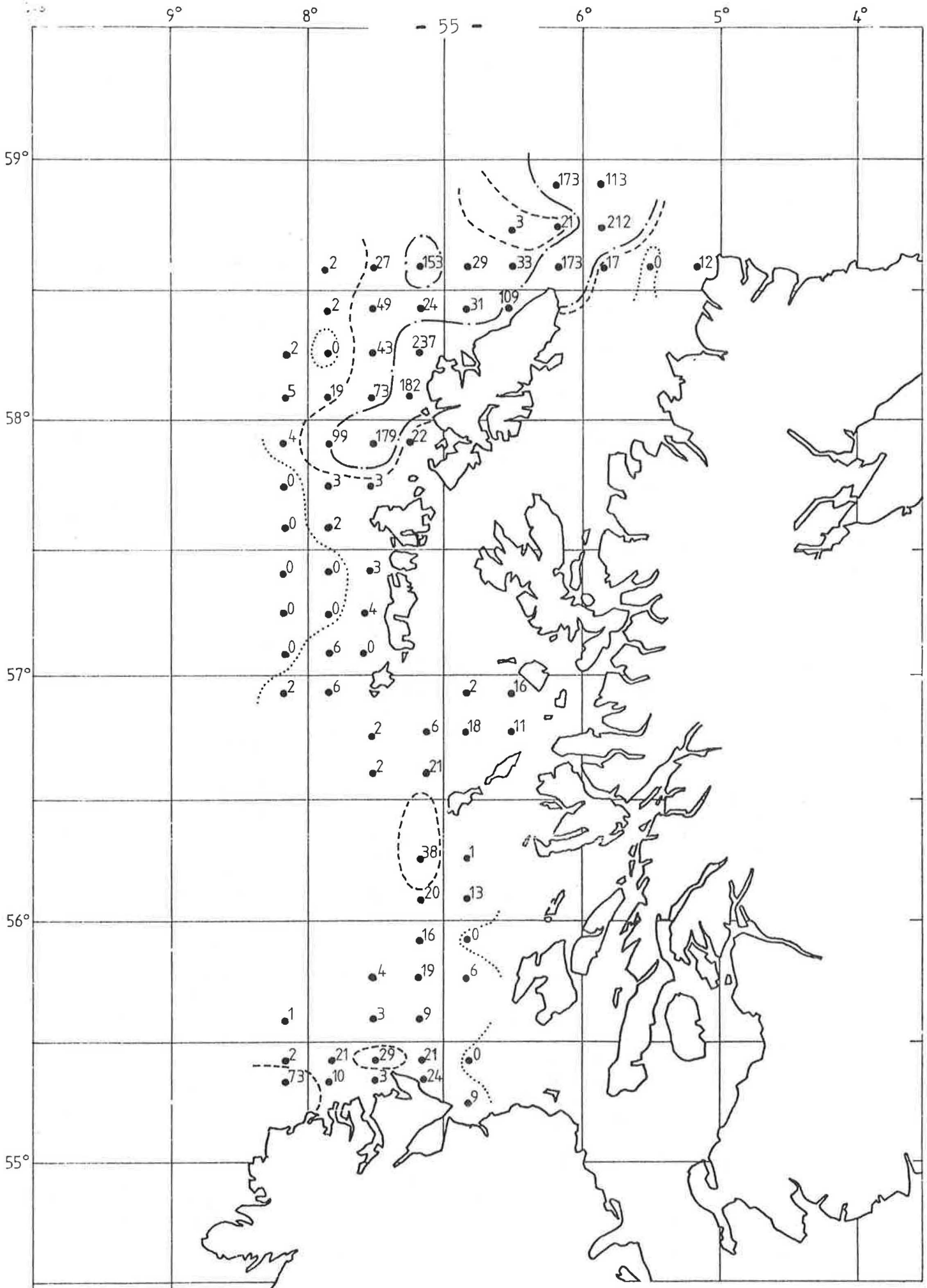

Figure 8 Numbers of larvae 10-15 mm long below 1 m^2 surface
West of Scotland 15-24 October 1977

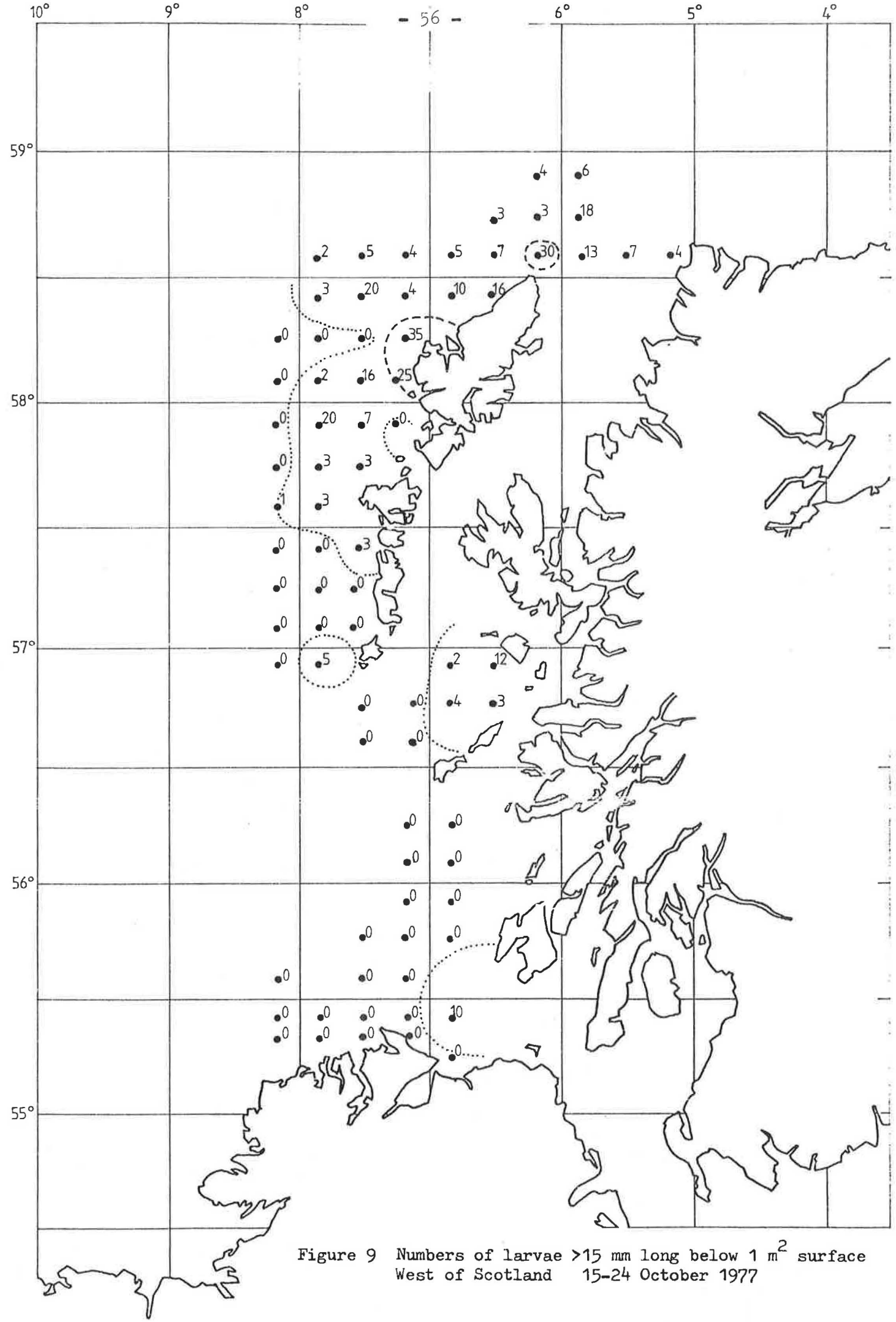

Figure 9 Numbers of larvae >15 mm long below 1 m^2 surface
West of Scotland 15-24 October 1977

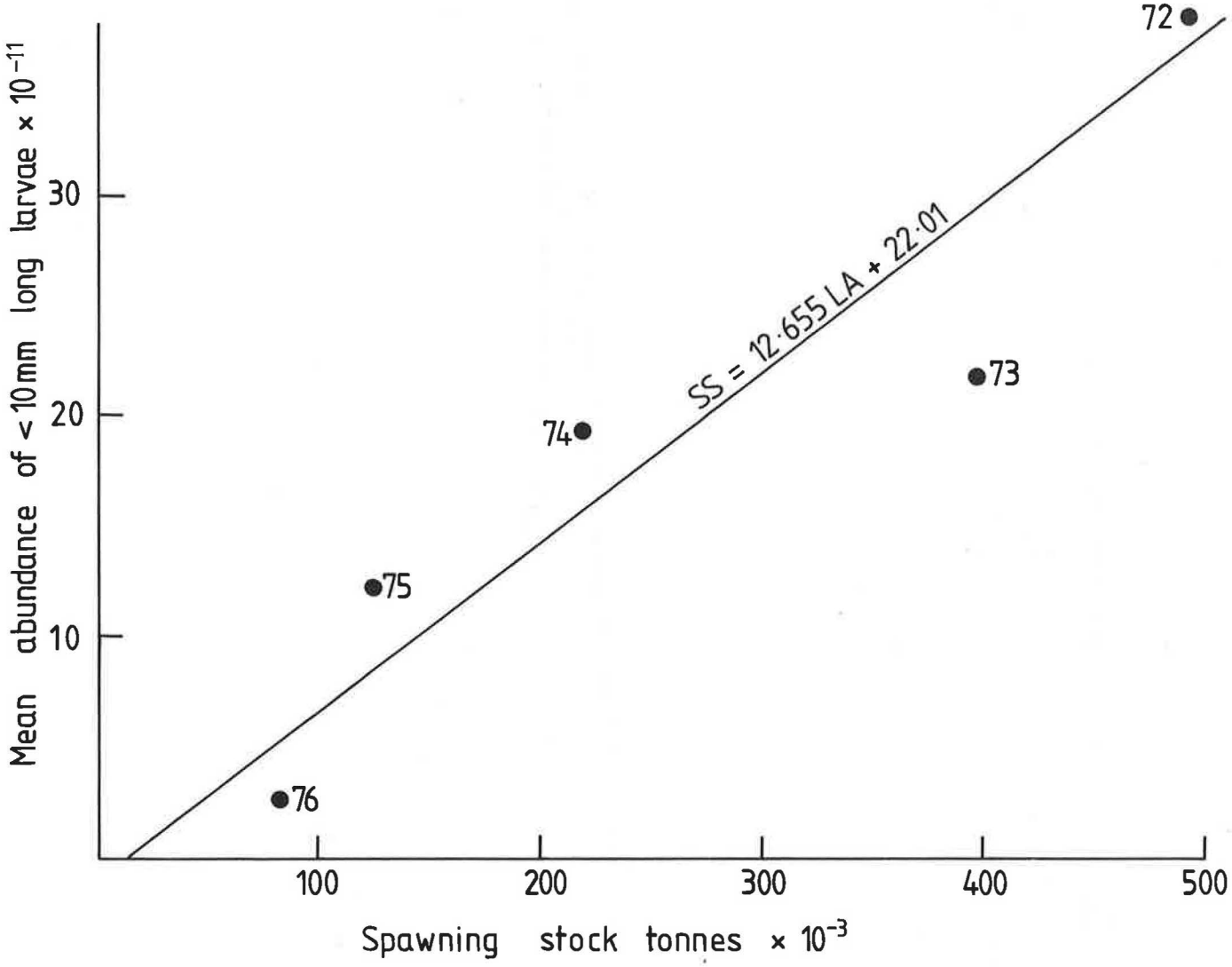

Figure 10 Relationship between spawning stock size and mean larval production in Division VIa during the period 1972-1976.

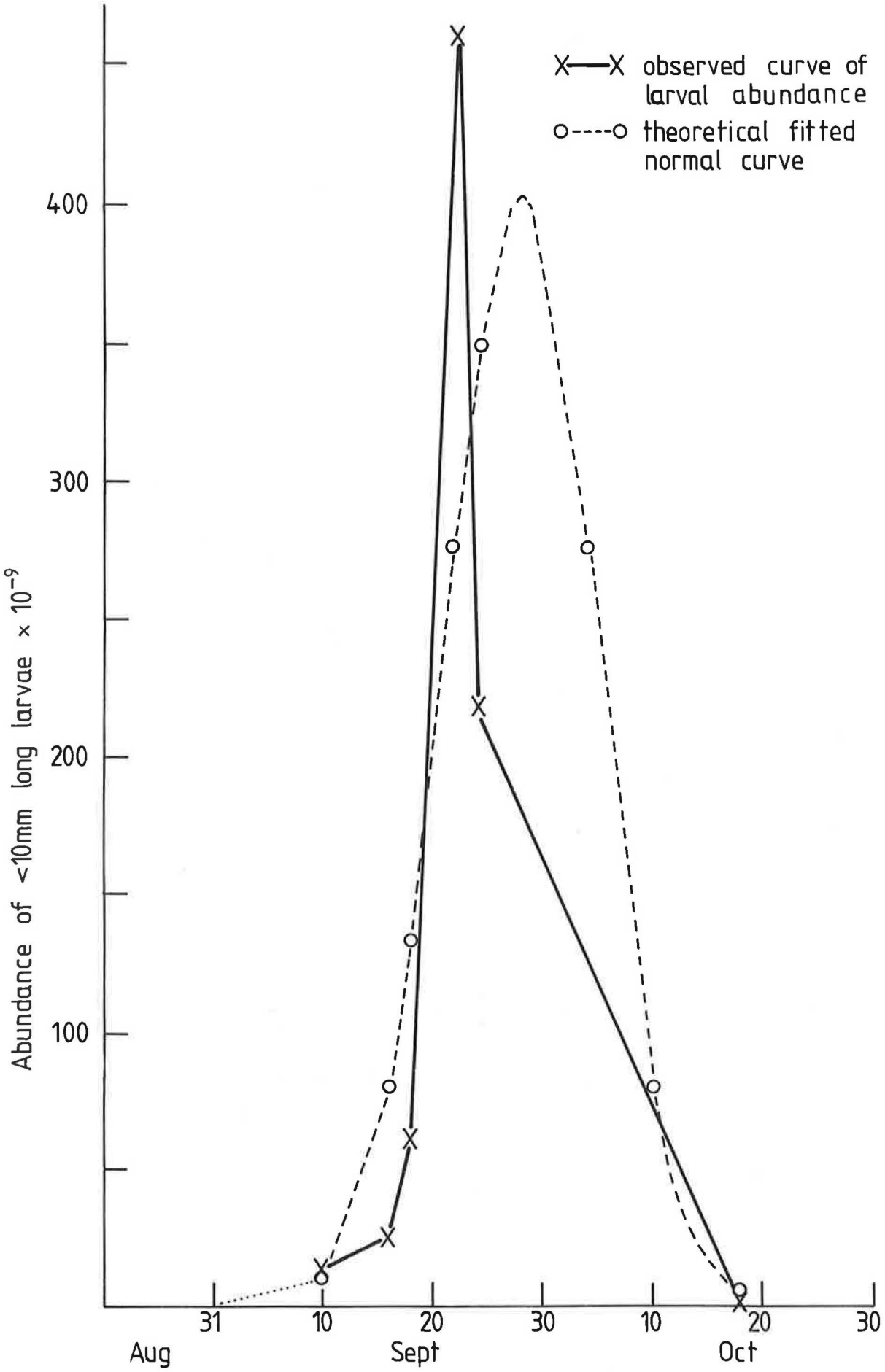

Figure 11 Pattern of larval abundance on the spawning grounds west of South Uist.

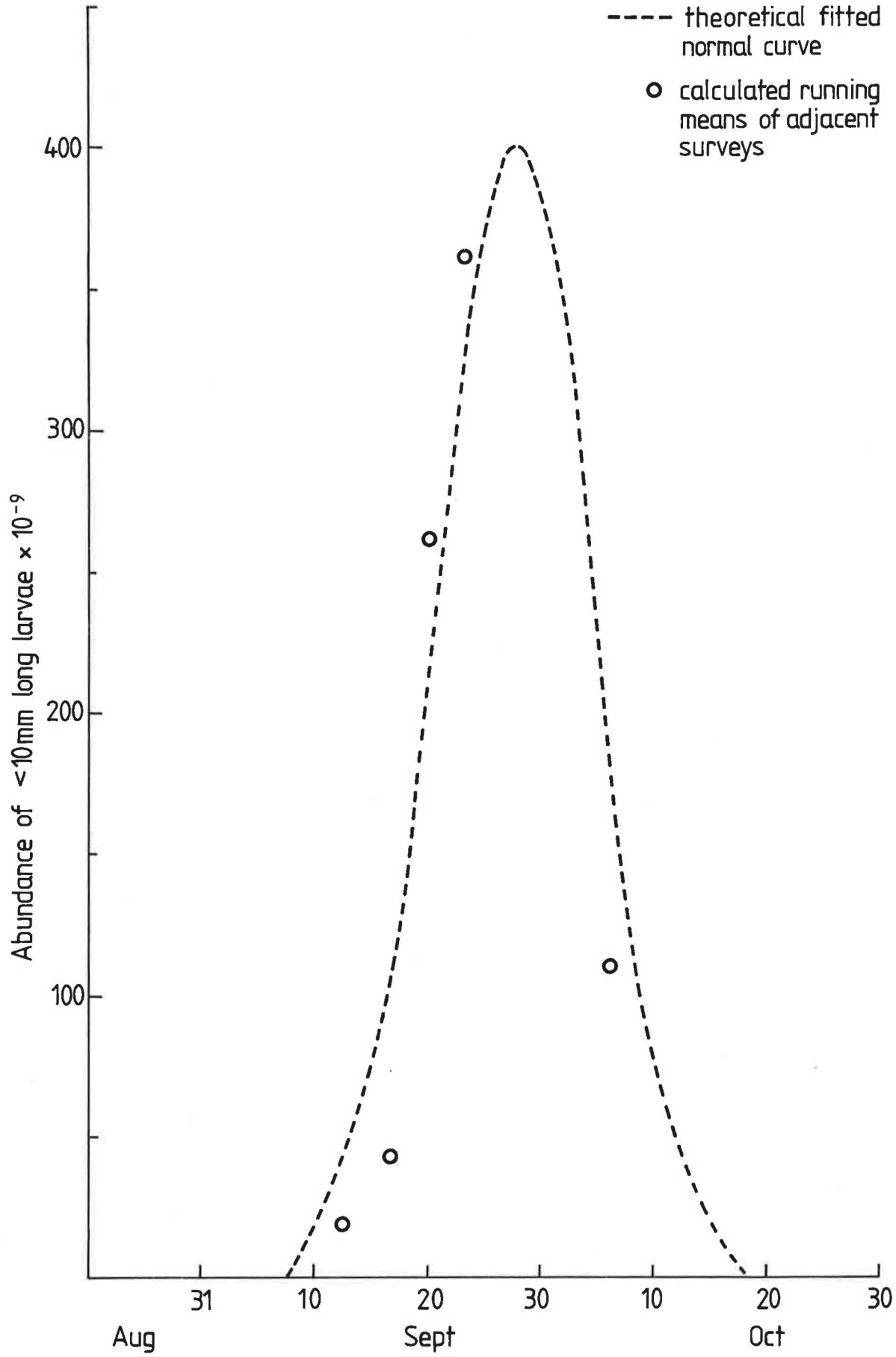

Figure 12 Theoretical normal curve fitted to larval abundance data and the running means of larval abundance from adjacent surveys.

Indication of spine colours

Reports of the Advisory Committee on Fishery Management	Red
Reports of the Advisory Committee on Marine Pollution	Yellow
Fish Assessment Reports	Grey
Pollution Studies	Green
Others	Black

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