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REPORT ON THE 1982 HERRING ACOUSTIC SURVEY IN THE NORTHWESTERN NORTH SEA

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INTRODUCTION

In accordance with Council Resolution 1981/2:22, a coordinated acoustic survey of herring stocks was carried out in the northwestern North Sea in July 1982. Plans for the survey are described in CM 1982/H:4. Vessels from Norway and the UK took part. This report contains reports on the cruises of the participating vessels with a comparison of the results.

PRELIMINARY REPORT ON THE SURVEY SOUTH AND EAST OF SHETLAND 9-18 JULY 1982 BY RV "G O SARS"

Methods

Distribution and abundance of herring were estimated by aid of echo integration and trawling. A Simrad EK 400/38 scientific echo sounder and a Simrad QM echo integrator were used for echo integration.

Settings and technical data:-

Frequency: 38 kHz
Transducer: 45 x 48 cm, nickel
10 log Ψ: -23.2 dB
TVG and Gain: 20 logR + 2αR - 10 dB, where α = 0.008
Threshold: approx 40 millivolts
Bandwidth: 3.3 kHz, pulse length 1.0 ms
SL + VR = 132.7 dB, measured by integrating over the echo from a -33.6 dB (60 mm) copper sphere (7 July 1982)
Basic range: 150 m

A 19 kHz sonar was run continuously, mostly at 1250 m basic range. A 120 kHz sonar was used for measurements of doppler shift in echoes received from herring. Average cruising speed was 10.5 knots. Hydrographic measurements were made with a CTD-zonde. A pelagic trawl with maximum opening of 16 x 16 m and a bottom trawl with 20 x 6 opening were used for sampling and identification of echo recordings. In addition an underwater camera was tried for identification of fish.

For each trawl catch species and size composition were recorded. Stomachs were preserved from saithe and mackerel. Herring samples were frozen for later examinations of maturity stage and age.

Average integrator values per nautical mile were obtained every two nautical miles sailed. Integrator readings were separated into two categories: fish recordings containing herring and other recordings. Average values (M_F) for the first category were calculated within each quarter statistical square.

Integrator values were converted to biomass by applying target strength values recommended by the "1982 planning group on ICES-coordinated herring and sprat acoustic surveys" (ICES, CM 1982/H:4). These values may be fitted by the equation TS = -10 log $\bar{L}$ -20.6 dB per kg. ($\bar{L}$ is average fish length (cm)). The corresponding conversion factor for the equipment used is

$$C = 16.7\ \bar{L}\ \text{kg/(n. mile)}^2 *$$

per mm integrator deflection.

Within squares the biomass of fish recordings containing herring was
(1) calculated as $B_F = M_F\ 16.7\ \bar{L}_F\ A$, where A is the area of the square. The average fish length, $\bar{L}_F$, was calculated for three different sub-areas (indicated in Figs 2 and 3). Only pelagic trawl catches giving more than 10 kg total catch were regarded as representative. Herring biomass was estimated by applying the average weight-fraction of herring within the same sub-areas.

After the survey all echo recordings were re-examined and attempts were made to "judge" (from the appearance of the recordings) how much the herring contributed to the integrator values. These "pure" values were averaged within squares (M_H) and the biomass of herring was calculated
(2) as $B_H = M_H\ 16.7\ \bar{L}_H\ A$, where $\bar{L}_H$ is average length of herring within the sub-area.

Results

Figure 1 shows the survey grid and stations. Herring seemed to occur over most of the area surveyed. The eastern limit is indicated in Figure 3. During daytime most of the herring were found in small schools at 50-100 m depth, usually 10-15 m above the bottom (see Fig. 4). Some of the schools rose and scattered during the darkest hours of the

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* This value also contains a factor of 1.5 correcting for wrong Pulse Repetition Frequency (PRF)-compensation in the echo integrator.

night. The herring were mixed with some whiting, haddock and Norway pout. It was difficult to obtain proper sonar contacts because of unfavourable fish distribution and temperature gradients.

Table 1 shows the composition of the trawl catches. Some of the hauls gave very low catches because the fish tended to avoid the trawl during daytime. Therefore many of the fish recordings were difficult to identify. Figure 4 shows one example of unidentified recordings. The biggest herring seemed to be the most difficult to catch.

Length distributions of herring are shown in Table 2. Table 3 shows the average fish length and average weight-percent of herring for the trawl catches regarded as representative.

Figure 2 shows herring biomass within 15 x 15 n. mile squares calculated from equation (1), while Figure 3 shows herring biomass calculated from equation (2).

The biomass estimates within sub-areas are compared in Table 3. The table also shows th estimates obtained when pelagic trawl catches made by FRV "Scotia" were combined with trawl catches made by RV "G O Sars".

It was agreed to use the four 15 x 15 n. mile squares indicated on Figure 2 for inter-ship comparisons. Two nearly complete coverages of this area with a 5 mile survey grid were made. The results are shown in Table 4. The averaged trawl data used for the middle sub-areas (Table 3) was used for both coverages.

Only three small samples of maturity stages were worked up during the survey. They indicate that about 70% of the herring in the northern sub-area, about 55% in the middle sub-area and about 30% in the southern sub-area were in stages 4 or 5. (No stage 6 was recorded.) If those stages represent the fish that will spawn during autumn 1982, the spawning stock estimate is 93 000 tonnes. (Maturity stages will be further analysed from frozen samples.)

REPORT OF SURVEY BY FRV "SCOTIA", 7-26 JULY 1982

The survey track and positions of trawl hauls are shown in Figure 5, and the details of the acoustic equipment and settings in Table 5. Three calibrations of the acoustic equipment were carried out during the survey and the results are given in Table 5. The four quarter statistical rectangles chosen for detailed coverage (Fig. 2) were surveyed on a 5 mile grid from 13-14 July.

Echo traces attributable to fish were widely distributed over much of the survey area, mostly occurring as relatively dispersed traces within 10-20 m of the seabed. Representative traces shown by trawling to be due to herring are shown in Figure 6. Integration was carried out over half hour periods (5 n. miles). Within each half-hour period,

that part of the echo integrator reading attributable to fish echo traces was extracted by summing the increments associated with shoals on the analogue trace (Fig. 6a), and ignoring the slope associated with plankton traces (Fig. 6b). In this way reverberation from diffuse planktonic organisms and noise were eliminated. During the hours of darkness (approx 2130-0230 GMT) fish traces became more diffuse and in some cases ascended towards the surface. At this time they were not separable from plankton traces and the integrator survey was therefore discontinued.

The identity of the fish echo traces was established from the results of trawl hauls (Fig. 5). During the cruise, 32 hauls were made using a Jackson midwater trawl fitted with a 20 mm mesh codend and the details are given in Table 6. Out of 31 valid hauls, herring were caught in 23 and were the predominant species in 16, indicating that herring were the main component of the fish traces in many of the areas surveyed. Other species of fish were caught usually in smaller quantities - whiting mainly southwest of Shetland and east of Orkney; and mackerel around Orkney and east of Shetland. Although adult Norway pout were caught in significant quantities in two hauls only, 0-group Norway pout and 0-group sandeels were frequently meshed in the funnel of the net. In one haul in midwater well clear of the bottom east of Shetland the net contained large numbers of 0-group haddock.

Herring were usually associated with well-defined high-intensity echo traces which recorded very markedly on the analogue recorder. The proportion of the integrator values from fish traces that was attributable to herring was estimated in two ways, firstly by attempting to identify traces from their appearance and the results of nearby trawl hauls, and secondly using the proportion of each species in the nearest trawl hauls made by either the "Scotia" or the "G O Sars". As a rule no difficulties were encountered in sampling echo traces by trawl and characteristic traces were identified in most areas.

Target strength values of herring used to convert the integrator recordings to fish density were those based on the target-strength (TS) length relationship given in ICES CM 1982/H:4. The TS values used in each sub-area were calculated from length compositions of herring in relevant trawl hauls, and are given with the relevant areas in Figure 7a. Since other species have different target strengths it is necessary to make assumptions about their value in order to partition the integrator values between component species. The TS values for gadoids and mackerel were assumed to be -34 dB ref 1 kg, and -45 dB ref 1 kg respectively.

The total biomass of herring per quarter statistical rectangle is given in Figure 8 for the analysis based on trace identification, and in Figure 9 for the analysis based on allocation by the composition of trawl hauls in thevicinity. In addition, to give an indication of an absolute upper limit, fish biomass was estimated (within the constraint of the TS values used) assuming all fish traces were attributable to herring, ie using the TS values of herring to convert the total integration attributable to fish. It should be stressed that this is not an estimate of total fish biomass because of the differences in TS of different species.

The estimates of herring biomass are 233 x 10^3 tonnes by trace identification and 188 x 10^3 tonnes by trawl haul composition. The estimated upper limit to the biomass assuming all fish traces were caused by herring was 412 x 10^3 tonnes and herring traces therefore accounted for 46-57% of the total integration. The estimated biomass of herring in areas south of Shetland chosen for detailed coverage is given in Table 4.

Biological Data

The herring caught during the survey were variable in size (Table 7). Large herring were found around the north of Shetland and in the northern Moray Firth. A mixed length distribution was recorded northeast of Orkney and around southern Shetland, while south of Fair Isle most were smaller herring (24-25 cm mode). The maturity stages followed that of size (Table 8). In the north the large herring were in stage 4, while south of Shetland the percentage of this maturity stage was only 35-50%. One sample offshore east of Shetland contained 35% at stage 8 which were probably spring spawners, and another northeast of Orkney contained 26% at this stage. The only area with significant numbers or ripe herring, including some ripe and running, was close inshore in the northern Moray Firth. Relatively few immature herring were caught.

Separate otolith samples of herring were taken for the sub-areas shown in Figure 7b. Age compositions for each sub-area are given in Table 9. There was a wide variation in age composition between areas, and to obtain an overall age composition those in Table 9 have been weighted by the estimated number of fish in each area obtained from the echo integration. Overall, the predominant age group was 2-ringers (1979 year-class), with 3-ringers (1978), 5-ringers (1976) and 7-ringers (1974) also well represented.

DISCUSSION

Following the plans put forward by the Acoustic Survey Planning Group (ICES CM 1982/H:4), the two ships participating in the survey in 1982 carried out an intensive survey of one statistical rectangle south of Shetland to obtain an estimate of the variance of the estimated biomass (Table 4). In the case of "G O Sars" which carried out two surveys two days apart, the difference between estimates was 22% of the mean of the two surveys using the analysis based on trawl allocation, and 42% using the analysis based on identification of individual traces. There was also a difference between the results using the two methods of analysis, which may have been due to the fact that a rather conservative approach was used on "G O Sars" in identifying herring traces. Comparing the results of the two ships, the "Scotia" estimate was higher using trace identification and lower by trawl composition analysis (Table 4). The two methods of analysis used on "Scotia", however, gave very similar results.

Over the 27 rectangles surveyed by both ships, the estimates of herring biomass made by "Scotia" and "G O Sars" were similar. The herring biomass estimates for the areas covered are as follows:-

		Area covered by "G O Sars"	Larger area covered by "Scotia"
G O Sars	Allocation by trawl haul catches	203700 t	-
G O Sars	Allocation by identification of traces	166800 t	-
Scotia	Allocation by trawl hauls catches	142500 t	188000 t
Scotia	Allocation by identification of traces	180000 t	233000 t

Since the "Scotia" estimates for the total area covered are 1.3 times the "Scotia" estimates for that part of the area covered by "G O Sars", the "G O Sars" estimates can be raised by this factor to give comparable estimates of the total biomass. Estimates for the entire Orkney-Shetland area obtained by both ships range from 188-265 thousand tonnes.

The biological data indicate considerable differences from 1981. Two-ring herring formed the predominant age group, whereas in 1981 this age group was recorded in significant quantities only in August outside the area surveyed in July.

The 1976 year-class which was abundant in 1981 was again well represented, but the 1973 year-class which was the predominant age group in 1981 was poorly represented. Instead, the 1974 year-class was prominent, especially in the area around northern Shetland. In addition, according to the evidence from the otoliths, spring spawners made up an estimated 6% of the total.

Table 1. Summarised trawl catch data , G O Sars

Pelagic-trawl catches made by "G.O.Sars" 10-17 July 1982

Haul No	Position	Data	Hour (GMT)	Dur. (Min.)	Catches in kg		Predominant species
					Herring	Others	
243	60°00'N 00°30'W	10/7	0800	30		5,2	Haddock, Whiting
244	59°56'N 00°49'W	10/7	1055	60		2,6	Haddock, Whiting
245	59°42'N 00°50'W	10/7	1400	20		1,3	Haddock, Whiting
247	60°00'N 01°29'W	11/7	0245	45	280,0	52,0	Herring
248	59°55'N 01°54'W	11/7	0936	10	333,0	57,0	Herring
249	59°46'N 01°38'W	11/7	1225	45	105,0	1,0	Herring
250	59°36'N 01°40'W	11/7	1710	25			No catch
253	59°58'N 01°28'W	13/7	0215	15	86,0	3,0	Herring
254	60°00'N 02°00'W	13/7	0530	15		7,0	Mackerel
255	59°53'N 01°33'W	13/7	0915	12	175,0	49,0	Herring
256	59°43'N 01°30'W	13/7	1440	15			No catch
257	59°34'N 02°00'W	13/7	2005	20	1,8	3,2	Whiting
259	59°33'N 00°40'W	14/7	1855	8	177	3	Herring
260	59°00'N 01°50'W	15/7	0500	30	33,6	5,1	Herring
261	58°50'N 01°42'W	15/7	0805	20			No catch
263	59°03'N 00°25'W	15/7	2105	15		18,0	Norway pout (0-gr.)
265	59°50'N 00°25'W	16/7	0405	25	0,7	7,5	Whiting
266	59°55'N 01°03'W	16/7	0925	30	349,0		Herring
267	59°53'N 00°34'W	16/7	1300	32		0,5	Whiting
268	60°05'N 00°56'W	16/7	1903	94	2,9	12,1	Whiting
269	60°05'N 00°58'W	16/7	2153	60	720,0	165,0	Herring
271	60°14'N 00°30'W	17/7	0745	20		1,4	Haddock (0-gr.)
272	60°20'N 00°03'W	17/7	0955	10		4,8	Mackerel
273	60°49'N 00°01'W	17/7	2010	13		454,0	Norway pout
					2264,0	853,0	

Bottom-trawl catches made by "G.O.Sars" 10-17 July 1982

Haul	Position	Date	Hour (GMT)	Dur. (Min.)	Catches in kg		Predominant species
					Herring	Others	
246	59°30'N 01°20'W	10/7	2150	30	1,6	378,0	Whiting
251	59°20'N 01°38'W	11/7	2305	30	1,5	198,0	Haddock, N.pout
252	59°25'N 01°08'W	12/7	1735	35		150	Haddock
258	59°49'N 01°06'W	14/7	0925	30		73	Cod, Haddock
262	58°40'N 01°56'W	15/7	1342	60	0,3	694,0	Haddock, Whiting
264	59°35'N 00°10'W	16/7	0113	15		84	Norway pout
270	60°10'N 00°44'W	17/7	0345	15		102,0	Haddock
					3,4	1079,0	

Table 2. Length distributions (%) of herring caught by "G.O.Sars" around Shetland, July 1982.

Length cm \ St.no.	247	248	249	253	255	259	260	266	269
21									
.5							1.0		
22				0.7			2.0		
.5			0.5	0.7	1.1	1.0	8.0		
23	0.8				0.5		17.0	0.9	
.5	0.4	0.4	0.5	1.4	1.1		16.0	2.6	
24	0.8	2.2	3.0	1.4	2.7		10.0	3.4	
.5	0.4	5.2	3.0	2.1	3.8		16.0	2.6	
25	3.1	19.7	11.2	9.7	12.5	5.0	8.0	1.7	0.9
.5	7.0	16.2	13.7	6.9	12.5	3.0	12.0	10.3	0.9
26	8.6	23.1	24.4	26.9	12.5	5.0	5.0	8.6	3.6
.5	7.4	9.6	10.2	13.8	13.6	7.0	3.0	15.5	4.5
27	8.9	10.0	9.6	5.5	6.5	6.0	1.0	15.5	5.5
.5	3.9	5.7	4.1	6.9	3.3	8.0	1.0	10.3	3.6
28	7.4	2.6	7.1	6.2	5.4	4.0		8.6	11.8
.5	7.0	1.7	2.0	4.1	4.3	8.0		3.4	4.5
29	7.0	1.3	2.0	2.8	4.3	8.0		2.6	2.7
.5	5.4	0.4	1.5	2.1	4.3	9.0		2.6	5.5
30	3.5	1.7	1.5	2.1	3.8	6.0		2.6	10.0
.5	4.3		1.0	0.7	1.1	6.0		0.9	4.5
31	3.9		0.5	1.4	1.6	3.0		1.7	0.9
.5	3.9			2.1	0.5	4.0		0.9	3.6
32	6.6		0.5	2.8	3.3	7.0		0.9	15.5
.5	3.9		1.0			2.0		1.7	10.9
33	3.1		1.0		1.1	3.0		1.7	5.5
.5	1.2					2.0		1.7	
34	0.4					2.0		0.9	2.7
.5	0.4								0.9
35			0.5					0.9	1.8
.5	0.4								
36									
.5	0.4								
Nos measured	257	229	195	145	184	100	100	116	110

Table 3. Subarea-estimates of average fish length, target strength and weight per cent of herring, together with biomass estimates. Numbers in brackets are based on the trawl catches from R/V "G.O. Sars" and R/V "Scotia" combined.

Subarea	*Trawl stations regarded as representative	Average fish length (cm)		Average target strength (dB)		Average weight per cent herring	Herring biomass (1000 tonnes)	
		Total catch	Herring	Total catch	Herring		Based on catch composition	Based on judging
North	268, 269	29.1	30.7	-35.2	-35.5	51.3	42	67
	(103, 104, 106)	(29.8)	-	(-35.3)	-	(58.8)	(50)	-
Middle	247,248,249,253, 255,259,266	27.3	27.2	-35.0	-34.9	91.7	35	62
	(94,96,97,98,99, 100)	(27.2)	-	(-34.9)	-	(85.9)	(88)	-
South	260	24.1	24.1	-34.4	-34.4	86.2	68	39
	(107, 108)	(24.6)	-	(-34.5)	-	(93.9)	(74)	-
Total							205	167
							212	-

* Scotia trawl haul numbers given in parentheses

TABLE 4 Estimates from repeated coverages of the area between 59°30' and 60°00'N and between 01°00' and 02°00'W.

	(Date)	Herring Biomass (1000 tonnes)	
		Based on catch composition	Based on "judging"
G O Sars	10-11 July	38.8	31.5
G O Sars	13-14 July	48.2	20.6
Average		43.6	26.0
Scotia	13-14 July	35.6	37.4

Table 5

Details of acoustic equipment and settings, FRV Scotia

Echo Sounder	Simrad EK400
Frequency	38 kHz
Receiver Gain	-10 dB + 20 log R + (2 x 0.008 R)
Pulse length	1.0 ms
Bandwidth	3.3 kHz
Transducer	ceramic 30 x 15 cm (34 elements)
Effective Beam Angle	-17.4 dB (measured)
Basic Range	250 m

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

1)	10/7/82	= +52.3 dB// 1 V rms
2)	20/7/82	= +52.6 dB// 1 V rms
3)	25/7/82	= +52.6 dB// .1 V rms
	VR + SL used for survey	= -52.5 dB// 1 V rms

measured using 38.1 mm diameter Tungsten Carbide sphere with TS = -42.36 dB

Integrator	Aberdeen Digital Integrator
Effective Threshold	-20 millivolts peak
Depth range of integration	(5 m below surface
	(3 m above bottom

Table 6 Details of trawl hauls, FRV 'Scotia'

No.	Date	Time (GMT)	Duration (h. m.)	Shooting Position		CATCH (kg) HERRING	WHITING	NORWAY POUT	OTHERS	Specify	Main modal length(cm) HERRING	Remarks
89	11 July	0940	1.20	59°30'N	03°53'W	4600	c 10	c 7	c 7	Haddock	26.5 29	
90	11 July	1640	0.20	59°35'N	02°16'W	–	c 11	–	–	–	–	
91	12 July	1235	0.40	59°47'N	02°49'W	–	c 7	1	1	Haddock	–	Meshing of 0-group pout and sandeels
92	12 July	2000	0.30	60°00'N	02°06'W	c 16	–	–	1	Haddock	25	meshed 0-group haddock
93	12 July	2110	0.20	60°00'N	02°08'W	c 40	–	–	–	–	26	
94	13 July	0750	1.00	59°54'N	01°46'W	175	103	–	12	Mackerel Haddock	25.5 16, 30.5	
95	13 July	0930	0.35	60°00'N	01°48'W	–	–	–	4	0-group haddock + whiting	–	Meshed 0-group haddock and whiting
96	13 July	1740	0.35	59°53'N	01°31'W	254	c 5	–	2	Haddock Mackerel	26 28.5	
97	14 July	0730	1.00	59°56'N	01°12'W	850	c 15	230	5	Haddock Sebastes	26 31.5	
98	14 July	1336	0.40	59°39'N	01°06'W	190	c 2	–	1	Haddock	26.5 29.5, 31.5	Meshed sandeels
99	14 July	2020	0.15	59°46'N	01°58'W	24	72	2	1	Haddock	25.5	
100	15 July	1238	0.37	60°26'N	01°37'W	–	1	4	1	Haddock mackerel, spurdog	–	Meshed 0-group pout
101	15 July	2030	0.40	60°00'N	01°26'W	520	17	–	1	Spurdog	25.5 26.5	
102	16 July	0730	0.30	60°41'N	01°16'W	254	–	2	–	–	33 26.5, 29.5	Meshed 0-group pout
103	16 July	1430	0.48	60°41'N	00°31'W	8	–	1	2	Haddock Gurnard	25.5 (32)	
104	16 July	1745	1.15	60°33'N	00°44'W	1907	–	18	1	Haddock	32 30, 28	
105	17 July			INVALID								
106	17 July	1030	0.45	60°02'N	00°55'W	2	1	2	12	Haddock Sebastes	–	Gear fishing incorrectly
107	18 July	0825	1.00	59°21'N	01°53'W	220	1	–	3	Mackerel	25.5	
108	18 July	1415	1.45	59°02'N	01°48'W	190	1	–	4	Mackerel	24	
109	21 July	0955	1.05	60°19'N	00°35'W	–	–	1	1		–	
110	21 July	1500	1.00	60°11'N	00°06'W	220	–	–	175	Saithe 95 kg Mackerel 40 kg Pollack 32 kg	26 29, 30, 31, 34.5	

Table 6 (contd.)

No.	Date	Time (GMT)	Duration (h. m.)	Shooting Position	CATCH (kg) HERRING	WHITING	NORWAY POUT	OTHERS	Specify	Main modal length(cm) HERRING	Remarks
111	21 July	1645	0.30	60°10'N 00°14'W	–	–	–	32	0-group haddock	–	
112	21 July	2015	0.30	60°09'N 00°53'W	80	c 2	15	1	–	32 27.5,29.5	
113	22 July	0730	1.00	59°19'N 01°07'W	760	14	5	2	–	25 26.5	Meshed 0-group sandeels
114	22 July	1400	1.00	58°50'N 01°16'W	16	2	64	1	–	25.5	
115	23 July	1415	0.30	59°28'N 03°45'W	3180	–	–	–	–	29.5 30.5	
116	23 July	1805	0.30	59°27'N 03°09'W	–	–	–	254	Mackerel	–	Meshed 0-group pout
117	24 July	0830	0.45	58°42'N 06°00'W	953	–	–	–	–	26	
118	24 July	1400	0.30	58°32'N 05°14'W	–	–	–	8	Spurdogs Haddock	–	
119	25 July	0800	0.10	58°26'N 03°00'W	12710	–	–	–	–	31 28.5, 26.5	
120	25 July	1220	0.15	58°50'N 02°34'W	14	1040	–	61	Haddock 53 kg Mackerel 8 kg	–	Meshed 0-group sprats and sandeels

Table 7 Length distributions (%) of herring caught by FRV 'Scotia', July 1982
(Haul positions given in Table 6 and Figure 5)

Length (cm)	Haul No 89	92	93	94	96	97	98	99	101	102	103	104	106	107	108	110	112	113	114	115	119	120
15																						
				0.1																		
16				1.1					0.3													
				0.9																		
17				0.5					0.5										2.5			
				0.2																		
18																						
19									0.3													
						0.4																
20						0.4			0.1													
				0.2		0.2													2.5			
21																		0.2	5.0			
				0.6	0.3	0.2			0.5						3.7			1.0	2.5			
22	0.2			1.4	0.8	0.4			2.0					0.5	3.7			1.9	7.5	0.3		
				0.6		0.9			0.9					2.3	8.5	0.2		2.4	5.0			
23	0.3	1.6	0.4	1.9	2.1	3.2			2.0					3.2	8.1	0.8		5.6				
	0.2			0.6	1.8	2.8	1.4	1.8	2.2					5.5	11.8	1.7	0.5	4.9	2.5		0.3	
24	0.6	1.6	1.1	4.1	3.8	3.0	2.8	4.1	4.1		7.9			9.1	14.2	2.9		4.9	10.0		0.3	8.3
	0.8	3.3	2.3	4.9	3.4	2.6	3.5	5.3	7.1		7.9			11.4	9.3	2.7	0.3	11.2	15.0	0.3	2.1	
25	5.3	24.6	11.4	12.7	12.1	3.0	5.7	10.0	6.0	0.5	2.6	0.7		14.6	10.2	4.5	0.8	13.9	5.0	0.5	2.4	
	8.7	23.0	14.8	20.9	12.6	5.3	6.7	25.9	18.1	0.8	21.1	1.7		15.5	12.6	8.0	1.4	12.9	20.0	1.0	1.6	16.7
26	10.9	16.4	18.6	13.6	13.9	11.1	7.4	19.4	13.1	2.6	10.5	1.9	11.1	13.2	6.9	8.5	1.6	8.3	10.0	0.5	2.7	25.0
	11.8	11.5	15.2	11.5	13.7	9.4	12.8	14.7	17.8	6.1	10.5	1.4		7.8	4.1	6.4	3.5	9.5	2.5	2.0	3.5	16.7
27	9.5	14.8	14.8	10.3	8.7	7.0	5.7	7.6	6.3	5.9	2.6	1.7		7.3	4.1	5.3	6.0	4.9	5.0	1.8	2.7	25.0
	5.9	1.6	3.0	2.9	3.8	4.5	5.3	6.5	3.6	4.1	5.3	1.7	11.1	3.2	1.2	4.9	6.3	4.6		4.1	2.7	8.3
28	7.0		3.8	3.7	3.6	3.8	7.8	0.6	2.5	4.6	5.3	2.6		2.3	0.8	4.2	2.7	1.7	2.5	6.9	3.7	
	8.1	1.6	2.6	2.1	5.9	1.9	4.6	0.6	2.0	1.5	5.3	1.4	11.1	0.9		4.5	7.3	3.4		9.7	5.9	
29	10.4		3.0	0.8	3.8	1.7	0.7	0.6	0.9	1.3	2.6	2.6	11.1		0.4	5.9	6.0	2.9		12.2	5.3	
	6.7		2.6	0.2	2.3	1.5	4.3		0.9	3.3		2.1		1.4		4.5	7.6	1.9		14.0	4.3	
30	5.9			0.6	2.8	1.3	2.1	1.2	0.9	3.3		4.1			0.4	5.1	6.0	0.7	2.5	7.7	6.1	
	3.6		0.8	1.6	1.3	3.4	2.1		0.9	1.3		2.6		0.9		3.2	1.6	0.7		10.7	11.7	
31	2.2		1.1	0.2	0.8	3.8	3.2	1.2	1.1	5.6		5.5				4.3	4.3	0.7		8.4	12.5	
	0.6		1.1	0.4	1.5	7.3	6.7		1.4	6.9	2.6	7.2		0.5		1.9	4.1	0.2		5.9	12.5	
32	0.6		1.1	0.4	0.3	6.4	5.3		0.9	8.9	5.3	15.5	11.1	0.5		4.2	9.5	1.0		4.3	10.4	
	0.5		0.8	0.4	0.5	5.5	3.9		1.4	10.5	2.6	13.1	22.2			1.6	7.6	0.2		3.6	6.4	

Table 7 (contd.)

Length (cm)	Haul No 89	92	93	94	96	97	98	99	101	102	103	104	106	107	108	110	112	113	114	115	119	120
33			0.4			3.4	3.5	0.6	1.4	10.5	2.6	11.5				2.3	7.3			3.1	2.1	
	0.2		0.8	0.2		3.4	3.5		0.5	10.2	2.6	7.9	11.1			1.9	7.3			0.8	0.8	
34						1.5	0.7		0.5	6.1		7.2				1.3	4.1	0.2		1.8		
	0.2		0.4			0.4				4.1		3.1				2.7	2.7			0.3		
35										1.3	2.6	2.1				2.5	1.1			0.3		
										0.8		1.0				1.3	0.3					
36												1.0	11.1			1.5						
												0.2				1.0						
37												0.2				0.2						
																0.2						
No measured	369	61	264	300	388	465	282	170	353	392	38	419	9	219	146	615	368	411	40	302	373	12

Table 8 Percentage maturity stages of herring, FRV "Scotia", July 1982

Areas (see Figure 6b)	MATURITY STAGE 1	2	3	4	5	6	7	8
Northwest Shetland (16 July)	-	-	21.6	74.9	3.5	-	-	-
Northeast Shetland (16 July)	-	0.3	10.4	75.6	6.0	-	-	7.7
Southeast Shetland (14-21 July)	0.5	14.5	33.1	50.7	-	-	-	1.2
East Shetland (offshore) (21 July)	-	12.9	36.4	15.4	-	-	-	35.2
Foula (12 July)	-	2.7	54.2	40.8	-	-	-	2.3
Southwest Shetland (13-15 July)	1.5	9.2	44.7	43.4	-	-	-	1.3
South of Fair Isle (18-22 July)	-	25.7	37.6	35.1	0.7	-	-	0.9
Northern Moray Firth (25 July)	-	-	1.9	43.8	43.5	10.8	-	-
Northwest Orkney (11 July)	-	4.7	59.6	35.8	-	-	-	-
Northwest Orkney (23 July)	-	0.6	10.8	60.3	3.0	-	-	26.2

Table 9 Percentage age compositions of herring, FRV "Scotia" July 1982

Area (see Fig. 7b)	Estimated number of herring x 10^{-6}	Age (rings) 1 (1980)	2 (1979)	3 (1978)	4 (1977)	5 (1976)	6 (1975)	7 (1974)	8 (1973)	>8	Spring Spawners (all ages)
NW Shetland	39.3	0.0	21.6	7.4	11.7	17.9	0.2	33.2	5.0	1.2	1.8
NE Shetland	204.9	0.0	8.1	9.5	3.0	26.2	6.1	33.5	4.0	0.6	8.9
E Shetland (offshore)	75.8	0.0	28.7	17.3	3.4	2.6	0.3	0.4	0.4	0.0	46.7
SE Shetland	187.4	0.7	44.4	18.9	6.4	9.5	3.9	11.8	1.7	2.2	0.4
SW Shetland	126.2	2.1	75.4	12.4	4.2	3.0	1.2	0.4	1.3	0.0	0.0
Foula	115.0	0.0	73.8	16.2	2.0	2.2	0.9	0.6	0.6	0.0	3.7
NE Orkney	70.4	0.0	27.8	23.4	10.7	15.5	2.3	3.9	3.8	0.3	12.3
South of Fair Isle	296.1	5.7	74.8	15.0	1.7	1.7	0.4	0.2	0.1	0.0	0.3
Northern Moray Firth	4.8	0.0	13.2	20.6	12.4	31.3	16.2	3.5	2.9	0.0	0.0
Weighted Mean		1.9	49.3	14.9	4.1	9.3	2.3	9.7	1.7	0.5	6.2
Total	1119.8										

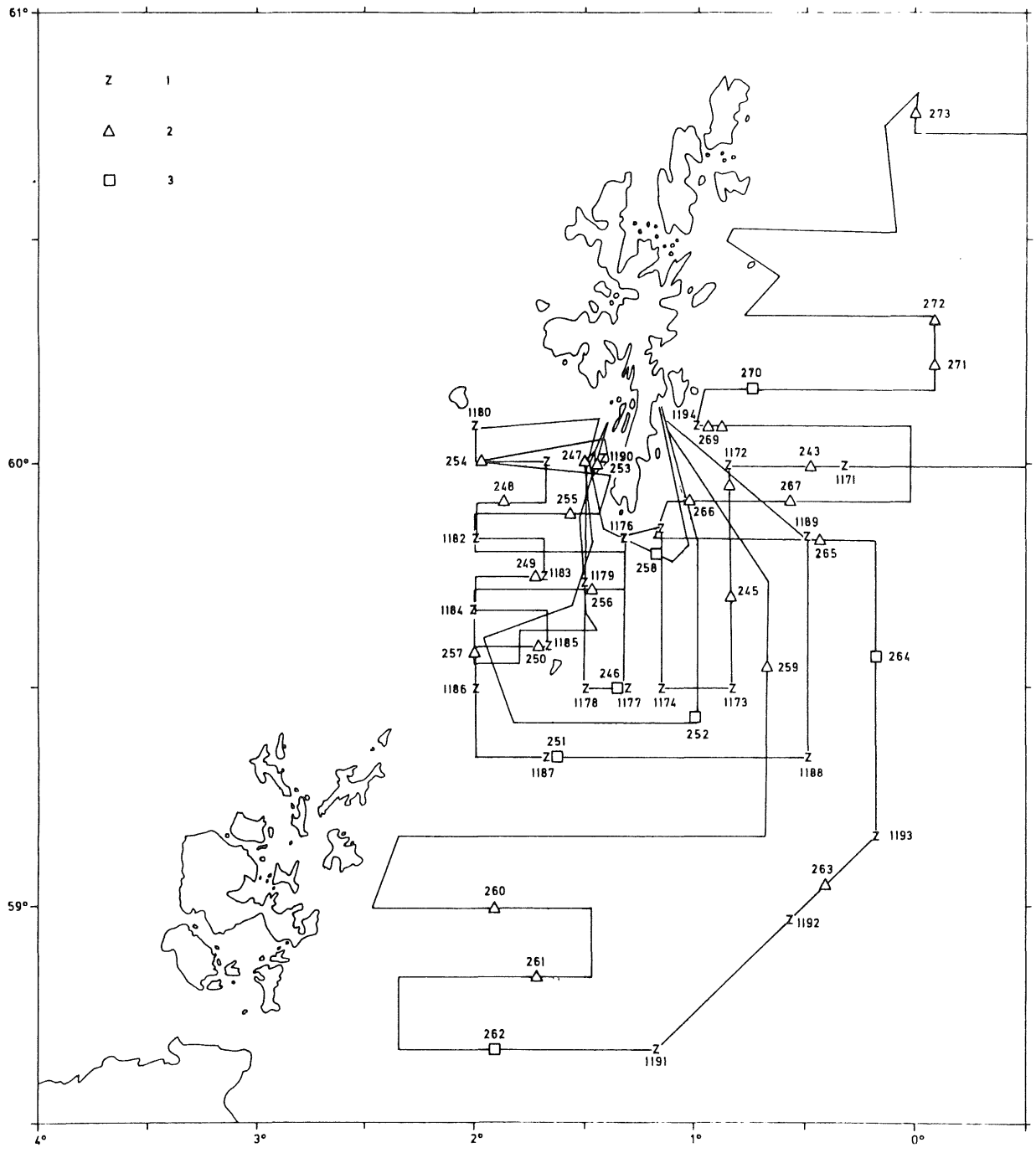


Figure 1. Survey grid and stations R/V "G.O.Sars", 10-17 July 1982.

1 : Hydrographic station (CTD-zonde)

2 : Pelagic trawl

3 : Bottom trawl

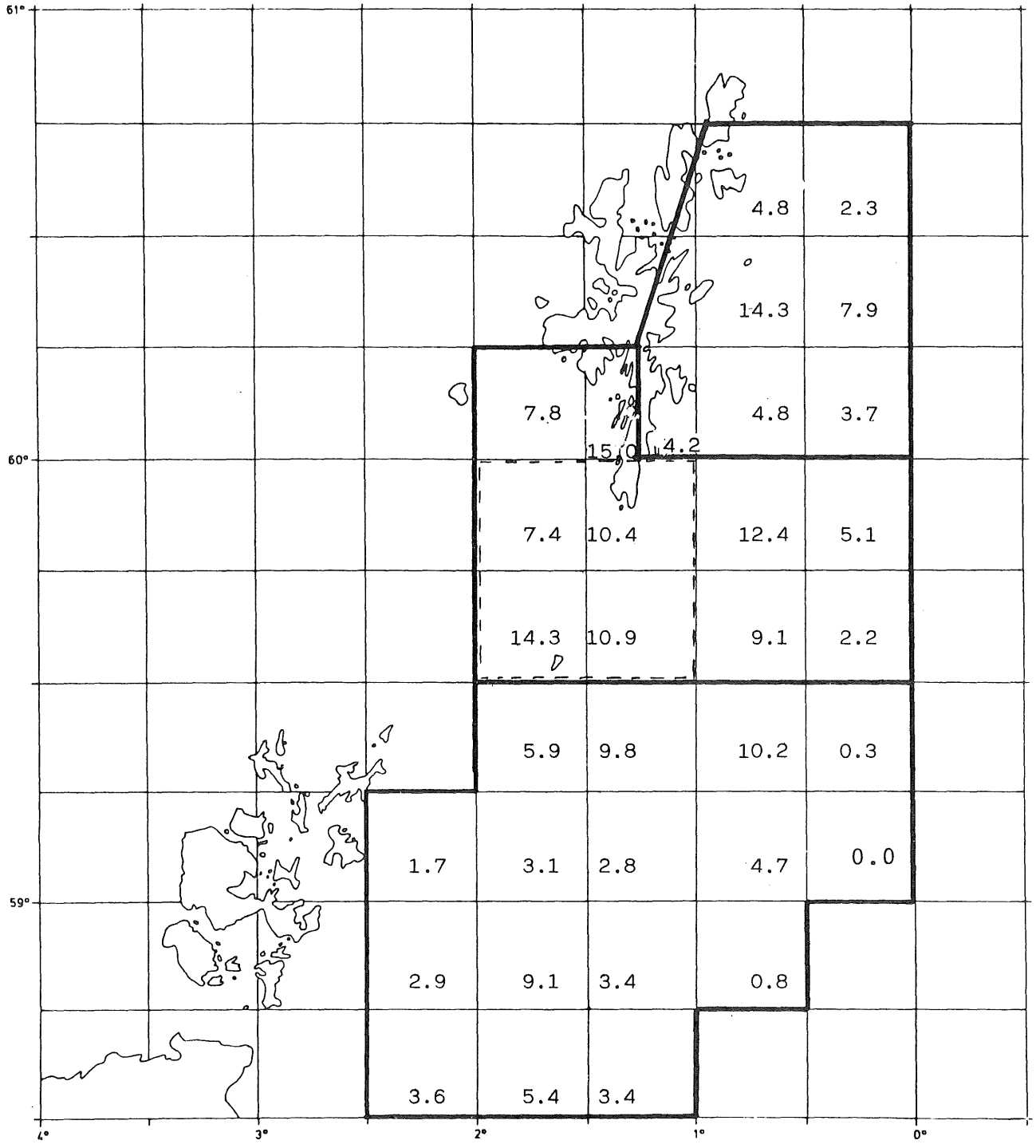


Figure 2. Herring biomass estimates based on echo integrator values for "Fish recordings containing herring" and the fraction of herring in the trawl catches. The unit is 1000 tonnes (per rectangle). The thick lines show the sub-areas used for averaging of trawl catch data. The dashed lines show the area used for inter-ship comparisons.

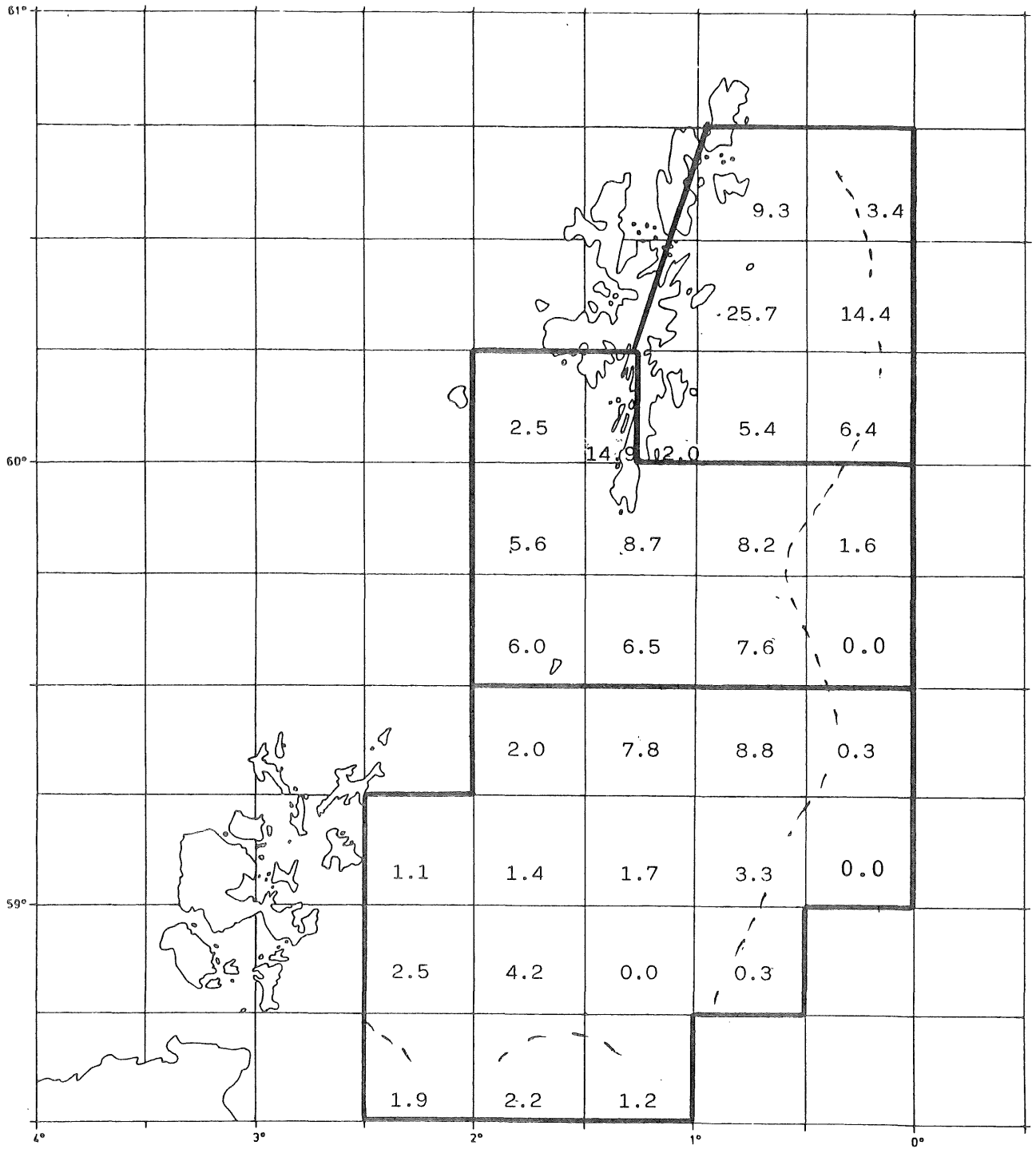


Figure 3. Herring biomass estimates (1000 tonnes) based on echo integrator values for "pure" herring. The thick lines show the sub-areas. The dashed lines indicate the eastern limit of herring recordings.

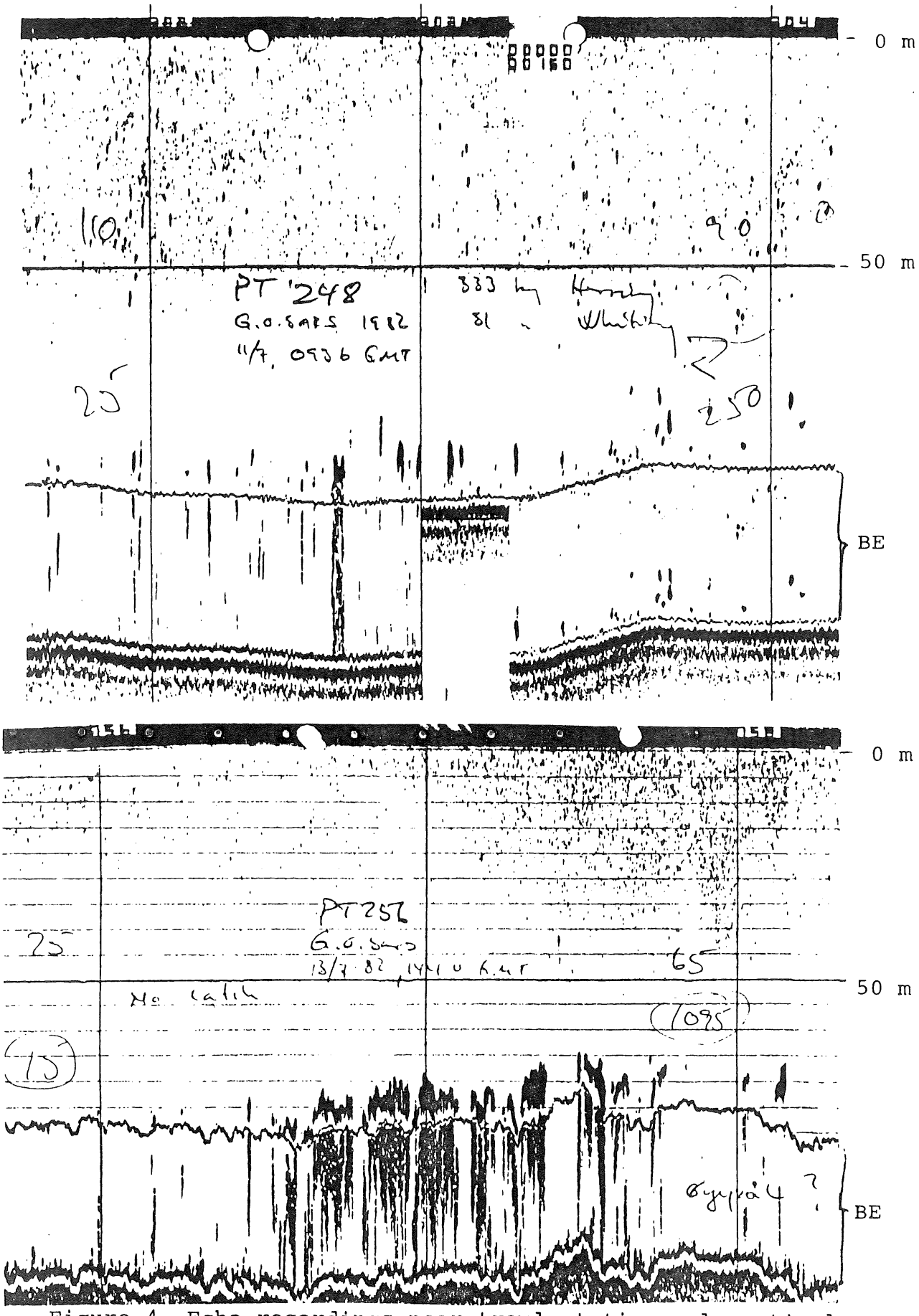
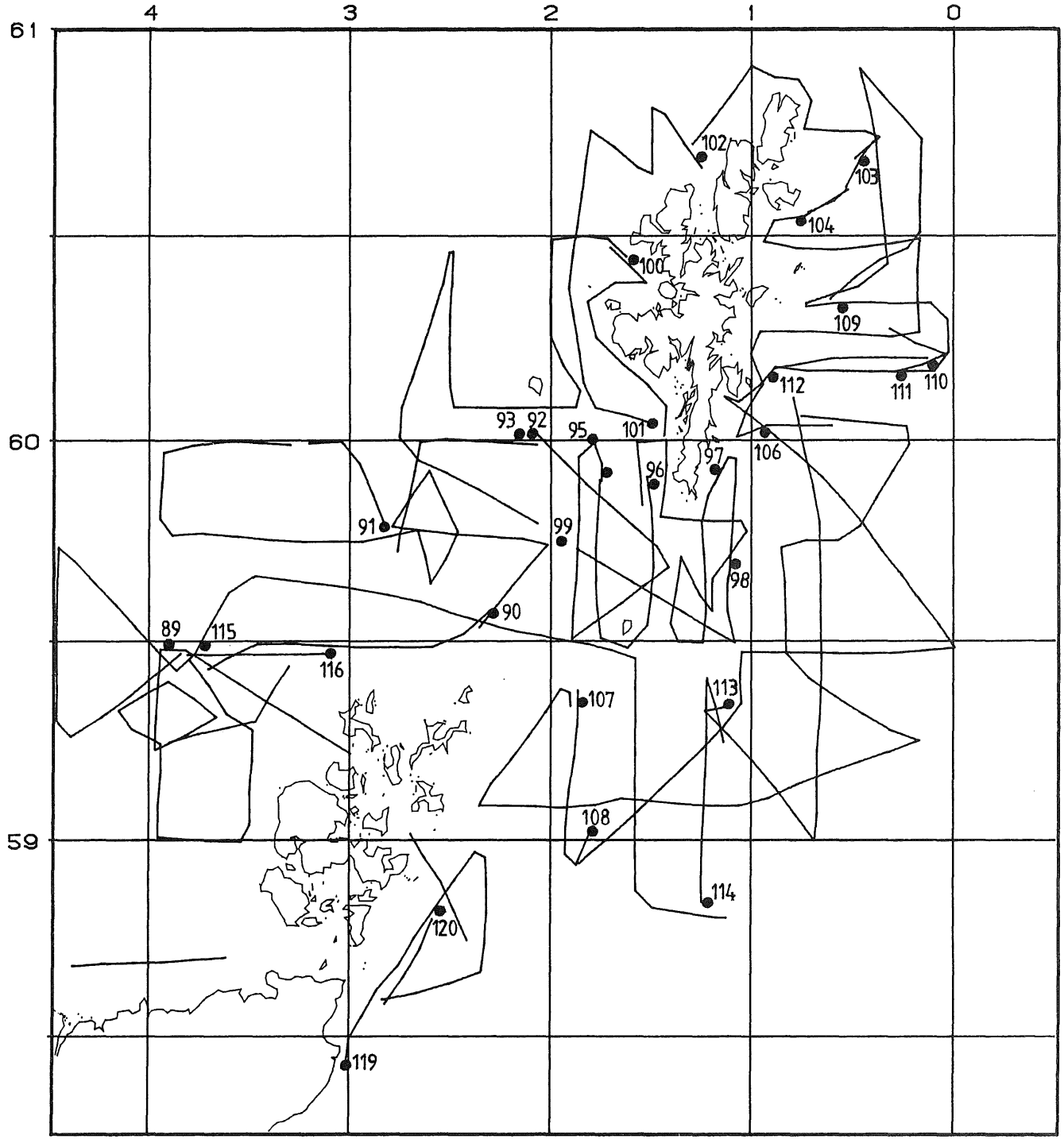


Figure 4. Echo recordings near trawl stations. 1 nautical mile between vertical lines. BE: Bottom expander (5m).
Upper: Schools identified as herring (TP 248).
Lower: Unidentified recordings. (TP256 was unsuccessful).

Figure 5 Survey track and trawl hauls FRV "Scotia"
7-26 July 1982.



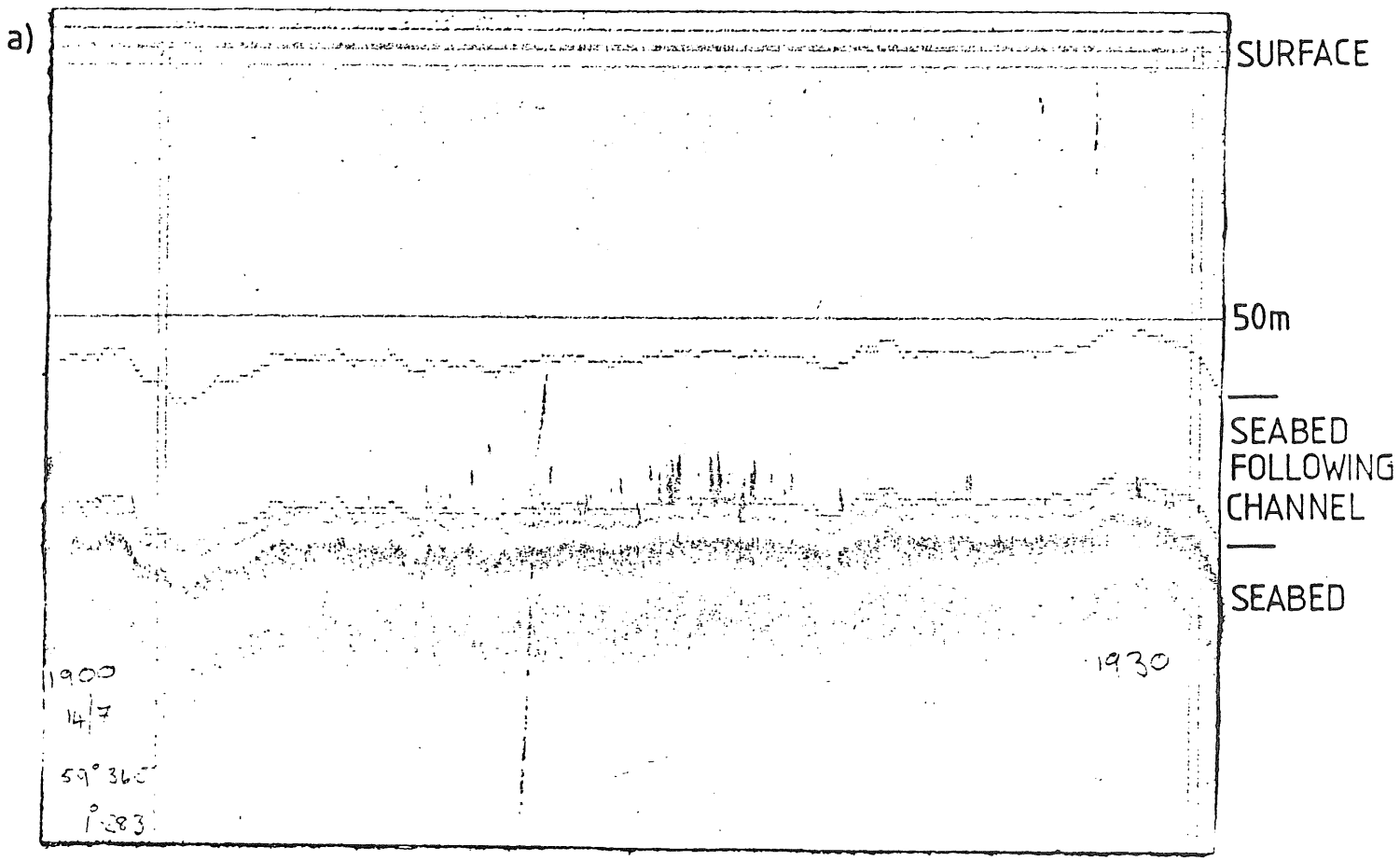
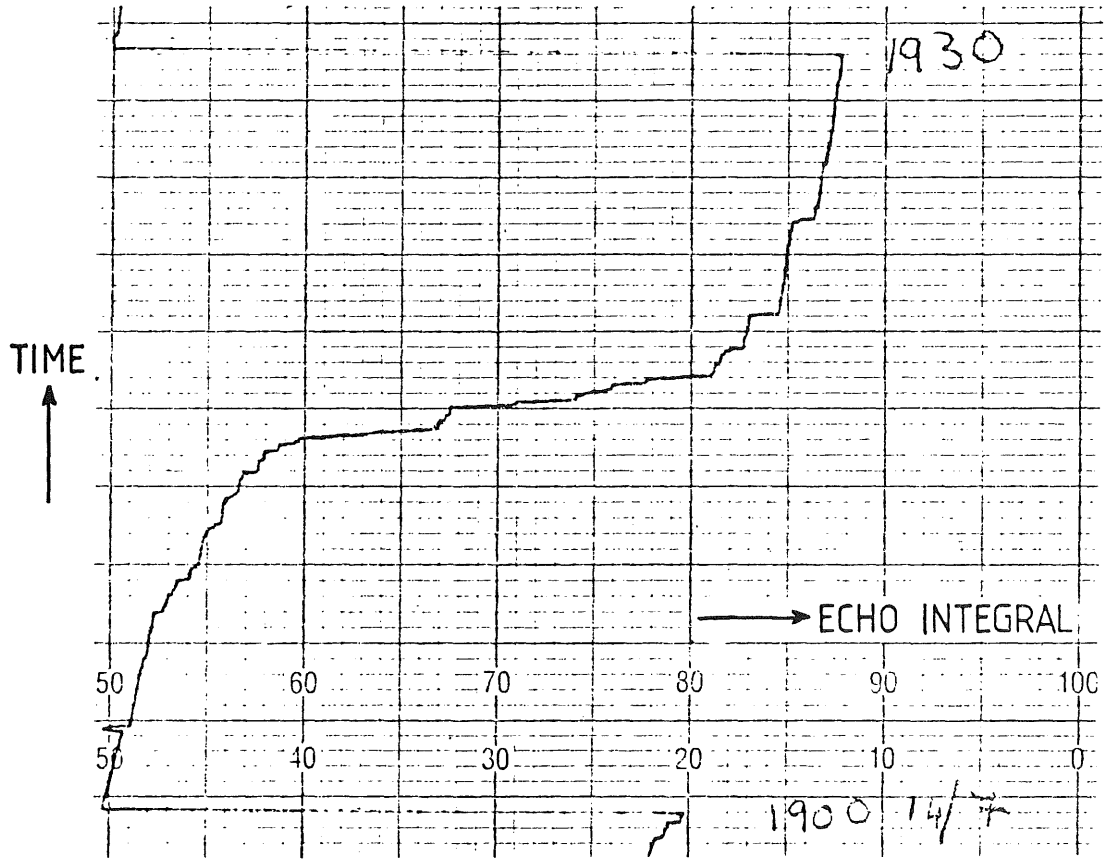


Figure 6a Representative herring echo traces and associated analogue recording of echo integral.



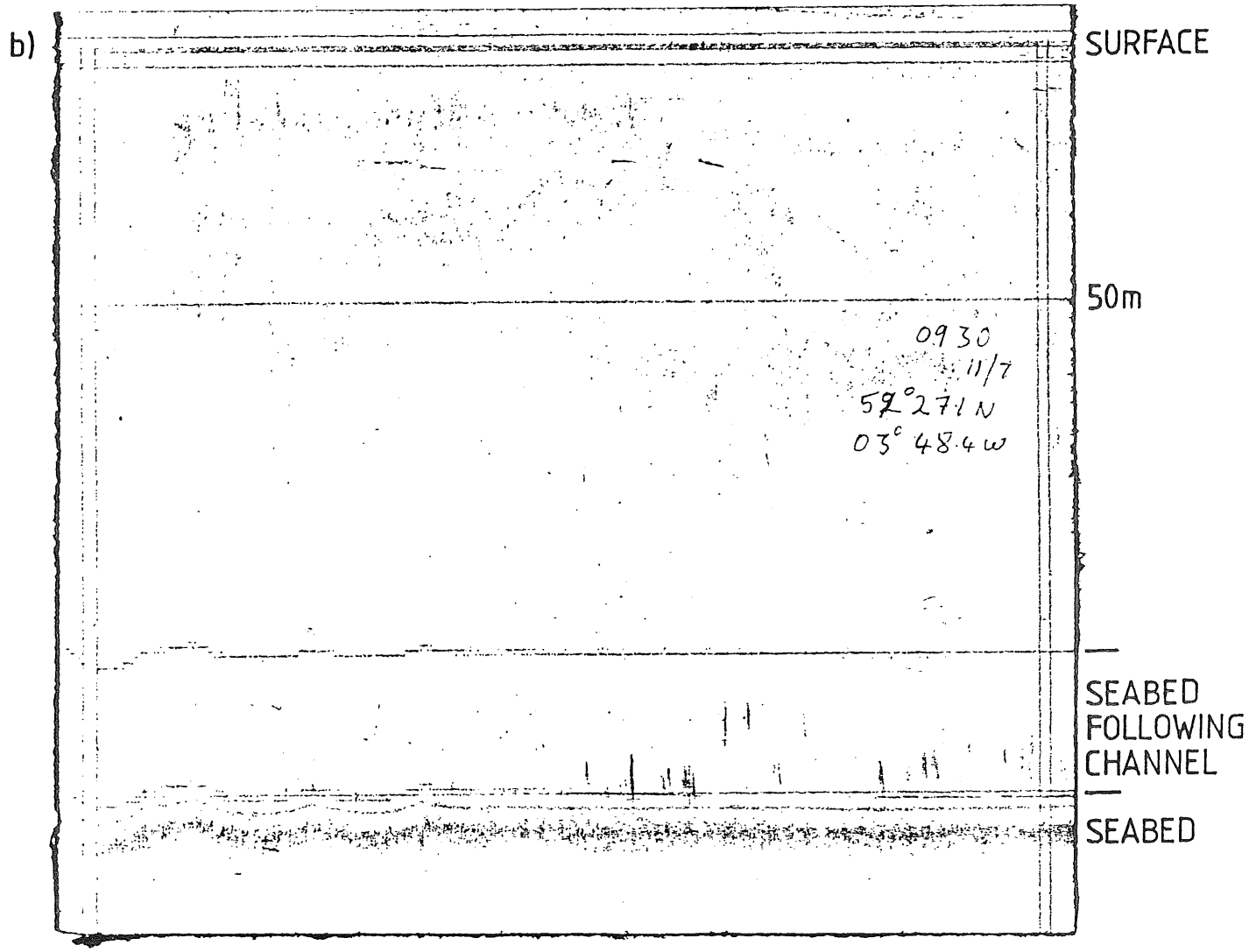
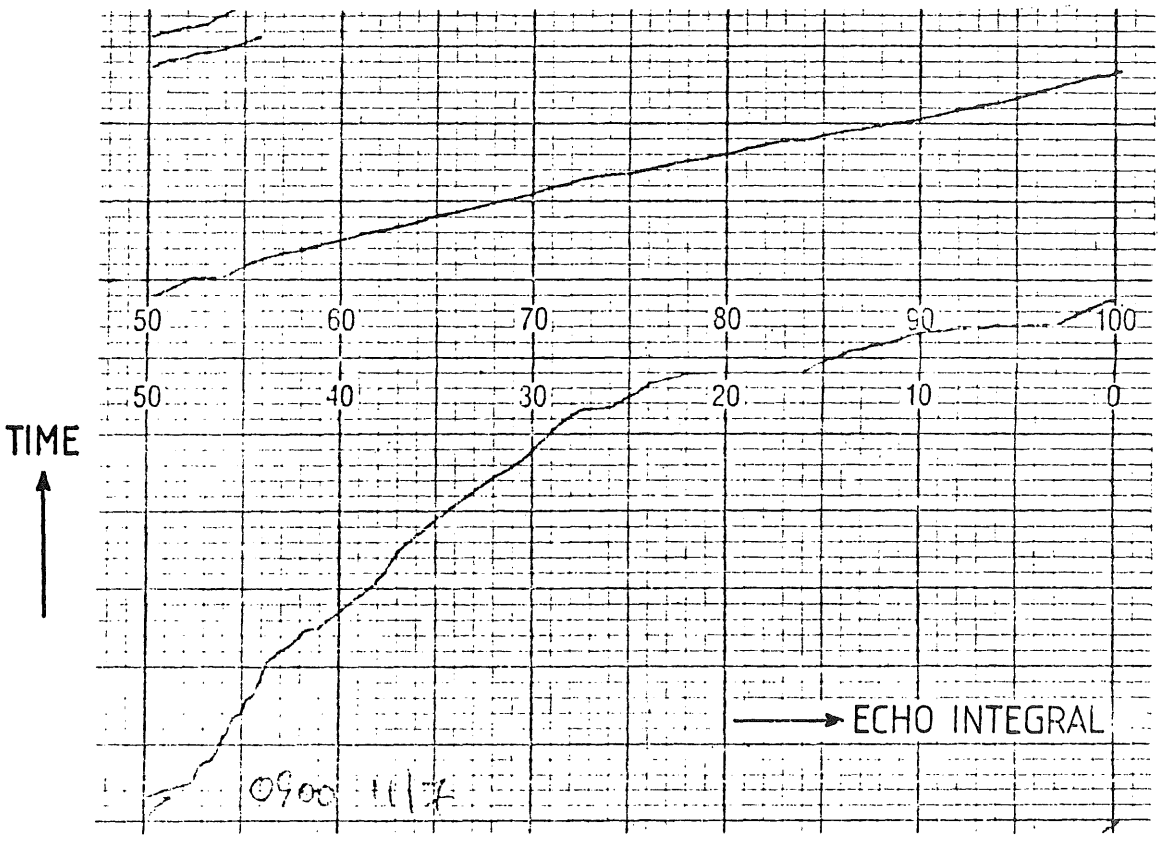
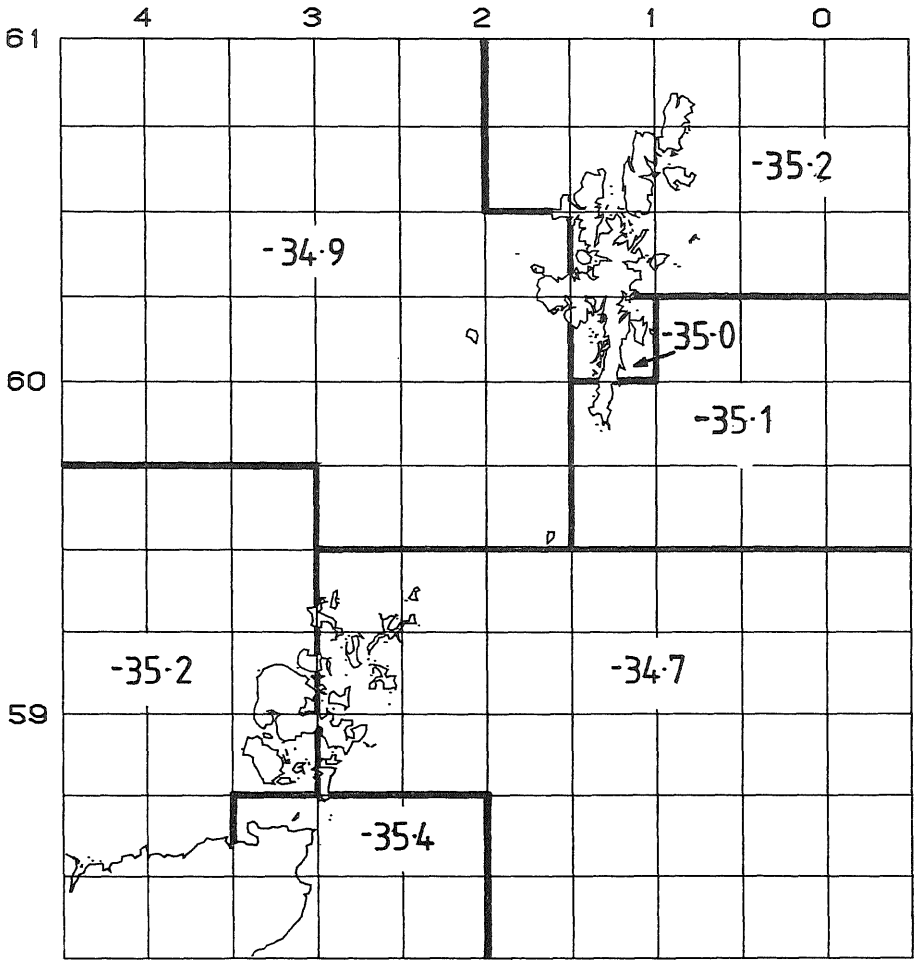


Figure 6b Representative herring echo traces and associated analogue recording of echo integral - showing steps for shoals and steady slope for dense plankton layer in midwater.



7a) Target strength values for herring (dB ref 1 kg) used to convert integrator values to fish density.



b) Sub-areas used for maturity and age composition given in Tables 8 and 9.

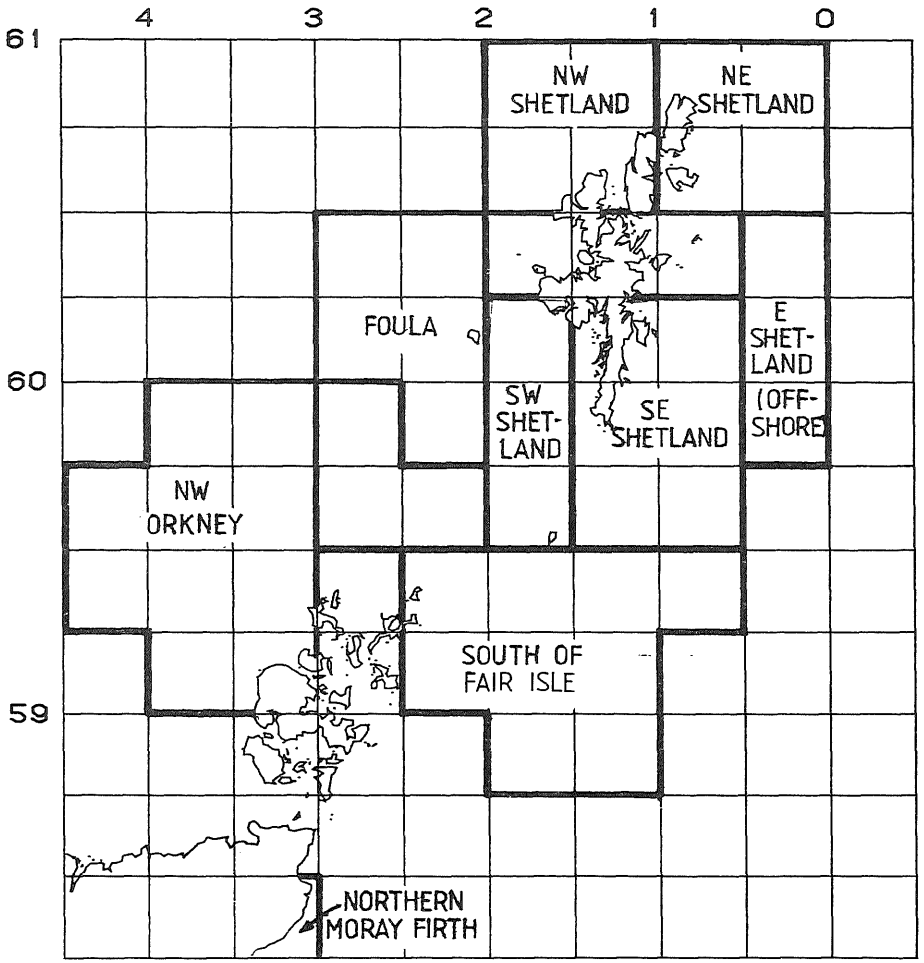


Figure 8 Herring biomass (t x 10^3) (upper figure) and number of half hour integrations (lower figure), FRV "Scotia", estimated by trace identification.

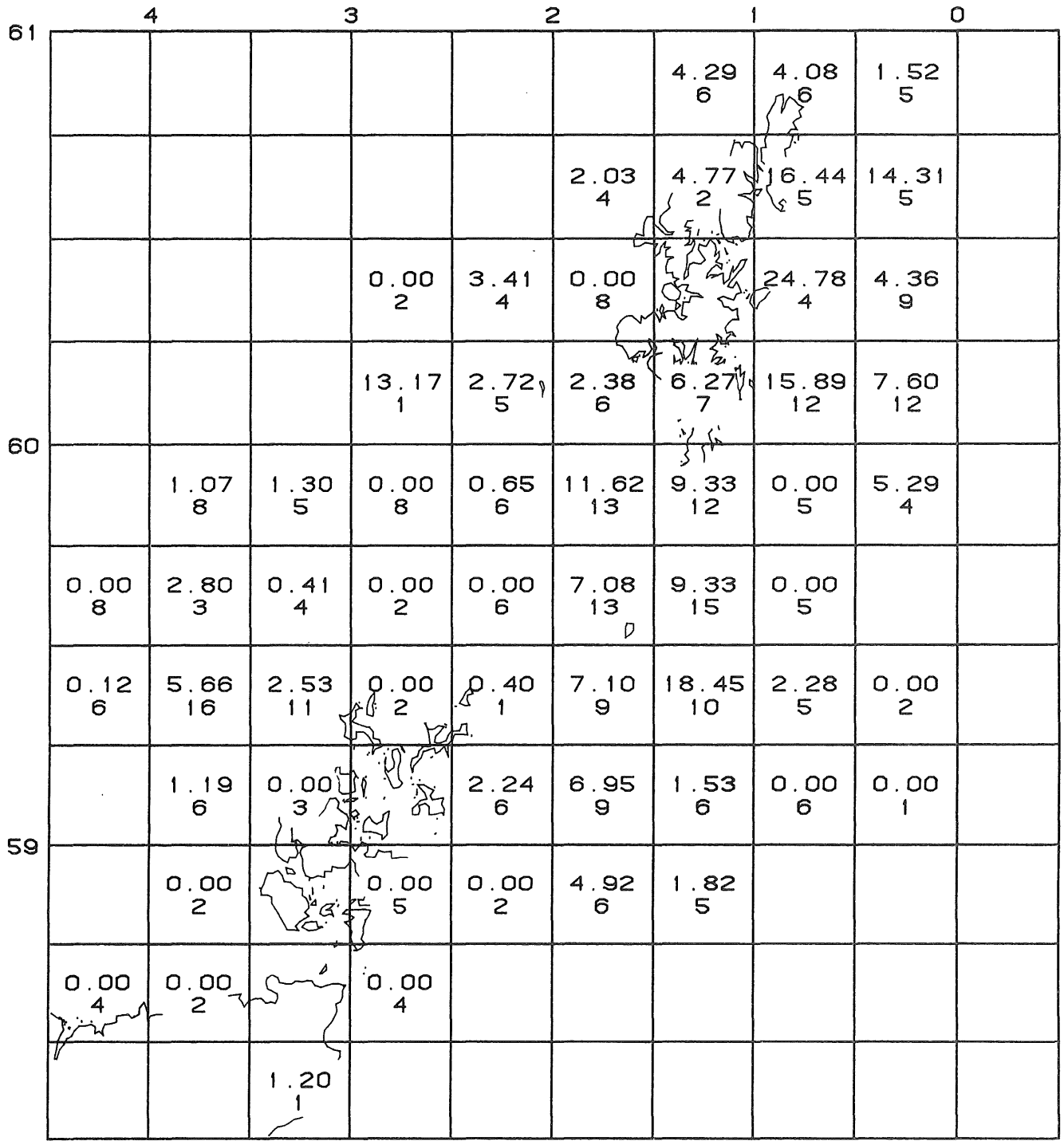


Figure 9 Herring biomass (t x 10^3) (upper figure) and number of half hour integration runs (lower figure), FRV "Scotia" estimated using proportion of species in trawl hauls.