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REPORT ON THE 1984 HERRING ACOUSTIC SURVEY IN THE NORTHERN NORTH SEA

by

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INTRODUCTION

In accordance with Council Resolution 1982/2:26 an acoustic survey of herring stocks was carried out in the northern North Sea in July 1984. The area covered was extended from previous years to cover most of the northern North Sea as far south as 57°N. This paper consists of separate reports on the contribution made by each country participating followed by a discussion of the results. In addition data are presented from previous years for comparison.

REPORT ON SURVEYS BY NORWEGIAN RESEARCH VESSELS JULY 1984

METHODS

During the period 17-31 July 1984 RV "G O Sars" surveyed the Orkney-Shetland area and the Chinese research vessel "Bei Dou", which was built in Norway in 1984, carried out a trial survey in the eastern part of this area in the period 19-25 July. In addition RV "G O Sars" and RV "Eldjarn" covered most of the northern North Sea during July. The survey track and positions of trawl hauls are shown for each vessel in Figures 1-4. The purpose of the surveys was to collect data on abundance and distribution of herring and 0-group gadoid fish. Only the results concerning herring are included in this report.

Observations on the distribution and abundance of herring were made by echo integration and trawling. Technical data and settings of the acoustic equipment are given in Table 1. Key data about the trawls used are given in Table 2.

The integrator outputs were compensated for the instrument constant (Table 1) and scaled by a factor of 10. Average integrator values were obtained every five nautical miles sailed. Contributions from traces considered to be herring were separated. This separation was based on experience from the trawl catches. An average value (M) for herring was calculated for each quarter statistical rectangle in the Orkney-Shetland area and for each whole rectangle in the rest of the northern North Sea.

The number of herring in each rectangle was calculated as $N = 0.1 \cdot M \cdot 10^{-0.1 \cdot TS} \cdot A$ where A is the area of the rectangle and TS is the average target strength of herring. The target strength of a L cm herring was assumed to be TS = 20 logL - 71.2 dB as recommended by Anon (1983). The average target strength within sub-areas was therefore calculated as TS = 10 $\log L^2$ - 71.2 dB where L^2 is the mean square length for the average length distribution of herring observed in the sub-area. Figure 5 shows the sub-areas.

Numbers of fish were converted to biomass using the weight-length relationship: weight in grams = $2.457 \cdot 10^{-7} \cdot (\text{length in mm})^{3.645}$. This was established on FRV "Scotia" during the herring survey at Shetland from 6-26 July 1983 (Bailey et al., 1983).

RESULTS

The Orkney-Shetland Area (58°30'-61°00'N and 0°00'-4°00'W)

Much of the effort was used along the east coast of Shetland. RV "G O Sars" worked an open and irregular grid east of Fair Isle where RV "Bei Dou" had a better coverage.

Some typical herring schools were recorded close to the east coast of Shetland (Fig. 6). In the other areas the herring mostly occurred in smaller schools in between schools of whiting and 0-group Norway pout 5-20 m off the bottom (Fig. 7). The pelagic trawl on RV "G O Sars" could not be towed close to bottom because the otterboards were not properly adjusted. The latter schools were therefore difficult to identify, and the allocation of integrator values was more uncertain in these areas. In the area east and south-east of the Orkneys some herring were caught in the bottom trawl. In this area the proportion of herring in the bottom trawl hauls was used to apportion the integrator values obtained from fish recordings near the seabed to herring.

During the darkest period of the night the herring scattered, and most of them moved close to the surface. The observations made between 2200 and 0300 GMT were therefore not used for abundance estimation, except in some rectangles without daytime observations.

The trawl catches are listed in Tables 3 and 4. The length compositions within each sub-area are shown in Table 5. In sub-areas SW and NW the length compositions obtained on FRV "Scotia" from 6-26 July were used (Table 6), because no samples were obtained by "G O Sars" in sub-area SW and only one from NW.

In Table 7 the average length compositions are compared for research vessel samples and purse seine catches landed in Norway from the sub-areas SW and NE. In sub-area NE they are nearly identical, while in SW the research vessel samples include some small herring which were not recorded in the purse seine catches. One possible reason for this is that the purse seine catches were taken outside the 12 n mile fishery limit, while the research vessel samples were taken closer to the coast. The average length composition from research vessel samples was used to calculate mean length, mean weight and mean target strength within each sub-area (Table 8).

The estimated numbers of herring within each quarter statistical rectangle are shown in Figures 8 and 9. The estimates from RV "Bei Dou" add up to 738 million in the 23 quarter rectangles covered. The results from RV "G O Sars" make 1029 million in the same quarter rectangles. The difference is 33% of the average. Both vessels recorded the main concentrations south and south-east of Sumburgh Head. RV "G O Sars" recorded some schools close to the coast between Bressay and Fetlar. RV "Bei Dou" did not sail that close to the coast, and this might explain some of the difference between the estimates.

Table 9 shows the age-length key obtained from 1264 otoliths sampled during the survey. This was used to calculate the number of herring per year-class within each sub-area (Table 10). The recruiting 2-ringers dominated the total estimate. The abundance of older fish was highest in the northern sub-areas, while the abundance of 1-ringers was highest in the southern sub-areas.

Samples of maturity stages showed that 90% of the 2-ringers were in stage 3 or higher. The estimate of the spawning stock in the Orkney-Shetland area is 1600 million fish or 330 000 tonnes (t), assuming that 90% of the 2-ringers and 100% of the older fish were spawning.

Other Areas

Outside the Orkney-Shetland area the most significant herring recordings were observed south and west of the Fladen Ground. Table 11 shows the length composition obtained from trawl catches with RV "G O Sars" and RV "Eldjarn" in sub-areas A and B. Trawl stations 99, 100, 102, 103, 104 and 106 from FRV "Scotia" were also included when calculating the average length composition for sub-area A. Further east and north (Sub-area C and D) a few herring schools were recorded, but no trawl samples were obtained. In these sub-areas the length composition of commercial purse seine catches taken in the same sub-area and time period were applied (Table 11). Table 12 shows the mean length, mean weight and mean target strength within each sub-area.

Figure 10 shows the estimated number of herring within each statistical rectangle. The age-length key obtained in the Orkney-Shetland area was used to calculate the number of herring per year-class within each sub-area (Table 13). Two-ringers predominated in all sub-areas. The abundance of 1-ringers was highest in sub-area A. Here also some 0-ringers were found. Using the same spawning criteria as in the Orkney-Shetland area we get 810 million (130 000 t) additional spawners in the Fladen area and a further 54 million (13 000 t) spawners east of 2° east.

A rather open survey grid was applied in sub-areas A-D and the sampling was incomplete. In addition both day and night observations were included in the estimates. For these reasons the estimates are less certain than the estimates for the Orkney-Shetland area. The results show, however, that a significant amount of

spawners occurred at Fladen. Some of these might belong to the Orkney-Shetland spawning population.

REPORT OF RV "TRIDENS" ECHO SURVEY 2-12 JULY 1984

RV "Tridens" operated in the Orkney-Shetland area using pelagic fishing gear to sample echo traces. Figure 11 shows the survey track and trawl catches. Table 14 shows the trawl haul details and Table 15 the length composition of herring in the samples.

REPORT OF SURVEY BY FRV "SCOTIA" 6-26 JULY 1984

METHODS

The acoustic survey on "Scotia" was carried out running synchronised EK400 38 and 120kHz sounders. The data from the 38kHz sounder was used for the quantitative analysis, the 120 kHz sounder being run for comparative purposes. Echointegration was carried out using an Aberdeen digital echo integrator with the ship steaming at a nominal speed of 10 knots. Readings were taken every 30 minutes. The survey track and positions of trawl hauls are shown in Figure 12 and the details of the acoustic equipment and settings are given in Table 16. Two calibrations of the acoustic equipment were carried out during the survey with a difference of 0.2dB between measurements (Table 16).

The part of the echointegration value attributable to fish echo traces was extracted in the way described in CM1982/H:47. Increments on the analogue trace associated with "shoals" on the echo sounder paper were summed. During the hours of darkness fish traces dispersed and usually became mixed with plankton. Separation of these was unreliable and only data from 0300-2130 hrs GMT were used for analysis.

The identity of fish echo traces was investigated by making trawl hauls at appropriate depths using a Jackson midwater trawl fitted with a 20 mm mesh codend. The echointegrator output was then partitioned between traces thought to be herring and those thought to be from other species.

RESULTS

The vessel track is shown in Figure 12. A total of 99 statistical rectangles were covered and a total of 445 half hour periods of acoustic data collected.

Details of the trawl hauls and catches are given in Table 17. Of 31 hauls carried out, 28 provided samples of the echo traces and 20 of these had significant proportions of herring. Norway pout, whiting, haddock and mackerel were also caught in significant quantities in some hauls. The mackerel were found around the north of Orkney between 2° and 4° west and south of 59° 30 north. Norway pout were found mostly to the east of Shetland, with O-group found in the meshes in hauls north of Orkney.

In order to calculate representative target strengths for each part of the area surveyed, the length distribution of herring from trawl hauls with more than 10 kg of herring larger than 15 cm were examined (Tables 18 and 19). For the northern part of the area the trawl information was poor and purse seine data from FV "Valiant", which was taking part in tagging experiments at the same time as the survey, are given in Table 18 along with trawl data from "Scotia". Within each part of the survey area there were only small differences in length composition between trawl hauls. These were not consistent however, and could have been due to a real change in distribution of the fish between samples. The two methods of fishing also gave very similar length compositions indicating that it is likely that both provided good estimates of the length composition of the population in the sea. On this basis the survey area was divided into sub-ares within which length compositions were broadly the same.

The target strength of herring in each length group was calculated using the formula recommended by the acoustic survey planning group (CM1983/H:12).

$$TS = 20 \log L - 71.2$$

where TS is in dB and L in cm.

The mean target strength for each of the sub-areas in Figure 12 was calculated by calculating the scattering cross-section at each length and obtaining a mean using the fractional length frequency as a weighting factor. The mean values for each sub-area are shown at the base of Tables 18 and 19.

The estimated number of herring in each quarter statistical rectangle is shown in Figure 13. Data for the six sub-areas (Fig. 12) have been broken down by age and maturity. Five age-length keys were obtained for the survey area and these correspond to one for each area 1 to 5 (the age-length key for area 3 covers both length areas 3 and 6). The number of fish at each age are given in Table 20 along with the mean length and mean weight, total biomass, percentage immature by both weight and length, the number of mature fish and their mean length, mean weight and biomass. The weight was calculated using the weight length relationship:-

$$W = 7.2851\ 10^{-7}\ L^{3.4501}$$

where W is in gm and L in mm, determined during the survey from weight length data from the whole area from 7 to 25 July 1984. This relationship differs slightly from the relationship found in 1983 and would give rise to differences of between 2 and 3% in total biomass estimates. Mature fish were defined as those at Stage 3 and above, Stages 1 and 2 being immature fish. Table 21 shows the number of fish used for determining the percentage immature at each length and age for the five otolith areas shown in Figure 12.

On the basis of these calculations there were an estimated 3.0 thousand million herring (480 thousand t) in the whole survey area of which 2.0 thousand million (390 thousand t) were mature. The estimated number of mature 2-ring recruits was 1.2 thousand million (190 thousand t). Of the total biomass attributed to fish 69% was allocated as herring.

1983 Survey

Because the report on the 1983 survey was prepared soon after the survey had finished it was not possible to incorporate all the information from the "Scotia" and "G O Sars" surveys. This section presents a breakdown by age and maturity from the "Scotia" survey in 1983 and a section comparing the results of a comparative survey undertaken east of Shetland in 1983.

Biological Data from 1983 Survey

Table 24 gives the estimated numbers at age, mean length and mean weight at age for the total and mature portion of the stock for each of the areas shown in Figure 14. These areas are not the same as those used for the analysis of the 1984 data because the grouping of trawl hauls by length composition of the herring was different.

Table 22 gives for all areas combined the proportion of fish at each length and age which were mature (stage 3 and over) and immature (stages 1 and 2). All fish 3-group and older were on this definition mature.

For comparison the percentage composition by maturation stages for 1983 and 1984 for FRV "Scotia" is given in Table 23. In both years most mature fish were in stages 3 and 4 with a small percentage in stage 5. Three-ringers and older were on average more advanced than recruiting 2-ringers indicating the possibility of later spawning by recruits. A small percentage of fish were at stage 8. It is possible that some of these had spawned in July, but they could also be spring spawners.

Comparison of Survey Analysis

At the suggestion of the Acoustic Survey planning group a small area (a quarter statistical rectangle) was surveyed on a 5 mile grid spacing on the same day by FRV "Scotia" and RV "G O Sars". The echosounder records and integrator readings were exchanged to evaluate the components of error in the estimates.

Estimate of Biomass in one quarter statistical rectangle ($t \times 10^{-3}$)

	Aberdeen Material	Bergen Material
Aberdeen analysis	90	207
Bergen analysis	109	224
Difference expressed as a percentage of the mean	19%	8%

These results indicate a subjective bias of 13-14% of the mean of the analysis. The wide disparity between absolute values obtained by the two vessels is attributable to the type of fish distribution. Approximately 70% of the total biomass estimate was made up of four or five large shoals. In fact one single shoal found during the Norwegian survey contributed about 80% of the difference between the estimates. This is to be expected with fish distributed contagiously but it is also expected that the error over the duration of a complete survey would be relatively small.

DISCUSSION

The numbers of herring at age in each sub area in Figure 5 are shown in Table 25. The results of the Scottish and Norwegian surveys may be compared in columns 1 to 5 and 10. The data from the Scottish survey of the Orkney, Shetland and Buchan areas has been partitioned along the same boundaries chosen for the Norwegian survey. Columns 1 to 5 show the results from the five sub-areas around Orkney and Shetland covered by "G O Sars" and "Bei Dou" for comparison with those from "Scotia". Column 6 shows the total for these five sub-areas. The variation between vessels within sub-areas is quite large but the estimates of total number of fish for the entire area differ by only 9.3% of the mean. There is some evidence to suggest that the stock moved south during the 10 to 14 days between the surveys (Figures 8 and 13) and this may explain some of the sub-area differences. Some parts of the area have not been included in the comparison because they were not covered by both vessels and are shown separately in Table 25. Columns 7 and 8 show the numbers of fish found by "Scotia" to the north east of 0° and west of 4°W respectively. Column 10 shows the number of fish at age for area A in Figure 5, the numbers found by FRV "Scotia" being raised to include the five quarter statistical rectangles not covered by assigning values equal to the adjacent quarter statistical rectangles for which there were data. This has increased the Scottish estimate for area A by 10.4% for a 33% increase in area. The estimates of the total number of fish in column 10 shows an overall difference of 11.6% of the mean. Part of the Moray Firth was not covered by RV "Eldjarn" and the numbers of fish are shown in column 9 for this area.

In order to calculate an overall estimate for the Orkney, Shetland and Buchan areas some assumptions had to be made about the parts of the area not covered by both Norwegian and Scottish surveys. A significant quantity of fish was found by FRV "Scotia" to the east of 0° and a survey of the same area by RV "Eldjarn" a week or so later indicated no traces of fish. An examination of the distribution shown in Figure 8 for "G O Sars" and Figure 13 for "Scotia" indicated that the population may have moved south. It was therefore decided to add the numbers of fish found east of 0° (column 7 in Table 25) to the total for "Scotia" in column 6 on the basis that those fish had moved into this area and had been covered by the Norwegian survey carried out a little later. However, no evidence of movement is shown for fish west of 4° or in the Moray Firth so these values from the "Scotia" survey have been added to the total for the area covered by both vessels. To obtain a best estimate for the main area surveyed the mean of the Norwegian and Scottish survey was taken (including column 7 mentioned above) from column 6 for the Orkney and Shetland area and from column 10 for area A and added to the two peripheral parts in columns 8 and 9. This overall estimate for the Orkney, Shetland and Buchan area is shown in column 11 of Table 25. The estimate for the Fladen area (RV "Eldjarn" Table 13 area B Figure 5) is reproduced in column 12. In addition to this main area a small quantity of fish were found by FRV "Scotia" off Aberdeen and by RV " Eldjarn" around the Norwegian Deeps. For completeness these are shown in columns 13 and 14 respectively.

Table 25 shows the numbers and biomass of herring in the spawning stock by sub-area and for the whole area. These have been worked out using the maturity information from each survey. The Norwegian survey found 10% of 2-ring fish immature and the Scottish survey 28% for the same sub-areas. In addition the number of 2-ring fish in the Scottish survey is a higher proportion of the total (53% as compared with 42% for the Norwegian estimate). This results in 28% of the Scottish estimate, by number, compared with 13% of the Norwegian estimate being classed as immature. It is not clear why these differences have arisen but they point to a need for more data for accurately determining numbers at age and maturity of two ring fish.

The overall totals indicate a stock of 2.9 thousand million fish in the Orkney-Shetland-Buchan area of which 2.1 thousand million (400 thousand t) were mature, with a further 530 million fish in the Fladen area of which 450 million (76 thousand t) were mature. This indicates that 11 thousand million 2-ring recruits were in the Orkney-Shetland and Buchan areas with a further 300 million in the Fladen area.

Table 1 Technical data and settings of acoustic equipment

	R/V "Bei Dou"	R/V "G.O.Sars"	R/V "Eldjarn"
Echo sounder	Simrad EK 400	Simrad EK 400	Simrad EK 400
Frequency	38 kHz	38 kHz	38 kHz
Receiver gain	- 20 dB	- 10 dB	- 20 dB
Time varied gain	20 logR + 2·0.008·R	20 logR + 2·0.008·R	20 logR + 2·0.008·R
Pulse length	1.0 ms	1.0 ms	1.0 ms
Bandwidth	3.3 kHz	3.3 kHz	3.3 kHz
Transducer	30 x 30 cm	45 x 48 cm	30 x 30 cm
Effective beam angle (10 log ψ)	- 19.6 dB	- 23.2 dB	- 19.6 dB
Basic range	250 m	150 m	150 m/250 m
Source level + Voltage response	141.6 dB	134.4 dB	141.3 dB
Integrator	Simrad QD	NORD-10 computer	NORD-10 computer
Integrator gain	30 dB	40 dB	40 dB
Integrator threshold	10 millivolts	17 millivolts	28 millivolts
Instrument constant (C_I) for survey settings	0.89	0.087	0.104
Date of calibration	20 August 1984	25 July 1984	14 June 1984

Table 2 Technical data of trawl equipment

	R/V "Bei Dou"		R/V "G.O.Sars"		R/V "Eldjarn"	
	Pelagic	Bottom	Pelagic x)	Bottom	Pelagic	Bottom
Trawl type	semi-pelagic trawl	"Alfredo 4"	Fotö (Mod.80) herring trawl	Campelen shrimp trawl	Capelin trawl	Campelen shrimp trawl
Vertical opening (typical)	17 m	5 m	15 m	5 m	15 m	5 m
Mesh size front (stretched)	400 mm	170 mm	6400 mm	80 mm	200 mm	80 mm
Mesh size cod end (stretched)	22 mm	100 mm	11 mm	6 mm	10 mm	6 mm
Bridle length	80 m	40 m	110 m	40 m	80 m	40 m
Door shape	Rectangular		Circular		Rectangular	
Door weight	750 kg		750 kg		1700 kg	
Door area	7 m^2		4.6 m^2		8 m^2	

x) During 10-17 July a capelin trawl identical to the one on "Eldjarn" was used.

Table 3. Trawl catches R/V "G.O.Sars" 17-31 July 1984.
P=Pelagic trawl, B=Bottom trawl

ST NO	DATE	GMT	POSITION N	POSITION W	CATCH (number of fish) Herring	Whiting	Haddock	N.pout	Others	TOTAL kg
P 356	17	0920	60°15'	00°51'	-	-	-	-	-	-
P 357	17	1050	60°14'	00°50'	60	-	-	-	-	12
P 358	17	1410	60°17'	00°10'	-	-	-	-	-	-
B 359	17	1725	60°35'	00°10'	-	-	17	1050	15	36
P 360	17	2315	60°35'	00°34'	-	-	-	-	-	-
B 361	18	0830	60°51'	00°32'	-	-	-	246	98	119
P 362	18	2330	60°29'	01°58'	-	-	-	-	2	1
P 363	19	0330	60°26'	01°48'	360	-	-	-	-	91
P 364	19	1245	59°59'	02°35'	-	1	1	-	-	-
P 365	20	0350	59°33'	03°14'	6	-	1	14600	-	21
P 366	20	0940	59°27'	02°54'	-	1	-	-	1	1
P 367	20	1125	59°25'	02°47'	-	-	-	-	-	-
B 368	20	1530	59°44'	02°32'	1	-	-	-	-	-
B 369	20	1655	59°40'	02°28'	-	12	41	90	255	109
P 370	20	2340	59°27'	01°58'	20	641	21	8822	6	23
P 371	21	0245	59°38'	01°56'	50	1	-	-	-	8
P 372	21	0955	59°59'	01°34'	4474	1	-	2	1	685
P 373	21	1250	59°49'	01°26'	119	100	-	-	-	51
P 374	22	0115	58°48'	01°44'	47	1374	103	-	6	9
P 375	22	0530	58°27'	02°03'	1260	48	14	1	6	8
P 376	23	2400	57°56'	01°10'	-	4218	309	-	2	13
P 377	24	0325	58°20'	01°08'	-	912	85	-	2	7
B 378	24	0525	58°29'	01°16'	116	134	616	3564	392	193
B 379	24	1115	58°38'	00°36'	-	-	-	-	-	-
B 380	24	1510	58°38'	00°19'	216	8	83	676	16	60
B 381	25	0155	59°58'	00°49'	1	42	277	5077	284	237
P 382	25	0445	59°57'	01°08'	3600	-	-	-	-	800
P 383	26	0050	59°55'	01°11'	3	15	82	15	-	2
P 384	26	0150	59°55'	01°03'	165	166	400	1063	7	51
B 385	26	0655	59°39'	00°45'	-	21	148	843	143	144
B 386	26	1115	59°10'	00°34'	164	28	422	12672	97	393
P 387	26	1515	58°55'	00°53'	-	171	87	-	63	3
P 388	26	1900	59°03'	01°25'	5	17	3	-	-	1
P 389	26	2250	59°17'	01°09'	-	26	171	544	5	13
P 390	27	0845	60°00'	02°40'	-	-	-	-	-	-
B 391	27	1130	60°00'	02°38'	-	27	70	91	167	112
P 392	27	1440	60°09'	02°16'	-	-	-	-	-	-
P 393	27	1715	60°11'	02°03'	-	-	-	-	-	-
B 394	27	1830	60°11'	02°03'	-	1	9	4	57	19
P 395	28	0240	59°50'	01°10'	66	-	6	6	2	18
P 396	28	0855	59°28'	01°10'	-	734	252	-	3	7
B 397	28	1105	59°18'	01°10'	-	180	2344	2036	346	245
B 398	28	1715	59°42'	00°50'	-	54	690	1734	-	-
P 399	28	2320	60°01'	01°04'	-	11	2	62	-	-
B 400	29	1100	60°10'	00°30'	-	59	469	716	80	209
P 401	29	2300	60°14'	00°41'	22	603	762	-	-	9
P 402	30	0045	60°11'	00°38'	7	117	154	-	-	3
P 403	30	0845	60°39'	00°38'	4	-	1	-	-	2
P 404	30	2200	60°37'	00°38'	-	90	2	2250	8	99
P 405	31	0055	60°26'	00°58'	-	63	2	8	29	1

Table 4. Trawling stations of R/V BEI DOU 16. - 27. July, 1984 with catch composition in number per hour trawling. P = pelagic trawl, B = bottom trawl

TRAWL	ST NO	DATE	HOUR (Norw.)	POSITION Lat.	Long.	CATCH (No. fish) Herring	Norw.pout	Haddock	Whiting	Others	TOTAL (kg)	REMARKS
B	01	18.	0315	59°59'N	03°38'E	-	5	-	-	205	40	
B	02	18.	0850	60°04'N	03°05'E	-	24	35	7	3500	2000	Saithe+0-gr.haddock
B	03	18.	1915	60°45'N	02°22'E	-	23	87	14	75	236	
P	04	19.	0155	60°47'N	00°53'E	-	-	100	-	2	3	
P	05	19.	1025	60°56'N	00°23'W	-	-	-	-	8	+	
B	06	19.	2010	61°01'N	01°32'W	-	108	121	6	210	113	
P	07	20.	1450	60°26'N	00°01'W	-	-	100	102	1	2	0-gr.
P	08	20.	1955	60°24'N	00°16'W	-	-	3139	400	3	21	0-gr.
B	09	21.	0640	60°08'N	00°08'W	-	4200	7	-	273	157	0-gr. haddock
B	10	21.	1655	59°54'N	00°46'W	20	10000	168	38	198	340	
P	11	22.	0405	59°28'N	01°29'W	11	-	29	129	3	4	
P	12	22.	0755	59°28'N	01°28'W	780	-	-	-	-	124	
B	13	22.	1100	59°36'N	01°20'W	-	-	2	6	8	4	+squid
B	14	22.	1400	59°36'N	01°14'W	1	-	433	154	119	58	0-gr.haddock+whiting
P	15	22.	1715	59°30'N	01°02'W	-	3029	18	82	-	52	0-gr.haddock+whiting
P	16	22.	2150	59°27'N	01°15'W	-	-	850	3040	-	13	0-gr.haddock+whiting
B	17	24.	1245	59°36'N	00°57'W	9	24000	5300	243	141	756	0-gr.haddock
P	18	24.	1900	59°27'N	00°48'W	-	-	268	3552	-	22	0-gr.haddock+whiting
P	19	25.	0020	59°39'N	00°39'W	6	-	2492	3673	1	38	0-gr.haddock+whiting
P	20	25.	1300	59°37'N	00°09'W	-	-	164	97	1	1	0-gr.haddock+whiting
B	21	25.	1500	59°36'N	00°06'W	15	14333	521	23	69	351	0-gr.haddock
P	22	25.	2100	60°04'N	00°10'E	-	36	412	92	4	26	0-gr.haddock+whiting
B	23	26.	1055	60°06'N	02°51'E	-	-	21	-	481	213	Saithe
B	24	26.	1430	60°03'N	03°21'E	-	136	13	3	1865	181	
B	25	26.	1730	60°06'N	03°30'E	-	86	-	-	283	61	
B	26	26.	1910	60°02'N	03°30'E	-	-	13	-	909	60	Blue whiting

Table 5 Length distribution (%) of herring, R/V "G.O.Sars" st.no. 357-401 and R/V "Bei Dou" st.no. 12.

LENGTH (cm)	SUB - AREA NW 363	NE 357	NE 382	NE 384	NE 395	M 371	M 372	M 373	SE 374	SE 380	SE 386	SE 12
17									8.3			
18									14.6	1.0	.6	
19									2.1	1.9	1.2	
20									6.2	13.6	2.4	
21							1.0		18.8	8.7	1.8	
22						2.0	1.0		31.3	12.6	3.0	1.0
23							6.0	.8	2.1	15.5	14.0	
24	1.6	3.3	.6	1.2		10.0	18.0	10.9	2.1	15.5	30.5	1.0
25	5.6	13.3	3.9	4.8		22.0	34.0	40.3	4.2	16.5	24.4	16.0
26	4.0	15.0	22.7	17.0	15.2	34.0	18.0	35.2	6.2	8.7	15.2	40.0
27	6.5	18.3	19.5	14.5	22.7	26.0	8.0	9.2	2.1	3.9	3.0	26.0
28	12.1	23.3	17.5	16.4	21.2	2.0	2.0	3.3		1.0	2.4	10.0
29	8.9	13.4	16.9	15.8	21.2	2.0	4.0	.8		1.0	.6	6.0
30	15.3	10.0	10.4	13.9	10.6		4.0		2.1			
31	15.3		5.8	12.1	4.5	2.0	3.0					
32	11.3		.6	1.8	3.0							
33	9.7		1.3	1.8	1.5		1.0					
34	5.6	3.3	1.3	.6							.6	
35	4.0											
No.meas.	124	60	154	165	66	50	100	119	48	103	164	100

Table 6. Trawl station numbers corresponding to the applied length compositions from R/V "Scotia" during 6-26 July 1984.

Sub-area	Trawl station
NW	83, 84
NE	81
M	86, 93, 94
SW	89, 91
SE	96

Table 7. Comparisons of average length compositions (%) of herring in trawl catches from research vessels and commercial purse seine catches. In sub-area SW the compositions are based on trawl station 89 and 91 R/V "Scotia" 14 July and 13 purse seine catches from the rectangles 47E6 and 48E6 16-31 July. In sub-area NE the compositions are based on trawl station 357, 382, 384 and 395 R/V "G.O.Sars" 17-28 July, trawl station 81 R/V "Scotia" 9 July and 7 purse seine catches from the rectangles 48E8, 48E9 and 49E9 16-31 July. The statistical rectangles are shown in Figure 10.

Length cm	Sub-area SW		Sub-area NE	
	Trawl	Purse seine	Trawl	Purse seine
17	.6			
18	1.0			
19	4.5			
20	15.7			
21	16.3	.2		
22	6.9	.4		
23	4.0	1.3	.1	.2
24	4.2	5.3	2.0	3.6
25	6.3	13.9	6.2	11.6
26	6.8	17.9	17.3	15.9
27	7.2	16.9	18.2	18.8
28	4.7	13.7	18.4	14.1
29	8.7	14.1	17.5	10.3
30	6.0	9.1	10.7	10.5
31	2.9	3.5	5.2	5.7
32	2.9	3.0	1.5	4.9
33+	2.1	.8	2.7	4.2
No measured	670	1078	769	654

Table 8. Mean length (cm), mean weight (gram) and mean target strength (dB) of herring within sub-areas.

SUB-AREA	NW	NE	M	SW	SE
mean length	29.2	28.5	26.0	24.9	23.9
mean weight	245	222	159	152	126
mean target strength	-41.9	-42.1	-42.9	-43.2	-43.6

Table 9. Total age-length distribution obtained from 17 random herring samples in the Orkney-Shetland area.

LENGTH CM	No of winter rings 0	1	2	3	4	5	6	7	8	9+	SUM
9	60										60
10	30										30
11											
12											
13											
14											
15											
16		1									1
17		8									8
18		6									6
19		10	1								11
20		33	1								34
21		37	5								42
22		7	38	2							47
23			101	6							107
24			181	10	1						192
25			206	30							236
26			107	41	1	1					150
27			30	59	9	4					102
28			3	41	34	6					84
29			1	28	23	8	3	1			64
30				7	18	8	6	4			43
31					7	4	3	5	2	1	22
32				1	1		1	6	3	2	14
33								1	3	3	7
34									1	1	2
35					1					1	2
SUM	90	102	674	225	95	31	13	17	9	8	1264
mean length	9.8	20.5	25.0	27.3	29.3	29.5	30.7	31.6	32.8	34.2	24.7
mean weight		68	136	189	242	242	287	313	340	305	163

Table 10. Estimated number of fish (millions) per age group in the Orkney-Shetland area.

No of winter rings	SUB-AREA					TOTAL	
	NW	NE	M	SW	SE	Number	Biomass (1000 tonnes)
0							
1	.1		1.7	14.2	163.1	179.1	12.2
2	36.9	208.1	254.7	11.5	298.2	809.5	118.4
3	56.2	277.2	81.1	5.8	75.2	495.5	99.2
4	39.1	174.2	15.3	3.7	14.5	246.8	60.3
5	13.0	58.2	5.6	1.3	4.8	82.9	20.7
6	6.4	25.2	1.4	.8	.7	34.5	9.8
7	11.0	26.2	1.3	1.1	.3	39.9	13.3
8	10.0	15.7	.6	.7	.3	27.3	11.2
9+	9.8	13.3	.4	.6	.3	24.4	10.5
TOTAL	182	798	362	40	557	1939	356
Spawning stock	179	777	335	24	365	1679	-
Spawning stock biomass (1000 tonnes)	44	174	54	5	55	-	332

Table 11. Length distribution (%) of herring within sub-areas, R/V "G.O.Sars" trawl station no. 375 and 378, R/V "Eldjarn" trawl station no 251, 264, 265 and 266. The distribution in sub-area C represents a commercial purse seine catch from rectangle 46F3, 10 August, and the distribution in sub-area D represents the average of 9 commercial purse seine catches from the rectangles 48F2 and 49F2 during 1-13 July. (Statistical rectangles are shown in Figure 10).

Length (cm)	SUB-AREA A				B		C	D
	375	378	264	265	251	266		
9	31.4							
10	67.8							
11								
12								
13								
14								
15								
16								
17	.1							
18	.1		1.7		1.6			
19			2.3		3.1			
20	.1	.9	14.9		4.7	1.0	9.9	
21	.5	1.7	21.1		3.1	4.1	25.4	
22	.1	5.2	17.1		4.7	4.1	36.6	
23		19.0	14.3	8.2	12.5	3.1	15.5	.2
24		19.0	7.4	16.3	35.9	9.3	2.8	2.7
25		22.4	5.1	32.7	15.6	18.6	2.8	10.6
26		15.5	6.9	21.4	6.3	29.9	7.0	6.8
27		6.9	4.6	14.3	1.6	16.5		7.9
28		3.4	1.7	2.0	1.6	6.2		11.7
29		1.7	1.7	3.1	1.6	6.2		12.7
30		1.7	.6	2.0				10.3
31		1.7	.6			1.0		10.2
32		.9			1.6			11.0
33								15.9
34					4.7			
35					1.6			
No.meas.	70	116	175	98	64	97	71	774

Table 12. Mean length (cm), mean weight (gram) and mean target strength (dB) of herring within sub-areas.

SUB-AREA	A	B	C	D
mean length	21.2	25.6	22.6	29.8
mean weight	99	158	96	267
mean target strength	-44.3	-43.0	-44.1	-41.7

Table 13. Estimated number of fish (millions) per age group in sub-areas A, B, C and D.

No of winter rings	SUB-AREA				TOTAL	
	A	B	C	D	Number	Biomass (1000 tonnes)
0	130.4				130.4	.6
1	171.3	45.9	6.1		223.3	14.4
2	291.3	331.5	9.5	9.1	641.4	86.2
3	73.7	93.1	.8	10.1	177.6	32.1
4	16.5	24.2	+	8.7	49.4	12.0
5	5.5	7.0	+	3.0	15.5	3.6
6	1.4	1.6		1.9	4.9	1.4
7	1.3	2.7		4.4	8.4	2.8
8	.4	9.8		4.5	14.7	6.0
9+	.2	11.4		4.2	15.8	6.7
TOTAL	692	527	16	46	1281	166
Spawning stock	361	448	9	45	863	-
Spawning stock biomass (1000 tonnes)	53	76	1	12	-	142

Table 14 - Length distributions Herring catches R.V. "Tridens", 2-12 July 1984

Haul \ Length	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38
1				2	- 3	6 8	2 11	6 12	4 11	3 6	3 5	3 -	1						
2				2 -	3 5	6 7	3 9	10 8	1 4	5 9	2 3	2 2							
3											1	- 1	1 3	2 -	- 1	- 4	2 5	3 2	- 1
4						1	1 -	- 4	1 7	2 12	3 6	9 6	5 6	6 -	2 4	2 1	2		
5					1 2	5 19	13 17	9 7	3 3	4 5	3 1	2 1	- -	- 2	1				
6			1 -	- 2	- 1	1 5	5 9	7 7	6 4	1 5	2 1	1 -	- -	1					
7						1 2	- 2	1 1	2 3	4 3	9 10	9 10	5 13	9 20	14 8	1			
8						2 2	5 9	9 7	9 7	12 9	8 7	3 2	2 -	- 1	- 1				
9				1 -	4 5	7 6	9 3	3 3	- 2	2 -	- -	- -	- -	1					
10					5	4 3	7 2	3 -	3 2	1 2	1 -	- -	1						
11		1	6 5	1 7	4 10	5 6	4 3	1 3	2 2	- 1									

Table 15 - Pelagic trawl catches by "Tridens", 2-12 July 1984.

Haul no.	Position	Date	Hour (GMT)	Dur. (min)	Catches in kg		Other species
					Herring	Others	
1	59°54'N 1°01'W	04-07	12.38	50	1.700☆	350	Whiting, Norway pout, haddock
2	59 56 N 1 04 W	04-07	15.30	15	6.000☆	-	
3	61 09 N 0 25 E	05-07	08.49	43	10	100	Haddock, whiting, mackerel
4	60 26 N 0 09 E	05-07	19.50	75	20	300	Norway pout, haddock, whiting, mackerel
5	60 31 N 0 39 W	06-07	07.00	95	3.000☆	1.250	Saithe, haddock, Norway pout, whiting
6	59 54 N 1 07 W	06-07	15.20	130	1.800☆	750	Norway pout, whiting, haddock
7	60 23 N 1 59 W	09-07	08.25	170	38.000☆	250	Saithe
8	60 00 N 2 23 W	09-07	19.05	35	25.000☆	200	Mackerel
9	59 45 N 2 59 W	10-07	11.16	30	50	1.450	Whiting, haddock, mackerel
10	59 45 N 2 31 W	10-07	13.15	90	300	800	Mackerel, whiting. haddock
11	59 30 N 2 08 W	10-07	16.55	30	70	200	Mackerel, haddock, whiting, Norway pout
12	59 27 N 1 37 W	10-07	19.10	20	-	-	

☆ - Through microtag detector (in total 75.5 tons)

Haul no. 7: 4 tagged herrings (34.0, 29.5, 33.0, 31,5 cm)

" " 8: 2 " " " " (33.0, 31.5 cm)

Table 16

Acoustic equipment and settings on FRV "Scotia"

Echosounders (1) Simrad EK400

Frequency	38 kHz
Power	High
Receiver gain	-10 dB + 20 log R + 2(0.008R)
Pulse length	1.0 ms
Bandwidth	3.3 kHz
Transducer	Ceramic 30x15 (34 elements)
Equivalent beam angle	-17.8 dB (measured)
Basic range	0-200 m

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

07/07/84	+54.46 dB//1VRMS
16/07/84	+54.30 dB//1VRMS

VR+SL used for survey +54.38 dB measured using a 38.1 mm diameter tungsten carbide sphere TS = -42.36 dB

Echosounders (2) Simrad EK400

Frequency	120 kHz
Power	High
Receiver Gain	-10 dB + 20 log R + 2(0.0366R)
Pulse length	1.0 ms
Bandwidth	3.3 msec
Transducer	Circular 9°
Equivalent beam angle	-16.8 dB
Basic range	0-200 mm
Uncalibrated	
Integrator	Aberdeen Digital Integrator
Effective threshold	20 millivolts peak
Depth range of integration	5 m below surface - 3 m above sea bed

Table 17. Trawl hauls FRV "Scotia" 6-26 July 1984.

Haul No	Shooting Position	Time BST	Date	Herring	Whiting	Mackerel	Pout	Haddock	Others	Observations
76	60°44'N 00°43'W	1830	7 Jul	–	1	–	4	3	–	
77	60°36'N 00°27'W	1000	8 Jul	–	–	–	–	–	–	
78	60°29'N 00°04'W	1630	8 Jul	–	–	–	1883	311	1	
79	60°09'N 00°23'W	1035	9 Jul	–	–	–	446	237	2	0-group pout and haddock meshed
80	60°08'N 00°47'W	1455	9 Jul	–	2	–	–	1	2	
81	59°58'N 00°58'W	1930	9 Jul	9072	–	–	–	–	–	
82	60°39'N 01°30'W	1600	10 Jul	1	–	1	–	–	1	
83	60°36'N 01°38'W	2020	10 Jul	79	–	–	1674	–	9	
84	60°08'n 02°13'W	1625	11 Jul	1475	–	–	1699	–	68	"Others" mainly sandeels (M. lanceslatus)
85	59°53'N 01°51'W	1340	12 Jul	16	70	–	–	4	4	
86	59°40'N 01°46'W	1820	12 Jul	524	126	212	28	–	4	
87	59°14'N 04°22'W	1010	13 Jul	12493	–	210	–	–	–	
88	59°08'N 03°32'W	1805	13 Jul	10	–	98	–	1	3	0-group pout meshed
89	59°25'N 03°04'W	1130	14 Jul	1138	–	63	–	–	2	
90	59°29'N 03°42'W	1550	14 Jul	–	4	2	–	1	1	
91	59°27'N 03°46'W	1730	14 Jul	1866	8	–	300	–	4	
92	59°17'N 00°32'W	1530	15 Jul	–	–	–	–	4	–	
93	60°00'N 02°25'W	1030	18 Jul	14674	–	–	–	–	–	
94	59°33'N 02°12'W	1745	18 Jul	2332	–	–	–	–	–	
95	58°50'N 01°18'W	1530	19 Jul	4	1	–	3	–	–	A few pout meshed
96	58°52'N 01°58'W	2100	19 Jul	152	84	–	1	3	137	Sprats and 0-group gadoids meshed
97	58°36'N 02°51'W	0920	20 Jul	–	–	–	–	–	–	Sandeels and 0-group pout meshed
98	58°20'N 03°04'W	1245	20 Jul	4	–	–	–	–	282	Sandeels meshed (A. marinus)
99	58°19'N 02°03'W	1830	20 Jul	898	2	–	–	–	92	"Others" mainly sprats
100	58°16'N 01°26'W	0950	21 Jul	14606	–	–	–	–	–	Sandeels meshed (Maurolicus)
101	58°04'N 02°55'W	0905	22 Jul	–	–	–	–	–	–	0-group sprats meshed
102	58°03'N 01°41'W	1720	22 Jul	11605	–	–	–	1	–	
103	58°03'N 00°59'W	2100	22 Jul	61	13	–	6	5	2	
104	57°52'N 00°30'W	0955	23 Jul	1680	–	87	–	–	–	
105	57°03'N 01°46'W	1445	24 Jul	1270	–	–	–	–	19059	Others mainly sprats
106	58°01'N 01°00'W	1130	25 Jul	4697	–	–	44	–	–	

Table 18. Percentage length composition of herring from trawl and purse-seine catches FRV "Scotia" and FV "Valiant" and calculated target strengths, showing individual catches and mean values for areas 1 and 2 (Fig.12).

	AREA 1								AREA 2					
	S81	V32	V34	V35	V36	V42	V45	Mean	S83	S84	V37	V39	V41	Mean
23				0.5			0.5	0.1	1.3			0.6		0.4
		2.8		0.5			0.9	0.6				0.6		0.1
24	0.6	5.1	2.6	2.9	0.9	0.6	0.9	1.9	2.5			1.2		0.7
	0.6	8.0	1.3	5.8	0.9	1.2	8.5	3.7	1.3		0.7	3.0		1.0
25	4.6	12.5	5.8	13.0	2.6	5.5	12.7	8.1	1.3	0.7	3.4	6.5		2.4
	3.1	13.6	11.6	12.0	6.1	11.0	11.8	9.9		2.4	4.7	8.3	0.9	3.3
26	6.1	12.5	12.9	9.1	1.8	9.1	21.7	10.5	7.6	3.7	6.0	9.5		5.4
	8.6	11.4	12.3	13.0	3.5	15.2	14.6	11.2	2.5	3.4	4.0	9.5		3.9
27	8.3	6.8	10.3	7.2	3.5	11.0	7.5	7.8	3.8	9.8	3.4	7.7		4.9
	7.9	4.0	11.6	5.3	1.8	9.1	6.1	6.6	10.1	11.5	6.0	9.5		7.4
28	8.3	4.5	7.1	4.3	6.1	9.1	4.7	6.3	13.9	14.9	4.0	6.5	0.9	8.1
	6.4	3.4	5.2	8.7	7.0	8.5	3.3	6.1	8.9	10.8	4.7	7.1		6.3
29	7.3	7.4	7.1	5.3	7.0	6.1	1.9	6.0	5.1	11.5	4.7	6.5	4.5	6.5
	8.9	4.5	2.6	5.8	9.6	3.0	1.9	5.2	15.2	9.2	9.4	7.7	8.9	10.1
30	11.3	1.7	4.5	2.4	6.1	3.0	0.9	4.3	5.1	7.5	9.4	6.5	8.0	7.3
	5.5	0.6	2.6	2.9	8.8	3.7	0.5	3.5	5.1	4.4	10.7	2.4	8.9	6.3
31	3.1	0.6		0.5	7.0	1.2		1.8	2.5	2.0	7.4	1.8	12.5	5.2
	2.4			0.5	6.1	0.6	0.9	1.5	2.5	2.0	6.7	1.2	7.1	3.9
32	1.2		0.6		4.4	1.2	0.5	1.1	2.5	1.0	2.0	1.2	4.5	2.2
	1.2		0.6	0.5	5.3			1.1	2.5	1.7	2.0	0.6	10.7	3.5
33	0.9		0.6		5.3			1.0		0.7	4.7	0.6	10.7	3.3
	0.6	0.6	0.6		1.8	0.6		0.6	3.8		3.4	1.2	8.0	3.3
34	1.2				2.6			0.6	2.5	1.7	0.7		9.8	2.9
	0.9				1.8			0.4		0.3	1.3		0.9	0.5
35										0.7			3.6	0.8
	0.3										0.7			0.1
36														
	0.3													
37	0.3													
TS	-42.0	-42.7	-42.4	-42.5	-41.7	-42.4	-42.7	-42.3	-41.9	-42.0	-41.7	-42.3	-41.1	-41.8

Table 19. Percentage length composition of herring from trawls FRV "Scotia" and calculated target strengths, showing individual catches and mean values for area 3 to 6 (Fig. 12).

	AREA 3				AREA 4			AREA 5							AREA 6
	S89	S93	S94	Mean	S87	S91	Mean	S96	S100	S102	S103	S104	S106	Mean	S89
17										1.4				0.2	
										2.4				0.4	
18										5.0		0.4		0.9	1.2
						0.2	0.1			5.0	1.6	1.7		1.4	0.4
19										13.8	6.3	5.0		4.2	1.2
						0.2	0.1	0.7	0.2	6.7	3.1	3.3	0.5	2.4	2.1
20								3.3	0.7	15.6		4.0	1.4	4.2	6.7
						0.6	0.3	5.3	0.9	16.6	4.7	4.8	1.4	5.6	10.8
21			0.3	0.1		0.6	0.3	17.1	3.4	16.3	10.9	6.3	6.3	10.1	19.2
						1.1	0.5	17.1	5.0	5.7	3.1	4.2	4.4	6.6	19.9
22		0.4		0.1		0.2	0.1	24.3	4.6	8.1	1.6	2.5	11.0	8.7	11.2
		0.8		0.3	0.3		0.1	3.9	1.4	2.1	9.4	2.3	3.7	3.8	7.1
23	1.9	1.6	0.3	1.3	0.3	0.6	0.5	3.3	3.9	0.4	7.8	2.5	5.4	3.9	5.0
	7.3	2.4	0.7	3.5	1.6	0.2	0.9	1.3	2.1		3.1	3.6	3.0	2.2	4.1
24	9.9	8.3	0.7	6.3	2.9	0.3	1.6	3.3	3.4		10.9	5.4	5.4	4.7	3.3
	11.5	13.0	1.4	8.6	5.4	1.3	3.3	3.9	3.9		10.9	4.0	2.8	4.3	2.9
25	14.1	12.3	5.0	10.5	13.9	1.9	7.9	5.9	7.8	0.7	6.3	6.8	10.3	6.3	2.1
	16.4	12.3	6.4	11.7	12.3	3.2	7.8	3.9	6.4		9.4	8.8	7.3	6.0	0.4
26	13.0	13.4	16.4	14.3	15.0	7.1	11.0	3.9	6.9			8.6	8.0	4.6	1.2
	10.7	15.0	17.9	14.5	10.5	3.5	7.0	0.7	9.4		3.1	7.5	8.0	4.8	0.4
27	3.8	9.5	18.2	10.5	12.6	9.0	10.8		9.2		4.7	7.5	9.1	5.1	
	5.0	5.5	12.1	7.5	6.4	5.5	6.0	1.3	8.7		1.6	4.2	4.2	3.3	
28	1.5	2.8	7.2	3.8	6.2	8.0	7.1	0.7	7.3	0.4	1.6	2.3	3.0	2.5	
	1.9	1.6	2.9	2.1	2.7	5.5	4.1		5.5			1.3	1.4	1.4	0.4
29	1.1	0.4	3.6	1.7	3.5	8.4	5.9		2.5			1.7	1.2	0.9	
	0.8	0.4	2.5	1.2	2.7	6.1	4.4		2.5			1.1	0.9	0.8	
30	1.1	0.4	1.4	1.0	1.6	10.3	5.9		3.0			0.2	0.5	0.6	
			1.4	0.5	1.6	6.1	3.9		0.5			0.2	0.2	0.2	
31			1.4	0.5		5.1	2.6					0.2	0.1	0.1	
						2.3	1.1		0.2				0.2	0.1	
32						3.2	1.6		0.2				0.1	0.1	
						2.6	1.3								
33					0.3	2.9	1.6								
						1.6	0.8		0.2						
34					0.3	1.6	0.9								
						0.3	0.2								
35						0.3	0.2								
36															
TS	-43.0	-42.9	-42.5	-42.8	-42.7	-41.9	-42.3	-44.1	-42.9	-45.0	-43.7	-43.4	-43.3	-43.7	-44.3

Table 20. Number and biomass of herring FRV "Scotia" 2-26 July 1984 by area (Fig. 12)

Area	Age	Total No x 10^6	Total cm	Total g	Biomass tonnes x 10^3	% Immature By No	% Immature By Wt	Mature No x 10^6	Mature cm	Mature g	Biomass tonnes x 10^3
1	1										
	2	475.9	26.2	157	74.5	14.9	12.5	405.2	26.4	161	65.2
	3	258.5	28.3	205	53.0	1.0	0.6	256.0	28.3	206	52.7
	4	99.2	29.7	242	24.0			99.2	29.7	242	24.0
	5	35.7	30.6	271	9.7			35.7	30.6	271	9.7
	6	16.1	32.2	318	5.1			16.1	32.2	318	5.1
	7	22.3	32.5	330	7.4			22.3	32.5	330	7.4
	8	9.3	33.3	362	3.4			9.3	33.3	362	3.4
	9	5.5	33.5	368	2.0			5.5	33.5	368	2.0
	10	0.7	34.8	415	0.3			0.7	34.8	415	0.3
	Total	923.2	27.7	194	179.4	7.9	5.3	849.9	28.0	200	169.8
2	1										
	2	54.8	26.8	170	9.3	6.7	5.3	51.1	26.9	173	8.8
	3	53.5	29.2	227	12.1	0.9	0.6	53.0	29.2	228	12.1
	4	37.0	30.0	251	9.3			37.0	30.0	251	9.3
	5	9.0	31.6	299	2.7			9.0	31.6	299	2.7
	6	8.5	32.1	316	2.7			8.5	32.1	316	2.7
	7	7.4	32.7	339	2.5			7.4	32.7	339	2.5
	8	8.9	33.5	366	3.3			8.9	33.5	366	3.3
	9	7.9	33.7	374	3.0			7.9	33.7	374	3.0
	10	2.1	33.3	360	0.7			2.1	33.3	360	0.7
	Total	189.1	29.5	241	45.6	2.2	1.2	184.9	29.6	244	45.1
3	1	0.5	22.0	84		100.0	100.0				
	2	225.9	25.9	151	34.2	17.5	14.2	186.4	26.2	157	29.3
	3	37.3	27.7	190	7.1			37.3	27.7	190	7.1
	4	9.3	28.9	221	2.1			9.3	28.9	221	2.1
	5	0.8	30.4	261	0.2			0.8	30.4	261	0.2
	6	0.3	30.8	271	0.1			0.3	30.8	271	0.1
	7										
	8										
	9										
	10										
	Total	274.0	26.3	159	43.6	14.6	11.2	234.1	26.6	165	38.7
4	1	1.9	21.0	72	0.1	100.0	100.0				
	2	201.2	26.2	157	31.6	13.5	10.9	174.2	26.4	162	28.1
	3	65.0	28.8	218	14.1	3.3	2.2	62.9	28.9	220	13.8
	4	61.0	29.7	241	14.7			61.0	29.7	241	14.7
	5	9.2	31.2	287	2.6			9.2	31.2	287	2.6
	6	6.3	31.9	310	2.0			6.3	31.9	310	2.0
	7	13.6	32.6	335	4.6			13.6	32.6	335	4.6
	8	1.7	34.8	416	0.7			1.7	34.8	416	0.7
	9	2.9	33.4	361	1.0			2.9	33.4	361	1.0
	10	0.6	34.8	415	0.2			0.6	34.8	415	0.2
	Total	363.6	27.8	197	71.8	8.6	5.4	332.4	28.1	204	67.9
5	1	383.9	20.9	72	27.7	98.6	97.5	5.3	24.9	131	0.7
	2	497.6	25.0	135	67.1	35.2	26.0	322.6	26.1	154	49.6
	3	47.7	28.0	197	9.4	3.9	3.1	45.8	28.1	198	9.1
	4	18.9	29.2	228	4.3			18.9	29.2	228	4.3
	5	3.8	29.6	240	0.9			3.8	29.6	240	0.9
	6	1.0	30.2	256	0.3			1.0	30.2	256	0.3
	7										
	8	0.6	32.6	333	0.2			0.6	32.6	333	0.2
	9										
	10										
	Total	953.6	23.6	115	109.9	58.2	40.7	398.2	26.5	164	65.1
6	1	182.8	21.3	76	13.9	100.0	100.0				
	2	176.4	22.6	95	16.7	82.9	76.3	30.2	24.9	131	3.9
	3	2.5	27.2	180	0.5			2.5	27.2	180	0.5
	4	0.3	28.8	214	0.1			0.3	28.8	214	0.1
	5										
	6										
	7										
	8										
	9										
	10										
	Total	362.1	22.0	86	31.1	90.9	85.6	33.0	25.1	135	4.5
Total	1	569.2	21.0	73	41.8	99.1	98.3	5.3	24.9	131	0.7
	2	1631.9	25.4	143	233.3	28.3	20.7	1169.7	26.3	158	185.1
	3	464.5	28.4	207	96.2	1.5	1.0	457.5	28.4	208	95.2
	4	225.7	29.7	241	54.5			225.7	29.7	241	54.5
	5	58.6	30.8	275	16.1			58.6	30.8	275	16.1
	6	32.2	32.0	314	10.1			32.2	32.0	314	10.1
	7	43.4	32.6	333	14.4			43.4	32.6	333	14.4
	8	20.6	33.5	367	7.6			20.6	33.5	367	7.6
	9	16.3	33.6	370	6.0			16.3	33.6	370	6.0
	10	3.3	33.9	381	1.3			3.3	33.9	381	1.3
	Total	3065.5	25.8	157	481.4	33.7	18.8	2032.5	27.6	192	391.0

Table 21. Numbers of herring and percentage immature by area (Fig. 12) FRV "Scotia" July 1984. Smaller fish were all immature, large fish all mature and - indicates no fish at this length.

Area	1		2		3		4				5					
Age	2		2		2		2		3		1		2		3	
Length	No	%	No	%	No	%	No	%	No	%	No	%	No	%	No	%
22.5	-	-	-	-	6	100	1	100	-	-	3	100	10	100	-	-
23	2	100	2	50	10	90	4	75	-	-	3	100	12	100	-	-
23.5	4	75	1	0	10	80	4	50	-	-	-	-	14	79	-	-
24	12	67	3	33	12	50	7	57	-	-	1	0	15	47	-	-
24.5	13	62	4	25	18	33	9	22	-	-	-	-	16	31	-	-
25	16	31	8	25	14	21	10	30	-	-	1	100	16	6	-	-
25.5	15	7	13	23	16	19	12	0	1	100	-	-	22	5	-	-
26	14	7	13	0	11	0	10	10	-	-	-	-	20	0	3	33
26.5	17	0	11	0	12	0	11	9	3	0	-	-	17	0	1	0
27	10	0	16	0	14	0	15	0	1	0	-	-	22	0	6	0

Table 22. Number of herring and percentage immature for the whole survey area (Fig. 14) FRV "Scotia" July 1983. Smaller fish were immature, large fish mature - indicates no fish at this length.

Age	1		2	
Length	No	%	No	%
20	41	100	2	100
21	42	100	4	100
22	43	100	8	88
23	9	89	24	79
24	-	-	37	51
25	-	-	45	16
26	-	-	42	2

Table 23. Percentage of herring at maturity stage for ages 2 and 3 for the whole survey areas FRV "Scotia" July 1983 (Fig.14) July 1984 (Fig.12).

Year	Age	Maturation Stage						
		2	3	4	5	6	7	8
	2	16.5	58.8	24.7	-	-	-	-
1983	3+	0.6	36.9	55.0	4.2	-	-	3.3
	combined	6.4	44.8	44.0	2.7	-	-	2.1
	2	27.1	51.3	21.1	0.3	0.03	-	0.2
1984	3+	0.6	37.5	55.1	3.8	-	-	3.0
	combined	17.9	46.5	32.9	1.5	-	-	1.2

Table 24 Number and biomass by area (Fig. 14) and by age (number mean length mean weight and biomass, totals, and mature and percentage immature)

Area	Age	Total No $\times 10^6$	Total cm	Total g	Total Biomass tonnes $\times 10^3$	% Immature By No	% Immature By Wt	Mature No $\times 10^6$	Mature cm	Mature g	Mature Biomass tonnes $\times 10^3$
0	1	608.2	19.8	60.6	36835	99.8	99.6	1.3	23.5	107.9	141
	2	171.5	26.3	164.3	28175	14.6	10.4	146.4	26.7	172.4	25244
	3	213.7	27.9	203.1	43399						
	4	20.3	28.2	211.2	4289						
	5	10.7	28.6	220.3	2356						
	6	0.9	31.1	298.7	265						
	7	0.3	31.1	300.2	99						
	8	0.1	31.5	313.9	31						
	9	0.1	31.5	313.9	31						
	≥10	0	-	-	0						
1	1	48.2	16.4	29.4	1415	0.0	0.0	0.0	-	-	0
	2	0.2	23.5	108.8	22	69.1	66.0	0.1	24.1	118.7	7
	3	0	-	-	0						
	4	0	-	-	0						
	5	0	-	-	0						
	6	0	-	-	0						
	7	0	-	-	0						
	8	0	-	-	0						
	9	0	-	-	0						
	≥10	0	-	-	0						
2	1	98.9	20.2	65.8	6519	0.0	0.0	0.0	-	-	0
	2	87.7	25.7	153.1	13423	25.5	18.4	65.3	26.5	167.8	10955
	3	37.9	27.6	197.2	7469						
	4	8.9	28.8	228.7	2039						
	5	2.1	29.6	251.5	522						
	6	0.6	31.2	304.1	182						
	7	0.4	32.2	343.4	123						
	8	0.1	32.9	370.3	55						
	9	0.2	33.3	384.6	90						
	≥10	+	-	437.3	14						
3	1	0	-	-	0	0.0	0.0	0.0	-	-	0
	2	+	-	217.9	3	0.0	0.0	+	-	-	3
	3	0.2	29.7	243.2	34						
	4	0.1	30.2	269.4	34						
	5	0.5	31.8	328.5	168						
	6	1.1	32.7	362.6	390						
	7	0.9	33.2	380.4	355						
	8	2.4	34.2	425.9	1040						
	9	1.3	33.9	411.5	526						
	≥10	+	-	392.8	11						

ctd

Table 24 (ctd)

Area	Age	No x 10^6	Total cm	Total g	Biomass tonnes x 10^3	% Immature By No	% Immature By Wt	Mature No x 10^6	Mature cm	Mature g	Biomass tonnes x 10^3
4	1	10.5	22.3	89.1	938	0.6	0.7	0.1	-	107.9	6
	2	33.4	26.1	161.4	5384	20.3	14.7	26.6	26.7	172.7	4591
	3	27.0	28.2	212.5	5735						
	4	12.3	29.3	242.7	2988						
	5	2.9	30.0	264.4	754						
	6	2.9	30.9	296.2	855						
	7	2.1	32.6	356.4	752						
	8	1.8	32.8	364.9	666						
	9	1.9	33.8	411.2	783						
	⩾10	0.2	34.5	437.3	93						
5	1	11.3	19.1	52.6	595	0.0	0.0	0.0	-	-	0
	2	72.4	26.3	164.9	11942	10.8	8.9	64.6	26.5	168.5	10878
	3	71.6	28.3	212.2	15184						
	4	8.4	30.0	242.7	2988						
	5	15.8	30.4	277.6	4384						
	6	13.5	31.4	312.7	4214						
	7	8.3	31.3	308.1	2563						
	8	7.6	32.2	343.3	2593						
	9	2.8	33.4	389.0	1083						
	⩾10	0	-	-	0						
6	1	+	-	83.3	1	0.0	0.0	0.0	-	-	0
	2	7.3	27.1	183.0	1342	6.2	4.4	6.9	27.2	186.4	1283
	3	7.6	28.1	207.7	1577						
	4	0.6	29.9	260.6	153						
	5	0.5	29.8	255.7	119						
	6	0.2	30.8	288.2	48						
	7	+	-	415.0	1						
	8	0.1	32.6	354.2	18						
	9	+	-	415.0	1						
	⩾10	0	-	-	0						
7	1	0	-	-	0	0.0	0.0	0.0	-	-	0
	2	5.7	27.7	197.4	1129	1.2	0.9	5.6	27.7	198.0	1118
	3	32.3	29.0	234.6	7589						
	4	24.0	29.7	257.2	6173						
	5	18.0	32.1	337.2	6073						
	6	39.1	32.6	358.4	13996						
	7	33.3	32.5	356.0	11847						
	8	34.4	33.4	391.1	13469						
	9	0	-	-	0						
	⩾10	0	-	-	0						
Total	1	777.3	19.7	59.6	46303	0.2	0.3	1.4	23.5	107.9	148
	2	378.2	26.2	162.4	61420	16.6	9.6	315.5	26.8	176.0	55510
	3	390.2	28.1	207.6	80992						
	4	74.6	29.2	239.5	17870						
	5	50.4	30.6	285.2	14375						
	6	58.1	32.2	343.1	19951						
	7	45.3	32.3	347.2	15740						
	8	46.6	33.2	383.9	17872						
	9	6.3	33.6	398.9	2514						
	⩾10	0.3	34.4	432.6	119						

Table 25. Total numbers of herring, spawning stock (No. = Number, t = tonnes) by area (Fig. 5) and for Norwegian and Scottish surveys July 1984.

Column		1		2		3		4		5		6		7	8	9	10		11	12	13	14
Area		NW		NE		M		SW		SE		Total 1-5		East of 0°	West of 4°W	Moray Firth	A 0-group omitted	(raised)	Orkney Shetland Buchan Total	B Fladen	Aberdeen	Norwegian Deeps
Age	Vessel	GO Sars	Scotia	GO Sars	Scotia	GO Sars	Scotia	GO Sars	Scotia	GO Sars	Scotia	GO Sars	Scotia	Scotia	Scotia	Scotia	Eldjarn	Scotia	Eldjarn	Eldjarn	Scotia	Eldjarn
1		0.1				1.7	133.8	14.2	50.5	163.1	98.8	179.1	283.1		1.0	14.7	171.3	253.8	459.4	45.9	40.3	6.1
2		36.9	54.8	208.1	446.7	254.7	354.6	11.5	149.0	298.2	131.2	809.5	1136.3	26.1	100.0	19.1	291.3	329.0	1415.2	331.5	52.2	18.6
3		56.2	53.5	277.2	242.6	81.1	39.1	5.8	33.4	75.2	14.0	495.5	382.6	14.2	32.3	1.8	73.7	31.5	533.0	93.1	5.0	10.9
4		39.1	37.0	174.2	93.1	15.3	9.5	3.7	30.8	14.5	5.5	246.8	175.9	5.4	30.3	0.7	16.5	12.5	259.6	24.2	2.0	8.7
5		13.0	9.0	58.2	33.5	5.6	0.8	1.3	4.6	4.8	1.2	82.9	49.2	2.0	4.6	0.1	5.5	2.5	75.8	7.0	0.4	3.0
6		6.4	8.5	25.2	15.1	1.4	0.3	0.8	3.2	0.7	0.4	34.5	27.4	0.9	3.1		1.4	0.7	35.7	1.6	0.1	1.9
7		11.0	7.4	26.2	20.9	1.3		1.1	6.9	0.3	0.1	39.9	35.4	1.2	6.8		1.3		45.7	2.7		4.4
8		10.0	8.9	15.7	8.7	0.6		0.7	0.9	0.3	0.2	27.3	18.8	0.5	0.9		0.4	0.4	24.6	9.8	0.1	4.5
9+		9.8	10.0	13.3	5.9	0.4		0.6	1.8	0.3		24.4	17.6	0.3	1.7		0.2		23.0	11.4		4.2
Total No		182.0	189.1	798.0	866.5	362.0	538.1	40.0	280.9	557.0	251.5	1939.9	2126.1	50.6	180.7	36.6	561.6	630.4	2872	527	100.1	62.0
Spawning stock	No	179	184.9	777	797.7	335	258.2	24	176.1	365	180.1	1679	1525.0	46.6	165.2	15.3	361	263.2	2118	448	41.8	54
	t	44	45.1	174	159.4	54	42.0	5	35.3	55	17.9	332	299.6	9.3	33.7	2.5	53	43.1	405	76	6.8	13

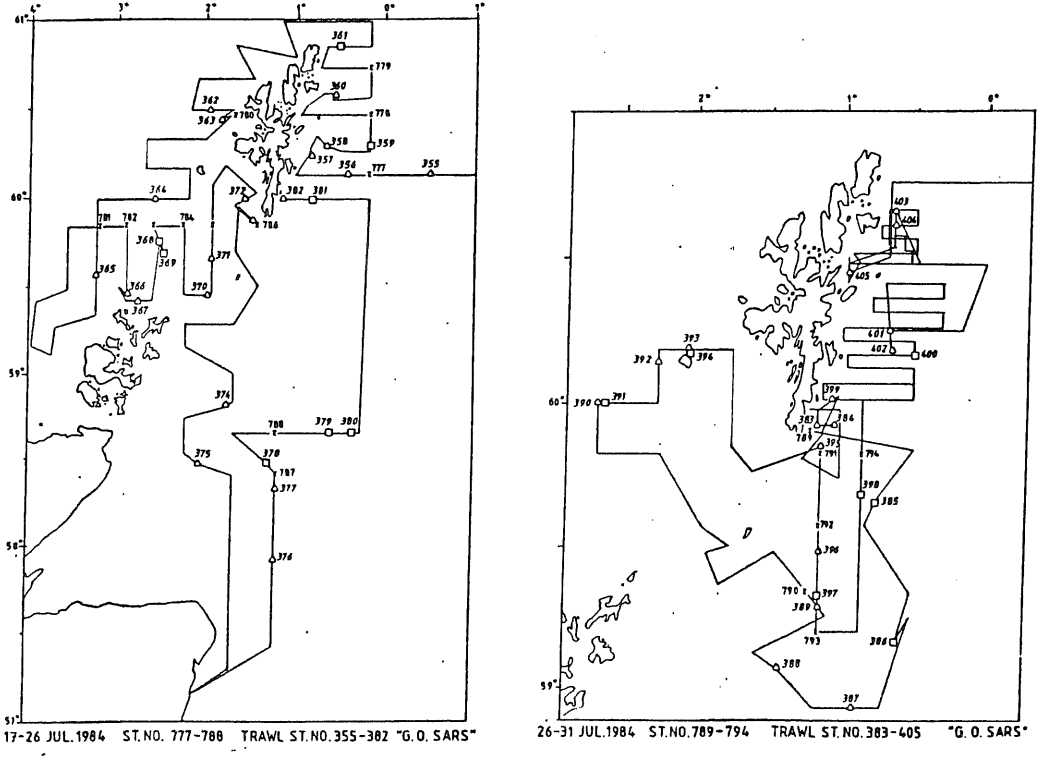

Figure 1. Survey track and stations R/V "G.O.Sars" 17-26 and 26-31 July 1984.
Triangle = pelagic trawl, square = bottom trawl, Z or $\bar{x}$ = hydrographic station.

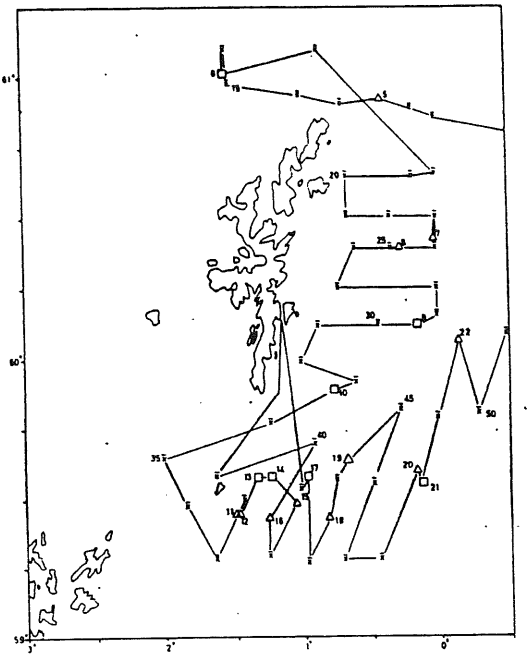

Figure 2. Survey track and stations R/V "Bei Dou" 19-25 July 1984.

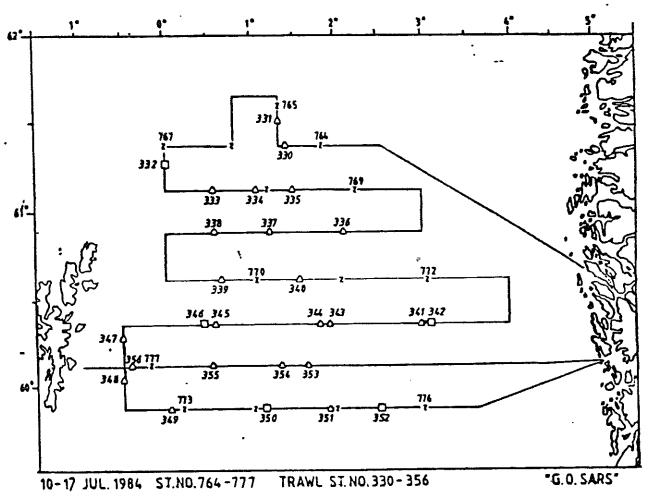

Figure 3. Survey track and stations R/V "G.O.Sars" 10-17 July 1984.

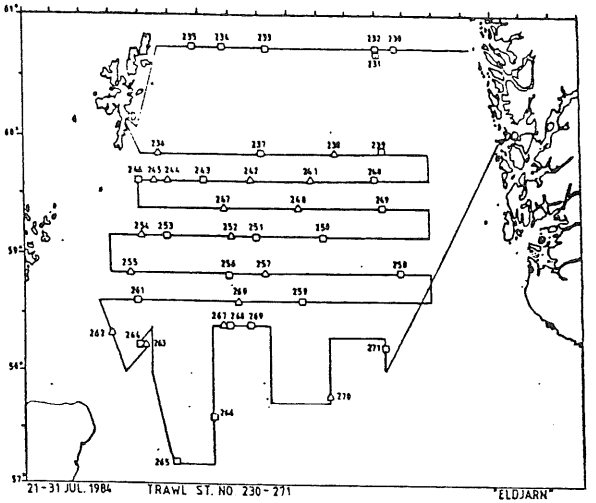

Figure 4. Survey track and stations R/V "Eidjarn" 21-31 July 1984.

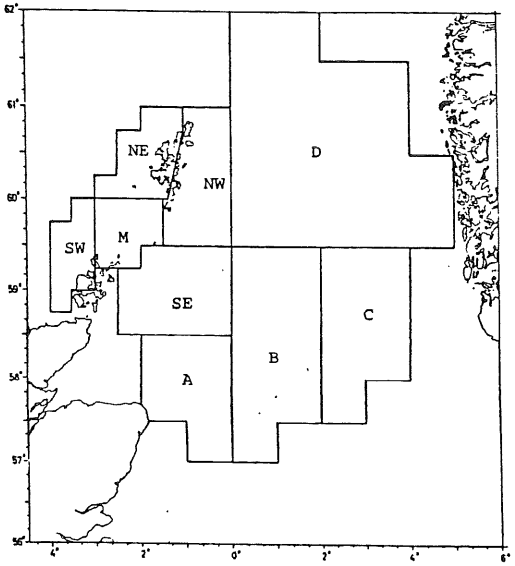

Figure 5. Definition of sub-areas.

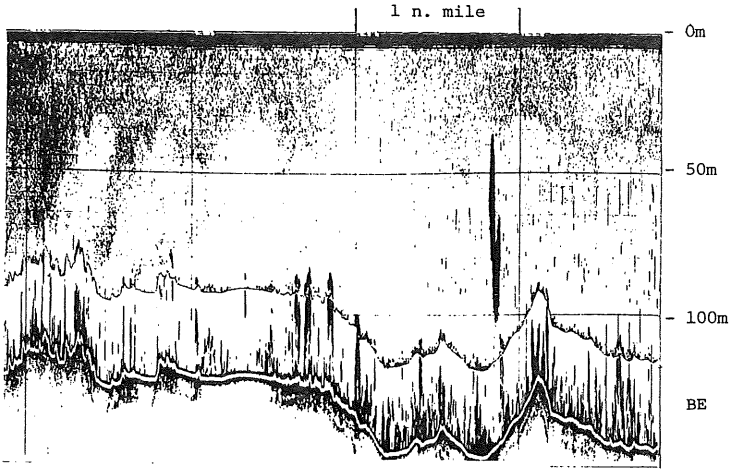

Figure 6. Echo recordings from east coast of Shetland, R/V "G.O.Sars" 17 July, 1300 GMT. Two herring schools at 40-100m clearly differed from the small schools close to bottom. Those were assumed to be whiting and Norway pout. The very small schools at about 70m to the right were identified as 0-group haddock and whiting. The recordings in the upper 50 m were assumed to be mainly plankton. Thin vertical lines of equal length are recordings of the transmitting pulse from the sonar.
BE = Bottom expander (5m).

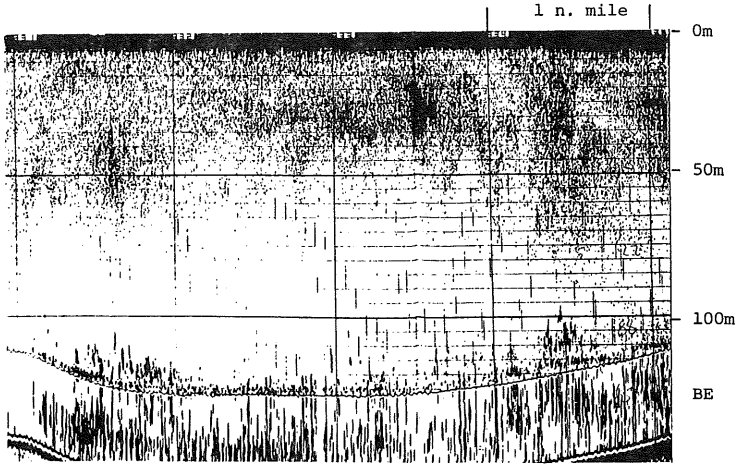

Figure 7. Echo recordings from south east of Foula, R/V "G.O.Sars" 21 July, 0900 GMT. The recordings 5-20m off bottom gave a mixture of herring and whiting (trawl stations 372 and 373). Recording in the upper 50 m were assumed to be mainly plankton.
BE = Bottom expander (5m).

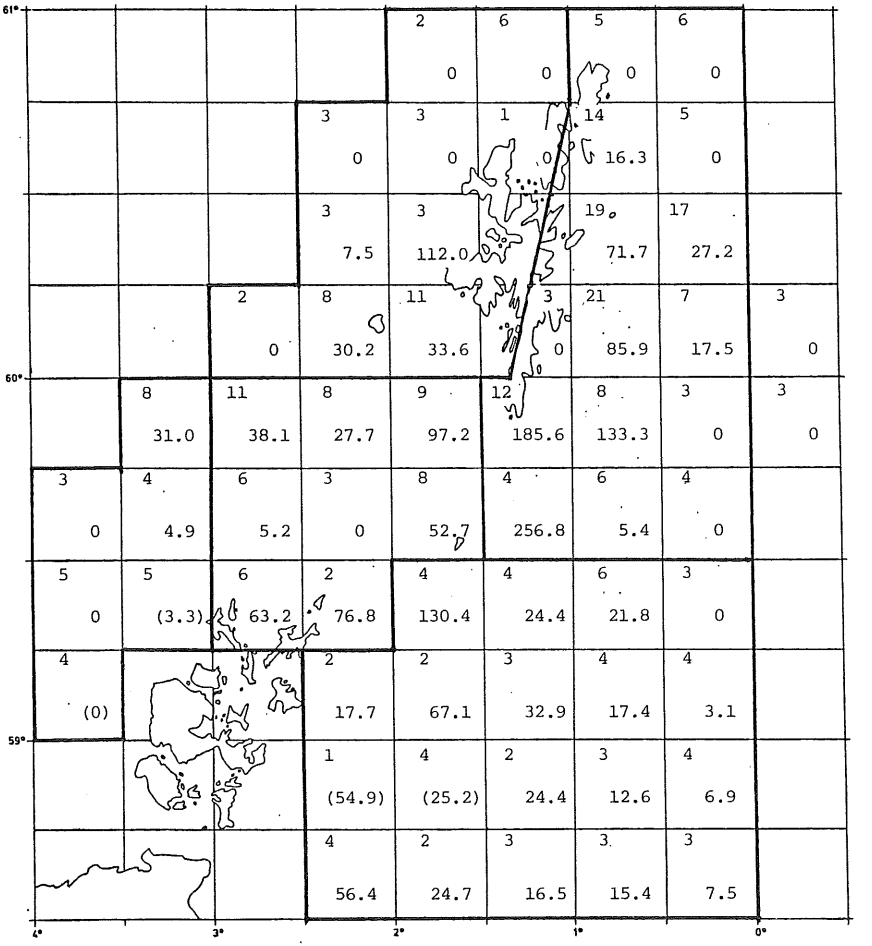

Figure 8. Estimated number of herring (millions) within quarter statistical rectangles, R/V "G.O.Sars" . Estimates based on night time observations are given in brackets. Number of five mile integrals is given in the upper left corners.

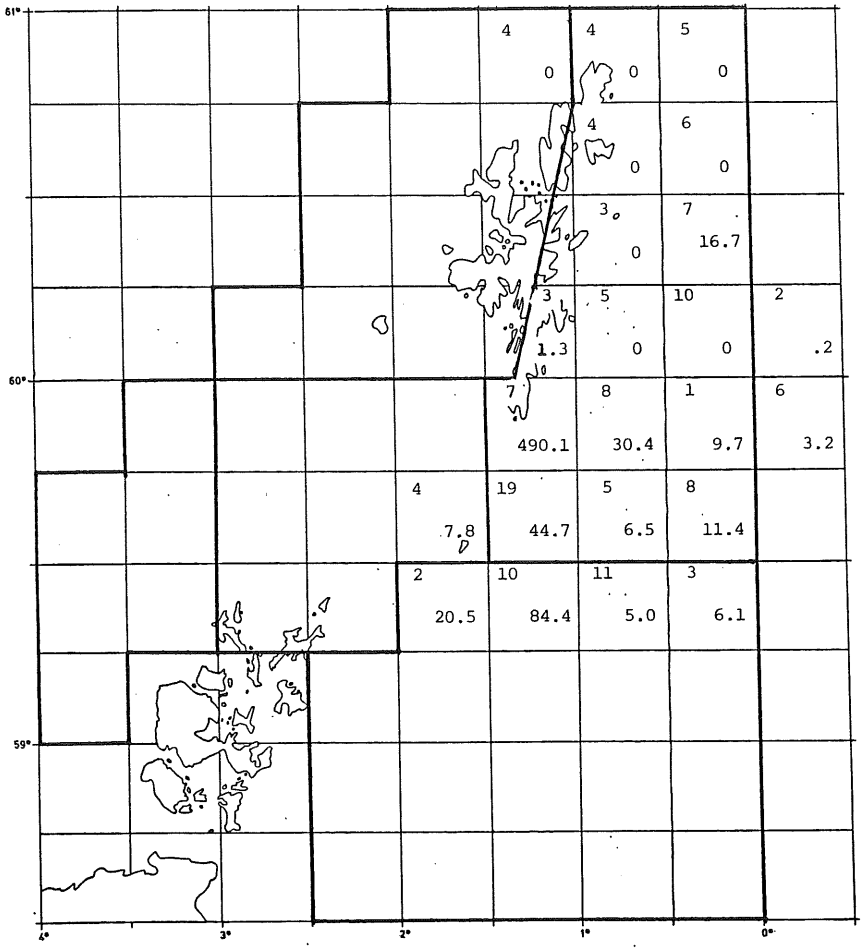

Figure 9. Estimated number of herring (millions) within quarter statistical rectangels, R/V "Bei Dou" . Number of five mile integrals is given in the upper left corners.

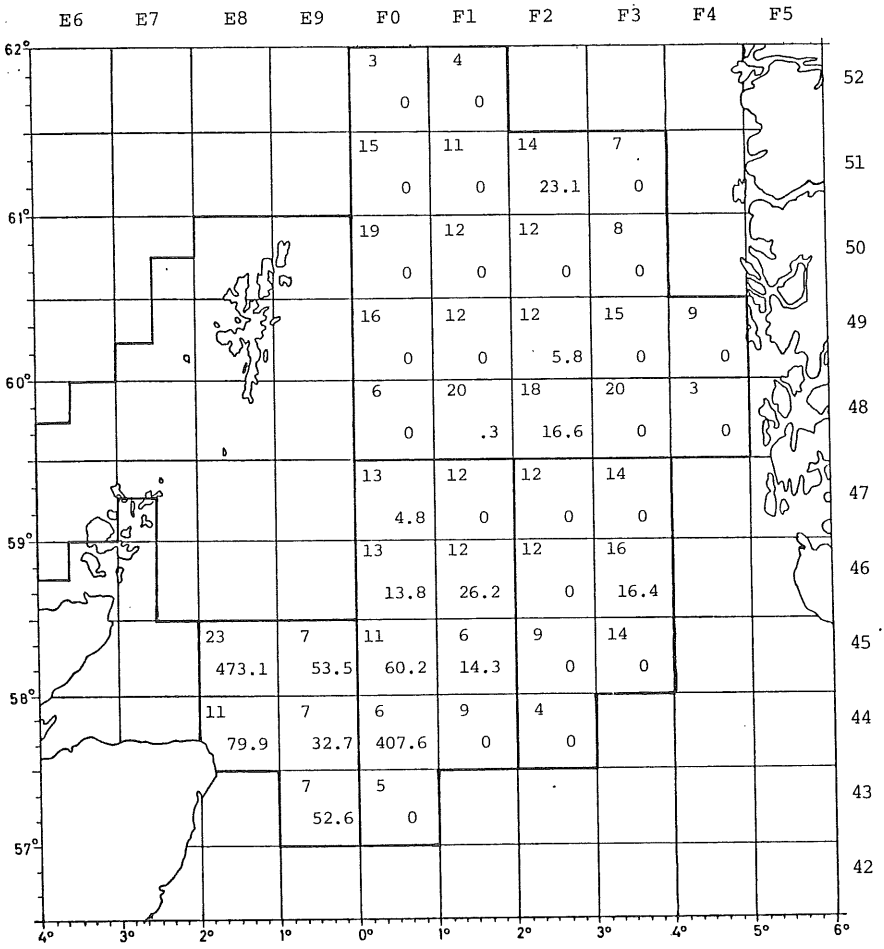

Figure 10. Estimated number of herring (millions) within statistical rectangles, R/V "Eldjarn" and R/V "G.O.Sars". Number of five mile integrals is given in the upper left corners.

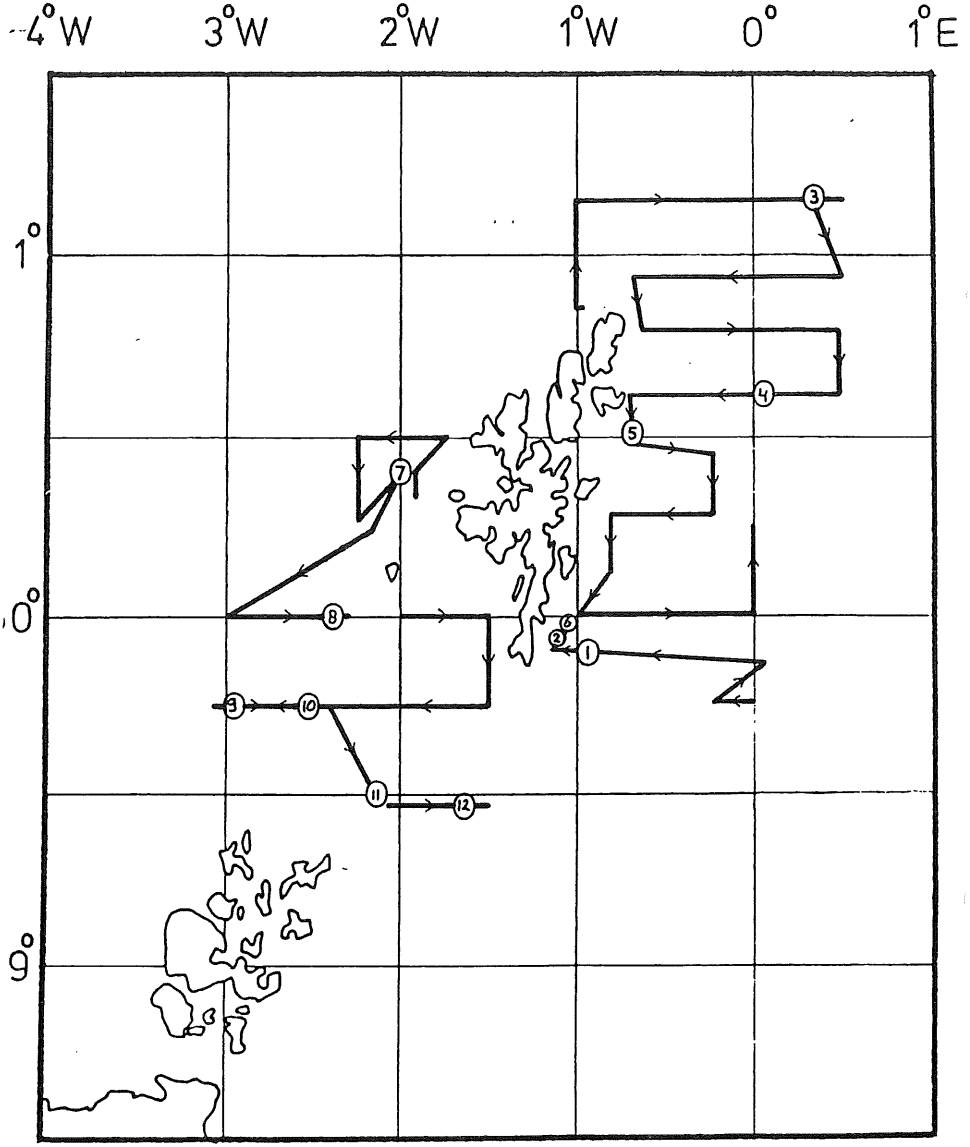

Figure 11

"Tridens" echosurvey 2-12 July 1984.

Cruise track and trawl stations.

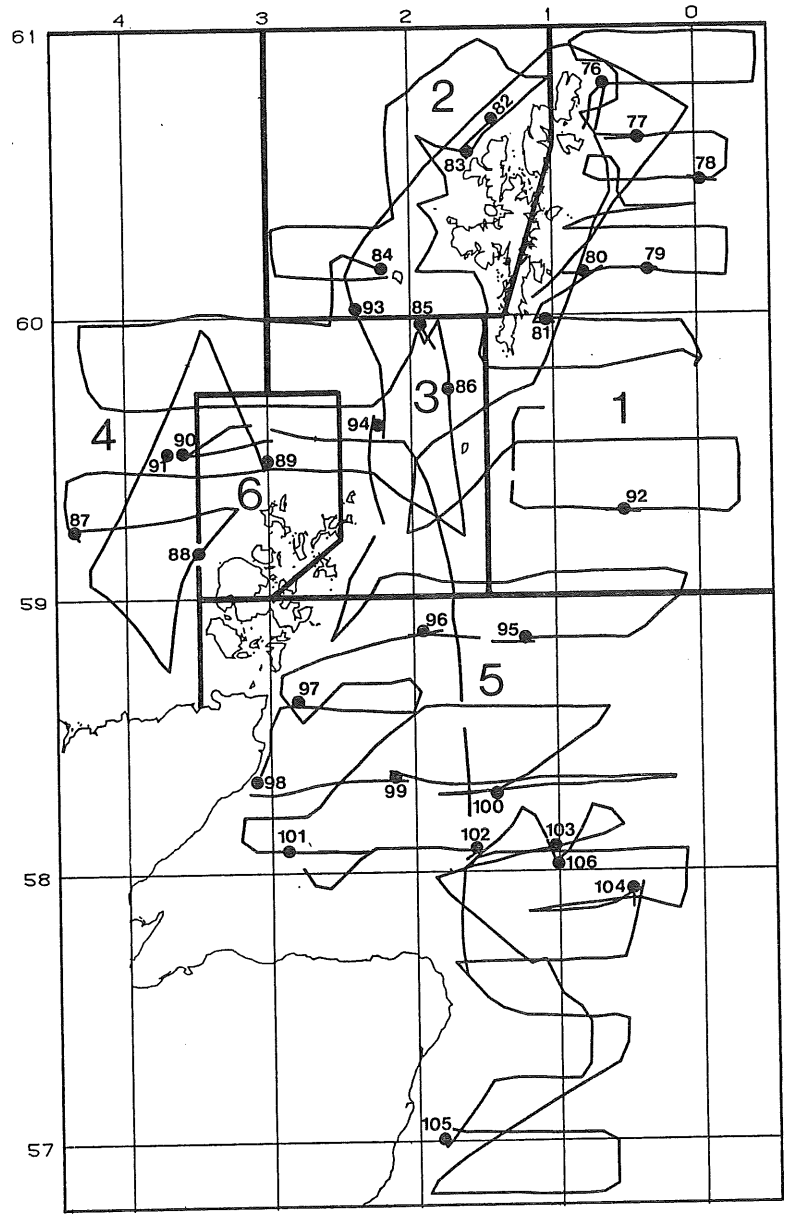

Figure 12. Cruise track, trawl hauls and analysis areas FRV "Scotia" 6-26 July 1984. Areas 1 to 5 are both length and otolith areas, area 6 is a separate length area but combined with area 3 for otoliths.

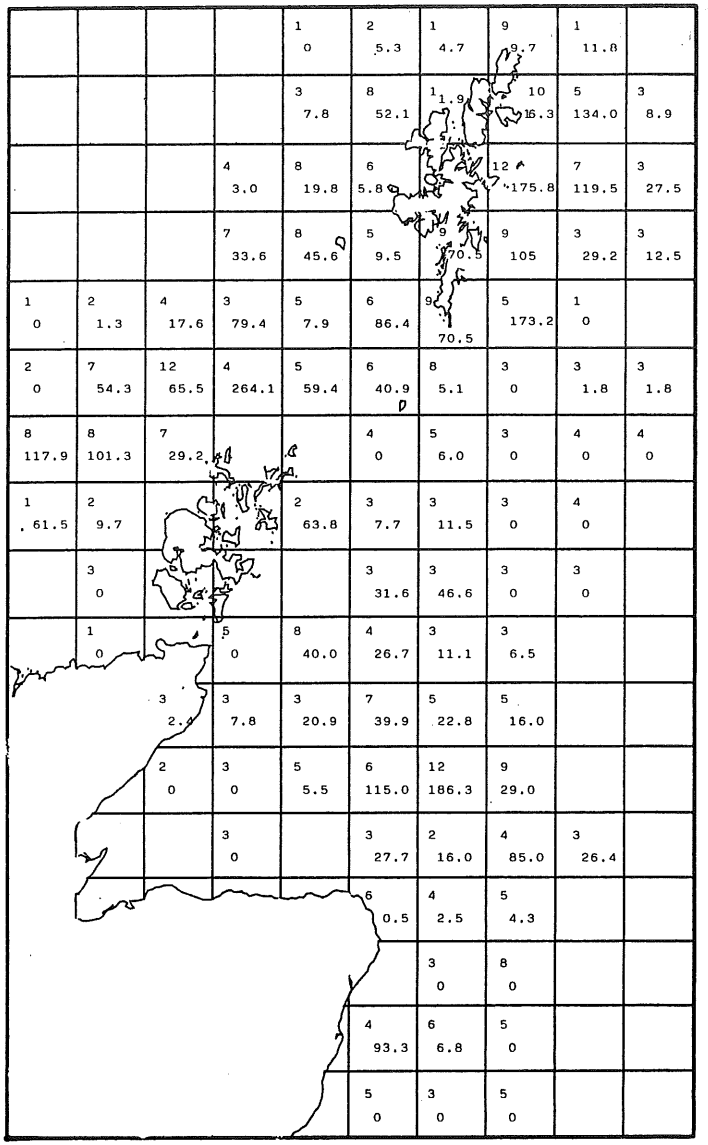

Figure 13. Numbers of herring (and number of ½ hour integrator runs (top left corner) by quarter statistical rectangle FRV "Scotia" July 6-26 1984.

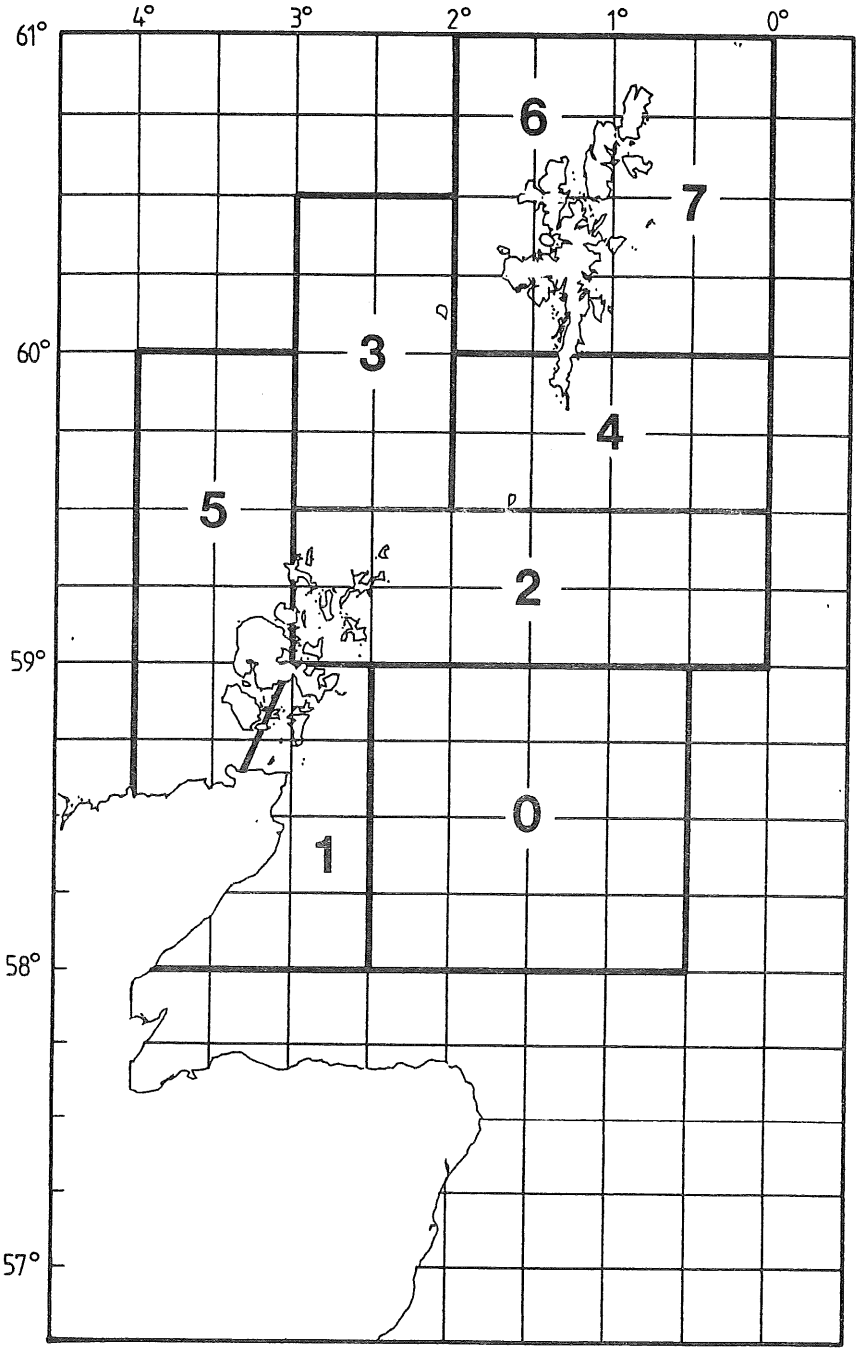

Figure 14. Areas used for analysis FRV "Scotia" July 1983.