International Council for the
Exploration of the Sea

Herring Tagging Experiments Bløden Ground 1957

Part III.

An analysis of the results to December 1957, by Olav Aasen, K.P. Andersen, and J.A. Gulland.

Introduction.

The present report is only concerned with the results of the internal taggings carried out by the Norwegian purse-seiner "Rygrunn".

The background to the experiment, the methods used, and some of the early results have been reported in Parts I. and II. presented at the Bergen Meeting of ICES. Briefly the main data available consist of

(i) catches of herring delivered each week at the main factories in Denmark and Germany;

(ii) catches and fishing effort, each week, in each square (about 15 miles square), for certain Danish cutters. These data cover about half the landings at Esbjerg, and rather less at other ports;

(iii) date of recovery of each tag returned, with usually, the estimated date and position of capture.

The bulk of the catches, and of the returns of tags, occur during the first six weeks following marking, i.e. up to the end of September, when the water became mixed by storms, and the thermocline vanished. There are several pieces of evidence showing a fundamental change in the fishery at the end of September (about week 39). The fishing position (see Figure 1a etc.) show a marked scattering of the fleet, particularly westwards. The market measurements (Figure 4) also show a big change in the size-composition of the stock. Finally the wind records (Figure 2) show 3 days of high winds on 27-29 September, and the hydrographical records suggest that this gale was responsible for mixing the water and removing the thermocline. The detailed analysis in this report will therefore be concerned only with the first six weeks. The returns from each marking, separated according to the place of landing (Esbjerg, other Danish ports, or Germany) are given in Table 1.

Table 1. Number of tags returned each week.

Week	Tagging Date	Exp. 1, 4041 tags 5th August			Exp. 2, 1989 tags 14th August			Exp. 3, 3900 tags 17th August		
		Es.	o.Da.	Ge.	Es.	o.Da.	Ge.	Es.	o.Da.	Ge.
32	(4/8 - 10/8)	29	2							
33	(11/8 - 17/8)	48	1							
34	(18/8 - 24/8)	48	14	1	85		37	3		32
35	(25/8 - 31/8)	5	1		6			3		2
36	(1/9 - 7/9)	5	3		2			9		4
37	(8/9 - 14/9)	7	0		3			1	1	0
38	(15/9 - 21/9)	0	0		0		1	0		0
39	(22/9 - 28/9)	9	0		3	1		0		0

This table shows marked differences in the return rates from the 3 liberations. From Experiment 1 there are about 1% for each of the first three weeks, and then a rapid decline; from experiment 2, 6% in the first week, and then nearly nothing; from experiment 3, nearly nothing. There is also big differences in the relative shares of the landing places in the three experiments. This suggests that at least for the first few weeks after marking, there was little mixing between the groups of marked fish, and, as a corollary, that the fish had not moved far from the marking position. Unfortunately when the reported positions of recaptured tags were examined in detail, it was obvious that they could not be relied upon. This is really only to be expected from the circumstances of recovery; the tag cannot reach the magnet until quite a time has passed, and cannot with certainty be allocated to a particular day of landing, far less to a particular cutter. There are exceptions for which movement can be proved where a tag is returned from a port whose fleet does not fish in the marking area. However for the bulk of the returns from ports whose ships have been fishing both in the marking area and elsewhere, we may strongly suspect that the tags coming back in the first few weeks are nearly all caught close to the marking position, but from the evidence of internal tags above, there is no direct way of proving it.

In the further analysis, therefore, particular emphasis has had to be placed on the data of catch, effort and position of the commercial fishing. In the analysis so far carried out only the data from Esbjerg has been used, both because this port handles the greatest catches and provides most returns, and because the catch and effort data from Esbjerg is the most complete. Using these data an effective fishing intensity (effort per unit area) was calculated on each batch of liberated fish for each week, making some assumptions about the dispersion of fish from the marking position. These calculations were made in three steps, set out in full in the appendix tables. First the total effort by Esbjerg ships in each square was calculated, using the relation

$$\text{Total effort} = \text{Effort by reporting ships} \times \frac{\text{Total catch}}{\text{catch by reporting ships}}$$

where the reporting ships are those for which data on catch, effort and position are known. The handling of these data was made easier by being compiled on punched cards, one card to each landing (or sometimes two or more, where a ship had fished in more than one square).

Secondly, the average effort per square was calculated for 4 areas of differing sizes (1,2,4 and 12 squares) surrounding the marking position. (For experiment 1, which was nearly on the border between two squares, the smallest area was not used). The particular squares used are shown in the appendix table, the choice being determined by the probable general movement from the liberation position, viz., north and west from experiment 1, north and slightly east from experiments 2 and 3.

Finally the best estimate of the fishing intensity on the tagged fish is found as the weighted mean of the intensities in the 4 areas. In the first week after marking greatest weight is given to the single square covering the marking area, and in later weeks greater weight to the other areas. With our present information the weights used must be purely arbitrary, and those actually used are given in Table 2. The weights for experiment 1, for which no single square region was used, were obtained by adding the first two weights.

Table 2. Weighting factors used to determine average fishing intensity.

Week after tagging:	1	2	3	4	5	6	7	8
1- square region	0.8	0.6	0.3	0.1	0.1	0.1	0.0	0.0
2- square region	0.1	0.2	0.3	0.3	0.1	0.1	0.1	0.1
4- square region	0.05	0.1	0.2	0.3	0.3	0.2	0.1	0.1
12- square region	0.05	0.1	0.2	0.3	0.5	0.6	0.8	0.8

For the week immediately after marking a factor must be applied to correct for that part of the landings which consists of fish caught before the tagging date. For instance, for a ship landing 3 days after the tagging, and which had been fishing for 6 days, only half the catch, and half the effort, should be used in the calculations. For experiment 1 this factor is o.5, for experiment 2 nearly 1, and for experiment 3 also nearly 1.

Using the estimate of fishing intensity thus obtained, a figure for tags caught per unit intensity (100 hours fishing per square), or more conveniently to allow for the different numbers tagged in each experiment, tags per 100 hours per square per 1000 fish tagged. These figures are given in Table 3, and are also plotted in Figure 3.

Table 3. Tags caught per 100 hours fishing per square per 1000 fish tagged.

Week:	32	33	34	35	36	37	39
Liberation 1	5.5	8.7	10.2	3.0	1.0	3.2	3.0
Liberation 2			5.0	12.0	0.3	>7.5	10.7
Liberation 3			6.7	7.5	13.2		

Notes: 1) in week 38 there were bad storms and the landings fell to only 200 tons. This week has therefore been omitted in the analysis;

2) in weeks 37 and 38 there was no fishing near the third liberation position, and only 1 tag was returned.

Though there is considerable variation in the table the results from the three liberations are reasonable consistent. Ideally the points in Figure 3 should lie on a line, falling off with a slope proportional to the decrease in marked fish in the sea (due to fishing and other causes). In fact the points are too scattered to draw such a line, though it is perhaps worth noting a line decreasing from 6.0 to 4.0 in 8 weeks is a reasonable fit and also gives a total mortality (33% in 2 months) which is not unreasonable, considering that most of the mortality at least due to fishing is concentrated in those months. Using this line, then, we have a figure, immediately after marking, of 6 tags per 100 hours fishing per square per 1000 fish tagged. That is, each 100 hours fishing will catch 6 out of 1000, i.e. 0.6% of the fish present in the square. Now, during the time of tagging the catch per unit effort was about 50 tons per 100 hours. Therefore the density of fish at the time and place of tagging was

$$50 \times \frac{1000}{6} = 8{,}333 \text{ tons per square.}$$

The area fished by the Esbjerg cutters on the Bløden Ground covers about 60 squares, and if we assume that the density in each of these squares is the same as in the marking position, the size of the exploited stock at the time of marking was 60 x 8,333 = 500.000 tons. If from this we can estimate the size of the stock at the beginning of the fishing season, this together with the size of the catch, will give us the percentage caught. Alternatively we can calculate the fishing mortality from the relation above that 100 hours fishing per square catches o.6% of the fish present, i.e. causes an instantaneous fishing mortality coefficient of 0.006. Then the fishing mortality for the whole season, for the whole fishery will be equal to

$$0.006 \times 100 \text{ hours fishing by reporting ships} \times \frac{\text{total catch}}{\text{catch of reporting ships}} \times \frac{1}{\text{number of squares occupied by Bløden stock}}$$

This assumes that the effective effort (i.e. the mortality caused) by 100 hours fishing per square is the same throughout the season. In fact the figures of catches per unit effort week by week (see appendix) show marked changes, some of which cannot be due to real changes in abundance of fish (e.g. the decrease after the thermocline disappear), but to changes in the effectiveness of the gear. For the present analysis, therefore, we have made the simple assumption that the stock weight was the same at the beginning of the season as at the time of marking; in effect that the mortality has been balanced by the growth of the individual fish. In fact the growth of fish between the spring and autumn fishing is about 2cm. i.e. about 10% in length, and therefore rather more than 30% in weight. If the mortality in the same period was 30%, then the total weight of the stock will remain almost exactly constant.

The figures used for total catch must of course include only catches from that part of the stock on which the tagging experiment was made. Considering the data from the Esbjerg market samples see Figure 4. (from data from Popp Madsen (MS.)) and the lengths distribution from the research vessels Figure 5. The sample from "Rygrunn" II was taken after tagging was finished, and consisted mainly of fish rejected as being too small to tag. The opinion of the naturalist-in-charge is that the fish tagged were the same size as for "Rygrunn" I i.e. 17-20cm. long. It seems that the tagged population consisted of fish mostly from 17-20cm. in length, and that this group of fish made up most of the landings at Esbjerg for the weeks 29-38. At the beginning and end of the season the catches included also a large number of smaller fish; as a working approximation we will take only half the Esbjerg catch during this period as coming from the tagged population. The landings at Thyborøn will be taken as having the same composition as the Esbjerg catch and the landings at Hirtshals as being taken from outside the tagged population (mostly in the Skagerak). The German catch, taken almost entirely in July and August will be assumed to be entirely from the tagged stock. The total catch from the tagged stock is therefore as follows:-

Half the Esbjerg and Thyborøn catch before 13/7	3,567 tons
Esbjerg and Thyborøn catch 14/7-21/9	37,553 "
Half the Esbjerg and Thyborøn catch after 22/9	5,667 "
German catch	15,000 "
Total	61,787 tons

The percentage taken of the stock at the beginning of the season is therefore:

$$61.8/500 \times 100 = \underline{12.4\%}$$

A correction must be made for those tags which do not go to a factory equiped with magnets, or which are not detected by the magnets. From Table 3 of Part II, the combined effect of these two factors is that only 95% of the tags landed at Esbjerg are likely to be detected. Therefore the estimated number of tags returned should be increased by a factor of 1/.95 = 1.05. The corrected figures are therefore as follows:

tags returned per 100 hours fishing per square = 6 x 1.05 = 6.3

weight of stock at marking = 500.000 x .95 = 475.000 tons

percentage taken by the Bløden fishery = 12.4 x 1.05 = 13%

Late recaptures.

Though by October the main season had finished and the later landings and number of tags returned are very small, they may be used to give a check on the calculations above. By the middle of November the tagged fish should be well mixed with the rest of the population. There should be then 10.000 tags mixed with 500.000 tons of fish i.e. 1 tag to each 50 tons of fish. In the period since say 16th November 5 tags have been returned from the Esbjerg factories. In fact because of the growth since tagging the figure for tons per tag should be rather greater. The catches from the tagged population are not easily determined because they are mixed with a large amount of other species, and with small herring. A good estimate is 300 tons, which gives 1 tag to every 60 tons of fish - in remarkable agreement with the detailed analysis, particularly considering the small numbers concerned.

Mortality at tagging.

Obviously it is impossible to guarantee that all fish tagged survive the shock of being tagged and marked. At the same time it is equally impossible to measure such mortality directly. The recovery of two tags in the stomach of whiting suggests that one form of this mortality during the Bløden experiment was a high mortality due to predators while the herring are recovering from the shock of marking and are less active. In fact, considering how slight must be the chances of finding a tag in the stomach while gutting a whiting, this form of mortality might well be considerable. If it does occur it probably would be higher among those fish kept longest in the live nets. Accordingly the tags used by each tagging team were divided in half, and the returns from the first and second sets noted separately. The results of this analysis are shown in Table 4.

Table 4. Percentage of tags returned from first and last sets of fish tagged by each team

	Experiment 1			Experiment 2			Experiment 3		
Tagging Team:	A	B	C	A	B	C	A	B	C
First fish tagged	4.0	3.9	7.3	6.4	8.9	4.4	1.2	2.0	1.0
Last fish tagged	4.0	3.3	4.4	6.8	7.0	9.2	1.6	1.5	1.0

There are no marked difference between the first and second halves; certainly the returns from the first half are not consistently greater than those from the second half. We may therefore conclude that the mortality of tagging is small.

Experiment 1.

Position squares used:

(a) 185, 186; (b) 165, 166, 185, 186;
(c) 145-7, 165-7, 185-7, 205-7.

Week	Tags		Total report. Effort	Report. Effort per Squares (hours)	Total Effort per Square	Tags per Unit Eff.	Tags per 100 h. per 1000 tags
32	29	(a)	155	72	289	0.10	
Raising factor 3.99		(b)	183	46	183	0.16	
		(c)	812	68	270	0.11	
				weighted mean	277	0.11	5.5
33	48	(a)	92	46	148	0.32	
		(b)	92	23	74	0.64	
R.f. 3.22		(c)	418	35	112	0.43	
				weighted mean	136	0.35	8.7
34	48	(a)	110	55	148	0.32	
R.f. 2.68		(b)	148	37	99	0.48	
		(c)	184	15	41	1.17	
				weighted mean	117	0.41	10.2
35	5	(a)	25	12	69	0.07	
R.f. 5.54		(b)	25	6	33	0.15	
		(c)	78	6	36	0.14	
				weighted mean	42	0.12	3.0
36	5	(a)	0	0	0	-	
R.f. 4.29		(b)	18	4	19	0.26	
		(c)	542	45	193	0.03	
				weighted mean	120	0.04	1.0
37	9	(a)	0	0	0	-	
R.f. 4.98		(b)	0	0	0	-	
		(c)	221	18	92	0.10	
				weighted mean	72	0.13	3.2
39	9	(a)	0	0	0	-	
R.f. 4.14		(b)	0	0	0	-	
		(c)	269	22	92	0.10	
				weighted mean	74	0.12	3.0

Experiment 2.

Position squares used:

(a) 270; (b) 250, 270; (c) 249, 250, 269, 270;
(d) 229-231, 249-251, 269-271, 289-291.

Week	Tags		Total report. Effort	Total report. Effort per Square	Total Effort per Square	Tags per 100 h.	Tags per 100 hours per 1000 releases
34	85	(a)	353	353	945	9.0	
		(b)	520	260	695	12.2	
Raising factor 2.68		(c)	822	205	550	15.5	
		(d)	1113	93	248	35.7	
				weighted mean:	865	9.8	4.9
35	6	(a)	0	0	0	-	
R.f. 5.54		(b)	0	0	0	-	
		(c)	124	31	172	3.5	
		(d)	200	17	92	6.5	
				weighted mean:	26	22.7	11.4
36	2	(a)	90	90	386	0.5	
R.f. 4.29		(b)	198	99	425	0.5	
		(c)	279	70	300	0.6	
		(d)	299	25	107	1.9	
				weighted mean:	325	0.6	0.3
37 R.F. 4.98	3	No fishing in a, b, c, or d nearest effort in square 228 3600 h. mean effort <20				>15	>7.5
39	3	(a)	0	0	0	-	
R.f. 4.14		(b)	0	0	0	-	
		(c)	0	0	0	-	
		(d)	71	5.9	24	12.5	
				weighted mean:	14	20.8	10.4

Experiment 3.

Position squares used:

(a) 310; (b) 310-309; (c) 310, 309, 290, 289;
(d) 331, 329, 311-309, 291-289, 271-269.

Week	Tags		Total report. Effort	Effort per square minutes	Total effort per square (hours)	Tags per 100 hours	Tags per 100 h. per 1000 releases
34	3	(a)	0	0	0	-	
		(b)	0	0	0	-	
Raising factor		(c)	173	43	116	0.03	
2.68		(d)	731	61	163	0.02	
				weighted mean:	13	23	6.7
35	3	(a)	0	0	0	-	
R.f.		(b)	0	0	0	-	
5.54		(c)	21	5	29	0.10	
		(d)	154	13	71	0.04	
				weighted mean:	10	0.3	7.5
36	9	(a)	0	0	0	-	
R.f.		(b)	0	0	0	-	
4.28		(c)	20	5	21	0.42	
		(d)	191	16	68	0.13	
				weighted mean:	17	0.53	13.2

Weeks 37 and 39 no fishing near to liberation position.

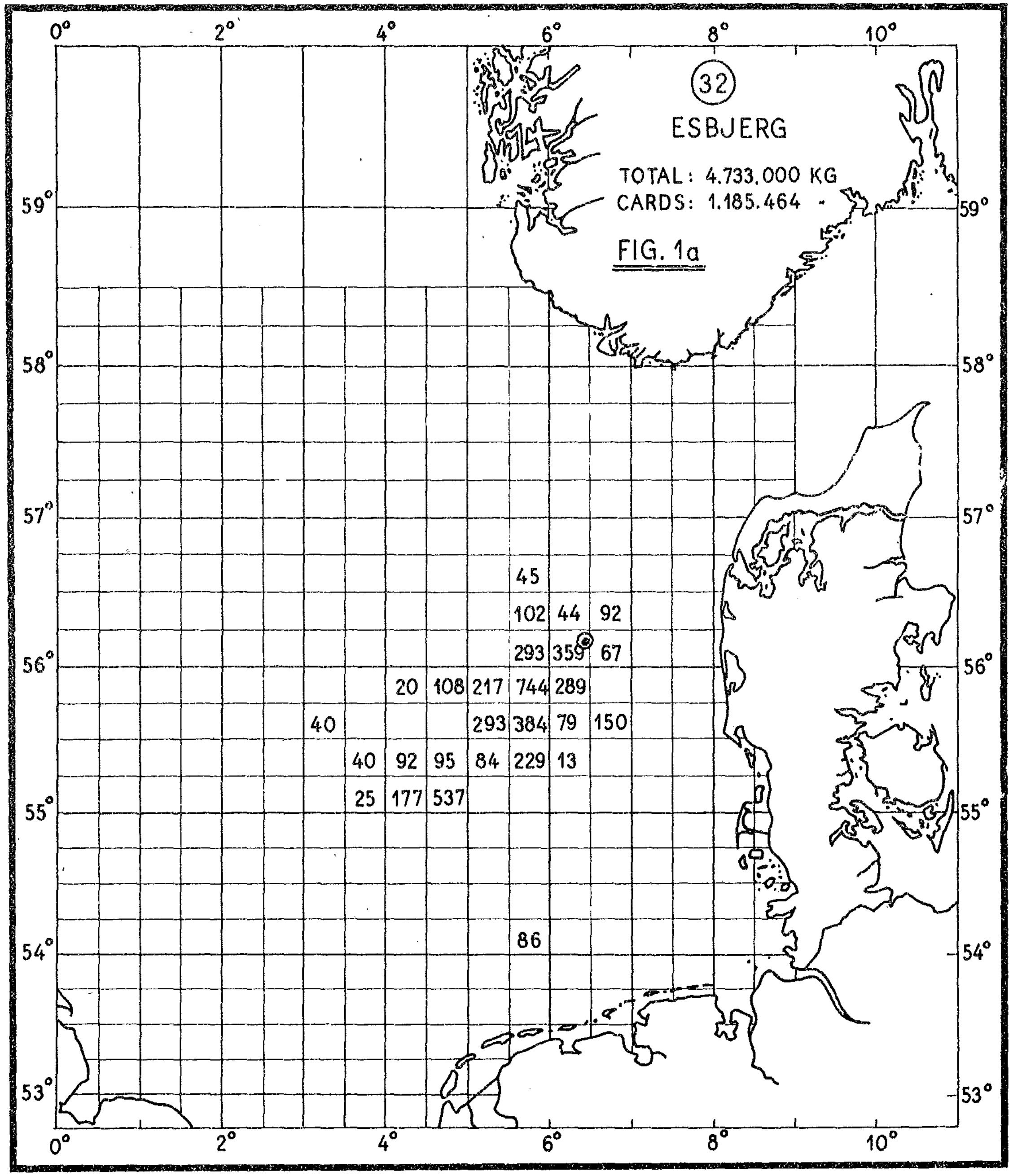

32
ESBJERG
TOTAL: 4.733.000 KG
CARDS: 1.185.464
45
102 44 92
293 359 67
20 108 217 744 289
40 293 384 79 150
40 92 95 84 229 13
25 177 537
86

FIG. 1a

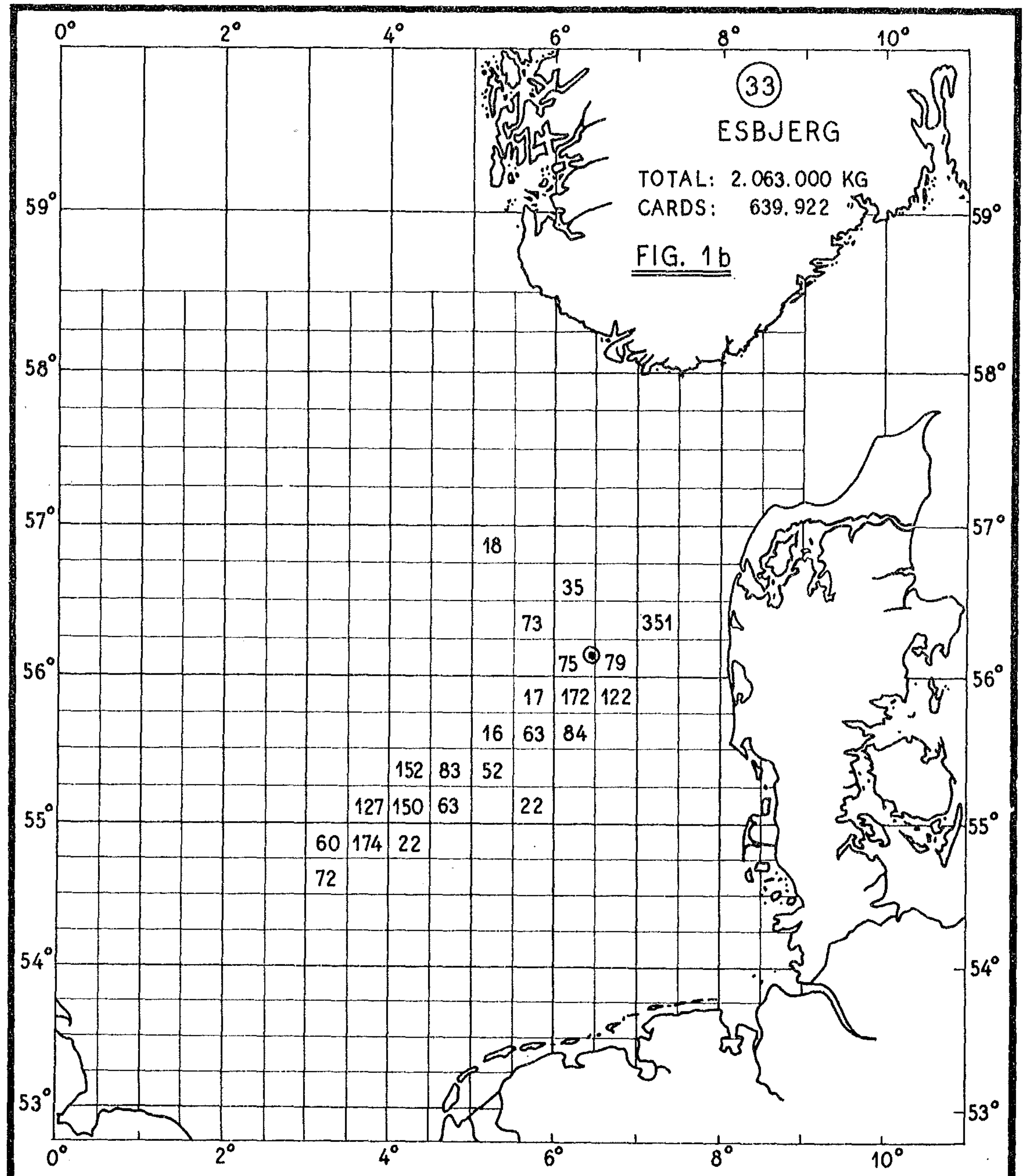

33
ESBJERG
TOTAL: 2.063.000 KG
CARDS: 639.922
18
35
73 351
75 79
17 172 122
16 63 84
152 83 52
127 150 63 22
60 174 22
72

FIG. 1b

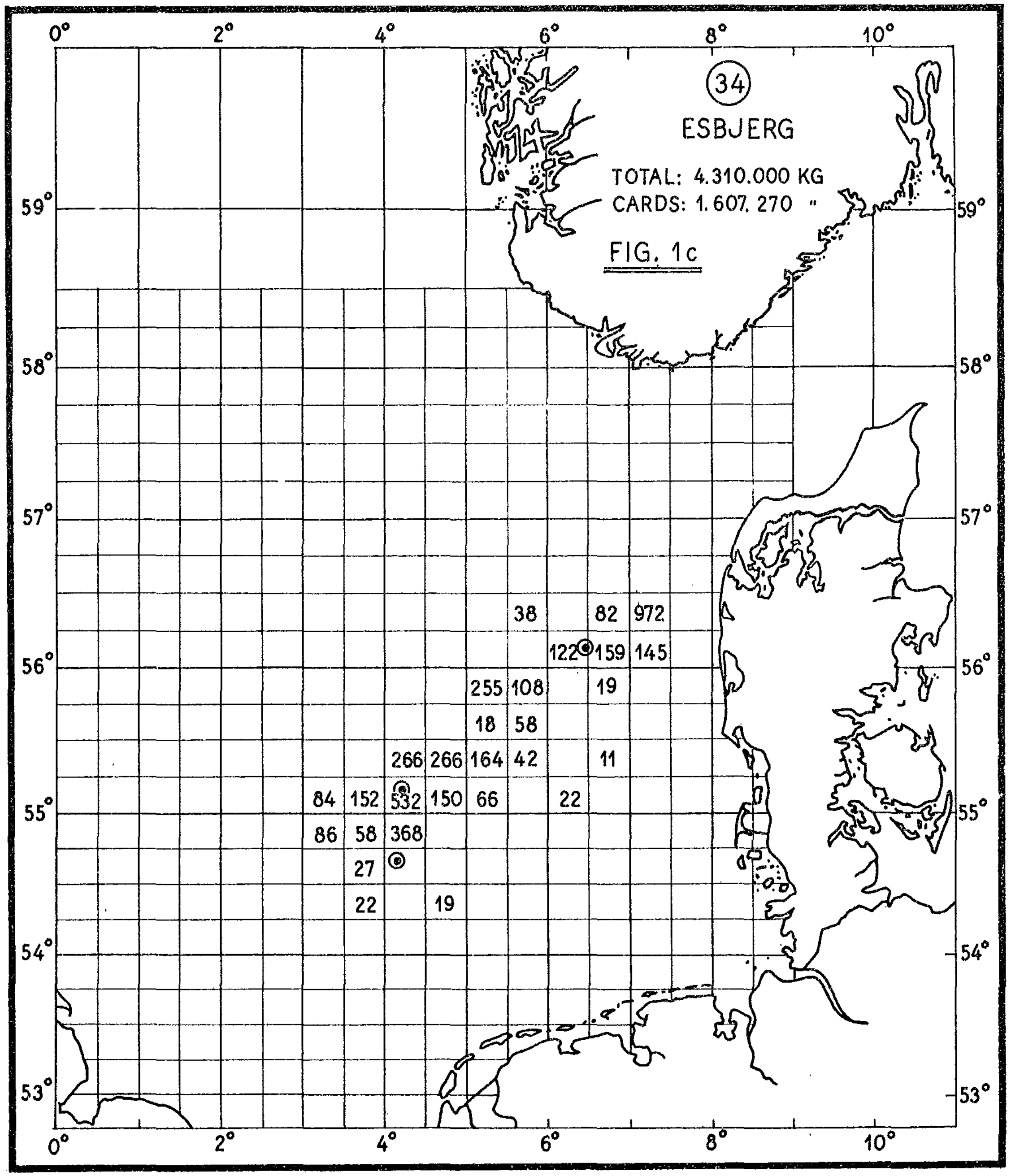

34
ESBJERG
TOTAL: 4.310.000 KG
CARDS: 1.607.270 "
38
82
972
122
159
145
255
108
19
18
58
266
266
164
42
11
84
152
532
150
66
22
86
58
368
27
22
19

FIG. 1c

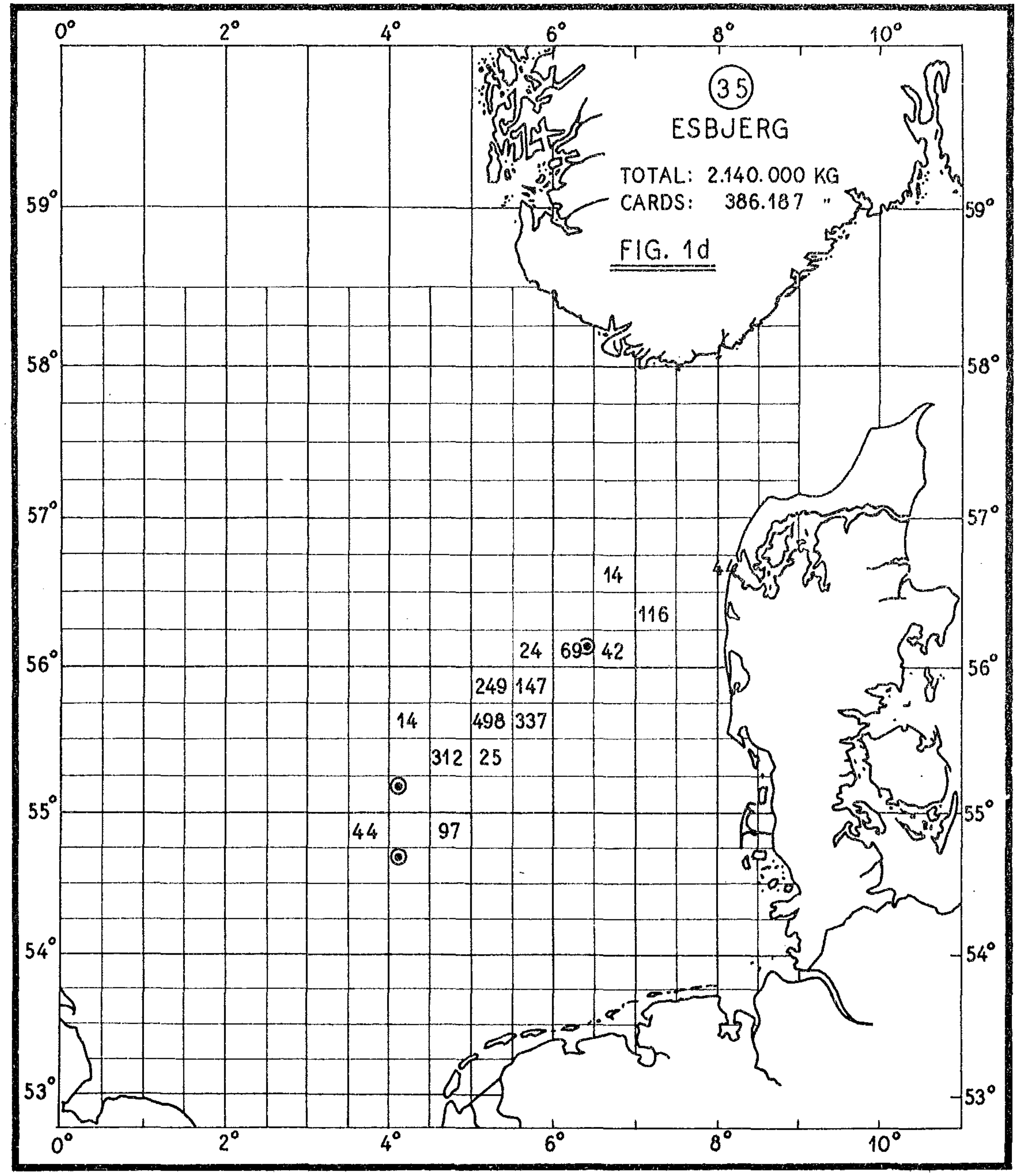
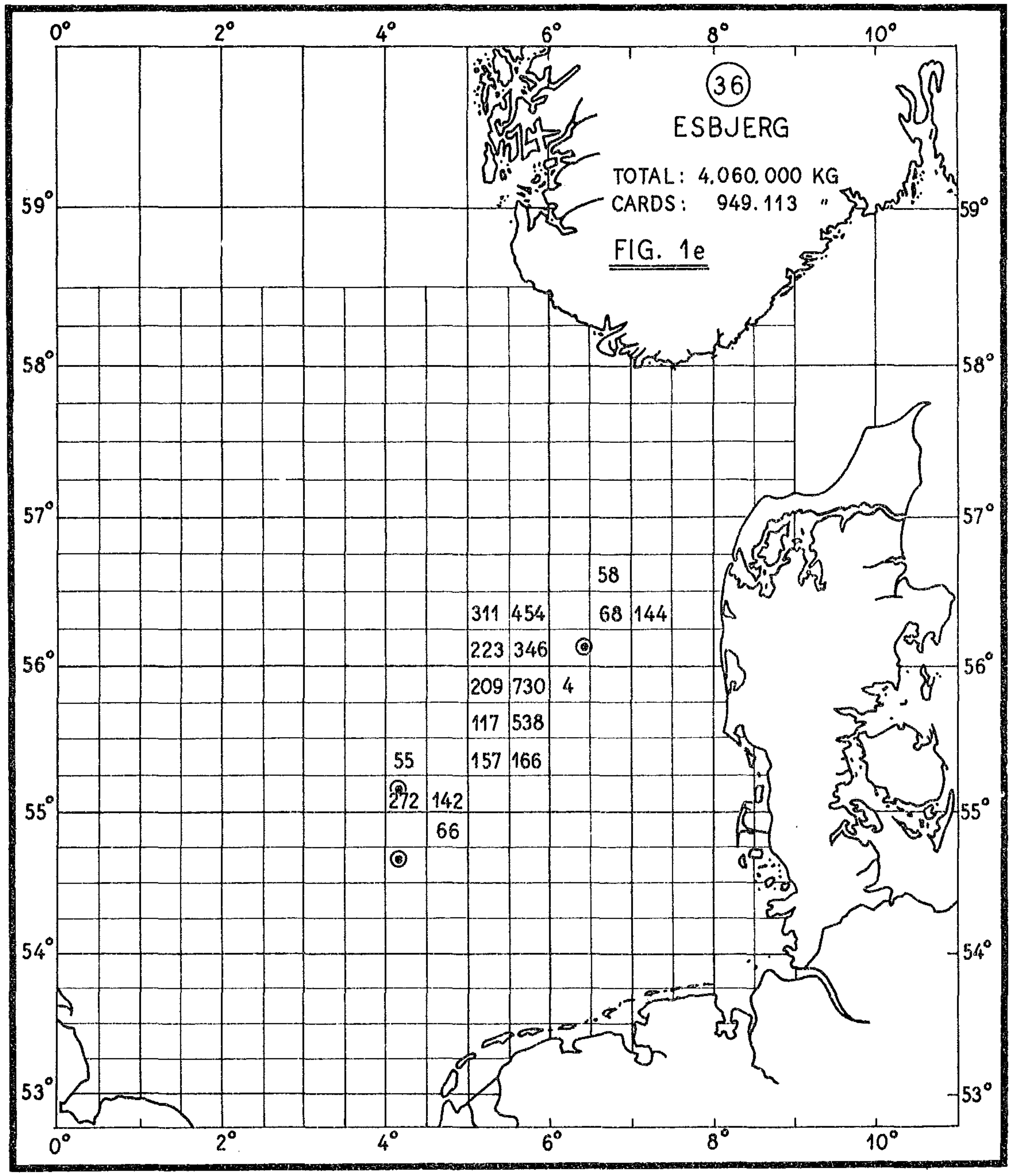
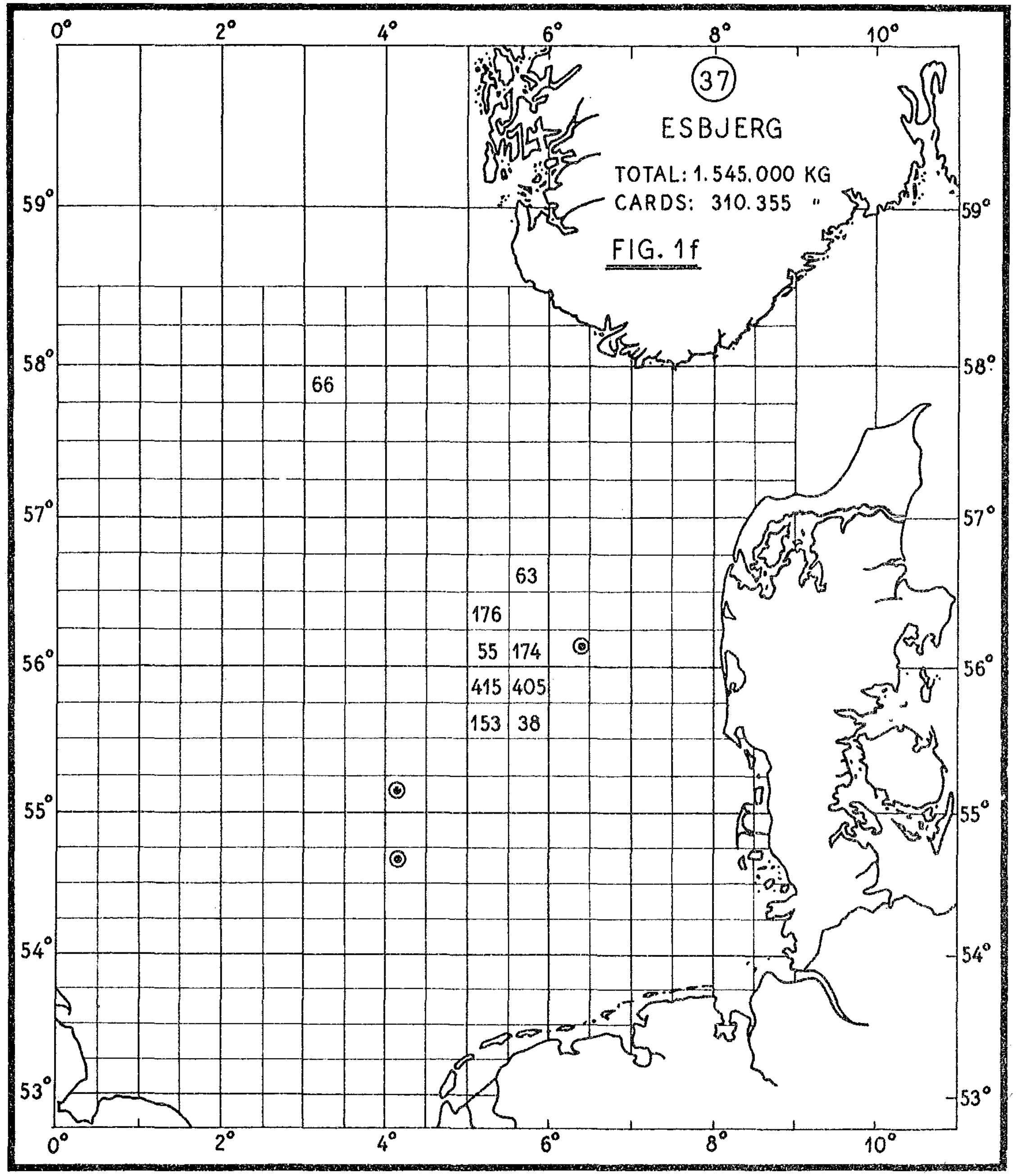
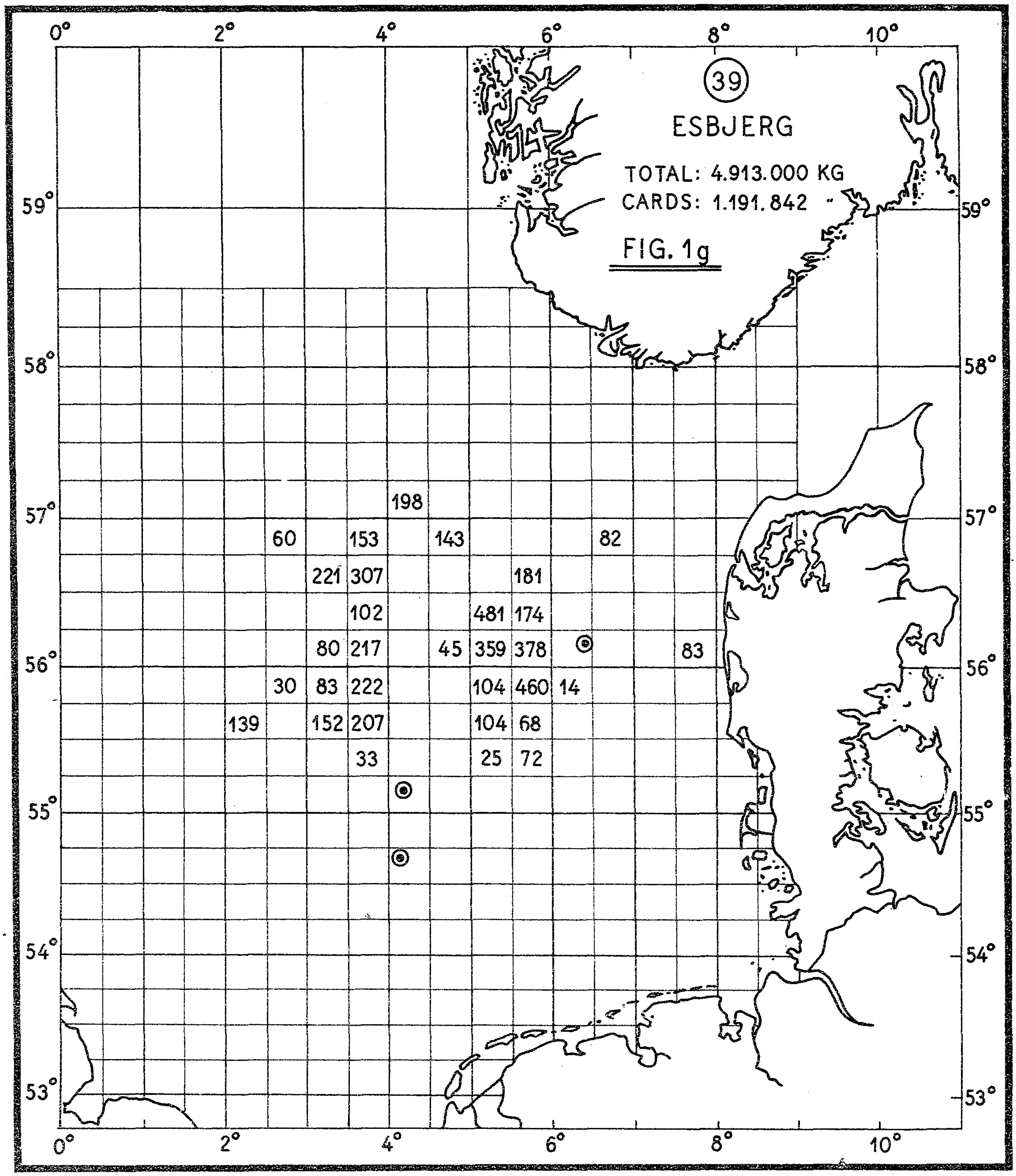

35
ESBJERG
TOTAL: 2.140.000 KG
CARDS: 386.187 "
14
116
24
69
42
249
147
14
498
337
312
25
44
97

FIG. 1d


36
ESBJERG
TOTAL: 4.060.000 KG
CARDS: 949.113 "
FIG. 1e
0° 2° 4° 6° 8° 10°
59° 58° 57° 56° 55° 54° 53°
58
311 454 68 144
223 346
209 730 4
117 538
55 157 166
272 142
66


37
ESBJERG
TOTAL: 1.545.000 KG
CARDS: 310.355 "
FIG. 1f
0° 2° 4° 6° 8° 10°
59° 58° 57° 56° 55° 54° 53°
66
63
176
55 174
415 405
153 38



39
ESBJERG
TOTAL: 4.913.000 KG
CARDS: 1.191.842
0° 2° 4° 6° 8° 10°
59° 58° 57° 56° 55° 54° 53°
198
60 153 143 82
221 307 181
102 481 174
80 217 45 359 378 83
30 83 222 104 460 14
139 152 207 104 68
33 25 72

FIG. 1g

FIG. 2: Daily wind speeds (knots) at E.R. lightship, 55°23'6 N - 6°57'4 E during the autumn fishing season.

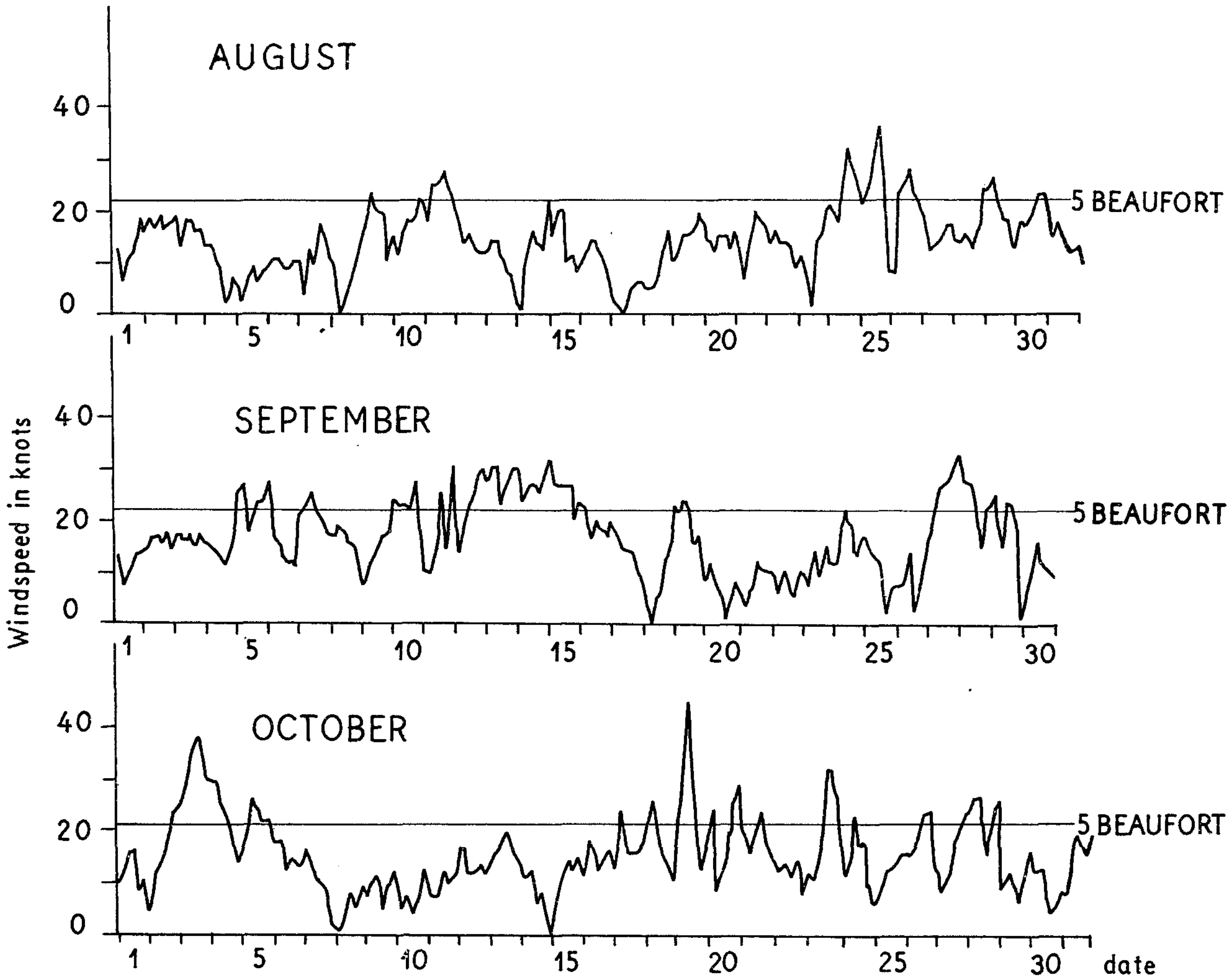
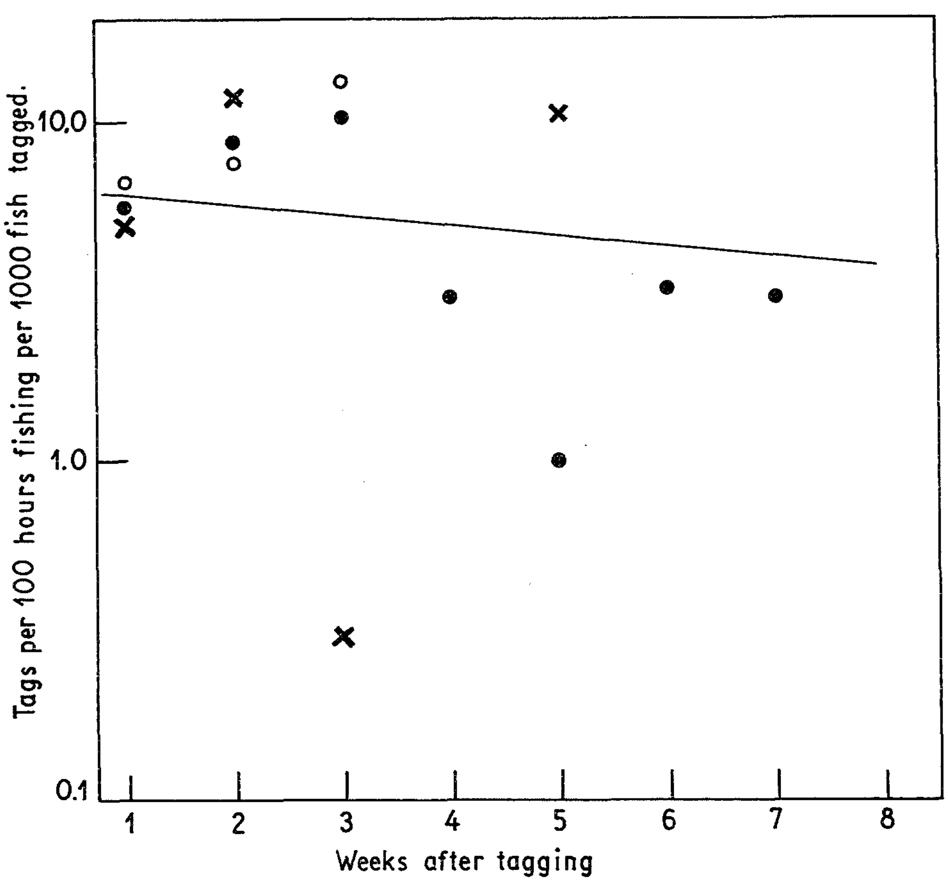


FIG. 3: Recapture of tags each week, in the form of number of tags caught per 100 hours fishing per square, for 1000 tags liberated.



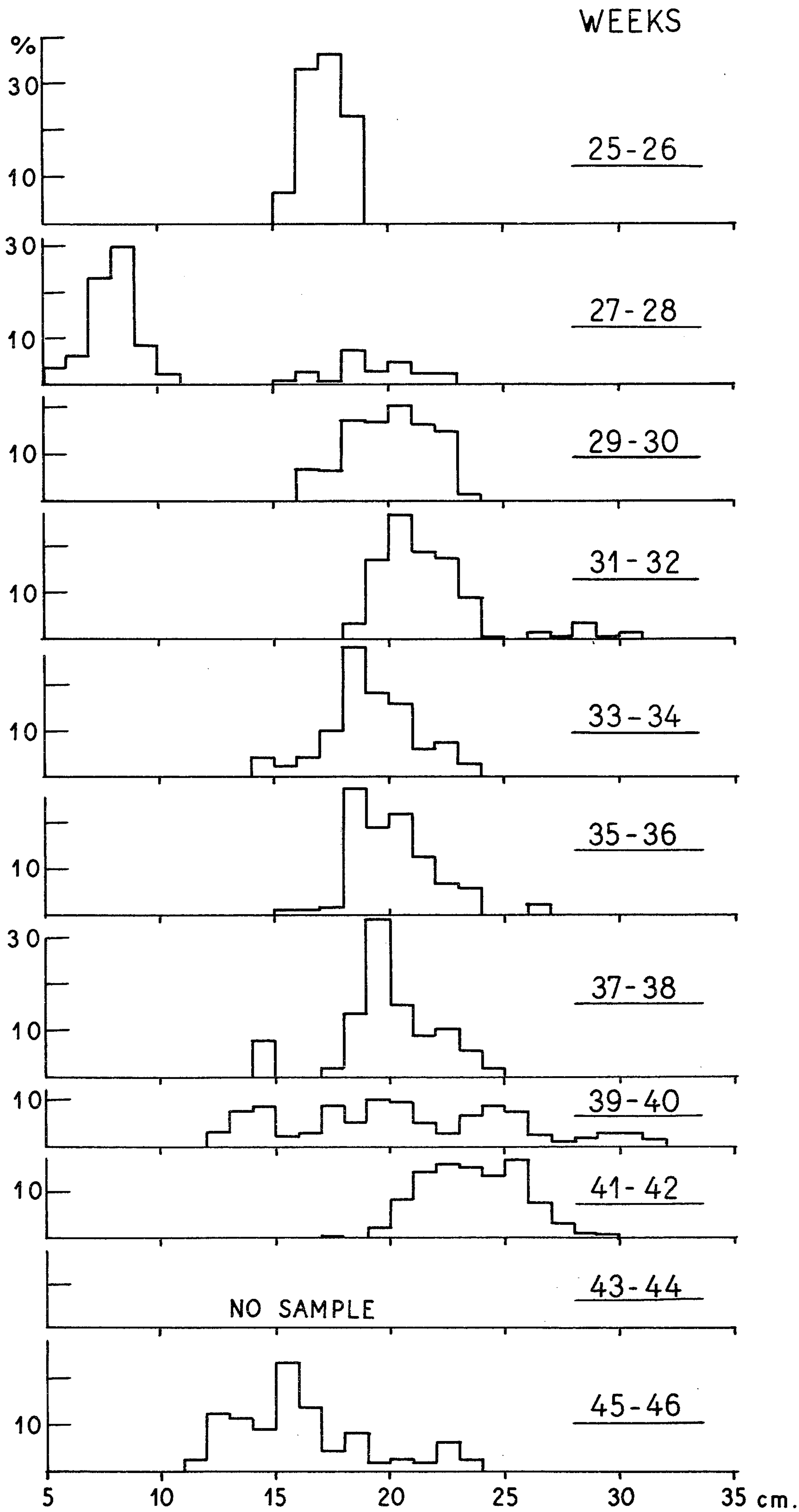
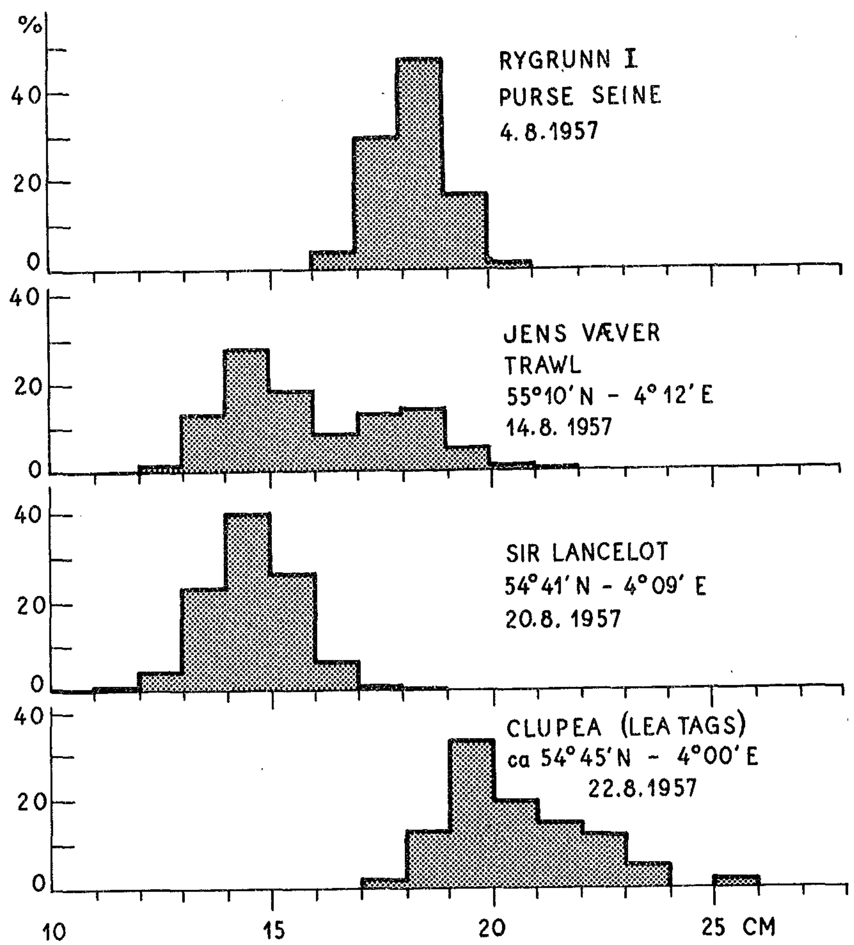
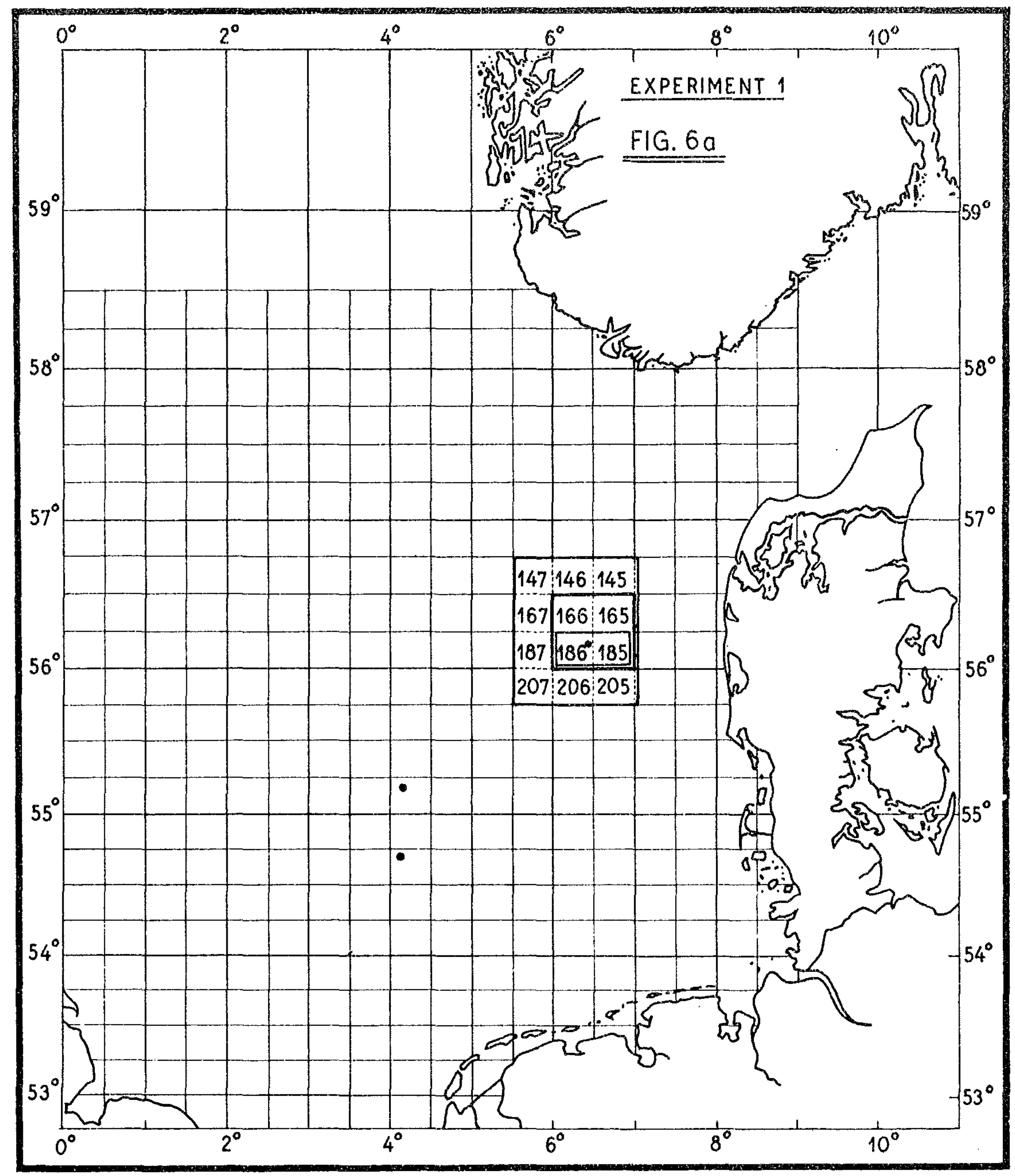
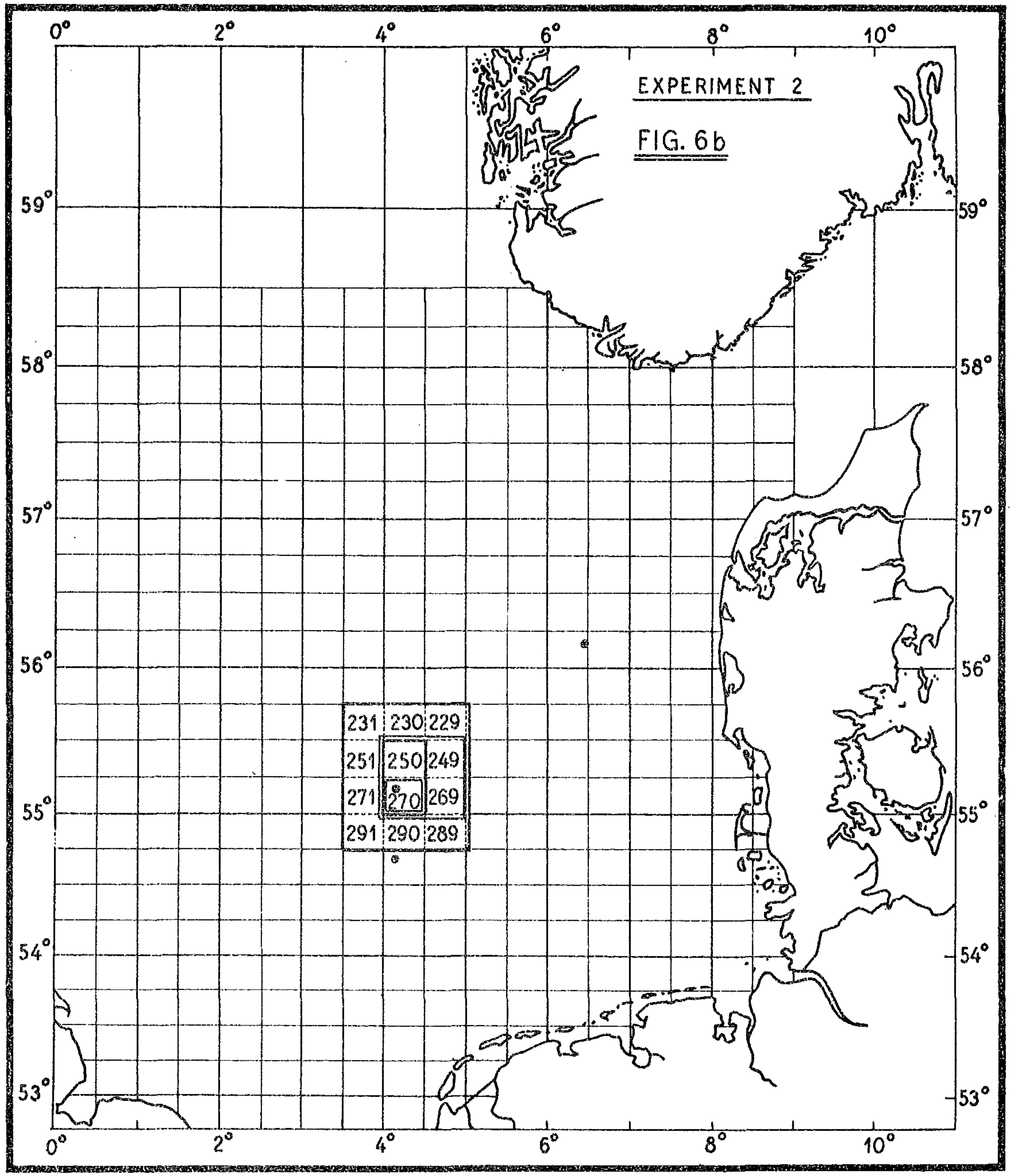


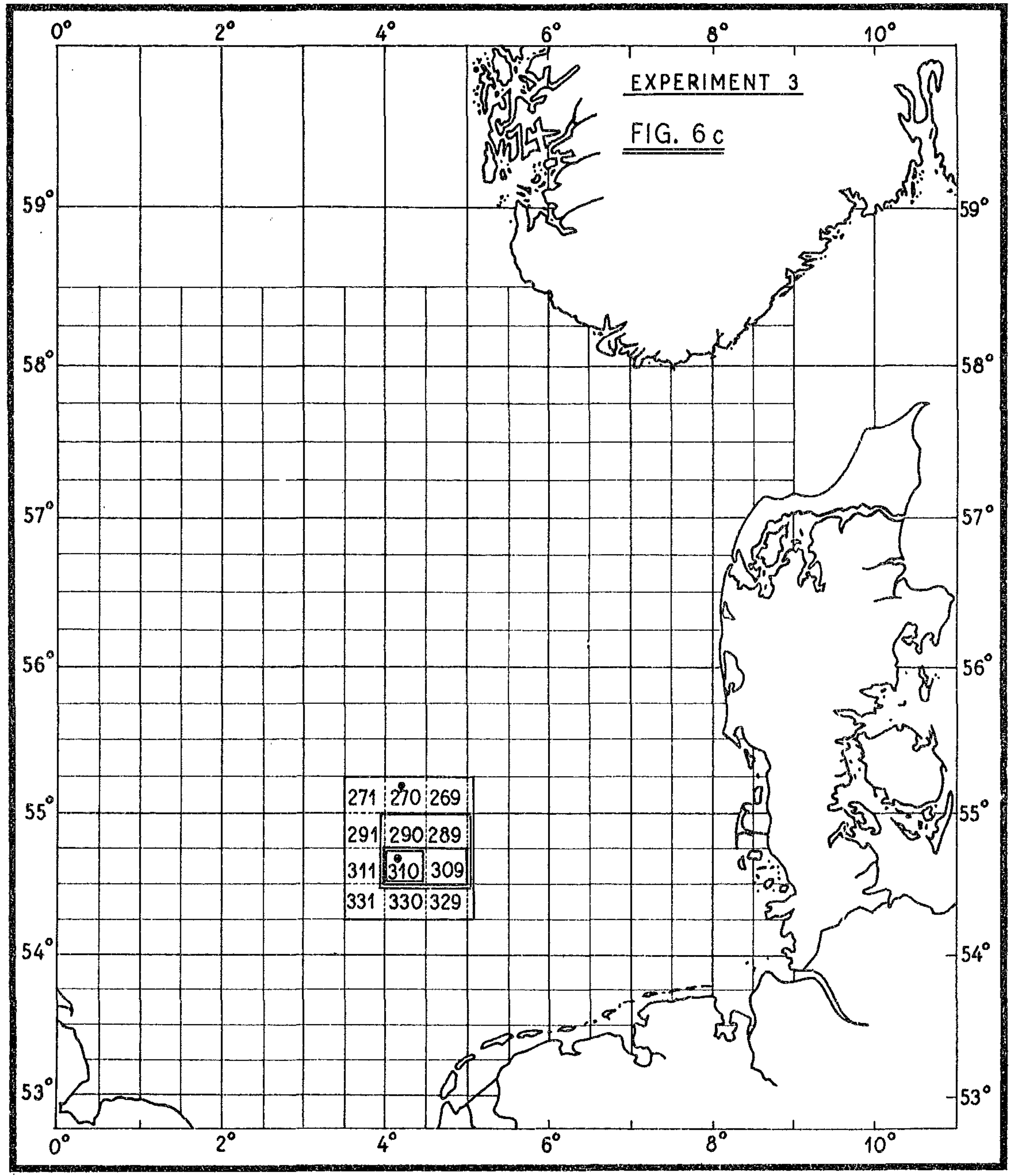
FIG. 4: Percentage lenght distribution of herring landed in each 2-week period at Esbjerg 1957.
(Data from K. Popp Madsen MS)

FIG. 5: Percentage length distribution of tagged herring.






EXPERIMENT 2
FIG. 6b
0°
2°
4°
6°
8°
10°
59°
58°
57°
56°
55°
54°
53°
231
230
229
251
250
249
271
270
269
291
290
289


EXPERIMENT 3
FIG. 6c
0°
2°
4°
6°
8°
10°
59°
58°
57°
56°
55°
54°
53°
271
270
269
291
290
289
311
310
309
331
330
329