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REPORT ON HERRING ACOUSTIC SURVEYS

IN NORTHERN AND CENTRAL NORTH SEA

DURING SUMMER 1987.

by

A. Aglen
Institute of Marine Research
Bergen, Norway

and

E. J. Simmonds
DAFS Marine Laboratory
Victoria Road
Aberdeen, Scotland

ABSTRACT

Acoustic surveys covering the Northern and Central North Sea were carried out by Scottish and Norwegian vessels during the period 24 June to 11 August. The estimated biomass of mature herring was 817 000 tonnes. For the area north of 57°N the estimate was 553 000 tonnes compared to 534 000 tonnes estimated in July 1986. For this area the estimates by age groups indicate a high mortality on the 1981-1983 year-classes. The estimated number of the 1984 year-class was about twice as large as the estimate for all older age groups together. The 1985 year-class was estimated to be quite strong ($13.7 \cdot 10^9$).

FRV "SCOTIA", IVaW. (E.J. Simmonds)

Methods

The acoustic survey on FRV "Scotia" was carried out using a Simrad EK400 38kHz sounder. Echo integration was carried out using an Aberdeen Echo Integrator. Table 1 shows the equipment settings and the results of two calibrations carried out during the survey.

The survey track was selected to cover the area in band 7.5 nautical miles wide (7.5Nm average transect spacing). The exact position of each east-west track was selected randomly within the central 5.5Nmile part of each 7.5 mile band, thus ensuring random positioning, whilst constraining the grid to lie between a minimum spacing of 2Nm and a maximum of 13Nm. A computer pseudo-random number generator was used to define the intended track positions to the nearest 1Nm. The ends of the tracks were also positioned randomly at 1/2 the actual track spacing from the area boundary, giving equal track length in any rectangle within the area. The between track data was then included in the data analysis. The cruise track is shown in Fig 1.

Trawl hauls were carried out during the survey on the denser echo traces and the positions of these hauls are also shown on Fig 1. Each haul was sampled for length, age, maturity and weight of individual herring. Up to 500 fish were measured to 1/2cm from each haul, otoliths were taken: 5 per 1/2cm below 22cm and 10 per 1/2cm at 22cm and above. Fish weights were collected at sea from a random sample of 50 fish per haul. Meristic samples were taken from selected hauls.

Data from the echo integrator were summed over quarter hour periods (2.5Nm at 10Knots). The data were divided into three categories, by visual inspection of the echo-sounder paper record and the integrator cumulative output; "herring traces", "probably herring traces" and "probably not herring traces". For the 1987 survey 87% of the stock by number was attributable to the "herring traces" and only 13% to the "probably herring traces". The third category was attributable mainly to Norway pout, whiting, haddock, sandeels and sprat in that order of importance. Most of these species were either easily recognisable or did not appear to occupy the same area with the exception of sprats in a low density area on the edge of the Moray Firth. Separation of these was done using haul proportions but referred only to a negligible part of the stock. Examples of herring traces are shown in Fig 2 to 5 inclusive.

To calculate integrator conversion factors the Target strength of herring was estimated using the TS/length relationship recommended by the acoustic survey planning group (Anon.1983):

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

and the relationship for sprats in the small area where they were found was:

$$TS = -8.71\log_{10}L - 19.26 \text{ dB per kg}$$

The weight of fish at length was determined by weighing fish from each trawl haul with more than 50 specimens. The resulting weight-length relationship from 700 fish was:

$$W = 1.649 \cdot 10^{-3} L^{3.505}$$

W in grams, L in cm.

Survey Results

The results from 23 hauls where more than 250 herring were caught are shown in Table 3. These have been used to define 4 areas (Fig 6) within which the length compositions were not very different. A Kolmogorov Smirnov test was used to aid this area allocation procedure. The areas were defined on a 15Nmile grid equidistant from the nearest trawl haul, except for the area to the east of the Moray Firth. There area III was connected north-south. This was supported by information from hauls with less than 250 fish and the absence of any data to the contrary. This follows the pattern of previous years data showing a size change offshore. The mean length frequency distributions for each area were derived giving equal weight to each haul with more than 250 fish and are shown in Table 3 along with the mean length, weight and target strengths for each haul and each area. The target strength per individual is derived from the TS/length formula given above and both the mean weight and the target strength per kilogramme were then derived from the length/weight formula. The age data from each haul was combined by summing the numbers of otoliths at age for each area.

The estimated number of herring in each quarter rectangle is shown in Fig 7. These values are based on the arithmetic mean integrator output within each quarter statistical rectangle and are shown with the number of 15 minute periods of integration in the upper left hand corner. The numbers of herring at age for each of the four areas is shown in Table 4 along with the mean length, weight and total biomass for each age and for totals for the whole area. Two and three ring fish are split into two categories: mature and immature based upon those reaching maturity stage 3 at the time of capture. The biomass of herring by quarter statistical rectangle is shown in Fig 8 for the total and for the two categories "herring trace" and "probably herring traces".

The total stock estimates for the area north of $57^{\circ} 25'N$ south of $61^{\circ} 00'N$ and between 0 and 4 degrees West is 4137 million fish giving a biomass of 529 thousand tonnes. This is split between 49% mature 51% immature by number giving a spawning stock of 2048 million fish or 365 thousand tonnes.

The mortality estimates based on acoustic surveys of Orkney Shetland and Buchan areas from stock estimates covering the last 4 years are shown in Table 5. The wild figures for the fish older than 4 years indicate some of the difficulties in assessing the proportions of the stock in the older age groups. The total mortality for 2 years and older of .92 .80 and 1.32 have much greater reliability.

R/V "ELDJARN" AND R/V "G.O.SARS", IVa AND IVb. (A. Aglen)

The main Norwegian herring survey was worked by R/V "Eldjarn" in IVb and eastern IVa. Area IVb was covered during 24 June - 14 July and eastern IVa during 14 - 29 July. In addition R/V "G.O.Sars" covered most of IVa during 4 - 25 July and R/V "Eldjarn" covered parts of IVa and IIIa during 31 July - 11 August. The herring data from those surveys are also used in this report. Figures 9 - 11 show survey grid and trawl stations. During the main herring survey the distance between transects was 15 nautical miles except for the south-eastern part of IVb.

Acoustic equipment and settings used are listed in Table 6. Echo integrator values were averaged over 5 nautical miles. Values allocated to herring were averaged within the sub-areas shown in Figure 12. Those average length distributions were used to calculate average target strength. Those values (based on $TS = 20 \log L - 71.2 \text{ dB}$) were used to convert echo integrator values

to herring densities. Estimated number of herring by statistical rectangles are shown in Figure 13.

Age distribution and average weights per age group were obtained by applying age-length and weight-length keys. Those keys were based on samples both from the surveys and from commercial catches during the same period. Maturity stages were taken on all aged fish. Table 7 shows length and target strength for the survey samples and number of fish sampled totally for age, weight and maturity. Table 8 shows mean weights per age group. Estimated number of herring per age group by sub-area is shown in Table 9. All fish in maturity stage 3-6 was classified as mature. The percentages of mature 2-ringers and 3-ringers are listed in the table.

The largest fish with highest proportion of mature 2-ringers was found in the northern sub-areas (A,C and E). The major part of the spawners was found in sub-areas B and G. The south eastern sub-areas (F,H,I,J and K) were dominated by 1-ringers and immature 2-ringers. Those areas also showed a higher proportion of immature 3-ringers and a considerably lower mean weight at age (particular sub-area I) compared to other areas.

Very little 0-ringers were recorded. They might have been concentrated closer to the coasts or they may have formed scattered echo recordings in the plankton layers.

Much of the herring was found close to bottom, particularly in the sub-areas G and D. This might have caused some underestimation. In parts of sub-areas D and F bad weather caused further underestimation.

COMBINED RESULTS OF THE SCOTTISH AND NORWEGIAN SURVEYS. (A. Aglen)

Table 10 shows the combined results within ICES-areas. To the west of 0° and between $57^{\circ}30'N$ and $61^{\circ}00'N$ only the results from FRV "Scotia" are included. The Norwegian effort in this area was rather low and was mainly aimed for saithe and 0-group gadoids. In the overlapping area the estimate from "G.O.Sars" is 1848 millions of all age groups (195 000 tonnes spawners), while the estimate from "Scotia" is 2914 millions (250 000 tonnes spawners). The difference in total number (37%) is higher than the difference in spawning biomass (22%) because "G.O.Sars" caught a higher proportion of large and mature fish.

The combined spawning stock estimates for area IVa is 487 000 tonnes and for IVb 330 000 tonnes. The sum of these (817 000 tonnes) can be considered as an estimate of the total North Sea spawning stock, because the adult part of the IVc + VIId stock is expected to be within the covered area at that time of the year.

Table 11 compares the biomass estimates for the areas covered during earlier years. The areas refers to the map shown in Figure 2.4.1 in Anon. (1987). Table 12 compares number per age group estimated in the area north of 57⁰N for the years since 1984.

There are no earlier summer surveys covering the whole IVa + IVb. In Table 13 the 1987-results are compared to the added results of the summer surveys north of 57⁰N and the autumn surveys on the spawning grounds in western IVb during 1984, 1985 and 1986. The resulting mortalities are generally lower than those for the area north of 57⁰N (Table 12) which again are lower than those for the Orkney-Shetland-Buchan area (Table 5). This is most pronounced for the 1983 year class. The proportions of the IVc+VIId stock included in the 1984-86 estimates are uncertain. It is also likely that some immature 2-ringers have been outside the area covered during those years. The estimates of 1-ringers during the years 1984-1986 do not include the most important 1-ringer areas and are therefore not comparable to the 1987 estimate in Table 13.

REFERENCES

- ANON. 1983. Report of the 1983 Planning Group on ICES-coordinated Herring and Sprat Acoustic Surveys. ICES C.M. 1983/H:12
- ANON. 1987. Report of the Herring Assessment Working Group for the area south of 62⁰N, Copenhagen 24 March - 3 April 1987. ICES C.M. 1987 / Assess:19
- Foote, K.G., H.P. Knudsen, G. Vestnes, D.N. MacLennan and E.J. Simmonds 1987. Calibration of Acoustic Instruments for Fish Density Estimation: A practical Guide. ICES Cooperative Research Report No 144

Table 1. Specifications, settings and calibration results of the acoustic equipment on FRV "Scotia"

Echo Sounder	EK400
Frequency	38kHz
Receiver gain	-10dB
TVG	20 logR + 2AR
A	.008dB/m
Pulse Length	1.0 ms
Bandwidth	3.3kHz
Range	150m
Transducer	15 by 30cm
equivalent Beam angle	-17.75dB
Integrator	Aberdeen
Threshold (effective)	20mv

Source level and Voltage response referred to 1metre on the TVG function measured twice for 38 kHz system using 38.1mm tungsten carbide ball.

17/7 +53.77 dB//1_{Vrms}
 25/7 +53.83 dB//1_{Vrms}

VR + SL used for the survey = +53.80dB//_{Vrms}

Table 3. % length composition by trawl and for 4 areas, showing mean length, weight, TS for hauls and for areas.

	AREA I				AREA II								AREA III						AREA IV										
	211	213	mean	205	207	209	210	212	214	215	216	224	228	230	232	234	mean	206	217	218	222	223	229	233	mean	225	mean		
14.5																													
15.0																													
15.5																													
16.0																													
16.5																													
17.0																													
17.5																													
18.0		0.2	0.1	0.2													0.0	0.3											
18.5				0.4													0.0												
19.0				0.9													0.1	3.5											
19.5				0.6				0.4									0.2	0.1	1.0										
20.0	0.2	0.2	0.2	5.0			0.6	0.4									0.2	0.4	0.5										
20.5	0.3	0.5	0.4	1.2	0.8	0.2	0.2	2.7									0.4	0.4	1.8	0.2									
21.0	2.3	4.1	3.2	3.1	1.4	1.1	1.3	3.9	0.4								0.7	1.7	2.3	2.4	0.5								
21.5	7.5	4.9	6.2	2.1	1.0	1.3	2.4	6.6	0.6								0.5	3.5	3.6	2.9	0.8	1.0							
22.0	8.9	7.9	8.4	2.1			4.3	6.6	1.1	0.3	1.2	3.7	4.7	4.1	2.2	1.2	2.4	8.9	4.5	13.9	5.4	3.1	4.1	4.7	6.4				
22.5	14.5	7.9	11.2	1.9	1.8	1.8	3.2	4.7	1.5	0.3	2.6	4.2	3.5	2.6	3.1	3.4	2.8	6.0	5.5	7.7	1.8	2.0	3.5	3.1	4.2				
23.0	9.1	12.3	10.7	3.5	3.2	4.8	3.0	8.6	1.7	1.7	3.4	5.2	4.4	5.4	8.1	5.2	4.5	5.1	3.6	5.9	3.4	2.5	5.5	4.4	4.3				
23.5	9.1	11.1	10.1	4.4	3.2	4.4	3.9	5.1	1.5	0.8	2.8	4.4	2.9	2.4	5.9	10.6	4.0	6.0	3.5	1.9	3.8	3.1	3.5	6.3	4.0	0.4	0.4		
24.0	7.3	12.3	9.8	7.7	4.0	10.9	4.3	5.8	3.2	0.9	4.5	5.8	3.5	4.2	4.2	11.2	5.4	3.5	3.6	1.1	7.7	2.9	4.9	5.1	4.1				
24.5	7.7	10.3	9.0	9.6	6.0	7.1	4.9	5.4	3.9	1.4	4.3	5.0	3.8	3.3	4.2	15.7	5.7	3.8	3.4	0.7	6.7	2.2	3.5	4.0	3.5				
25.0	6.6	11.1	8.9	12.1	8.3	10.5	5.1	6.6	7.8	2.2	8.0	9.0	6.0	5.5	5.4	17.7	8.0	4.8	2.7	0.9	6.0	3.8	2.3	6.0	3.8				
25.5	7.0	3.9	5.5	7.5	9.3	10.1	4.1	5.1	9.6	2.2	8.1	7.5	4.9	5.5	4.8	15.1	7.1	5.6	2.7	1.0	6.6	1.7	1.7	3.4	3.2				
26.0	4.0	4.7	4.4	8.9	10.5	14.3	3.4	6.2	14.7	3.9	7.6	9.4	6.6	5.2	6.8	8.2	8.1	5.1	2.7	1.0	5.1	1.5	1.7	5.0	3.1				
26.5	6.5	2.5	4.5	8.5	11.5	10.5	4.5	4.3	13.2	4.4	6.5	7.9	6.7	5.4	5.9	5.2	7.3	2.4	2.7	1.7	3.7	0.8	0.9	3.1	2.2				
27.0	3.8	2.7	3.3	5.6	12.3	10.9		2.7	12.1	6.4	6.0	6.9	6.6	6.4	6.5	1.4	6.4	1.9	1.5	1.5	3.4	0.7	1.2	2.2	1.8				
27.5	3.0	1.4	2.2	4.4			2.4	1.6	9.3	5.3	3.4	4.0	3.9	3.7	4.4	0.8	3.3	2.5	1.5	1.3	0.9	0.3	0.3	1.6	1.2				
28.0	1.0	0.6	0.8	2.1	8.5	2.3	1.7	2.3		8.1	4.3	3.3	4.4	4.1	4.8	1.0	3.6	1.4	0.6	0.6	0.3			0.7	0.5				
28.5	0.5	0.2	0.3	2.3	5.8	1.5	3.9	1.6	4.5	5.3	3.4	2.5	3.8	4.6	5.1	1.0	3.5	1.4	0.1	0.8	0.5	0.1	0.9	0.5					
29.0	0.3	0.5	0.4	1.7	3.6	1.5	5.6	3.1	3.2	9.0	5.4	3.7	6.6	4.1	7.5	0.6	4.3	1.1	0.8	0.3			0.7	0.4					
29.5	0.2	0.3	0.2	1.7	4.2	2.1	6.4	3.1	3.2	9.0	6.0	1.9	4.4	4.2	3.6		3.8	1.1	0.1	0.1				0.2					
30.0		0.5	0.2	1.4	0.6	1.1	7.5	3.1	3.9	10.9	6.9	1.9	4.1	4.9	7.3		4.1	1.0	0.3	0.1	0.6	0.1	0.3	0.3	0.4				
30.5				0.6	1.6	0.4	5.4	0.8	2.4	7.3	4.1	2.1	2.5	4.1	3.4		2.7	1.3	0.1	0.3			0.3	0.3	0.3				
31.0				0.1	1.2	0.6	4.5	0.4	1.1	7.8	4.1	0.4	3.2	3.1	1.5		2.2	1.1	0.1	0.1		0.3	0.4	0.3					
31.5				0.2	1.2		4.5	2.7	0.7	5.6	2.9	0.4	2.0	1.6	2.2		1.9	0.3					0.2	0.4	0.1				
32.0				0.2	0.6		3.6	2.7	0.2	3.4	1.3	0.4	0.6	1.1	0.7		1.1	0.8						0.1	0.1				
32.5				0.2		0.2	3.2	1.6		1.4	0.8			0.2	0.3		0.6												
33.0				0.2			2.6	1.9	0.2	1.1	0.7			0.1	0.3		0.6												
33.5							0.9		0.2	0.3	0.2			0.1		0.2													
34.0						0.2	1.1			0.6				0.1															
34.5							0.9			0.2																			
35.0							0.9			0.2																			
35.5										0.2																			
36.0																													
Number	1716	5697		8666	503	20920	467	257	539	24080	966	96200	10305	6140	39267	10040		630	12490	2930	42380	53400	344	11899		1984			
mean length	24.2	24.1	24.2	25.2	26.6	25.7	27.8	25.5	26.8	29.1	27.3	25.6	26.3	26.2	26.8	25.0	26.5	23.8	22.1	22.1	23.1	21.1	20.8	22.8	22.2	18.5	18.5		
mean weight	120	118	119	140	168	149	205	152	172	228	187	148	166	164	175	132	168	118	91	88	104	76	75	100	93	47	47		
TS/individual	-43.5	-43.5	-43.5	-43.1	-42.7	-43.0	-42.2	-43.0	-42.6	-41.9	-42.4	-43.0	-42.7	-42.8	-42.6	-43.2	-42.7	-43.6	-44.2	-44.3	-43.9	-44.7	-44.8	-44.0	-44.2	-45.8	-45.8		
TS/kilogramme	-34.3	-34.3	-34.3	-34.6	-34.9	-34.7	-35.4	-34.8	-35.0	-35.5	-35.1	-34.7	-34.9	-34.9	-35.0	-34.4	-35.0	-34.3	-33.8	-33.7	-34.1	-33.5	-33.5	-34.0	-33.9	-32.5	-32.5		

Table 4. Number of fish, mean length, mean weight and total biomass at age for 4 areas and for totals. 2 ring and 3 ring fish are shown separated into Immature (I) and Mature (M) categories. All fish at stage 3 or greater were classed as mature.

Age (ring)	Number	Mean Length	Mean Weight	Biomass
AREA I				
1A	5.57	21.50	80.81	0.45
2I	98.03	22.96	101.80	9.98
2M	57.39	25.29	142.63	8.19
3I	0.37	26.00	155.33	0.06
3M	5.21	26.79	173.55	0.90
4A	3.07	27.13	182.81	0.56
5A	0.72	28.62	217.47	0.16
6A	0.00			0.00
7A	0.00			0.00
8A	0.00			0.00
9+	0.00			0.00
Total	170.35	23.92	119.12	20.29
AREA II				
1A	51.13	20.61	69.86	3.57
2I	433.31	23.17	105.61	45.76
2M	792.02	25.68	150.20	118.96
3I	9.90	26.25	163.32	1.62
3M	264.67	28.00	203.26	53.80
4A	201.77	29.33	237.99	48.02
5A	127.56	30.37	268.43	34.24
6A	35.09	31.34	298.43	10.47
7A	15.14	32.30	331.06	5.01
8A	5.75	32.38	335.50	1.93
9+	9.41	33.48	376.36	3.54
Total	1,945.75	26.20	168.02	326.92
AREA III				
1A	818.06	19.78	61.19	50.06
2I	537.03	21.89	86.72	46.57
2M	438.76	24.93	135.94	59.65
3I	0.00			0.00
3M	53.62	27.17	182.55	9.79
4A	25.34	29.38	239.65	6.07
5A	9.60	30.38	268.16	2.57
6A	1.25	31.47	301.74	0.38
7A	0.43	33.50	374.82	0.16
8A	0.36	29.50	240.88	0.09
9+	0.43	34.00	394.64	0.17
Total	1,884.88	21.99	93.11	175.50
AREA IV				
1A	133.65	18.21	45.92	6.14
2I	2.64	21.33	79.27	0.21
2M	0.00			0.00
3I	0.00			0.00
3M	0.00			0.00
4A	0.00			0.00
5A	0.00			0.00
6A	0.00			0.00
7A	0.00			0.00
8A	0.00			0.00
9+	0.00			0.00
Total	136.28	18.27	46.56	6.35
Total				
1A	1,008.41	19.62	59.71	60.22
2I	1,071.00	22.50	95.72	102.52
2M	1,288.17	25.41	145.01	186.79
3I	10.27	26.24	163.03	1.67
3M	323.50	27.85	199.35	64.49
4A	230.18	29.30	237.44	54.65
5A	137.88	30.36	268.14	36.97
6A	36.34	31.34	298.55	10.85
7A	15.57	32.33	332.26	5.17
8A	6.11	32.21	329.87	2.02
9+	9.83	33.51	377.16	3.71
Total	4,137.27	23.93	127.88	529.06

Table 5. Mortality estimates for the Orkney-Shetland Buchan areas from acoustic stock estimates from 1984 to 1987.

	1984	1985	1986	1987	Z 84-85	Z 85-86	Z 86-87
85				1008.4			
84		48.8	496.1	2359.2			
83		660.1	1933.9	343.8			1.73
82	443.7	1316.2	729.0	230.2		0.59	1.15
81	1296.2	570.4	190.4	137.9	0.82	1.10	0.32
80	498.8	173.0	45.3	36.3	1.06	1.34	0.22
79	228.5	62.7	10.9	15.6	1.29	1.75	-0.36
78	71.0	22.1	4.6	6.1*	1.17	1.57	-0.28
77	32.4	11.7		* 9.8*	1.02		
76	38.8	21.3*	* 2.7*	* pre 77	0.60	2.07	
75	23.7	* 17.0*	* pre 76		0.33		
74	21.3	* pre 75					
-81	2210.7	878.2	253.9	205.7	0.92	1.24	0.21
-82		2194.4	982.9	435.9		0.80	0.81
-83			2916.8	779.7			1.32

Table 6. Acoustic instruments and settings used 24 Jun - 11 Aug 1987.

	R/V "Eldjarn"	R/V "G.O.Sars"
Echo sounder	Simrad EK400	Simrad EK400
Frequency	38 kHz	38 kHz
Receiver gain	-10 dB	- 10 dB
TVG	20 log R+2·0.008R	20 log R+2·0.008R
Pulse length	1.0 ms	1.0 ms
Bandwidth	3.3 kHz	3.3 kHz
Range	150 m	150 m
Transducer	8 ⁰ x 8 ⁰	5 x 5.5 ⁰
Eq. beam angle	- 19.6 dB	- 23.2 dB
Integrator	NORD computer	NORD computer
Threshold (peak)	14 mv	14 mv
Instrument constant*	0.18	0.42

* Calculated as described in Foote et al. (1987)

Table 9. Estimated number of herring (millions) per age group within the sub-areas shown in Figure 4. N=number (millions), B=biomass (thousand tonnes), m-2r= Percentage mature 2-ringers, m-3r=percentage mature 3-ringers. "Eldjarn" and "G.O.Sars" 24 Jun - 11 Aug 1987.

ICES-division	IVa W				IVa E		IVb					Outer IIIa
Sub-area	A	B	C	D	E	F	G	H	I	J	K	L
Age (winter rings)												
0								1482.3	21.6	62.2	8.4	17.0
1		240.3		18.8		297.2	103.4	6074.8	311.6	582.1	5344.5	498.6
2	2.5	1145.9	0.6	106.1	0.3	415.4	1368.3	15.1	69.9	16.6	57.8	18.7
3	18.5	260.7	5.4	62.1	2.5	72.1	450.6		39.8		0.2	19.8
4	43.3	128.0	13.6	61.2	6.3	40.0	277.6		14.8			9.0
5	46.1	56.2	14.1	62.3	6.6	7.1	99.8		18.0			0.6
6	15.6	13.3	5.1	17.3	2.4		3.8		3.8			0.4
7	11.9	2.8	4.1	5.3	1.9		2.3		1.8			0.4
8	4.1	0.8	1.4		0.6							0.4
9+	7.8	0.3	3.6		1.7							0.4
Total N	149.8	1848.3	47.8	333.1	22.2	831.8	2305.8	7572.2	481.3	660.8	5410.9	565.3
Total B	38.6	234.6	12.6	61.8	5.8	82.2	339.1	220.5	28.9	28.9	202.9	31.3
m-2r	91.0	70.9	91.0	69.0	91.0	46.7	87.0	0.0	41.7	0.0	0.0	0.0
m-3r	100.0	100.0	100.0	100.0	100.0	82.8	100.0	-	57.7	-	0.0	90.0
Spawning N	149.6	1274.5	47.7	281.4	22.2	300.8	2024.5	0.0	90.0	0.0	0.0	29.0
Spawning B	38.6	194.9	12.6	58.0	5.8	43.0	317.5	0.0	12.2	0.0	0.0	4.4

Table 10. Estimated number of herring (millions) per group within ICES-areas. N = number (millions). B = biomass (thousand tonnes), m-2r = percentage mature 2-ringers, m-3r = percentage mature 3-ringers. Acoustic surveys with "Scotia", "Eldjarn" and "G.O.Sars" 24 Jun - 11 Aug 1987.

Age (winter rings)	IVa W		IVa E	IVa Total	IVb	IVa + IVb
	Area covered by Scotia	Other areas				
0					1574.5	1574.5
1	1003.9	18.8	297.2	1319.9	12416.4	13736.3
2	2250.9	108.5	415.7	2775.1	1527.7	4302.8
3	309.5	80.6	74.6	464.7	490.6	955.3
4	212.4	105.4	46.3	364.1	292.4	656.5
5	126.6	110.0	13.7	250.3	117.8	368.1
6	33.2	33.4	2.4	69.0	7.6	76.6
7	14.3	17.8	1.9	34.0	4.1	38.1
8	5.6	4.3	0.6	10.5		10.5
9+	9.0	9.1	1.7	19.8		19.8
Total N	3965.4	486.8	854.0	5306.2	16431.0	21737.0
Total B	500.2	101.7	88.0	689.9	820.3	1510.2
m - 2r	54.1	69.5	46.7	53.6	79.8	62.9
m - 3r	97.0	100.0	83.4	95.3	96.5	95.9
Spawning N	1919.4	434.8	323.0	2677.2	2115.0	4792.2
Spawning B	340.3	97.9	48.8	487.0	329.7	816.7

Table 11. Spawning biomass estimates ('000 tonnes) for comparable areas for the years 1982-1987. The areas correspond to Figure 2.4.1 in Anon. (1987).

Area	1982	1983	1984	1985	1986	1987
Orkney/Shetland	224	250	320	285	374	367
Moray Firth/Buchan	?	?	57	13	40	60
Fladen	?	?	76	73	100	60
Eastern area	?	?	13	43	10	47
Egersund bank	?	?	?	20	10	19
Total	>224	>250	>466	434	534	553

Table 12. Numbers (millions) per year class estimated in the approximate area north of 57°N for the years 1984-1987 and estimates of mortality (Z).

Year class	1984	1985	1986	1987	Z(84-85)	Z(85-86)	Z(86-87)
1985				2425			
84			1639	2888			
83		726	2156	501			1.46
82	551	1819	999	386		0.60	0.95
81	1718	836	310	258	0.72	0.99	0.18
80	610	228	82	69	0.98	1.02	0.17
79	264	81	19	34	1.18	1.44	-0.58
78	82	29	7.5	11	1.05	1.34	-0.38
77	36	13	1.2	20	1.00	2.40	-1.61
76	46	23	2.8		.68	2.72	
75	38	19			1.35		
pre-75	37						
≥ 2-ringers	2830	3048	3577	4137			
≥ 3-ringers	1112	1229	1421	1249	0.83	0.76	1.05

Table 13. Numbers (millions) per year class estimated in IVa + IVb for the year 1984 - 1987 and estimates of mortality (Z). For 1984, 1985 and 1986 the estimates are the sum of the summer survey north of 57°N and the autumn survey in IVb.

Year class	1984	1985	1986	1987	Z(84-85)	Z(85-86)	Z(86-87)	1/3 Z(84-87)
1985				13736				
84			1639	4303				
83		726	2916	955			1.12	
82	551	2215	1230	657		0.59	0.63	
81	2674	1191	725	368	0.81	0.50	0.68	0.66
80	747	274	122	77	1.00	0.81	0.46	0.76
79	321	100	29	38	1.17	1.24	-0.27	0.71
78	111	36	21	11	1.13	0.54	0.65	0.77
77	43	16	6	20	0.99	0.98	-0.36	0.72
76	51	23	8		0.80	1.66		
75	39	19			1.41			
pre-75	39							
≥ 2-ringers	4025	3874	5057	6429				
≥ 3-ringers	1351	1659	2141	2126	0.89	0.59	0.87	
SSB ('000 tonnes)	674	573	815	817				

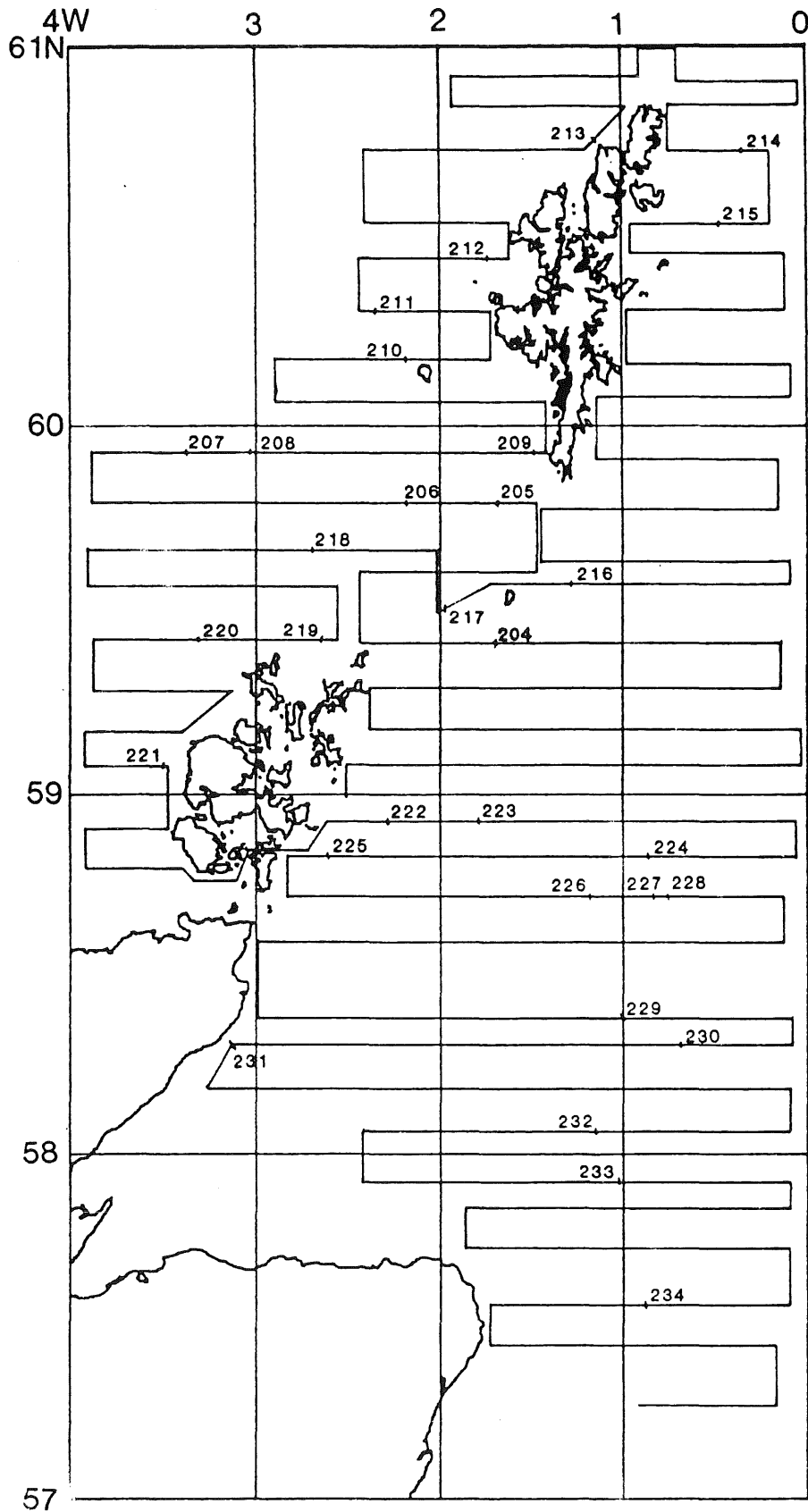


Figure 1. Cruise track and trawl positions for FRV "Scotia" survey 15 July to 3 August 1987.

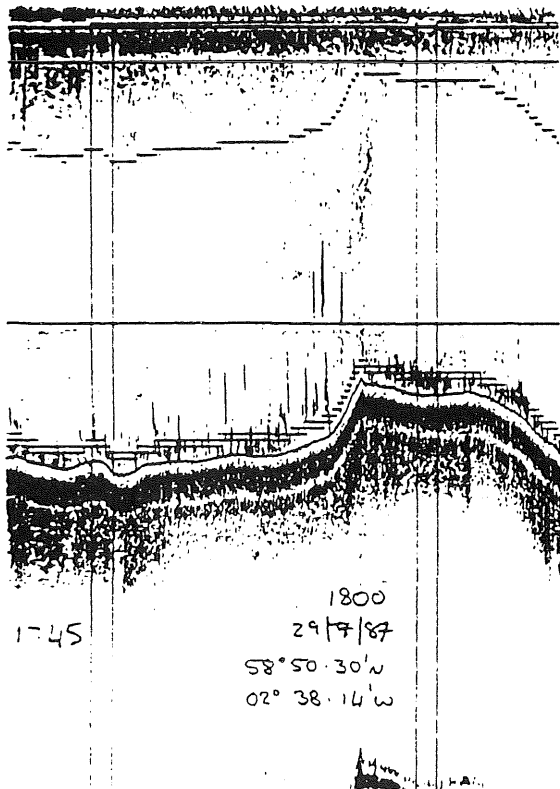


Fig. 2. Small herring east of Orkney.

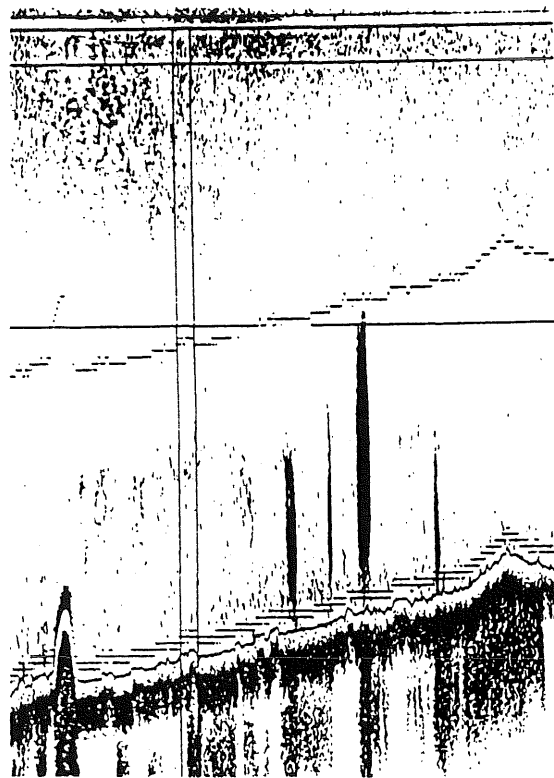


Fig. 3. Medium herring west of Shetland.

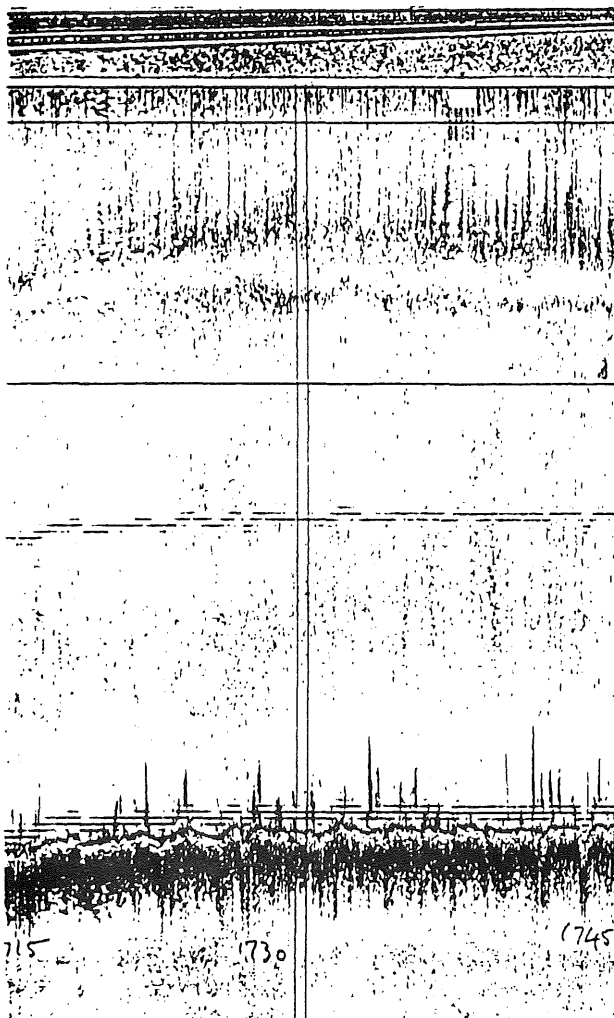


Fig. 4. Medium herring east of Moray Firth.

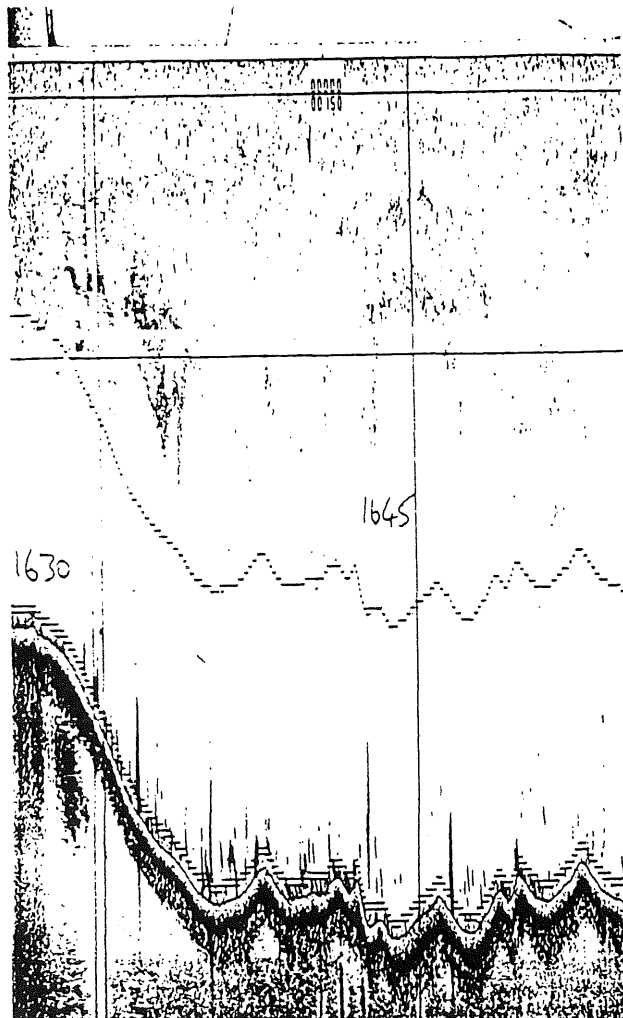


Fig. 5. Large herring east of Shetland

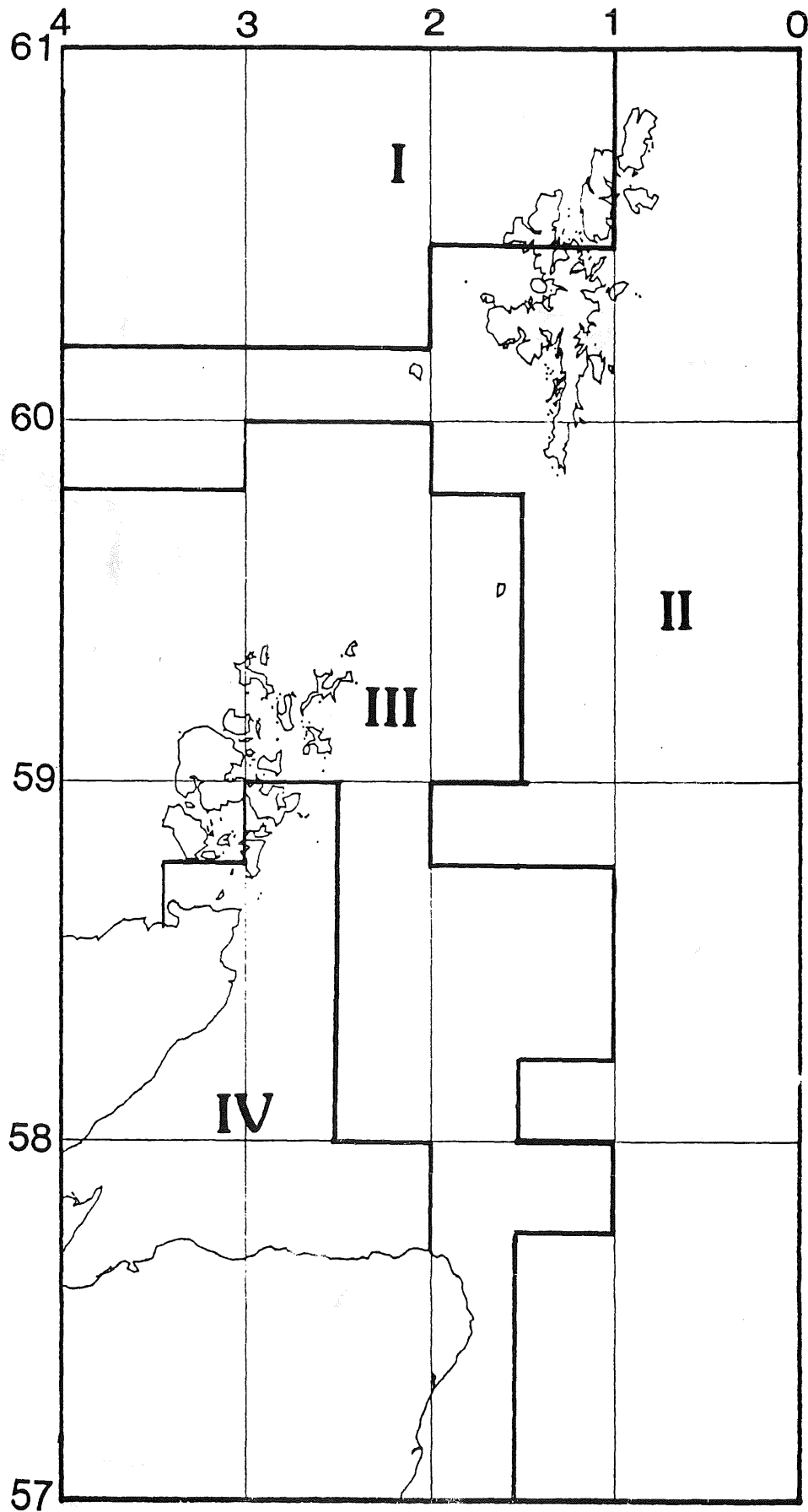


Figure 6. Areas of similar length composition.

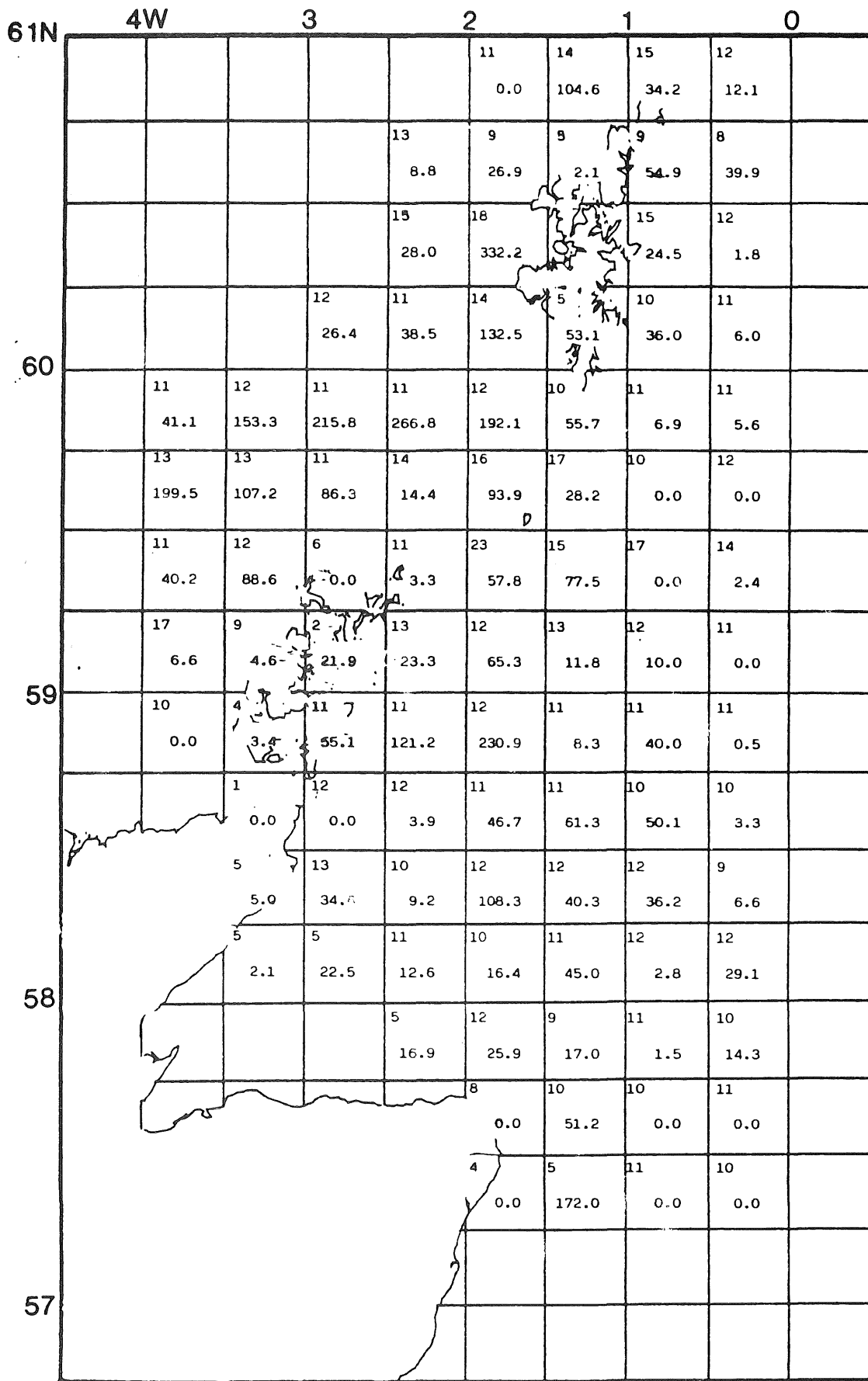


Figure 7. Number of herring ($\times 10^{-6}$) by quarter statistical rectangle with number of $\frac{1}{4}$ hour integrator runs in the upper part of each square.

	4W	3	2	1	0				
61N					0.00 0.00 0.00	11.94 0.52 12.46	3.48 2.26 5.75	0.77 1.26 2.03	
			1.05 0.00 1.05	3.20 0.00 3.20	0.25 0.00 0.25	6.66 2.55 9.22	6.48 0.21 6.70		
			3.33 0.00 3.33	55.82 0.00 55.82	4.11 0.00 4.11	0.30 0.00 0.30			
		4.44 0.00 4.44	5.69 0.79 6.48	20.45 1.81 22.26	3.62 5.29 8.92	5.53 0.51 6.05	1.02 0.00 1.02		
60	6.56 0.33 6.90	24.93 0.83 25.76	20.10 0.00 20.10	24.84 0.00 24.84	32.28 0.00 32.28	6.04 3.31 9.36	1.17 0.00 1.17	0.93 0.00 0.93	
	18.58 0.00 18.58	9.98 0.00 9.98	8.04 0.00 8.04	1.34 0.00 1.34	8.15 0.59 8.75	4.74 0.00 4.74	0.00 0.00 0.00	0.00 0.00 0.00	
	0.00 3.74 3.75	0.00 8.25 8.25	0.00 0.00 0.00	0.06 0.24 0.31	2.34 3.04 5.38	11.19 1.83 13.03	0.00 0.00 0.00	0.28 0.13 0.41	
	0.00 0.61 0.61	0.00 0.43 0.43	0.00 2.04 2.04	1.88 0.29 2.17	5.47 0.61 6.08	0.76 1.27 1.99	0.00 1.68 1.68	0.00 0.00 0.00	
59	0.00 0.00 0.00	0.00 0.31 0.31	2.24 0.33 2.57	11.29 0.00 11.29	21.24 0.26 21.50	1.39 0.00 1.39	6.72 0.00 6.72	0.08 0.00 0.08	
		0.00 0.00 0.00	0.00 0.00 0.00	0.36 0.00 0.36	7.84 0.00 7.84	10.30 0.00 10.30	8.41 0.00 8.41	0.55 0.00 0.55	
		0.23 0.00 0.23	0.54 1.07 1.61	0.00 0.86 0.86	1.08 9.00 10.08	3.75 0.00 3.75	6.09 0.00 6.09	1.12 0.00 1.12	
		0.00 0.09 0.10	0.42 0.62 1.05	0.39 0.78 1.17	1.53 0.00 1.53	7.56 0.00 7.56	0.47 0.00 0.47	4.90 0.00 4.90	
58			0.79 0.00 0.79	2.42 0.00 2.42	1.59 0.00 1.59	0.25 0.00 0.25	2.40 0.00 2.40		
					0.00 0.00 0.00	8.60 0.00 8.60	0.00 0.00 0.00	0.00 0.00 0.00	
					0.00 0.00 0.00	28.90 0.00 28.90	0.00 0.00 0.00	0.00 0.00 0.00	
57									

Figure 8. Biomass of herring (Thousands of tonnes) by quarter statistical rectangle for "herring traces", "probably herring traces" and totals.

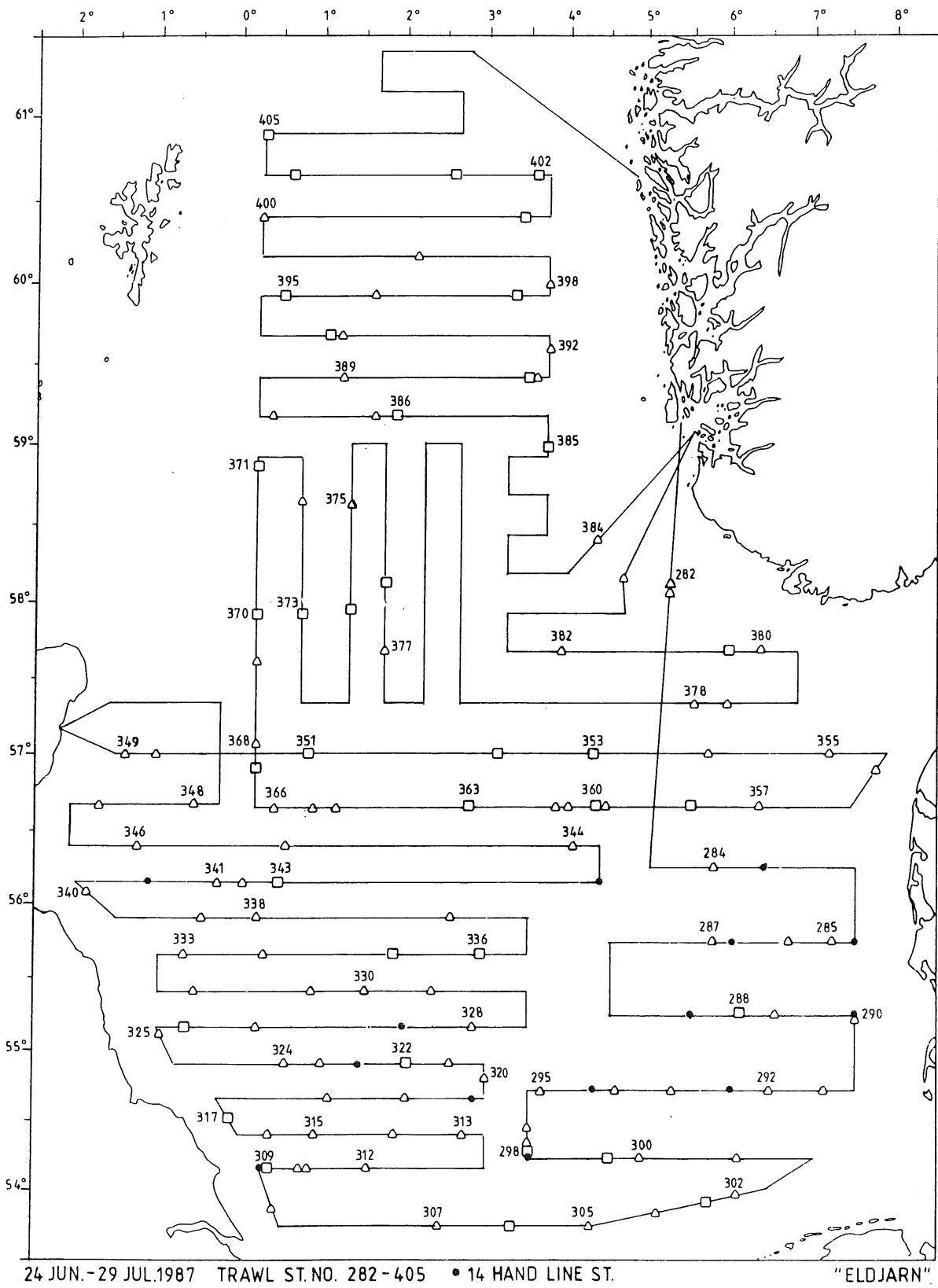


Fig. 9. Survey grid and trawl stations, R/V "Eldjarn", 24 Jun - 29 Jul 1987.

△ Pelagic trawl, □ Bottom trawl.

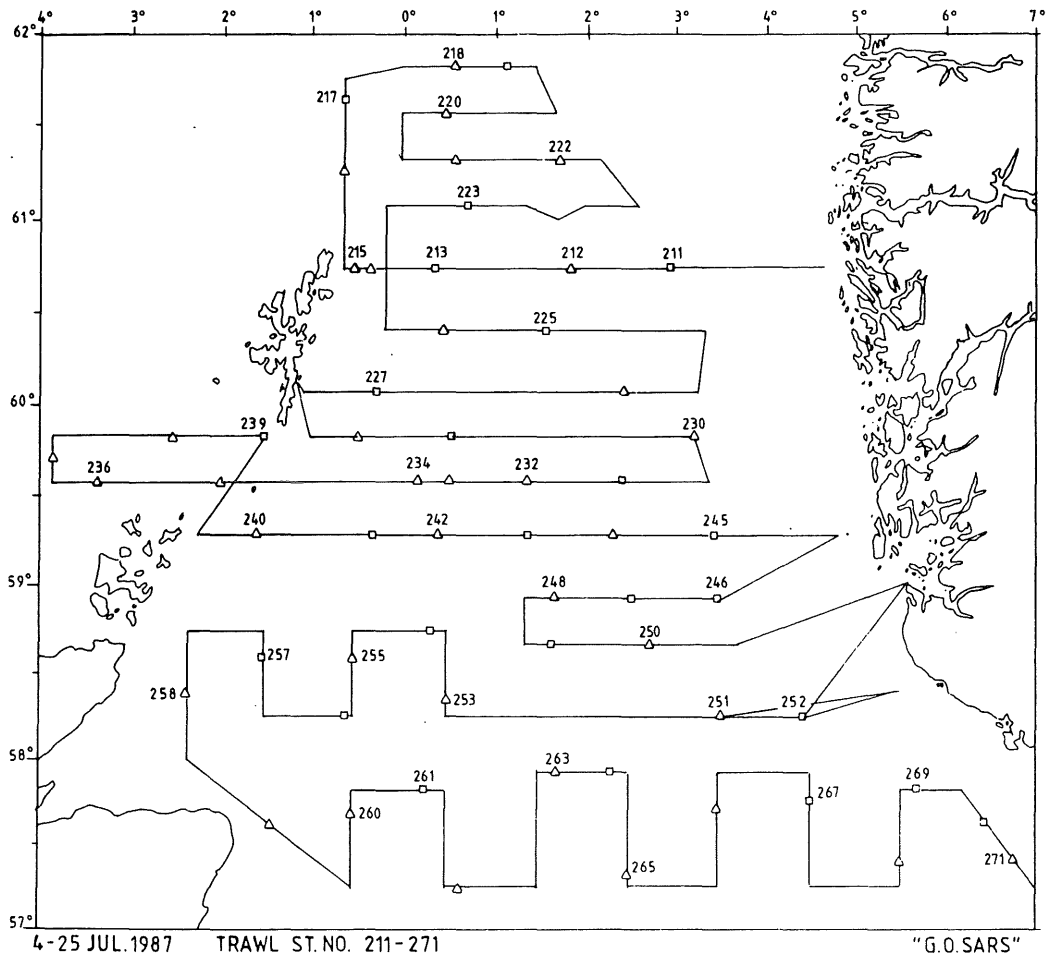


Fig. 10. Survey grid and trawl stations, R/V "G.O. Sars",
4 - 25 Jul 1987.

△ Pelagic trawl, □ Bottom trawl.

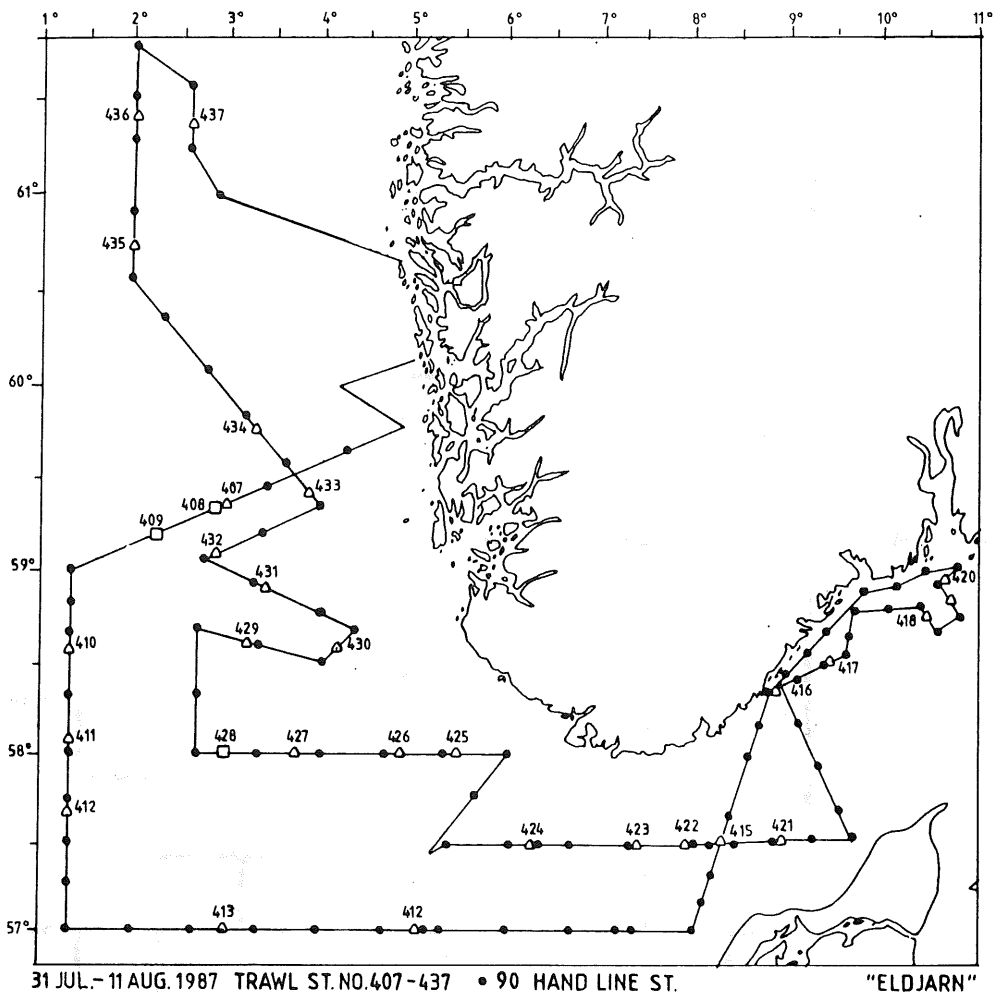


Fig. 11. Survey grid and trawl stations, R/V "Eldjarn", 31 Jul - 11 Aug 1987.

△ Pelagic trawl, □ Bottom trawl.

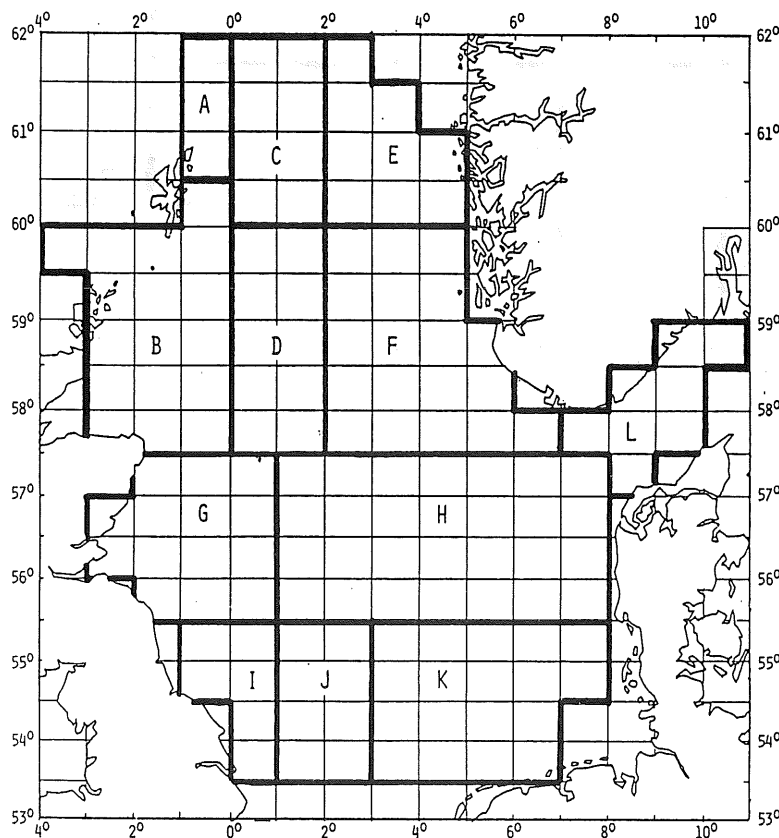


Fig. 12. Definition of subareas.

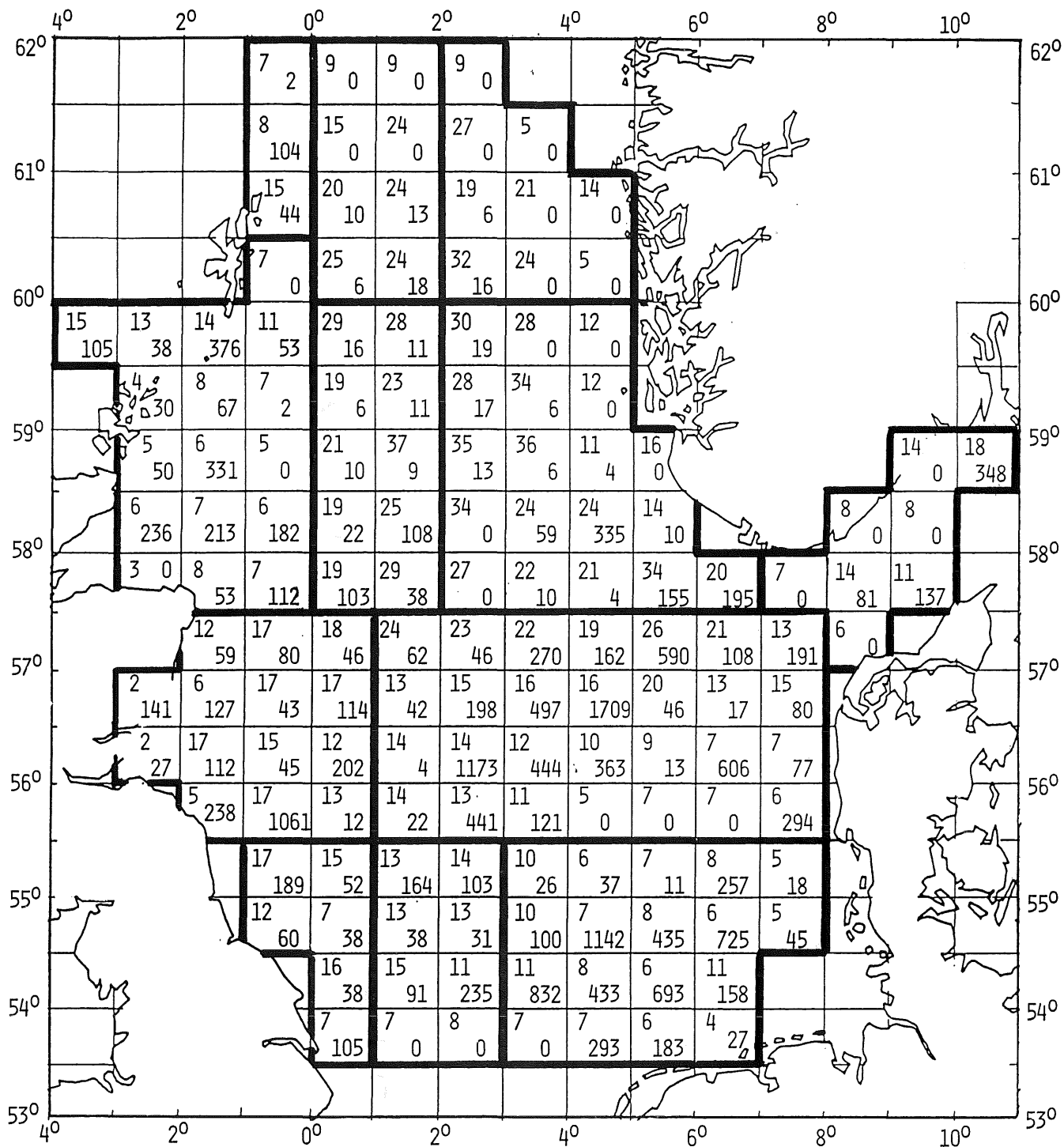


Fig. 13. Estimated number (millions) of herring by statistical rectangle, R/V "Eldjarn" and R/V "G.O. Sars", 24 Jun - 11 Aug 1987. Number of 5-mile integrals shown in the upper left corner.