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REPORT ON THE 1983 HERRING ACOUSTIC SURVEY IN THE NORTHWESTERN NORTH SEA

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INTRODUCTION

In accordance with Council Resolution 1982/2:26, a coordinated acoustic survey of herring stocks was carried out in the northwestern North Sea in July 1983. Plans for the survey were made at a meeting of the Acoustic Survey Planning Group held at Aberdeen, UK in February 1983 (CM 1983/H:12). Vessels from the Netherlands, Norway and the UK took part in the survey. This paper consists of separate reports on the cruises of the participating vessels with a comparison of the results.

PRELIMINARY REPORT ON THE SURVEY BY R/V 'G O SARS' IN THE SHETLAND AREA 18-30 JULY 1983

by Asgeir Aglen

Methods

Distribution and abundance of herring were estimated by echo integration and trawling. Technical data and settings of acoustic equipment are given in Table 1. A 19kHz sonar was run continuously to give indications of schools while surveying and to guide the vessel towards schools during trawling. A 120kHz sonar was connected to a tape recorder to record fish echoes for later doppler analysis. A large-meshed pelagic trawl ("Fotø, Modell 80") was used for sampling and identification of traces. The mesh size was 3200mm (bar) at the trawl opening, gradually decreasing to 11mm (bar) in the codend. The upper and lower panels had 21 meshes at trawl opening and the side panels had 10 meshes. Vertical trawl opening was usually 15-20m at a speed of 4 knots.

To sample newly hatched herring larvae a "Bongo 20" net was used for double oblique plankton hauls from 0-30m depth. Following the recommendations from the Planning Group (CM 1983/H:12) plankton samples were taken in the rectangle southwest of Foula.

Average integrator values per nautical mile were obtained every two nautical miles sailed. Contributions from traces considered to be herring were separated. This separation was based on experience from the trawl catches. An average integrator value ($\bar{M}_H$) for herring was

calculated for each quarter statistical rectangle. The number of herring per quarter rectangle was calculated as $N = \bar{M}_H . C_I . C_F . A$, where A is the area of the rectangle, $C_I = 0.0814 m^2$ back-scattering cross-section needed per square nautical mile to give an integrator reading of 1mm/nautical mile. $C_F = 10^{-0.1 \cdot TS} = 13.2 \cdot 10^6 \cdot L^{-2}$ which is the number of L cm herring needed to give $1 m^2$ back-scattering cross-section, assuming TS = 20 log L -71.2dB as recommended by the Planning Group (CM 1983/H:12).

Results

Figure 1 shows the survey grid and stations. Most of the herring was recorded in four small areas indicated in Figure 2. The surveyed area was divided into four sub-areas, each containing one of these concentrations (Fig. 2). In sub-areas East and South all schools identified as herring during daytime had a rather narrow horizontal extension and wide vertical extension compared to other fish schools. Typically the width of the herring schools was 30-100m and the height 10-40m (Fig. 3). They also occurred higher up in the water column than most other fish recordings, except for some heavy traces of Norway pout close to the east coast of Shetland (Fig. 4). Those schools were wider and had a more irregular shape than the herring schools. Further from the coast all Norway pout was recorded as smaller schools less than 20m off bottom, like the deepest recordings in Figure 4.

In the Middle sub-area most of the herring occurred in schools like those described above, but in the deepest basin west of Sumburgh some small schools 10-20m off the bottom gave a few herring mixed with whiting and mackerel. In sub-area West the herring schools had a more irregular shape and were closer to the bottom (Fig. 5).

During the night some herring kept in schools while others (possibly the smaller herring) scattered. Therefore the allocation of integrator values was more difficult at night.

Table 2 shows the composition of trawl catches and Table 3 shows the length distributions of herring. Distributions of maturity stages are given in Table 4. Some trawl hauls were unsuccessful because the herring tended to avoid the net both sideways and downwards. The big herring off the east coast of Shetland were the most difficult to catch. 0-group Norway pout were too small to be caught representatively. The trawl catch compositions are therefore not considered to be representative of the composition of the echo recordings. Owing to this it was decided that the catches should only be used for identification of traces.

Within each sub-area the average length distribution was used to calculate an average target strength (Table 5) and number of herring per cm-group (Table 6). Numbers were converted to weights using the equation:

$$\text{weight in grams} = 2.457 \cdot 10^{-7} \cdot (\text{length in mm})^{3.645}$$

which is the regression of length and weight data obtained on board FRV "Scotia" in the whole Orkney-Shetland area from 6-26 July 1983.

The maturity samples showed that all herring below 25cm and about 30% of the 25cm herring were immature (Stage I and II). A few in Stage VIII were found in sub-area East, while all the rest were expected to spawn this autumn (Stages III-VII). The total estimate of 1 279 million herring (250 000 tonnes) thus consists of 456 million immatures (27 000 tonnes) and 820 million spawners (222 000 tonnes).

The quarter rectangle between 60°00' and 60°15'N and 01°00' and 00°30'W was covered with north-south legs 2.5 nautical miles apart during daytime on 21 July. This was done for comparison with the results obtained by FRV "Scotia", which covered the same area during the same day. The estimate from this coverage was 224.2 million herring, based on 48 integrator-readings (96 nautical miles). Combining all track lines in the same square (92 nautical miles) during the rest of the survey, another estimate of 118.8 million herring was obtained.

This estimate is based on both day and night observations, while the first one is based on only daytime observations. Comparisons of day and night observations in other squares did not, however, indicate systematic differences. The difference between the two estimates might be random or caused by movements of the herring schools. The estimates given in Figure 2 and Table 6 are based on all observations in the square.

No herring larvae were caught in the 8 plankton hauls made in sub-area West. The maturity stages observed also did not indicate any early spawning in the area.

PRELIMINARY REPORT ON ECHO SURVEY RV "TRIDENS" 4-20 JULY 1983

by A Corten

"Tridens" was not equipped with an echo-integrator, so no quantitative estimates of herring abundance could be obtained. The ship's 30kHz Elac sounder was used for scouting, and a 150kHz Elac colour sounder was used to obtain additional information on the nature of the echo-traces. Sampling of echo-traces was done with a 2 000 mesh pelagic trawl.

A coarse grid was worked between 56°30'N and 60°00'N in order to study the general distribution of the herring, and to compare typical herring traces between various sub-areas. Particular attention was paid to the Fladen Ground, to see whether the once important herring concentrations in this area have returned in recent years.

Fig. 6 shows the cruise track and also the positions of trawl stations and herring-type echo-traces. Although this report deals mainly with surveys in the Shetland/Orkney area, the information for the area south of 58°00'N has also been included for comparison.

During this survey, identification of herring shoals seemed to be less of a problem than during earlier surveys carried out by "Tridens". This may be due either to the increase in experience after 5 years of echo surveys, or to the greater abundance of herring this year. In most areas, herring was either the dominant species as regards fish echoes, or it was of very low importance. There were few areas where herring occurred in 50/50 mixtures with other species (Table 7).

In general, the main concentrations of herring occurred in a zone extending about 50 miles off the Scottish coast. The biggest concentration was found off the Pentland Firth, between 58°30'N-59°00'N and 1°00'W-2°00'W. This area coincided with the main fishing ground of Dutch herring trawlers in June. Fish in this area were in an advanced stage of maturity (Stage IV-V). At the northwestern boundary of this concentration (trawl station 22), two females in Stage VI were caught. Some of the shoals in this area did not rise to the surface at night, but remained in a more diffuse form near the seabed.

The second most important concentration was found 30-40 miles off Peterhead and Aberdeen. The catches here consisted of fish in an advanced stage of maturity (Stage IV-V), and immatures. The length composition of the adult fish was fairly uniform in most of the hauls, with a mode at 26-27cm (Table 8).

Immature herring around 21cm were found in most of the catches at the western edge of the survey grid (hauls 4, 5, 10, 12, 13, 22, 23). Traces typical of immature herring (Fig. 7) were also very common in these areas.

A very large surface shoal (Fig. 8) was observed at night in coastal waters southeast of Shetland. This shoal extended from the surface to about 40m depth, and continued over 2.0 miles. It was assumed that the shoal consisted of herring, as it was found in the area where the main purse seine fishery had been going on in the previous week.

If so, the herring must have been very concentrated on this particular night, as hardly any other herring-type traces were encountered during the rest of the track along the SE coast of Shetland.

Following the recommendation of the Planning Group, some plankton samples were collected in square 48E7 north of Orkney, in order to check the presence of newly hatched herring larvae. No such larvae were detected on first inspection, but the samples still have to be further analysed.

Contrary to expectation, no major herring concentrations were encountered on the Fladen Ground.

REPORT OF SURVEY BY FRV "SCOTIA", 7-25 JULY 1983

by R S Bailey and E J Simmonds

The acoustic survey on "Scotia" was carried out using a Simrad EK 400 sounder working on 38KhZ frequency. Echointegration was carried out using an Aberdeen digital echo-integrator at a nominal speed of 10 knots and readings were taken every 30 minutes. The survey track and positions of trawl hauls are shown in Figure 9 and the details of the acoustic equipment and settings in Table 9. Three calibrations of the acoustic equipment were carried out during the survey and gave results within 0.08dB of the mean (Table 9).

That part of the total echo-integration value attributable to fish echo-traces was extracted in the way described in CM 1982/H:47, ie increments on the analogue trace associated with "shoals" on the echogram were

summed. During the hours of darkness fish traces often became mixed and indistinguishable from those of plankton and echointegration was therefore confined to the period 0300-2130hrs GMT.

The identity of fish echotraces was established wherever possible by making trawl hauls at the appropriate depth with a Jackson midwater trawl fitted with a 20mm mesh codend. Details of all trawl hauls and the catches made are given in Table 10. Herring were caught in 20 of the 28 hauls in which any fish were caught. Other species caught in significant quantities were whiting, Norway pout, mackerel, haddock and pearlsides Maurolicus muelleri, and in addition sandeels and 0-group Norway pout were frequently meshed in the funnel of the net, the latter often in large numbers.

Examples of echotraces recorded during the survey are shown in Figure 10, together with the composition of trawl catches made in the vicinity. On the basis of identification by trawl, herring were responsible for two different types of echotrace. Distinct plume traces in midwater in the areas east of Shetland and west of Orkney were shown to be attributable to large herring, although the fish were difficult to catch (Fig. 10b, g). Further south, the shoals tended to be smaller and nearer the bottom (Fig. 10c, d, h). In comparison, however, traces of whiting, mackerel and Norway pout appeared to be more diffuse and generally closer to the seabed (Fig. 10a, d). Close to the east coast of Shetland, towing through areas in which large dense midwater traces were found resulted in extensive meshing by 0-group Norway pout (Fig. 10f).

The fish component of the echo-integration values was allocated to herring and other species using the results of appropriate trawl hauls to identify the echo-traces. Since 0-group Norway pout were not retained by the codend, no attempt was made to allocate the integration values from the quantitative composition of the trawl hauls.

The length compositions of herring sampled during the survey are given in Table 11. Since sampling was inadequate in some areas, samples obtained by all three vessels were used to calculate the appropriate length distribution and target strength for each area using the target strength/length relationship recommended by the Planning Group (CM 1983/H:12).

$$\text{TS per fish} = 20 \log_{10} L - 71.2\text{dB}$$

where L is length in cm. The target strength values applied in each area in Figure 11 are given in Table 12.

Individual weights of herring were obtained during the cruise on a balance that was programmed to take an average of 30 readings once a second. These were used to calculate an overall weight-length relationship:

$$W = 2.457 \times 10^{-7} \times L^{3.645}$$

where W is in g and L in mm.

Details of hauls in which weights were obtained are given in Table 13.

By taking the mean of integrator readings attributed to herring and the appropriate target strength value given in Table 12, the estimated number of herring in each quarter statistical rectangle was calculated. These are given in Figure 12 together with the number of half-hour integrator runs. In Figure 13 are given the estimated biomass of herring (upper figure) and estimates of the biomass of all fish assuming that all species have the same target strength as herring (lower figure). This gives an indication of the proportion of the total integration allocated as fish that was attributable to herring.

The estimates obtained for the whole survey area are 1 827 million herring equivalent to a biomass of 243 000t. Assuming all fish traces were herring, the estimate of total biomass was 1 371 000t, so traces thought to be herring accounted for only 18% of the total acoustic scattering by fish.

Using a maturity-length key derived from samples, the estimates of herring have been partitioned into mature and immature components:

	No. x 10^{-6}	biomass (t x 10^{-3})
immature	835	44.8
spawning	992	198.0
Total	1 827	242.8

Most of the adult herring caught during the survey were in maturation stages III-V. Very small numbers of stage VIII herring were caught but from the appearance of the gonads, it is unlikely that they had spawned recently. No herring at stage VI (ripe and running) were caught.

One quarter statistical rectangle ($60^{o}00'$-$60^{o}15'$N, $01^{o}00'$-$00^{o}30'$W) was surveyed intensively by a grid of north-south legs spaced 2.5 nautical miles apart on 21 July. The estimated number of herring in this area was 89.6 million equivalent to 27 300t, based on 95 nautical miles of integration. During the routine survey the estimated number of herring in the same area was 98.4 million, equivalent to 30 000t.

DISCUSSION

The pattern of herring distribution recorded by the three vessels was similar. Large herring were found east of Shetland and the proportion of small herring in catches tended to increase towards the south. In the area south of Fair Isle, however, samples obtained by "Tridens" contained a higher proportion of adult fish (> 25cm in length) than "Scotia" samples and this could have a big effect on the estimate of numbers of herring in each age group depending on which samples are used in the analysis.

Allocation of the echotraces was more problematical than in 1982. Close to the Shetland coast, for example, intense echotraces thought at first to be attributable to herring appeared from trawl hauls to be caused by 0-group Norway pout (see Fig. 10f).

The estimates of herring abundance made on the "G O Sars" and "Scotia" are given in the text table below.

	44 rectangles covered by both vessels	Total area covered by "Scotia" (62 rectangles)
'GO SARS'no x 10^{-6}	1279	-
immature	456	-
spawning	823	-
biomass t x 10^{-3}	250	-
immature	27	-
spawning	223	-
"SCOTIA" no x 10^{-6}	1029	1827
immature	349	835
spawning	680	992
biomass t x 10^{-3}	164	243
immature	18	45
spawning	146	198

The spawning stock biomass in 1983 is therefore estimated to be in the range 198,000t (Scotia) - 302,000t (G.O. Sars) if the "GO Sars" estimate is raised to account for the additional area surveyed by "Scotia". These compare with estimates ranging from 188-265,000t in 1982 (CM 1982/H:47). While there is doubt about the absolute value of the estimates because of the possibility of inaccuracies in the target strength values caused primarily by avoidance behaviour, these estimates indicate no significant increase in spawning stock biomass in 1983. While a full analysis by age group has not been possible in the absence of age data, this result should be viewed against the fact that an international fishery took place in this area in June and July 1983. In addition, the length compositions in Tables 3,8 and 11 show that only a small proportion of the stock was in the 25-26cm size group indicating that 2-ringer recruits were probably not abundant. This contrasts markedly with the size composition in 1982 when 2-ringers (modal length 25-26cm) were the predominant age group. The much higher proportion of 1-ringers in 1983 is also markedly different from that in 1982 when they were very scarce.

The acoustic survey planning group which met in February 1983 made some specific recommendations for the 1983 survey (CM 1983/H:12). Investigations carried out in response are commented on briefly below:

a. Since herring were found in 1982 in the north eastern part of the survey area, the "G.O.Sars" survey was extended in that direction to $0^{\circ}30'$E. There was no evidence of herring in this area in 1983 (Fig 2).

b. The occurrence of stage VIII herring in July 1982 indicated the possibility that early spawning had taken place and, if so, then these fish may not have been included in the acoustic estimate because of their more dispersed distribution. To investigate whether this is likely to lead to significant underestimation, the area north of Orkney (where early spawning is most likely to occur) was surveyed by "Scotia" from 8-11 July and by "G.O. Sars" on 28 July. Adult herring sampled on the two surveys were at stages III-IV and V-VII respectively, indicating that spawning began in this area around the middle of July. In other parts of the survey area most adult herring were at stages III-V.

The area to the east of Orkney was investigated by "Tridens" from 11-14 July and while most adult herring caught were in stages IV-V two herring at stage VI were caught on 14 July.

c. A further check on the possibility of early spawning was made by plankton hauls. No herring larvae were recorded indicating that significant spawning in early July is unlikely to have occurred.

d. The comparison of a small area surveyed by two ships on the same day gives an indication of the precision of a single estimate. The estimated number of herring in the area is given in the text table below, with the number of nautical miles of integration in parentheses:-

	Intensive survey	Routine survey	Both combined
"G.O.SARS"	224.2 (96)	118.8 (92)	172.6 (188)
"SCOTIA"	89.6 (95)	98.4 (95)	94.0 (190)

The herring in this area were distributed in the form of large shoals in midwater and the coefficient of variation of thefour independent estimates is 47%. The cause of this variability will be investigated by an exchange of echograms and integration data for this area to evaluate the effect that analysis technique has on the estimates. In addition, however, the distribution of herring in the form of large patchily distributed shoals is likely to have resulted in major sampling errors at least in this part of the survey area.

Table 1. Technical data and setting of acoustic equipment, R/V "G.O.Sars".

Echo sounder	Simrad EK 400
Frequency	38 kHz
Receiver gain	-10 dB+20 log R+2·0.008·R
Pulse length	1.0 ms
Bandwidth	3.3 kHz
Transducer	45x48 cm
Effective beam angle (10 log Ψ)	-23.2 dB
Basic range	150 m
Source level + Voltage response	134.5 dB at 0 dB receiver gain
Integrator	NORD-100 computer
Threshold	17 millivolts peak
Instrument constant (C_I) for survey settings	0.0814 m^2 backscattering cross section per square nautical mile per integrator unit

Table 2. Trawl catches, R/V "G.O.Sars" 18.-30. July 1983. P = pelagic trawl, B = bottom trawl.

ST NO	DATE	HOUR (GMT)	POSITION NORTH	POSITION WEST	CATCH (number of fish) Herring	Whiting	N. pout	Mackerel	Others	TOTAL (kg)	Remarks
B 824	18	1405	60°45'	00°01'	-	3	1 227	-	180	454	
P 827	18	1825	60°44'	00°27'	-	-	-	-	-	-	Salps meshed
P 832	19	1445	60°36'	00°19'	-	-	-	15	-	7	Krill meshed
B 833	19	1520	60°30'	00°06'	1	27	1 014	-	421	192	
P 835	20	0000	60°27'	00°47'	7	47	3 000	-	-	80	
P 837	20	0710	60°19'	00°47'	10	280	10 000	-	4	151	
P 839	20	0900	60°14'	00°58'	-	57	60 000	-	3	155	
P 841	20	1300	60°09'	00°30'	-	3	-	-	28	26	
P 842	20	1550	60°10'	00°54'	8 333	20	-	-	-	2 512	
P 845	21	0123	59°56'	01°09'	-	29	750	-	2	12	
P 846	21	0320	59°26'	01°10'	-	-	4 500	-	-	15	
P 849	21	1230	60°15'	00°48'	-	-	-	-	6	3	Schools avoided
P 850	21	1740	60°14'	00°37'	1	-	-	-	10	14	Schools avoided
P 851	21	1915	60°12'	00°38'	2	-	-	-	48	36	Schools avoided
P 852	21	2340	60°12'	00°51'	17 000	-	-	-	-	5 000	
P 853	22	1000	60°02'	00°10'	-	1	50	1	59	43	0-gr.haddock meshed
P 855	22	1445	59°50'	00°34'	-	-	-	-	9	8	Schools avoided
P 858	22	2130	59°55'	01°36'	35	1 990	-	60	7	594	
P 859	22	2317	60°00'	02°27'	-	2	810	-	-	3	
P 863	23	0535	59°48'	01°41'	11	22	-	76	16	49	
B 864	23	0800	59°45'	01°40'	-	-	340	-	41	44	
P 865	23	1130	59°56'	01°49'	3	726	-	278	2	566	
P 870	23	2300	59°41'	01°57'	1 900	4	3 600	-	-	202	
P 871	24	0125	59°46'	01°58'	20	700	1 050	-	-	235	
P 873	24	0570	60°05'	02°20'	1	2	100	106	-	28	
P 878	24	1725	59°26'	01°21'	260	1 290	-	44	19	370	
P 881	24	2236	59°40'	01°00'	650	530	-	-	900	300	0-gr.haddock meshed
P 883	25	1730	60°01'	01°01'	-	-	18 000	-	-	60	
P 884	25	1845	59°58'	01°04'	-	-	4 280	-	-	20	
P 887	26	0515	59°23'	00°14'	-	-	-	-	10 000	22	Müllers pearlside
P 889	26	1128	59°20'	01°24'	-	170	-	-	-	45	
P 890	26	1325	59°20'	01°22'	12	3 450	23 400	-	2	1 500	
P 891	26	1700	59°05'	01°37'	63 300	-	-	-	-	10 000	
P 895	27	0255	59°17'	01°48'	4 130	1	-	4	-	351	
P 902	27	2200	59°46'	03°20'	-	-	9 000	2	-	30	
P 906	28	0300	59°43'	02°29'	-	-	1 500	-	-	5	
B 909	28	0650	59°53'	02°55'	-	1	19	-	97	29	Bad bottom
P 911	28	0945	60°01'	02°41'	7 710	-	-	1	-	2 500	
P 913	28	1425	60°06'	02°37'	-	-	-	-	-	0	Schools avoided
P 914	28	1530	60°04'	02°41'	1 456	-	-	1	-	521	
P 915	28	1850	60°11'	02°13'	284	2	-	95	32	142	
P 916	29	0410	60°41'	01°31'	-	-	-	-	-	0	Krill meshed
P 917	29	0635	60°47'	01°07'	1	-	-	9	1	4	Schools avoided
P 919	29	1400	60°41'	00°43'	-	-	1 923	-	-	52	
P 920	29	1645	60°39'	00°41'	1	-	-	-	-	0	Missed the schools

Table 3. Length distribution (%) of herring R/V "G.O.Sars" 18.-30. July 1983

LENGTH (cm) \ SUB-AREA / ST.NO.	WEST			EAST		MIDDLE				SOUTH		
	911	914	915	842	852	858	870	871	881	878	891	895
14												0.8
16												3.1
18												22.1
20										2.8		14.2
22							2.0			22.6		7.9
24										22.6		7.9
26										2.8		17.3
28							20.0			0.9	1.8	8.7
30							34.0	10.0		4.7	13.2	3.1
32						2.9	30.0	5.0		0.9	11.5	5.5
34							8.0		1.0	0.9	5.3	3.1
36						2.9	2.0				2.6	0.8
						11.4	2.0	5.0	7.0		3.1	4.7
				1.5		22.9		35.0	11.0	1.9	17.2	0.8
				5.4	3.0	34.3		15.0	34.0	9.4	20.3	
	2.9			7.7	5.0	19.8		10.0	20.0	10.4	16.3	
	3.9	1.1	3.0	10.8	9.0			5.0	16.0	13.6	5.3	
	11.7	4.4	3.0	10.8	8.0	2.9		5.0	7.0	3.8	2.6	
	2.9	6.6	8.1	9.2	13.0				1.0	0.9		
	12.6	12.1	21.2	13.8	22.0	2.9	2.0		2.0		0.4	
	28.2	33.0	29.3	22.3	20.0			5.0	1.0	0.9	0.4	
	32.0	27.5	29.3	10.8	19.0			5.0		0.9		
	5.8	13.2	6.1	6.9	1.0							
		2.2		0.8								
No. meas.	103	91	99	130	100	35	50	20	100	106	227	127

Table 4. Distribution (%) of maturity stages of herring R/V "G.O.Sars" 18.-30. July 1983.

SUB-AREA	ST. NO.	I	II	III	IV	V	VI	VII	VIII	No in sample
WEST	911				1.0	23.3	19.4	56.3		103
"	914			1.1	6.6	62.6	27.5	2.2		91
"	915					40.0	5.0	55.0		100
EAST	842			6.0	60.0	31.0			3.0	100
"	852			4.0	96.0					100
MIDDLE	858		5.7	34.3	60.0					35
SOUTH	891	32.6	2.6	11.0	30.8	22.5	0.4			227

Table 5. Average target strength ($\overline{TS}$) of individual herring within sub-areas, R/V "G O Sars" 18-30 July 1983

Sub-area	WEST	EAST	MIDDLE	SOUTH
$\overline{TS}$ (dB)	-40.9	-41.2	-42.9	-44.1

Table 6. Estimated number (N millions) and weight (W 1000 tonnes) of each cm-group of herring within sub-areas.

	WEST		EAST		MIDDLE		SOUTH		TOTAL	
cm	N	W	N	W	N	W	N	W	N	W
14							1.8	0.03	1.8	0.03
							5.9	0.12	5.9	0.12
16							48.8	1.30	48.8	1.30
					1.4	0.05	72.3	2.40	73.7	2.45
18					-	-	60.0	2.45	60.0	2.45
					-	-	21.2	1.05	21.2	1.05
20					13.8	0.83	39.4	2.36	53.2	3.19
					30.3	2.17	52.4	3.75	82.7	5.92
22					26.2	2.22	30.6	2.59	56.8	4.81
					6.3	0.63	22.9	2.29	29.2	2.92
24					3.3	0.38	11.2	1.30	14.5	1.68
					17.6	2.38	7.6	1.03	25.2	3.41
26			1.9	0.29	47.4	7.39	46.5	7.25	95.8	14.93
			9.9	1.78	57.3	10.25	60.0	10.74	127.2	22.77
28	1.8	0.36	16.3	3.33	34.4	7.03	52.4	10.70	104.9	21.42
	4.8	1.11	23.4	5.43	14.6	3.39	37.1	8.60	79.9	18.53
30	11.4	2.99	21.0	5.52	10.2	2.68	12.4	3.25	55.0	14.44
	10.5	3.10	26.2	7.76	0.8	0.24	1.8	0.52	39.3	11.62
32	27.2	9.03	42.3	14.05	4.7	1.56	0.6	0.20	74.8	24.84
	53.6	19.95	50.1	18.62	4.1	1.54	2.4	0.87	110.2	40.98
34	52.6	21.80	35.2	14.59	3.6	1.48	1.8	0.73	93.2	38.60
	14.9	6.87	9.4	4.35					24.3	11.22
36	1.2	0.63	0.9	0.48					2.1	1.11
TOTAL	178.0	65.85	236.6	76.22	276.0	44.22	588.8	63.53	1279	250
IMMATURE	-	-	-	-	87	7	369	20	456	27
SPAWNING STOCK	178	66	233	75	189	37	220	44	820	222

Table 7 - Pelagic trawl catches by "Tridens" 4-20 July 1983

Haul No.	Position	Date	Hour (GMT)	Dur. (Min.)	Catches in kg		Other species
					Herring	Others	
1	56°29'N 00°53'W	5/7	1205	50	-	600	N. Pout
2	56°30'N 00°04'W	5/7	1550	30	-	70	Mackerel, Haddock
3	56°31'N 00°12'W	5/7	1740	35	-	800	N. Pout
4	56°50'N 01°02'W	6/7	0615	30	1000	400	N. Pout ,Haddock, Whiting
5	56°59'N 00°50'W	6/7	0915	90	12000	170	Haddock, Whiting
6	57°10'N 01°00'E	6/7	1745	45	2000	2200	Mackerel, Haddock
8	57°21'N 00°59'E	7/7	1140	35	-	800	N. Pout , Mackerel
9	57°30'N 00°11'W	7/7	1650	60	500	500	N. Pout
10	57°30'N 00°42'W	7/7	2000	60	75	80	Mackerel, Whiting
11	58°00'N 00°24'W	8/7	0930	30	-	2	**Maurolicus**
12	57°29'N 01°20'W	8/7	1430	40	1500	-	
13	58°17'N 01°59'W	11/7	0925	20	200	-	
14	58°30'N 01°02'W	11/7	1415	40	1000	130	Mackerel, Whiting
15	58°55'N 02°00'W	11/7	2015	65	1000	220	Mackerel, Whiting, Haddock
16	59°00'N 01°25'W	12/7	0620	55	7000	600	Whiting,N.Pout ,Haddock
17	59°00'N 00°40'W	12/7	1015	105	-	3100	N. Pout
18	59°20'N 00°35'W	12/7	1742	33	-	120	**Maurolicus** , N.Pout
19	59°20'N 01°05'W	12/7	2015	75	240	-	
20	59°20'N 01°45'W	13/7	0620	55	10	750	Whiting, Mackerel
21	60°00'N 00°36'W	13/7	1930	45	-	20	Whiting, Haddock
22	59°04'N 02°18'W	14/7	1500	30	180	420	Mackerel, Whiting
23	58°56'N 02°00'W	14/7	1740	20	200	-	
27	57°13'N 01°09'W	15/7	0855	25	80	-	
29	57°13'N 00°53'W	15/7	1240	100	800	200	Mackerel, N. Pout
30	55°43'N 01°15'W	18/7	1015	75	5000	-	
31	55°04'N 00°57'W	18/7	1845	90	400	100	Sprat, N. Pout
32	55°14'N 01°14'W	19/7	0700	60	75	1425	Sprat
34	55°07'N 00°42'W	19/7	1210	65	180	120	Sprat

Table 8. Length distributions of herring catches RV "Tridens" 4-20 July 1983

Haul	4	5	6	9	10	12	13	14	15	16	19	22	23	27	29	30	31	32	34
length cm.																			
15.0							3												
							3						2						
16.0									1			210	2						
							2					224	2						
17.0							2					154	5					1	
						2				1		42	6				1		
18.0						1	1			3			2					1	1
					1	1						28	4			2	4	5	
19.0	1				1	2				1			1			4	6	5	
	2	1	1			2				1		84	1		3	15	9	6	1
20.0	6	3		1	2		3			1		14	2		4	23	8	6	7
	14	23		2	1	6	7			1	1	14	8			37	13	4	3
21.0	13	24		1	2	3	9			2	4	56	6		1	22	7	2	2
	23	39		2	2	2	16		1	5	1	28	14		1	21	4	1	2
22.0	7	15		2	1	4	2			3	3		7			10	6		3
	4	18		2	1	2	1				3				1	7		1	1
23.0	3	10	1	1	1	2	2				1					5	2	1	2
		9	5	1	2	1	1				3			1	2				1
24.0	1	6	11	1	2	1			1	2	2	1			1	1	3		
		7	6	3				1		3	4	2		1	3		5		3
25.0	1	3	13	3	3			2	1	3	3	9	2		2		5		3
	3	2	14	5	4	2		2	1		4	8		2	7	1	6		3
26.0	1	6	14	6	8	1		7	5	6	3	12	2	3	8	1	4		1
	1	8	12	6	4	3		4	6	2	8	13	6	6	6		4		
27.0	2	6	7	2	2	3		7	8	5	8	16	5	10	6	2	2		3
		9	6	5	7	4		5	10	5	8	15	10	9	2		2		3
28.0		6	3	4	3	6		5	5	1	4	7	5	13	3	2			2
	1	7	1	2	4	9		5	9	3	4	5	7	8	2	1	1		1
29.0		5	1	2	4	2		1	4		1	5	1	7					1
		3	1		3	1		6		1	1	2	2	3	1				2
30.0			1		3	4		1			1	5		3	1				
		2		1		3					1			5					
31.0					2	3					1		1	2					
						3								2	2				
32.0		1		1		2								5	1				
														2					
33.0		1			1	1													
34.0														1					

Table 9. Details of acoustic equipment and settings, FRV "Scotia"

Echosounder	Simrad EK 400
Frequency	38kHz
Power	High
Receiver Gain	-10dB + 20 log R + (2 x 0.008 R)
Pulse length	1.0ms
Bandwidth	3.3kHz
Transducer	Ceramic 30 x 15cm (34 elements)
Equivalent beam angle	-17.8dB (measured)
Basic range	0-200m

Source level and voltage response referred to 1 metre on TVG function measured on three occasions

1) 08 07 83	+54.73dB//1 V rms
2) 16 07 83	+54.84dB//1 V rms
3) 23 07 83	+54.71dB//1 V rms

VR + SL used for survey +54.76dB//1 V rms measured using a 38.1mm diameter tungsten carbide sphere with TS = -42.36dB

Integrator	Aberdeen Digital Integrator
Effective threshold	20 millivolts peak
Depth range of integration	5-10m below surface (depending on weather conditions) - 3m above bottom

Table 10. Details of trawl hauls, FRV "Scotia"

Haul number	Date	Time GMT	Duration h.m.	Shooting position		Catch (kg) Herring	Whiting	Norway pout	Mackerel	Others		Remarks
60	8 July	1325	0.30	59°26'N	02°07'W	95	0	0	0	0	-	0-group Norway pout, few sandeels meshed.
61	8 July	1500	-	59°28.5'N	02°12.7'W	-	-	-	-	-	-	NET FAILED TO OPEN, Sandeels meshed.
62	9 July	0740	1.00	59°57'N	02°31.8'W	16	16	0	95	0	-	0-group Norway pout meshed.
63	9 July	1120	1.30	59°45'N	02°35'W	16	127	0	32	0	-	0-group Norway pout meshed.
64	10 July	1355	1.20	59°25'N	04°00'W	350	48	0	4	15	cod, haddock	0-group Norway pout + blue whiting meshed.
65	11 July	1145	0.20	59°45'N	02°51'W	-	-	-	-	-	-	NET FOULED
66	11 July	1250	0.30	59°43'N	02°53'W	8	48	0	64	0	-	0-group Norway pout meshed
67	11 July	1930	1.00	60°04.5'N	01°34.5'W	858	0	0	40	0	-	-
68	12 July	0805	0.40	60°41'N	01°22'W	0	2	0	1	1	-	-
69	12 July	1140	0.20	60°39'N	01°22.5'W	2	16	0	1	48	haddock	-
70	13 July	0845	1.05	59°55'N	01°00'W	2066	0	0	0	0	-	-
71	13 July	2010	0.35	59°46'N	01°25.5'W	2	0	0	191	0	-	0-group Norway pout meshed.
72	14 July	1155	0.50	59°34'N	00°52'W	318	1	4	16	3	-	-
73	14 July	1855	0.55	59°26'N	01°21'W	95	191	2	4	5	-	0-group Norway pout meshed
74	15 July	0935	0.30	59°16'N	01°41.5'W	167	969	0	40	0	-	-
75	15 July	1730	0.10	59°02'N	00°50'W	6	0	0	10	636	610 Maurolicus 26 0-grp haddock	-
76	16 July	1150	0.25	60°01.5'N	01°07'W	-	-	-	-	-	-	Badly damaged net: sample = whiting; sandeels + 0-group pout meshed
77	17 July	1225	0.35	60°23'N	00°41'W	16	0	1	0	0	-	-
78	17 July	1450	0.30	60°16'N	00°46.5'W	0	0	0	0	1	-	-
79	20 July	1015	0.45	60°03'N	01°04'W	0	0	0	0	0	-	0-group Norway pout meshed.
80	20 July	1205	0.45	60°03'N	01°04'W	0	0	0	1	0	-	0-group Norway pout meshed.
81	20 July	1500	1.00	60°00'N	01°02'W	1	0	0	0	0	-	0-group Norway pout meshed.
82	21 July	1155	1.30	60°07'N	00°45'W	0	4	0	0	1	-	-
83	21 July	1415	0.30	60°12'N	00°37'W	0	0	0	0	0	-	-
84	22 July	0805	1.55	60°25'N	00°31'W	0	2	191	1	16	haddock	Euphausiids + fish larvae meshed.
85	22 July	1530	0.30	60°05'N	00°53'W	3972	0	0	0	0	-	-
86	23 July	1410	0.45	58°17'N	03°05'W	16	9	0	0	7	haddock	sandeels meshed
87	24 July	0720	0.55	58°47'N	01°47'W	24	0	0	0	0	-	-
88	24 July	0920	0.35	58°50.5'N	01°48'W	0	0	0	0	0	-	-
89	24 July	1025	1.00	58°51'N	01°48'W	254	0	0	0	0	-	-
90	24 July	1445	1.15	58°20'N	01°37'W	1	0	0	0	0	-	-

Table 11. Length distributions (%) of herring caught by FRV "Scotia", July 1983 (haul positions given in Table 10 and Figure 9) (Hauls containing >10kg of herring only)

Length (cm)	Haul No. 60	62	63	64	67	70	72	73	74	77	85	86	87	89
15												3.4		
			0.3									27.9		
16	0.4		5.1	0.4					0.3			44.8	5.6	
	0.4		7.5						5.3			16.0	13.7	3.8
17	8.2		8.0	1.4					8.4			1.7	17.8	4.9
	12.0	1.2	7.0	0.7					6.1			1.1	15.2	3.0
18	12.0	1.9	5.4	0.4					2.8			0.8	11.1	4.9
	6.4	3.8	1.6						0.6			0.4	9.2	6.8
19	7.8	1.9	3.0	0.4					0.6			1.1	7.7	7.9
	11.6	3.8	3.0	0.4								0.4	3.9	7.9
20	9.4	6.9	8.8					2.7	2.0			0.8	5.6	11.3
	10.3	14.4	12.9	0.7			1.3	8.5	2.0			0.6	5.4	14.3
21	9.4	5.6	11.3	0.4			3.9	13.9	3.1				2.6	12.1
	7.8	4.4	7.0	0.4			6.6	31.1	3.3			0.2	1.6	9.8
22	1.3	4.4	2.4	0.4			12.8	17.4	5.3			0.2	0.5	6.8
	1.7	1.9	3.0				10.5	11.2	4.8			0.2		3.7
23		2.5	2.1		0.3		6.0	3.1	6.5				0.2	1.7
		2.5	1.6	0.4	0.3		6.4	3.8	9.8					0.2
24		1.9	1.6	1.4	0.3		8.4	0.8	9.5			0.2		0.5
	0.2	5.6	2.4	1.7	2.3		7.1	1.9	9.8					
25	0.4	8.1	1.6	5.9	2.0	0.2	10.1	1.5	9.2					0.2
		4.4	1.1	3.8	3.5	1.2	5.1		2.8		0.5			
26		8.8	1.6	5.2	9.8	4.2	6.2		2.0		0.5			
	0.2	3.1	1.3	9.3	8.7	8.4	6.0	1.5	1.7		1.0			
27		3.1		8.9	14.1	12.3	3.8	0.3	2.5		0.5			
		1.2		10.3	14.1	10.8	2.2	0.8	0.6		4.8			
28		1.9	0.5	8.2	14.1	16.0	0.8	0.8	0.6		3.4			
		0.6		5.9	12.7	9.9	0.4	0.8	0.6		4.8			
29		1.2		4.8	8.7	7.1	0.4			17.4	5.3			
		1.2		5.9	4.0	5.9	0.2			10.9	5.7			
30		0.6		6.8	3.7	4.7					7.6			
		0.6		4.1	0.8	3.9				2.2	9.1			
31				4.1	0.3	2.5				13.0	8.1			
		1.2		1.4		3.0				13.0	8.1			
32				2.4	0.3	2.5				8.7	8.6			
				1.7		2.0				8.7	8.1			
33				1.1		2.5				17.4	9.1			
		1.2		1.1		0.7					6.2			
34						1.2				4.4	5.3			
				0.4		0.5				2.2	1.0			
35										2.2	1.4			
											0.5			
36						0.5								
											0.5			
Number measured	237	160	373	290	303	415	533	255	357	46	209	222	402	274

Table 12. Mean length, mean weight, target strength (TS per individual) values of herring and percentage of herring immature in each sub-area shown in Figure 11.

Sub-area	Mean length cm	Mean weight g	Target strength dB	Percentage by number	Immature by weight
A	31.3	305	-41.3	0.03	0.01
B	28.9	228	-42.0	0.19	0.12
C	24.2	119	-43.6	57.31	46.08
D	27.9	198	-42.3	2.05	1.26
E	21.8	82	-44.5	93.95	86.31
F	27.5	188	-42.5	2.79	1.78
G	33.1	370	-40.9	0.00	0.00
H	23.5	114	-43.8	60.02	38.77
I	19.8	61	-45.3	92.58	85.28
J	27.9	205	-42.3	8.98	3.61
K	19.6	55	-45.4	99.42	98.46
L	20.8	75	-44.8	80.50	64.36
M	23.4	117	-43.8	59.47	34.84
N	24.5	131	-43.4	43.15	24.60
O	25.6	151	-43.1	32.72	18.03
P	18.7	53	-45.7	89.99	66.07
Q	22.2	100	-44.2	65.30	36.22
R	27.6	190	-42.4	2.39	1.68
S	20.7	68	-44.9	98.81	98.11
T	16.4	28	-45.3	99.92	99.67

Table 13. Trawl hauls on which weights of individual herring were obtained for use in the weight-length relationship.

Haul No	Date	Area	No. of fish weighed	Length range of herring weighed	Predominant maturity stages
60	8 July	Northeast Orkney	98	16-25cm	1 and 2
64	10 July	Northwest Orkney	46	23-33cm	3 and 4
70	13 July	Southeast Shetland	118	25.5-36cm	3 and 4
73	14 July	Fair Isle	54	20.5-33.5cm	1 and 2
77	17 July	East Shetland	22	29-35cm	4
85	22 July	East Shetland	135	26.5-35.5cm	4 and 5

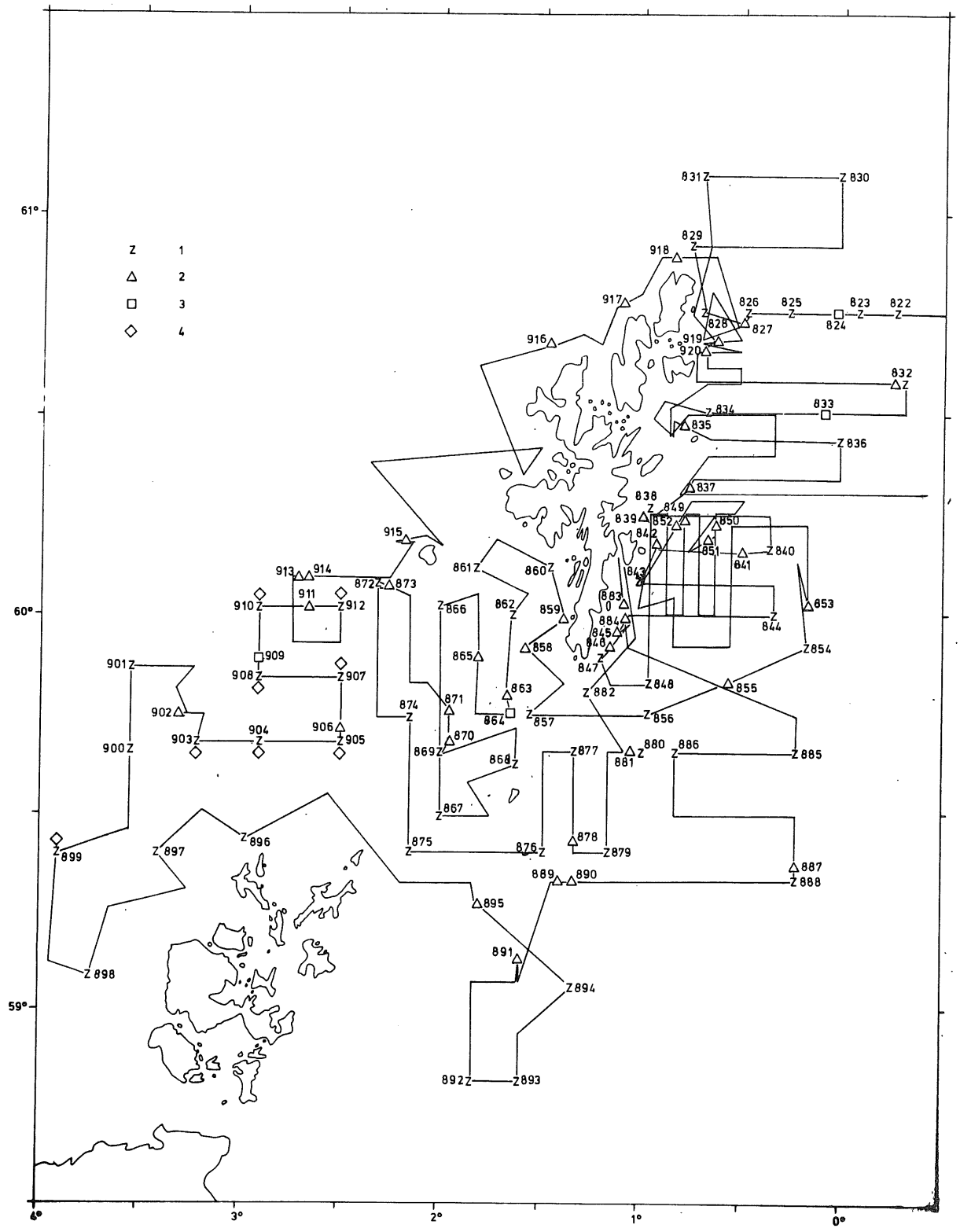

Figure 1. Survey grid and stations R/V "G.O.Sars" 18-30 July 1983.

1: Hydrographic station (CTD-zonde)

2: Pelagic trawl

3: Bottom trawl

4: Plankton station (Bongo 20)

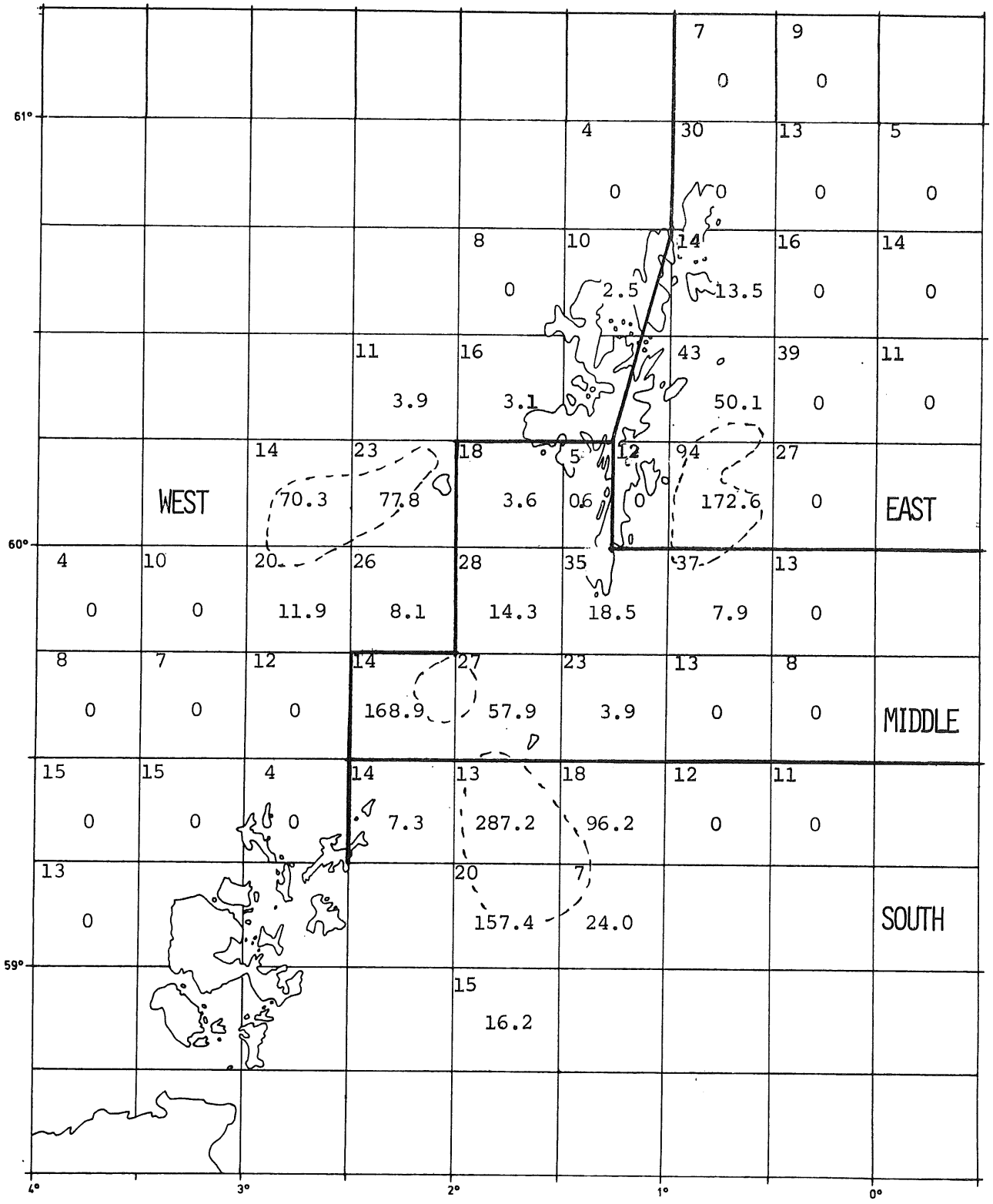

Figure 2. Estimated number (millions) of herring within squares. Number of integrator readings is given in the upper left corner of the squares. Sub-areas are divided by thick lines. The areas with significant herring recordings are indicated by broken lines.

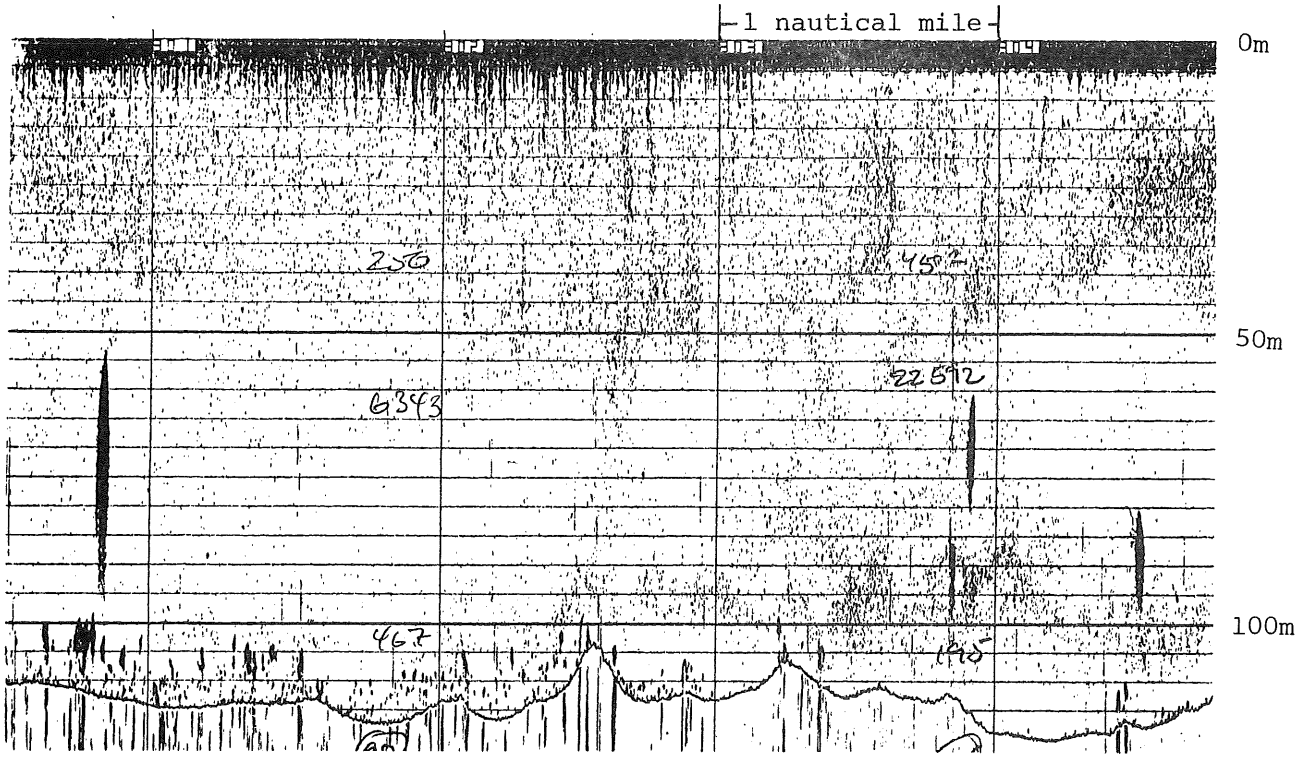

Figure 3. Typical herring schools at 50-100 m depth, identified at trawl station 842. Recordings 5-15 m above bottom are expected to be a mixture of whiting and 0-group Norway pout. The trawl stations 837,839 and 884 represent such mixed recordings.

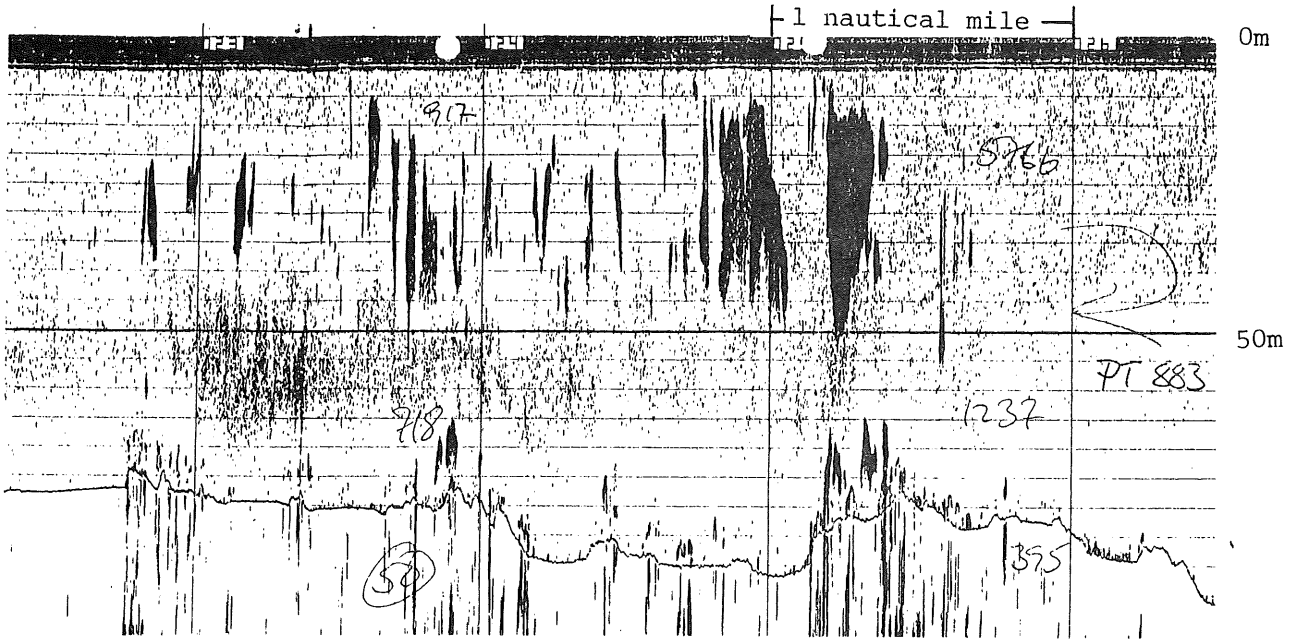

Figure 4. Schools of Norway pout recorded close to the coast **south-east of** Lerwick. The shallow schools are identified at trawl station 883 and the deepest ones at trawl station 884.

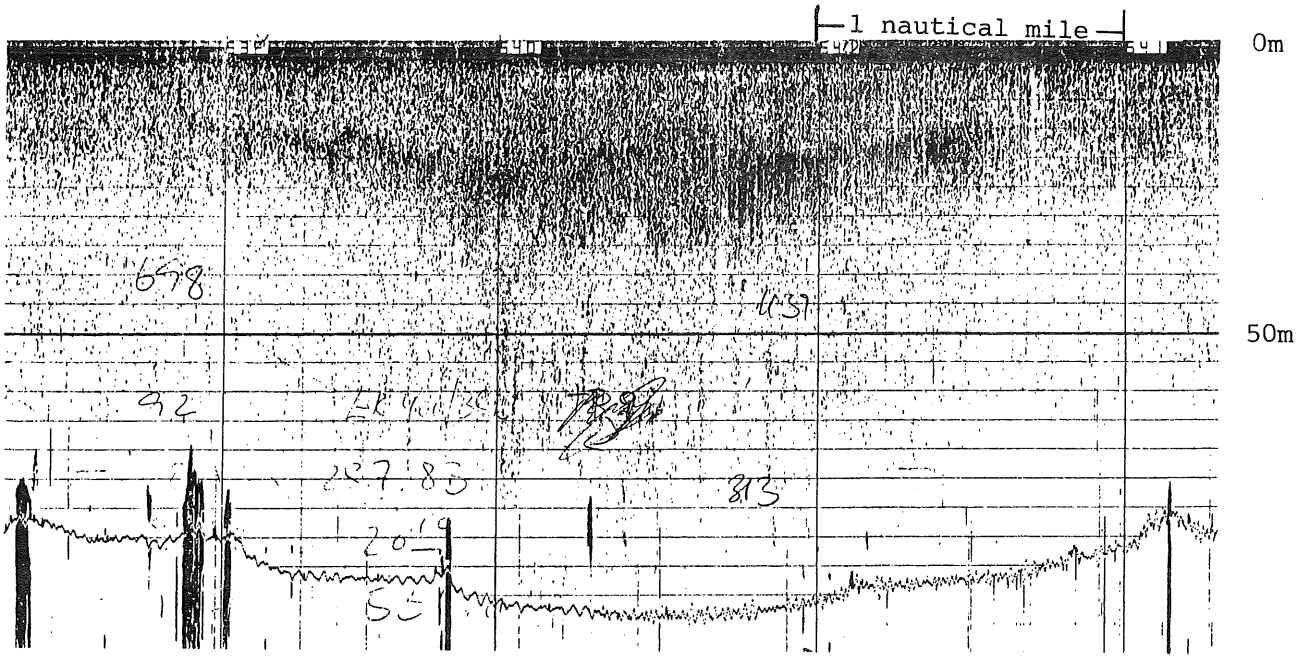

Figure 5. Herring schools identified at trawl station 911, south-west of Foula.

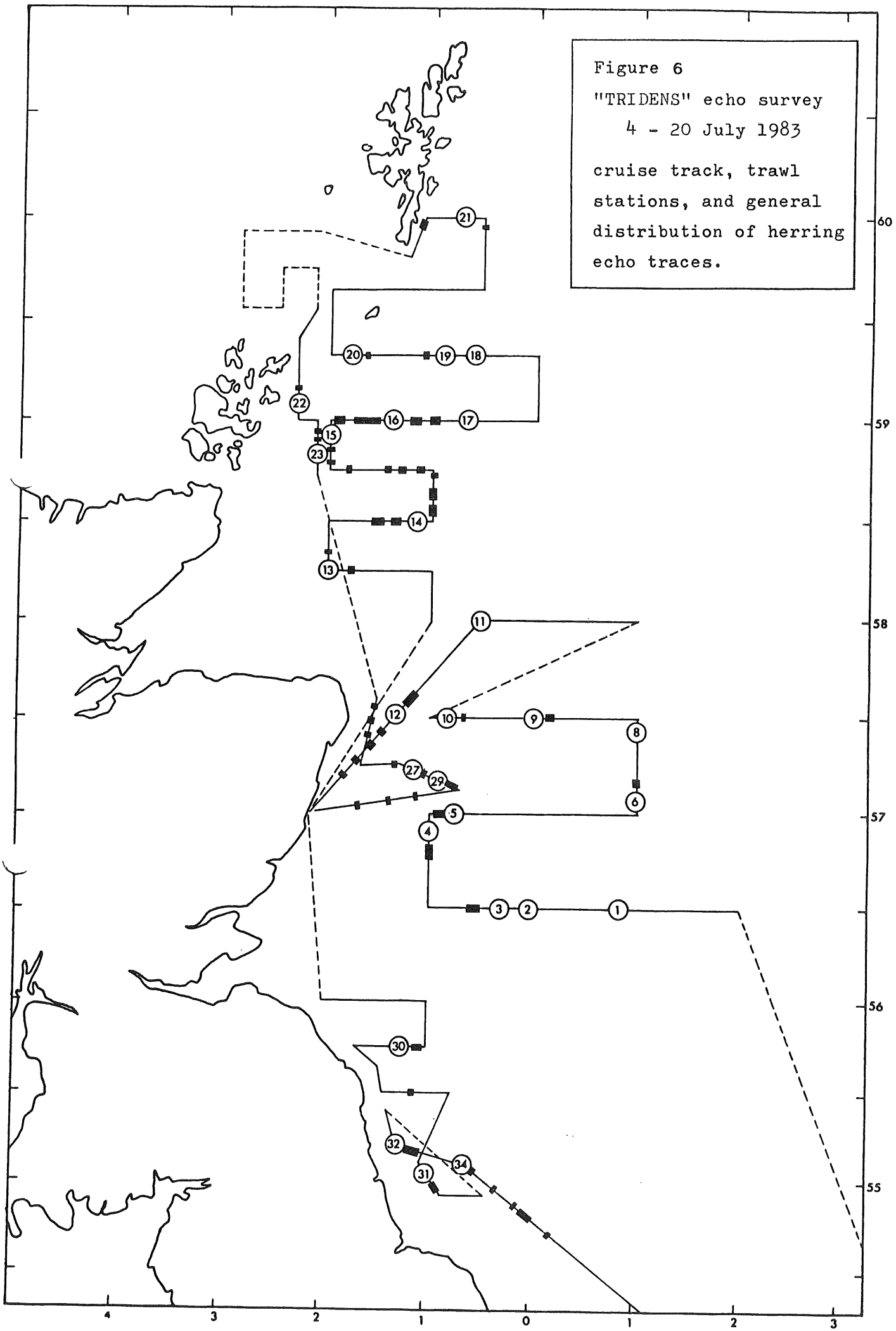
Figure 6
"TRIDENS" echo survey
4 - 20 July 1983
cruise track, trawl stations, and general distribution of herring echo traces.
60
59
58
57
56
55
4
3
2
1
0
1
2
3
21
20
19
18
22
16
17
15
23
14
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11
12
10
9
8
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29
6
5
4
3
2
1
30
32
31
34

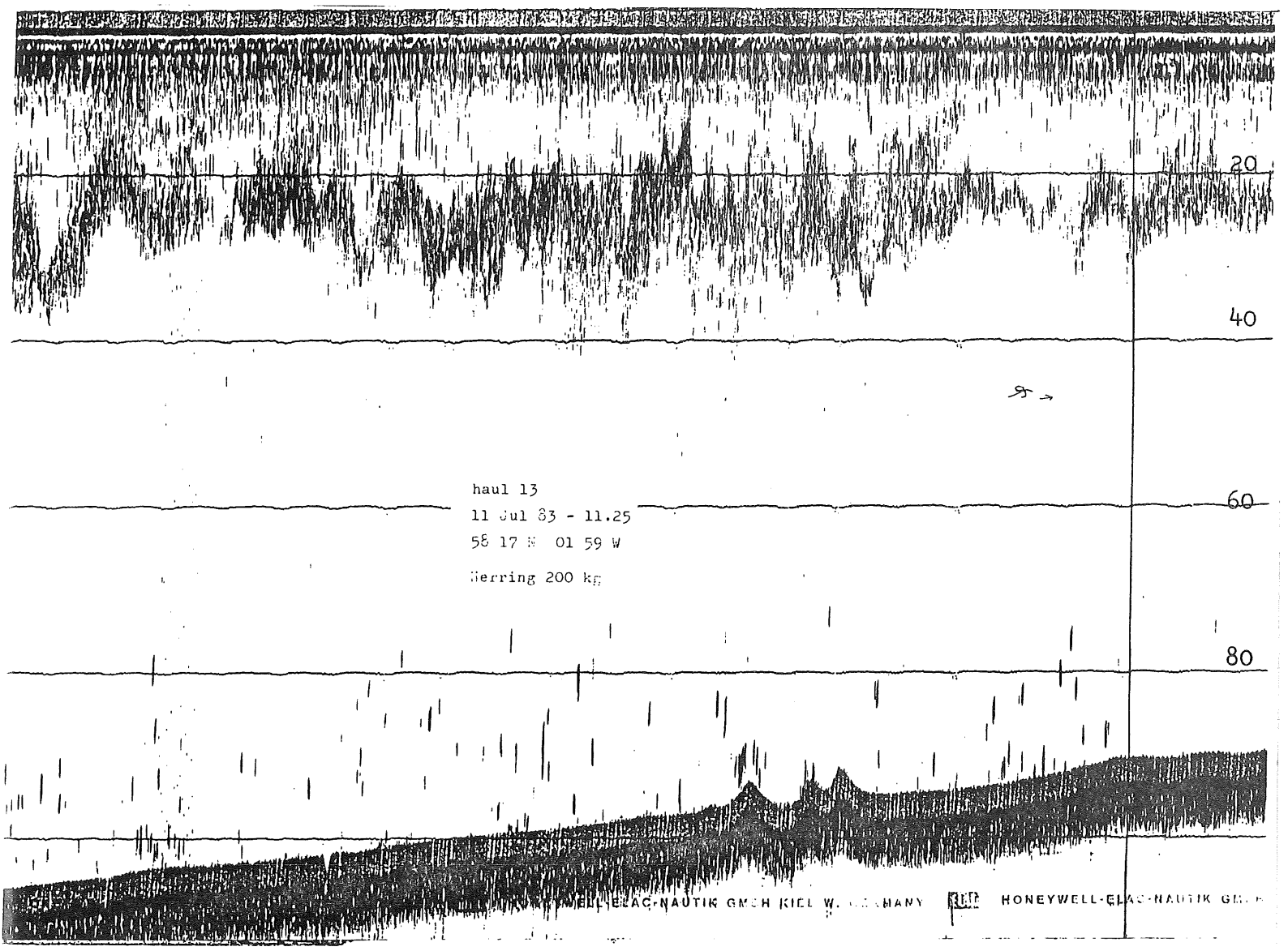

Figure 7. Typical echo traces of juvenile herring near the sea bed. Haul No. 13, 11 July 1983, 09.25 GMT, 58°17 N, 01°59 W.

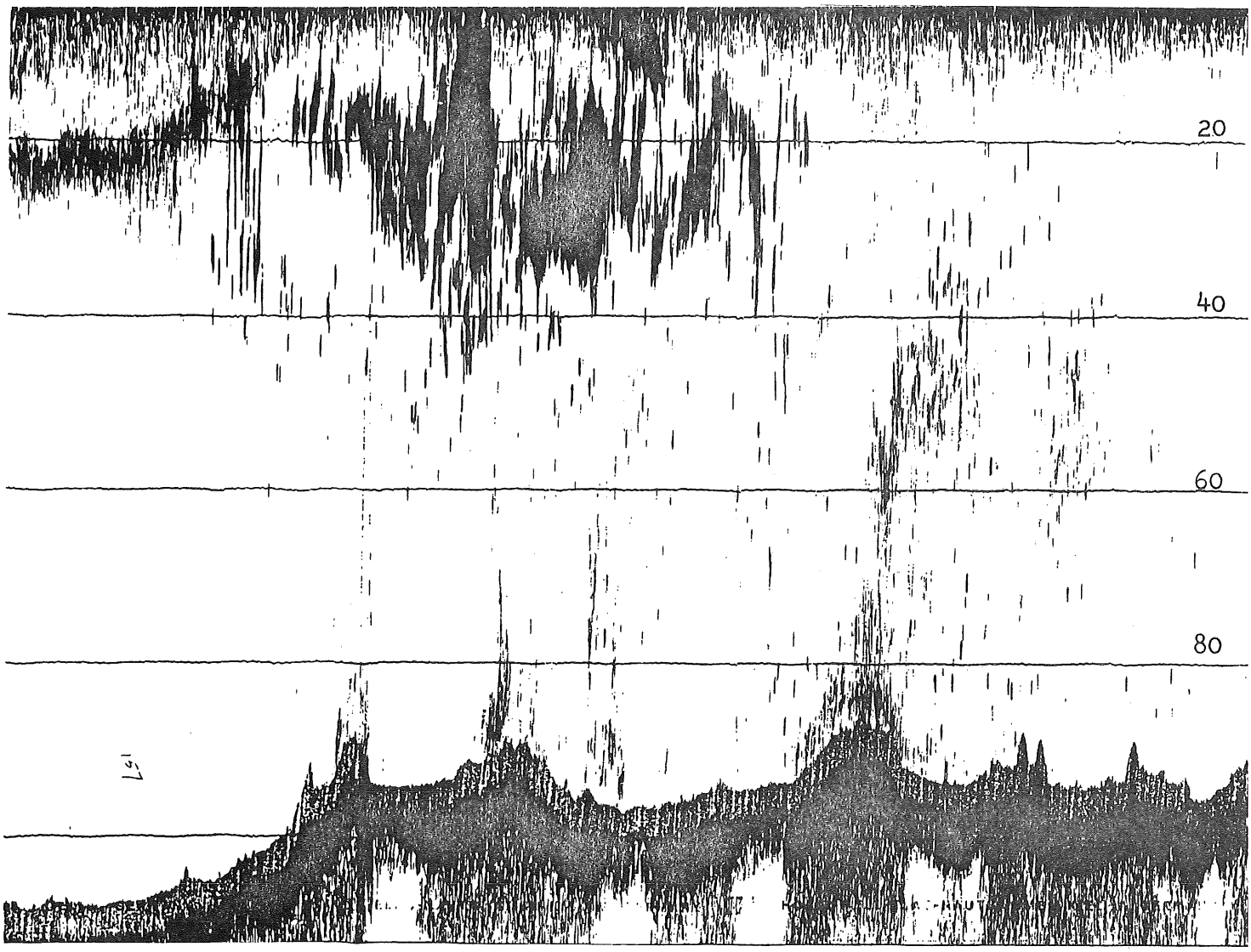

Figure 8. Large surface shoal, presumably of herring, at night southeast of Shetland. 13 July 1983, 21.45 GMT, 59°59 N, 01°07 W.

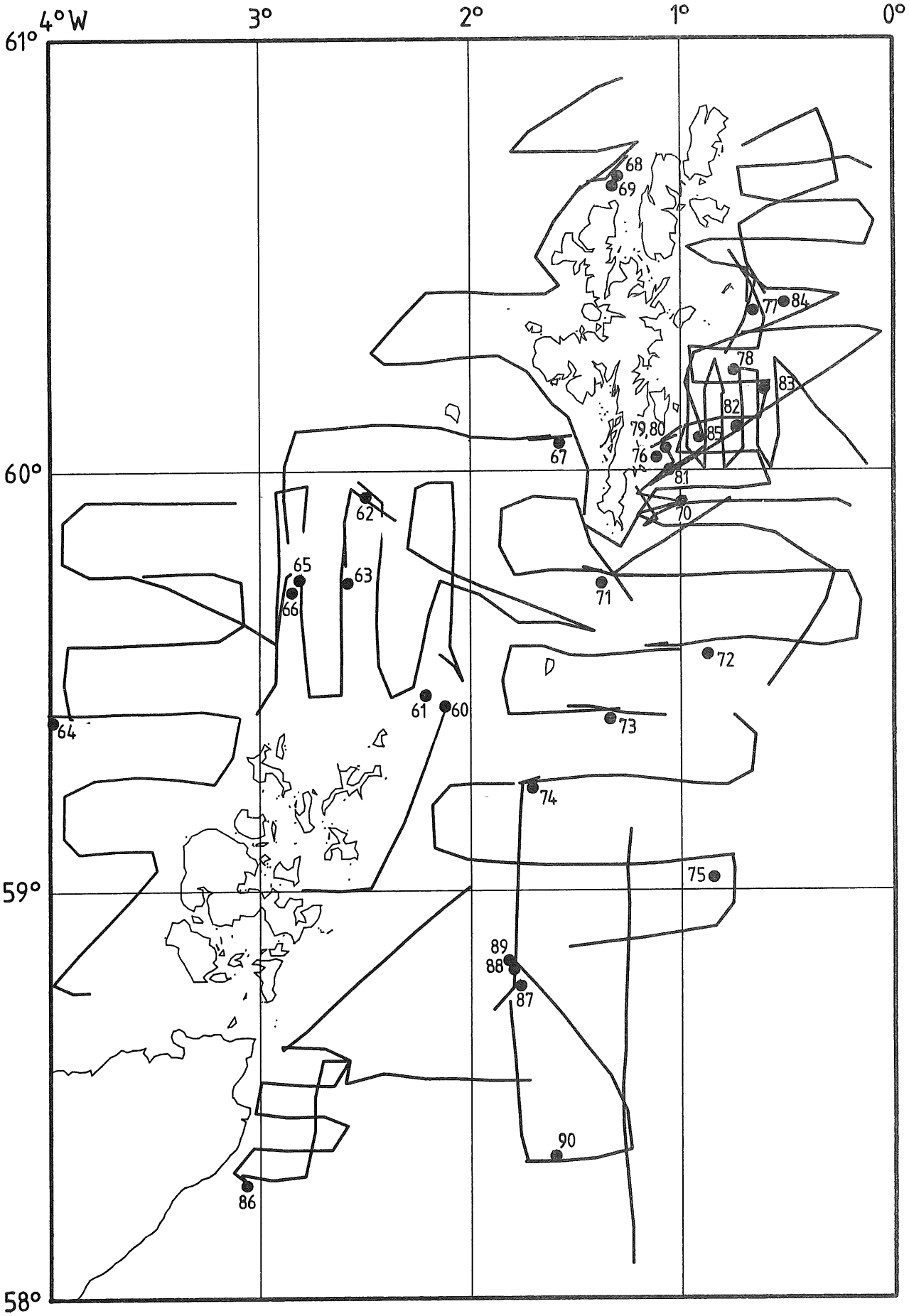

Figure 9. Survey track and trawl haul positions FRV "Scotia" 7-25 July 1983

Figure 10. Examples of echotraces recorded by FRV "Scotia" (all at 10 knots survey speed) and midwater trawl catches in vicinity

a) 1030 GMT 9 July 1983 59°52'N 02°36'W
Haul 63 contained 16kg herring (modal length 20.5cm), 127kg whiting, 32kg mackerel. 0-group Norway pout meshed in funnel.

b) 1600 GMT 10 July 1983 59°24'N 03°48'W
Haul 64 contained 350kg herring (modal length 27.5cm), 48kg whiting, 4kg mackerel, 15kg other gadoids, 0-group Norway pout meshed in funnel.

c) 1900 GMT 11 July 1983 60°05'N 01°37'W
Haul 67 contained 860kg herring (modal length 27.5cm), 40kg mackerel.

d) 0830 GMT 15 July 1983 59°16'N 01°49'W
Haul 74 contained 170kg herring (modal length 24cm), 970kg whiting, 40kg mackerel. Midwater shoals assumed to be herring, bottom traces other species.

e) 1630 GMT 15 July 1983 59°04'N 00°55'W
Haul 75 contained 6kg herring, 10kg mackerel, 610kg pearlsides, 26kg 0-group haddock.

f) 0900 GMT 20 July 1983 60°04'N 01°01'W
Haul 79 contained no fish in codend, but vast numbers of 0-group Norway pout meshed in funnel.

g) 1730 GMT 21 July 1983 60°05'N 00°52'W
Haul 85 contained 3970kg herring (modal length 30.5 and 33cm)

h) 0600 GMT 24 July 1983 58°46'N 01°47'W
Haul 87 contained 24kg herring (modal length 17cm)
Haul 89 contained 254kg herring (modal length 20.5cm).

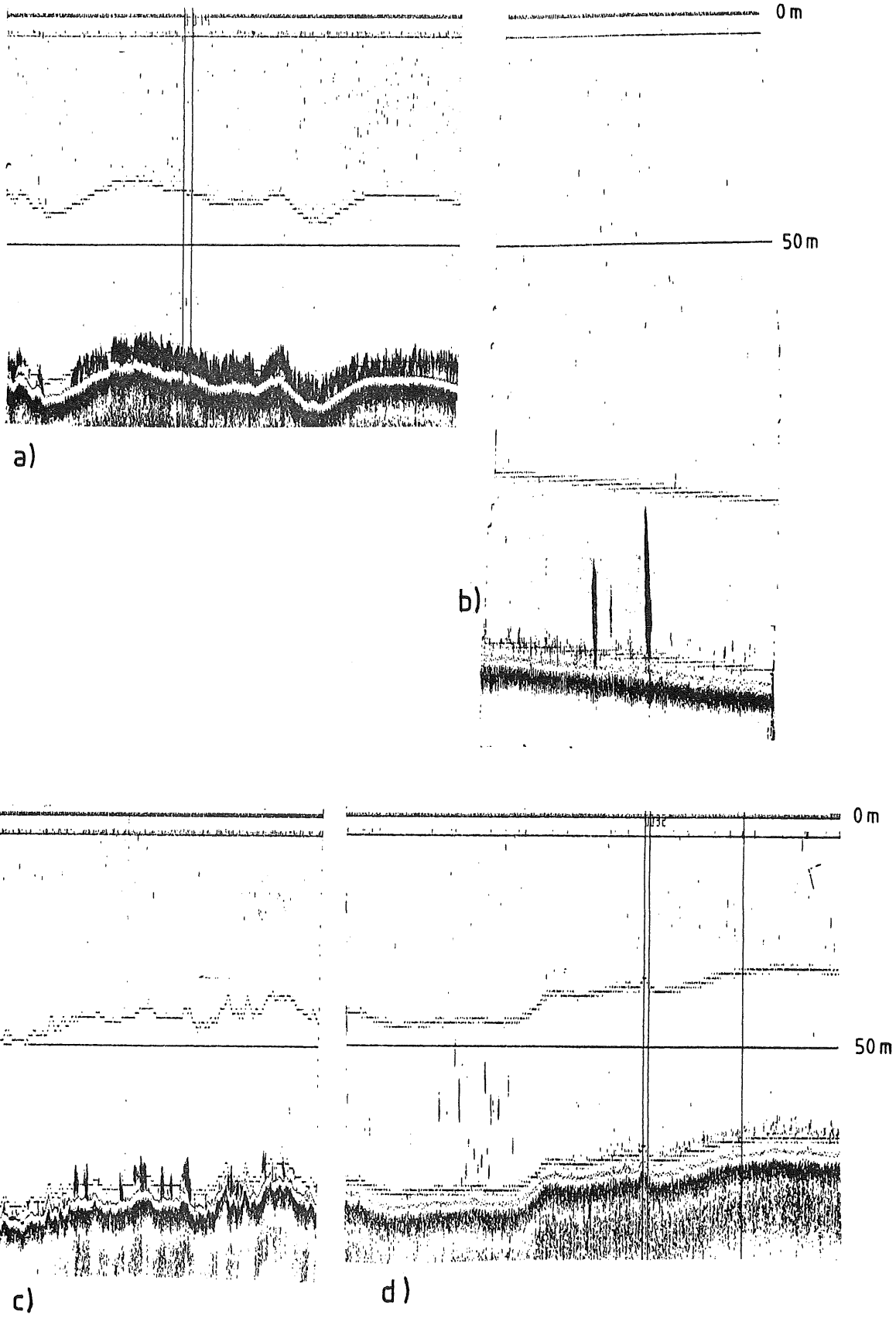

Figure 10

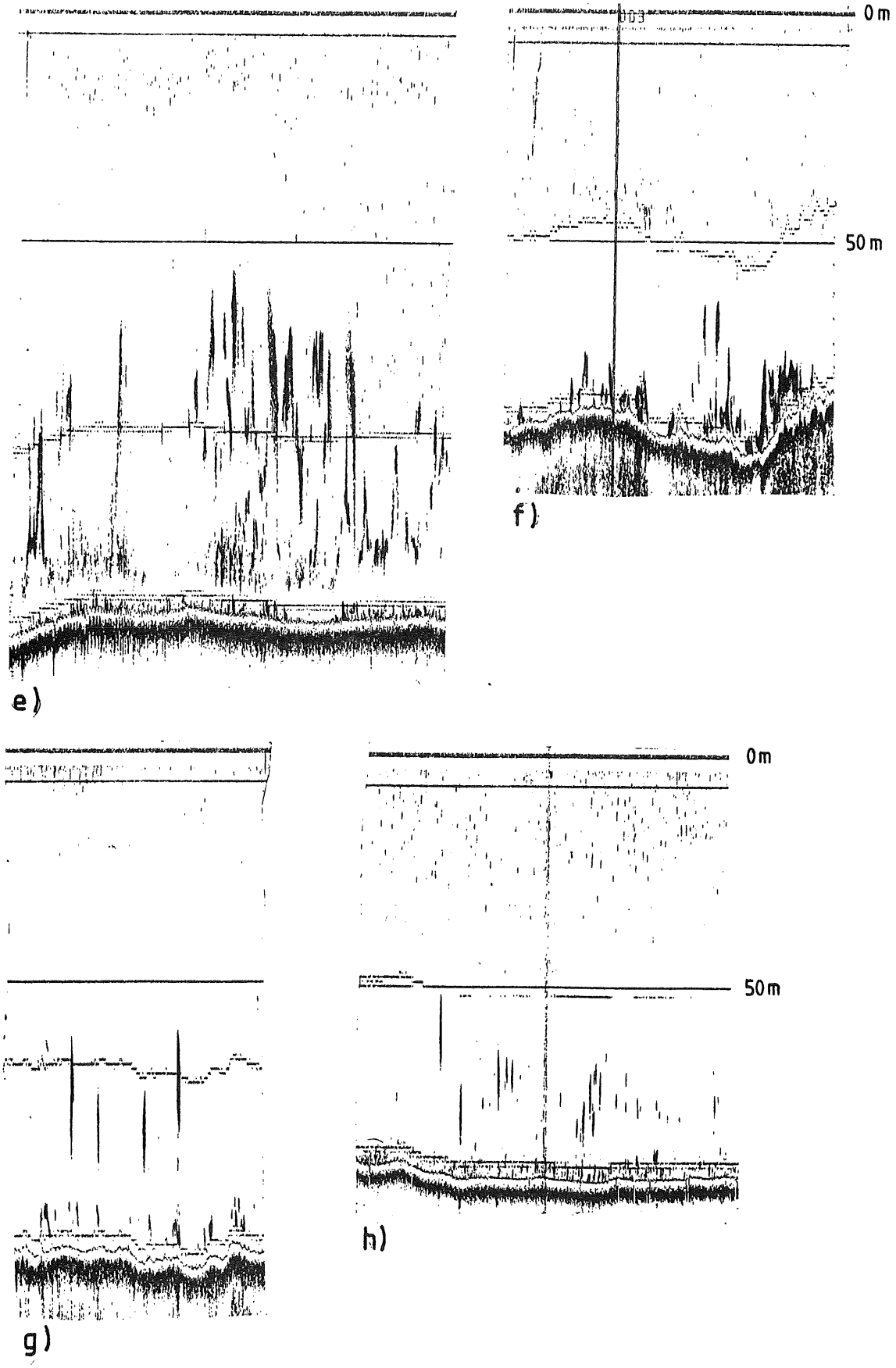

Figure 10 (contd.)

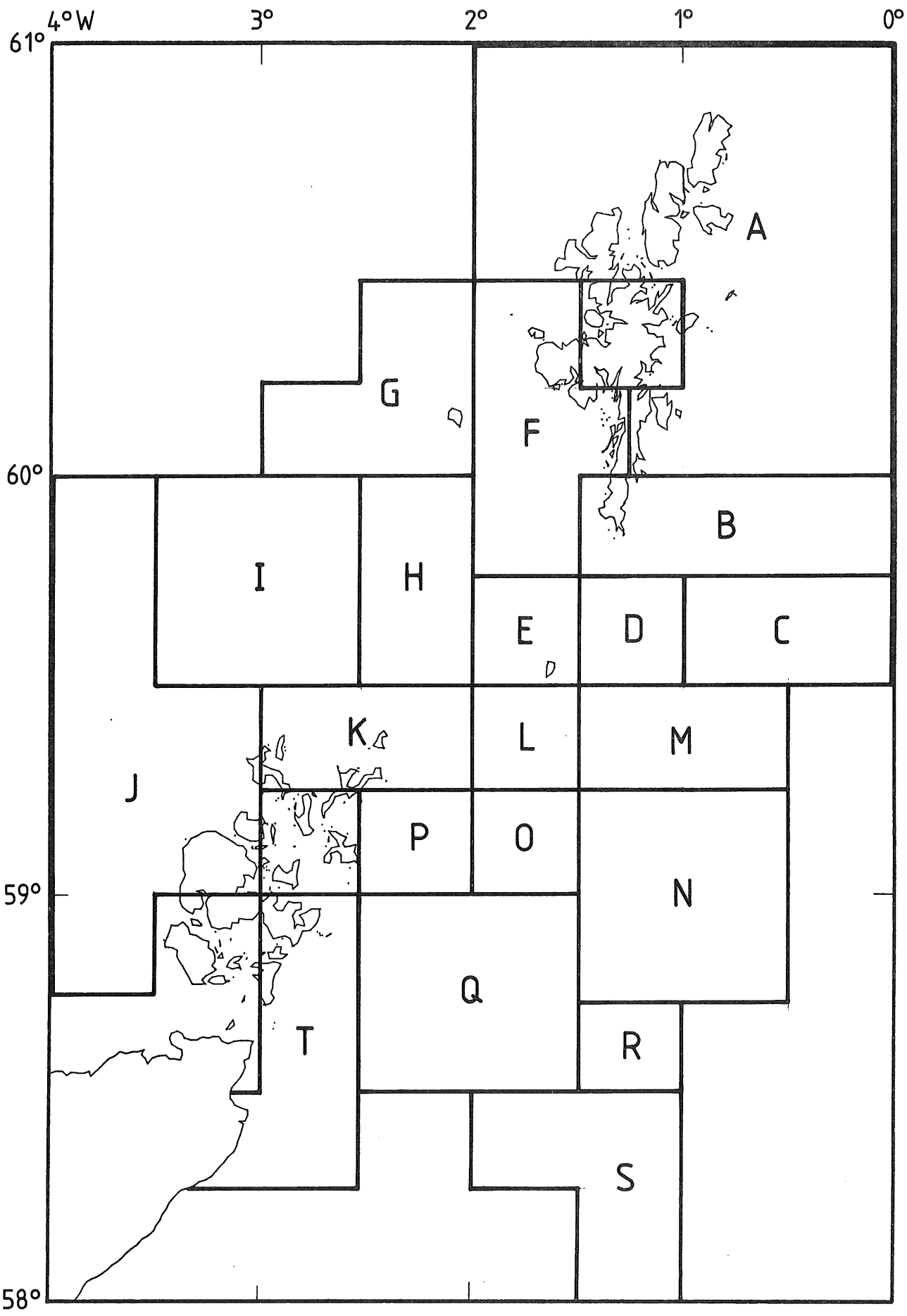

Figure 11. Sub-areas referred to in Table 12 in which different target strength values were used to convert integrator values to fish density.

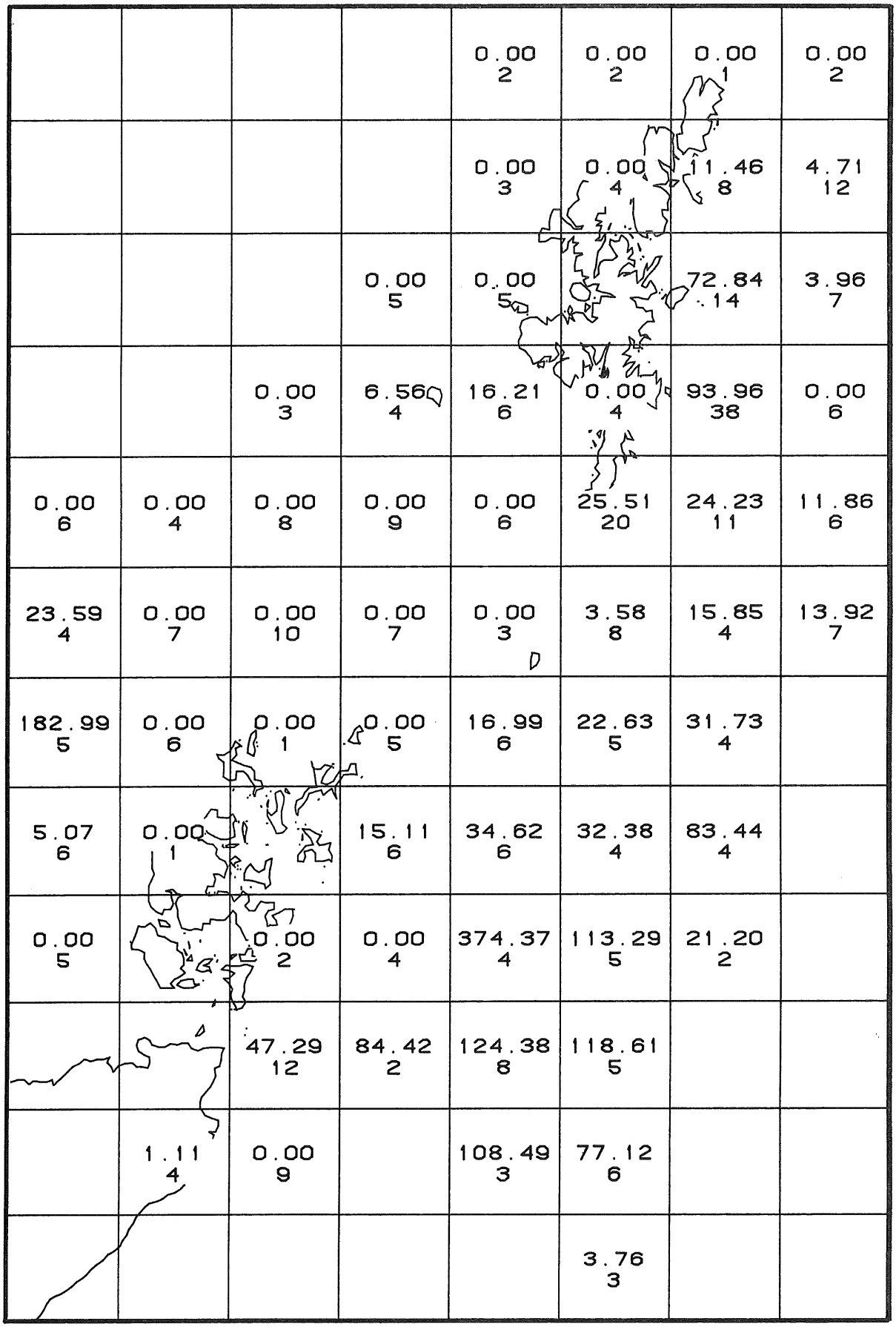

Figure 12. Estimated numbers of herring (x 10^{-6}) (upper figure) and number of half-hour integrations (lower figure), FRV "Scotia"

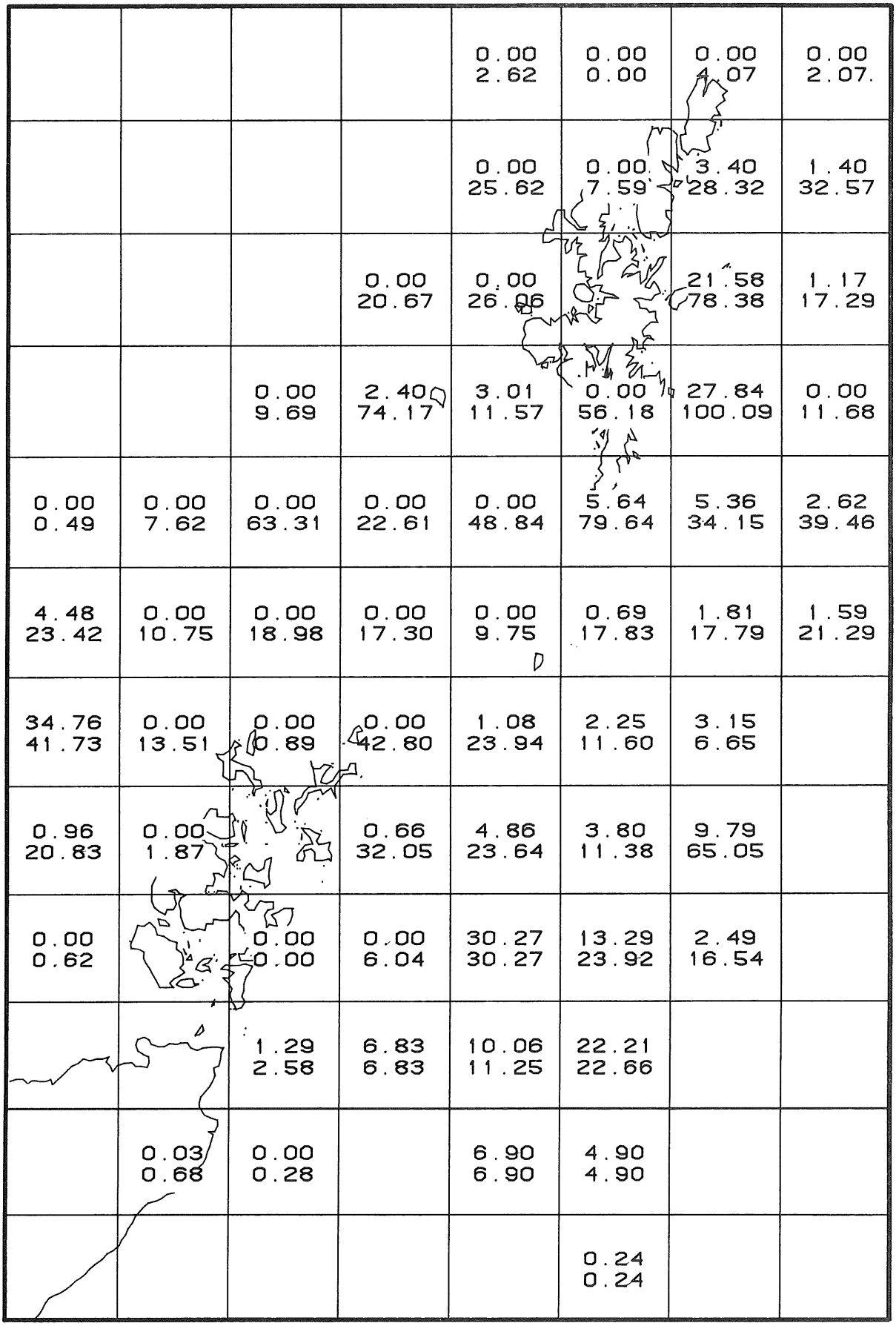

Figure 13. Estimated biomass of herring (t x 10^{-3}) (upper figure) and estimated biomass of all fish species (lower figure), FRV "Scotia"