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Pelagic Fish (Northern) Committee

PRELIMINARY REPORT OF THE ICES WORKING GROUP ON THE BLØDEN TAGGING EXPERIMENT

Charlottenlund, 27 June - 3 July 1973

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CONTENTS

Page

T E X T

T A B L E S and F I G U R E 1

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Preliminary Report of the ICES Working Group on the Bløden Tagging Experiment

1. Introduction

The Bløden Herring Tagging Experiment took place during July 1969 to March 1970. The tagged herring were expected to remain in the area of the juvenile herring fishery until early 1971 at least. The Working Group met again in March 1971 (C.M. 1971/H:3) to examine the material so far available and to consider useful methods of analysing the data. At this meeting a contrast between these tagging experiments and those of 1957-58 (Aasen et al. 1961) was apparent in that a higher percentage of tagged fish released was recaptured and were returned over a relatively long period. Because of these features it was thought that the greater number of recaptures might allow a more extensive model of the dispersion of tagged fish from the liberation areas. Such a model could be used to simulate the distribution of tagged fish in the fishing area. A number of requests for the supply of various data were made and it was decided to meet again at ICES Headquarters prior to the Statutory Meeting in September 1971 to further consider the available data and to discuss the type of dispersion model required.

The Marine Laboratory, Aberdeen offered the assistance of a mathematician/programmer and the facilities of a computer of adequate capacity. A time-table was drawn up for transference of the data from computer files in Copenhagen to Aberdeen and for the development of the programme, which was expected to be operational during autumn 1972. It was agreed that the Group should meet again when output from the computer was available.

The participants at the most recent meeting (27 June-3 July 1973) at ICES Headquarters were:

Mr A. C. Burd (Chairman)	UK (England)
Mr H. Becker	Netherlands
Mr A. Maucorps	France
Mr M. D. Nicholson	UK (Scotland)
Mr J. A. Pope	UK (Scotland)
Mr K. Popp Madsen	Denmark
Mr Ø. Ulltang	Norway

Apologies were received from Dr A. Ackefors and Mr G. Wagner, who were unable to attend.

1.1 Terms of reference

At the 5th meeting of the North East Atlantic Fisheries Commission ICES was asked to prepare plans for a new Bløden herring tagging experiment.

The purposes of this experiment would be:

"(a) to obtain a minimum estimate of the proportion of the juvenile herring stock in the Bløden area taken by the fishery there. This estimate is required to assess the effect of the Bløden fishery on recruitment to the total adult herring population in the North Sea. Further, provided adequate sampling for racial analysis is conducted, it is hoped also to provide estimates of its effect on recruitment to each of the main spawning stocks separately.

(b) In addition it should provide valuable information on the distribution and migration pattern of the juvenile herring within and away from the Bløden area."

1.2 Experimental design

It was considered necessary that tags should be distributed over the widest possible area during the experiment. Four tagging areas were defined in the eastern North Sea with the boundaries 54°N to 57°N and west to 1°E and from 5°E north to the Norwegian coast and into the Skagerak. It was intended that each month tags should be liberated in each area. A Norwegian purse seiner, MV GERDA MARIE, was chartered as catching and tagging vessel. At various times assistance in searching for herring shoals was given by research vessels from

Denmark, France, Germany, Norway, Poland and the Netherlands and those participating in the ICES Young Herring Survey.

Mr G. Sangolt, a member of the staff of the Institute of Marine Research, Bergen, Norway was Supervisor on board the ship and the two tagging teams, whose membership was kept unchanged, consisted of crew members. The herring were either tagged directly from keep nets alongside the ship or transferred to flooded hold tanks aboard the vessel. The tags used were small "sprat" type internal tags. The ultimate aim was to release 100 000 tagged fish, however only 57 496 fish were released due to scarcity of herring.

Samples of fish from each tagging experiment were measured and preserved for subsequent analysis for age and racial characters. Special arrangements were made for the biological sampling of the commercial catches in Esbjerg during the period when tags were being recaptured.

As the success of the experiment was dependent on the high efficiency of detection of tags, it was stressed that all major plants handling herring catches from the North Sea and the Skagerak should be fitted with magnets and that magnet efficiencies should be regularly tested. The collection of detailed catch and effort statistics by fishing position was not considered adequate in January 1969. At that level the Group doubted that the tagging experiment results could be analysed effectively.

1.3 Data processing

For each recaptured tag, the following information was prepared on an IBM punched card. The first 12 columns provide the actual recapture information and columns 13 to 56 details of the experiment from which the tagged fish was released.

IBM column	Information
1- 5	Tag number
6- 7	Country
8- 9	Factory
10-12	Week number
13-14	Experiment number
15-20	Time and place of liberation
21-23	Size of catch
24-34	Weather conditions
35-56	Further information of liberations

Table 2.1 Dates and positions of liberations

Experiments	Dates	Tagging positions		Numbers tagged
	1969			
1	25 July	57°52'N	10°30'E	1 996
2	31 July	55 02	05 36	1 800
3	1 Aug	55 04	05 56	2 000
4	4-5 Aug	54 41	05 30	4 000
5	7 Aug	54 57	05 20	2 000
6	20 Aug	56 25	06 33	2 000
7	28 Aug	57 34	11 38	2 000
8	5 Sept	56 28	06 45	2 000
9	8 Sept	56 24	06 48	2 000
10	9 Sept	55 59	07 17	2 000
11	15 Sept	55 01	07 03	1 100
12	19 Sept	54 13	03 40	1 600
13	10 Oct	59 35	10 39	1 000
14	15 Oct	58 05	06 31	1 000
15	23 Oct	56 30	07 02	2 000
16	23 Oct	56 05	07 15	2 000
17	24 Oct	55 28	06 53	2 000
18	26 Nov	56 40	06 32	3 000
19	11 Dec	55 06	04 34	2 000
	1970			
20	7 Jan	55 05	04 23	2 000
21	8 Jan	54 32	04 27	2 000
22	13 Jan	54 29	06 12	2 000
23	13 Jan	54 43	06 31	600
24	13 Jan	54 45	06 34	2 400
25	11 Feb	54 12	05 06	2 000
26	12 Feb	54 01	04 54	3 000
27	26 Feb	54 41	05 56	2 000
28	27 Feb	54 41	05 56	2 000
29	27 Feb	54 41	05 56	2 000
			Total	57 496

The ages of the fish tagged and in the catches was determined from the biological data collected on the tagging vessel and at the ports. When adequate data are available from the 1967 and 1968 year-classes as spawning fish it is the intention to carry out a racial analysis.

At its meeting in September 1971 the Group was informed that a general computer program of a dispersion model was currently being developed at the Danish Fishery Laboratory by Mr Hans Lassen and it was decided that a modified version of this program, suitable for handling the present material, should be written and applied. This task was undertaken by Mr M. Nicholson (Marine Laboratory, Aberdeen) using the large computer facilities available at the Scottish Office Computer Service Centre (Edinburgh) and at the North European University Computer Centre (Denmark).

The model developed is described in detail in Section 4.

2. The liberations

The execution of the plan for the distribution of tags throughout the North Sea and Skagerak was unsuccessful. Primarily this was due to the scarcity of herring of a suitable size for tagging (15-23 cm). Research vessels reported the occurrence of echo traces to GERDA MARIE and also fished with trawls in these locations to determine the size of the fish. Despite considerable searching, the tagging locations were restricted in both time and area. Table 2.1 gives the total numbers of fish tagged and the date and location of the liberations (Figure 1). Of the total of 57 496 tagged fish liberated, 6 035 tags were recovered. In addition to making the tag liberations, six experiments were performed over 3-5 days to try to determine the mortality caused by tagging.

2.1 Tagging mortality experiments

The experiments were either conducted in flooded hold tanks on board the ship or in keep nets alongside. A known number of tagged and untagged fish were placed in the experimental environments and after 3 or 5 days the tank or keep nets were emptied and the numbers of survivors tagged by each tagging team were recorded. The results of these

Table 2.2 Mortality experiments - GERDA MARIE

Experiments	Dates	Holding unit	Duration (days)	Temperature (°C)	Location
1	31 July 1969	Ship's tank	5	18	South of Tail End
2	5 Sept 1969	Ship's tank	5	15	North of Ringkjöbing Ground
3	9 Oct 1969	Ship's tank and keep net	5	12	Oslofjord*
4	10 Oct 1969	Ship's tank and keep net	5	12	Oslofjord
5	29 Nov 1969	Keep net	3½	8	Stavanger Fjord†
6	7 Jan 1970	Ship's tank	3	6	South of Tail End

Experiments	Treatment	Total	Alive	Dead	Tag shed	Lost	Effective liberation	% alive	% daily mortality
1	Untagged	108	77	31			108	71.3	5.74
	Team 2	100	67	33	(5)		100	67.0	6.60
2	Untagged	100	78	22			100	78.0	4.40
	Team ?	100	68	32			100	68.0	6.40
3	Untagged	200	144	49		7	193	74.6	5.08
	Team 1	200	112	73		15	185	60.5	7.89
	Untagged	200	142	50		8	192	74.0	5.21
	Team 2	200	90	94		16	184	48.9	10.22
4	Untagged	100	77	20		3	97	79.4	4.12
	Team 1	104	88	16			104	84.6	3.08
5	Untagged	100	98	1		1	99	99.0	0.29
	Team 1	100	98	2			100	98.0	0.57
	Team 2	100	84	12	1	3	96	86.6	3.57
6	Untagged	108	96	12			108	88.9	3.70
	Team 1	100	83	15	2		98	84.7	5.10
	Team 2	100	68	30	2		98	69.4	10.20

* Fish bought from purse seiner in Oslofjord.

† This experiment was performed on fish caught on the Monkey Bank and transported to Stavanger Fjord (27-hour steam).

experiments are summarized in Table 2.2. The results are reasonably consistent between experiments.

The mean daily percentage mortalities, excluding experiment 5, were:

Untagged	4.71%
Team 1	5.36%
Team 1	9.01%.

The experiments have been combined to obtain estimates of survival rates for fish tagged by teams 1 and 2 (Table 2.3).

Table 2.3 Survival of herring

	Untagged	Tagged	
		Team 1	Team 2
Number liberated	798	387	382
% survival	76.94	73.12	58.90
Range	71.3-88.9	60.5-84.7	48.9-86.6

The range of survival in untagged fish is only 17.6%, while for team 1 the range is 24.2% and 37.7% for team 2. It is quite probable that the survival may have been much lower than the average values used in the following analysis.

2.2 Effective liberations

Assuming there is no further mortality due to tagging beyond the 5 days of the experiments, the total numbers of fish liberated may be adjusted to give an effective number of tags liberated. Table 2.3 gives the numbers of fish tagged by each team and the numbers recaptured.

The mean recapture rate, ρ, of fish tagged by team 2 relative to team 1 was 0.7313 ± 0.139.

Let N_{ij} = number of fish tagged by team i (i = 1, 2) in experiment j (j = 1-29);

S_i = percentage survival after tagging;

R_{ij} = total number of recaptures by team i from experiment j.

Table 2.4 Recaptures and liberations by tagging team

Experiments	Recaptures			Number tagged	
	Team 1	Team 2	Team 1 + Team 2	Team 1	Team 2
1	95	61	156	996	1 000
2	160	114	274	900	900
3	193	159	252	1 000	1 000
4	282	267	549	2 050	1 950
5	171	98	269	1 050	950
6	59	100	159	1 000	1 000
7	56	50	106	1 000	1 000
8	95	57	152	1 000	1 000
9	151	73	224	1 000	1 000
10	172	109	281	1 000	1 000
11	47	17	64	600	500
12	72	42	114	800	800
13	6	2	8	500	500
14	22	7	29	500	500
15	185	130	315	1 000	1 000
16	200	141	341	1 000	1 000
17	211	165	376	1 000	1 000
18	277	205	482	1 500	1 500
19	105	108	213	1 000	1 000
20	87	87	174	1 000	1 000
21	155	134	289	1 000	1 000
22	65	32	97	1 000	1 000
23	17	8	25	300	300
24	181	154	335	1 200	1 200
25	118	93	211	1 000	1 000
26	134	116	250	1 500	1 500
27	24	26	50	1 000	1 000
28	17	10	27	1 000	1 000
29	30	14	44	1 000	1 000
Total	3 387	2 579	5 966	28 896	28 600

Experiments	Percentage recapture			Effective liberation		
	Team 1	Team 2	Ratio: $\frac{\text{Team 1}}{\text{Team 2}}$	Team 1	Team 2	Team 1 + Team 2
1	9.54	6.10	0.6394	765	562	1 327
2	17.78	12.67	0.7126	691	506	1 197
3	19.30	15.90	0.8238	768	562	1 330
4	13.76	13.69	0.9949	1 575	1 096	2 671
5	16.29	10.32	0.6335	807	534	1 341
6	5.90	10.00	1.6949	768	562	1 330
7	5.60	5.00	0.8929	768	562	1 330
8	9.50	5.70	0.6000	768	562	1 330
9	15.10	7.30	0.4834	768	562	1 330
10	17.20	10.90	0.6337	768	562	1 330
11	7.83	3.40	0.4342	461	281	742
12	9.00	5.25	0.5833	615	449	1 064
13	1.20	0.40	0.3333	384	281	665
14	4.40	1.40	0.3182	384	281	665
15	18.50	13.00	0.7027	768	562	1 330
16	20.00	14.10	0.7050	768	562	1 330
17	21.10	16.50	0.7820	768	562	1 330
18	18.47	13.67	0.7401	1 152	843	1 995
19	10.50	10.80	1.0286	768	562	1 330
20	8.70	8.70	1.0000	768	562	1 330
21	15.50	12.40	0.8645	768	562	1 330
22	6.50	3.20	0.4923	768	562	1 330
23	5.67	2.67	0.4709	230	168	398
24	15.08	12.83	0.8508	922	674	1 596
25	11.80	9.30	0.7881	768	562	1 330
26	8.93	7.73	0.8656	1 152	843	1 995
27	2.40	2.60	1.0833	768	562	1 330
28	1.70	1.00	0.5882	768	562	1 330
29	3.00	1.40	0.4667	768	562	1 330
Total	11.72	9.02		22 194	16 072	38 266

Taking the percentage survival of team 1 fish in the mortality experiments, the effective liberation is

$$L_{1j} = N_{1j} \times S_1 + N_{2j} \times S_1 \times \rho , \quad (1)$$

or in terms of survival of team 2 fish effective liberation is

$$L_{2j} = \frac{1}{\rho} \times N_{1j} \times S_2 + N_{2j} \times S_2 . \quad (2)$$

Numerically

$$L_{1j} = 0.7312\, N_{1j} + 0.5347\, N_{2j} \quad (3)$$

and

$$L_{2j} = 0.8054\, N_{1j} + 0.5890\, N_{2j} . \quad (4)$$

As there is no reason to suppose that one estimate of S is better than the other, means have been taken of the values in equations 3 and 4. The following relationship was used for calculating the effective number of fish liberated in each experiment and they are given in Table 2.4:

$$L_j = 0.7683\, N_{1j} + 0.5618\, N_{2j} \quad (5)$$

While tagging a record was kept of the serial numbers of each fish liberated in each hour from commencement of tagging. The recaptures for teams 1 and 2 have been grouped by hour of tagging. These have been summarized and expressed as percentages of the total tag releases in Table 2.5. In experiment 4 tagging was curtailed after 2 hours and resumed 10 hours later.

As can be seen from the table, most liberations were conducted into or beyond the third hour from commencement. Taking all liberations up to and including the third hour, analyses of variance were made within teams to test whether differences in recovery rate were associated with hour of liberation. The results are given in Table 2.6.

Table 2.6 Analysis of variance of recaptures by hour of tagging

Team	Source	Sum of squares	df	Mean square
1	Between liberations	0.2060	22	0.00936
	Between hours	0.0009	2	0.00045
	Residual	0.0149	44	0.00033
	Total	0.2218	68	
2	Between liberations	0.1243	22	0.00565
	Between hours	0.0009	2	0.00045
	Residual	0.0160	44	0.00036
	Total	0.1412	68	

Significant differences for both teams occur between liberations but not between recaptures by hour of liberation.

Considering the position of liberations, data on length and age composition of the herring tagged, some of the liberations have been combined for the purposes of further data analysis (Table 2.7). The mixed liberations tend to an average of 40%, 1967 year-class, and 60%, 1968 year-class.

Table 2.7 Liberations by position and year-class

Location	Liberation	Dates	Effective liberation	Year-class
North of 57°	1	25 July 1969	1 327	1967
	7	28 Aug 1969	1 330	1967
	13	10 Oct 1969	665	1967
	14	15 Oct 1969	665	1967
South of 57° and north of 55°30'	6	20 Aug 1969	1 330	mixed
	8-10	5-9 Sept 1969	3 990	1968
	15-17	23 Sept-4 Oct 1969	3 990	1968
	18	26 Nov 1969	1 995	1968
South of 55°30'	2- 5	31 July-7 Aug 1969	6 539	1967
	11	15 Sept 1969	742	1968
	12	19 Sept 1969	1 064	mixed
	19	11 Dec 1969	1 330	1967
	20-23	7-13 Jan 1970	4 388	1967
	24	13 Jan 1970	1 596	mixed
	25-26	11 Feb 1970	3 325	mixed
	27-29	26 Feb 1970	3 990	1968

3. Recaptures

In this report only recaptures up to 30 April 1971 are considered. Since that date a further 1 193 tags have been returned, mostly from the fisheries in the north-western North Sea. Because of the time taken for tags to pass through processing plants it was thought that the minimum reportage time which could be considered was by month. The recaptures up to April 1971 were tabulated by months, country and factory.

Recaptures from Sweden were too few to consider and the Scottish plant was not operative until late in the season. The English plants at Hull and Grimsby are mainly offal processing.

In order to facilitate a comparison of the number of tags returned per liberation, the returns have been raised to a standard liberation of 10 000 tags. These values are given in Table 3.1 for Denmark, Norway and Germany. The data are grouped by the year-class of the fish tagged. It is interesting to note that the liberations 1 and 7 in the Skagerak and 2-5, 19 and 20-23 south of 55°30'N consisted of almost only 1967 year-class. Returns from 1 and 7 were almost entirely from the northern Danish plants at Skagen and Hirtsals. Whereas with the liberations 2-5 early returns came from Esbjerg, but later were returned from the northern Danish plants.

In the case of Norway a considerable quantity of the 1967 year-class recaptures were returned from May 1970, when a major part of the Norwegian catch was reported as coming from the north-western North Sea (Table 3.5).

3.1 Commercial statistics

Statistics of the quantities of herring caught in the North Sea and landed for industrial purposes were available from Denmark, Norway and Germany. The Danish data, the most detailed statistics provided, are shown by port in Tables 3.2a-d. In addition to recording the total amount of herring processed, samples were taken at Skagen, Thyborön and Esbjerg for age determination and the estimated number of herring of different year-classes obtained from these samples are also given there. Repeated measurements of magnet efficiencies at the reduction plants

Table 3. 3 North Sea herring catch processed in Norway

	Catch in tons		Magnet efficiency
	Total	Effective	
1969			
July	29 629	22 216	74.98
August	16 513	13 387	81.07
September	62	41	67.21
October			
November	80	63	79.35
December			
1970			
January	13 107	10 654	81.29
February	2 286	1 882	82.33
March			
April	29	18	63.89
May	1 780	1 561	87.70
June	55 559	42 260	76.06
July	70 112	52 774	75.27
August	8 292	6 607	79.67
September	4 137	3 156	76.28
October	82	72	88.71
November	215	165	76.81

Table 3.4 Germany (Federal Republic) - herring landings of cutters fishing for industrial purposes in the North Sea (in tons): (1) on the basis of the Federal Statistical Office, Wiesbaden; (2) landings split into biological samples (made by the Institute of Coastal and Inland Waters Fishery)

	1969		1970		1971	
	1	2	1	2	1	2
January	-	-	1 449.3	5 113.9	4.4	-
February	-	-	8 520.4	7 584.4	36.8	3.5
March	-	-	2 736.4	2 513.5	132.3	72.9
April	-	-	1 002.0	1 116.0	-	19.7
May	-	-	2 186.0	207.7	250.2	21.5
June	1 149.1	-	1 890.0	33.3	24.1	152.1
July	627.3	31.8	2 929.5	1 992.7	-	-
August	3 979.1	5 091.8	8 054.7	2 159.6	-	-
September	4 457.6	4 071.8	3 289.0	1 022.7	-	-
October	3 562.7	3 903.0	1 544.3	1 775.7	-	-
November	-	167.2	10.1	966.2	-	-
December	19.0	-	89.2	-	-	-

were used to convert the total quantity of herring processed into effective quantities (Table 3.2).

Norwegian landings of herring (for industrial and human consumption) split according to area of capture are shown in Table 3.5. Estimates of the North Sea herring age composition for each month were not available. Magnet efficiencies on an annual basis were available from Norwegian factories (Table 3.3).

Landings of herring for industrial purposes by German cutters were presented from two sources for the period June 1969-June 1970 (Table 3.4). The agreement between the two sets of statistics is not good.

From the information on magnet efficiencies tables have been constructed showing the number of tags recaptured per 10 000 tags effectively liberated in each experiment (Tables 3.6 and 3.7). In the case of the returns which came from factories at Esbjerg, Skagen and Thyborön, it was possible, by using the available age composition data, to calculate the number of recaptures per 10 000 tags released per 10^6 herring processed. These data are given in Tables 3.8, 3.9, 3.10 and 3.11. The data for Esbjerg show no systematic variation with time, suggesting that no change took place in the ratio between tagged and untagged fish.

3.2 Distribution of catch and effort

The most detailed information on the distribution of herring fisheries from July 1969 to April 1971 concerns the Danish, Norwegian and Scottish catches which, between them, account for by far the greatest part of the recaptured tags. German recaptures are quite significant in some experiments, but no data on the distribution of the German fishery are available.

The Danish catch statistics cover Esbjerg where 68-93% of the monthly landings are accounted for, and Skagen where 8-68% coverage was obtained in individual months. There are no data available from Skagen in 1971.

The distribution of the Danish herring catches shows two rather permanent areas of fishing, one around the Skaw at the entrance to the Kattegat and an area in the south-western North Sea - identical with the

Table 3.12 Distribution of recaptured tags per 10 000 released by country (not corrected for magnet efficiency)

Tagging location	Experiment	1967 year-class							
		Denmark							
		Eb*	Th	H	Sk	Nw	G	Sc	Sw
Skagerak	1	15		580	422	98	52	8	8
	7	60		364	236	84	54	8	
Northern Bløden 57° to 55°30'									
Southern Bløden	2- 5	1 063	9	182	54	552	264	64	3
55°30' and	19	278		263	105	774	92	68	8
southerly	20-23	264	9	200	75	661	90	39	2

Tagging location	Experiment	1968 year-class							
		Denmark							
		Eb	Th	H	Sk	Nw	G	Sc	Sw
Skagerak									
Northern Bløden	8-10	920	256	70	85	105	248		5
57° to 55°30'	15-17	1 562	208	111	88	78	559	2	8
	18	1 398	315	100	70	40	681	10	10
Southern Bløden	11	592	40			27	188		
55°30' and	27-29	228	43			5	27		
southerly									

*Eb = Esbjerg, Denmark
Th = Thyborön, Denmark
H = Hirtsals, Denmark
Sk = Skagen, Denmark
Nw = Norway
G = Germany
Sc = Scotland
Sw = Sweden

Bløden ground. Fishing in the north-western North Sea is more patchy and was mainly carried out in January-April 1970 and again from September 1970 to April 1971.

The Norwegian purse-seine catches are mainly concentrated in the Skagerak and the north-eastern North Sea in the period July-December 1969. In January-June 1970 additional fishing was carried out in the central North Sea east of the Danish Bløden fishery. In the second half of 1970 a Norwegian fishery around the Shetland-Orkneys developed. Only sporadic landings are taken from the North Sea in the early part of 1971.

The Scottish North Sea herring fishery is mainly concentrated around the Shetland-Orkneys and only a few landings are made in the period October 1969-March 1970 and in the early months of 1971. The largest catches are taken in June-August 1970 when the Scottish herring fishery extends towards west into ICES Statistical Area VIa and only minor catches are made east of Shetland.

It is important to note that there is almost no overlap in the area of the fisheries of Norway, Scotland and Denmark. The rate of return of tags from these fisheries is in part a reflection of the emigration from the tagging areas (Table 3.12).

The distribution of I-group herring in the North Sea as described from the ICES Young Herring Surveys in February 1970 and 1971 may be compared with the distribution of the fisheries in the same months, with one exception. There is a good agreement between the locations of the fisheries and the major concentrations of herring. This exception is a major concentration of young herring in the Texel area, which is not covered by the industrial fishery. This fishery seldom extends south of 54°N latitude.

3.3 Analysis of returns

To obtain estimates of stock size and mortalities, several methods were tried.

(a) Petersen method

As a first approach the simple Petersen method was used. Stock size in numbers was calculated by

Table 3.13 Estimated stock size in millions (upper figure) and fishing mortality (lower figure)

Tagging location	1967 year-class				1968 year-class		
	Experiments	Esbjerg	Norway Jan/Feb 1970	Skagen	Experiments	Esbjerg	Thyborön
Skagerak	1			653			
	7			765			
Northern Bløden					8-10	6 887 0.20	4 200 0.36
					15-17	3 596 0.43	2 259 0.80
					18	4 020 0.38	1 133
Southern Bløden	2- 5	3 251 1.02	2 232 2.5		11	13 206 0.10	8 925 0.15
	19	5 519 0.47	1 686		27-29	17 860 0.07	8 302 0.17
	20-23	5 812 0.45	2 033				
Catch 1970* (excluding Skagerak)		2 002.8				1 196.2	
Mean of stock size estimates and corresponding fishing mortality (excluding Skagerak)		3 422 0.94				7 039 0.20	

*From Table 9, C.M.1972/H:13.

$$\hat{N} = T\frac{C}{R},$$

where T is the effective number of tagged fish, R the number of recaptures and C the corresponding catch in numbers corrected for magnet efficiency. By using the number of recaptures and corresponding catch of one year-class, the estimate above should give the size of the year-class at the time of tagging. Only returns from the factories in Esbjerg, Thyborön and Skagen and from the Norwegian factories were used in these estimates. The estimates from Norwegian recaptures are based on returns in January and February 1970 only. The Norwegian fleet was then fishing in the southern part of the central North Sea, just outside the Bløden area, and it was therefore assumed that the catch composition from Esbjerg in autumn 1969 could be applied to these catches. Estimates from the various experiments are summarized in Table 3.13. Fishing mortalities were estimated by assuming that the stock size estimates refer to 1 January 1970 and then calculating F from

$$C = N \times \frac{F}{Z}(1 - e^{-Z}),$$

where C is the total catch of the year-class in 1970. It was further assumed that M = 0.1. In the cases where estimated stock sizes were lower or about equal to the catch no estimate of F could be made.

A basic assumption in the Petersen method is that the proportion of tagged fish in the catches used to estimate N is the same as in the rest of the population or year-class. The big differences in the estimates of the 1968 year-class from the southern and northern experiments may be explained by different behaviour of the tagged fish in the southern and northern parts of the area. If the tagged fish in the southern area migrated out of the main area fished, these experiments will give overestimates of the stock size. Similarly, if fish tagged in the northern area migrated into the main area fished and concentrated there, the northern experiments will underestimate the stock size. Such under- or over-representation of tagged fish in the catch may result in a serious error in the estimates.

Using the German biological samples to estimate the catch in numbers, the reported recaptures in January-April 1970 from the factory with the highest production gives the following estimates of stock size (Table 3.14).

Table 3.14 Stock size estimates in millions from German data

Tagging location	1967 year-class			1968 year-class		
	Experiments	Returns	Stock	Experiments	Returns	Stock
Skagerak	13	15				
	14	15				
Northern				8-10	148	10 300
Bløden				15-17	379	4 000
				18	521	2 900
Southern	2- 5	43	8 800	11	148	10 300
Bløden	19	38	9 900	27-29	13	117 800
	20-23	19	19 900			

The estimates for the 1967 year-class are much higher than those based on Danish and Norwegian recaptures. Those for the 1968 year-class, except that from experiments 27-29, are in general agreement with the estimates based on Danish recaptures. The return of tags from liberations 13 and 14 in the Skagerak by the German plant can be due to the processing of offal from fish imported to Germany. They highlight one of the uncertainties in the German material. In addition, because of the uncertainties in the German catch figures, one should not consider the stock estimates as equally good as the others.

The Norwegian recaptures in June-August 1970 were also used to estimate stock size. Almost all the catch in this period came from area IVa W (Shetland), and it is assumed that all the reported tags came from this area.

The estimated age composition of the catch for the whole year and all countries in this area was used to estimate catch in numbers by age groups (Anon. C.M.1972/H:13). Very little of the 1968 year-class were caught and the relative precision of the estimate of numbers caught of

this year-class is too low to make any estimate of stock size. The results for the 1967 year-class are shown in Table 3.15.

Table 3.15 Stock size estimates, in millions, for the 1967 year-class, from Norwegian data

Tagging location	Experiments	Returns	N
Southern Bløden	2- 5	93	23 300
	19	181	12 000
	20-23	148	14 600

These estimates give considerably higher values than the others. Possible explanations could be that the tagged fish in the Bløden area have not migrated to Shetland in the same proportion as the rest of the year-class or the Shetland stock of adult herring is not recruited from Bløden alone.

In Table 3.13 the recoveries from experiments 1 and 7 at Skagen should give an estimate of the Skagerak 1967 year-class, as almost all returns from these experiments seem to be recaptured in that area. As the catch of the Skagerak stock is not known no estimate of F could be made.

(b) Maximum likelihood estimates (Paulik 1963)

This method uses only the number of returns (corrected for magnet efficiency) with time and the effective number of tags released to estimate total and fishing mortality. Grouping the recovery period into three-monthly intervals and using all reported tags from Esbjerg, Thyborön, Skagen and Norway, the method gave the estimates shown in Table 3.16.

Table 3.16 Estimates of fishing and total mortality - Paulik method

Year-class	Experiments	F	Z
1967	1	0.31	1.66
	2- 5	1.00	3.02
	7	0.22	1.54
	14	0.36	4.50
	19	0.50	2.36
	20-23	0.46	2.81
1968	8-10	0.18	0.42
	11	0.17	2.04
	15-17	0.48	1.54
	18	0.52	1.75

As every return is not included, the method should underestimate F. The estimate of Z will not be influenced if the proportion of the returns that are reported is constant from interval to interval. However, a basic assumption in this method is that fishing and total mortality are constant and the method may give seriously biased estimates if the mortalities are changing with time. In many of the experiments the number of returns with time indicates that there is a higher fishing mortality on the tagged fish just after tagging than later on. The Paulik method may in such cases seriously overestimate Z.

(c) Number of recaptures per unit effort

The only series of comprehensive effort data is that from the Danish port of Esbjerg. Table 3.17 gives the total number of hours fished per month by industrial vessels engaged in herring fishing. Using these data and the numbers of tags per 10 000 liberated per million fish processed of Tables 3.8 and 3.9 the numbers of returns per catch per unit effort have been derived (Table 3.18). Regression of the logarithm of these recaptures per unit effort on time was made for the 1967 and 1968 year-classes using data from Esbjerg. The time unit used was one month.

For the different experiments the following values for the slope and intercept of the regression equations were obtained (Table 3.19). The slope equals F + X, where X represents all other apparent mortality not

Table 3.17 Total effort as hours fishing, Esbjerg

	Single	Pair	Total: (2 x pair) + single
1969			
August	9 368.0	3 993.5	17 355.0
September	8 608.5	3 547.5	15 703.5
October	4 143.6	2 815.0	9 773.6
November			
December			
1970			
January	1 645.5		1 645.5
February	9 646.5	48.0	9 742.5
March	9 212.5		9 212.5
April	8 562.0	606.0	9 774.0
May	4 578.0	782.0	6 142.0
June			
July	12 189.0	3 288.5	18 266.0
August	13 318.5	7 343.8	28 006.1
September	14 804.5	5 077.5	24 959.5
October	8 939.0	3 795.5	16 530.0
November	8 196.5	103.0	8 402.5
December	4 567.5	1 581.5	7 730.5
1971			
January	11 069.6	480.0	12 029.6
February	18 800.8	1 291.0	21 382.8
March	23 531.7	2 108.0	27 747.7
April	26 426.5	2 590.0	31 606.5

Table 3.18 Tags returned per catch per unit effort x 10^{-6}, Esbjerg

Recapture month	1967 year-class			1968 year-class				
	Experiments			Experiments				
	2-5	19	20-23	8-10	11	15-17	18	27-29
1970								
January	1 124			547	322	875	1 373	
February	730	595	435	211	139	342	277	
March	1 217	1 552	2 759	130	126	560	444	56
April	194	138	166	293	137	481	344	147
May	356	381	342	339	200	534	467	35
June								
July	225	308	226	154	85	272	244	50
August	20	19	34	61	55	122	91	47
September	23		14	59		72	127	7
October	46	40	46	176	60	245	301	37
November								3
December								
1971								
January				20				
February	277			25	33	56	101	20
March						8		3
April	10		10	8		22	16	3

due to fishing (F) and is an estimate of the monthly total mortality (Z).

Table 3.19 Regression parameters

Year-class	Experiments	Slope	Intercept
1967	2- 5	-0.26	6.93
	19	-0.43	7.65
	20-23	-0.35	8.61
1968	8-10	-0.24	6.38
	11	-0.15	5.57
	15-17	-0.26	7.10
	18	-0.20	6.84
	27-29	-0.23	5.25

Attempts to estimate the fishing mortality from the intercept,

$$\ln \frac{F\ N_o}{F+X}\left\{1 - e^{-(F+X)}\right\},$$

gave no reasonable results due to its large sampling variation.

(d) Estimation of catchability coefficient

The catch per unit effort in any time interval is proportional to the abundance at the beginning of that interval. The abundance at any time is a function of the product of the total effort expended up to that time and the catchability coefficient (q). The latter may be estimated from successive values of the catch per unit effort and the cumulative effort. This method of estimating q due to DeLury (see Ricker 1958) was used, using data for Esbjerg given in Tables 3.17 and 3.18 over the period January 1970 to April 1971 inclusive. Months in which there was fishing effort but no tags were returned were omitted from the analysis, but the effort was included in the accumulated sum. The estimates of q and their standard errors, obtained by carrying out an ordinary regression analysis of ln catch per unit effort on cumulative effort (measured in units of thousand hours fishing), are given in Table 3.20. These estimates of q are very similar, their average (obtained by weighting by their inverse variances) being -0.01378 ± 0.00106.

Table 3.20 Estimates of the catchability coefficient, q, from Esbjerg data

Experiments	Catchability coefficient, q	Standard error	Degrees of freedom
2- 5	-0.01688	0.00526	9
8-10	-0.01585	0.00232	10
11	-0.01100	0.00203	7
15-17	-0.01445	0.00192	9
18	-0.01358	0.00261	9

4. The model

The numbers of tagged fish recaptured depends on the way they become dispersed over the area in relation to the fishing intensity.

Movement of the tagged fish away from the centre of liberation was assumed to be made up of two components: (a) a symmetrical dispersion outwards from the point of liberation, and (b) a general drift in a given direction. This was simulated by assuming that a fish in a particular square at the end of a time interval had a given probability of remaining in the same square and given probabilities of moving into any one of the eight surrounding squares by the beginning of the next time interval.

It was further assumed that tagged fish could not move outside the Bløden area. This was simulated by assuming that if a fish in a boundary square tried to move outside the boundary, it was reflected back into that square or into the adjacent boundary squares on either side with given probabilities.

These probabilities were derived from a dispersion coefficient (d) and parameters (n, e) representing northerly and easterly components of movement.

During each time interval fish may die or may be recaptured, the number dying depending on the value of the instantaneous natural mortality coefficient (M) and the number being recaptured depending on the fishing intensity and the catchability coefficient according to the formula

$$\text{number recaptured} = n_{ij}\, qf_{ij} \left\{1 - \exp(-M-qf_{ij})\right\}/(M+qf_{ij}) \ ,$$

where n_{ij} = number present at beginning of interval in square (ij),

q = catchability coefficient (constant),

f_{ij} = fishing intensity in square (ij).

Knowing N, the effective number of tags liberated and assuming a value for M, the problem is to find values of d, n, e and q which will produce values for the numbers of recaptures in each time interval as nearly as possible equal to the observed number of recaptures. Because the positions of recapture of tagged fish are not known, this matching process has to be done on the total recaptures summed over all squares in each time interval.

The process of finding the best set of parameters starts by guessing initial values and thereafter proceeds by iteration to the final, best-fitting values, provided convergence is possible. The criterion chosen for obtaining the best set of parameters was that they should be the ones which minimize the sum of squares of the differences between the observed and the predicted recaptures in each time interval. The time interval chosen throughout was four weeks.

The assumption that none of the tagged fish can leave the Bløden area was thought to be unrealistic for fish of the 1967 year-class. This was borne out by the failure of the model to produce estimated recaptures compatible with those observed. In order to handle data from liberations composed of fish from the 1967 year-class changes will have to be made in the model to permit fish to emigrate from the area.

For the 1968 year-class it is reasonable to assume that there will be a smaller emigration as compared to the 1967 year-class and the model should provide a closer approximation to the true behaviour of the fish. A study of data from 12 four-week periods from experiments 15, 16 and 17 was therefore made, and although no convergence to a best set of parameter values was achieved, the overall performance of the model was better than for 1967 year-class experiments.

After 10 iterative cycles, the sum of squared differences between observed and predicted tag returns reached a minimum, after which the solutions began to diverge, producing successively worse predictions of

tag returns (Table 4.1). For this computer run, only Esbjerg effort data and tags returned through Esbjerg factories have been used. Natural mortality has been set at 0.1. The numbers liberated and numbers returned have been adjusted for tagging mortality and magnet efficiencies respectively.

Table 4.1 Summary of 9th, 10th and 11th cycles

Period	Observed	Predicted 9	Predicted 10	Predicted 11
1	2.0	11.1	3.6	9.7
2	0.0	4.1	1.0	4.5
3	18.7	79.9	30.9	42.4
4	233.8	457.6	160.6	266.0
5	65.8	209.1	80.7	68.6
6	71.1	214.8	91.1	47.3
7	88.8	103.5	51.6	14.0
8	1.4	0.0	0.0	0.0
9	42.0	104.9	65.5	46.3
10	78.9	125.1	95.8	6.5
11	50.0	39.7	43.2	2.4
12	36.5	19.0	25.2	0.2
Total	688.8	1 368.8	649.1	507.7

Parameter values

	Catchability coefficient in Cycle 9	Cycle 10	Cycle 11
Catch coefficient	0.0042	0.0016	0.0027
Migration east	-0.8362	-0.4280	-0.3707
Migration north	-3.0000	-3.0000	-3.0000
Diffusion rate	1.5000	2.0733	0.5000

Although the performance of the model here is better than for the 1967 year-class, it is still not very good. This may be due to shortcomings in the available data, or perhaps because this type of diffusion model does not correspond to the actual movements of a shoaling species such as herring.

5. Discussion

In planning the present tagging experiment it was natural to regard the young herring taggings in 1957-58 as a pilot experiment (Aasen et al. 1961). The shortcomings of the latter derived from

1. inadequate catch and effort statistics for detailed distribution in time and space;
2. too few fish liberated at too few localities;
3. too few factories with effective installations for recovery of tags;
4. no direct attempt to assess initial tagging mortality;
5. insufficient biological sampling of the tagged population and of the commercial fisheries;
6. too many different tagging teams to ensure a reasonable uniform handling of the tagging operations throughout the period.

As a consequence of these deficiencies the analysis of the comparatively low number of tag returns was difficult.

In the present experiments the necessary increase in tagged fish and in tagging positions was achieved by extending the period from one month to eight months and by releasing 30% more fish per station. Even so the number achieved fell far below the intended target of 100 000.

The need for experimental work on tagging mortalities was met with and facilitated by the presence of huge tanks on board the hired tagging vessel. More uniform handling of the fish was obtained by the deployment of the same two tagging teams throughout the entire experiment.

While improvements in the work at sea also included sampling each haul, it proved difficult to obtain clear improvements of the equally vital activities ashore. In working up the new data, difficulties were again met in the same categories of the commercial fishery data sampling and magnet efficiencies.

During the course of the tagging experiment fish were tagged probably of only the 1967 and 1968 year-classes. Judging from the biological samples taken at the time of tagging, some experiments were virtually conducted on single year-classes.

The 1967 year-class entered the adult fisheries in early summer 1970. Tags were recovered from liberations of this year-class from July 1969 until spring 1971 in the young herring fisheries. After that they occur with increasing rates in fisheries over deep water and even to the north of Scotland.

In contrast, the 1968 year-class was 0-group when the taggings began in 1969 and there are indications that this year-class remained in the eastern North Sea throughout 1970. In 1971 this year-class shows the same drop in abundance as did the 1967 year-class one year earlier.

There is a striking difference between the recent experiment and the earlier one in the length of time over which tags were returned. Few tags were recovered beyond eight weeks in 1957 and 1958, while many tags were recovered after eight months in this experiment. The Working Group did not investigate the reason for this difference, but either a change in migration rate of the fish and/or an increase in fishing power and range of the industrial cutters could be explanations.

In view of the differences in the 1967 and 1968 year-classes mentioned above, the recaptures from them must be considered separately. In consequence, the lack of relevant age data has resulted in material being left out of the analysis. In effect, this means that the main analysis is again dependent on the data from Esbjerg.

A number of methods for analysing tagging data were tried. For various reasons explained above, the only reliable estimates were derived from the Petersen method relating number of tags recaptured to fish processed.

Stock and fishing mortality estimates for the 1967 and 1968 year-classes (Table 5.1) are close to those derived by the North Sea Herring Assessment Working Group from cohort analysis.

Table 5.1 Stocks at 1 January 1970 and fishing mortalities in 1970

	1967 year-class		1968 year-class	
	Tagging	Cohort	Tagging	Cohort
Stock x 10^{-9}	3.42	3.32	7.04	4.93
Fishing mortality	0.94	0.99	0.20	0.29

The I-group (1968 year-class) had about the same fishing mortality in 1970 as had the corresponding age group in the 1957-58 experiments. The year-class strength might, however, be less than half that of the 1956 year-class in January 1958.

The 1957-58 experiments were analysed using a simple diffusion model. With the increased information available from the present experiment and the increased experience in the use of computers for simulation studies, a more sophisticated model was developed. The results so far obtained are not fully satisfactory but indicate that further development should be undertaken. It seems especially necessary to make some more realistic assumptions about emigration and to develop methods for testing the parameters obtained.

Table 2.5 Tag recaptures by team by hour as percentage of total tag releases

Experiments	Number tagged by		Hour									
			1		2		3		4		5	
	Team 1	Team 2	Team 1	Team 2	Team 1	Team 2	Team 1	Team 2	Team 1	Team 2	Team 1	Team 2
1	996	1 000	0.085	0.077	0.080	0.055	0.100	0.015	0.100	0.070		
2	900	900	0.157	0.143	0.173	0.100	0.197	0.130				
3	1 000	1 000	0.208	0.168	0.195	0.152	0.135	0.125				
4*	2 050	1 950	0.124	0.177	0.153	0.106						
5	1 050	950	0.160	0.117	0.152	0.082	0.180	0.120				
6	1 000	1 000	0.075	0.080	0.055	0.145	0.025	0.095	0.020	0.075	0.110	0.090
7	1 000	1 000	0.042	0.050	0.063	0.057	0.057	0.037				
8	1 000	1 000	0.098	0.065	0.067	0.037	0.087	0.053				
9	1 000	1 000	0.125	0.062	0.142	0.072	0.140	0.070				
10	1 000	1 000	0.180	0.096	0.146	0.106						
11	600	500	0.053	0.043	0.097	0.020						
12	800	800	0.070	0.040	0.080	0.057	0.110	0.060				
13	500	500	0.013	0.007	0.010	0.000						
14	500	500	0.053	0.013	0.010	0.015						
15	1 000	1 000	0.150	0.127	0.178	0.115	0.180	0.107				
16	1 000	1 000	0.178	0.135	0.202	0.115	0.150	0.160				
17	1 000	1 000	0.212	0.145	0.167	0.167	0.193	0.143				
18	1 500	1 500	0.178	0.108	0.172	0.135	0.155	0.100	0.145	0.140	0.210	0.140
19	1 000	1 000	0.102	0.110	0.113	0.103	0.087	0.097				
20	1 000	1 000	0.092	0.070	0.070	0.073	0.070	0.107				
21	1 000	1 000	0.158	0.135	0.167	0.160	0.123	0.100				
22	1 000	1 000	0.055	0.020	0.057	0.043	0.077	0.037				
23	300	300	0.053	0.027								
24	1 200	1 200	0.152	0.102	0.163	0.127	0.135	0.125	0.080	0.150		
25	1 000	1 000	0.112	0.078	0.120	0.080	0.100	0.087				
26	1 500	1 500	0.122	0.082	0.102	0.122	0.060	0.038	0.047	0.033		
27	1 000	1 000	0.015	0.030	0.040	0.027	0.010	0.017				
28	1 000	1 000	0.012	0.005	0.023	0.013	0.013	0.013				
29	1 000	1 000	0.038	0.008	0.010	0.017	0.040	0.010				
			Hour									
			12		13		14		15			
4*			0.102	0.120	0.117	0.110	0.170	0.093	0.140	0.123		

Table 3.1a Denmark - Esbjerg: recaptures per 10 000 fish tagged by year-class and country

Recapture month	1967 year-class							1968 year-class					Mixed			
	Liberation							Liberation					Liberation			
	1	2-5	7	13	14	19	20-23	8-10	11	15-17	18	27-29	6	12	14	25-26
1969																
July																
August		549											23			
September		101						10					383	19		
October		50						22	54				75	56		
November		17				8		5	27	5	5		8	47		
December																
1970																
January		6			15			22	13	35	55		8			
February	7	203	15		105	165	121	268	176	434	351		90	179	670	427
March		11	7			15	25	28	27	120	95	12		28	25	66
April		21	8			15	18	85	40	140	100	43	23	19	56	72
May		28	7		15	30	27	105	54	173	146	12	45	38	44	102
June								8	13	5	10					
July		11	8			15	11	98	54	173	155	32	30	28	107	54
August	8	24		30		22	39	120	108	241	180	93	37	66	182	148
September		15	7				9	68		83	146	8	7	9	63	57
October		9	8		15	8	9	38	13	53	65	8			63	24
November		2						10		20	10	2				9
December																3
1971																
January								2								
February		8						10	13	22	40	8	8			21
March										5		2				3
April		5			15		5	20		53	40	8		9	31	15
?		3														
Total	15	1 063	60	30	165	278	264	920	592	1 562	1 398	228	737	498	1 272	1 001

Table 3.1b Denmark - Thyborön: recaptures per 10 000 fish tagged by year-class and country

Recapture month	1967 year-class							1968 year-class					Mixed			
	Liberation							Liberation					Liberation			
	1	2-5	7	13	14	19	20-23	8-10	11	15-17	18	27-29	6	12	24	25-26
1969																
July																
August													30			
September		1						30					23			
October								141		50						
November																
December																
1970																
January																
February																
March		2					2									
April																
May																
June																
July																
August		3			15			40	27	88	175	30	7	9	50	21
September							5	25	13	48	95	13	23	19	38	30
October								5		12	25				25	3
November																
December								5		2	5				6	3
1971																
January																
February																
March																
April																
?		3					2	10		8	15				13	6
Total		9			15		9	256	40	208	315	43	83	28	132	63

Table 3.1c Denmark - Hirtsals: recaptures per 10 000 fish tagged by year-class and country

Recapture month	1967 year-class							1968 year-class					Mixed			
	Liberation							Liberation					Liberation			
	1	2-5	7	13	14	19	20-23	8-10	11	15-17	18	27-29	6	12	24	25-26
1969																
July	30															
August	158															
September	121		53										22			
October	90	2	60													
November	22		53													
December	22		45		15	15				2						
1970																
January	15	21				45	41	2			10		8			
February	22	61	8		15	38	34	20		10	15		23	47	38	12
March	8	20	45			45	41	3			5		8			
April	15	23	23			38	29	12		5	5		7	10	38	6
May	23	24	30	30	30	44	22	11		33	15			28	69	
June	15	5	8			16	8									
July	15						3									
August	8	2	15	15			2				5					
September		6								3	10					
October		4				8	2								12	
November	8	2	8			7	9			5					6	3
December								2		25	15				6	
1971																
January	8	6	8				2	8		20	5			9	13	6
February		1	8		30		2	12		3	5					3
March		2				7	5			5	10					6
April																
?		3														
Total	580	182	364	45	90	263	200	70		111	100		68	94	182	36

Table 3.1d Denmark - Skagen: recaptures per 10 000 fish tagged by year-class and country

Recapture month	1967 year-class							1968 year-class					Mixed			
	Liberation							Liberation					Liberation			
	1	2-5	7	13	14	19	20-23	8-10	11	15-17	18	27-29	6	12	24	25-26
1969																
July	15															
August	136															
September	30		60													
October	30		15					2								
November	8		15		15											
December	37		53		60					13						
1970																
January		4	8	30	45					2						
February	22	23	8	15		15	18	15		10	20		15	19	13	3
March						8	4	5								
April		6	22			7	2									
May	8						2									
June	8		8					3								
July	8									2						
August	8	2				7	5	3								
September	15		8			8	2			8						
October	15	2				8	9	10		2	5			9		
November	22	3	15			30	7	5		3			8		13	
December		2	8			7	9	20		20			7	19	6	12
1971																
January	30	4	8		30		2	2		5	25					6
February											10					
March	8	3	8			8	5	10		5					13	3
April		3			15	7	5	10		13	10					
?	22	2					5			5						
Total	422	54	236	45	165	105	75	85		88	70		30	47	45	24

Table 3.1e Norway: recaptures per 10 000 fish tagged by year-class and country

Recapture month	1967 year-class							1968 year-class					Mixed			
	Liberation							Liberation					Liberation			
	1	2-5	7	13	14	19	20-23	8-10	11	15-17	18	27-29	6	12	24	25-26
1969																
July																
August	15															
September																
October													8			
November								2								
December																
1970																
January	8	338	15			466	443			10			60	94	6	
February		104	8			120	43	33	14	38	15		15	10	69	66
March								33								6
April																
May		6			15		16			5		2	15	9	19	15
June	30	41	38			68	62	8		5			15		44	21
July	21	40	15			75	59	10					15	19	12	3
August	8	12				38	27	5			15		7			
September			8				2			10	5					9
October	8	3				7	9	10		8		3				3
November								2								
December																
1971																
January									13							3
February								2								
March		5					5									
April										2	5		8			
?	8	3					5									
Total	98	552	84		15	774	661	105	27	78	40	5	143	132	150	126

Table 3.1f Germany, 01 + 02: recaptures per 10 000 fish tagged by year-class and country

Recapture month	1967 year-class							1968 year-class					Mixed			
	Liberation							Liberation					Liberation			
	1	2-5	7	13	14	19	20-23	8-10	11	15-17	18	27-29	6	12	24	25-26
1969																
July																
August		32														
September		33											15	9		
October		41												57		
November																
December																
1970																
January		5						5	13	28	30					
February		23		15	15	15	14	78	27	206	301		15	28	88	30
March		11					3	43	68	110	155	3	7	19	69	12
April		4				23	2	22	40	35	35	10	8	9		
May																
June																
July		3					2	2		10					12	3
August		15	8			8	4	18	13	31	15	10	15	29	38	18
September																
October																
November																
December																
1971																
January		2						2								
February																
March		2						3		2			8			
April								10		7	10					3
?										2	5			9	6	6
Total		171	8	15	15	46	25	183	161	431	551	23	68	160	213	72

Table 3.1g Germany, 04: Recaptures per 10 000 fish tagged by year-class and country

Recapture month	1967 year-class							1968 year-class					Mixed			
	Liberation							Liberation					Liberation			
	1	2-5	7	13	14	19	20-23	8-10	11	15-17	18	27-29	6	12	24	25-26
1969																
July																
August		4														
September		4														
October		11	15											28		
November																
December																
1970																
January		2														
February		2					2	2	13	25	5			9		
March	7	3					2	2			5				6	3
April		2					2	2		3					6	6
May								3		5					12	6
June											5					
July		2									5					
August	8									3			8		7	
September		6					2			2					6	6
October		4										2			6	
November		2	8				7	3	14				7	10		
December		4	7				5	3						9	7	6
1971																
January		8				8	5				10					
February								13		12	10					
March	7	4					7	10		25	5					6
April							2	5							6	6
?																
Total	22	58	30			8	34	43	27	75	45	2	15	56	56	39

Table 3.1h Germany, 07: recaptures per 10 000 fish tagged by year-class and country

Recapture month	1967 year-class							1968 year-class					Mixed			
	Liberation							Liberation					Liberation			
	1	2-5	7	13	14	19	20-23	8-10	11	15-17	18	27-29	6	12	24	25-26
1969																
July																
August																
September																
October																
November																
December																
1970																
January	7	3								2	5					
February		6					2	2		18	35			9		
March		6				15	7	5		5	10		8	10	6	3
April	8	3	8			15	5				5		7		6	3
May																
June							5									3
July																
August							2									
September							2							9		
October								3						10		3
November							2	2								
December		4					2									
1971																
January		2								8						3
February																
March																
April																
?																
Total	15	24	8			30	27	12		33	55		15	38	12	15

Table 3.2a Total catch of herring processed in Skagen, Denmark. Effective tonnage is based on magnet efficiency and this quantity in numbers is given by age

	Catch in tons		Millions of herring by year-class				
	Total	Effective	1966	1967	1968	1969	Total
1969							
August	7 402	1 831	0,43	9.48	68.28	-	78.19
September	4 779	1 067	0.56	4.11	29.39	-	34.06
October	2 934	551	0.04	1.21	16.32	-	17.57
November	1 860	347	0	0.49	13.31	-	13.80
December	1 127	265	0	0.17	13.02	-	13.19
1970							
January	1 232	260	-	0.29	10.51	0	10.80
February	1 162	219	-	0.55	7.20	0	7.75
March	2 331	490	-	0.42	15.64	0	16.06
April	2 162	327	-	0.37	12.27	0	12.64
May	1 787	368	-	0.41	10.59	0	11.00
June	2 971	713	-	1.85	10.37	0	12.22
July	3 681	644	-	3.06	6.21	0	9.27
August	5 755	1 178	-	0	0.54	90.10	90.64
September	4 948	1 001	-	0.13	1.44	34.33	35.90
October	4 673	822	-	0	1.18	21.71	22.89
November	2 278	482	-	0	0.19	16.52	16.71
December	2 046	333	-	0	0.19	10.67	10.86

Table 3.2b Total catch of herring processed in Hirtsals, Denmark, and by factory 03. Magnet efficiency data insufficient. No fish sampling for age

	Catch in tons	
	Total	Total factory 03
1969		
August	9 272	3 847.125
September	8 877	217.633
October	4 982	1 266.100
November	2 496	609.631
December	3 603	966.087
1970		
January	1 809	564.723
February	3 952	1 030.942
March	3 617	1 296.134
April	4 169	909.502
May	2 389	711.109
June	2 042	694.104
July	5 899	1 058.130
August	6 319	2 391.205
September	7 898	2 406.875
October	6 848	1 519.331
November	3 141	1 042.859
December	2 802	705.917
1971		
January	3 920	1 200.830
February	3 945	1 152.635
March	2 658	
April	4 601	

Table 3.2c Total catch of herring processed at Thyborön, Denmark. Effective tonnage is based on magnet efficiency and this quantity in numbers is given by age. (Corrected for sprat)

	Catch in tons		Millions of herring by year-class					
	Total	Effective	1965	1966	1967	1968	1969	Total
1969								
August	8 333.6	4 106.0	0	16.34	34.69	0.38	-	51.41
September	798.1	469.3	0	0.85	4.22	1.20	-	6.27
October	749.9	588.8	0	0.80	4.66	5.67	-	11.13
November	-	-	-	-	-	-	-	-
December	-	-	-	-	-	-	-	-
1970								
January	-	-	-	-	-	-	-	-
February	432.9	155.3	-	0.08	0.68	3.10	0	3.86
March	93.2	10.4	-	0	0.01	0.35	0	0.36
April	72.5	11.4	-	0.00	0.06	0.17	0	0.23
May	-	-	-	-	-	-	-	-
June	-	-	-	-	-	-	-	-
July	2 031.5	1 300.5	-	-	0.88	11.51	16.62	29.01
August	4 183.8	2 191.0	-	-	7.74	13.24	44.04	65.02
September	1 361.8	639.2	-	-	1.94	3.53	3.58	9.05
October	939.8	474.5	-	-	1.84	2.06	4.01	7.91
November	69.1	46.0	-	-	0.04	0.19	1.10	1.33
December	458.4	237.4	-	-	0.11	1.12	4.04	5.27
1971								
January	501.8	180.4	-	-	0.07	0.52	4.32	4.91
February	1 628.6	659.6	-	-	0.10	1.33	21.27	22.70
March	1 731.8	677.7	-	-	0.03	1.22	19.44	20.69
April	387.1	139.1	-	-	0.19	0.98	2.17	3.34

Table 3.2d Total catch of herring processed at Esbjerg, Denmark. Effective tonnage is based on magnet efficiency and this quantity in numbers is given by age. (Corrected for sprat)

	Catch in tons		Millions of herring by year-class					
	Total	Effective	1965	1966	1967	1968	1969	Total
1969								
August	20 273	6 518	0	25.95	55.07	0.61	-	81.63
September	14 698	10 656	0	19.36	95.92	27.33	-	142.61
October	5 903	4 811	0	6.52	38.06	46.37	-	90.95
November	-	-	-	-	-	-	-	-
December	-	-	-	-	-	-	-	-
1970								
January	1 538	1 158	-	0.08	3.24	24.39	0	27.71
February	9 048	6 533	-	3.32	28.52	130.03	0	161.87
March	914	690	-	0	0.98	23.24	0	24.22
April	2 526	2 011	-	0.08	11.14	29.77	0	40.99
May	4 359	3 232	-	0.30	12.83	54.34	0	67.47
June	-	-	-	-	-	-	-	-
July	5 165	3 939	-	-	2.67	34.86	50.34	87.87
August	15 074	11 705	-	-	41.39	70.74	235.36	347.49
September	11 557	8 361	-	-	25.39	46.23	46.88	118.51
October	4 177	3 019	-	-	11.71	13.08	25.51	50.30
November	260	208	-	-	0.16	0.88	4.96	6.00
December	1 294	882	-	-	0.41	4.16	14.99	19.56
1971								
January	4 615	2 895	-	-	1.18	8.39	69.26	78.83
February	11 439	9 117	-	-	1.35	18.43	293.86	313.64
March	16 809	12 943	-	-	0.64	23.49	371.42	395.55
April	13 623	11 013	-	-	15.09	77.91	171.88	264.88

Table 3.5 Landings of herring in Norway (in tons) from north-west Scotland-northern Ireland, North Sea and Skagerak, 1969, 1970 and 1971

	1969					1970					
	Area				Total	Area					Total
	IVA w*	IVA e	IVB	IIIA		VIA	IVA w	IVA e	IVB	IIIA	
January	11.0	2 809.0	-	-	2 820.0	-	3.3	338.2	20 587.8	-	20 929.3
February	18.6	261.3	-	-	279.9	-	-	2.4	4 908.0	-	4 910.4
March	-	200.6	-	-	200.6	-	-	0.8	51.2	-	52.0
April	300.7	522.8	-	0.2	823.7	-	911.2	465.5	-	-	1 376.7
May	102.5	6 673.0	-	695.3	7 470.8	-	5 733.6	161.6	1 592.6	227.4	7 715.2
June	49 044.3	4 171.2	-	67.6	53 283.1	7 885.9	67 333.9	156.2	457.6	3 674.3	79 507.9
July	40 708.9	416.3	-	235.7	41 360.9	14 082.3	62 304.1	12.8	-	1 865.7	78 264.9
August	8 532.1	217.3	-	11 726.7	20 476.1	5 493.9	8 165.4	354.2	-	555.4	14 568.9
September	-	-	-	73.7	73.7	-	801.0	1 782.9	-	591.2	3 175.1
October	-	107.9	-	-	107.9	-	196.1	56.0	16.2	88.4	356.7
November	103.8	69.6	-	202.9	376.3	-	948.8	-	-	-	948.8
December	-	79.5	4.4	-	83.4	-	-	-	-	34.3	34.3
Total	98 821.9	15 528.5	4.4	13 002.1	132 699.8*	27 462.1	146 397.4	3 330.6	27 613.4	7 036.7	220 882.2*
	*5 342.9 tons not specified by months or area					*9 042 tons not specified by month or area					
Delivered to meal and oil	-	-	-	-	-	25 916.2	132 376.3	3 591.2	17 319.4	6 442.0	185 645.1

	1971						
	Area						Total
	VIIA	VIA	IVA w	IVA e	IVB	IIIA	
January	-	-	402.4	1 088.9	-	-	1 491.3
February	-	-	-	-	-	-	-
March	-	35.8	88.0	2.3	-	-	126.1
April	60.1	-	451.5	-	-	-	511.6
May	34.6	-	26.6	-	-	-	61.2
June	-	35 419.6	61 785.3	-	-	246.9	97 451.8
July	-	39 929.5	19 184.9	18.6	-	79.3	59 212.3
August	-	305.1	16 773.8	261.4	-	-	17 340.3
September	-	973.9	423.3	-	-	-	1 397.2
October	-	55.9	12 349.5	9 050.4	-	5 634.7	27 090.5
November	-	-	368.7	-	13.9	-	382.6
December	-	-	259.8	20.0	-	-	279.8
Total	94.7	76 719.8	112 113.8	10 441.6	13.9	5 960.9	205 344.7
Delivered to meal and oil	43.2	72 952.1	100 290.1	8 159.6	7.2	5 257.2	186 709.9

VIIA = Irish Sea
VIA = north-west Scotland-northern Ireland (west of 4°W)
IVA w = northern North Sea
IVA e = northern North Sea
IVB = central North Sea
IIIA = Skagerak

Table 3.6 1968 year-class recaptures corrected for magnet efficiency for Danish and Norwegian plants (per 10 000 fish liberated)

Recapture month	Experiments 8-10					Experiment 11					Experiments 15-17				
	Source					Source					Source				
	Eb*	Th	Sk	Nw	Total	Eb	Th	Sk	Nw	Total	Eb	Th	Sk	Nw	Total
1969															
August															
September	14	50			64										
October	33	178	11		222	99				99					
November				3	3						6	63			69
December													55		55
1970															
January	29				29	17				17	46		9	12	67
February	371		80	40	491	244			17	261	601		53	46	700
March	37		24		61	36				36	159				159
April	107				107	50				50	176				176
May	152				152	90				90	240				240
June			13	11	24									7	7
July	128			13	141	71				71	227		11		238
August	154	76	15	6	251	139	52			191	310	169			479
September	94	54			148		28			28	115	104	40	13	272
October	53	10	57	11	131	18				18	73	24	11	9	117
November	12		23	3	38						25		14		39
December		10	123		133							4	123		127
1971															
January	3				3										
February	12				12	16				16	28				28
March											6				6
April	25				25						66				66

Recapture month	Experiment 18					Experiments 27-29				
	Source					Source				
	Eb	Th	Sk	Nw	Total	Eb	Th	Sk	Nw	Total
1969										
August										
September										
October										
November										
December										
1970										
January	73				73					
February	486		106	18	610					
March	126				126	16				16
April	126				126	54				54
May	210				210	16				16
June										
July	203				203	42				42
August	232	337		19	588	120	58			178
September	202	207		7	416	11	28			38
October	90	50	28		168	11			3	14
November	12				12	2				2
December		10			10					
1971										
January										
February	50				50	10				10
March						3				3
April	19				19	10				10

*Eb = Esbjerg, Denmark
Th = Thyborön, Denmark
Sk = Skagen, Denmark
Nw = Norway

Table 3.7 1967 year-class recaptures corrected for magnet efficiency for Danish and Norwegian plants (per 10 000 fish liberated)

Recapture month	Experiment 1					Experiments 2-5					Experiment 7					Experiment 13				
	Source					Source					Source					Source				
	Eb*	Th	Sk	Nw	Total	Eb	Th	Sk	Nw	Total	Eb	Th	Sk	Nw	Total	Eb	Th	Sk	Nw	Total
1969																				
August			551	19	570	1 708				1 708										
September			135		135	139				139			269		269					
October			160		160	82				82			80		80					
November			43		43								80		80					
December			157		157								226		226					
1970																				
January				10	10	8		19	416	443			38	18	56			142		142
February	10		117		127	281		122	126	529	21		43	10	74			80		80
March						15				15	9				9					
April						26		40		66	10		146		156					
May			39		39	38			7	45	9				9					
June			33	39	72				54	54			33	50	83					
July	10		46	28	84	14			53	67	10			20	30					
August			39	10	49	31		10	15	56						39				39
September			74		74	21				21	10		40	10	60					
October			85	9	94	12		11	3	26	11				11					
November			102		102	2		14		16			70		70					
December								12		12			49		49					
1971																				
January																				
February						10				10										
March																				
April						6				6										

Recapture month	Experiment 14					Experiment 19					Experiments 20-23				
	Source					Source					Source				
	Eb	Th	Sk	Nw	Total	Eb	Th	Sk	Nw	Total	Eb	Th	Sk	Nw	Total
1969															
August															
September															
October															
November			80		80										
December			255		255	10				10					
1970															
January	20		213		233				573	573				544	544
February	145				145	228		80	146	454	168		96	104	368
March						20		38		58	33		19		52
April						19		46		65	23		13		36
May	20			17	37	40				40	36		20	18	74
June									89	89				82	82
July						20			100	120	14			78	92
August						28		34	48	110	50		24	34	108
September								40		40	12		10	3	25
October	21				21	11		45	8	64	12		51	10	73
November								139		139			32		32
December								43		43			55		55
1971															
January															
February															
March															
April	18				18						6				6

*Eb = Esbjerg, Denmark
Th = Thyborön, Denmark
Sk = Skagen, Denmark
Nw = Norway

Table 3.8 Number of recaptures per 10 000 tags released per 10^6 herring processed, Esbjerg, 1968 year-class

Recapture month	Experiments					1968 year-class; numbers caught x 10^{-6}
	8-10	11	15-17	18	27-29	
1969						
September	0.37					27.33
October	0.58	1.75				46.37
November			0.11	0.11		
December						
1970						
January	0.90	0.53	1.44	2.26		24.39
February	2.06	1.35	3.34	2.70		130.03
March	1.20	1.16	5.16	4.09	0.52	23.24
April	2.86	1.34	4.70	3.36	1.44	29.77
May	2.08	1.23	3.28	2.87	0.22	54.34
June						
July	2.81	1.55	4.96	4.45	0.92	34.86
August	1.70	1.53	3.41	2.54	1.31	70.74
September	1.47		1.80	3.16	0.17	46.23
October	2.91	0.99	4.05	4.97	0.61	13.08
November	11.36		22.73	11.36	2.27	0.88
December						4.16
1971						
January	0.24					8.39
February	0.54	0.71	1.19	2.17	0.43	18.43
March			0.21		0.09	23.49
April	0.26		0.68	0.51	0.10	77.91
?						
Total no. processed x 10^{-6}	633.64	559.94	559.94	559.94	405.52	
Recaptures	920	424	1 557	1 393	228	

Table 3.9 Number of recaptures per 10 000 tags released per 10^6 herring processed, Esbjerg, 1967 year-class

Recapture month	Experiments			1967 year-class; numbers caught x 10^{-6}
	2-5	19	20-23	
1969				
August	9.96			55.07
September	1.05			95.92
October	(1.75)			38.06
November				
December		0.21		
1970				
January	1.85			3.24
February	7.12	5.80	4.24	28.52
March	11.22	15.31	25.51	0.98
April	1.90	1.35	1.62	11.14
May	2.19	2.34	2.10	12.83
June				
July	4.12	5.62	4.12	2.67
August	0.58	0.53	0.94	41.39
September	0.59		0.35	25.39
October	0.76	0.69	0.76	11.71
November	12.50			0.16
December				0.41
1971				
January				1.18
February	5.93			1.35
March				0.64
April	0.33		0.33	15.09
Total no. processed x 10^{-6}	345.75	153.45	153.45	
Recaptures	1 063	278	264	

Table 3.10 Number of recaptures per 10 000 tags released per 10^6 herring processed, Thyborön, 1968 year-class

Recapture month	Experiments					1968 year-class; numbers caught x 10^{-6}
	8-10	11	15-17	18	27-29	
1969						
August						0.38
September	25.00					1.20
October	24.87		8.82			5.67
November						
December						
1970						
January						
February						3.10
March						0.35
April						0.17
May						
June						
July						11.51
August	3.02	2.04	6.65	13.22	2.27	13.24
September	7.08	3.68	13.60	26.91	3.68	3.53
October	2.43		5.83	12.14		2.06
November						0.19
December	4.55		1.79	4.46		1.12
1971						
January						0.52
February						1.33
March						1.22
April						0.98
Total no. processed x 10^{-6}	35.70	35.70	35.70	35.70	35.70	
Recaptures	85	40	158	315	43	

Table 3.11 Number of recaptures per 10 000 tags released per 10^6 herring processed, Skagen, 1967 year-class

Recapture month	Experiments		1967 year-class; numbers caught x 10^{-6}
	1	7	
1969			
August	14.35		9.48
September	7.30	14.60	9.11
October	24.79	12.40	1.21
November	16.33	30.61	0.49
December	217.65	311.76	0.17
1970			
January		27.59	0.29
February	40.00	14.55	0.55
March			0.42
April		59.46	0.37
May	19.51		0.41
June	4.32	4.32	1.85
July	5.23		3.06
August			
September	115.38	61.54	0.13
October			
November			
December			
1971			
January			
February			
March			
April			
Total no. processed x 10^{-6}	27.54	18.06	
Recaptures	422	236	

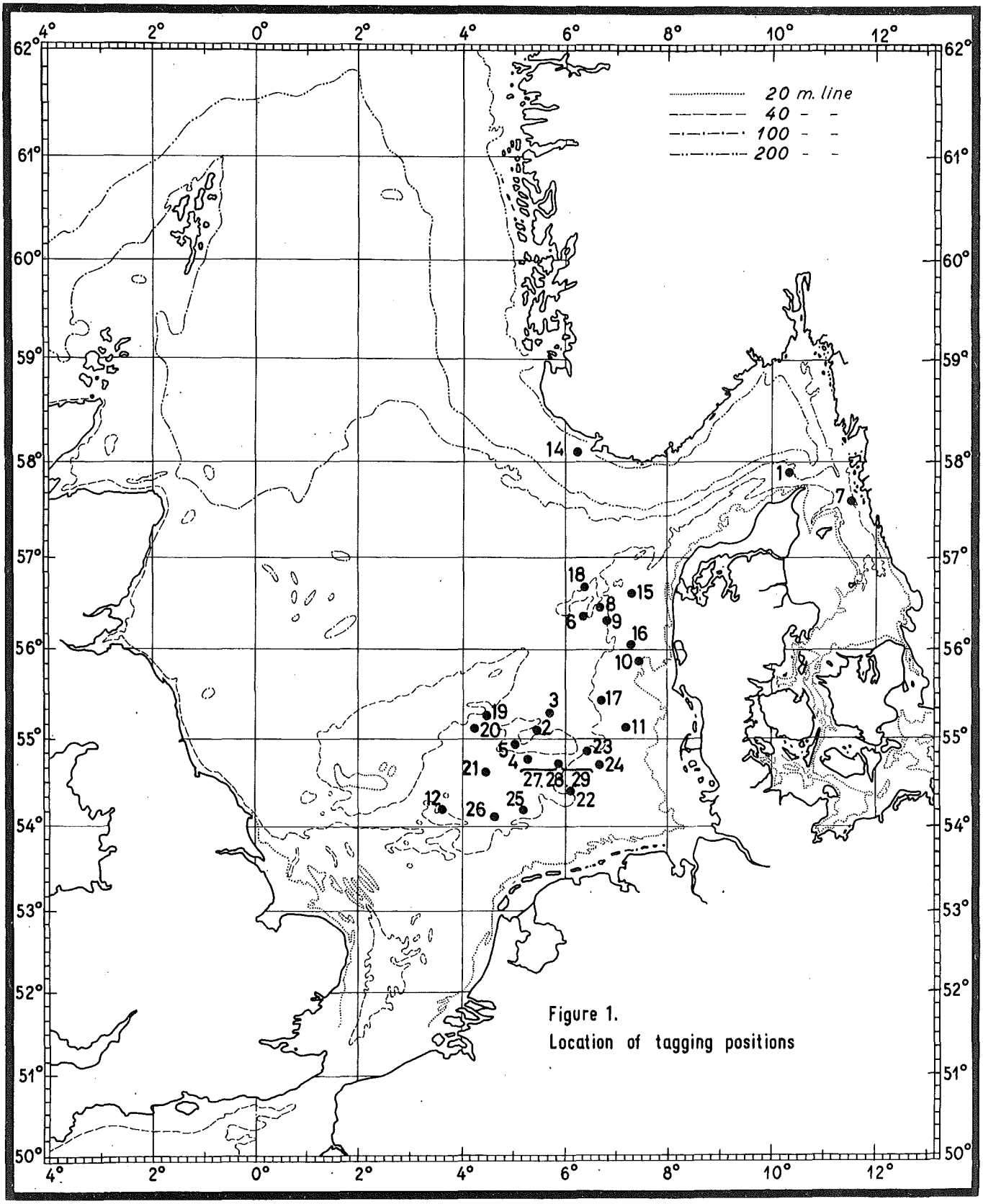

Figure 1.
Location of tagging positions