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Migrations and stock size of herring in the northern North Sea in 1966; analyses of Norwegian tagging experiments

By

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ABSTRACT

8000 herring were tagged with internal steel tags in the summer of 1966; 4000 were released in the north-eastern North Sea and 4000 east of Shetland. On the basis of returned tags during the first year after tagging, Haraldsvik (1967 and 1969a) determined migrations and stock size. In the present paper the data are re-examined taking into consideration the returns from later years.

A high degree of intermingling of herring between the north-eastern North Sea and the Shetland area was found. 30-35% of the autumn spawning herring tagged in the Egersund Bank area were in the following years found at Shetland. Vice versa, 20-40% of those tagged east of Shetland were in later years

found in the north-eastern North Sea.

The data on tag returns in 1967 and 1968 have been used to estimate the stock size of herring applying a modified, simple Petersen method. The number of autumn spawners, 3 years and older, in the northern North Sea in the summer of 1966 was estimated to be 12-17 x 10^9, corresponding to 2.3-3.3 million tons. The errors adhering to this estimate are discussed, and it is concluded that the stock in the northern North Sea is overestimated, while the estimate probably is somewhat below the total size of the adult autumn spawning stock in the North Sea as a whole, excluding the Skagerrak.

INTRODUCTION

Tagging experiments on North Sea herring have been carried out by the Institute of Marine Research, Bergen in the years 1964-1970. The experiments in 1964 and 1965 are dealt with by Dragesund and Haraldsvik (1966 and 1968). Haraldsvik (1966, 1967 and 1969a) describes the taggings in 1966, and gives preliminary results on migrations and stock size.

8000 herring were tagged with internal steel tags in the summer of 1966; 4000 were released in the Egersund Bank area and 4000 east of Shetland.

Up to July 1967 957 tags had been returned. The returns indicated a migration from the north-eastern North Sea both to the eastern Shetland area and to Skagerrak, and a migration from east of Shetland to the north-eastern North Sea and Skagerrak (Haraldsvik 1967). However, about 70% of the tags were returned within 5 months after tagging and about 85% were taken within the area of release.

Stock size estimates were made on the basis of returns during the first 3 months after tagging. The herring stock in the north-eastern North Sea was estimated to be 0.54 million tons

and in the Shetland area 0.57 million tons in the summer of 1966 (Haraldsvik 1969a). These estimates were considered by the North Sea Herring Assessment Working Group (Anon. 1971). The group found that the experiments only partly fulfilled the requirements for making quantitative assessments, particularly because of uncertainties about the composition of catches in relation to composition of the estimated stock.

Tagging data provide a basis for analysis of herring migrations and for estimates of stock size which can be compared and coordinated with the results obtained by other methods allowing more reliable conclusions to be drawn. This is of particular interest when changes in the North Sea herring stock are studied e.g. by the technique of virtual population analyses.

The data from the 1966 herring taggings were therefore re-examined, taking into consideration the returns from later years, excluding unreliable tag reports, and base calculations on an assumed random distribution of the tagged fish.

MATERIAL

Herring for tagging were obtained from commercial purse-seiners. The weather was favourable during the tagging operations, and a low mortality due to tagging is assumed.

4000 herring were tagged during 25-27 June 1966 near Sira Hole and on the Egersund Bank. 91% of the herring belonged to the autumn spawning group and the 1960 year class dominated (Experiment 97, Egersund Bank).

Another 4000 herring were tagged during 25 July - 1 August in the area east of Bressay-Sumburgh Head. Separated on otolith characters 69% was found to be autumn spawners dominated by the 1960 and 1963 year classes (Experiment 101, Shetland).

Further information regarding the tagging is given by Haraldsvik (1966 and 1967).

More than 90% of the Norwegian catches of North Sea herring has been utilized for the production of fish meal and oil. Most reduction plants have installed magnets to collect the steel tags, and up to the end of 1970 a total of 1302 had been returned from Norwegian and foreign plants, as detailed below:

1966	808	tags
67	316	"
68	129	"
69	32	"
70	17	"

Information pertaining to the returned tags, date of recapture, location and size of catch etc., are lacking for about 25%. Some reduction plants have inefficient magnets or process small quantities of herring and thereby return few tags. Tests have demonstrated that the data from such plants are unreliable (Hamre 1971). A selection of the returned tags has therefore been carried out including only tags obtained from larger Norwegian reduction plants with known magnet efficiency and with all relevant information available.

This procedure reduced the number of returned tags in 1966, 1967 and 1968 utilized for the calculations to a total of 1076. The distribution of the tags on years, months and areas, together with catch of herring is given in Table 1. ICES statistical areas are used, and the area IVa is divided in two along the longitude 2^{o}E, giving areas indicated IVa E and IVa W which cover Shetland and the north-eastern North Sea respectively.

RESULTS AND DISCUSSION

Migrations

The tagging data have been used to study the exchange and migration of herring between the Shetland area on one side and the north-eastern and central North Sea and Skagerrak on the other.

Let x_p be the proportion of herring tagged in area IVa W (Experiment 101, Shetland) which is found in this area in year p, and let y_p be the proportion of herring tagged in area IVa E (Experiment 97, Egersund Bank) which is found in this area or in IVb, Central North Sea and IIIa, Skagerrak, in year p.

Assuming equal mortality due to tagging and natural causes in the two areas, we have

$$\frac{x_p}{1 - y_p} = \frac{R_{101,p}}{R_{97,p}} \qquad \text{Area IVa W}$$

and

$$\frac{y_p}{1 - x_p} = \frac{R_{97,p}}{R_{101,p}} \qquad \text{Area IVa E}$$

where $R_{t,p}$ is the number of recaptures from experiment t in year p.

From the two equations, x_p and y_p were calculated, and the results (proportions in %) are summarized below:

	Experiment 97, IVa E		Experiment 101, IVa W	
Year	In IVa W	In IVa E	In IVa W	In IVa E
1966	7.4	92.6	76.1	23.9
1967	35.2	64.8	79.2	20.8
1968	31.0	69.0	59.7	40.3

As mentioned above recaptures in Central North Sea and Skagerrak are included in area IVa E. However, few tags were returned from these bordering area (Table 1), and nearly all were from catches taken close to area IVa E.

A random dispersion of the tagged herring can not be expected within the first months following tagging, and the distribution of fishing by purse-seine is hardly ever random. The percentages found for 1966 may consequently be biased. The result, however, seems to indicate that only a small proportion of the herring present in the Egersund Bank area (IVa E) migrated to Shetland in late summer, while a significant proportion moved in the opposite direction from east of Shetland (IVa E) to the north-eastern North Sea in early autumn 1966.

In 1967 and 1968 a random dispersion of the tagged herring can be assumed. The calculated relative proportions of returns demonstrate a high degree of intermingling of herring between the two areas. 30-35% of the herring in the Egersund Bank area were in the following years found at Shetland. These belonged to the autumn spawning group (91%) with age $>$ 4 years in 1967. 20-40% of the herring east of Shetland were in later years found in the north-eastern North Sea. 69% of this herring were autumn spawners, in 1967 likely dominated by the 4 and 7 year olds.

These results confirm earlier findings (Höglund 1954, Dragesund and Haraldsvik 1966, Haraldsvik 1967) which have demonstrated herring migrations between the eastern and western part of the northern North Sea. The migrations are most likely connected with the northward movement to the feeding areas in the spring, and return movements in the autumn.

Stock size

The data on tag returns in 1967 and 1968 have been used to estimate the total stock size in numbers, S, of autumn spawners in the northern North Sea at the time of tagging (summer 1966).

A modified, simple Petersen method was applied, assuming the same mortality of tagged and untagged herring with corrections for tagging mortality, shedding of tags, efficiency of magnets in reduction plants, and recruitment.

If N is the number of tagged fish, s ratio of survival after tagging mortality and shedding, R number of recaptures, e overall magnet efficiency coefficient, and C catch of autumn spawners after subtracting recruitment, we have

$$\frac{R}{C \cdot e} = \frac{N \cdot s}{S} \quad , \text{ i.e.}$$

$$S = \frac{N\ C \cdot e \cdot s}{R} \qquad (1)$$

and S is then the stock number.

Samples of the herring used for tagging (Haraldsvik 1967, Table 2) show that in both areas the youngest herring tagged were 2-"ringers", i.e. 2 year old spring spawners and near 3 year old autumn spawners. When correcting C in (1) recruits were therefore taken as the 3-ringers and younger in 1967 and the 4-ringers and younger in 1968.
The estimated stock, S, is consequently the number of autumn spawners, 3 years and older in 1966. The two tagging experiments (E 97 and E 101) are considered as one, and the basic data for the calculations appear from Table 2.

The catch figures, as in Table 1, relate to herring from the northern North Sea (area IVa W and IVa E) landed at 20 Norwegian reduction plants equipped with magnets for tag collection. The calculated average number of herring per kg, the percentage of autumn spawners and the percentage of recruits are derived from samples of commercial catches taken mainly during the summer. Details on composition and age distribution of the herring are reported by Haraldsvik (1968 and 1969b).

From (1) two estimates of S are obtained, S_1 based on tags returned in 1967 and S_2 from returns in 1968. Not correcting for magnet efficiency, e, and survival of tagging, s, these estimates are:

$$\frac{S_1}{e \cdot s} = \frac{8000 \cdot 570.7 \cdot 10^6}{217} = 21.0 \times 10^9$$

and

$$\frac{S_2}{e \cdot s} = \frac{8000 \cdot 237.8 \cdot 10^6}{73} = 26.1 \times 10^9$$

The overall magnet efficiency may be considered equal for the two years, and thus a generally good agreement is found between the two estimates.

The factor s, reflecting mortality due to tagging and shedding of tags, has been determined experimentally in tanks (Haraldsvik 1968). Tagging mortality and shedding were found to be 10 and 5% respectively. The taggings in 1966 were carried out under favourable working conditions, except for a batch of about 1000 in Experiment 101. A large part of the herring tagged, especially in the Shetland experiment (E 101), were in a pre-spawning condition which may give a higher percentage of shedding than determined in the tank experiments. Considering all factors together, the overall loss due to tagging and shedding is estimated to be 15-20%.

The efficiency, e, of the magnets screening the fish meal and collecting the steel tags has been determined by tests at most reduction plants. The plants from which tag returns are utilized here have efficiencies between 0.60 and 0.95. The calculated average, weighted according to the quantity processed, is 0.79. The efficiency, however, varies not only among plants, but is also for any one plant depending on the condition of the processed herring, the cleaning of the machinery and the magnets, the cooperation of factory workers and management etc. The influence of these factors has not been determined, but rough checks indicate that the determined overall efficiency should be reduced with an additional 5-10%.

The stock size estimates (S_1 upper and S_2 lower figures) for alternative values of s and e are:

s \ e	0.8	0.7
0.85	14.3 17.7	12.5 15.5
0.80	13.4 16.7	11.8 14.6

Based on this, the total stock of adult autumn spawners in the northern North Sea in the summer of 1966 was

$$12 - 17 \times 10^9 \text{ herring.}$$

Using an average number of 5.2 per kilogram this corresponds to

2.3 - 3.3 million tons.

This estimate is considerably higher than that obtained by Haraldsvik (1969a). He calculated the stock to be about 1 million tons, of which about one half was found in the Shetland area, and another half in the north-eastern North Sea. As outlined above, these estimates were based on the returns of tags shortly after tagging and before a random dispersion of the tagged herring had taken place. Most of the returns, about 85%, came from the areas of release where the fishing was intense. Most likely, this resulted in an underestimation of the stock.

Analyses, by virtual population technique, carried out by the North Sea Herring Assessment Working Group provide estimates of the stock size (Anon. 1972) which is in general agreement with those obtained from tagging data. Depending on the value of the instantaneous mortality coefficient, M, the stock of herring in 1966 in the North Sea, 2-ringers and older, was found to be

$$M = 0.1 \qquad S = 10.8 \times 10^9$$
$$M = 0.2 \qquad S = 13.5 \times 10^9$$

The stock estimates based on the taggings in 1966 may be biased in several ways. Calculations were restricted to return data from area IVa, since very few returns with reliable accompaning data from localities outside this area were available. Migrations of tagged herring out of the area and untagged ones into the area increase the ratio of untagged/tagged herring as time elapse. This effect is likely to occur; tagged herring have been recaptured outside the area and young herring are known to invade the area from the south. Consequently, the stock in area IVa is overestimated. The total herring stock in the North Sea is, on the other hand, underestimated since the ratio untagged/tagged is lower in area IVa than in the rest of the North Sea. Most of the adult herring, however, are in summer found in area IVa.

These considerations lead to the conclusion that the estimate of 2.3 - 3.3 million tons probably is somewhat below the total size of the stock of adult herring in the North Sea (excluding Skagerrak) in the summer of 1966.

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Tab. 1. Tag returns (Experiment 97, Egersund Bank and Experiment 101, Shetland) and catch in tons.

Month	Shetland (IVa W) Returns E97	Returns E101	Catch	NE North Sea (IVa E) Returns E97	Returns E101	Catch	Central N.S. (IVb) Returns E97	Returns E101	Catch	Skagerrak (IIIa) Returns E97	Returns E101	Catch
Jan.						3 141						1 025
Feb.			5			37						
March			35			109						
April			12			3 868						
May						39 588						
June			35 367	8		42 534						
July	8	19	50 287	113		27 630				4		1 026
Aug.	24	303	54 348	114	20	12 797						9 945
Sept.	1	17	2 744	34	30	10 998				1	1	7 047
Oct.			91	35	27	13 844				4	4	1 278
Nov.										1		
Des.												
1966	33	339	142 889	304	77	154 545				10	5	20 321
Jan.					2	17						31
Febr.				1	7							61
March						27						
April				3	1	923						
May				27	3	14 178			1 385			
June	9	15	13 256	58	7	52 714	3	3	11 098			
July		3	3 863	5	2	21 880			1 033			11 475
Aug.	4	16	9 726	11	7	22 340			760			43 160
Sept.	1	1	221	18	8	574						5 181
Oct.	2			3	1	1 372						448
Nov.		1		1		2						7
Dec.						229					1	286
1967	16	36	27 066	127	38	114 254	3	3	14 275		1	60 650
Jan.				8	4	1 124						337
Febr.						9						
March			89			437						
April	1		89	3		5 176				4		
May			417	6	7	10 773			535	2	1	1 317
June	4		35 338	3	1	8 477						803
July	8	22	33 906		1	4 063						
Aug.		2	5 996			1 581	1		8 340		2	38 594
Sept.			429	1		42			696	1		3 076
Oct.			170			271			78			182
Nov.					1	3 370			103			3 363
Dec.		1	56			2 624						629
1968	13	25	76 491	21	14	37 947	1		9 751	7	3	48 301

Table 2. Data used for estimates of stock size.
C is catch of autumn spawners in numbers,
corrected for recruitment.

Area	Returns		Catch, tons	No/kg	Autumn sp.,%	Recr., %	C, $x10^6$
IVa E	1967	52	27 066	5.3	79.9	16.4	95.9
	1968	38	76 491	5.6	75.8	47.2	171.4
IVa W	1967	165	114 254	8.7	78.7	39.3	474.8
	1968	35	37 947	7.2	81.6	70.2	66.4
IVa	1967	217					570.7
	1968	73					237.8