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A Preliminary Report on the ICES-coordinated Acoustic Survey of Herring Stocks in 1979

by

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INTRODUCTION

At the 1978 Statutory Meeting, the Council adopted a resolution put forward by the Pelagic Fish Committee to carry out a co-ordinated acoustic survey for herring in the North Sea and Division VIa in 1979. The guidelines for the survey were set out in the Report of the Herring Assessment Working Group (CM 1978/H:67 Revised), and the objectives of the survey were to estimate the biomass of adult herring north of 57°N in subdivision IVa W and Division VIa. The recommended timing of the survey was July.

To organise the survey the council set up a Planning Group and the following representatives were nominated:

*R S Bailey (Convener)	UK
*A Corten	The Netherlands
M Diner	France
H Dornheim	Federal Republic of Germany
*W I Dunn	UK
*S Iversen	Norway
*A Maucorps	France
R B Mitson	UK
R J Wood	UK

The members of the group asterisked in the above list met at the Marine Laboratory, Aberdeen, from 6- 7 March 1979 and a further informal meeting was held on board the THALASSA in Lerwick, Shetland, on 18 July 1979, while the survey was in progress.

This report is a synthesis of cruise reports received by the convener from participants in the survey and does not represent an agreed consensus.

Planning of the Survey

The areas to be covered by the survey were decided from an analysis of the distribution of herring catches made by the Netherlands and Scottish vessels during the period 1971-1978. To limit the survey to manageable proportions, three areas in

which the largest catches had been taken were defined (Figure 1): area I - the northeast coast of England, area II - the Orkney-Shetland area, and area III - the Hebrides. Because of its importance, the Planning Group decided to include the western part of Division IVb in the survey (area I) despite the recommendation by the Pelagic Fish Committee to limit the survey to areas north of 57°30'N.

To utilise the available vessels to the full, it was planned that wherever possible a scouting vessel should survey each area a few days in advance of the vessel carrying an echointegrator, and that both vessels should carry out trawling to identify the composition of echotraces and to establish the diurnal behaviour pattern of herring. Echointegration was to be employed only when the limits of herring concentrations had been defined.

Immediately before and during the survey, reports of herring concentrations were obtained from commercial fishing vessels and, where appropriate, these were used in the detailed planning of each ship's track. Information was exchanged during the survey by radio contact at sea and by radio telephone to Aberdeen.

Participation of vessels

The following vessels took part in the survey:

Nationality	Name	Dates	Scientist in charge
France	THALASSA	13-30 July	A Maucorps
France	MOUSSE	9-21 July	J Masset
The Netherlands	ANNIE HILLINA	2-20 July	A Corten
Norway	JOHAN HJORT	10-18 July	J Lahn-Johannessen
UK	SCOTIA	25 July-15 August	R S Bailey
UK	EXPLORER	6-28 August	I G Baxter

The acoustic and trawling gear used on each vessel are listed in Table 1. An additional survey was carried out independently of the ICES-co-ordinated survey by the UK vessel CORELLA and a brief account of her work was kindly made available for the report by the Fisheries Laboratory, Lowestoft.

DESCRIPTION OF THE SURVEY

In the text below a brief account is given of the work carried out by each vessel or pair of vessels. Track charts are given in Figures 2-9.

a) ANNIE HILLINA and JOHAN HJORT

The ANNIE HILLINA surveyed area I off the northeast English coast from 4-7 July (Figure 2a), three days before the JOHAN HJORT arrived in this area. She found no evidence of major concentrations of herring and the only fishable traces found in this area were on Berwick Bank (55°50'N). Since it was thought possible that central North Sea herring might still have been distributed further north, a 30 mile grid was carried out (Figure 2b) north to area II (Shetland) where the spacing of transects was reduced to 10 miles (Figure 2c). The area off the east coast of Shetland was investigated in detail and herring traces were found around Fair Isle, south of Shetland and close inshore northeast of Shetland. The sensitivity of the echosounder on ANNIE HILLINA appeared to be inadequate to record low density traces such as scattering layers.

The JOHAN HJORT spent from 10-13 July in area I delimiting the herring concentrations, investigating the behaviour of the fish and carrying out an echointegrator survey (Figure 3a). The remainder of her time up to 19 July was spent searching in the

area between south Shetland and Noup Head, Orkney (Figure 3b) and investigating herring behaviour patterns.

b) THALASSA and MOUSSE

The MOUSSE left Boulogne on 9 July and, passing directly through area I, carried out an extensive sonar and echosounder search in area II around Orkney and Shetland (Figure 4). The track chosen was based at first on the results of the Dutch and Norwegian vessels, but for most of the survey it was based on the past experience of the skipper, Mr Francois Libert, and on recent information from Boulogne trawlers passing through this area. Each area in which echotraces were found was investigated both by day and night. Trawl hauls were carried out to identify traces which were reasonably substantial and which were sufficiently far above the bottom for integration by THALASSA. On information from a commercial vessel intensive work was carried out NW of Noup Head where considerable herring concentrations were found on 15 July. On the voyage to Boulogne a further unsuccessful search was made off northeast England.

THALASSA also searched unsuccessfully in the offshore zone off northeast England during the northward passage, and then proceeded directly to carry out echo-integration in the area off Noup Head (Figure 5). Subsequently THALASSA surveyed the area south and southwest of Shetland before searching in the North Minch and around North Rona. Before returning south, a survey was made in the south-eastern part of area II where herring bycatches had been reported by French trawlers. On the return voyage a short joint survey was carried out with SCOTIA over Turbot Bank off Aberdeen.

c) SCOTIA

After a brief survey of Turbot Bank off Aberdeen on 26 July, SCOTIA spent from 27-31 July completing the survey of the Shetland area by carrying out a searching grid up the east and west sides of Shetland (Figure 6). Further searching was carried out unsuccessfully around North Rona, but in the North Minch herring were found in an area off Stornoway (Figure 7). After a detailed echointegrator survey, the search was continued into the South Minch and then to the St Kilda area. A further integrator survey was carried out in this area, and the search continued to the north coast of Scotland.

d) EXPLORER

From 7-16 August, EXPLORER carried out an extensive echosounder grid around the Shetlands (Figure 8), but the only herring concentrations found were near Foula, where an integrator survey was carried out. The second half of the cruise was devoted to an intensive survey off the northeast coast of England (Figure 9), using a bottom trawl for sampling.

METHODS

Within each of the areas shown in Figure 1, the recommended procedure was as follows:

a) searching for echotraces characteristic of herring using echosounders and sonar;
b) establishment of the identity and composition of traces by trawling;
c) investigation of herring behaviour patterns, particularly vertical migration and dispersion;
d) establishment of the area of herring distribution;
e) detailed echointegration within the area of distribution.

In most areas, searching and trace identification took up a high proportion of the available time and in no cases was the above procedure carried out to the letter. Since most herring traces found were on or close to the seabed, sonar did not prove to be a particularly useful searching tool in most areas and most concentrations were found by vertical echosounder.

Identification of echotraces was carried out using both pelagic and bottom trawls. In some areas, midwater traces proved difficult to sample. For this reason, for example, EXPLORER used only a bottom trawl after a trial period as midwater trawling was unsuccessful.

Echointegration

The method of estimating the herring abundance in area I used by JOHAN HJORT is described below in the section on results. Essentially, the method relied on finding an area where herring were sufficiently dispersed to record single fish echoes and then fitting a regression of the number of fish recorded against the integrator deflection as a calibration. The proportion of herring in the total biomass was estimated using back scattering strength measurements of fish of different lengths provided by Nakken and Olsen (1977) and the results of trawl hauls in the area to allocate the acoustic biomass to species.

On SCOTIA and EXPLORER "acoustic biomass" was related to the back scattering strength of a known target used for calibration (a table tennis ball) through an assumed target strength of herring (-34dB kg^{-1}). Where necessary the proportion of the estimated biomass attributable to herring could be estimated from their proportion in appropriate trawl hauls.

THALASSA used the same type of equipment as JOHAN HJORT and obtained calibration factors by carrying out inter-calibration experiments with both JOHAN HJORT and SCOTIA. In the former case the inter-calibration was carried out over a track of 33 nautical miles on an even bottom west of Noup Head (Orkney), taking separate recordings every mile. By fitting a regression line, the factor for converting THALASSA (TH) readings to JOHAN HJORT (JH) readings (mm deflection) was:

$$JH = 10.1 \times TH + 357.5 \quad (r = 0.93)$$

Using a hull-mounted transducer, however, the threshold required on THALASSA's equipment was so high that even zero readings are equivalent to a considerable acoustic biomass.

The inter-calibration with SCOTIA was carried out over Turbot Bank but in this case transducer problems on SCOTIA meant that most of her recordings were close to zero. The high correlation coefficient of 0.90 between the two series of 17 readings is due to two values which were appreciably above zero.

Owing to the inadequacy of the two inter-calibration experiments, no attempt has been made in this preliminary report to convert the THALASSA integrator results to biomass estimates. To enable some evaluation of the echointegrator techniques used on the other vessels to be made, however, selected examples are given in the section on results. Since there has been no opportunity for a joint evaluation of the validity of the estimates of herring biomass in each area, no attempt has been made in this report to provide an estimate for the entire area covered on the survey.

RESULTS

The results of the survey are presented below for each area separately:

The results of trawl hauls carried out during the survey are listed in Table 2, and the length composition in samples containing more than 10 herring in Table 3. Trawl hauls mentioned in the text refer to code numbers in the tables.

Central North Sea

a) Area I - Northeast English coast

Searching by ANNIE HILLINA was confined to daylight, when small pelagic schools were detected up to 20 miles offshore, the highest density being off the mouth of the River Tyne (Figure 2a). Bottom schools were recorded in a small area on Berwick Bank (55°50'N), where one trawl haul contained large herring (Plate Ia). The small midwater schools, however, were not identified by trawling as they were too near the surface.

During their passages through the more offshore parts of this area, neither the MOUSSE nor THALASSA found any evidence of herring schools.

Despite the apparent scarcity of herring in this area reported by ANNIE HILLINA, the JOHAN HJORT carried out a detailed survey of the coastal area (Figure 3a) on the basis of reports of herring bycatches made by UK commercial vessels (per J Wood, Fisheries Laboratory, Lowestoft). Ten trawl hauls were carried out in the area and herring were caught in eight of them, the largest catch being 140kg by pelagic trawl. In addition the hauls contained a variable proportion of other species, notably sprats, whiting and spurdogs. By day herring were caught by bottom trawl when the shoals were invisible to the echosounder. From 2000-2400 hours traces appeared and ascended towards the surface.

They remained there for two hours and then descended between 0200 and 0400 more rapidly than they ascended (Plate II). At night, pelagic trawl hauls contained herring. It therefore seems likely that herring were only accessible for echo-integration for about six hours at dusk and dawn.

In the second half of August, EXPLORER found herring in the coastal area somewhat further south than those reported in early July (Figure 9). She was only able to sample by bottom trawl but, nevertheless, herring were caught in 10 out of 17 hauls. At this time, the shoals thought to be herring were distributed close to the bottom by day, whereas at night there was little evidence of them except that more diffuse marks were occasionally recorded in midwater (Plate Ib, c). The areas where traces of this type were observed are indicated as areas B and C in Figure 9.

The limits of herring distribution were established by the JOHAN HJORT by making transects at night when the fish were above the seabed. The area of their distribution extended about 60 miles north to south and from 5-20 miles from the coast (Figure 10). Within the area outlined, herring appeared to be continuously distributed whereas outside the area similar traces were insignificant.

The JOHAN HJORT made an abundance estimate of herring in area I by:

1) Using the single fish counting method described by Midttun and Nakken (1977) to estimate the constant C in the equation (1) $\rho = Cu$, where ρ is the total number of fish per square nautical mile and u is the integrator deflection (mm) per nautical mile;

2) Estimating the constant C'in the equation (2) $C' = C \times al^b$, where al^b is the maximum dorsal aspect scattering cross section of a fish of length l (Nakken and Olsen 1977);

3) Estimating the abundance of herring by splitting the species composition according to the equation (3) $\rho_i = k_i \, K\bar{u}$, where ρ_i is the number of fish and k_i is the fraction of fish in category i (Nakken and Dommasnes 1975). When $\bar{u}$ represents n different categories of fish, equation (3) gives

$$K = \left(\sum_{i=1}^{n} k_i/C_i\right)^{-1}.$$

Owing to the behaviour pattern of herring in this area only the integrator values recorded from pelagic fish at night were used for the abundance estimate. As the survey grid density was not uniform throughout the herring area, separate means were calculated for each of the four sub-areas A to D in Figure 10 (Table 4).

Within the herring area the species composition in pelagic trawl hauls by night and the length composition of all herring caught were rather homogeneous in sub-areas A to C, whereas the catch by day in sub-area D (trawl haul JH 171) contained predominantly 0-group herring (Table 3). An overall mean of the percentage by numb of the main species was therefore calculated for the combined sub-areas A+B+C and another mean for sub-area D (Table 5).

Single fish echoes were recorded on the EK50 sounder just before dusk near trawl station JH 172 which yielded an almost pure catch of herring. The numbers of fish (assumed to be herring) per nautical mile were calculated and the regression between these values (ρ_i) and the corresponding integrator values of $\bar{u}_i$ when applied to equation (1), gave $\rho = 1560\bar{u}$ or $C = 1560$ (Figure 11).

The constant C^1 was estimated from equation (2), $C^1 = C \times al^b$ where $a = 2.09 \times 10^6$ and $b = 1.36$ for herring (Nakken and Olsen 1977). By using the length composition data of herring from trawl station JH 172, the mean of al^b was found to be 180×10^4. Hence from equation (2), $C^1 = 0.2811$ and this constant was assumed to be applicable to other species for which a and b have been determined.

By applying the estimated C^1 value to sprat, whiting and spurdogs for values of a and b given by Nakken and Olsen (1977), a length-dependent C value for each species was calculated (Table 6). The mean C values for each species within sub-areas A+B+C combined and another mean value for sub-area D were then calculated by using mean length compositions of each species in the area (Table 7).

Abundance estimates for herring, sprat, whiting and spurdogs were obtained by applying the mean proportion of each species in pelagic trawl catches as estimates of the k_i values in equation (3), thus solving K (Table 8), and then applying the mean $\bar{u}$ of pelagic fish. The results given in Table 9 indicate an adult stock of herring numbering nearly 100 million with a biomass of about 16 000 tonnes.

An intensive integrator survey carried out by EXPLORER between Hartlepools and Flamborough Head covered an area of about 2 200 square kilometres (area C in Figure 9). Depth of water in the survey area was mainly 40-60 metres. Separate measurements were made of echo returns above and below the 20m depth level, and since echotraces of a type expected from herring generally occurred at depths greater than 20m, echo returns above 20m were not used for the biomass calculations. A grid of squares 6 nautical miles by 6 nautical miles was placed over the survey area and the acoustic biomass for each square or half square was estimated. The results in tonnes per square are given in Figure 12. The total acoustic biomass for the survey area was estimated to be 20 500 tonnes.

From trawl hauls made in the survey area the total catch was 89 baskets of which there were 48 baskets of herring (54%). Sub-dividing the biomass on the basis of the catch gives an estimate of herring biomass of 11 000 tonnes.

A similar calculation carried out for the survey in the Bayman's Hole region (area B in Figure 9) which covered an area of 810 square kilometres gave a total acoustic biomass of 10 676 tonnes. On the basis of the catch the herring biomass was estimated to be about 900 tonnes.

A further survey of area I was carried out from 23 August to 5 September by CORELLA. Just prior to this cruise commercial demersal trawlers reported catching full herring off Robin Hood's Bay. By day the shoals recorded by CORELLA were very compact and mostly extended only a few metres above the seabed. After dark the fish remained in shoals although these were generally far less compact and rather higher above the seabed - few above 30 metres when the bottom depth was approximately 55-60metres. Exceptionally a very small number of shoals extended to within 10-15 metres of the surface and a few shoals were still very dense during the middle of the night. Once it began to get light the fish rapidly descended and shoals again became very compact. It appeared that most of the shoals were sufficiently dispersed for successful integrator surveys for almost 6 hours during the night from approximately 2200h to 0400h GMT.

The behaviour of herring in the Longstone area could not be assessed with certainty owing to the presence of considerable numbers of sandeels (observed with a TV camera). However, traces of the 'plume' type were found off Beadnell Bay where commercial demersal trawlers, at the same time, were catching reasonable numbers of ripe herring. A considerable number of newly hatched herring larvae were taken close by in a plankton haul. Traces of the 'plume' type were observed to rise and then break up into a scattered trace in the top 15 metres or so at dusk. Identification was attempted with a TV camera but most fish were observed by the echo sounder to avoid the lights on the underwater vehicle. Some sandeels were seen, however, and in addition sprat or 0-group herring were seen at the surface in the stern lights as CORELLA drifted. Within these areas a number of successful acoustic surveys was made but it will be some time before the results can be properly evaluated.

No concentrations of fish which might have been spawning herring were observed off Whitby/Skinningrove or at the Dowsing.

b) Turbot Bank

Although outside the areas included in the survey programme, a survey of Turbot Bank (30 miles NE of Aberdeen) was carried out after reports were received of heavy bycatches there by commercial trawlers. Herring were located on 26 July by both THALASSA and SCOTIA. By day the shoals were located close to the seabed and two trawl hauls contained predominantly large herring (TH 670; S78 in Tables 2 and 3). At dusk the shoals became more diffuse, but did not appear to migrate upwards (Plate Id, e). After a short search to delimit the area of herring distribution, SCOTIA carried out an integrator survey.

During the preliminary survey the distribution of herring traces was limited to an area 5 x 3.5 nautical miles in extent (Figure 13). Total integrator values for each leg of a zig-zag survey were recorded and weighted by the area to which that leg applied. Using this method a total biomass of 1.4×10^3 tonnes was estimated, but the proportion of fish below the lower limit of the integrator (2m from the seabed) is not known. In addition, the fact that some traces were found on the edge of the survey area indicates the likelihood that it did not cover the entire area of herring distribution.

c) Other areas

No significant concentrations of herring were located in other parts of the Central North Sea, although herring-like traces were observed by JOHAN HJORT on Aberdeen Bank, and a small catch was made at 56°30'N (AH3).

Northern North Sea

Area II Orkney-Shetland

An extensive area of herring-like traces mostly near the seabed was found by ANNIE HILLINA south of Fair Isle and further concentrations to the west of the island and south of Shetland (Figure 2c). Trawling in these areas indicated that the echo-traces were of mixed composition (herring and whiting predominantly). Trawl hauls in areas of similar traces east of Shetland, however, contained mainly Norway pout. The only other area where herring were caught was inshore to the northeast of Shetland.

Because of the large area involved the JOHAN HJORT also devoted most time in this area to searching and trawling. By day, herring-like shoals were detected close to the seabed, while at night they became less dense and rose somewhat off the bottom. They did not, however, form scattering layers as they did in area I. Traces which were attributed to herring from their general appearance were recorded SE of Fair Isle, between Fair Isle and Sumburgh Head, SW of Sumburgh and between Sumburgh and Lerwick (E. Shetland). In this area two trawl hauls contained herring. Further traces of this type were also recorded west of Noup Head (Orkney). Owing to the shoaling behaviour, even at night, and to the variable mixture of species caught in trawl hauls, a detailed echointegrator survey was not carried out in this area.

Using sonar as the main detection method, the MOUSSE found very few typical herring plumes in area II (Figure 4). Off Noup Head (Orkney), there was no sign of herring traces on 10-11 July, whereas on 15 July they found relatively large quantities. Furthermore, the shoals were apparently not visible on the echosounder until the afternoon (1200 GMT). In that area the shoals were close to the bottom with a height of 10-15m, becoming less dense in the evening and reappearing towards mid-night as midwater plumes 20-50m in height, and finally disappearing towards 0500 GMT. The trawl hauls carried out by MOUSSE also confirmed the mixed species composition of traces in area II.

THALASSA carried out echointegrator surveys in a number of areas in which MOUSSE had recorded herring (Figure 5). In the area northwest of Orkney two detailed surveys were carried out at an interval of five days and, despite the large catch of herring made by MOUSSE, the quantities recorded were not large during either of them. South-west of Shetland the shoals remained at the same depth (just clear of the bottom) by day and night (Plate IIIa, b), although by night they were less compact.

Integrator surveys were also carried out by THALASSA around south Shetland (Figure 5). In this area, one trawl haul (TH 660) contained a mixture of herring, whiting and Norway pout, the last two of which may have formed the rather diffuse echotrace close to the bottom shown in plate IIIc, while the herring may have caused the more distinct plumes. Southwest of Shetland and around Foula a further survey indicated considerable concentrations of fish but a trawl haul south of Foula (TH 661) contained mainly whiting.

THALASSA also found a concentration of herring southeast of Fair Isle where French trawlers had reported herring bycatches. Again in this area the echotraces were composed of plumes above the bottom and more diffuse traces close to the bottom. No shoals were seen at night, but there was evidence of dispersed fish still relatively close to the bottom. Two trawl hauls contained predominantly herring (TH 668) and whiting (TH 669) respectively.

SCOTIA largely confirmed the distribution of herring recorded by other vessels and in addition carried out a further search to the east and west of Shetland. In neither of these areas were herring caught by pelagic trawl, although traces similar to those found south of Shetland were recorded. In the Fair Isle/Shetland area, near-bottom traces were locally intense. One component of the traces rose to near the surface between 2115 and 2200 GMT, while another component remained 20-30m above the seabed (Plate IVa, b). Owing to a transducer fault, no integration was possible in this area.

On an extensive survey of the Shetland area in August, EXPLORER found typical herring traces only in the area south of Foula, and even in that small area, the density of shoals was very low (Figure 8). In that area by day intense plumes were recorded extending from the seabed to 50m above (Plate IVc). Despite extensive searching no shoals were recorded at night, although scattering layers were observed.

An echo survey of the Foula area was carried out by EXPLORER. The results were analysed in two different ways: by estimating the biomass of individual shoals encountered from individual transmissions and multiplying up to the total area surveyed; and secondly by calculating the mean acoustic density over the entire track and raising to the area surveyed. By these methods the average biomass of the larger shoals was estimated to be 23 tonnes and the small area hatched in Figure 8 is estimated to have contained 2030 and 1490 tonnes by the two methods respectively. Unfortunately, however, few shoals were recorded, so the error of the estimate is likely to be high in this area.

From the above it is clear that the interpretation of the survey results in the Orkney-Shetland area is highly complex. To summarise, herring were distributed widely over the area, at least in July, but were usually mixed with other species, notably whiting. The shoals were in most cases fairly small and only rarely were typical plumes observed. By day they were mostly on or close to the bottom, while by night they appeared to remain near the bottom and became rather more diffuse. It proved almost impossible to delimit the exact area of herring distribution because traces identical to those proved to contain herring by trawling were found over a large area, yet in some areas (eg east and west of Shetland) trawls contained only species other than herring.

West of Scotland

Area III

a) North Rona area

THALASSA searched this area in late July and found traces characteristic of herring in the area south of North Rona. The herring in this area appeared to be difficult to catch although two catches were taken fishing close to the bottom. As in the area south of Shetland, there was apparently little change in behaviour at night, the shoals remaining close to the bottom but becoming a little more dispersed. THALASSA carried out a detailed integrator survey of the area (Figure 5). An example of echotraces found in this area is shown in Plate Va.
Despite considerable searching from 31 July-4 August, SCOTIA found no signs of herring in this area (Figure 7).

b) North Minch

In the western half of this area SCOTIA found fairly extensive bottom echotraces. Plume traces were also recorded in one area but two trawl hauls there contained only sprats and 0-group gadoids. Three hauls on the bottom traces, however, contained a variable mixture of herring and other species. On the east side of

the North Minch, a heavy surface scattering layer was present at night, but it is not known if this contained herring as it was too near the surface to trawl. After delimiting the area of bottom traces, an intensive integrator survey was carried out. In an area of 220 square nautical miles, the total acoustic biomass was estimated to be about 5 000 tonnes, but it is not known what proportion of this is likely to have been herring or what proportion of herring were too close to the bottom to integrate.

c) South Minch

Heavy traces were found in several parts of this area, but two trawl hauls contained pure 0-group Norway pout, and a mixture of this species, whiting and saithe. One haul near the surface northwest of Tiree on traces which ascended at dusk contained a mixture of Norway pout, whiting and herring. Herring concentrations in this area, however, did not appear to warrant further attention.

d) St Kilda

On SCOTIA there was little evidence of characteristic herring echotraces in this area. Bottom traces containing herring were found near St Kilda, but their distribution seemed to be very localised and again catches were very mixed. Nevertheless, since some traces in this area appeared characteristic of herring, a detailed integrator survey was carried out. In an area of 120 square nautical miles south of St Kilda the total acoustic biomass was estimated to be 15 000 and 10 000 tonnes on two surveys carried out on the same day, but once again the proportion of herring is not known.

Other catches of herring were made in the area between St Kilda and the Flannan Is., but time prevented further investigation there.

e) North of Scotland

A short survey by SCOTIA in this area located typical herring plumes on Whiten Head Bank, but the single trawl haul there was unsuccessful.

In the area west of Scotland, as at Shetland, echotraces appeared to be of a highly complex composition. Typical herring plumes were found in some areas, but in general herring were caught together with other species in near-bottom traces. The research vessel effort in this area was inadequate to carry out a comprehensive survey.

Biological Data

The biological data (eg age and maturation stages) on herring sampled during the survey are not yet fully analysed. The mean length of herring in each sample (Figure 14), however, shows that in most areas adult herring predominated. The only areas with a high proportion of small, mostly immature, herring (less than 24cm) were the North Minch, around Fair Isle and in a few samples off northeast England.

Herring immediately to the south of Shetland were in stages 4 and 5 (ripening and ripe), while those caught northeast of Shetland were mainly in these stages with a small component of low maturity stage fish which were probably spring spawners.

The herring caught in the central North Sea in July were a mixture of fish in low maturity stages and maturing fish and may therefore have consisted of a mixture of Bank and Downs spawners. In August most caught there were in stages 3 and 4 with a relatively small percentage of stage 5, and in some hauls some at stage 8. West of the Hebrides in early August, the mature herring were also mainly in stages 4 and 5.

Thus, overall, the survey did not provide evidence of large quantities of immature recruits; those that were found were located in relatively small localised areas.

DISCUSSION

From the accounts given above for each area it is clear that the results of the survey are complex and that no adequate estimate can at present be made of the total biomass of herring in any of the areas surveyed. In an attempt to analyse the reasons for this, each stage of the procedure is discussed separately below.

Searching

Without prior knowledge of the likely whereabouts of herring, the ships had to spend a considerable proportion of their time searching. As might be expected, herring were located most easily in areas in which commercial vessels had reported either echotraces or bycatches in the previous one or two weeks. In other areas, there was little indication of what type of echotraces were likely to be attributable to herring and this may partly explain the relatively small quantities recorded by the MOUSSE, which was searching primarily for typical herring plumes. In addition the low sensitivity of the echosounder on board ANNIE HILLINA probably resulted in her missing a number of concentrations, for example in area I. Since most traces in July and August were close to the bottom by day and dispersed at night, sonar did not prove a particularly useful tool for searching.

Experience from this year's survey should greatly increase searching efficiency on future surveys because it is now clear what type of traces may contain herring. Furthermore, prior information from commercial vessels is clearly an advantage.

Identification of traces

Few of the herring echotraces identified on the survey were in the form of characteristic herring plumes, and in most areas the herring appeared to be one component of rather complex traces near the bottom. In the area around south Shetland, similar if not identical traces appeared to contain variable mixtures of herring, whiting and Norway pout and because of this it was almost impossible to delimit the exact area of herring distribution, or which traces should be attributed to herring. One possible solution to this problem would be to use the proportion of different species of fish in trawl hauls to allocate the acoustic biomass estimated by echointegrator. This requires the rather demanding assumption that the composition of trawl hauls is representative of what is in the sea in that area. Furthermore, more information would be required about the target strength (back scattering strength) of different sizes and species of fish. This is of course one of the fundamental difficulties of carrying our acoustic surveys for fish which constitute only a small percentage of the total fish biomass. To make a biomass estimate from the present survey would require some subjective judgment of the composition of traces.

The investigation of the behaviour of herring by trawling and echo survey is one aspect of the identification of traces. Off the northeast coast of England in early July, the echotraces indicated that fish were migrating upwards and dispersing at night. South of Shetland, the evidence suggested that the vertical migration was less pronounced or non-existent, although there appeared to be some dispersal of traces at night. Confirming these behaviour patterns in each area can be extremely time-consuming because trawl hauls need to be carried out at different depths and different times of day and night. Off northeast England, for example, JOHAN HJORT carried out hauls using a bottom trawl by day, and confirmed the presence of herring close to the seabed, and using a pelagic trawl at night confirming the presence of herring in midwater. Combined with the echosounder records (Plate II), this evidence strongly suggests a diurnal migration of herring in that area. Off

Shetland, on the other hand, the traces near the bottom by day appeared to divide at night into those ascending to the surface and those remaining fairly close to the bottom. In the situation where successive trawl hauls contain widely different proportions of different species, a considerable number of hauls is needed to confirm the behaviour of one of them. When this procedure has to be carried out in all areas where herring are found, the time required is a major part of that available. This is perhaps the main reason why the results of trawl hauls are not adequate to allocate the biomass estimates to species. During the survey, this also provided the main logistic dilemmma, whether to remain in one small area of unknown importance to clarify the distribution and behaviour of herring, or whether to continue searching in other areas. The only solutions to this problem are either to increase the boats and time allocated, or to match the area to be surveyed to the available effort.

Delimitation of herring distribution

The difficulty of proving the identification of complex echotraces was the main reason why the limits to the areas of herring distribution could not be defined in most areas. Furthermore, the results of trawling (Figure 14) indicated that herring were widely distributed sometimes at low density. For this reason, one participant in the survey has suggested the possibility of carrying out a grid of trawl stations over a wide area to estimate the proportion of the total herring population present in the areas integrated.

Echointegration

In addition to the problem of trace allocation discussed above, in some areas echointegration was impossible either because the shoals were too dense or because they were too close to the seabed or sea surface. Off northeast England a period of four hours at dusk and two at dawn appeared to be the only possible times for integration. In other areas, an unknown proportion of the traces were too close to the seabed by day. Even if this proportion were known, the proportion of different species above and below the limit might not be the same.

In practice, the difficulties of echointegration during the survey lay in inadequate calibration and intercalibration between vessels. Without discussion between acoustic experts, for example, it would not be possible to decide on the most appropriate conversion factors between JOHAN HJORT, SCOTIA and THALASSA. In future, this might to some extent be overcome by standardising the calibration procedure, which differs in principle in the different countries taking part, and by expressing the results of echointegration in a standard way.

Biomass estimates

The Planning Group decided at its meetings that it would not be possible to provide an overall estimate of biomass without a meeting to analyse the results. As a basis for discussion, the results of individual surveys of small areas are presented in this report. In each case, the biomass estimates appear rather low. The reason for this is not clear but must presumably mean either that they do not cover the most important herring areas, or that a substantial part of the herring biomass was outside the integrator depth limits, or that the highly contagious distribution of herring resulted by chance in heavily biased estimates. On several surveys, it was noted that the echointegrator survey failed to record appreciable concentrations of herring despite intensive searching beforehand to delimit the areas in which integration should be carried out. A possible reason for this is the potential mobility of herring. JOHAN HJORT, for example, experienced considerable difficulty in relocating herring found by ANNIE HILLINA only a few days before. To solve this problem, it may be appropriate to concentrate effort on a number of vessels within a small area to maintain continuous surveillance of the distribution of the herring until the integrator survey of that area is complete.

Timing of the survey

Owing to the long period during which this year's survey was carried out, some information is available on the appropriateness of July as the month for future surveys. Off northeast England, vertical migration reduced the available time for echointegration during July, but nevertheless ensured that the herring were accessible in a relatively dispersed state for part of each day. In late August, the extent of vertical migration appeared to be less and again the herring appeared to be accessible for about six hours.

In area II (Shetland), the results from different vessels were somewhat conflicting. In early July, herring were rather close to the bottom by day and it is not clear if they were migrating upwards to any significant extent at night. In the Noup Head area, plume traces were very compact and may have been too dense for successful integration. In August, EXPLORER experienced considerable difficulty in locating herring, while in July there were some reports of herring closer inshore than the survey area. For this area, therefore, it is not yet clear which is the best time of year for the survey.

In Division VIa, herring also appeared to be fairly close to the bottom by day and again there were reports from commercial vessels of inshore shoals likely to have been missed on the survey. It is therefore possible that in areas II and III an earlier timing might be more appropriate.

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Table 1. Details of acoustic equipment and trawling gear used on survey vessels

VESSEL	TRAWL	ECHOSOUNDER	SONAR	ECHOINTEGRATOR
THALASSA	Pelagic trawl (sprat-mesh blinder)	Simrad EK S38	-	Simrad QM MK II
MOUSSE	2000 mesh-Pelagic trawl (15mm mesh blinder)	Simrad	Simrad	-
ANNIE HILLINA	Pelagic trawl	Simrad EQ (Sensitivity poor)	Simrad SB	-
SCOTIA	1000hp Delagic trawl (20mm codend) and 900hp Blue whiting trawl (20mm codend)	Simrad EK38/S	Simrad SK3	Aberdeen Echointegrator
JOHAN HJORT	Pelagic 1600-mesh capelin trawl, 16 x 16 fathom opening (22mm codend)	Simrad EK38 A	Simrad	2-channel Simrad QM MK II
	Demersal 1800-mesh shrimp trawl 21 x 6m high (40mm codend, and smaller mesh cover)	Simrad EK50 A		Aberdeen Echointegrator
EXPLORER	6-700hp Delagic trawl (20mm codend) Demersal herring wing trawl	Simrad EK38	—	

Table 2 (Continued) CATCHES (kg) OF HERRING AND OTHER MAJOR SPECIES

Vessel	Haul No	Date	Position	Gear	Stat rect	Catch (kg) Herring	Haddock	Whiting	Norway Pout	Others	Herring percentage
Johan Hjort	177	12 July	56°00'N 01°20'W	Bottom trawl	41E8	3	116	297	+	150	1%
"	178	12 July	56°02'N 02°00'W	"	41E8	14	4	20	0	6	32%
"	179	13 July	55°32'N 01°24'W	Pelagic trawl	40E8	34	0	14	0	246	12%
"	180	13 July	57°37'N 01°00'W	"	44E9	0	0	0	0	0	-
"	181	14 July	58°41'N 01°00'W	"	46E9	1	+	1	+	2	25%
"	182	14 July	59°15'N 01°19'W	"	47E8	78	0	290	0	24	20%
"	183	14 July	59°15'N 01°28'W	"	47E8	1	+	+	0	+	100%
"	184	14 July	59°50'N 01°16'W	"	48E8	0	+	+	0	+	0%
"	185	15 July	59°38'N 02°00'W	"	48E8	0	0	0	0	0	-
"	186	15 July	59°50'N 03°23'W	Bottom trawl	48E6	0	16	0	4	23	0%
"	187	15 July	60°15'N 01°45'W	Pelagic trawl	49E8	+	0	560	0	0	0%
"	188	16 July	59°50'N 01°51'W	"	48E8	7	+	+	+	+	100%
"	189	16 July	59°18'N 03°51'W	Bottom trawl	47E6	0	0	+	0	0	0%
Thalassa	657	15 July	55°42'N 00°34'W	Pelagic trawl	40E9	0	0	0	0	0	-
"	658	15 July	55°40'N 00°34'W	"	40E9	0	0	0	0	0	-
"	659	15 July	55°39'N 00°34'W	"	40E9	0	0	+	0	+	0%
"	660	19 July	59°55'N 01°12'W	"	48E8	108	0	87	235	0	25%
"	661	20 July	60°04'N 02°05'W	"	49E7	14	0	1650	0	12	1%
"	662	21 July	59°22'N 03°59'W	"	47E6	0	0	0	0	0	-
"	663	22 July	58°50'N 05°36'W	"	46E4	0	5	0	0	0	0%
"	664	22 July	58°52'N 05°24'W	"	46E4	1	0	+	0	1	50%
"	665	223 July	58°46'N 05°44'W	""	46E4	484	0	8	0	161	74%
Lpejrsee	666	23 July	58°37'N 06°00'W	"	46E4	5440	10	15	8	527	91%
"	667	24 July	59°11'N 01°36'W	"	47E8	350	0	934	3	61	26%
"	668	25 July	59°28'N 00°52'W	"	47E9	417	0	84	10	36	76%
"	669	25 July	59°29'N 00°56'W	"	47E9	0	31	452	63	+	0%
"	670	26 July	57°23'N 01°07'W	"	43E8	1581	1	1	0	10	99%

Table 2 (Continued) CATCHES (kg) OF HERRING AND OTHER MAJOR SPECIES

Vessel	Haul No	Date	Position	Gear	Stat rect	Catch (kg) Herring	Haddock	Whiting	Norway Pout	Others	Herring percentage
Mousse	01	11 July	59° 29'N 03° 47'W	Pelagic trawl	47E6	50	64	29	115	11	19%
"	02	13 July	60° 56'N 00° 47'W	"	50E9	0	0	27	420	0	0%
"	03	14 July	60° 37'N 00° 45'E	"	50F0	30	18	106	100	+	12%
"	04	15 July	60° 28'N 01° 17'E	"	49F1	0	112	2	750	2	0%
"	05	16 July	59° 16'N 03° 50'W	"	47E6	15000	0	0	0	0	100%
"	06	17 July	59° 44'N 02° 32'W	"	48E7	44	0	22	0	0	67%
"	07	18 July	59° 47'N 01° 45'W	"	48E8	750	0	300	0	0	71%
"	08	20 July	55° 31'N 00° 22'W	"	40E9	0	0	675	0	308	0%
"	09	20 July	54° 17'N 00° 13'E	"	37F0	0	0	0	0	245	0%
Scotia	78	26 July	57° 25'N 01° 06'W	Pelagic trawl	43E8	880	+	+	+	+	96%
"	79	28 July	60° 36'N 00° 34'W	"	50E9	0	+	0	+	+	0%
"	80	28 July	60° 22'N 00° 36'W	"	49E9	0	34	93	+	+	0%
"	81	29 July	60° 31'N 02° 00'W	"	50E8	0	+	+	0	+	0%
"	82	29 July	60° 28'N 02° 00'W	"	49E8	0	+	+	0	+	0%
"	83	29 July	60° 34'N 01° 40'W	"	50E8	0	+	+	0	+	0%
"	84	30 July	59° 50'N 01° 42'W	"	48E8	702	1	491	+	42	57%
"	85	30 July	59° 40'N 01° 50'W	"	48E8	372	+	+	0	0	100%
"	86	31 July	59° 15'N 05° 53'W	"	47E4	0	+	+	0	17	0%
"	87	1 August	58° 56'N 06° 21'W	"	46E3	0	+	+	+	+	0%
"	88	3 August	58° 29'N 06° 01'W	"	45E3	0	+	+	+	+	0%
"	89	4 August	58° 54'N 06° 11'W	"	46E3	0	+	+	0	+	0%
"	90	4 August	58° 28'N 06° 02'W	"	45E3	+	+	+	+	85	1%
"	91	5 August	58° 09'N 06° 08'W	"	45E3	17	+	+	17	8	40%
"	92	5 August	58° 11'N 06° 03'W	"	45E3	8	+	+	7	+	50%
"	93	5 August	58° 03'N 06° 10'W	"	45E3	643	+	+	+	+	100%
"	94	5 August	58° 04'N 06° 10'W	"	45E3	0	+	+	+	+	0%
"	95	6 August	57° 52'N 06° 04'W	"	44E3	1	+	+	+	34	3%
"	96	7 August	57° 07'N 06° 51'W	"	43E3	2	0	68	135	51	1%
"	97	7 August	56° 56'N 07° 17'W	"	42E2	0	+	+	68	0	0%

Table 2 (Continued) CATCHES (kg) OF HERRING AND OTHER MAJOR SPECIES

Vessel	Haul No	Date	Position	Gear	Stat rect	Catch (kg)					
						Herring	Haddock	Whiting	Norway Pout	Others	Herring percentage
Explorer	201	25 August	54° 48'N 00° 19'W	Bottom trawl	38E9	34	+1	34	0	17	40%
"	202	26 August	55° 06'N 00° 50'W	"	39E9	•	34	•	8	68	0%
"	203	26 August	55° 26'N 01° 28'W	"	39E8	0	25	42	0	17	0%
"	204	27 August	55° 38'N 01 27'W	"	40E8	0	17	8	0	25	0%

Table 3 Length compositions of herring from hauls in which at least 10 were caught. AH=Annie Hillina JH= Johan Hjort TH=Thalassa M=Mousse S=Scotia E=Explorer

Northern North Sea (IVa)

Stat rect	50E9		50F0	49E7	48E7	48E8					48E9	47E6		47E8					47E9	46E9	45E9
	AH	AH	M03	TH	M06	AH	JH	TH	M07	S85	AH11	M01	M05	AH8	AH9	AH10	JH	TH	TH	JH	AH5
	18	19		661		12	188	660	S84								182	667	668	181	
Length to ½cm below																					
15.5																1				1@13.5	
16																1				3@15.5	
17														1		6				6@16	
17.5					2						1					15				2@16.5	
18					1						2	2		1		21	2	1		2@17	
											1	19		5	1	14		6		3@17.5	
19					4					4	2	51		8	1	19	) 14	4		2@18	
					1					12	1	61		28		12	)	7		1@19	2
20					1					44		65		35	1	4	) 27	20			
										86		44		42		8	)	20			1
21					2					107		39		41		4	) 54	31			
					4					133		19		46	1	4	)	42			
22					1					98		9		16		2	) 31	43			
					2				1	69		9		13			)	38			
23				3					1	26		9		2	1	1	) 8	29			
				2	1	1			2	23		2		2	1		)	15	1		
24				2	2	3		1	6	22		5		1		1	) 7	11	8		1
			1	8		6	2	4	11	27	1	11		1	5		)	14	23		1
25				11	3	12		5	26	23	1	5		1	5		) 4	10	72		2
			1	16	4	19		15	6 44	22		12			8	2	)	15	54		2
26	2		1	11	15	20	2	29	10 69	28		14		1	7	2	) 1	17	59		2
	3		3	8	22	18		33	19 43	14	2	11	2		13	1	)	29	49		2
27	5		2	5	19	12		54	20 71	20	1	9	3		22	3	) 3	11	37		3
	5	1	3	7	17	12	1	64	19 34	8		5	2		17	2	)	14	13		3
28	7		5	4	17	3	2	37	24 41	9			2		4	2		13	3		3
	2		5	2	21	2	1	16	7 17	1	1	2	7		8			1	3		1
29	3	4	6		14	1	3	13	19 23	3			12		7				4		1
	8	1	2	2	15	3	2	7	21 20	5		2	26		5	1		2	2		2
30	5	3	8		6	3	2	10	21 32	1			35		4				1		
	6	11	6		16	2	1		25 30				33		3				2		
31	5	14	3	2	10	1	3	3	21 44	1			44		2			1	1		
	2	19	7		8		2		13 34			2	20			1		1			
32	5	21	11	1	7	1	1	1	12 16	2			10								
	1	18	8		3				8 14				5						1		
33	1	13	12						2 11				3								
	2	5	6						1												
34		5	9					1													
		2	6													1					
35	1	3	2					1	1												
			1																		
36			1																		
Total measd	63	120	109	86	218	119	22	293	240 592	788	13	405	204	244	116	128	150	395	333	20	26

Table 3 (contd.)
West of Scotland (VIa)

Stat. rect.	46 E4		45 E1		45 E3			44 E1	42 E2
Haul No	TH 665	TH 666	S 104	S 105	S 91	S 92	S93	S 99	S 98
Length to ½cm below									
16.5					1	1@14			
17.5					2		1		
18							1		
					2				
19					2		1		
					8	2	6		
20					10	1	23		
					14	4	42		
21					26	1	54		
					22	7	81		2
22					16	5	55		1
	1				11	5	54		8
23	1				16	5	48	2	16
					7	6	64	3	19
24					14	3	34	2	29
	10	4	1		9	1	27	9	34
25	30	8	1	1	6	2	26	4	26
	26	8		3	6	2	22	8	45
26	58	11	2		8	3	14	11	26
	50	14	4		2		7	5	21
27	62	11	2				1	9	18
	43	7	1	3				9	15
28	36	6	2	2	1			8	6
	25	8	3	2	1	1		4	11
29	24	9		4			1	4	5
	19	16		1	1		1	3	3
30	17	11	1	2			1	4	3
	25	15	1	1				2	1
31	14	2	1	5				1	1
	6	3	2	1					1
32	2	1							
				1					
Total measured	449	134	21	26	185	49	564	88	291

Table 4 Mean integrator values μ (mm per nautical mile) of pelagic fish by night in sub-areas shown in Figure 10.

Sub-area	A	B	C	D	Sum A-C
Area in square nautical miles	196.9	384.3	259.4	215.6	840.6 [1]
μ	173.9	144.5	138.9	241.7	149.7 [1]

1) Weighted mean by sub-areas

Table 5 Percentage (by numbers) of the main fish species in pelagic trawl catches by night (sub-areas A-C) and by day (sub-area D).

	Trawl st.	Herring O-group	Herring Older	Sprat	Whiting	Dogfish
Sub-areas A-C	172	-	99.4	-	-	0.4
"	174	-	11.8	84.5	3.0	0.7
"	175	-	3.4	93.5	3.1	-
"	179	-	3.2	91.8	1.8	3.2
	Mean	-	29.45	67.45	2.0	1.1
Sub-area D	171	68.1	0.8	27.6	3.5	-

Table 6 Length-dependent C-values for the main pelagic species.

Herring: $C = 1.34 \times 10^5 \times l^{-1.36}$ $(a = 2.09 \times 10^{-6}, b = 1.36)$

Sprat: $C = 3.38 \times 10^5 \times l^{-1.72}$ $(a = 8.32 \times 10^{-7}, b = 1.72)$

Whiting: $C = 1.28 \times 10^6 \times l^{-2.46}$ $(a = 2.19 \times 10^{-7}, b = 2.46)$

Dogfish[1]: $C = 7.1 \times 10^5 \times l^{-2}$ $(a = 4 \times 10^{-7}, b = 2)$

1) Approximate figures.

Table 7 Mean C-values within sub-areas[1].

Sub-area	Herring O-gr.	Herring Older	Sprat	Whiting	Dogfish
A-C	-	1638	5957	952	197
D	10685	2032	10592	778	-

[1] Number of fish per square nautical mile per mm deflection per nautical mile.

Table 8 K-values within sub-areas (herring+sprat+whiting+dogfish)

Sub-area A-C: $K = \left(\frac{0.297}{1638} + \frac{0.672}{5957} + \frac{0.021}{952} + \frac{0.011}{197}\right)^{-1} = 2688$

Sub-area D: $K = \left(\frac{0.707}{10685} + \frac{0.008}{2032} + \frac{0.248}{10592} + \frac{0.036}{778}\right)^{-1} = 7154$

TABLE 9 Abundance estimates of herring, sprat, whiting and dogfish in area I.

	Sub-area A+B+C			Sub-area D			Area I total	
	Mean density (♂) 000' per square mile	Abundance Number in millions	Tonnes	Mean density (♂) 000' per square mile	Abundance Number in millions	Tonnes	Abundance Number in millions	Tonnes
Herring 0-gr	-	-	-	1222.4	263.5	461	263.5	461
Older	119.5	100.5	16716	13.8	3.0	301	103.5	17017
Sprat	270.4	227.3	2023	428.8	92.4	324	319.7	2347
Whiting	8.5	7.1	705	69.2	14.9	1491	22.0	2196
Dogfish	4.4	3.7	3721	-	-	-	3.7	3721

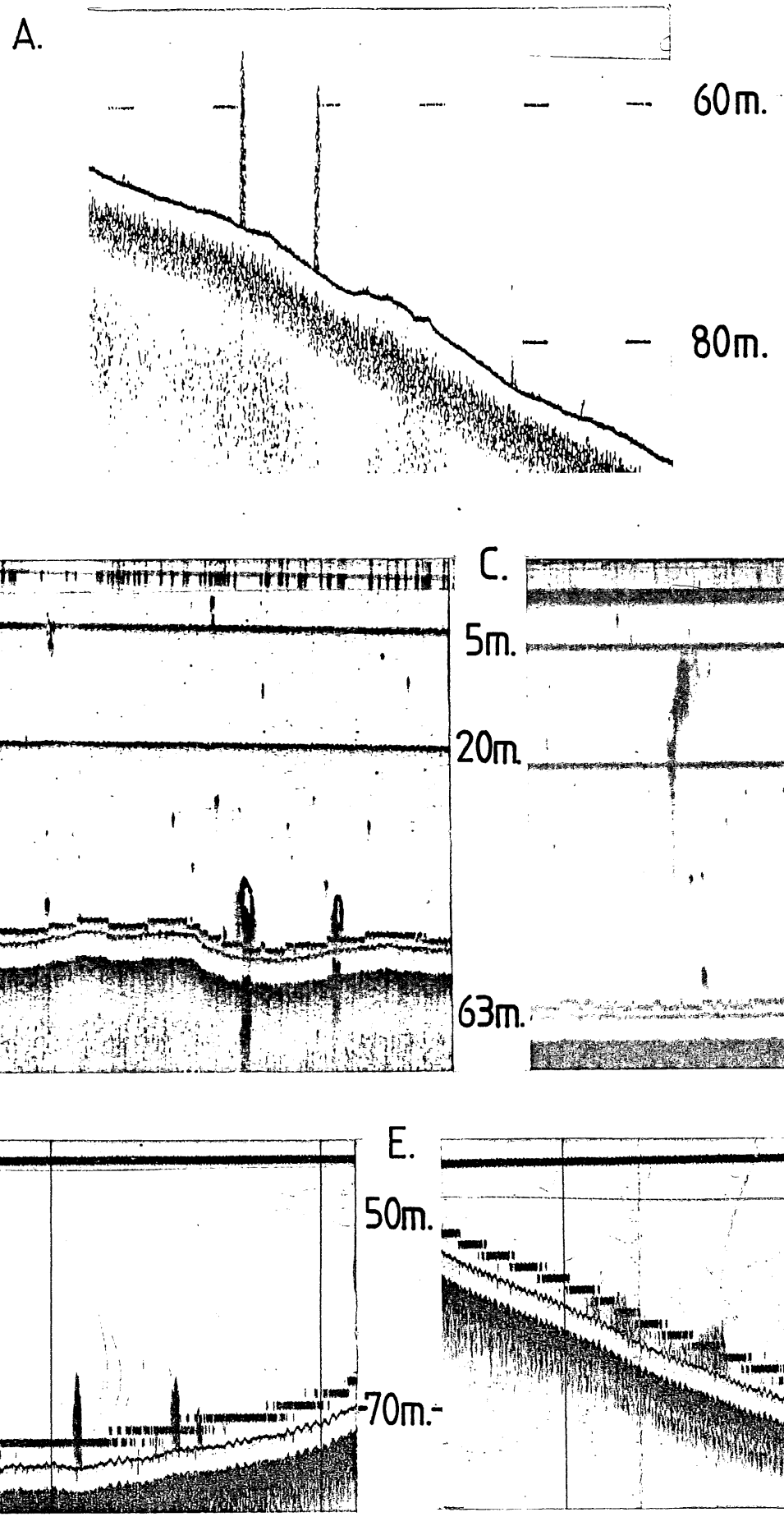
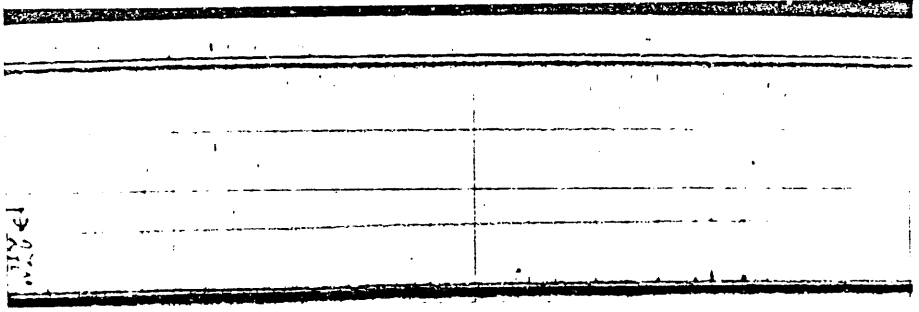


PLATE I
a) ANNA HILLINA 1610 GMT 6 July 55°50'N 01°33'W (Berwick Bank)
b) EXPLORER 1400 GMT 20 August 54°19'N 00°01'W
c) EXPLORER 1830 GMT 24 August 54°47'N 00°20'W
d) SCOTIA 1900 GMT 26 July (Turbot Bank)
e) SCOTIA 2040 GMT 26 July (Turbot Bank)

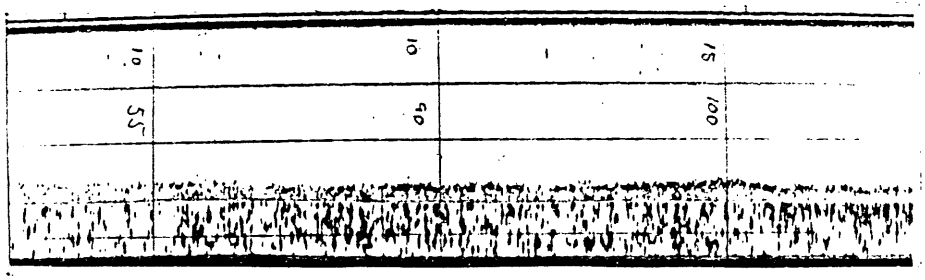
A.

1545.GMT



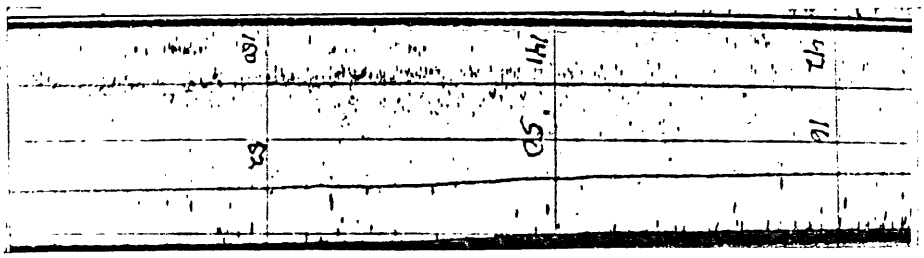
B.

1845.GMT



C.

2215.GMT



D.

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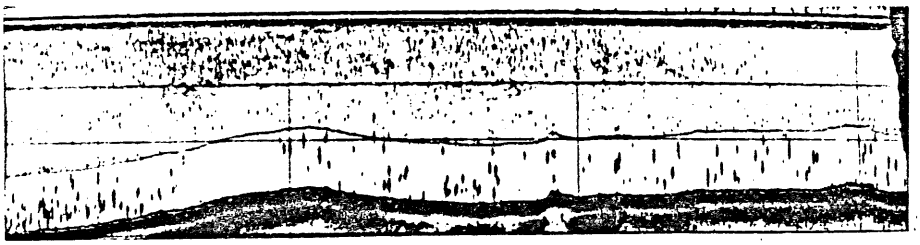

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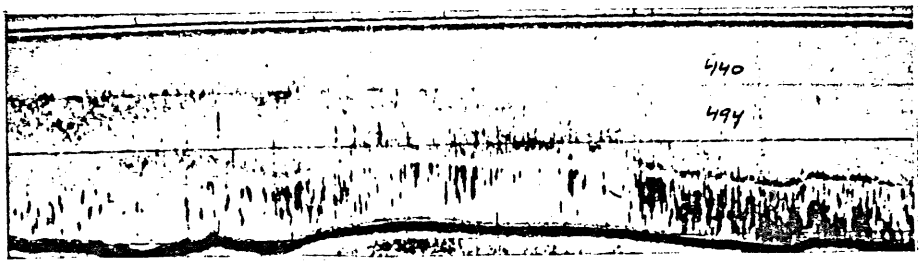

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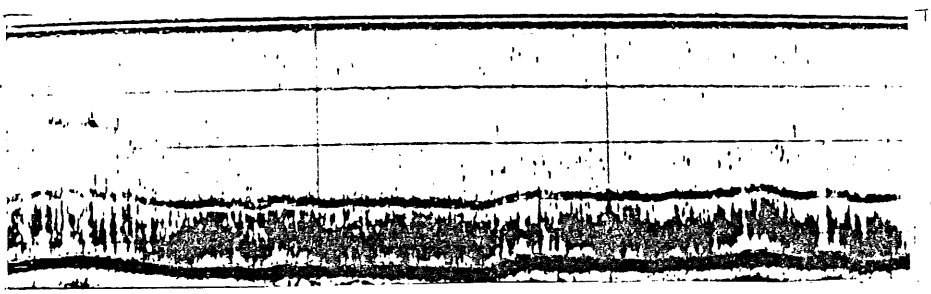


PLATE II Ascent and descent of herring traces 11 - 12 July 1979 JOHAN HJORT
Approx Positions 54°51'N - 55°38'N; 01°02'W - 01°31'W

*Expanded bottom

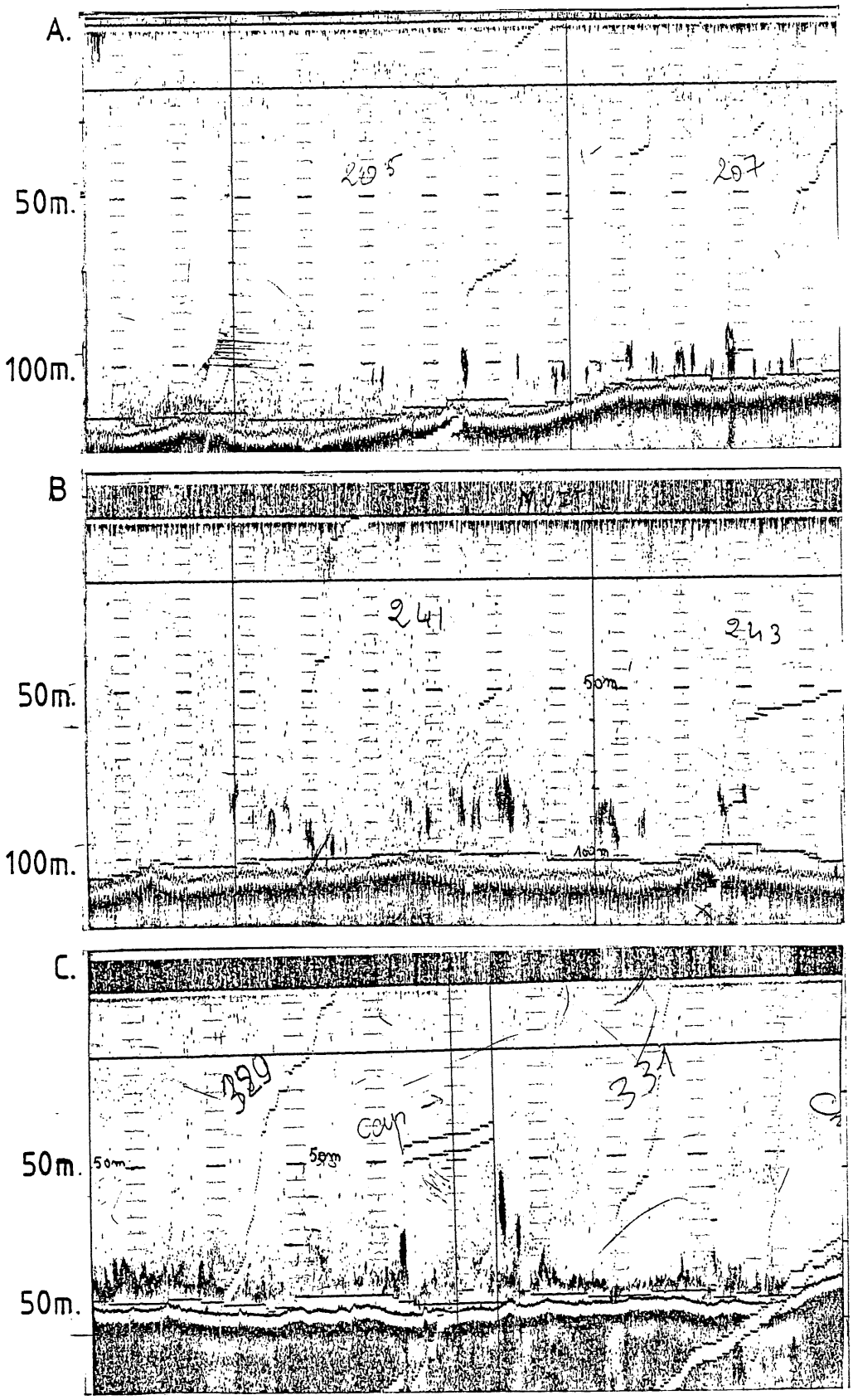
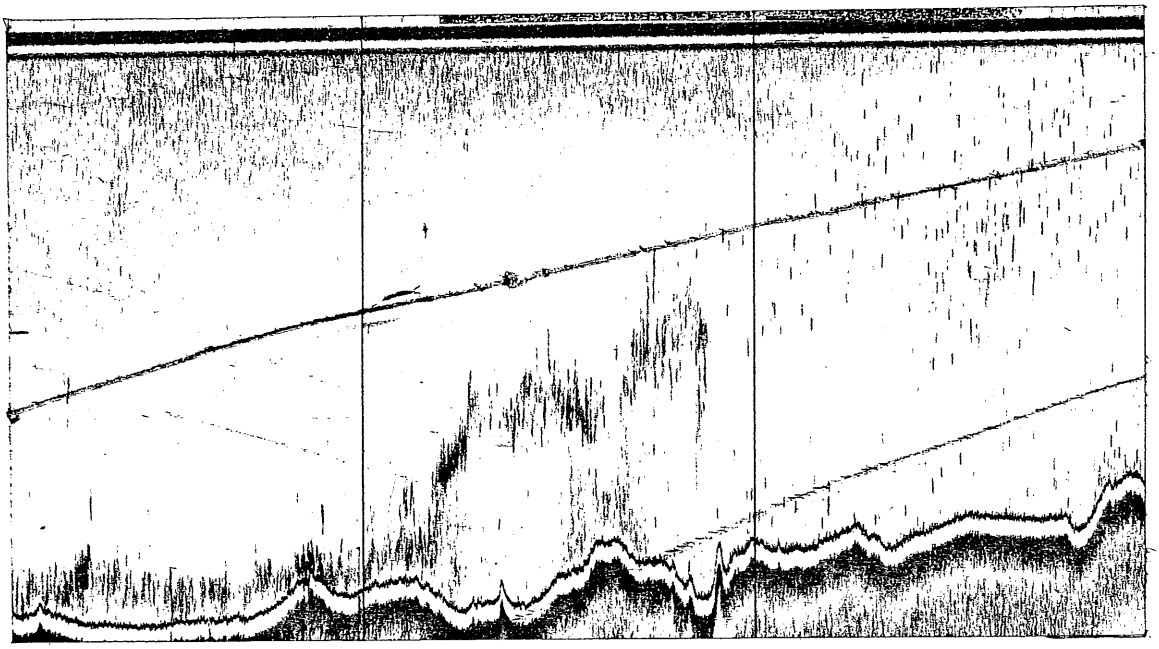


PLATE III a) THALASSA 1820 GMT 17 July 59°43'N 01°42'W SW Shetland
b) THALASSA 2217 GMT 17 July 59°44'N 01°47'W SW Shetland
c) THALASSA 1515 GMT 19 July 59°53'N 01°13'W SE Shetland

A.



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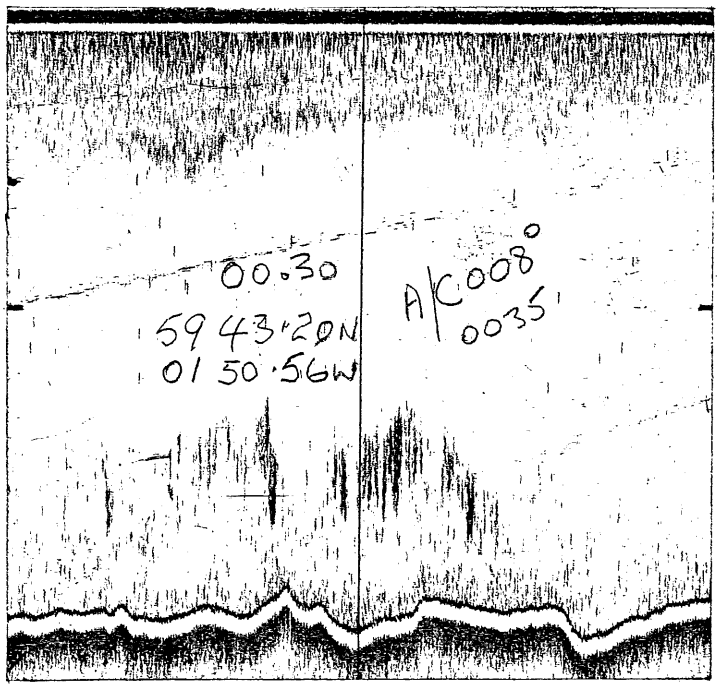

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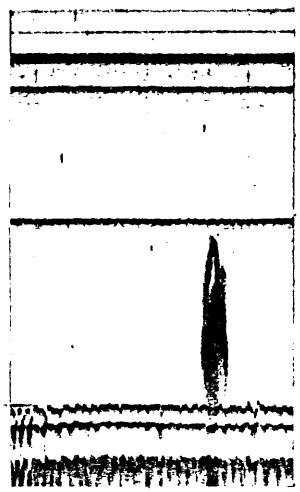
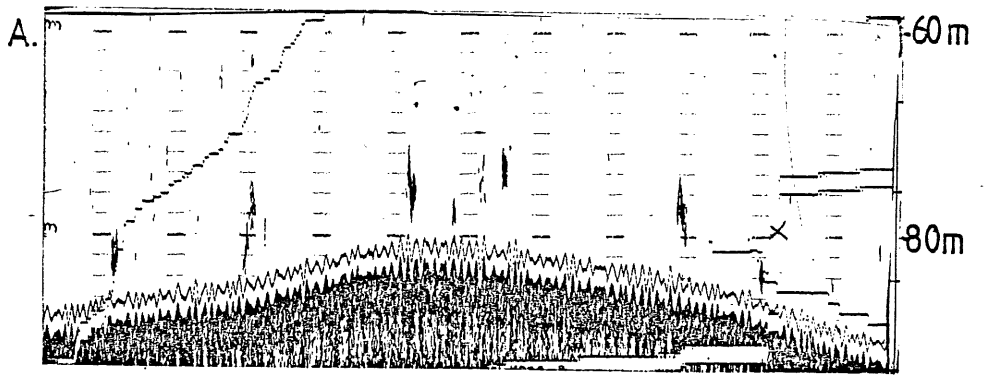
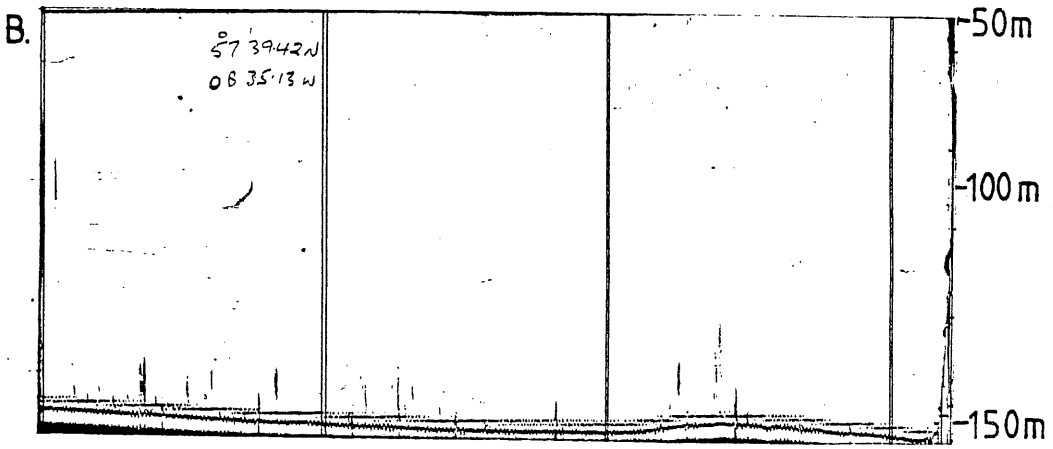


PLATE IV a) SCOTIA 2100 GMT 30 July 59°50'N 01°06°W South Shetland
b) SCOTIA 2315 GMT 30 July 59°44'N 01°42'W South Shetland
c) EXPLORER 1200 GMT 12 August 60°00'N 02°10'W South of Foula





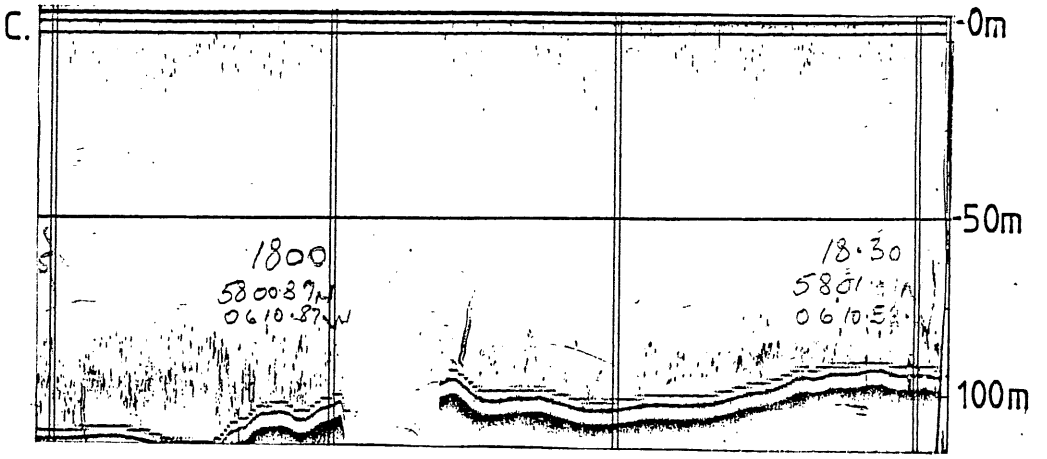


PLATE V

a)	THALASSA	1800 GMT	22 July	58°52'N	05°30'W	NW Cape Wrath
b)	SCOTIA	1115 GMT	9 August	57°40'N	08°35'W	St Kilda
c)	SCOTIA	1700 GMT	5 August	58°01'N	06°11'W	North Minch

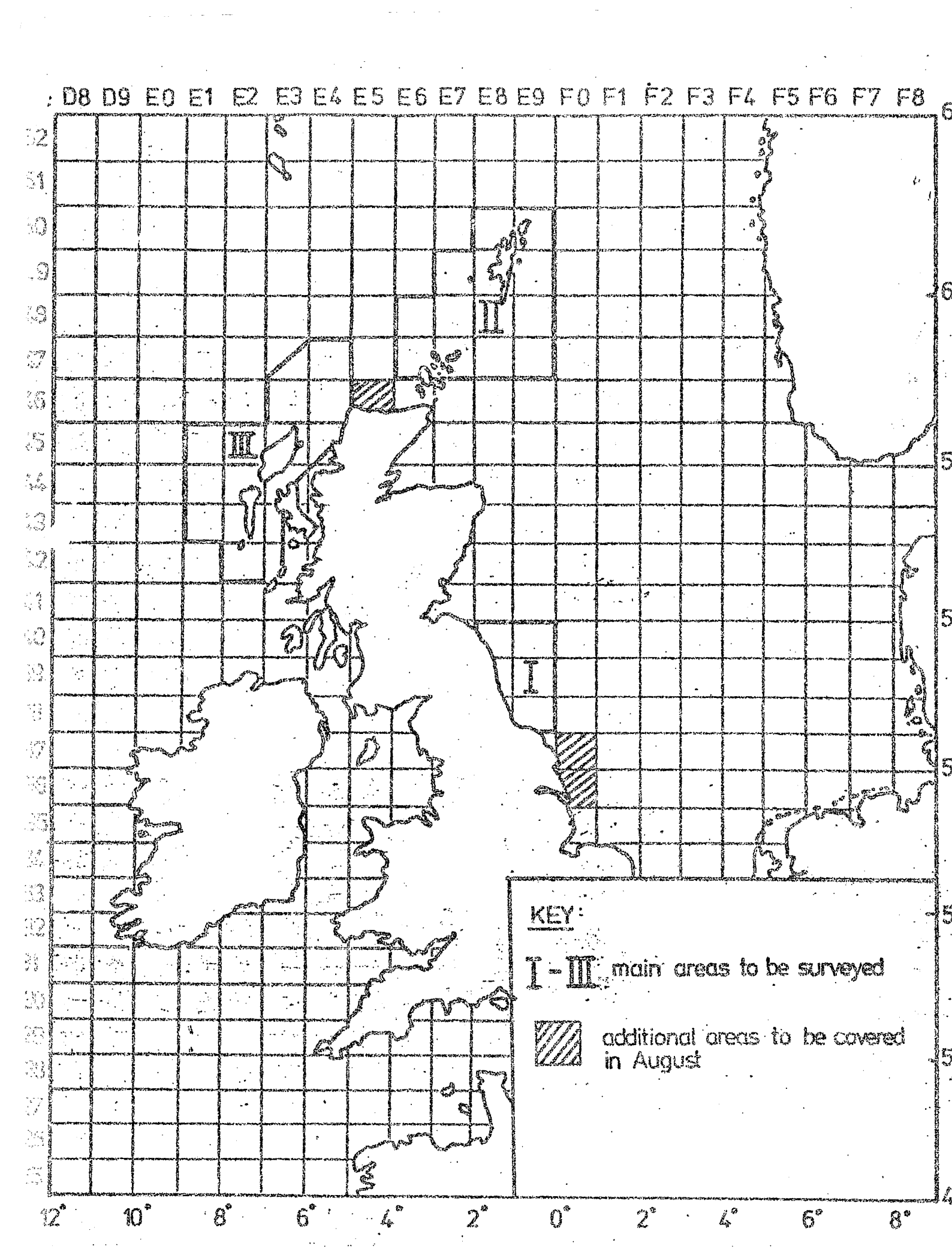


FIGURE 1 Areas identified by the Planning Group to be covered during the survey.

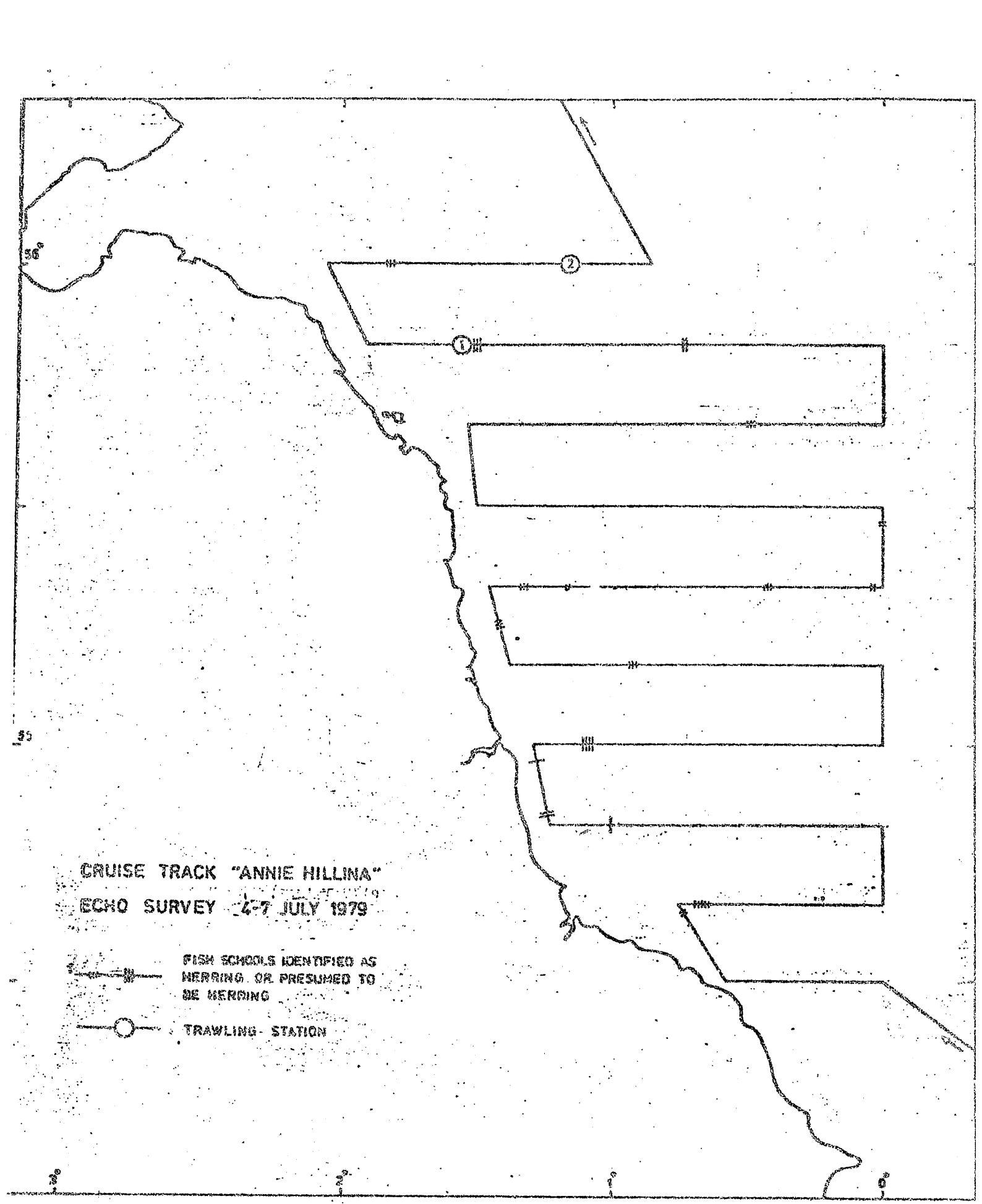
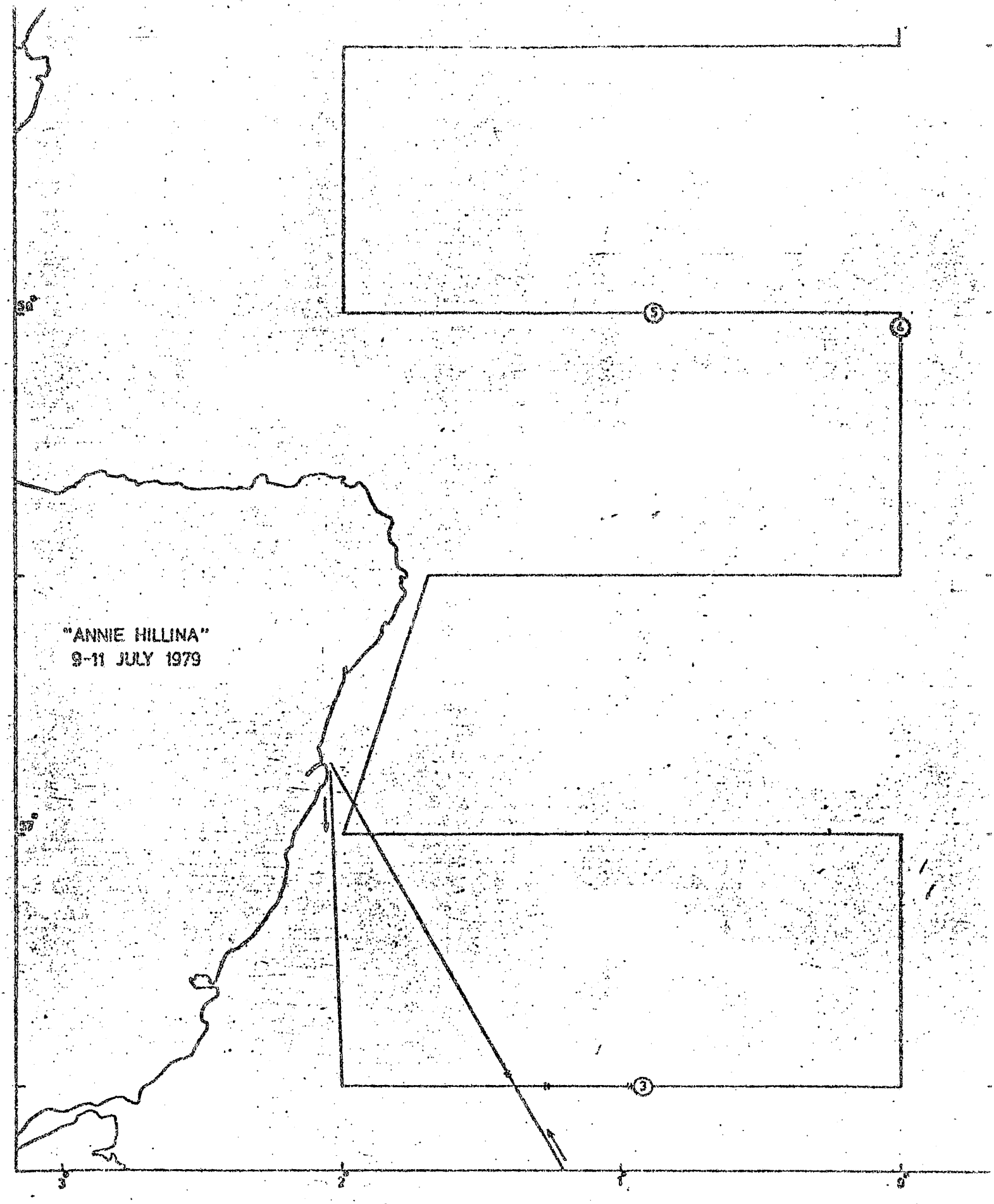
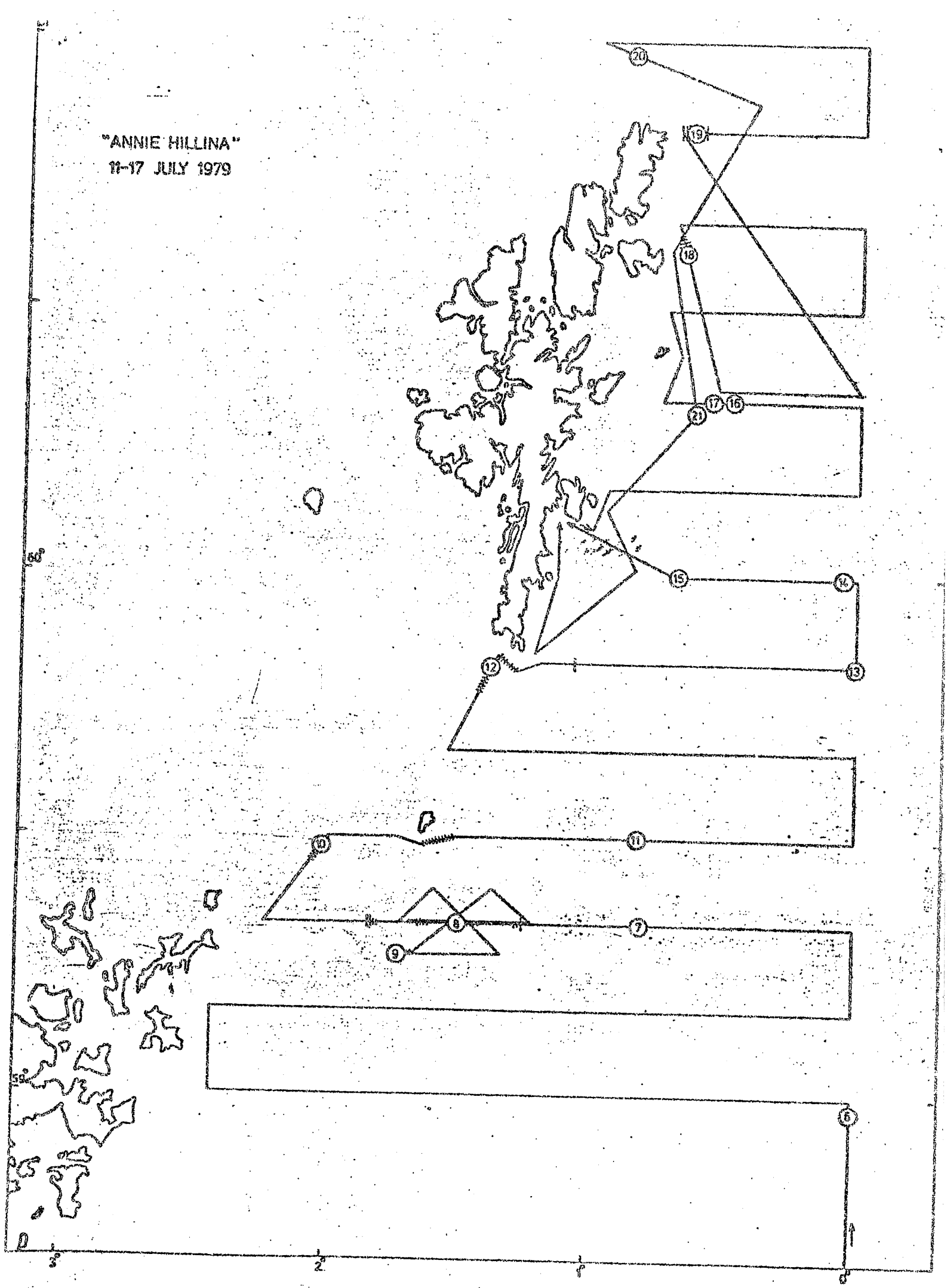


FIGURE 2 Cruise track, trawling positions and areas of herring schools located by ANNIE HILLINA.

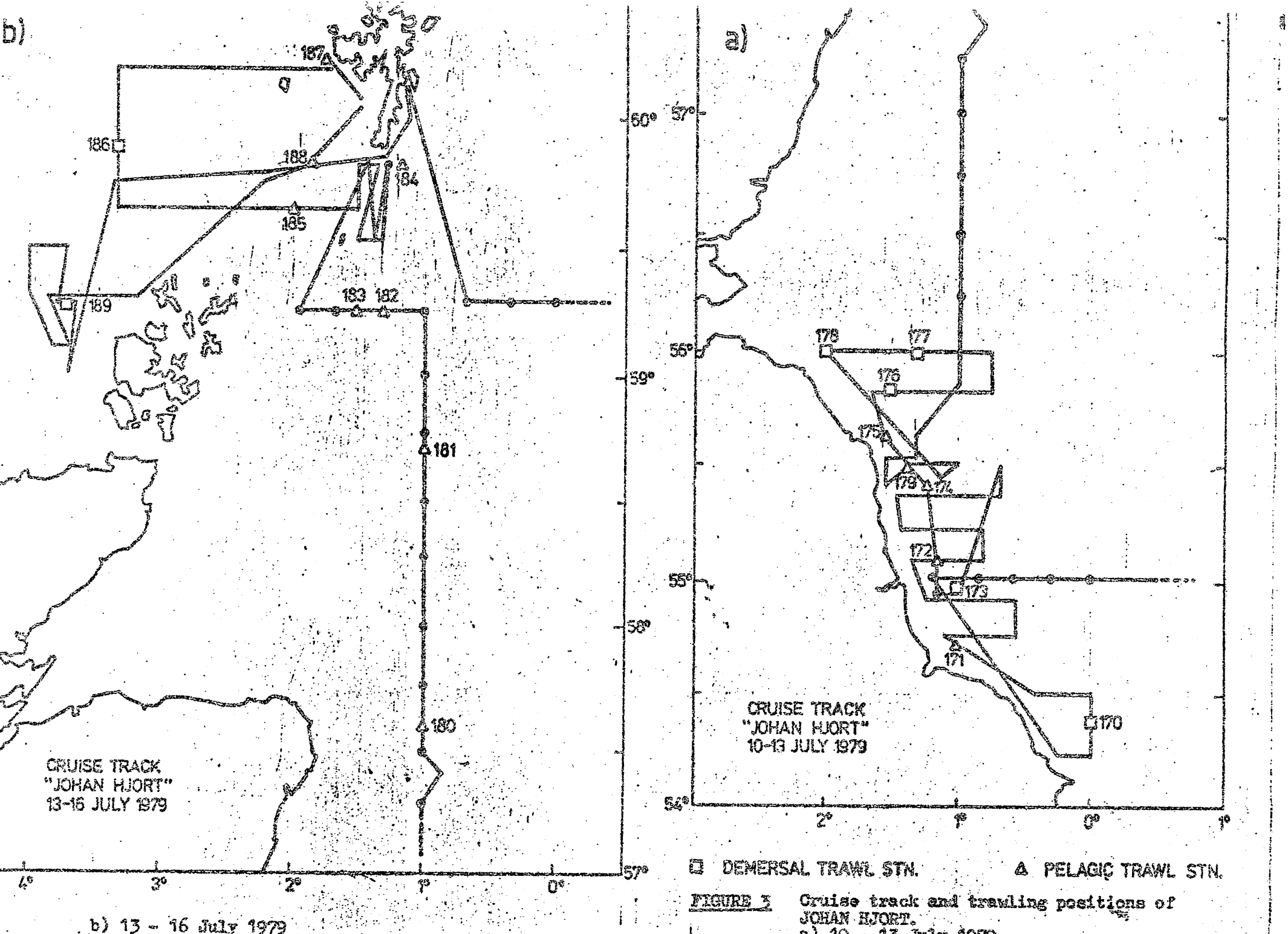
a) 04 - 07 July 1979



b) 09 - 11 July 1979



c) 11 - 12 July 1979



b) 13 - 16 July 1979

FIGURE 3 Cruise track and trawling positions of JOHAN HJORT.
a) 10 - 13 July 1979

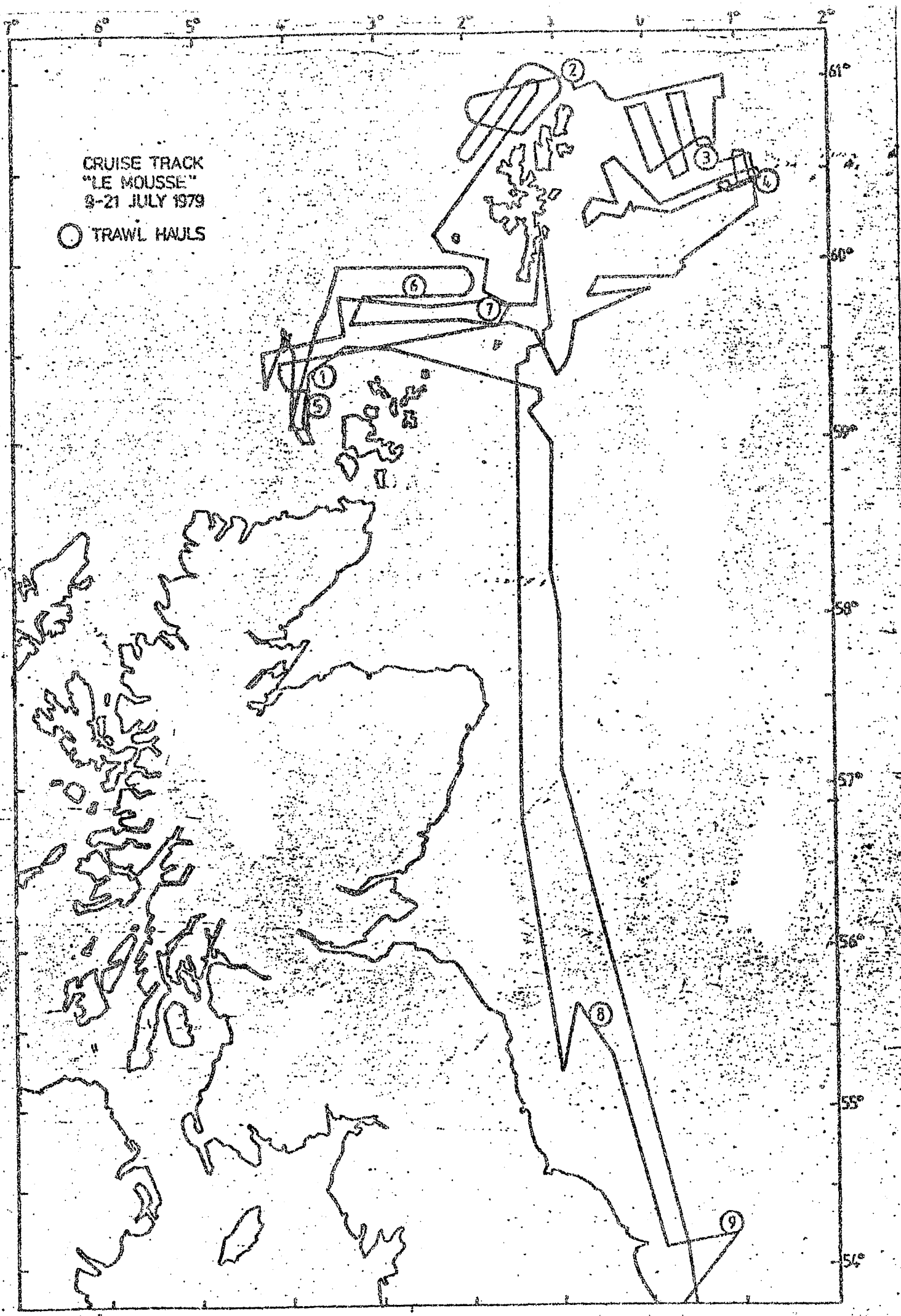


FIGURE 4 Cruise track and trawling positions of MOUSSE, 09 - 21 July 1979.

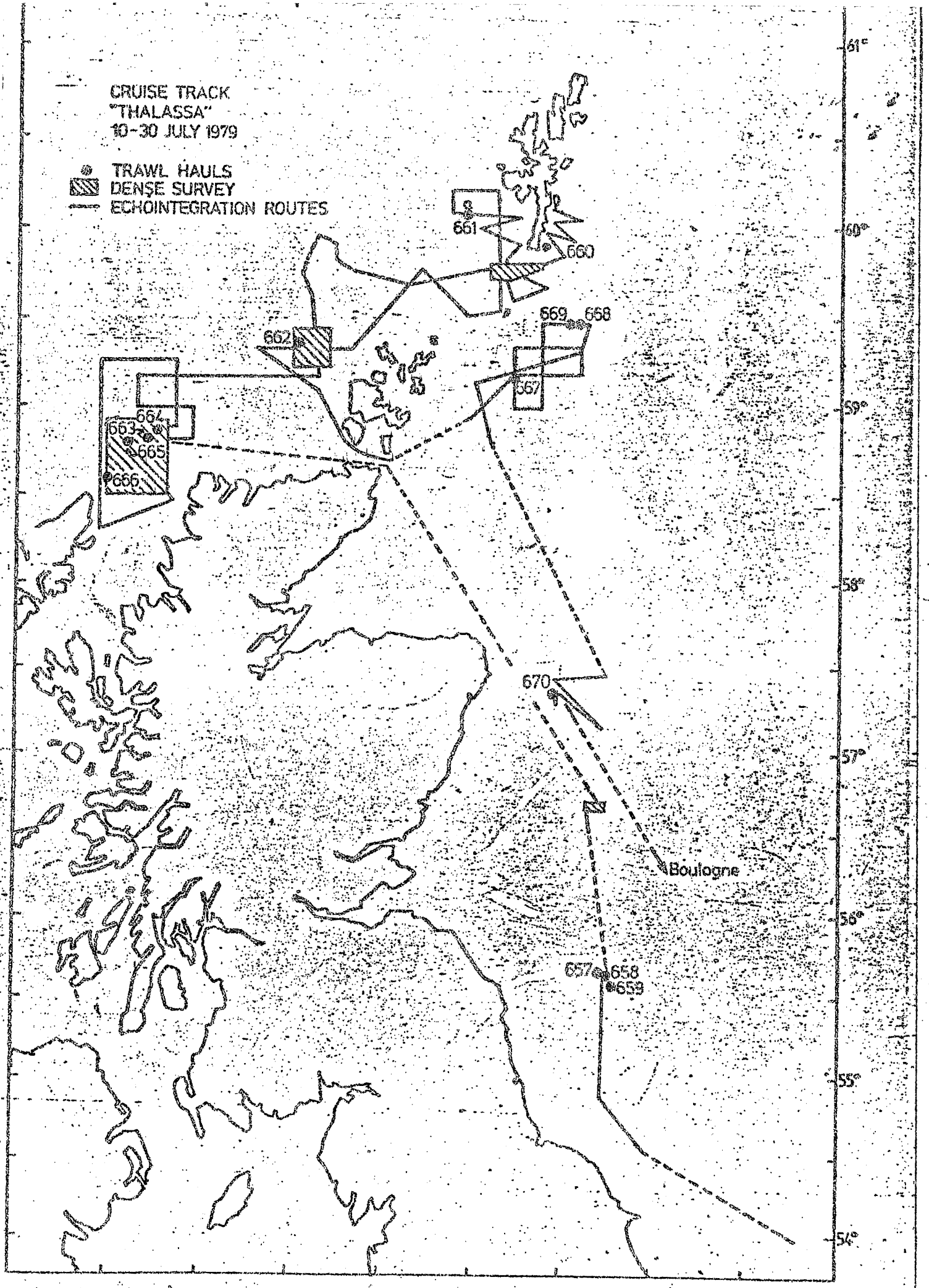


FIGURE 5 Cruise track and trawling positions of THALASSA, 10 - 30 July 1979, showing areas of echointegrator surveys.

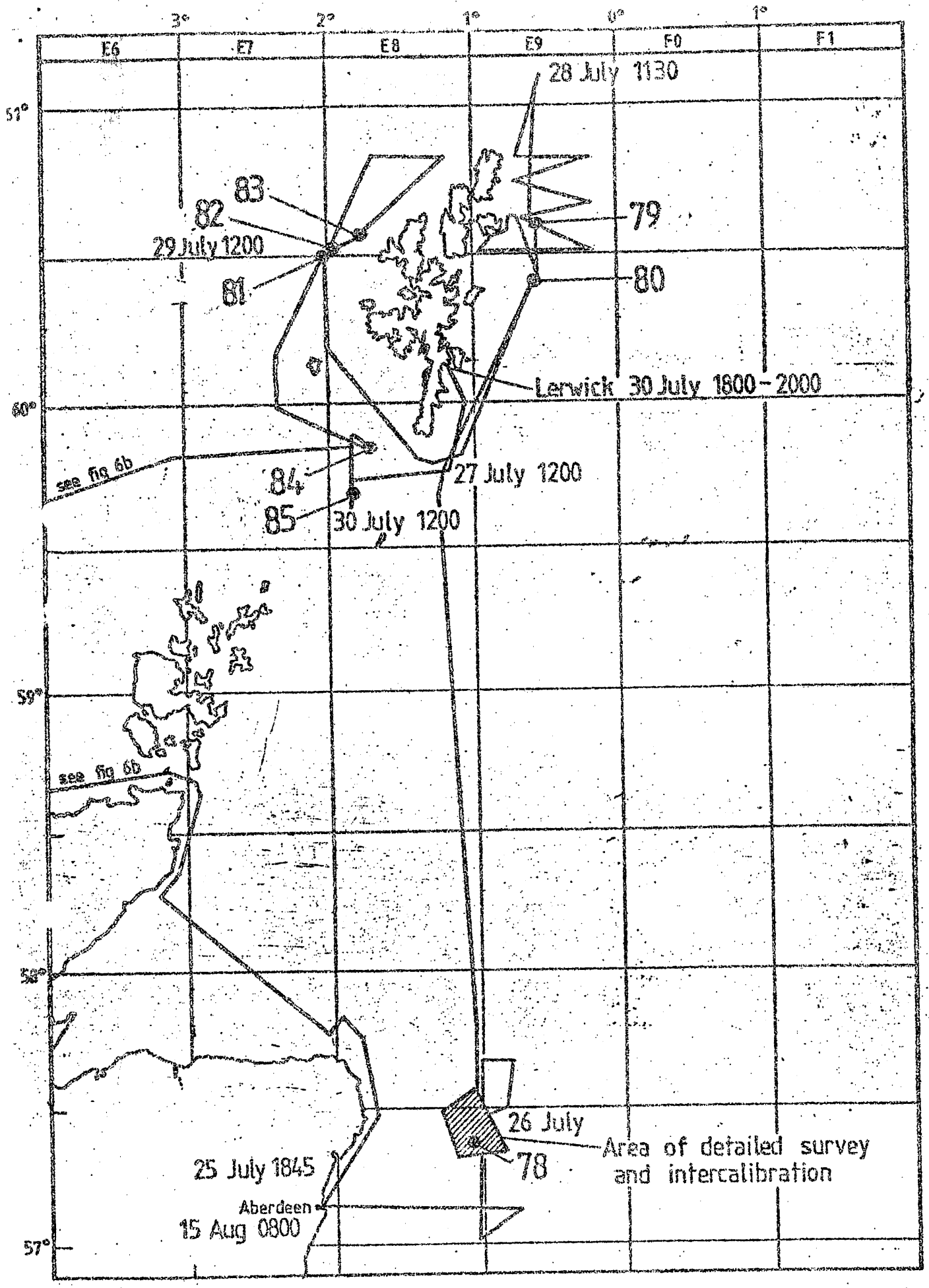


FIGURE 6 Cruise track and trawling positions of SCOTIA, 25 - 31 July 1979.

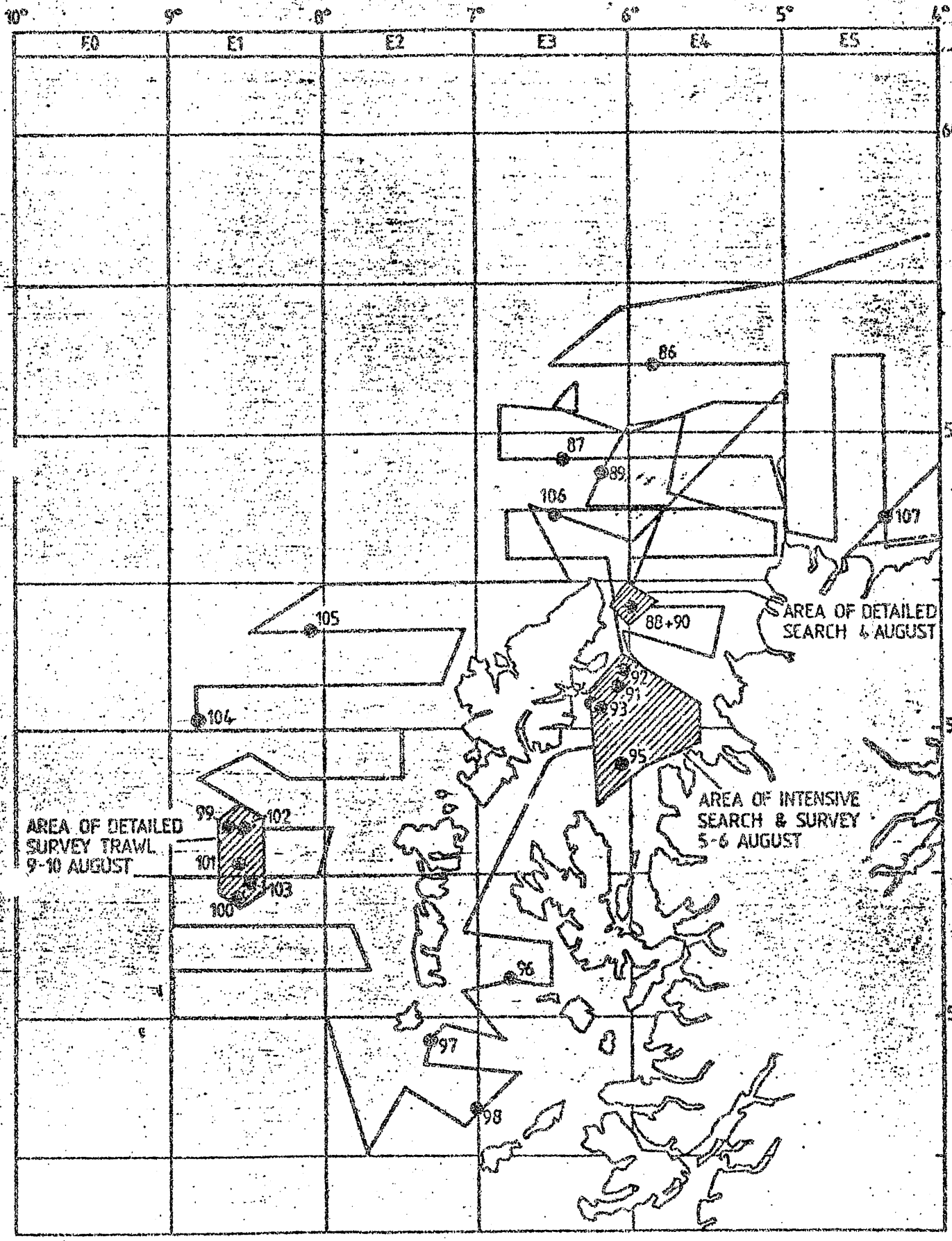


FIGURE 7 Cruise track and trawling positions of SCOTIA, 31 July - 14 August 1979.

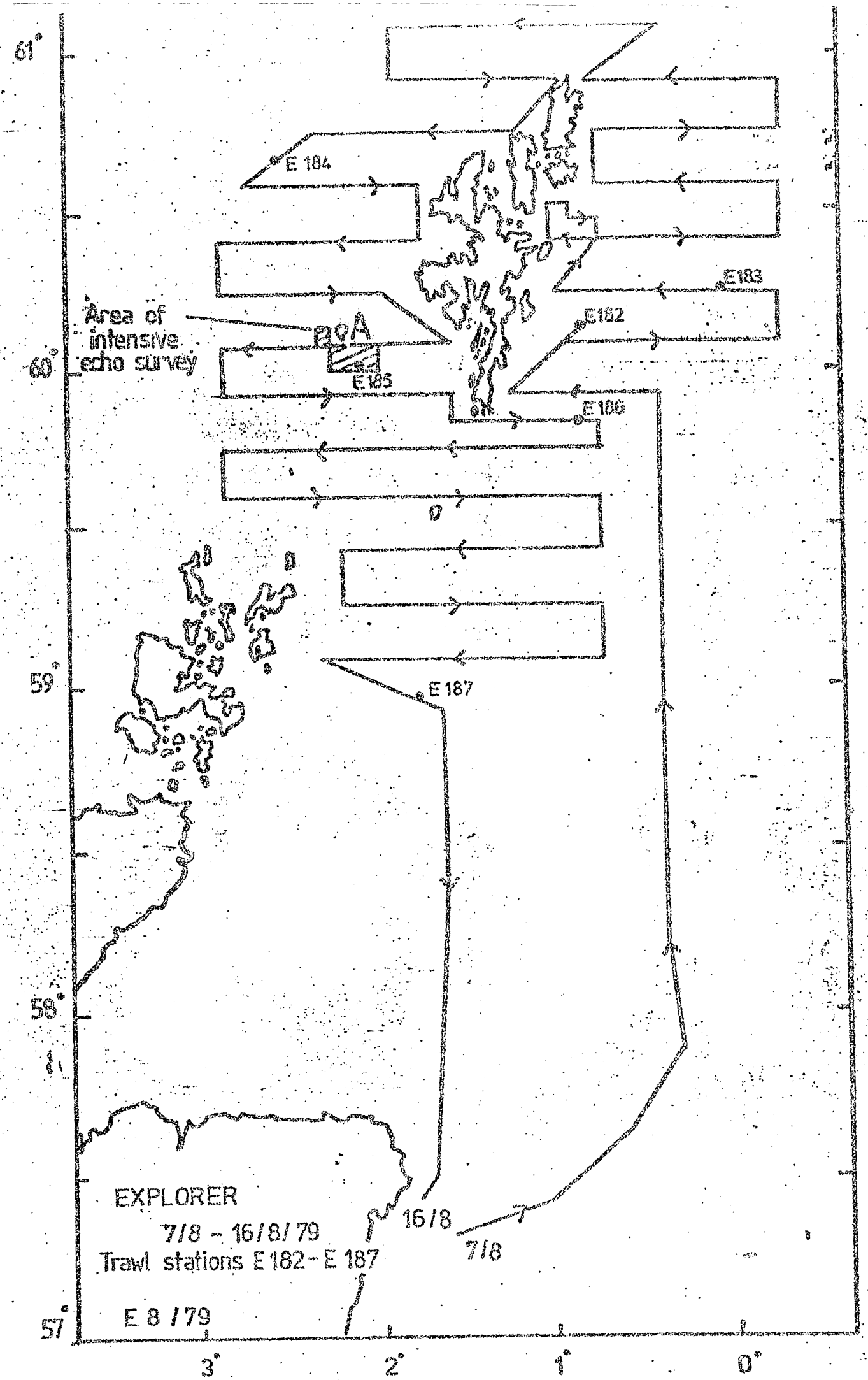


FIGURE 8 Cruise track and trawling positions of EXPLORER, 07 - 16 August 1979.

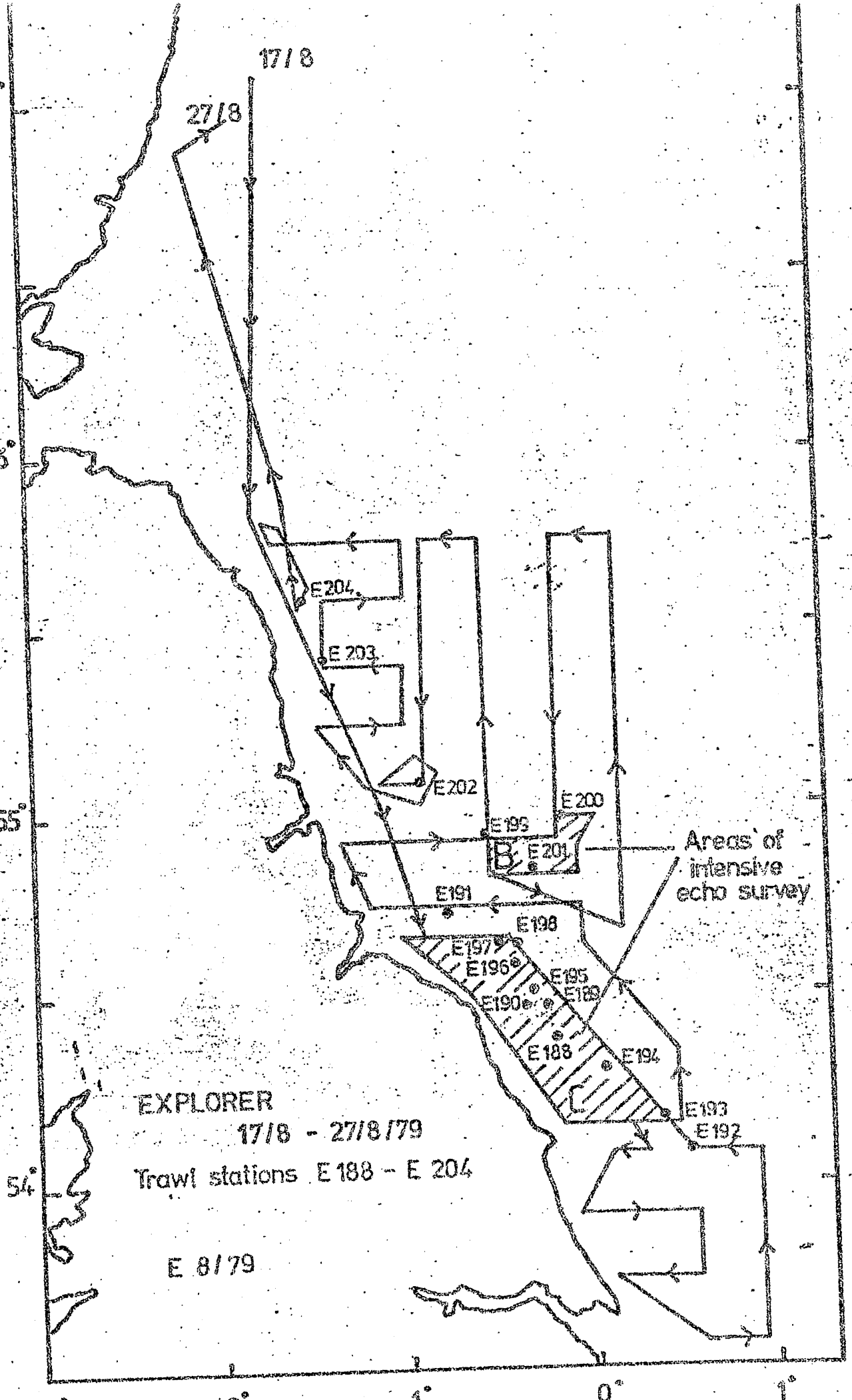


FIGURE 9 Cruise track and trawling positions of EXPLORER, 17 - 27 August 1979.

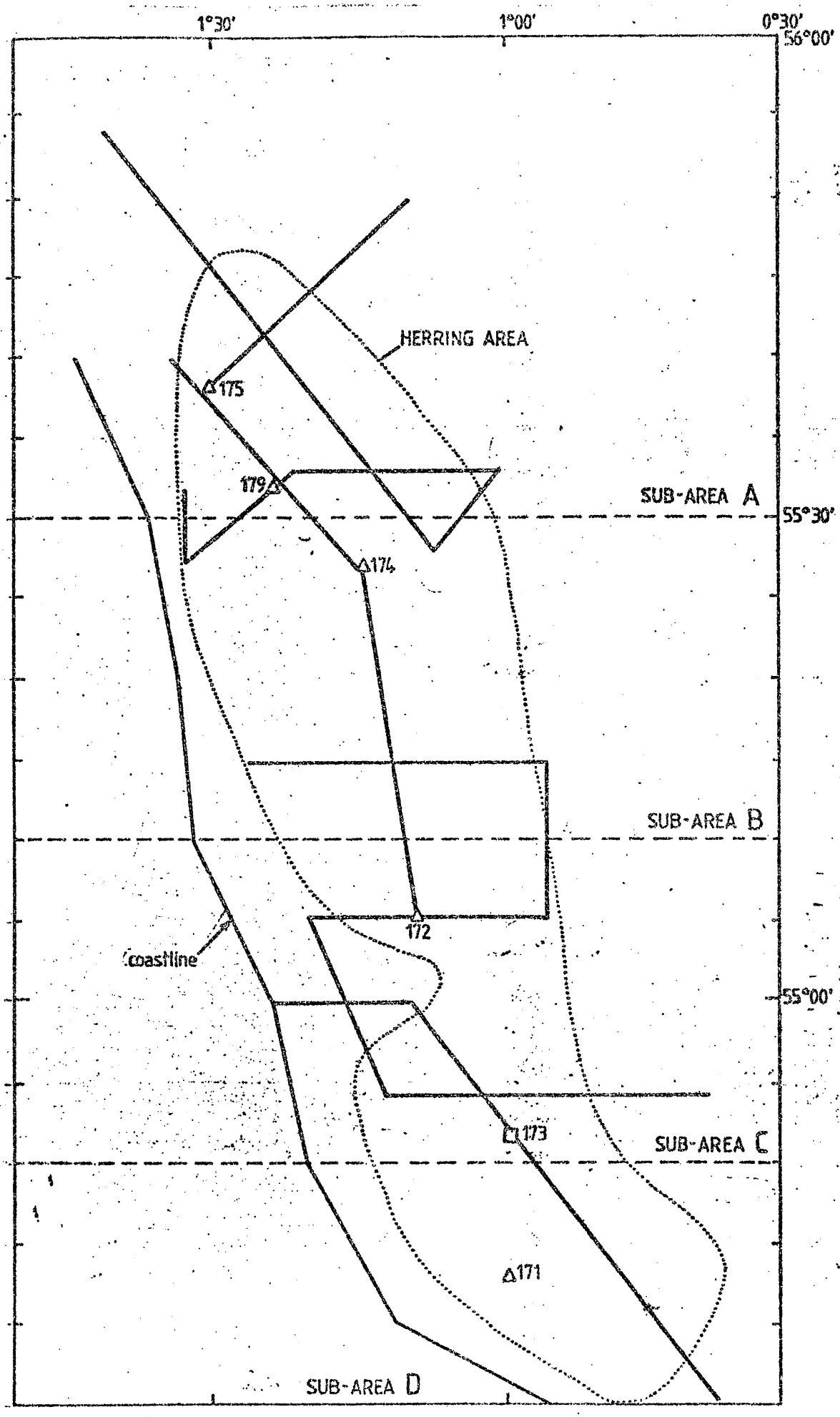


FIGURE 10 Echointegrator survey and trawling positions of JOHAN HJORT off northeast England with area of herring distribution.

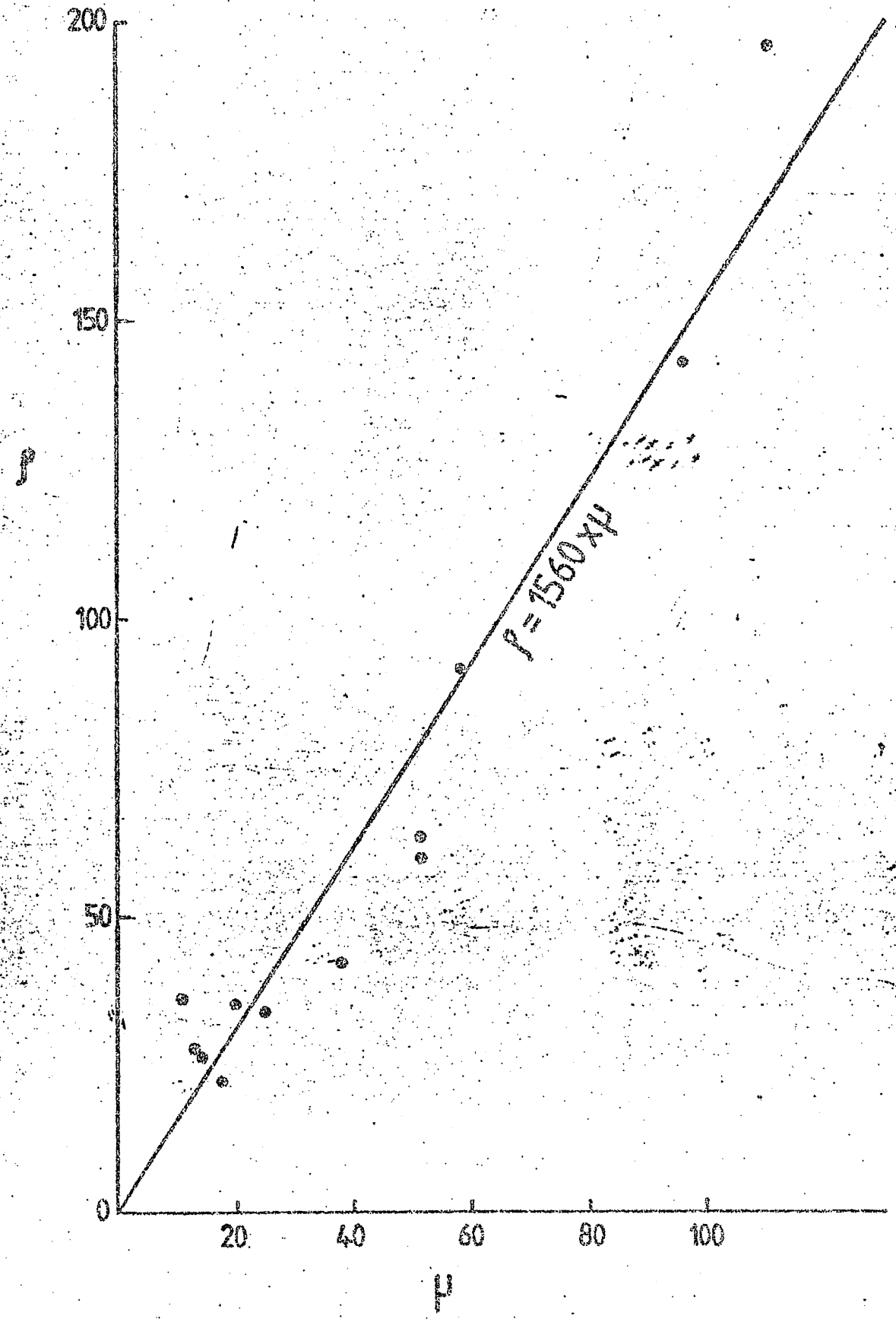


FIGURE 11 Regression between number of fish (P) and integrator deflection in mm (μ) in area I, JOHAN HJORT.

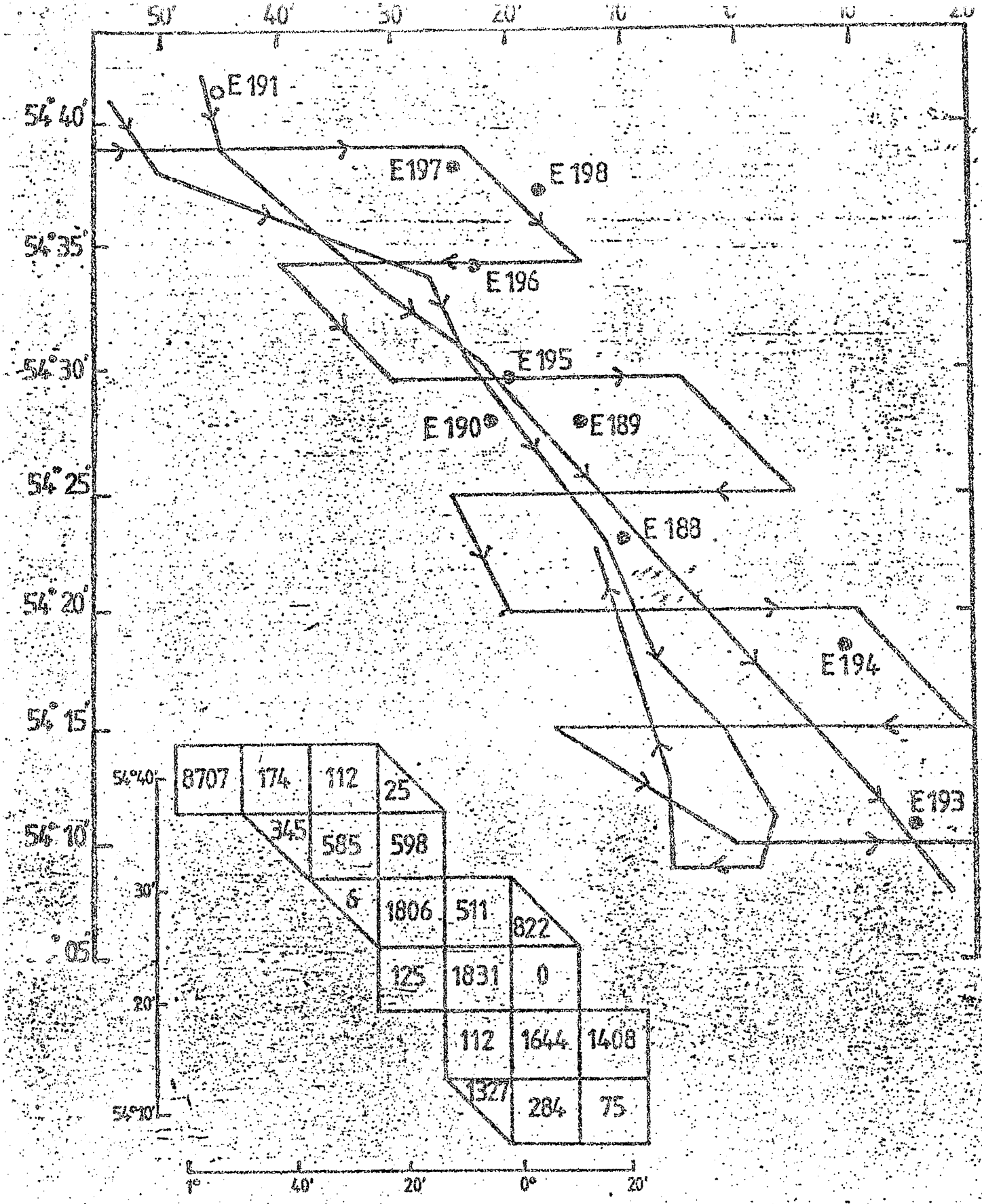


FIGURE 12 Echointegrator survey and bottom trawl hauls, carried out by EXPLORER in area I, August, with estimated total acoustic biomass (tonnes) in 6 x 6 nautical mile squares, between depths of 20m from surface and 5m from the seabed.

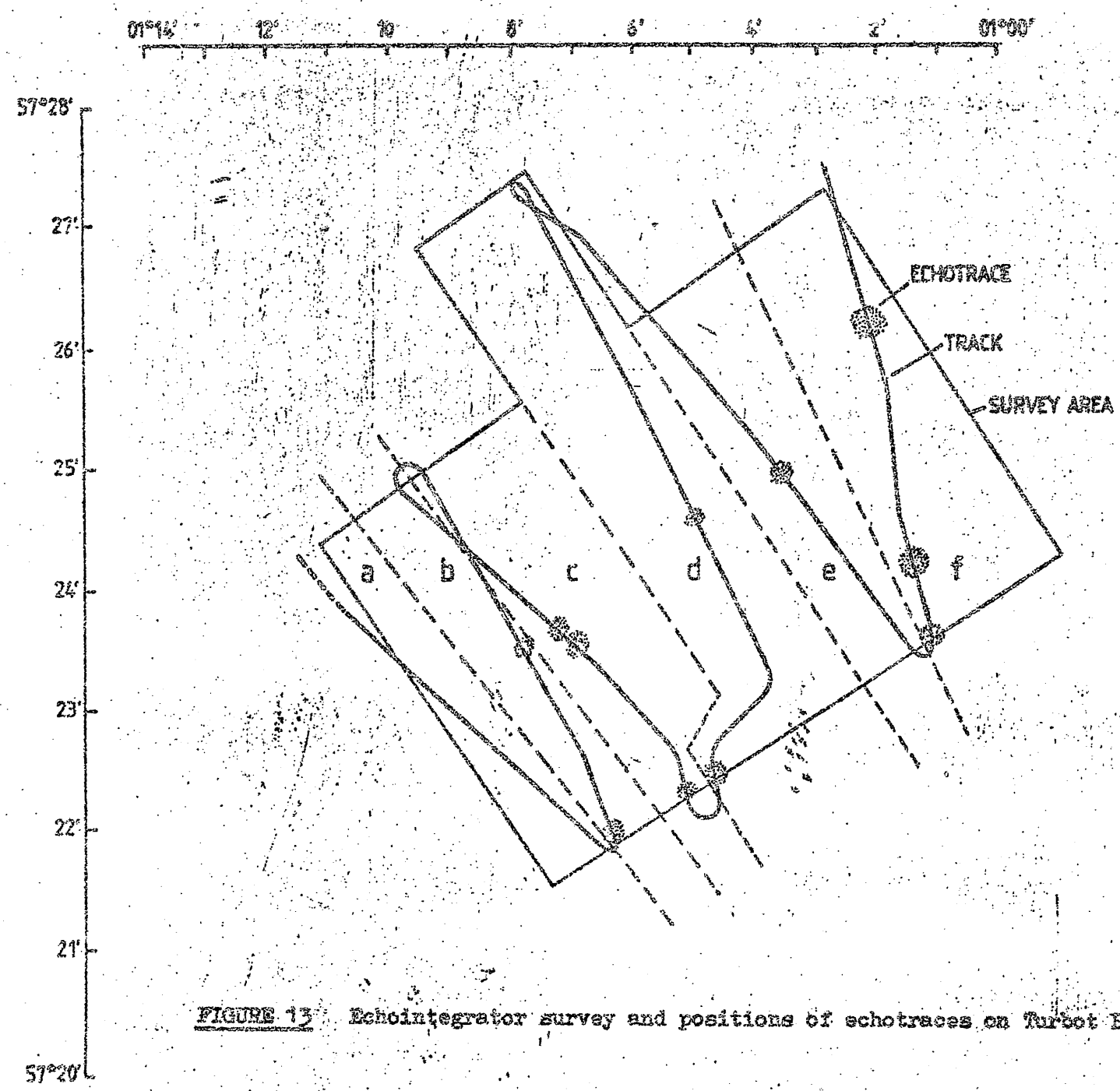


FIGURE 13 Echointegrator survey and positions of echotraces on Turbot Bank, SCOTIA.

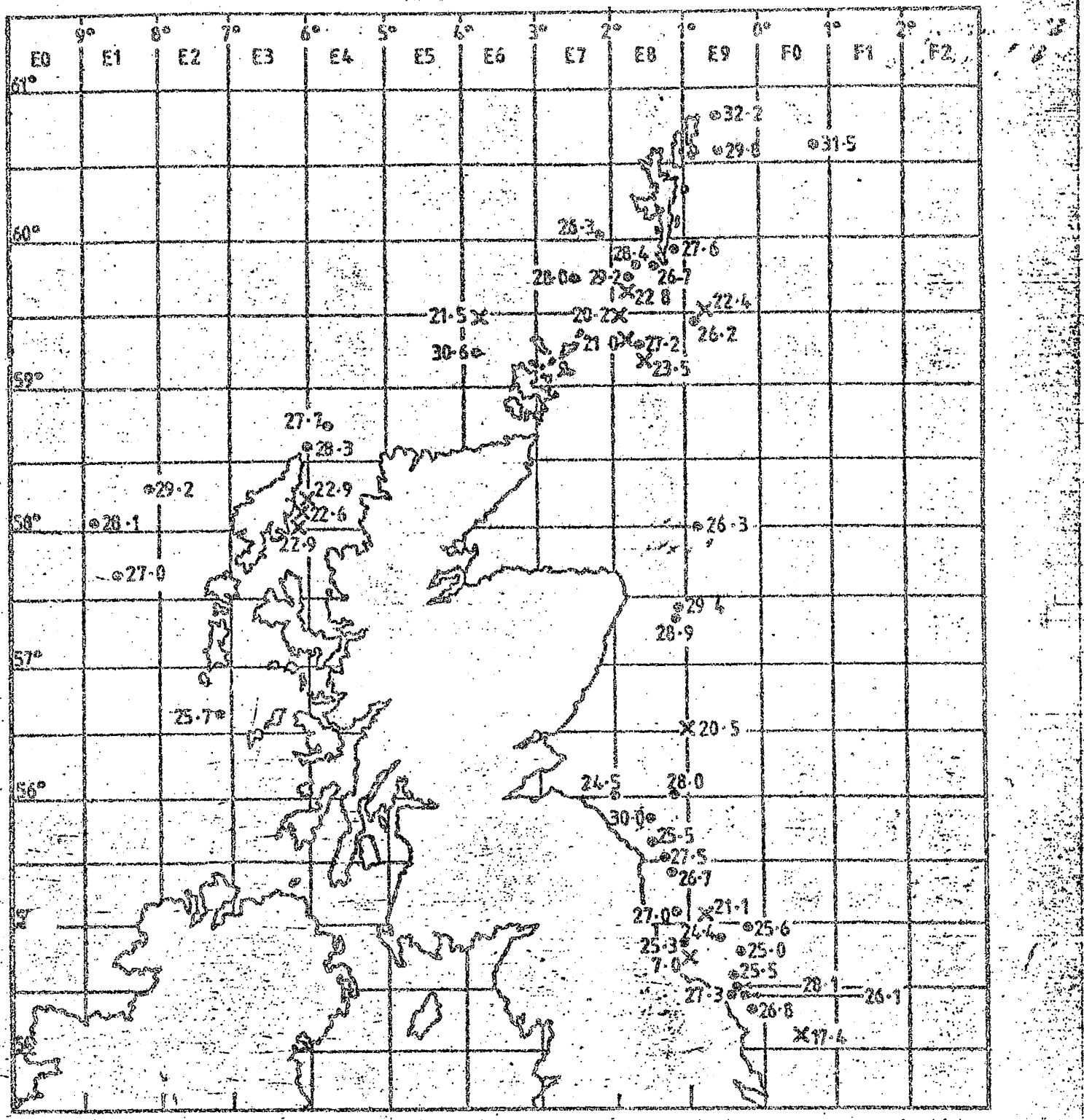


FIGURE 14 Mean lengths of herring (cm) in hauls containing more than 10 herring. (Crosses show positions of hauls containing predominantly small fish (< 23cm).

Table 1. Details of acoustic equipment and trawling gear used on survey vessels

VESSEL	TRAWL	ECHOSOUNDER	SONAR	ECHOINTEGRATOR
THALASSA	Pelagic trawl (sprat-mesh blinder)	Simrad EK S38	-	Simrad QM MK II
MOUSSE	2000 mesh-Pelagic trawl (15mm mesh blinder)	Simrad	Simrad	-
ANNIE HILLINA	Pelagic trawl	Simrad EQ (Sensitivity poor)	Simrad SB	-
SCOTIA	1000hp Delagic trawl (20mm codend) and 900hp Blue whiting trawl (20mm codend)	Simrad EK38/S	Simrad SK3	Aberdeen Echointegrator
JOHAN HJORT	Pelagic 1600-mesh capelin trawl, 16 x 16 fathom opening (22mm codend)	Simrad EK38 A	Simrad	2-channel Simrad QM MK II
	Demersal 1800-mesh shrimp trawl 21 x 6m high (40mm codend, and smaller mesh cover)	Simrad EK50 A		Aberdeen Echointegrator
EXPLORER	6-700hp Delagic trawl (20mm codend) Demersal herring wing trawl	Simrad EK38	—	

Table 2 (Continued) CATCHES (kg) OF HERRING AND OTHER MAJOR SPECIES

Vessel	Haul No	Date	Position	Gear	Stat rect	Catch (kg) Herring	Haddock	Whiting	Norway Pout	Others	Herring percentage
Johan Hjort	177	12 July	56°00'N 01°20'W	Bottom trawl	41E8	3	116	297	+	150	1%
"	178	12 July	56°02'N 02°00'W	"	41E8	14	4	20	0	6	32%
"	179	13 July	55°32'N 01°24'W	Pelagic trawl	40E8	34	0	14	0	246	12%
"	180	13 July	57°37'N 01°00'W	"	44E9	0	0	0	0	0	-
"	181	14 July	58°41'N 01°00'W	"	46E9	1	+	1	+	2	25%
"	182	14 July	59°15'N 01°19'W	"	47E8	78	0	290	0	24	20%
"	183	14 July	59°15'N 01°28'W	"	47E8	1	+	+	0	+	100%
"	184	14 July	59°50'N 01°16'W	"	48E8	0	+	+	0	+	0%
"	185	15 July	59°38'N 02°00'W	"	48E8	0	0	0	0	0	-
"	186	15 July	59°50'N 03°23'W	Bottom trawl	48E6	0	16	0	4	23	0%
"	187	15 July	60°15'N 01°45'W	Pelagic trawl	49E8	+	0	560	0	0	0%
"	188	16 July	59°50'N 01°51'W	"	48E8	7	+	+	+	+	100%
"	189	16 July	59°18'N 03°51'W	Bottom trawl	47E6	0	0	+	0	0	0%
Thalassa	657	15 July	55°42'N 00°34'W	Pelagic trawl	40E9	0	0	0	0	0	-
"	658	15 July	55°40'N 00°34'W	"	40E9	0	0	0	0	0	-
"	659	15 July	55°39'N 00°34'W	"	40E9	0	0	+	0	+	0%
"	660	19 July	59°55'N 01°12'W	"	48E8	108	0	87	235	0	25%
"	661	20 July	60°04'N 02°05'W	"	49E7	14	0	1650	0	12	1%
"	662	21 July	59°22'N 03°59'W	"	47E6	0	0	0	0	0	-
"	663	22 July	58°50'N 05°36'W	"	46E4	0	5	0	0	0	0%
"	664	22 July	58°52'N 05°24'W	"	46E4	1	0	+	0	1	50%
"	665	223 July	58°46'N 05°44'W	""	46E4	484	0	8	0	161	74%
Lpejrsee	666	23 July	58°37'N 06°00'W	"	46E4	5440	10	15	8	527	91%
"	667	24 July	59°11'N 01°36'W	"	47E8	350	0	934	3	61	26%
"	668	25 July	59°28'N 00°52'W	"	47E9	417	0	84	10	36	76%
"	669	25 July	59°29'N 00°56'W	"	47E9	0	31	452	63	+	0%
"	670	26 July	57°23'N 01°07'W	"	43E8	1581	1	1	0	10	99%

Table 2 (Continued) CATCHES (kg) OF HERRING AND OTHER MAJOR SPECIES

Vessel	Haul No	Date	Position	Gear	Stat rect	Catch (kg) Herring	Haddock	Whiting	Norway Pout	Others	Herring percentage
Mousse	01	11 July	59° 29'N 03° 47'W	Pelagic trawl	47E6	50	64	29	115	11	19%
"	02	13 July	60° 56'N 00° 47'W	"	50E9	0	0	27	420	0	0%
"	03	14 July	60° 37'N 00° 45'E	"	50F0	30	18	106	100	+	12%
"	04	15 July	60° 28'N 01° 17'E	"	49F1	0	112	2	750	2	0%
"	05	16 July	59° 16'N 03° 50'W	"	47E6	15000	0	0	0	0	100%
"	06	17 July	59° 44'N 02° 32'W	"	48E7	44	0	22	0	0	67%
"	07	18 July	59° 47'N 01° 45'W	"	48E8	750	0	300	0	0	71%
"	08	20 July	55° 31'N 00° 22'W	"	40E9	0	0	675	0	308	0%
"	09	20 July	54° 17'N 00° 13'E	"	37F0	0	0	0	0	245	0%
Scotia	78	26 July	57° 25'N 01° 06'W	Pelagic trawl	43E8	880	+	+	+	+	96%
"	79	28 July	60° 36'N 00° 34'W	"	50E9	0	+	0	+	+	0%
"	80	28 July	60° 22'N 00° 36'W	"	49E9	0	34	93	+	+	0%
"	81	29 July	60° 31'N 02° 00'W	"	50E8	0	+	+	0	+	0%
"	82	29 July	60° 28'N 02° 00'W	"	49E8	0	+	+	0	+	0%
"	83	29 July	60° 34'N 01° 40'W	"	50E8	0	+	+	0	+	0%
"	84	30 July	59° 50'N 01° 42'W	"	48E8	702	1	491	+	42	57%
"	85	30 July	59° 40'N 01° 50'W	"	48E8	372	+	+	0	0	100%
"	86	31 July	59° 15'N 05° 53'W	"	47E4	0	+	+	0	17	0%
"	87	1 August	58° 56'N 06° 21'W	"	46E3	0	+	+	+	+	0%
"	88	3 August	58° 29'N 06° 01'W	"	45E3	0	+	+	+	+	0%
"	89	4 August	58° 54'N 06° 11'W	"	46E3	0	+	+	0	+	0%
"	90	4 August	58° 28'N 06° 02'W	"	45E3	+	+	+	+	85	1%
"	91	5 August	58° 09'N 06° 08'W	"	45E3	17	+	+	17	8	40%
"	92	5 August	58° 11'N 06° 03'W	"	45E3	8	+	+	7	+	50%
"	93	5 August	58° 03'N 06° 10'W	"	45E3	643	+	+	+	+	100%
"	94	5 August	58° 04'N 06° 10'W	"	45E3	0	+	+	+	+	0%
"	95	6 August	57° 52'N 06° 04'W	"	44E3	1	+	+	+	34	3%
"	96	7 August	57° 07'N 06° 51'W	"	43E3	2	0	68	135	51	1%
"	97	7 August	56° 56'N 07° 17'W	"	42E2	0	+	+	68	0	0%

Table 2 (Continued) CATCHES (kg) OF HERRING AND OTHER MAJOR SPECIES

Vessel	Haul No	Date	Position	Gear	Stat rect	Catch (kg)					
						Herring	Haddock	Whiting	Norway Pout	Others	Herring percentage
Explorer	201	25 August	54° 48'N 00° 19'W	Bottom trawl	38E9	34	+1	34	0	17	40%
"	202	26 August	55° 06'N 00° 50'W	"	39E9	•	34	•	8	68	0%
"	203	26 August	55° 26'N 01° 28'W	"	39E8	0	25	42	0	17	0%
"	204	27 August	55° 38'N 01 27'W	"	40E8	0	17	8	0	25	0%

Table 3 Length compositions of herring from hauls in which at least 10 were caught. AH=Annie Hillina JH= Johan Hjort TH=Thalassa M=Mousse S=Scotia E=Explorer

Northern North Sea (IVa)

Stat rect	50E9		50F0	49E7	48E7	48E8					48E9	47E6		47E8					47E9	46E9	45E9
	AH	AH	M03	TH	M06	AH	JH	TH	M07	S85	AH11	M01	M05	AH8	AH9	AH10	JH	TH	TH	JH	AH5
	18	19		661		12	188	660	S84								182	667	668	181	
Length to ½cm below																					
15.5																1				1@13.5	
16																1				3@15.5	
17														1		6				6@16	
17.5					2						1					15				2@16.5	
18					1						2	2		1		21	2	1		2@17	
											1	19		5	1	14		6		3@17.5	
19					4					4	2	51		8	1	19	) 14	4		2@18	
					1					12	1	61		28		12	)	7		1@19	2
20					1					44		65		35	1	4	) 27	20			
										86		44		42		8	)	20			1
21					2					107		39		41		4	) 54	31			
					4					133		19		46	1	4	)	42			
22					1					98		9		16		2	) 31	43			
					2				1	69		9		13			)	38			
23				3					1	26		9		2	1	1	) 8	29			
				2	1	1			2	23		2		2	1		)	15	1		
24				2	2	3		1	6	22		5		1		1	) 7	11	8		1
			1	8		6	2	4	11	27	1	11		1	5		)	14	23		1
25				11	3	12		5	26	23	1	5		1	5		) 4	10	72		2
			1	16	4	19		15	6 44	22		12			8	2	)	15	54		2
26	2		1	11	15	20	2	29	10 69	28		14		1	7	2	) 1	17	59		2
	3		3	8	22	18		33	19 43	14	2	11	2		13	1	)	29	49		2
27	5		2	5	19	12		54	20 71	20	1	9	3		22	3	) 3	11	37		3
	5	1	3	7	17	12	1	64	19 34	8		5	2		17	2	)	14	13		3
28	7		5	4	17	3	2	37	24 41	9			2		4	2		13	3		3
	2		5	2	21	2	1	16	7 17	1	1	2	7		8			1	3		1
29	3	4	6		14	1	3	13	19 23	3			12		7				4		1
	8	1	2	2	15	3	2	7	21 20	5		2	26		5	1		2	2		2
30	5	3	8		6	3	2	10	21 32	1			35		4				1		
	6	11	6		16	2	1		25 30				33		3				2		
31	5	14	3	2	10	1	3	3	21 44	1			44		2			1	1		
	2	19	7		8		2		13 34			2	20			1		1			
32	5	21	11	1	7	1	1	1	12 16	2			10								
	1	18	8		3				8 14				5						1		
33	1	13	12						2 11				3								
	2	5	6						1												
34		5	9					1													
		2	6													1					
35	1	3	2					1	1												
			1																		
36			1																		
Total measd	63	120	109	86	218	119	22	293	240 592	788	13	405	204	244	116	128	150	395	333	20	26

Table 3 (contd.)
West of Scotland (VIa)

Stat. rect.	46 E4		45 E1		45 E3			44 E1	42 E2
Haul No	TH 665	TH 666	S 104	S 105	S 91	S 92	S93	S 99	S 98
Length to ½cm below									
16.5					1	1@14			
17.5					2		1		
18							1		
					2				
19					2		1		
					8	2	6		
20					10	1	23		
					14	4	42		
21					26	1	54		
					22	7	81		2
22					16	5	55		1
	1				11	5	54		8
23	1				16	5	48	2	16
					7	6	64	3	19
24					14	3	34	2	29
	10	4	1		9	1	27	9	34
25	30	8	1	1	6	2	26	4	26
	26	8		3	6	2	22	8	45
26	58	11	2		8	3	14	11	26
	50	14	4		2		7	5	21
27	62	11	2				1	9	18
	43	7	1	3				9	15
28	36	6	2	2	1			8	6
	25	8	3	2	1	1		4	11
29	24	9		4			1	4	5
	19	16		1	1		1	3	3
30	17	11	1	2			1	4	3
	25	15	1	1				2	1
31	14	2	1	5				1	1
	6	3	2	1					1
32	2	1							
				1					
Total measured	449	134	21	26	185	49	564	88	291

Table 4 Mean integrator values μ (mm per nautical mile) of pelagic fish by night in sub-areas shown in Figure 10.

Sub-area	A	B	C	D	Sum A-C
Area in square nautical miles	196.9	384.3	259.4	215.6	840.6 [1]
μ	173.9	144.5	138.9	241.7	149.7 [1]

1) Weighted mean by sub-areas

Table 5 Percentage (by numbers) of the main fish species in pelagic trawl catches by night (sub-areas A-C) and by day (sub-area D).

	Trawl st.	Herring O-group	Herring Older	Sprat	Whiting	Dogfish
Sub-areas A-C	172	-	99.4	-	-	0.4
"	174	-	11.8	84.5	3.0	0.7
"	175	-	3.4	93.5	3.1	-
"	179	-	3.2	91.8	1.8	3.2
	Mean	-	29.45	67.45	2.0	1.1
Sub-area D	171	68.1	0.8	27.6	3.5	-

Table 6 Length-dependent C-values for the main pelagic species.

Herring: $C = 1.34 \times 10^5 \times l^{-1.36}$ $(a = 2.09 \times 10^{-6}, b = 1.36)$

Sprat: $C = 3.38 \times 10^5 \times l^{-1.72}$ $(a = 8.32 \times 10^{-7}, b = 1.72)$

Whiting: $C = 1.28 \times 10^6 \times l^{-2.46}$ $(a = 2.19 \times 10^{-7}, b = 2.46)$

Dogfish[1]: $C = 7.1 \times 10^5 \times l^{-2}$ $(a = 4 \times 10^{-7}, b = 2)$

1) Approximate figures.

Table 7 Mean C-values within sub-areas[1].

Sub-area	Herring O-gr.	Herring Older	Sprat	Whiting	Dogfish
A-C	-	1638	5957	952	197
D	10685	2032	10592	778	-

[1] Number of fish per square nautical mile per mm deflection per nautical mile.

Table 8 K-values within sub-areas (herring+sprat+whiting+dogfish)

Sub-area A-C: $K = \left(\frac{0.297}{1638} + \frac{0.672}{5957} + \frac{0.021}{952} + \frac{0.011}{197}\right)^{-1} = 2688$

Sub-area D: $K = \left(\frac{0.707}{10685} + \frac{0.008}{2032} + \frac{0.248}{10592} + \frac{0.036}{778}\right)^{-1} = 7154$

TABLE 9 Abundance estimates of herring, sprat, whiting and dogfish in area I.

	Sub-area A+B+C			Sub-area D			Area I total	
	Mean density (♂) 000' per square mile	Abundance Number in millions	Tonnes	Mean density (♂) 000' per square mile	Abundance Number in millions	Tonnes	Abundance Number in millions	Tonnes
Herring 0-gr	-	-	-	1222.4	263.5	461	263.5	461
Older	119.5	100.5	16716	13.8	3.0	301	103.5	17017
Sprat	270.4	227.3	2023	428.8	92.4	324	319.7	2347
Whiting	8.5	7.1	705	69.2	14.9	1491	22.0	2196
Dogfish	4.4	3.7	3721	-	-	-	3.7	3721

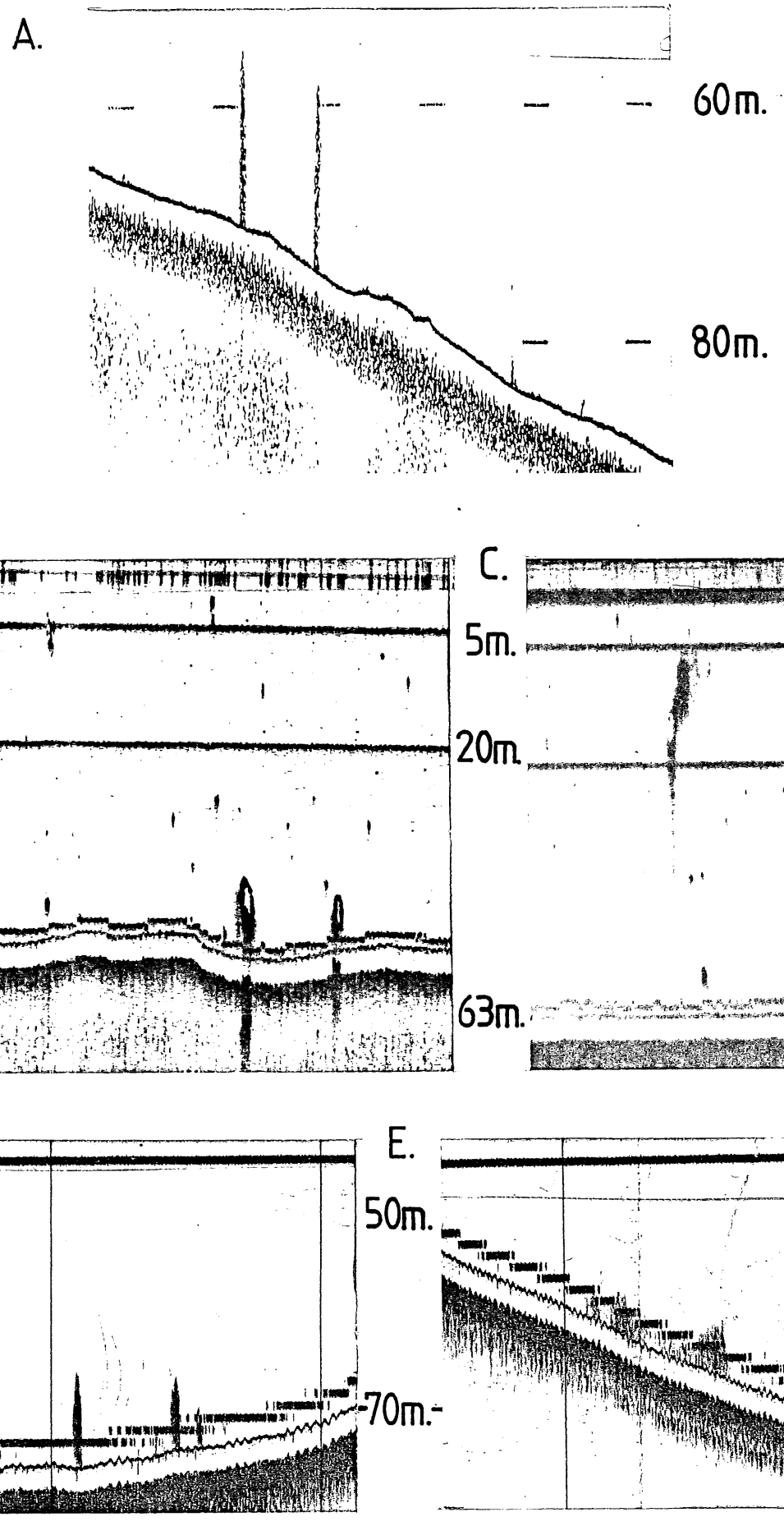
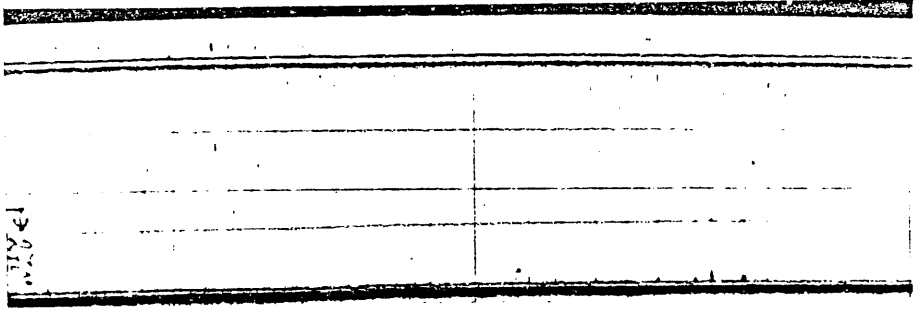


PLATE I
a) ANNA HILLINA 1610 GMT 6 July 55°50'N 01°33'W (Berwick Bank)
b) EXPLORER 1400 GMT 20 August 54°19'N 00°01'W
c) EXPLORER 1830 GMT 24 August 54°47'N 00°20'W
d) SCOTIA 1900 GMT 26 July (Turbot Bank)
e) SCOTIA 2040 GMT 26 July (Turbot Bank)

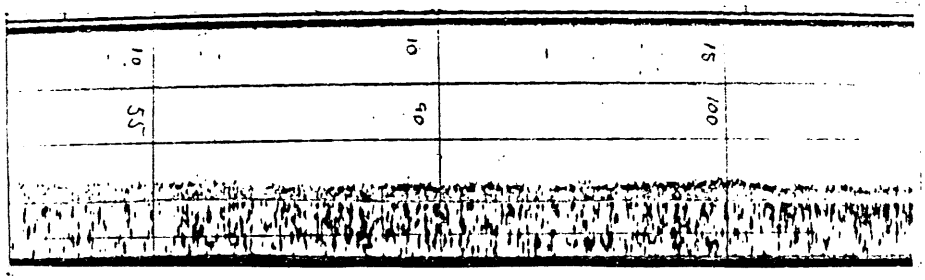
A.

1545.GMT



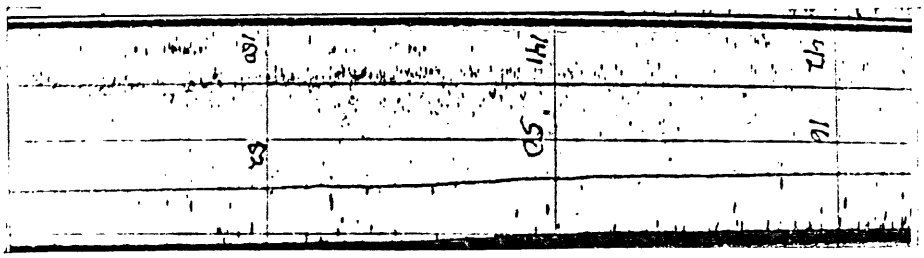
B.

1845.GMT



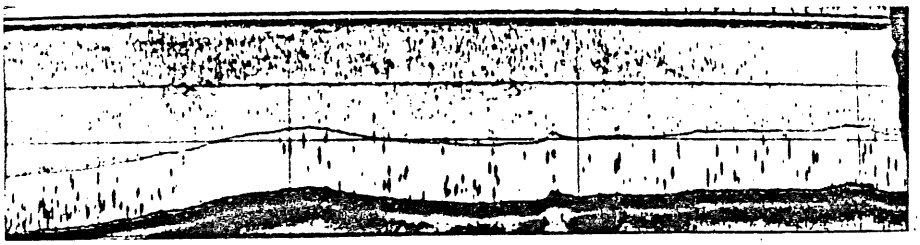
C.

2215.GMT



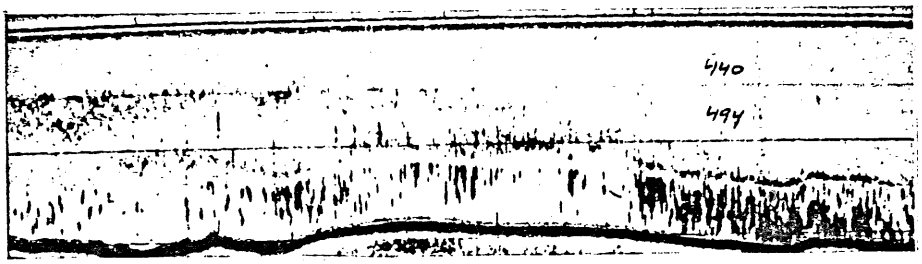
D.

0218.GMT



E.

0230.GMT



F.

0255.GMT

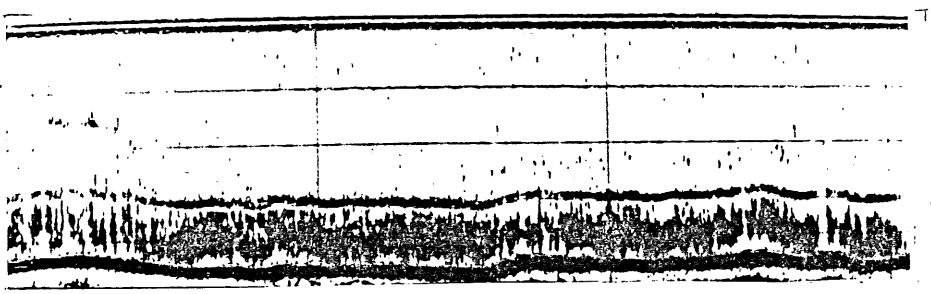


PLATE II Ascent and descent of herring traces 11 - 12 July 1979 JOHAN HJORT
Approx Positions 54°51'N - 55°38'N; 01°02'W - 01°31'W

*Expanded bottom

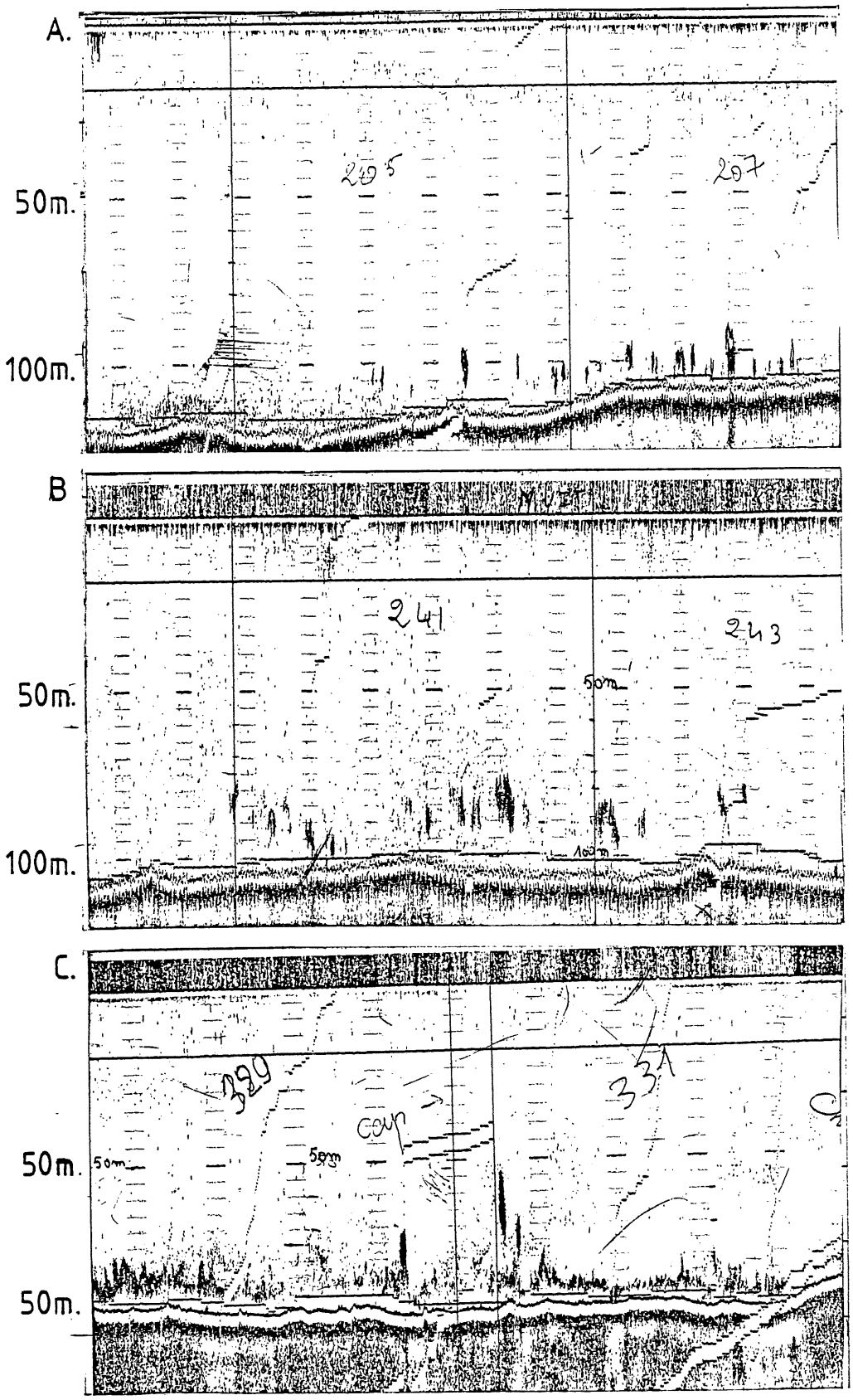
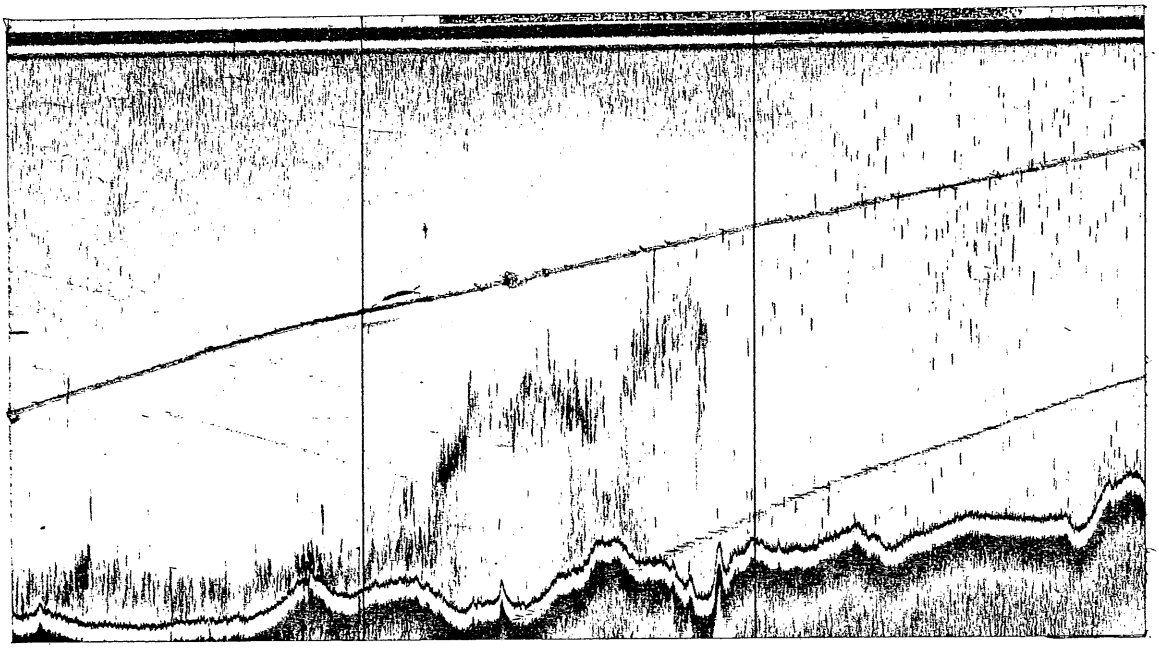
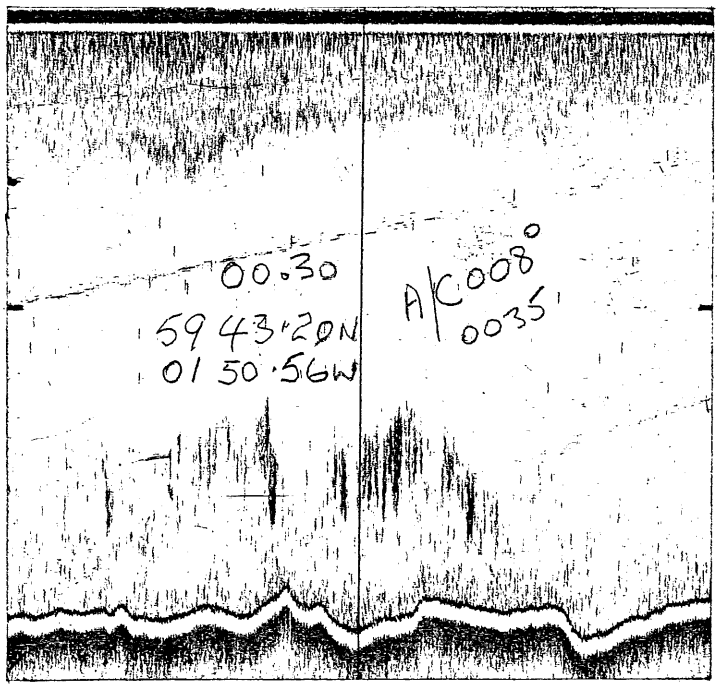


PLATE III a) THALASSA 1820 GMT 17 July 59°43'N 01°42'W SW Shetland
b) THALASSA 2217 GMT 17 July 59°44'N 01°47'W SW Shetland
c) THALASSA 1515 GMT 19 July 59°53'N 01°13'W SE Shetland

A.



B.



C.

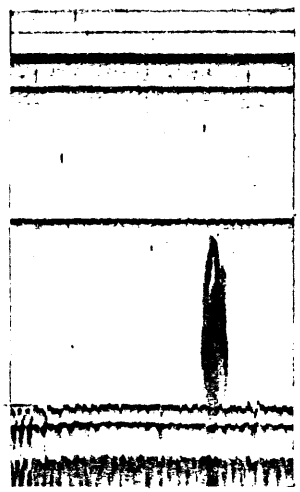
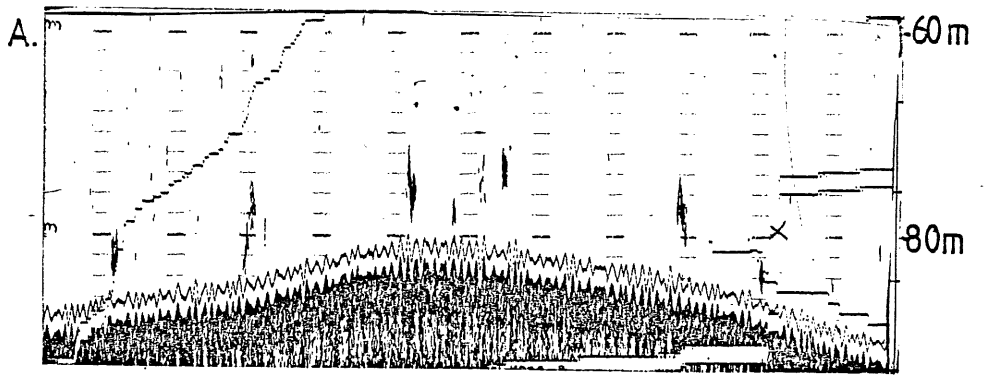
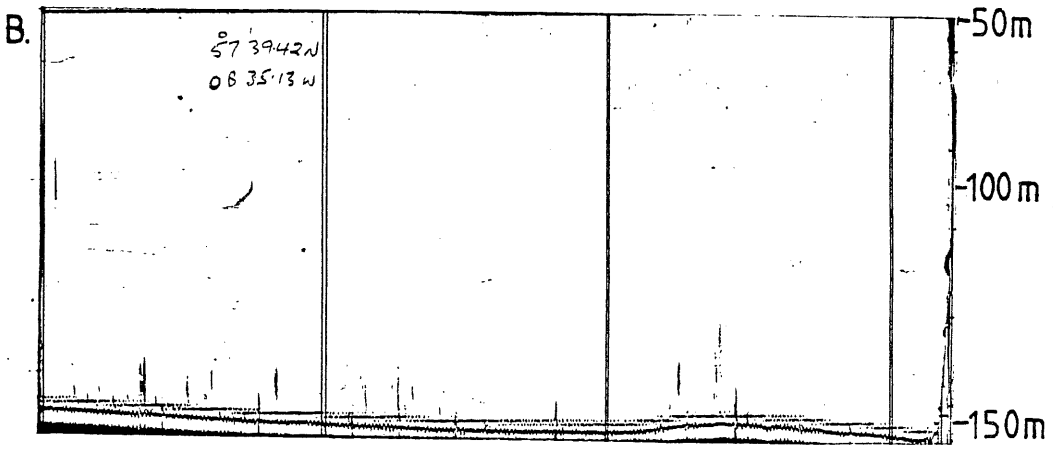


PLATE IV a) SCOTIA 2100 GMT 30 July 59°50'N 01°06°W South Shetland
b) SCOTIA 2315 GMT 30 July 59°44'N 01°42'W South Shetland
c) EXPLORER 1200 GMT 12 August 60°00'N 02°10'W South of Foula





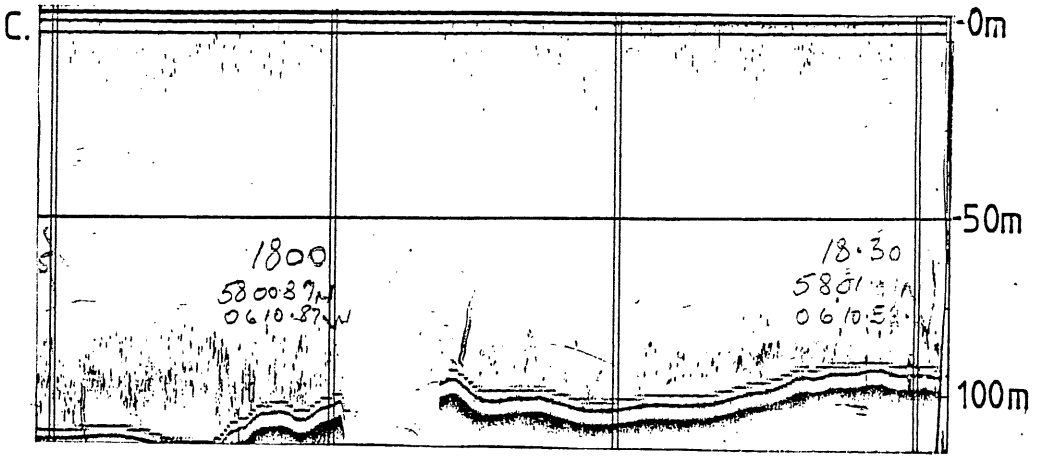


PLATE V

a)	THALASSA	1800 GMT	22 July	58°52'N	05°30'W	NW Cape Wrath
b)	SCOTIA	1115 GMT	9 August	57°40'N	08°35'W	St Kilda
c)	SCOTIA	1700 GMT	5 August	58°01'N	06°11'W	North Minch

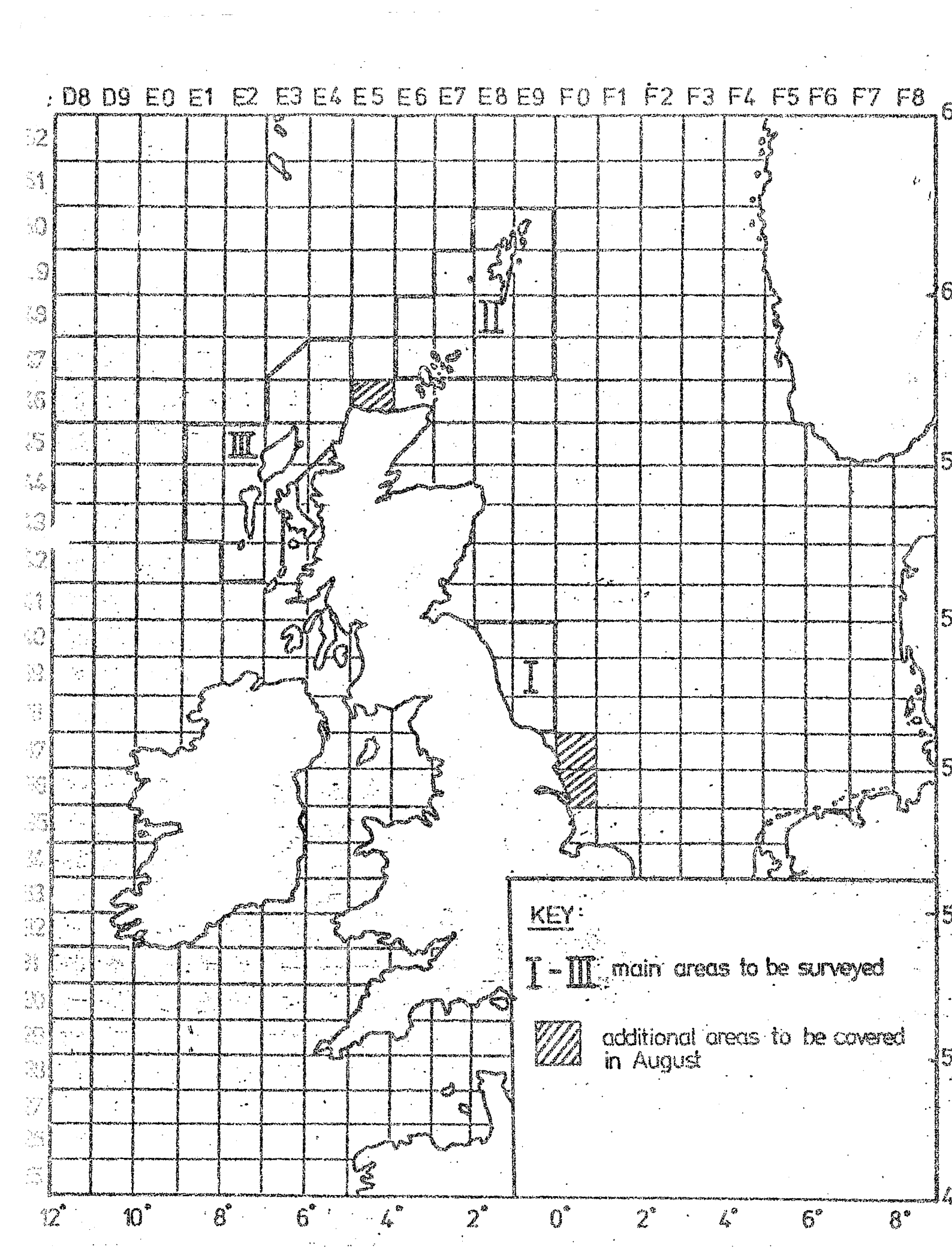


FIGURE 1 Areas identified by the Planning Group to be covered during the survey.

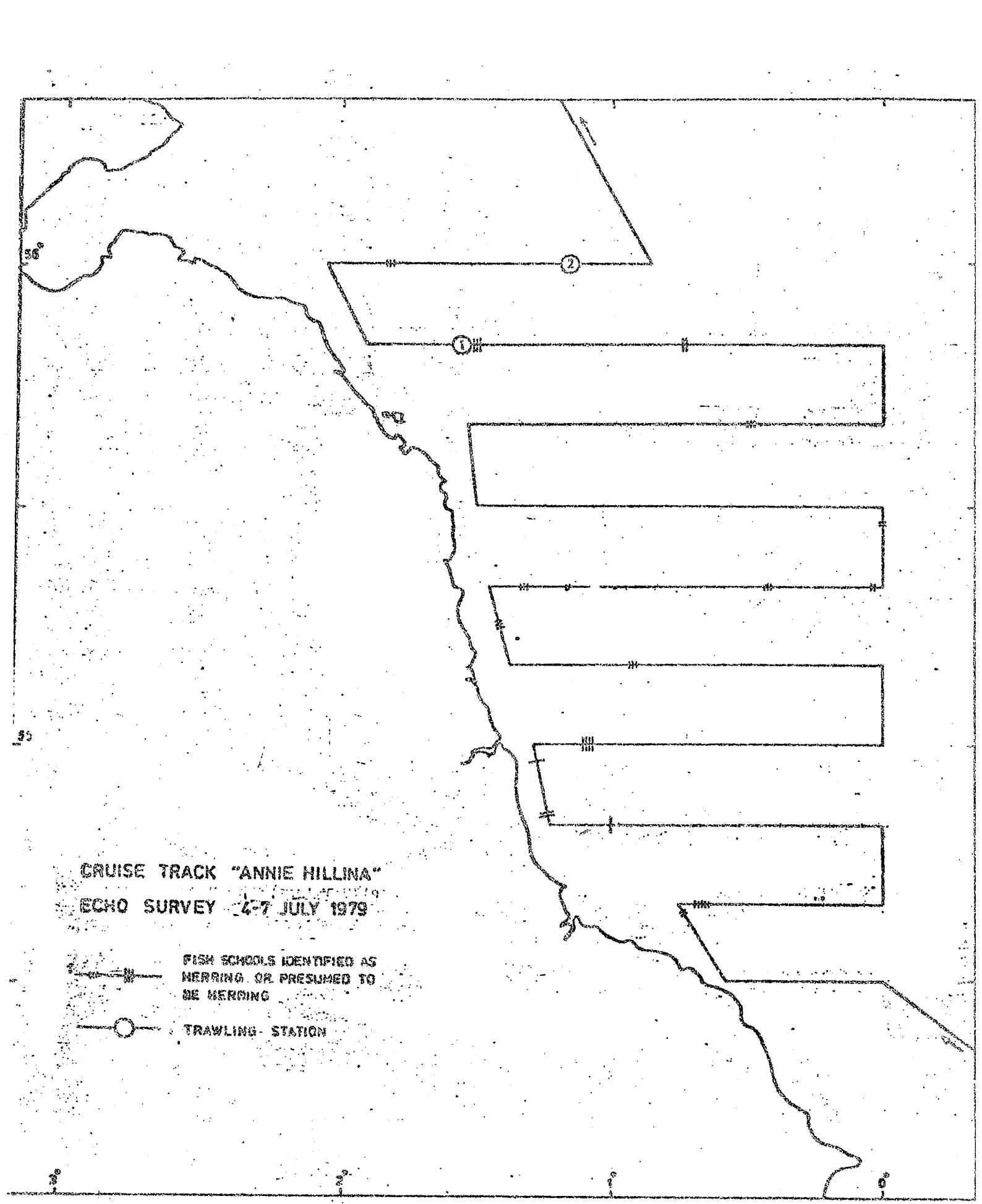
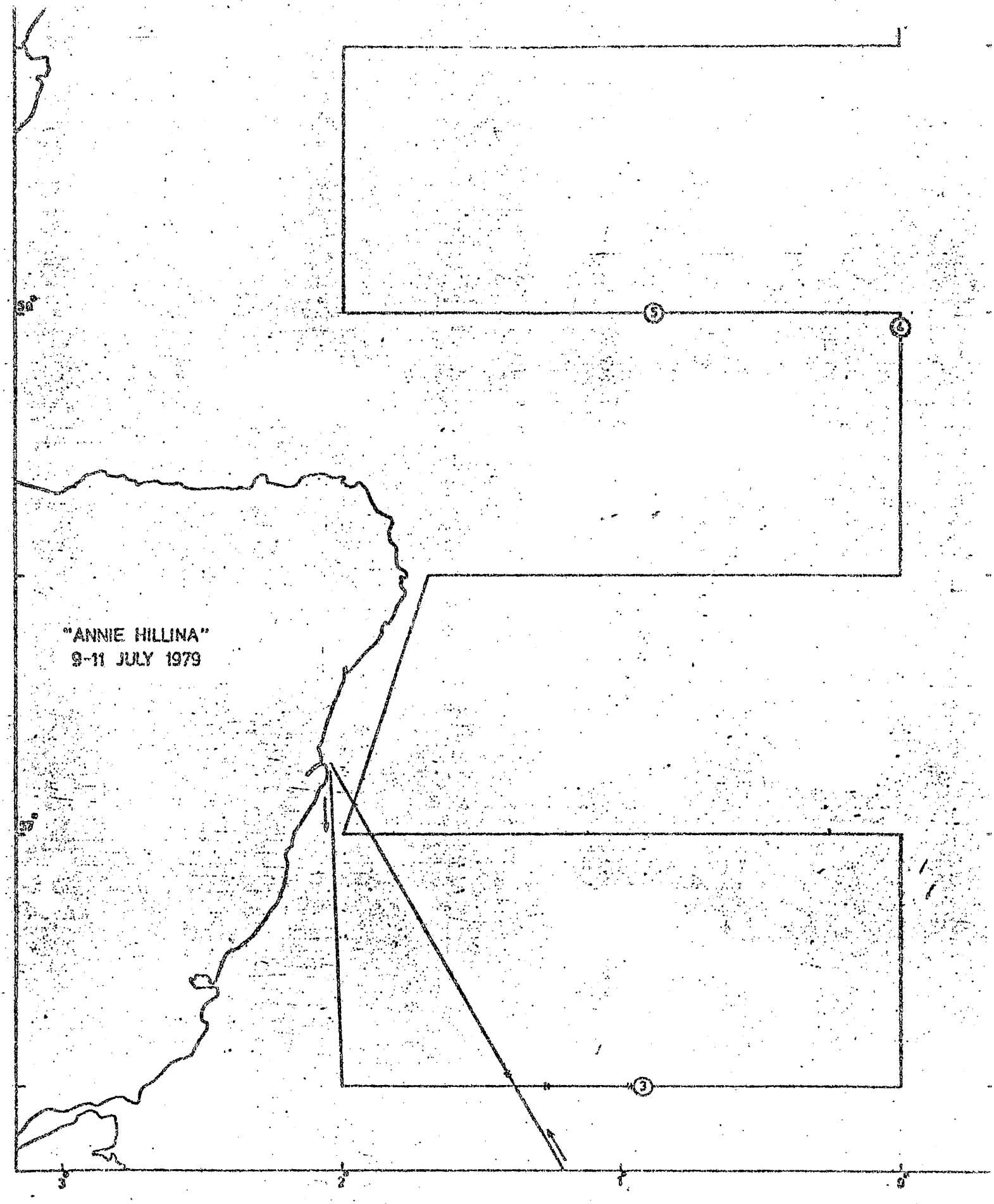
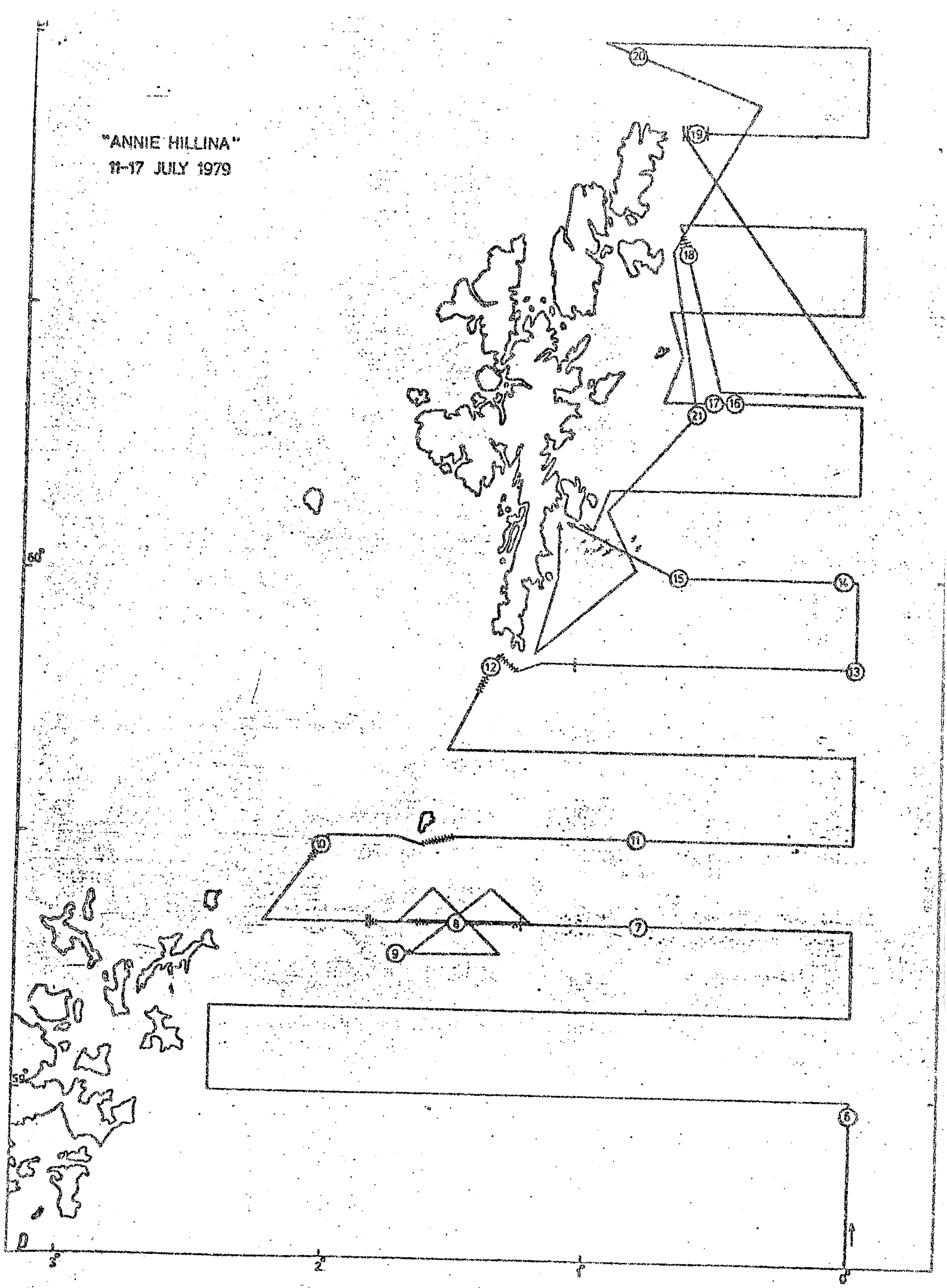


FIGURE 2 Cruise track, trawling positions and areas of herring schools located by ANNIE HILLINA.

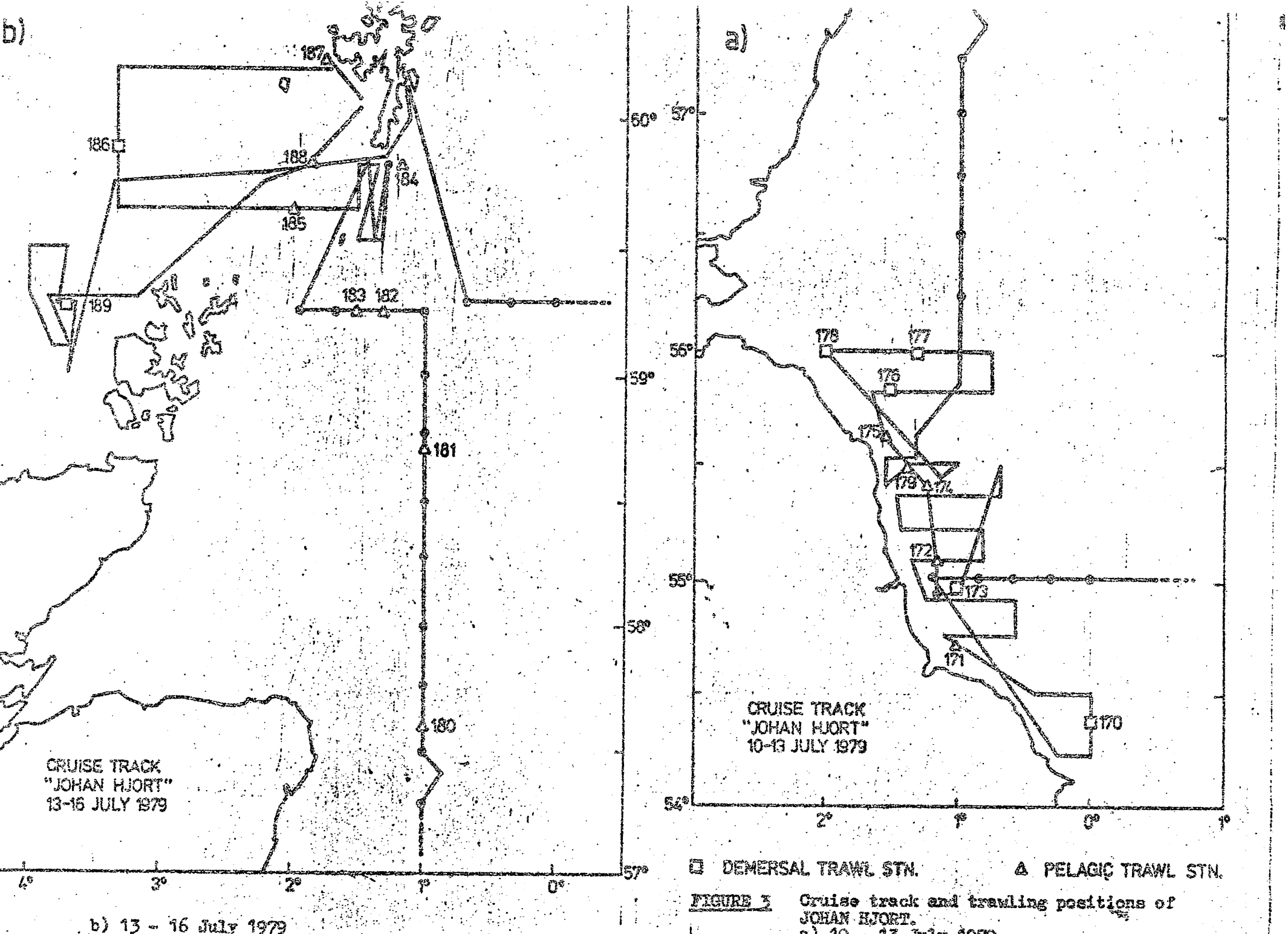
a) 04 - 07 July 1979



b) 09 - 11 July 1979



c) 11 - 12 July 1979



b) 13 - 16 July 1979

FIGURE 3 Cruise track and trawling positions of JOHAN HJORT.
a) 10 - 13 July 1979

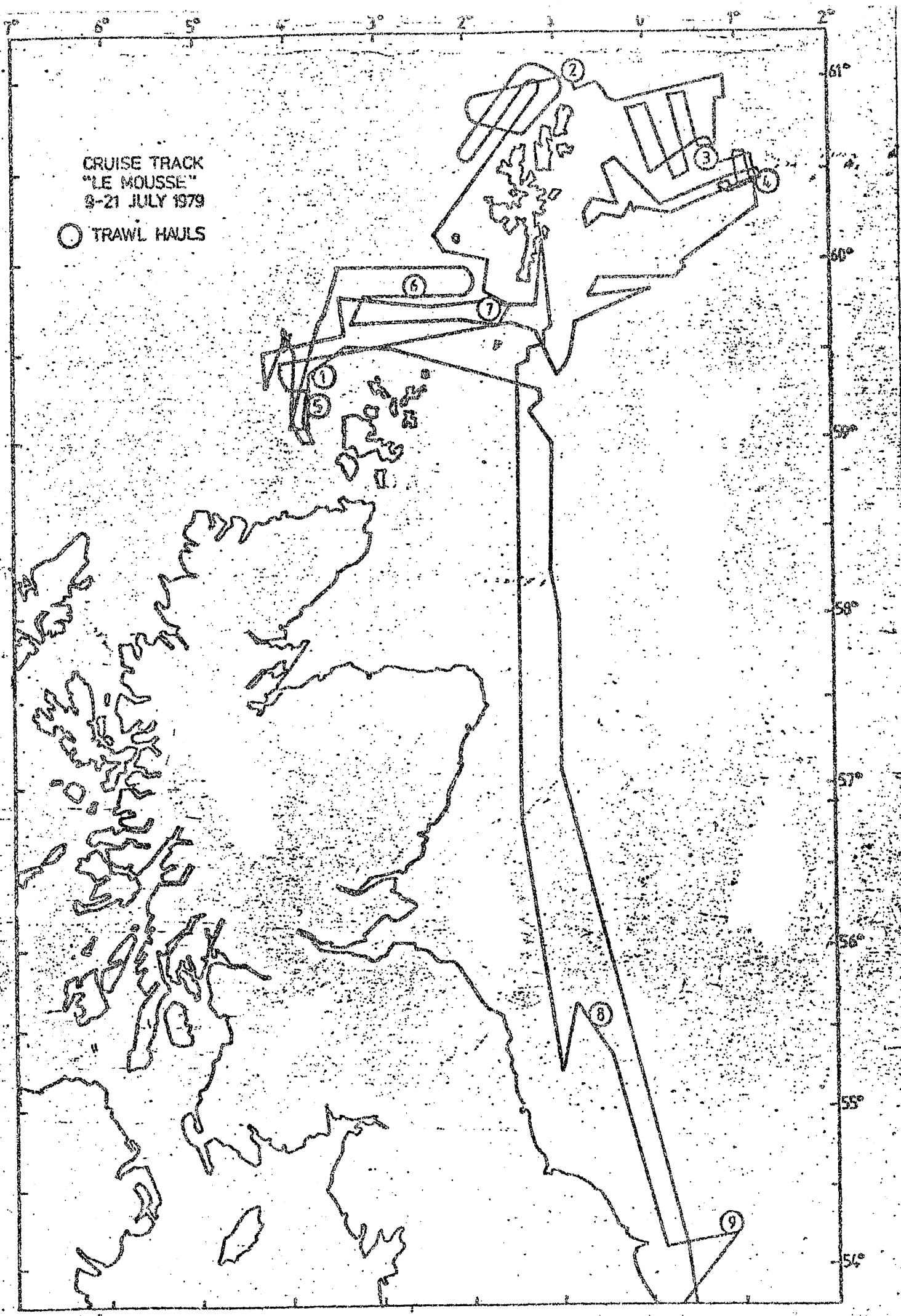


FIGURE 4 Cruise track and trawling positions of MOUSSE, 09 - 21 July 1979.

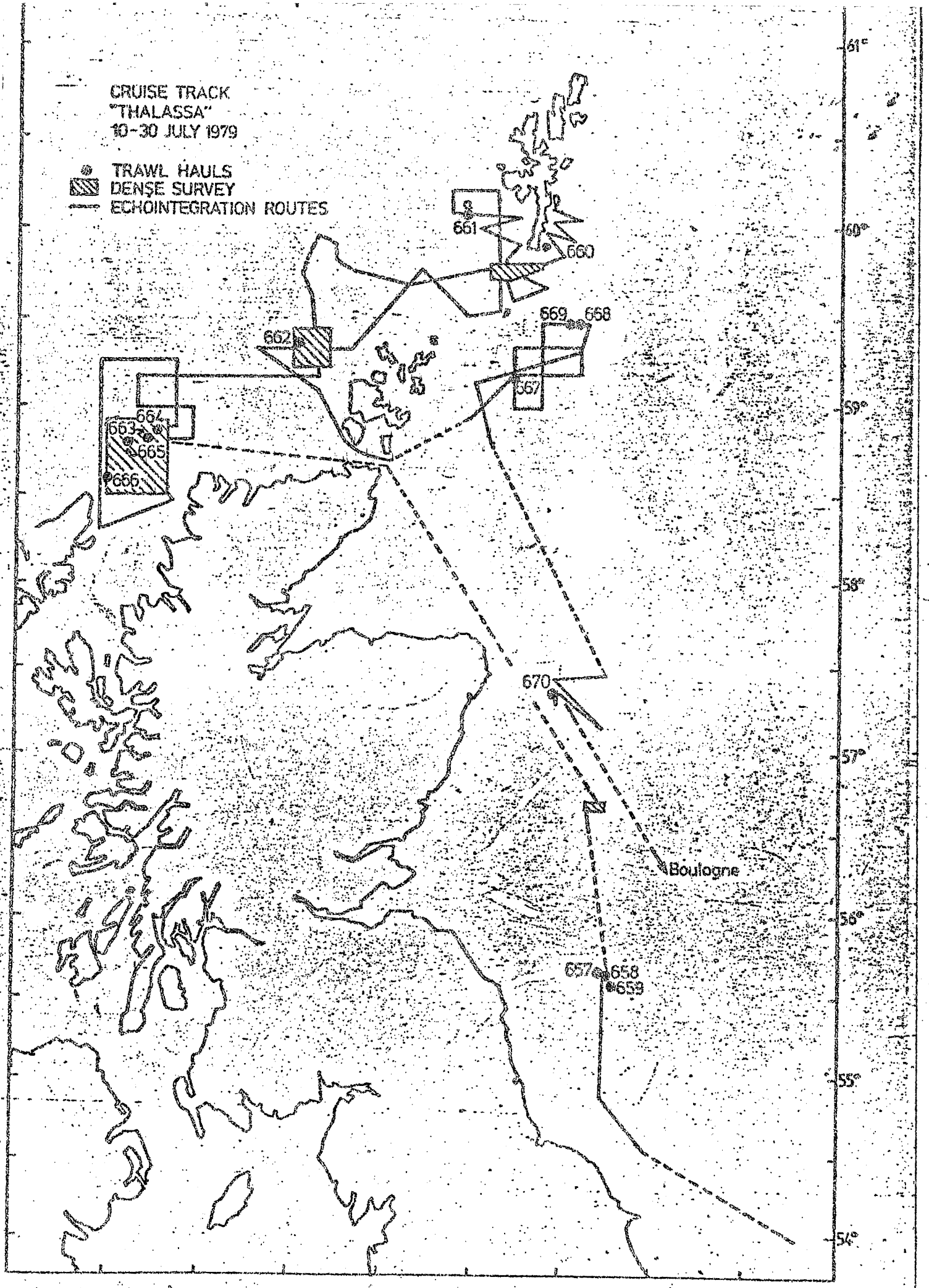


FIGURE 5 Cruise track and trawling positions of THALASSA, 10 - 30 July 1979, showing areas of echointegrator surveys.

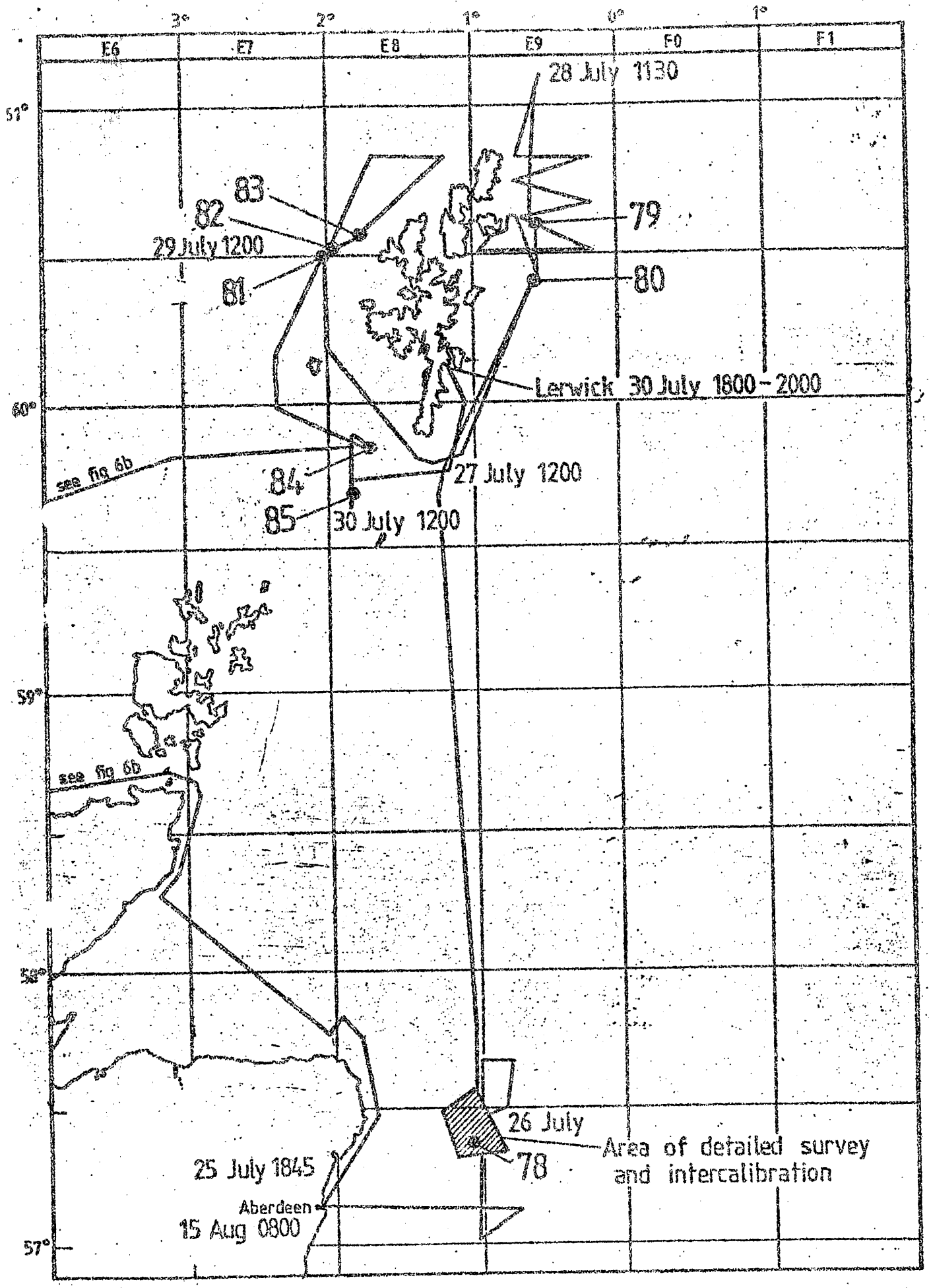


FIGURE 6 Cruise track and trawling positions of SCOTIA, 25 - 31 July 1979.

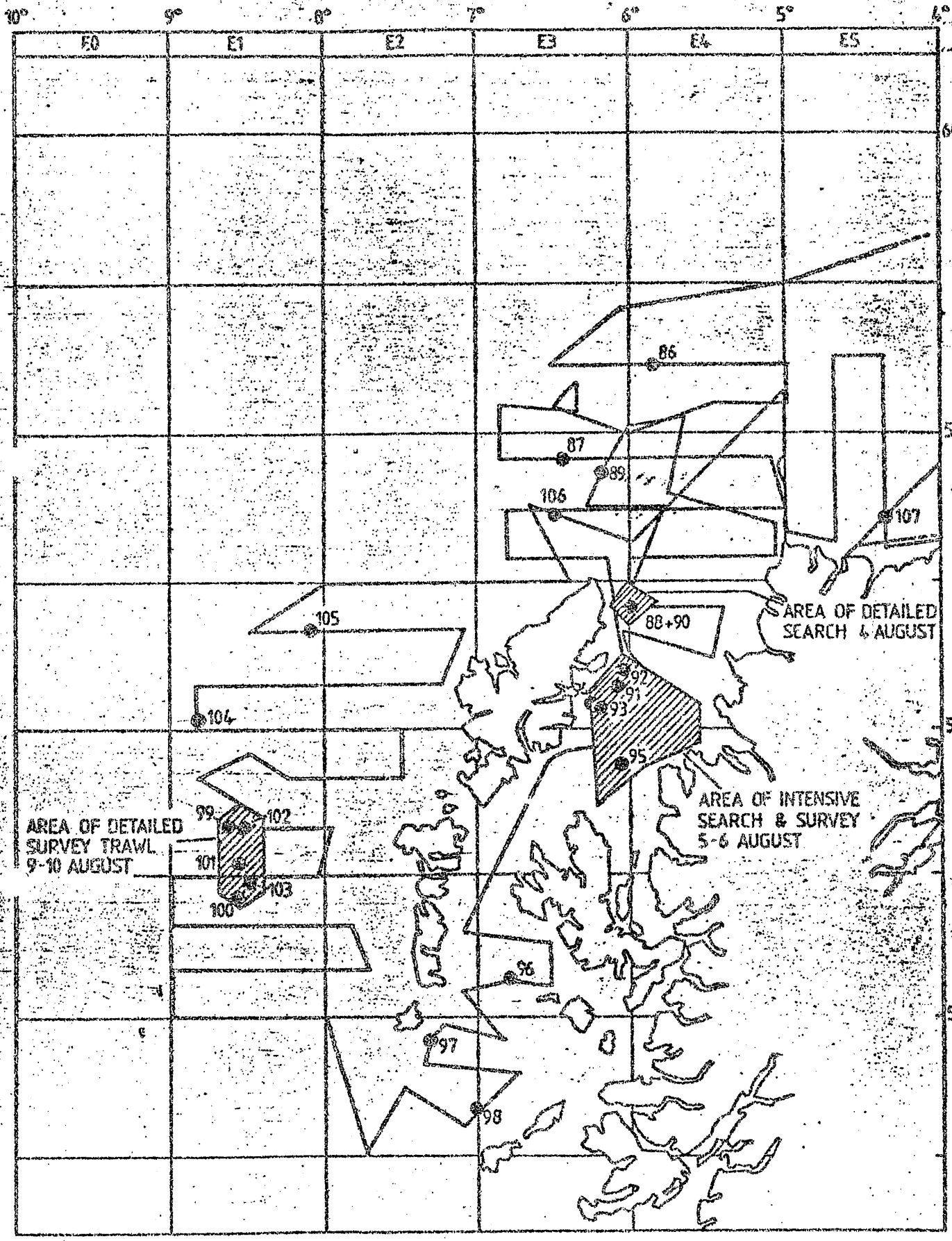


FIGURE 7 Cruise track and trawling positions of SCOTIA, 31 July - 14 August 1979.

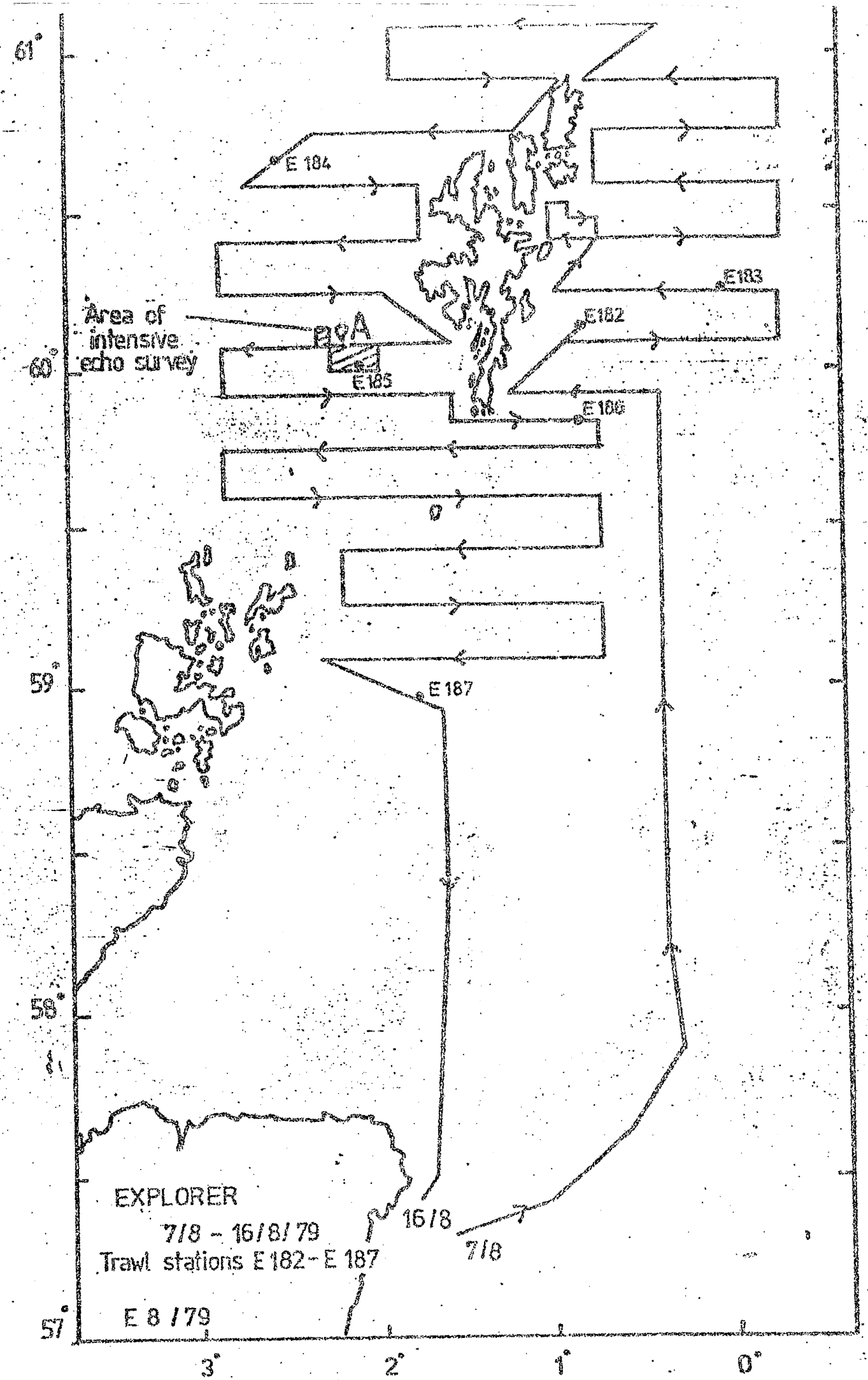


FIGURE 8 Cruise track and trawling positions of EXPLORER, 07 - 16 August 1979.

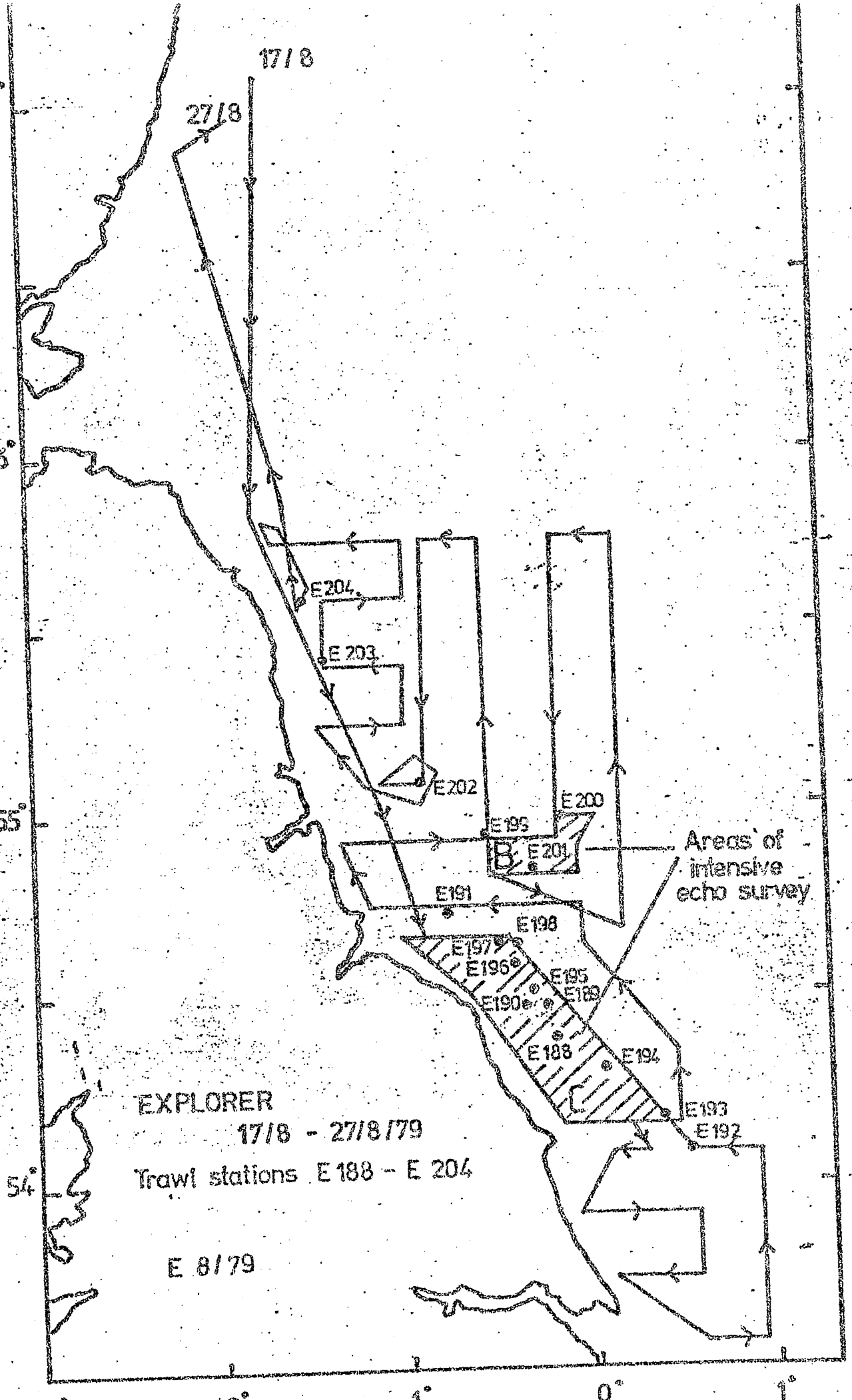


FIGURE 9 Cruise track and trawling positions of EXPLORER, 17 - 27 August 1979.

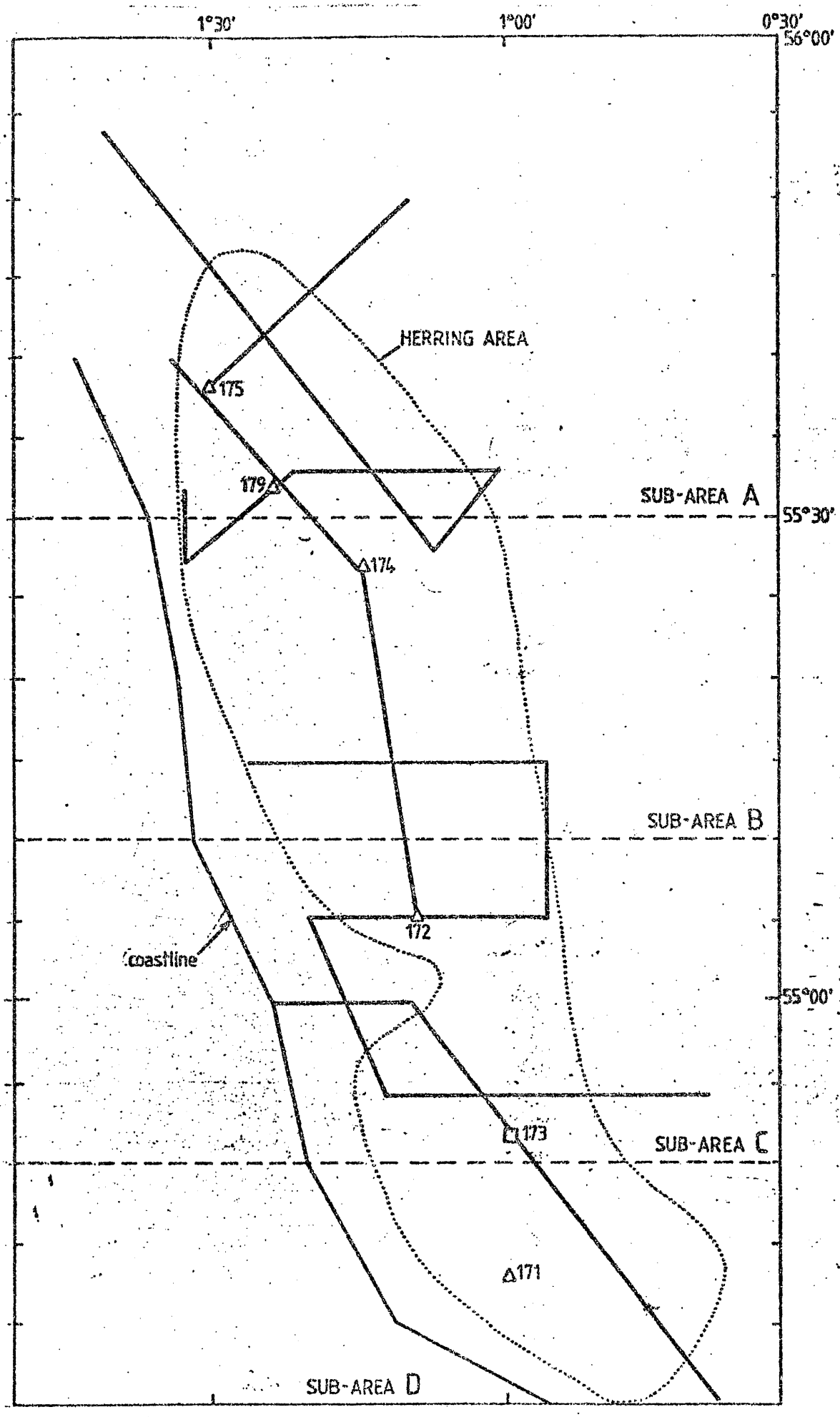


FIGURE 10 Echointegrator survey and trawling positions of JOHAN HJORT off northeast England with area of herring distribution.

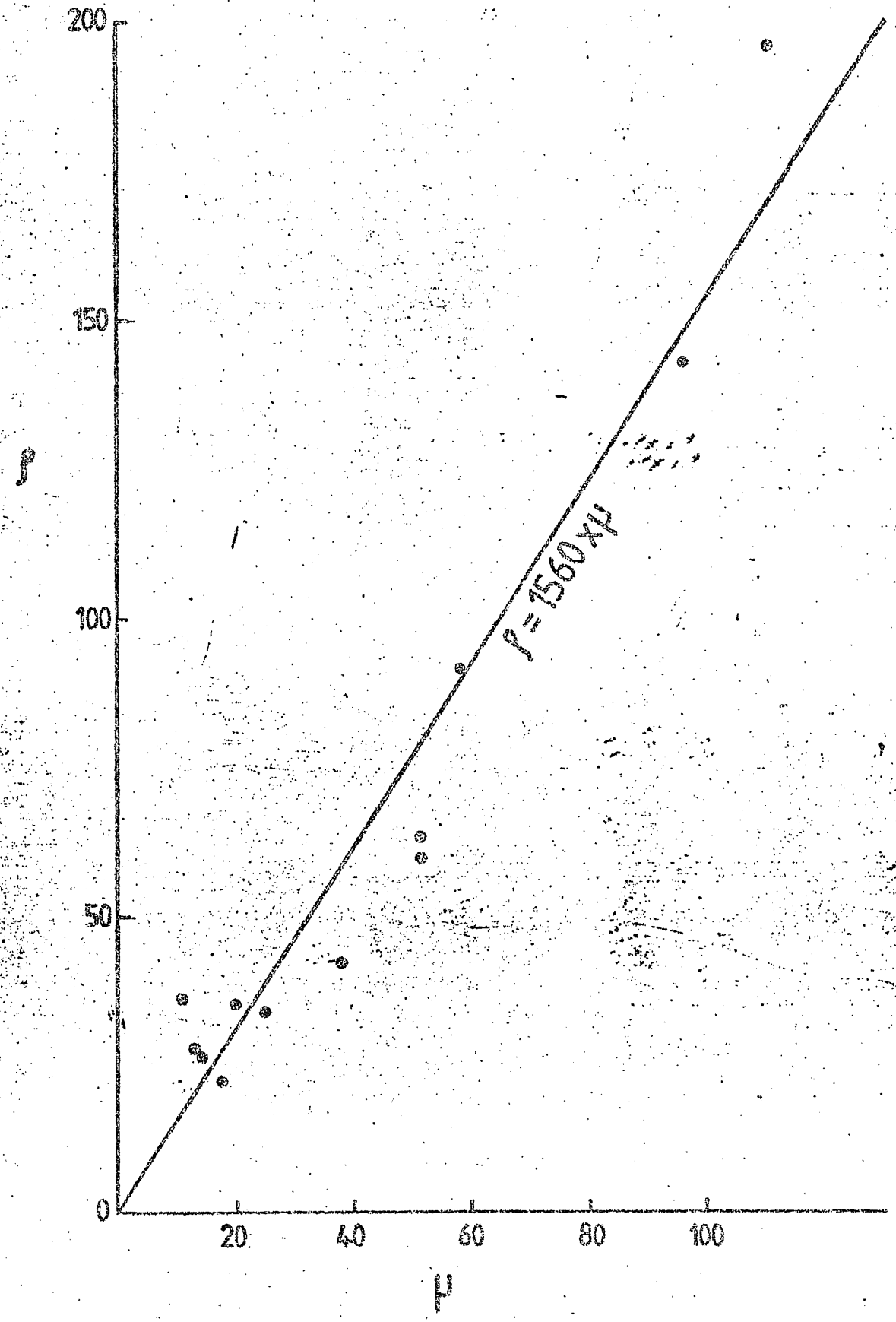


FIGURE 11 Regression between number of fish (P) and integrator deflection in mm (μ) in area I, JOHAN HJORT.

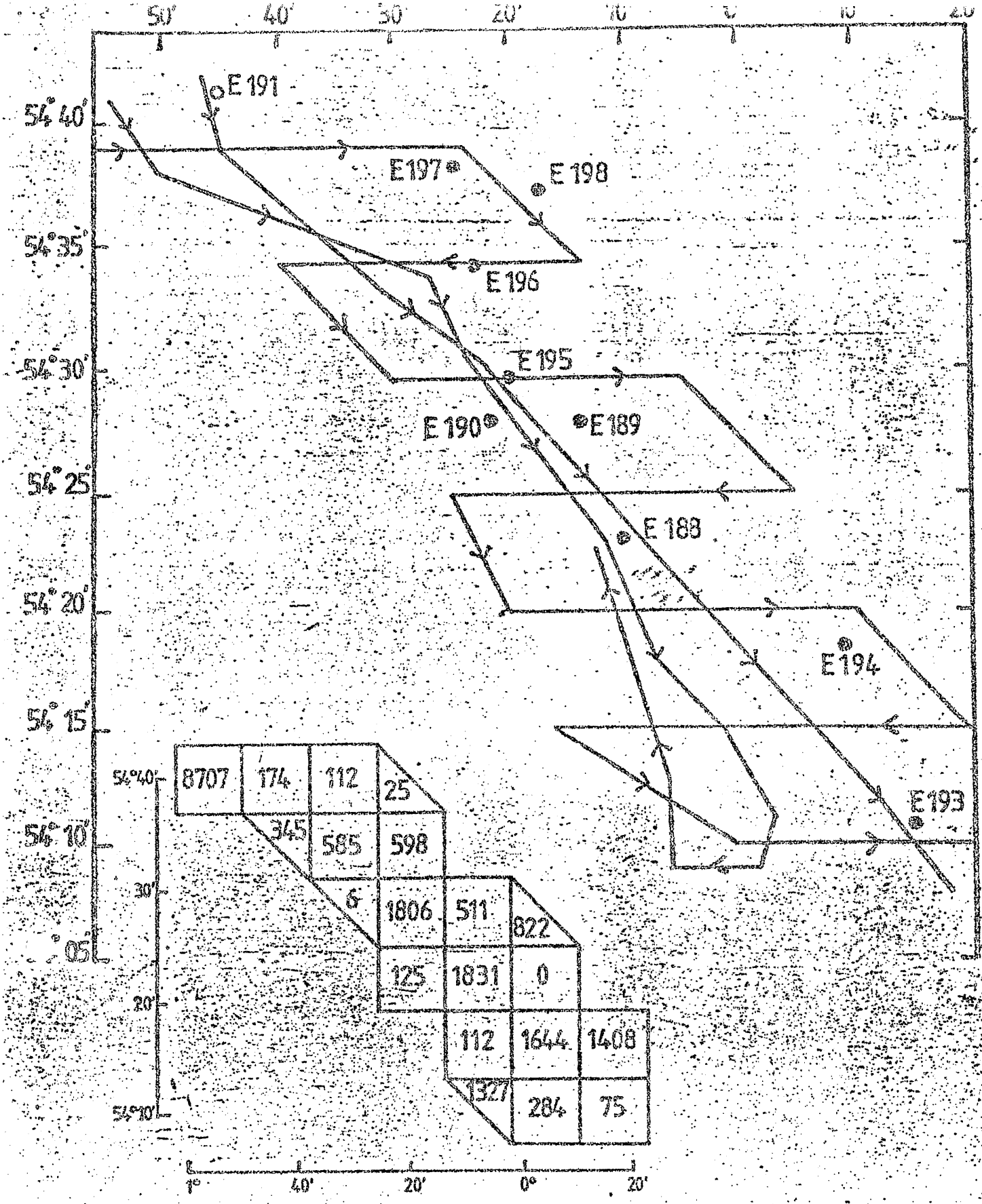


FIGURE 12 Echointegrator survey and bottom trawl hauls, carried out by EXPLORER in area I, August, with estimated total acoustic biomass (tonnes) in 6 x 6 nautical mile squares, between depths of 20m from surface and 5m from the seabed.

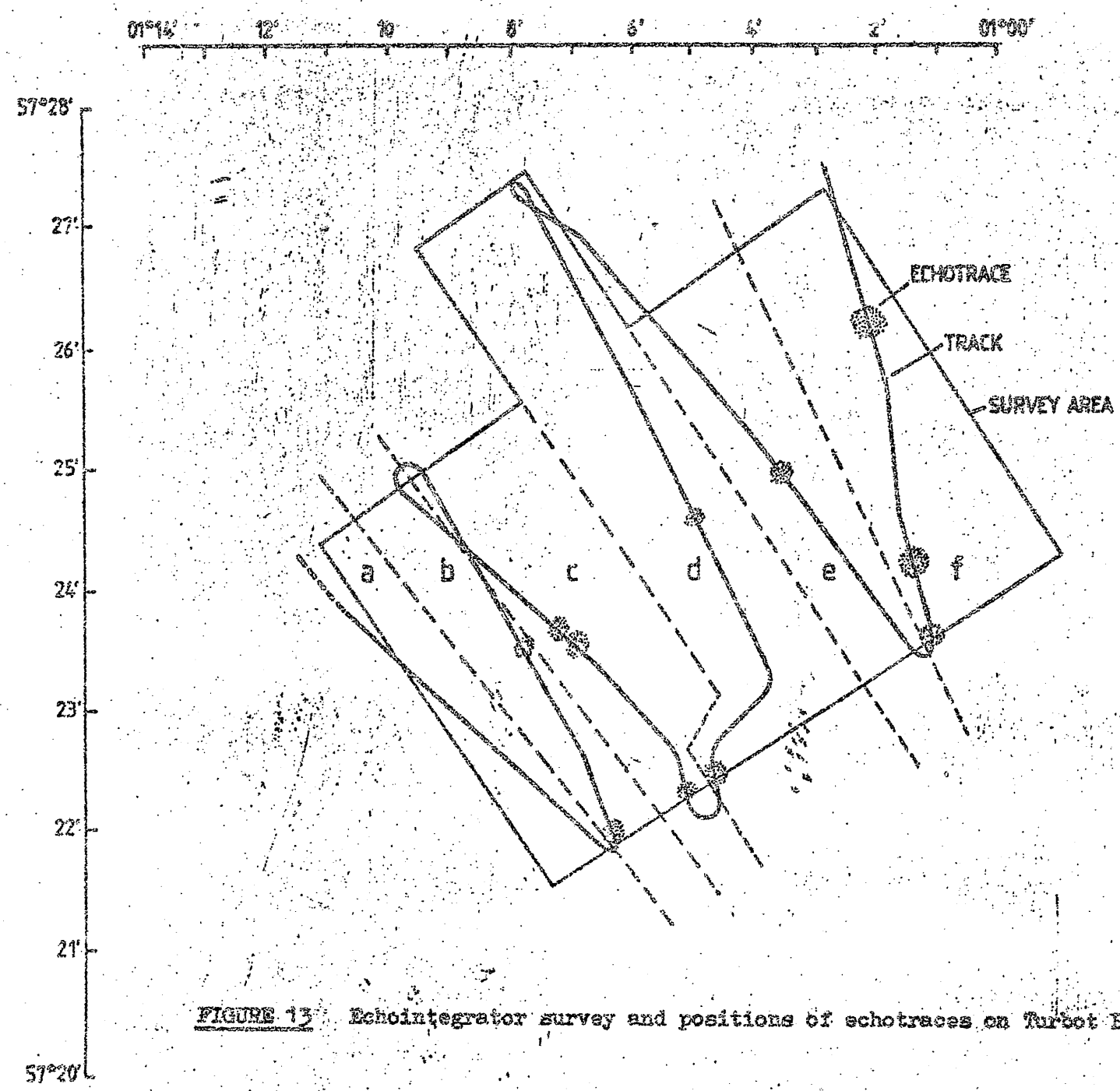


FIGURE 13 Echointegrator survey and positions of echotraces on Turbot Bank, SCOTIA.

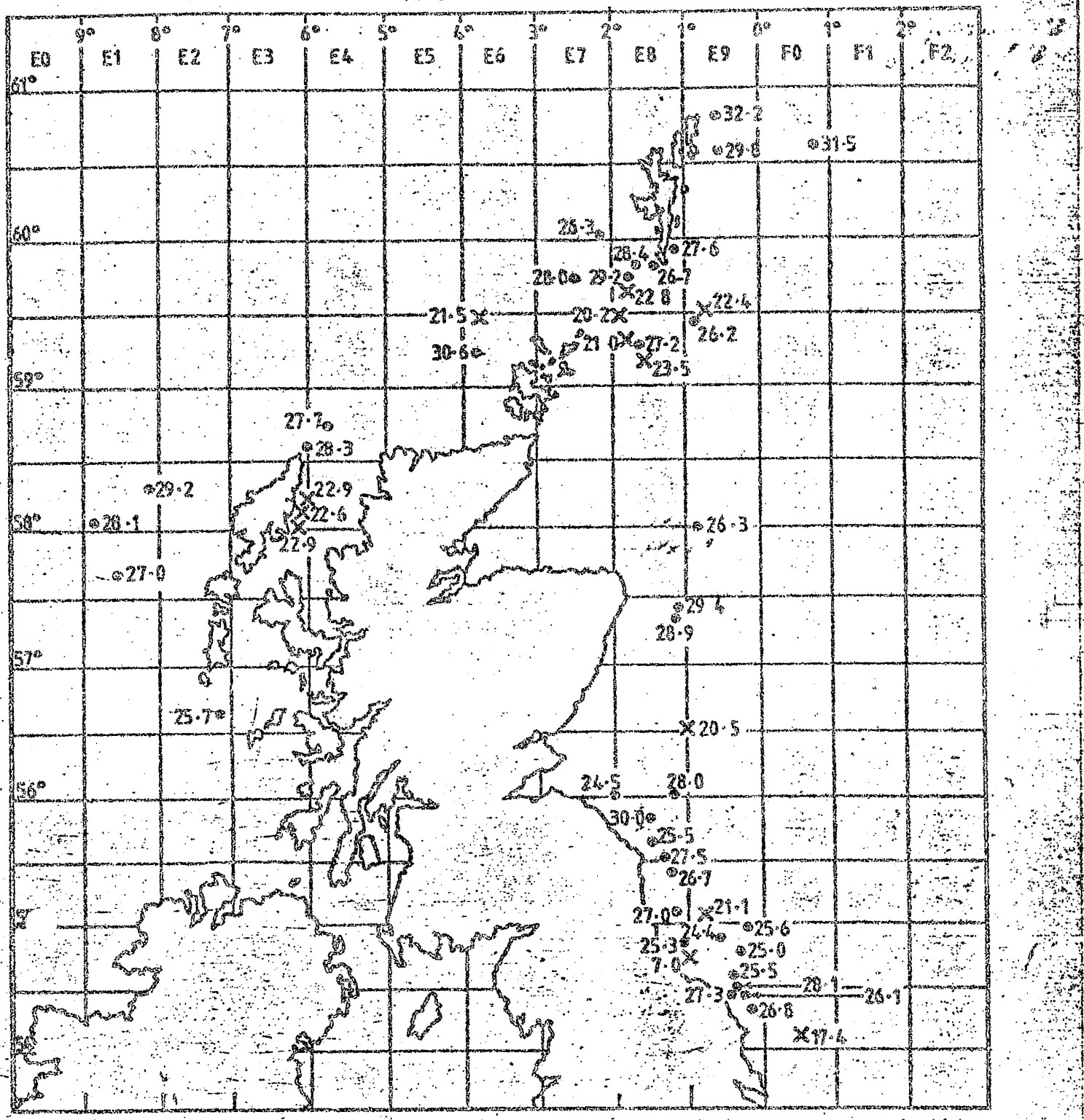


FIGURE 14 Mean lengths of herring (cm) in hauls containing more than 10 herring. (Crosses show positions of hauls containing predominantly small fish (< 23cm).