

NORWEGIAN TAGGING EXPERIMENTS IN THE NORTH-EASTERN NORTH SEA AND SKAGERAK, 1964 AND 1965

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INTRODUCTION

Except for the ICES herring tagging experiments in 1957 and 1958 on the Bløden Ground (Aasen, Andersen, Gulland, POPP-MADSEN and SAHRHAGE 1961) no large scale tagging of herring with internal metal tags have been carried out in the North Sea. In view of the rapid development of the herring fisheries in the northern and north-eastern North Sea in the recent years, the Herring Committee of ICES (ANON. 1965) in October 1965 recommended that both internal and external tagging of overwintering herring in the north-eastern North Sea and tagging of feeding and spawning herring in the western North Sea should be carried out.

By that time the Institute of Marine Research, Bergen had already in the winter 1964 carried out one tagging experiment with internal tags in the Skagerak. Since the recommendation of the Herring Committee was passed, Norway has carried out three further experiments (November 1965, June 1966 and July 1966).

This report describes the Norwegian tagging experiments, carried out in 1964 and 1965, and considers some preliminary results that can be drawn from the recaptures up to November 1966.

MATERIAL AND METHODS

All the herring were tagged with internal steel tags and the method applied was briefly the same as described by FRIDRIKSSON and AASEN (1950 and 1952). The lengths of the herring released were recorded, and scales were taken from each fish for age determination. The taggings were performed from a small, unanchored boat. Herring were taken individually from a keep net with a dip-net, and were after tagging released directly into the open sea. The fish used for tagging were caught by purse-seine. Weather conditions were favourable during the tagging operations.

The 1964 tagging was carried out in January during a cruise of

Table 1. Norwegian tagging experiments with internal tags in north-eastern North Sea and Skagerak, 1964 and 1965 (purse-seine catch).

Date	Lib. No.	Position		Serial number	Number of fish tagged
		N	E		
1964 17 Jan.	1	57°37'	06°35'	N 240501-241500	1 000
1965 5 Nov.	1	57°30'	07°20'	N 255501-256900	1 400
1965 5 Nov.	1	57°30'	07°20'	N 257001-257300	300
1965 7 Nov.	2	58°12'	10°53'	N 256901-257000	100
1965 7 Nov.	2	58°12'	10°53'	N 257301-259500	2 200
Total					5 000

R/V «G. M. Dannevig» and a total of 1000 herring were tagged about 30 nautical miles south-west of Lindesnes (Table 1). A sample from the same catch was secured. Unfortunately no otoliths were taken and it is difficult, therefore, with certainty to classify them into autumn and spring spawners. However, it can be concluded that the herring in maturity stages VII and VIII were autumn spawners (Table 2). Further,

Table 2. The maturity stages of the herring in samples taken from the same catches as the tagged fish.

Maturity stage	1964		1965					
			Liberation 1			Liberation 2		
			Autumn spawners		Spring spawners	Autumn spawners		Spring spawners
	No.	%	No.	%	No.	No.	%	No.
I	27	27.0	4	4.7	1	57	60.6	1
II	14	14.0	4	4.7	1	35	37.2	-
III	3	3.0	-	-	-	1	1.1	2
IV	4	4.0	-	-	3	-	-	-
V	-	-	-	-	4	-	-	-
VI	-	-	-	-	-	-	-	-
VII	5	5.0	7	8.2	-	1	1.1	-
VIII	46	46.0	70	82.4	1	-	-	-
Total	99	100.0	85	100.0	10	94	100.0	3

the mean vertebral count of the herring in maturity stages I and II was 56.51, showing that most of the herring in this group were also autumn spawned fish. The herring in maturity stage IV had a mean vertebral count of 57.25, indicating that they were spring spawners. The 3-ringers (most likely the 1960 year-class of the autumn spawned fish) predominated in the sample (Table 3).

Table 3. Age composition of herring in samples taken from the same catches as the tagged fish.*

Winter-rings	1964		1965							
			Autumn spawners				Spring spawners			
	No.	%	Year-class	Lib. 1		Lib. 2		Year-class	Lib. 1	Lib. 2
				No.	%	No.	%		No.	No.
0	—	—	1963	4	4.8	91	96.8	1964	—	1
1	—	—	1962	13	15.7	2	2.1	1963	1	1
2	28	30.4	1961	23	27.7	—	—	1962	3	—
3	53	51.6	1960	33	39.8	1	1.1	1961	3	—
4	2	2.2	1959	—	—	—	—	1960	1	—
5	—	—	1958	2	2.4	—	—	1959	—	—
6	2	2.2	1957	1	1.2	—	—	1958	—	—
7	2	2.2	1956	7	8.4	—	—	1957	—	—
8	4	4.3	1955	—	—	—	—	1956	—	—
8+	1	1.1	> 1955	—	—	—	—	> 1956	—	—
Total	92	100.0		83	100.0	94	100.0		8	2

*) 8 herring from the 1964 sample and 9 herring from the 1965 samples were not fit for age determinations and are omitted.

The 1965 taggings were carried out during a cruise of R/V «Johan Hjort» (HARALDSVIK 1965). The first batch (1700 herring, liberation 1) was released on 5 November, 25 nautical miles south of Ryvingen (Table 1 and Fig. 1). The herring consisted of 91.2 % autumn spawners, and the 1960 year-class predominated, followed by the 1961 year-class (Table 3). The distribution of maturity stages of the herring is shown in Table 2.

The next batch (2300 herring, liberation 2) was released on 7 November, 20 nautical miles north of Skagen (Table 1 and Fig. 1). The herring were almost entirely autumn spawned fish (97.9 %) of the 1963 year-class (Table 3). Most of these autumn spawners were in maturity stages I and II (Table 2) and the mean number of vertebrae was 56.59.

RESULTS AND DISCUSSION

THE RETURNS

In Table 4 is given a complete list of all tag returns from the 1964 experiment during the period up to 31 October 1966. Altogether 22 tags have been recaptured from this experiment, of which 14 were detected at Norwegian reduction plants, equipped with magnets. Most of

Table 4. Summary of returns from the 1964 experiment arranged according to area recovered at Norwegian plants

Area	Months																	
	1	2	3	4	5	6	7	8	9	10	11	12	Un- cer- tain	13	14	15	16	17
	1964																	
Skagerak											1 (1)	1 -						
Egersund B., Coral B.	3 (3)	1 (1)	1 (1)	1 (1)				1 (1)										
Shetland																		
Uncertain				3 -								1 -						
Total	3 (3)	1 (1)	1 (1)	4 (1)				1 (1)			1 (1)	2 -						

the tags were recaptured in the Egersund Bank-Coral Bank area. However, internal tags recovered at reduction factories cannot be allocated with certainty to a particular area and day of capture, because the tag may not reach the magnet and be recovered until some time after the herring have been caught. Notwithstanding this disadvantage it is likely that most of the tags recovered can be mapped out according to the information given by the factories, which usually know the time it takes a fish from landing until it passes through the machinery. As the fishing area of the catch reduced is known, the area of recapture can be estimated fairly well. It should be noted that only one tag of the 1964 experiment was recovered in 1965, even though the yield from the North Sea and Skagerak that year was much higher than in 1964. In 1966, only 8 tags were returned up to 31 October.

Table 5 summarizes the returns up to 31 October 1966 for the two liberations in 1965. A total of 178 recoveries were returned from liberation 1, of which 141 were detected at Norwegian plants equipped with magnets. From liberation 2, 136 tags were recovered, 100 at Norwegian plants equipped with magnets. These tags were mainly recaptured in the Egersund Bank—Coral Bank area and in the Skagerak. Most of the 21 recoveries from the Skagerak were from Danish reduction factories.

and number of months after the release. The figures in brackets are number of tags equipped with magnets.

after release														Un- cer- tain	Sum			
18	19	20	21	22	23	24	25	26	27	28	29	30	31			32	33	34
1965							1966											
																		2 (1)
										2 (2)		1 (1)	1 (1)					11 (11)
		1 (1)										2 (1)						3 (2)
																	2 -	6 -
		1 (1)									2 (2)	2 (1)	1 (1)	1 (1)	2 -			22 (14)

Only the recoveries from herring landed in Norway will be dealt with quantitatively, and special attention will be paid to the returns from reduction factories. However, not all the returns from factories equipped with magnets can be dealt with quantitatively due to low efficiency of the magnets and unreliable data on the catch reduced.

Before analysing the tag returns it is necessary to take into account the catch distribution and some biological characteristics of the herring caught in the Skagerak and the northern North Sea. This is important as the recaptures are used for stock size estimates, and for discussion of the movements of herring.

It appears from data published in *Annales Biologiques* (HARALDSVIK 1966, 1967 and 1968) that the north-eastern North Sea and the Skagerak can be regarded as the main overwintering area for the mature autumn spawned stock of the Bank herring. The north-western North Sea is considered to be the main feeding grounds for the same stock.

The recaptures, therefore, from the following periods and areas are of special interest: (1) 1 November to 31 May, Skagerak and Egersund Bank—Coral Bank and (2) 1 June to 31 October, Shetland area.

During the period 15 January to 31 May 1964 all the 6 recoveries were detected at one factory (Tables 4 and 6). Out of a total catch of

Table 5. Summary of returns from the 1965 experiment arranged according to area and month after release. The figures in brackets are number of tags recovered at Norwegian plants equipped with magnets.

Lib.	Area	Month after release												Un- cer- tain	Total
		1965			1966										
		1	2	3	4	5	6	7	8	9	10	11	12		
1	Skagerak	11 (6)	3 (2)									1 (1)	3 (1)		18 (10)
»	Egersund B., Coral B.		1 (1)	2 (2)			6 (6)	8 (7)	35 (32)	13 (13)	10 (10)	4 (4)	10 (9)		89 (84)
»	Shetland								10 (9)	17 (13)	27 (23)	2 -			56 (45)
»	Uncertain	3 (1)		2 -	1 (1)	2 -							1 -	6 -	15 (2)
»	Total	14 (7)	4 (3)	4 (2)	1 (1)	2 -	6 (6)	8 (7)	45 (41)	30 (26)	37 (33)	7 (5)	14 (10)	6 -	178 (141)
2	Skagerak	7 -	4 (2)		1 -	1 -	2 -				1 -		2 (2)	3 (1)	21 (5)
»	Egersund B., Coral B.		1 (1)	3 (3)			1 (1)	16 (16)	16 (16)	24 (24)	18 (18)	5 (5)	1 (1)		85 (85)
»	Shetland									4 (4)	6 (4)	2 (2)			12 (10)
»	Uncertain	4 -	1 -	1 -	1 -	8 -	1 -	1 -	1 -						18 -
»	Total	11 -	6 (3)	4 (3)	2 -	9 -	4 (1)	17 (16)	17 (16)	29 (28)	24 (22)	9 (9)	4 (2)		136 (100)
	Grand total	25 (7)	10 (6)	8 (5)	3 (1)	11 -	10 (7)	25 (23)	62 (57)	59 (54)	61 (55)	16 (14)	18 (12)	6 -	314 (241)

34106 tons landed in the same period, 12113 tons were reduced to oil and meal at four factories equipped with tested magnets. The recapture rate was estimated to 0.54 ‰ returns per 1000 tons.

From June to October the same year it is likely that part of the herring

Table 6. Quantity of processed herring (tons) and number of returns from the 1964 experiment at Norwegian plants equipped with magnets, 15 January to 31 May 1964.

Factory No.	Jan.	Febr.	March	April	May	Quantity (p)	Efficiency (e)	Corrected quantity (e.p)	Returns
2	5125.0	898.5	391.5	343.1	61.5	6 819.6*	0.95	6 478.6	6
12	233.7	567.6	199.6	546.9	27.4	1 575.2	0.94	1 480.7	—
16	56.4	502.6	189.8	170.2	—	919.0	0.93	854.7	—
31	21.3	172.7	146.9	424.0	2034.8	2 799.7	0.80	2 239.8	—
Total	5436.4	2141.4	927.8	1484.2	2123.7	12 113.5		11 053.8	6

* 953.7 tons derive from landings of foreign fishing boats in Norway.

tagged were outside the fishing area of the Norwegian fleet. Judging from Tables 7 and 8 the catches were also dominated by recruits. A lower number of returns, therefore, is reasonable during this period although only one recapture (from factory No. 2) is less than expected. From 1 November 1964 to 31 May 1965 one tag was recovered (Tables 4 and 9). Such a low recovery again was unexpected taking into account the relatively good fishery that took place in this period (HARALDSVIK 1966, 1967) and since the same year-classes as in the previous year predominated in the catches. The per mille returns per 1000 tons was estimated to only 0.01.

During the next period (1 June to 31 October 1965) one tag was recovered off Shetland. No herring were recaptured from the Skagerak and the Egersund Bank—Coral Bank area in the same period. This is also reasonable since the 1962 and 1963 year-classes made up more than 46.0 % of the herring caught (autumn spawners). Off Shetland, however, the purse-seiners exploited the same year-classes as those tagged.

In the 1965 experiment (Table 5) all the returns from 1 November 1965 to 31 May 1966 came from the Skagerak and the Egersund Bank—Coral Bank area. Pooling the number of recoveries during this period from liberations 1 and 2, a total number of 43 tags were detected at 11 factories (Table 10), giving 0,21 ‰ returns per 1000 tons.

During the second period (1 June to 31 October 1966) the number of reduction plants processing herring increased to 16 and the returns from the Egersund Bank—Coral Bank area amounted to 137 tags, and from Shetland to 55 tags (Table 11). The recapture rates were estimated to 0.27 ‰ and 0.15 ‰ returns per 1000 tons for the two respective areas.

Table 7. Age composition of autumn spawned herring (%) from Skagerak and northern North Sea arranged according to period, area and spawning component (number in brackets).

Period	Area	Type		Year-class														
		Autumn spawners	Spring spawners	Autumn spawners														
				1964	1963	1962	1961	1960	1959	1958	1957	1956	< 1956					
1964																		
1 Jan.– 31 May	Skagerak, Egersund B., Coral B.	82.5 (245)	17.5 (52)				36.9	48.5	2.9	0.4	0.8	8.7	1.7					
1 June– 31 Oct.	Egersund B., Coral B.	83.8 (599)	16.2 (116)			38.0	21.3	34.7	1.9	1.1	1.1	1.7	0.2					
1964/65																		
1 Nov.– 31 May	Skagerak, Egersund B., Coral B.	92.9 (184)	7.1 (14)			12.3	30.4	52.0	0.6	0.6	1.8	2.3						
1965																		
1 June– 31 Oct.	Skagerak, Egersund B., Coral B.	89.7 (741)	10.3 (85)				30.3	16.3	14.0	28.2	1.4	1.3	1.9	6.1	0.1			
»	Shetland	84.2 (358)	15.8 (67)			7.6	18.3	51.2	1.5	3.1	3.7	14.3	0.3					
1965/66																		
1 Nov.– 31 May	Skagerak, Egersund B., Coral B.	91.1 (717)	8.9 (70)						0.3	46.0	16.9	9.4	21.1	0.6	0.4	1.0	4.3	0.1
1966																		
1 June– 31 Oct.	Skagerak, Egersund B., Coral B.	92.7 (447)	7.3 (35)						4.4	30.7	15.5	12.2	26.6	0.5	1.2	2.1	6.9	
»	Shetland	75.2 (682)	24.8 (225)						0.2	17.8	5.8	13.1	38.1	1.3	2.4	3.8	17.0	0.5

Table 8. Age composition of spring spawned herring (%) from Skagerak and northern North Sea arranged according to period, area and spawning component (number in brackets).

Period	Area	Type		Year-class												
		Autumn spawners	Spring spawners	Spring spawners												
				1965	1964	1963	1962	1961	1960	1959	1958	1957	1956	<1956		
1964																
1 Jan.- 31 May	Skagerak, Egersund B., Coral B.	82.5 (245)	17.5 (52)				5.8	78.8	13.5	1.9						
1 June - 31 Oct.	Egersund B., Coral B.	83.8 (599)	16.2 (116)			1.0	3.0	72.2	7.9	10.9	4.0					1.0
1964/65																
1 Nov. - 31 May	Skagerak, Egersund B., Coral B.	92.9 (184)	7.1 (14)				7.1	58.0	35.7		7.1					
1965																
1 June - 31 Oct.	Skagerak, Egersund B., Coral B.	89.7 (741)	10.3 (85)		6.2	8.6	6.2	54.3	7.4	14.8	1.2					1.2
»	Shetland	84.2 (358)	15.8 (67)				3.1	73.8	6.2	16.9						
1965/66																
1 Nov.- 31 May	Skagerak, Egersund B., Coral B.	91.1 (717)	8.9 (70)		34.8	17.4	18.8	14.5	2.9	10.1	1.5					
1966																
1 June - 31 Oct.	Skagerak, Egersund B., Coral B.	92.7 (447)	7.3 (35)	2.9	31.4	8.6	11.4	28.6	2.9	8.6		2.9			2.9	
»	Shetland	75.2 (682)	24.8 (225)	1.8	42.4	2.2	3.6	34.4	8.5	6.7	0.4					

Table 9. Quantity of processed herring (tons) and number of returns from the 1964 experiment at Norwegian plants equipped with magnets, 1 November 1964 to 31 May 1965.

Factory No.	Nov.	Dec.	Jan.	Febr.	March	April	May	Quantity (p)	Efficiency (e)	Corrected quantity (e.p)	Returns
2	5 439.2	4 146.2	6 517.0	570.6	678.0	337.3	4 482.3	22 170.6*	0.95	21 062.1	1
3	-	-	2 725.1	-	-	351.0	268.3	3 344.4	0.81	2 709.0	-
7	-	-	5 269.9	4 671.1	680.0	300.4	1 011.4	11 932.8	0.80	9 546.2	-
12	480.8	473.5	436.0	741.5	156.8	77.2	527.2	2 893.0	0.94	2 719.4	-
16	618.5	1 249.2	650.5	807.0	24.2	1 556.9	3 603.5	8 509.8	0.93	7 914.1	-
18	-	-	511.5	511.5	182.4	692.2	2 396.2	4 293.8	0.87	3 735.6	-
20	-	-	1 062.8	2 042.7	131.3	295.2	1 701.3	5 233.3	0.86	4 500.6	-
31	631.4	1 222.7	1 082.0	2 109.7	166.5	2 641.6	12 686.3	20 540.2	0.80	16 432.2	-
Total	7 169.9	7 091.6	18 254.8	11 454.1	2 019.2	6 251.8	26 676.5	78 917.9		68 619.2	1

* 1 602.2 tons derive from landings of foreign fishing boats in Norway.

Table 10. Quantity of processed herring (tons) and number of returns from the 1965 experiment at Norwegian plants equipped with magnets, 1 November 1965 to 31 May 1966.

Fact. No.	Eff. (e)	November			December			January			February			March			April			May		
		Corr. quant. (e.p)	Returns		Corr. quant. (e.p)	Returns		Corr. quant. (e.p)	Returns		Corr. quant. (e.p)	Returns		Corr. quant. (e.p)	Returns		Corr. quant. (e.p)	Returns		Corr. quant. (e.p)	Returns	
			Lib. 1	Lib. 2		Lib. 1	Lib. 2		Lib. 1	Lib. 2		Lib. 1	Lib. 2		Lib. 1	Lib. 2		Lib. 1	Lib. 2		Lib. 1	Lib. 2
1	0.93	2 697	-	-	-	-	-	535	-	3	-	-	-	-	-	1 205	1	-	3 914	3	3	
2	0.95	3 913	3	-	413	1	2	1 121	2	-	34	-	-	128	-	-	1 267	5	1	4 549	1	5
3	0.81	1 420	-	-	-	-	-	305	-	-	-	-	-	-	-	-	-	-	893	-	-	
7	0.80	1 833	-	-	240	-	-	1 198	-	-	-	-	-	-	-	-	-	-	4 424	1	-	
12	0.94	38	-	-	-	-	-	70	-	-	58	-	-	129	-	-	124	-	-	960	-	-
16	0.93	132	1	-	-	-	-	26	-	-	-	-	-	9	-	-	210	-	-	2 991	2	4
18	0.87	300	1	-	-	-	-	79	-	-	5	-	-	-	-	-	358	-	-	1 886	-	-
20	0.86	197	-	-	-	-	-	-	-	-	-	1	-	-	-	-	133	-	-	2 786	-	-
21	0.91	44	-	-	31	-	-	46	-	-	-	-	-	-	-	-	97	-	-	2 233	-	1
31	0.80	246	1	-	-	-	-	-	-	-	-	-	-	-	-	-	123	-	-	4 395	-	-
42	0.72	116	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	236	-	-	
Total		10 936	7	-	684	1	2	3 380	2	3	97	1	-	266	-	-	3 517	6	1	29 267	7	13

FACTORS AFFECTING THE RETURNS

The per mille returns of tags may be influenced by several factors, among which the following are the most important: (1) uneven dispersion of the tagged fish and the fishing effort in the area under consideration, (2) non-returns of recovered tags and losses of tags not being detected, (3) mortality due to tagging, handling and bad condition of the tagged fish, (4) losses of tags from the fish by shedding and (5) losses of tags through migration.

Up to August 1965 only one factory (No. 2) has detected tags from the 1964 experiment (Tables 4, 6 and 9). It should be noted that during the first five months of 1964 the herring landed were reduced at only a few factories compared with the period from 1 November 1964 to 31 May 1965. Nevertheless, tags were expected to be found at all factories listed in Tables 6 and 9. The explanation for this bias in returns may be the failure of the tagged herring to disperse randomly. Since also the fleet obviously did not fish at random, such an uneven distribution of the returns may occur.

The herring tagged in 1965 seemed not to mix evenly during the first period (1 November 1965 to 31 May 1966) after release. Using the mean number of returns per million herring reduced as the expected number and, comparing it with the estimated number of returns per million number in each reduction plant a χ^2 -test was applied. The χ^2 -values obtained ($p < 0.05$) indicated that the tags were not randomly distributed between reduction plants, when pooling the returns from liberations 1 and 2. Also when excluding the recaptures during the first three months after release the distribution of the tag returns was biased ($p < 0.05$). However, considering liberation 1 separately, the returns were randomly distributed between factories ($p > 0.05$).

The non-return rate of recovered tags of cod, coalfish, haddock, halibut and catfish in Norway was estimated to be at least 4—6 % (HYLEN 1963). However, it should be noted that the reward for each of these tags is N.kr. 5, whereas the reward for a herring tag is N. kr. 10. Almost all the recoveries of internal tags come from oil and meal factories, and in these plants there are only a few workers who attend to that part of the machinery where the magnets are placed. Thus, only a fairly limited number of people are concerned, and in all the plants there are placed posters with detailed instructions of what to do with the recovered tags. For this reason and the worth while reward, it is considered that the loss in Norwegian plants due to non-returns of tags recovered is probably negligible.

The returns from factories without magnets and with magnets of

Table 11. Catches of herring (tons) in the Egersund Bank—Coral Bank (Eg.) and (1 June to 31 October 1966) together with the number of

Fact. No.	Eff. (e)	June						July					
		Corr. quant. (e.p)		Returns				Corr. quant. (e.p)		Returns			
				Lib. 1		Lib. 2				Lib. 1		Lib. 2	
		Eg.	Sh.	Eg.	Sh.	Eg.	Sh.	Eg.	Sh.	Eg.	Sh.	Eg.	Sh.
1	0.93	6 627	—	8	—	7	—	6 549	78	5	—	12	—
2	0.96	8 840	47	6	—	4	—	8 900	—	5	—	9	—
3	0.77	1 702	—	2	—	1	—	1 610	31	—	—	—	—
4	0.81	2 969	—	—	—	—	—	3 804	73	3	—	1	—
7	0.80	5 764	35	3	—	—	—	5 190	161	—	—	1	—
12	0.94	941	391	—	—	—	—	765	245	—	—	—	—
16	0.93	2 416	1 079	2	—	—	—	1 499	3 274	—	1	—	2
18	0.96	1 880	1 291	2	—	—	—	1 165	4 081	—	2	1	1
20	0.86	2 381	2 093	4	—	—	—	690	2 152	—	—	—	—
21	0.91	1 729	1 616	1	4	2	—	1 248	3 019	—	3	—	—
24	0.66	1 429	3 443	—	3	—	—	7	4 093	—	1	—	—
31	0.76	2 925	2 984	2	2	2	—	147	6 566	—	1	—	—
35	0.86	1 463	1 865	—	—	—	—	—	3 378	—	1	—	—
37	0.84	—	—	—	—	—	—	—	2 199	—	2	—	—
42	0.72	68	1 437	2	—	—	—	4	2 606	—	—	—	—
43	0.94	31	2 949	—	—	—	—	—	3 549	—	2	—	1
Total		41 165	19 230	32	9	16	—	31 578	35 505	13	13	24	4

especially low efficiency are not considered for further quantitative treatment. To test the efficiency (e) of the magnets the returns from a known number of tagged fish introduced into each factory is measured (Tables 6, 9 and 11). The efficiency (e) at each factory multiplied by the quantity (p) gives the effective quantity of herring reduced.

No special test was carried out to investigate the tagging mortality in the present experiments. However, several attempts have been made to study this problem on Norwegian spring spawners (FRIDRIKSSON and AASEN 1950, 1952). These experiments indicated that the tagging mortality was negligible.

During the period 17 June to 19 September 1966 a tank experiment was carried out to test mortality of internal tagged herring. The fish were already brought to the Institute from a purse-seine catch near Bergen in autumn 1965 and were before the experiment kept in a tank. A total of 79 herring were tagged and, thereafter transferred into another tank (Table 12). Just after the tagging the herring did not shoal and refused eating for the first two days. A total of 8 herring died during the experiment, 4 of these during the first three days. When examining the

Shetland areas (Sh.) and processed at Norwegian plants equipped with magnets returns from the 1965 experiments in the two fishing areas.

August				September				October									
Corr. quant. (c.p)		Returns		Corr. quant. (c.p)		Returns		Corr. quant. (c.p)		Returns							
		Lib. 1	Lib. 2			Lib. 1	Lib. 2			Lib. 1	Lib. 2						
Eg.	Sh.	Eg.	Sh.	Eg.	Sh.	Eg.	Sh.	Eg.	Sh.	Eg.	Sh.						
5 932	1 570	-	-	3	-	3 788	-	-	-	3	-	3 121	-	6	-	-	-
8 374	1 783	5	-	7	-	4 224	8	2	-	2	-	2 787	-	-	-	1	-
2 153	613	-	-	-	-	1 116	-	-	-	-	-	916	-	1	-	1	-
3 939	1 125	1	2	4	-	2 838	-	2	-	-	-	2 085	-	-	-	-	-
4 524	1 738	4	1	4	2	3 296	-	-	-	1	-	1 653	-	1	-	-	-
-	524	-	-	-	-	100	-	-	-	-	-	195	-	-	-	-	-
104	2 566	-	3	-	-	335	40	1	-	1	2	605	-	-	-	-	-
50	3 151	-	3	-	-	175	183	-	-	-	-	456	-	1	-	-	-
325	2 863	-	2	-	1	273	444	-	-	-	-	497	-	1	-	-	-
117	3 517	-	-	-	-	93	288	-	-	-	-	263	-	-	-	-	-
-	3 430	-	5	-	-	123	41	-	-	-	-	49	-	-	-	-	-
-	3 026	-	1	-	1	360	50	-	-	-	-	55	-	-	-	-	-
-	5 641	-	1	-	-	56	64	-	-	-	-	70	-	-	-	-	-
-	2 402	-	3	-	-	-	-	-	-	-	-	287	-	-	-	-	-
34	1 902	-	2	-	-	-	189	-	-	-	-	67	-	-	-	-	-
-	2 783	-	-	-	-	-	49	-	-	-	-	430	-	-	-	-	-
25 552	38 634	10	23	18	4	16 777	1 256	5	-	7	2	13 536	-	10	-	2	-

Table 12. Length distribution (%) of herring tagged with internal steel tags in the tank experiment.

Dimension of tag (mm)	Lenth in cm													
	13.0	13.5	14.0	14.5	15.0	15.5	16.0	16.5	17.0	18.0	18.5	18.5	19.0	19.5
15 x 2 x 0.5	25.0	-	12.5	25.0	15.0	35.0	10.0	-	-	-	-	-	-	-
20 x 3 x 1	-	-	-	-	1.6	4.8	27.0	22.0	23.8	6.3	4.8	3.2	3.2	3.2

dead herring and the position of the tag, apparently none of the herring had been directly damaged by the tag itself. A more likely reason for the mortality was the tagging operation, including the catching and handling of the fish. The tagging mortality was estimated to be 10.1 %.

The tank experiment showed that 4 tags (5.1 %) were lost by shedding. The wound caused by the insertion of the tag was healed after 6 weeks. Shedding tests have also been made on Norwegian spring spawners by DRAGESUND (unpublished data). According to his experiments special attention should be made to herring tagged in the immediate prespaw-

ning and spawning stages as tags were frequently found in one or both gonads. These tags are subject to a pressure during the spawning process, and consequently the shedding will be relatively high in these fish. Since the herring tagged were in a post spawning condition or immature (Table 2), the shedding rate should be compareable with that of the herring in the tank experiment.

A different way of handling the fish by the various tagging operators may affect the mortality of the tagged fish. In the present investigation all the herring tagged in 1964 were tagged by the same person, whereas the 1965 tagging was performed by three different persons. Judging from Table 13 no special difference between operators was noticed.

Table 13. Number of herring tagged and tags returned separated according to taggers (1965 experiment).

Liberation	Tagger No.	Number tagged	Returns	Rate of recapture %
1	1	850	87	10.24
»	2	850	91	10.71
2	1	750	43	5.73
»	2	750	39	5.20
»	3	300	14	4.67

Especially in open sea taggings, where herring have to be provided by purse-seiners and transferred into a keep net before the tagging can start, sometimes in unfavourable weather, the herring may soon be descaled and the condition of the fish be reduced. In two cases (Table 14) the rate of recapture was higher for the first half of release, whereas

Table 14. Number of returns from the first and second half of the tagged batch of each liberation.

Experiment	Number of returns from the first half of the tagged batch	Number of returns from the second half of the tagged batch	Total
1964.....	13	9	22
1965 (lib. 1)	105	73	178
» (lib. 2)	66	70	136

in one case it was slightly lower. However, testing the 1:1 ratio of the recaptures from the first and second half of release by applying a χ^2 -test no significant differences could be found ($p > 0.05$). 98 % of the herring

Table 15. Comparison between length (cm) at liberation for the total number of herring tagged and herring recaptured.

Length(L)at liberation (cm)	1964		1965			
	Number of fish tagged	Number of fish recapt.	Lib. 1		Lib. 2	
			Number of fish tagged	Number of fish recapt.	Number of fish tagged	Number of fish recapt.
19.0	—	—	—	—	3	—
.5	1	—	—	—	1	—
20.0	3	—	—	—	27	1
.5	2	—	1	—	59	4
21.0	14	—	1	—	190	7
.5	15	—	—	—	352	13
22.0	20	1	1	—	408	25
.5	26	—	2	—	413	22
23.0	63	2	9	—	371	28
.5	51	—	5	—	229	14
24.0	68	1	11	1	130	11
.5	63	1	9	1	61	4
25.0	84	3	15	1	14	—
.5	79	—	17	2	7	2
26.0	97	4	50	7	7	1
.5	75	1	36	1	6	—
27.0	91	3	84	11	2	—
.5	52	—	92	8	2	1
28.0	54	—	147	11	1	—
.5	41	2	105	18	2	1
29.0	24	1	181	28	—	1
.5	20	—	137	16	3	—
30.0	27	2	236	23	2	—
.5	6	—	132	7	2	—
31.0	13	—	182	15	1	1
.5	5	—	86	11	1	—
32.0	2	—	83	10	—	—
.5	—	—	25	2	1	—
33.0	3	1	29	—	—	—
.5	1	—	9	1	—	—
34.0	—	—	4	1	—	—
.5	—	—	4	—	—	—
35.0	—	—	2	—	—	—
Total	1 000	22	1 695	175	2 296	136
\bar{L}	25.81	26.45	29.32	29.27	22.46	22.78
s^2	5.40	6.69	4.08	3.19	1.50	2.27

landed from the North Sea and Skagerak have been caught by purse-seine. It is unlikely, therefore, to expect any selection effect due to fishing on the numbers of returns. However, the mortality of the tagged herring may be associated with the size of the fish so that the larger fish survive better than the smaller ones, or vice versa.

In Table 15 are given the length distributions at liberation of the tagged and recaptured fish, together with the means and variances. The differences between the means are small and are not significant ($p > 0.01$) according to the t-test.

Losses of tags may also take place by segregation. From Tables 7 and 8 it will be seen that mainly old herring were caught off Shetland by the purse-seiners in the summers of 1965 and 1966. It could be that after spawning the older age-groups of the tagged herring remained in this area and did not return to the Skagerak and the Egersund Bank—Coral Bank area to the same extent as the younger fish. However, this possibility can hardly explain the low rate of recapture of the 1964 experiment during the period from 1 November 1964 to 31 May 1965, since the same year-classes occurred in the catches from the Skagerak and the Egersund Bank—Coral Bank area as among the tagged fish (Tables 3, 7 and 8).

CONCLUDING REMARKS

MIGRATION

The distribution of the recaptures from the 1965 experiment clearly demonstrates a westward migration of herring tagged in Skagerak during the winter and spring (Fig. 1).

Up to 31 May 1966 no significant difference in total number of returns from liberation 1 and 2 is noticed. However, considering the recoveries from Norwegian plants only during the same period (Table 5), the number of returns from liberation 1 is somewhat higher than from liberation 2. If it is assumed that the tagging mortality in the two liberations was the same, the lower percentage of returns from liberation 2 indicates that these herring were not available for the Norwegian purse-seiners to the same extent as those from liberation 1.

The difference in number of returns for the two liberations seems even clearer when studying the recaptures during the next period, i. e. from 1 June to 31 October 1966 (Fig. 2). In June the main fishery still took place in the Egersund Bank—Coral Bank area, and the majority of the recoveries in this month derived from liberation 1. During the following two months (July and August) the Norwegian fleet was centered off Shetland and 54 herring (44 from liberation 1 and 10 from liberation 2) were recaptured in this area (Fig. 2).

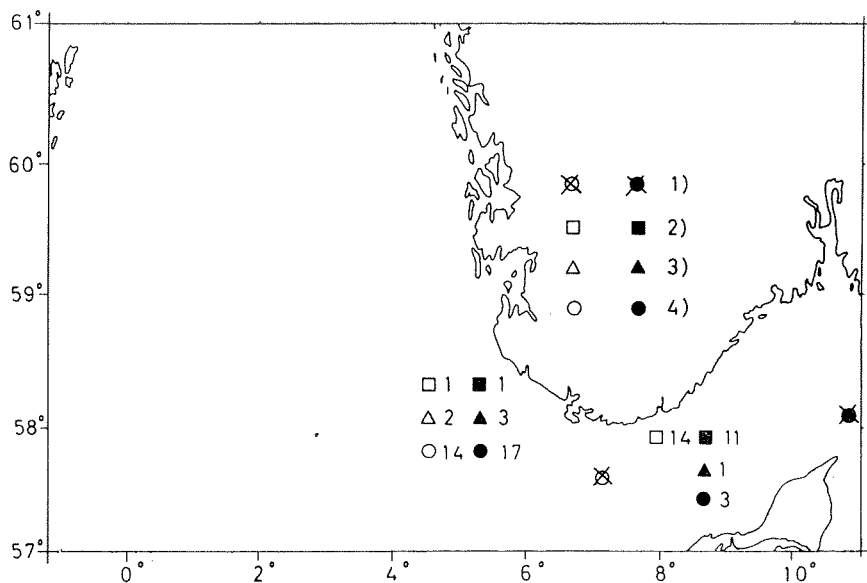


Fig. 1. Tagging localities and distribution of returns from the 1965 experiment. Open symbols refer to liberation 1 and filled symbols to liberation 2. 1) tagging localities, 2) returns November—December 1965, 3) returns January—February 1966 and 4) returns March—May 1966. The figures represent number of returns.

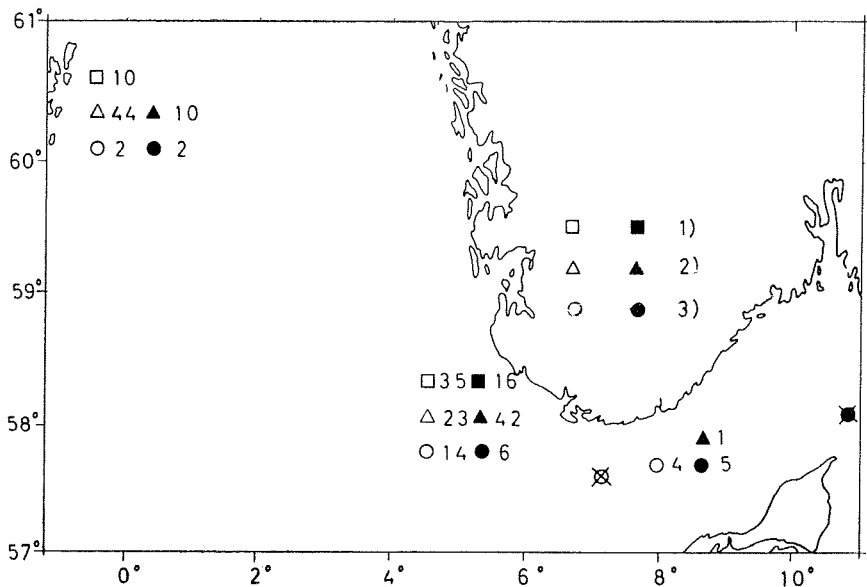


Fig. 2. Distribution of returns from the 1965 experiment. Open symbols refer to liberation 1 and filled symbols to liberation 2. 1) returns June 1966, 2) returns July—August 1966 and 3) September—October 1966. The figures represent number of returns.

At the same time part of the fleet fished in the Egersund Bank—Coral Bank area and, in contrast to the previous month most of the recoveries from this area came from liberation 2. In the next two months (September and October) most of the returns derived from the Egersund Bank—Coral Bank area, although a few tags were recaptured both off Shetland and in the Skagerak.

Judging from the figures of the per mille returns at Norwegian plants according to time and area for the two liberations (Table 16), significantly higher figures for liberation 1 are found off Shetland. The value for September-October is probably not reliable due to the difficulty in allocating all the recaptures with certainty.

Table 16. Per mille returns per 1000 tons according to time and area, the 1965 experiment.

Experiment	1965/1966	1966					
	November -May	June		July-August		September -October	
	Egers. B. - Coral B.	Egers. B. - Coral B.	Shetland	Egers. B. - Coral B.	Shetland	Egers. B. - Coral B.	Shetland
Lib. 1	0.27	0.46	0.27	0.24	0.29	0.29	-
Lib. 2	0.16	0.17	-	0.32	0.05	0.13	0.67

The same trend as off Shetland is found for the Egersund Bank—Coral Bank area except for the period July-August.

The connection therefore, between the herring appearing in the eastern Skagerak during late autumn and those present off Shetland in summer and early autumn, was not so strong as between the herring found at the western entrance of Skagerak and those off Shetland during the same period.

Comparing the age composition for the tagged herring with those fished in Skagerak and off Shetland, two possibilities may exist for the discrepancy in pattern of returns: (1) the herring in liberation 2 were dominated by Kattegat autumn spawners. These fish most likely have a feeding migration towards the Egersund Bank—Coral Bank area, resulting in many recaptures there in July-August, (2) the herring tagged in eastern Skagerak (liberation 2) consisted of Bank herring recruits, which did not migrate to the north-western part of the North Sea to the same extent as the older fish (liberation 1).

Due to the high number of vertebrae of the fish in liberation 2

(59.56) it is suggested that these herring mainly belonged to the Bank herring stock and consequently the latter explanation is the most reasonable.

STOCK SIZE

Due to the low number of recaptures of the 1964 experiment, the returns from it cannot be used for stock size assessment.

Although the requirements are only partly fulfilled for applying the returns of the 1965 experiment for quantitative assessment, they allow a tentative estimate of the stock size in the overwintering area in the north-eastern North Sea. This area is defined to cover the Skagerak and the Egersund Bank—Coral Bank and the overwintering period includes the time from 1 November to 31 May.

To adjust for losses of tags the data presented in Table 10 and the results of the tank experiment are used. Applying the figures for tagging mortality and shedding of tags obtained in the tank experiment, the effective number of tagged herring is calculated to be 3392 (1442 in liberation 1 and 1950 in liberation 2).

The losses of tags due to migration are difficult to judge from the material available. It is likely that recruits were present throughout the period in question, although the samples collected indicated that the 1963 year class was relatively less abundant from the middle of March onwards (Table 17).

Table 17. Age composition (%) of the autumn spawned herring in the samples from Skagerak—Egersund Bank—Coral Bank, 1 November 1965 to 31 May 1966.

Year-class	1965		1966						Total	
	8.11	10.12	22.1	10.3	10.3	20.4	25.5	27.5	No.	%
1964	—	1.1	—	1.2	—	—	—	—	2	0.3
—63	63.0	94.3	70.0	85.2	18.7	23.1	8.7	19.6	324	45.9
—62	31.0	4.6	11.3	3.7	11.0	24.1	18.4	29.3	119	16.9
—61	1.2	—	2.5	3.7	9.9	17.2	21.4	15.2	66	9.4
—60	3.6	—	15.0	5.0	40.6	26.4	39.8	31.5	149	21.1
—59	—	—	—	—	—	—	1.9	2.2	4	0.6
—58	—	—	—	—	2.2	—	1.0	—	3	0.4
—57	1.2	—	—	—	3.3	2.3	1.0	—	7	1.0
—56	—	—	1.2	1.2	14.3	6.9	6.8	2.2	30	4.3
> 1956	—	—	—	—	—	—	1.0	—	1	0.1
Number	84	87	80	81	91	87	103	92	705	100.0

The relative proportions of spring and autumn spawners were almost the same during the period under consideration.

The westward migration from the overwintering area to the feeding and spawning grounds in the northern and western North Sea probably started in May–June. It is reasonable, therefore, to assume that the dominant part of the autumn spawners was concentrated in the Skagerak and north-eastern North Sea during the period from November to May.

In the absence of reliable fishing effort statistics and data on local fishing intensity a reasonable estimate of the stock size in the overwintering area can be obtained using a modification of the Petersen method (AASEN, ANDERSEN, GULLAND, POPP-MADSEN and SAHRAGE 1961).

The calculated number of tags returned each month at factories equipped with tested magnets, have been plotted against the number of herring processed at the same factories in that month. From the time of tagging throughout the period up to 31 May 1966 a reduction of the effective number of tagged fish has taken place due to fishing and natural mortality. No data on total mortality of herring in the north-eastern North Sea is available, but tentative values (Anon. 1964) for the total instantaneous mortality rates ($Z_1 = 0.5$ and $Z_2 = 0.9$) have been used to estimate the effective number of tagged fish present on the fishing grounds each month. The actual number of returns have been multiplied by a raising factor $\frac{N_e}{N_i}$; N_e being the effective number tagged at release and N_i the estimated number of effectively tagged herring present in the different months calculated according to the equation:

$$N_i = N_e e^{-Zt}$$

The number of herring reduced at Norwegian plants according to month are obtained from samples of the catches landed at the factories. Normally three samples from each landing are taken, and the average number of herring per kg is estimated. These data have been fitted to a simple proportion line, pooling liberations 1 and 2 and, considering liberation 1 separately (Fig. 3).

Using $Z_1 = 0.5$ and pooling liberations 1 and 2 the average number of effectively tagged herring present during the period was 3 017 and the stock in million numbers estimated to be $\frac{100}{14.74} 3\ 017 = 20\ 454$.

Converting this figure to tons the stock size has been calculated to 3.31 million tons.

For $Z_2 = 0.9$ the corresponding figures are 15 777 million numbers and 2.55 million tons.

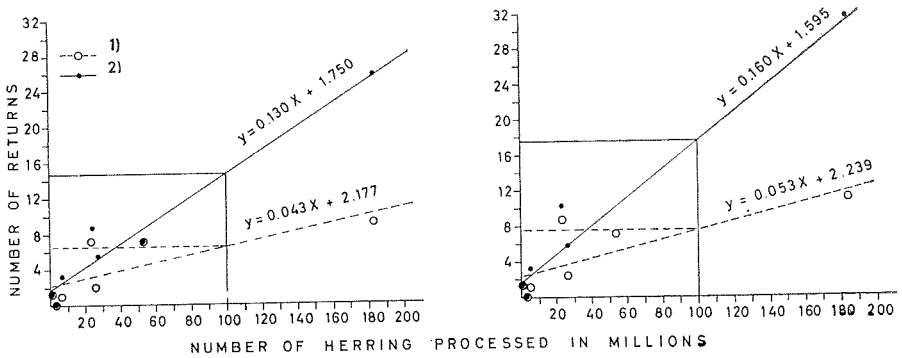


Fig. 3. Correlation between the monthly number of herring reduced at factories equipped with magnets and the estimated number of returns. Left: $Z = 0.5$, right: $Z = 0.9$. 1) liberation 1, 2) liberations 1 and 2 pooled.

Omitting liberation 2 and using $Z_1 = 0.5$, the estimated stock size in million numbers and in million tons are respectively 19 793 and 3.20, and when using $Z_2 = 0.9$ the figures are 15 565 million numbers and 2.53 million tons.

Judging from the figures no great differences in the stock size estimates are found when pooling liberations 1 and 2, and considering liberation 1 separately. Comparing the composition of the tagged herring with those obtained from samples later in the period, it is suggested that the estimates for liberations 1 and 2 pooled give the most representative values for the stock size.

In the absence of exact data on total mortality rates in the overwintering area a reasonable stock size in 1965/1966 should range between 2.55 and 3.31 million tons.

SUMMARY

1. Norwegian herring tagging experiments carried out with internal metal tags in Skagerak in 1964 and 1965 are described.
2. The returns from these taggings up to 31 October 1966 are reviewed and factors affecting the losses of tags discussed.
3. Evidence for a movement of herring from Skagerak towards the Egersund Bank—Coral Bank area and further westward to the Shetland area was found.
4. Quantitative treatment of the recaptures from Norwegian reduction plants equipped with magnets are dealt with and, tentative estimates for the stock size in the Skagerak—Egersund Bank—Coral Bank areas during the period November 1965—May 1966 are given.

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