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**COALFISH TAGGING EXPERIMENTS
AT ICELAND**

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INTRODUCTION

Very few coalfish tagging experiments have previously been carried out in Icelandic waters. Results of tagging experiments which have been conducted in other fishing areas in the north-east Atlantic have shown that migrations of coalfish between different fishing areas occur on a substantial scale but with rather variable intensity.

Results of Norwegian tagging experiments on the Norway coast have been reported by Olsen (1959a, 1959b, 1961). He showed that the mature coalfish of the Norwegian coast and north-east Arctic made regular annual spawning migrations southwards to the spawning areas off western Norway and in the northern North Sea. Olsen also concluded from recaptures of Norwegian-tagged fish at both Iceland and Faroe that catches from these two areas during the period under study contained a considerable element of coalfish of Norwegian origin. Similarly English (Jones, 1961) and Faroese (Joensen, 1961 and personal communication) liberations of tagged fish at Faroe, west of Scotland and on the Norwegian coast have also shown that there is considerable mixing of coalfish from different regions. Table 1 gives a summary of recaptures from coalfish tagged in the English experiments prior to 1964. Recaptures of fish tagged on Faroe Bank in particular have been widespread, with a high proportion of recaptures being reported from Iceland. The available evidence suggests that the magnitude and direction of migrations between different fishing areas vary from year to year.

The present experiments carried out at Iceland in 1964 and 1965, which this paper describes, were designed to study the dispersal of young fish from the inshore areas into deeper water where they become available to the international trawler fleet. Recaptures would also provide information on local spawning migrations and would indicate the magnitude of emigration from Iceland. The recapture data could also be used to study mortality rates and growth.

The experiments were conducted jointly by the Fisheries Laboratory, Lowestoft and the Marine Research Institute, Reykjavik. Two liberations

TABLE 1.
Distribution of recaptures of coalfish tagged in English experiments prior to 1964.
Liberations at Iceland not included.

Tagging locality	Recapture locality							Total		
	Northern Norway	Halten Bank	Svinøy Bank	Northern North Sea	North and west Scotland	Faroe Plateau	Faroe Bank		Iceland	Unknown
Northern Norway	127	8	6	9	3	1	1	4	3	162
Halten Bank	1	2	1		1					5
Svinøy Bank		1	11	4	3		1			20
Northern North Sea				2					1	3
North and west Scotland .	1			9	35		2	1	3	51
Faroe Plateau				3	3	24	2	8	1	41
Faroe Bank	3	2		7	15	23	43	26	7	126

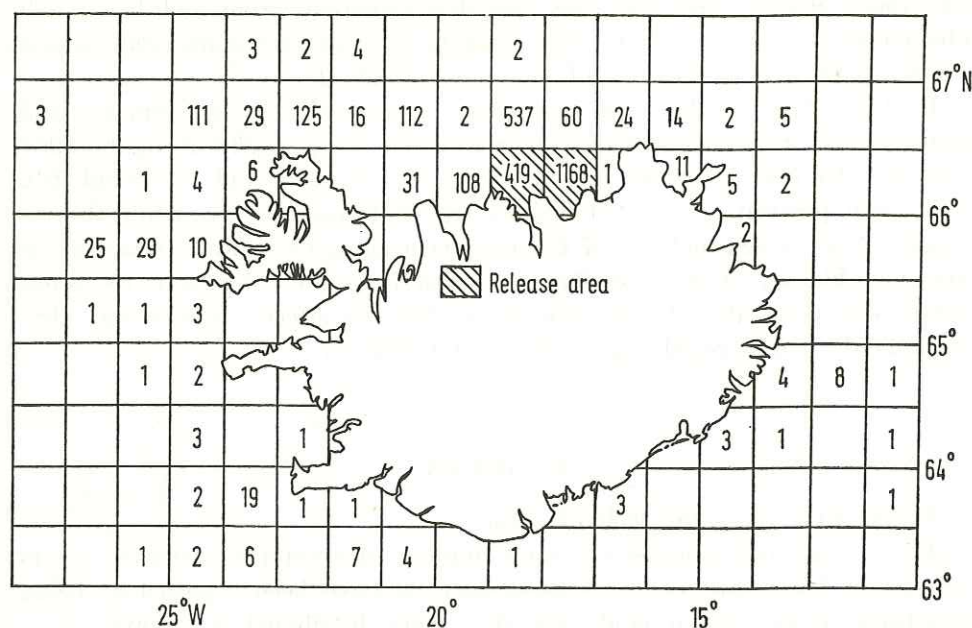


FIGURE 1. Distribution by statistical rectangles of all recaptures of known position of recapture from the 1964 and 1965 experiments combined.

were planned, one year apart; each was to consist of 3000 fish, and the conditions of capture, tagging and release were to be kept as similar as possible for the two experiments.

LIBERATION DATA

All fish were obtained from commercial purse-seine catches in the summer fishery for coalfish off the north coast of Iceland. The fish were transferred to a keep-net from which they were removed individually for tagging with Lowestoft plastic flag tags. All fish were in perfect condition and tagging mortality was expected to be very low. The smallest fish obtained in the catches, the I-group, and most of the II-group, were considered too small for tagging.

In 1964, 2999 coalfish were tagged during the last two weeks of July; the same number was released during the same period of 1965. In both years the tagging took place in the area between Siglufjord in the west and Mánáreyjar in the east (Fig. 1). Length compositions of the tagged fish are given in Table 2, where the length compositions of the fish rejected as being too small for tagging are also shown, in parentheses. Otolith samples for age determination were obtained at the time of tagging. Age-length keys, both

from these otoliths and also from age determinations from otoliths of fish subsequently recaptured, have been used to reconstruct the age composition of the tagged fish at the time of liberation (Table 2).

In 1964, fish of the 1960 year-class (4-year-olds) were dominant and made up 86% of the fish tagged, the remainder being nearly all of the 1961 year-class. In 1965, the 1960 and 1961 year-classes, as 5- and 4-year-old fish, were again present and contributed 25 and 26% respectively, while the remainder were 3-year-old fish of the 1962 year-class. From the overlap of the same year-classes in the two liberations and from the subsequent recapture pattern it appears that the experiment in 1965 was effectively a second addition into the same population as the first liberation.

RESULTS

1. Emigration from the Iceland area.

From these two releases the total number of recaptures reported up to the end of 1969 was 3175. Of these only 20 have been reported as being recaptured outside the Iceland area; they were distributed as follows:

<i>Recapture area</i>	<i>Number of recaptures</i>
Faroe	8
Norway coast	6
West Greenland	3
Northern North Sea	2
North of Scotland	1

It is possible that some of these recaptures were incorrectly reported, but even assuming all to be valid, they constitute less than 1% of total recaptures, and it is clear that there has been no large-scale emigration from Iceland in these experiments.

2. Migrations around Iceland.

All recaptures from both experiments for which the recapture positions are known have been plotted by statistical rectangle in Figure 1. It can be seen that during the five-year total recapture period recaptured fish have been reported from virtually all around the Icelandic coastline. The pattern of dispersion from the tagging is best studied from charts showing the distribution of recapture prepared for three-monthly periods as in Figures 2 to 5. These charts show the distribution of recaptures for which the recapture position is known for both experiments combined, with the exception of year 1, when only fish from the first experiment had been released. Recaptures from the two liberations have been combined because the pattern of recaptures

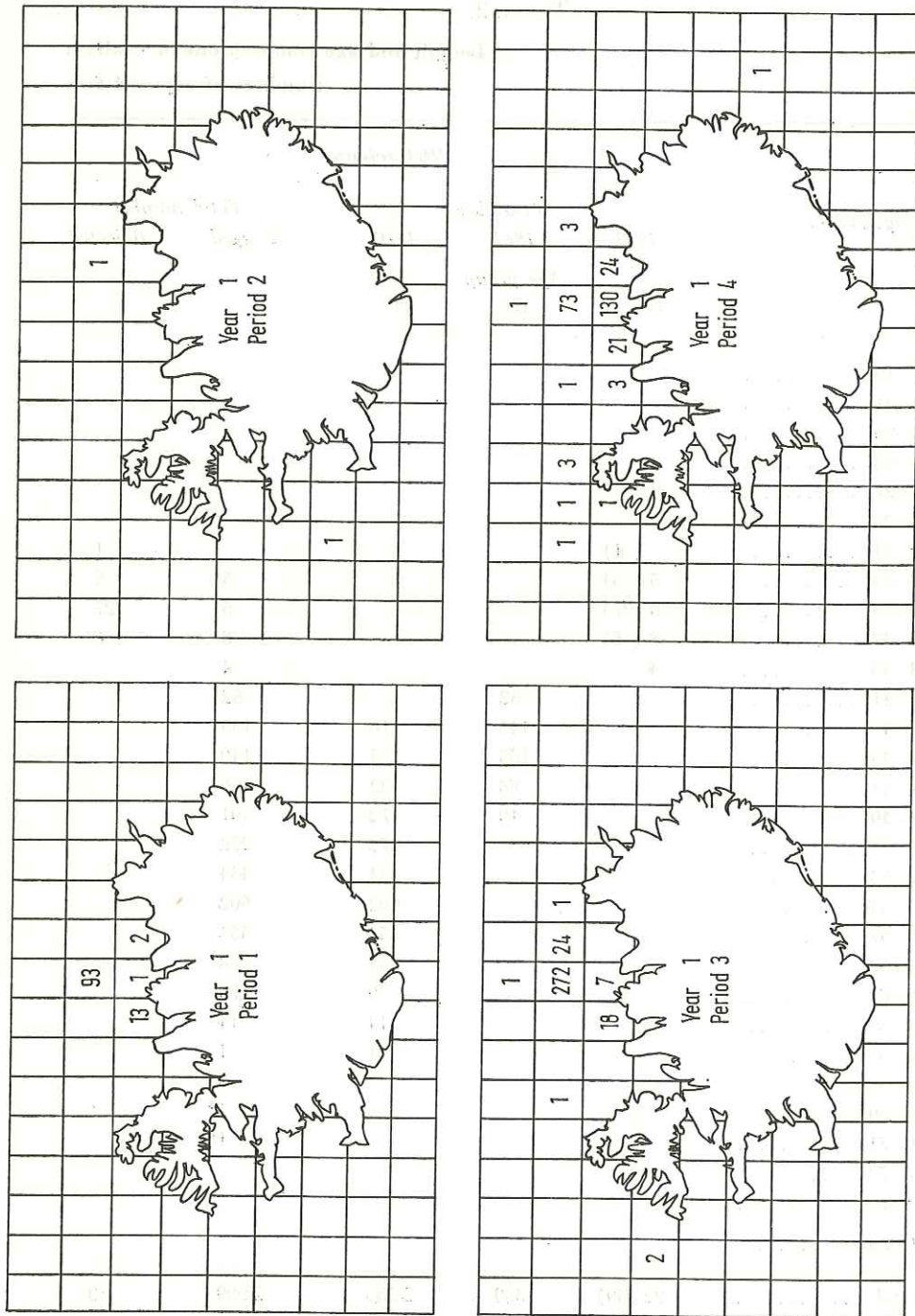


FIGURE 2. Distribution by statistical rectangles of recaptures in the first year at liberty. 1964 experiment.
 Period (1) July-September 1964,
 (2) October-December 1964,
 (3) January-March 1965,
 (4) April-June 1965.

TABLE 2.

Length and age compositions of coalfish
Numbers of rejected fish

Length (cm)	1964 releases				
	1962	Year-class		Total number	
		1961	1960	Tagged	Rejected
	II	Age group			
	III	IV			
18-19					
20-21					
22-23					
24-25					
26-27					
28-29					
30-31	(1)				
32-33	5 (5)			5	1
34-35	5 (27)			5	5
36-37	8 (6)			8	27
38-39	4			4	6
40-41		52		52	
42-43		145	10	155	
44-45		105	35	140	
46-47		68	122	190	
48-49		19	172	191	
50-51			272	272	
52-53			434	434	
54-55			602	602	
56-57			554	554	
58-59			288	288	
60-61			79	79	
62-63			14	14	
64-65			1	1	
66-67				3*	
68-69				1*	
70-71				1*	
72-73					
74-75					
Unknown					
Total	22 (39)	389	2 583	2 999	39

* Age unknown.

tagged in the 1964 and 1965 experiments.
are shown in parentheses.

1965 releases						
1964	1963	Year-class 1962	1961	1960	Total number	
I	II	Age group III	IV	V	Tagged	Rejected
(2)						2
(10)						10
(19)						19
(9)						9
	(1)					1
	(1)					1
	(5)					5
	(15)					15
	(8)					8
	(5)					5
	7	42 (1)			49	1
		291			291	
		614 (2)			614	2
		424			424	
		96			96	
		6	47		53	
			145	12	157	
			301	22	323	
			207	44	251	
			51	102	153	
			10	133	143	
			17	183	200	
				166	166	
				65	65	
				10	10	
					1*	
					1*	
					2*	
(40)	7 (35)	1 473 (3)	778	737	2 999	78

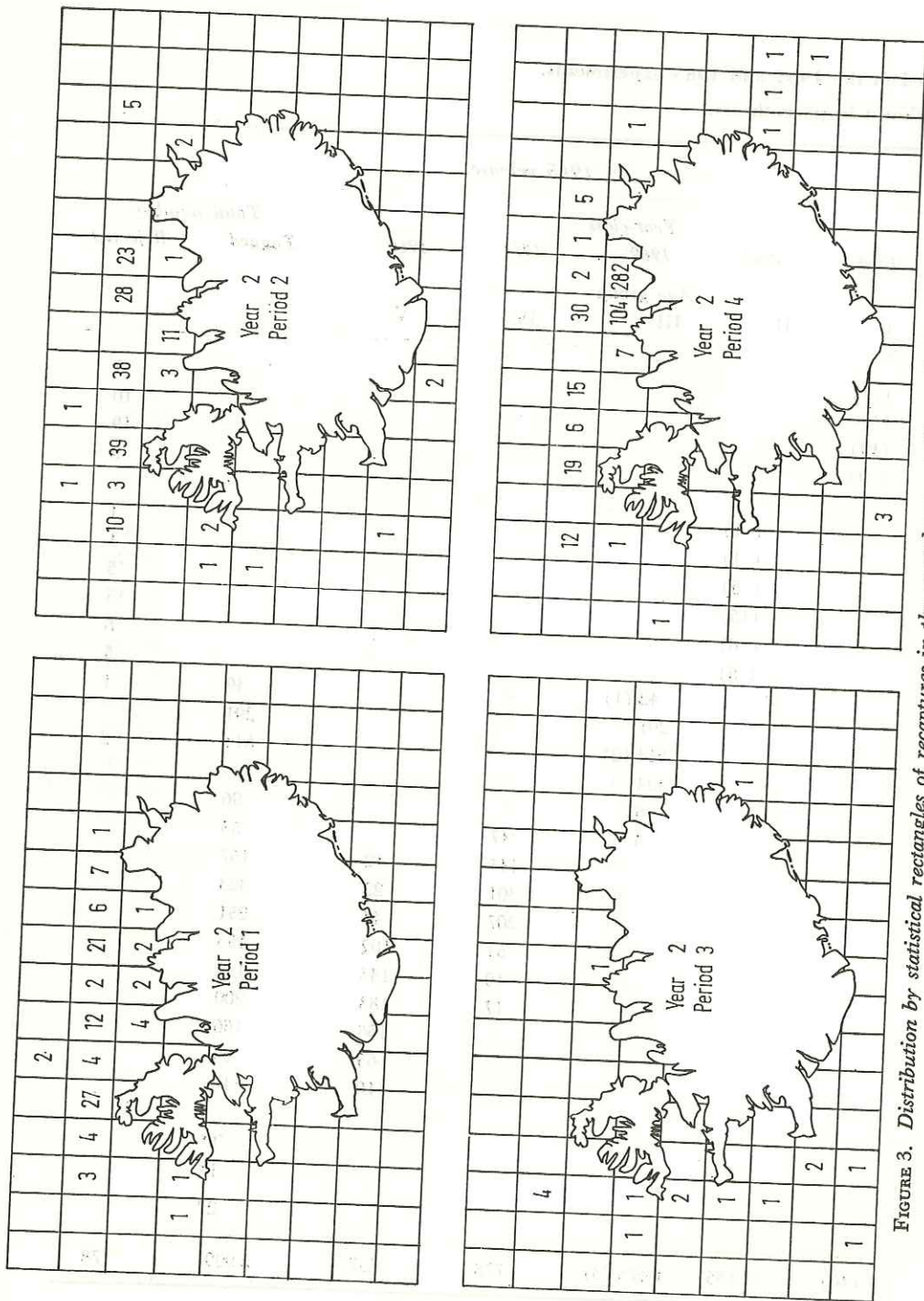


FIGURE 3. Distribution by statistical rectangles of recaptures in the second year at liberty. Both experiments combined.
 Period (1) July-September 1965,
 (2) October-December 1965,
 (3) January-March 1966,
 (4) April-June 1966.

FIGURE 3. Distribution by statistical rectangles of recaptures in the second year at liberty. Both experiments combined.
 Period (1) July-September 1965,
 (2) October-December 1965,
 (3) January-March 1966,
 (4) April-June 1966.

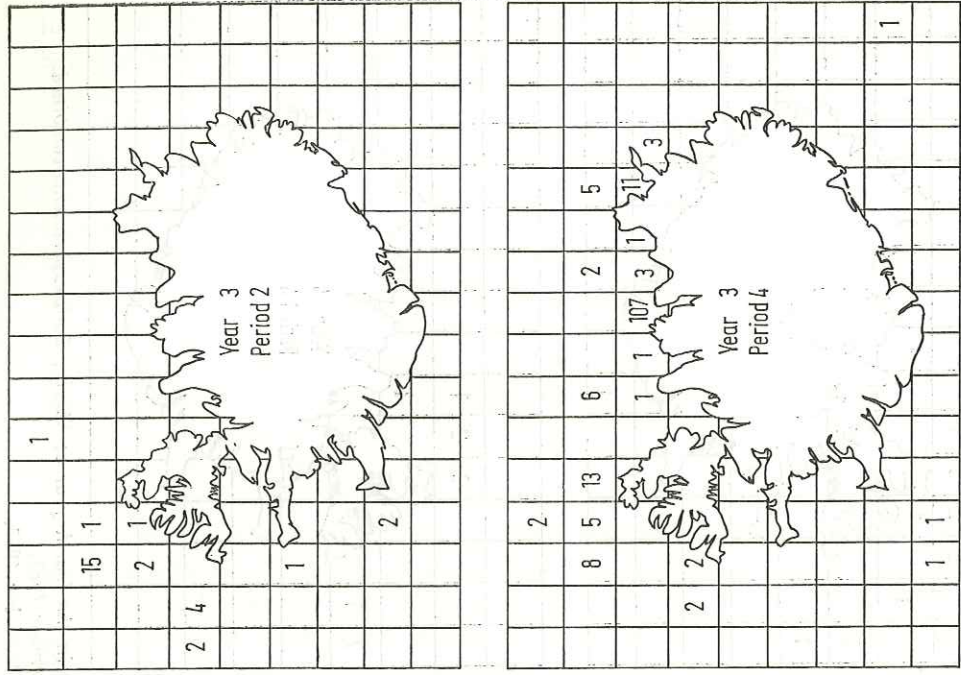
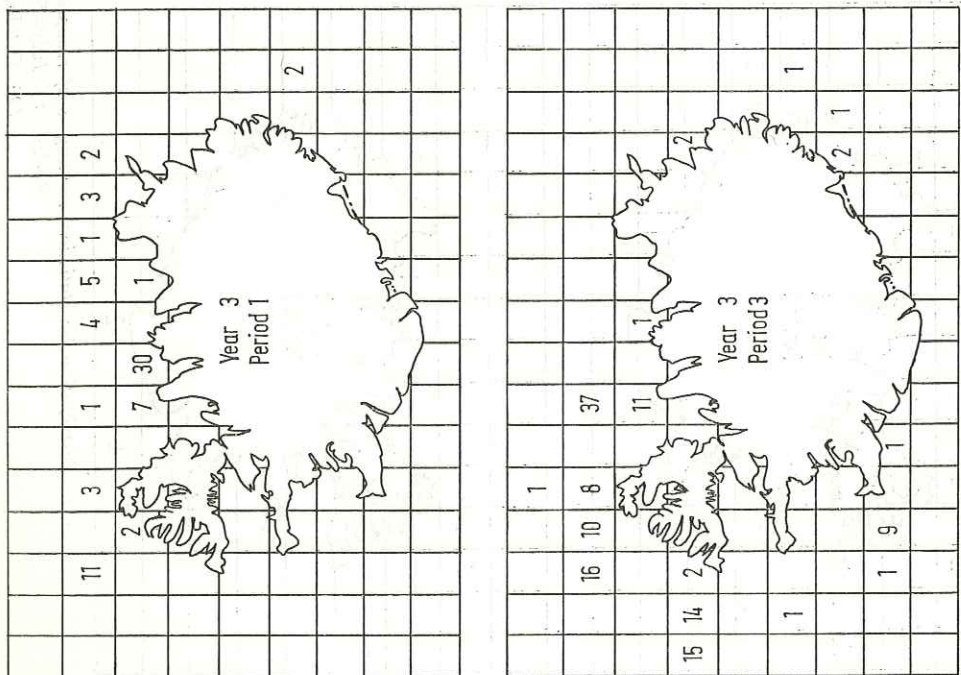


FIGURE 4. Distribution by statistical rectangles of recaptures in the third year at liberty. Both experiments combined.
 Period (1) July-September 1966,
 (2) October-December 1966,
 (3) January-March 1967,
 (4) April-June 1967.



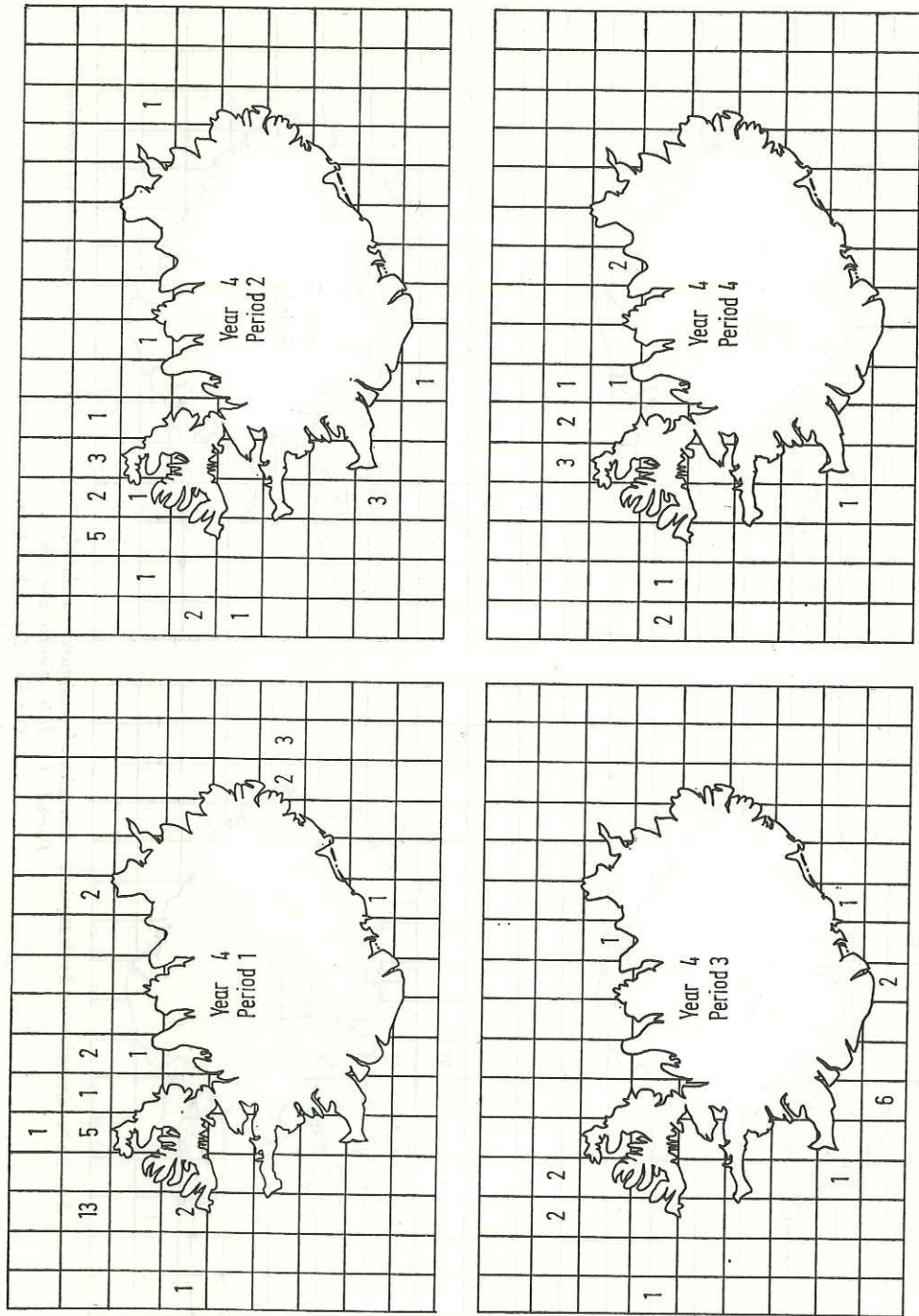


FIGURE 5. Distribution by statistical rectangles of recaptures in the fourth year at liberty. Both experiments combined.
 Period (1) July-September 1967, (2) October-December 1967,
 (3) January-March 1968, (4) April-June 1968.

has been very similar for both experiments, the tagged fish in both cases being effectively of the same population. In interpreting the migration pattern it must be remembered that the distributions of recaptures are uncorrected for fishing effort, which is not known for many of the fisheries, and so could be equally representative of the distribution of fishing effort as of the distribution of fish. However, in this case, although fishing effort is known not to be distributed equally over the whole area it is believed that there is enough fishing all around the coast for recaptures to be reasonably representative of the distribution of the tagged fish.

During the first year at liberty virtually all the tagged fish were recaptured off the north coast, mainly in the vicinity of the liberation area. During this time only a very small proportion of the tagged fish could be expected to be sexually mature, and any indication of a spawning migration would not be expected at this stage.

From the second year onwards an increasing proportion of the tagged population became sexually mature, and a regular seasonal pattern of movement developed which was repeated year by year. In Period 1 (July–September) of the second and third years the majority of recaptures were reported from the north coast. In the same period of the fourth year most of the recaptures were recorded from the northwest corner. During Period 2 (October–December) of the second year, and particularly in the third and fourth years, the main centre of tag recapture moved westwards to the north-west corner and this movement continued in Period 3 (January–March) when most of the recaptures were recorded from off the west and south-west coasts. During Period 4 (April–June) of the second and third years the fish returned to the summer fishery on the north coast. Recaptures did not reappear in the north coast summer fishery after the summer of 1967, and in subsequent summers the main area of recapture was the north-west corner.

The pattern of recaptures indicates that the tagged population was more or less static on the north coast during the first year, but subsequently, as an increasing proportion of the population became sexually mature, a regular annual cycle developed with a migration to the west and south-west coasts in the spring. This movement is almost certainly associated with spawning, the main spawning area for coalfish at Iceland being off the south-west corner. There was a return migration to the north coast where the fish arrive in the early summer, but after 1967 the fish returning from the spawning migration did not appear to go any further east than the north-west corner and did not return to the area of the Icelandic summer fishery. By this time the majority of surviving tagged fish would have been six or more years old, and from the samples of fish obtained in 1964 and 1965 it appears that fish older than five years are not taken in the Icelandic summer fishery; thus the summer distribution of tagged fish after 1967 is consistent with what is known about the summer fishery, which is essentially a fishery for juvenile

FIGURE 5. Distribution by statistical rectangles of recaptures in the fourth year at liberty. Both experiments combined.

Period (1) July–September 1967,
 (2) October–December 1967,
 (3) January–March 1968,
 (4) April–June 1968.

TABLE 3.

Distribution of recaptured tagged fish in three-month recapture periods from the 1964 experiment, with a breakdown by nationality of recapturing vessel, and by recapture gear.

3-month recapture period	Total recap- tures	Nationality of recapturing vessel				Recapturing gear		
		Icelandic	English	German	Others and unknown	Purse seine	Trawl	Others and unknown
1	205	204		1		153	51	1
2	2	1	1				2	
3	332	329	3				324	8
4	515	502	10	3		430	81	4
5	91	35	49	4	3		89	2
6	119	39	60	15	5		116	3
7	10	4	1	5			9	1
8	133	93	22	17	1	92	40	1
9	30	14	7	6	3	6	22	2
10	30	1	4	24	1		26	4
11	52	5	24	19	4		50	2
12	54	23	10	20	1	21	32	1
13	13	5	3	5			13	
14	9	1	2	6			9	
15	2	1		1			2	
16	8	1	1	5	1		8	
17	3	1		2				3
18	3	1		1	1			3
19	5	3		1	1			5
20								
21	1				1			1
Total .	1 617	1 263	197	135	22	702	874	41

fish. A few recaptures have been reported from the east and south-east coasts. Whether the fish reached these parts of the coast by moving clockwise from the north coast or whether they moved anti-clockwise along the south coast, perhaps after spawning in the south-west, is not clear, but the latter possibility seems more likely.

3. Distribution of recaptures between different gears and fishing vessels of different nationalities.

Detailed recapture data for the two experiments are given in Tables 3 and 4. A certain amount of adjustment was made to the original data to make allowance for recaptured fish which could not be definitely assigned to a

TABLE 4.

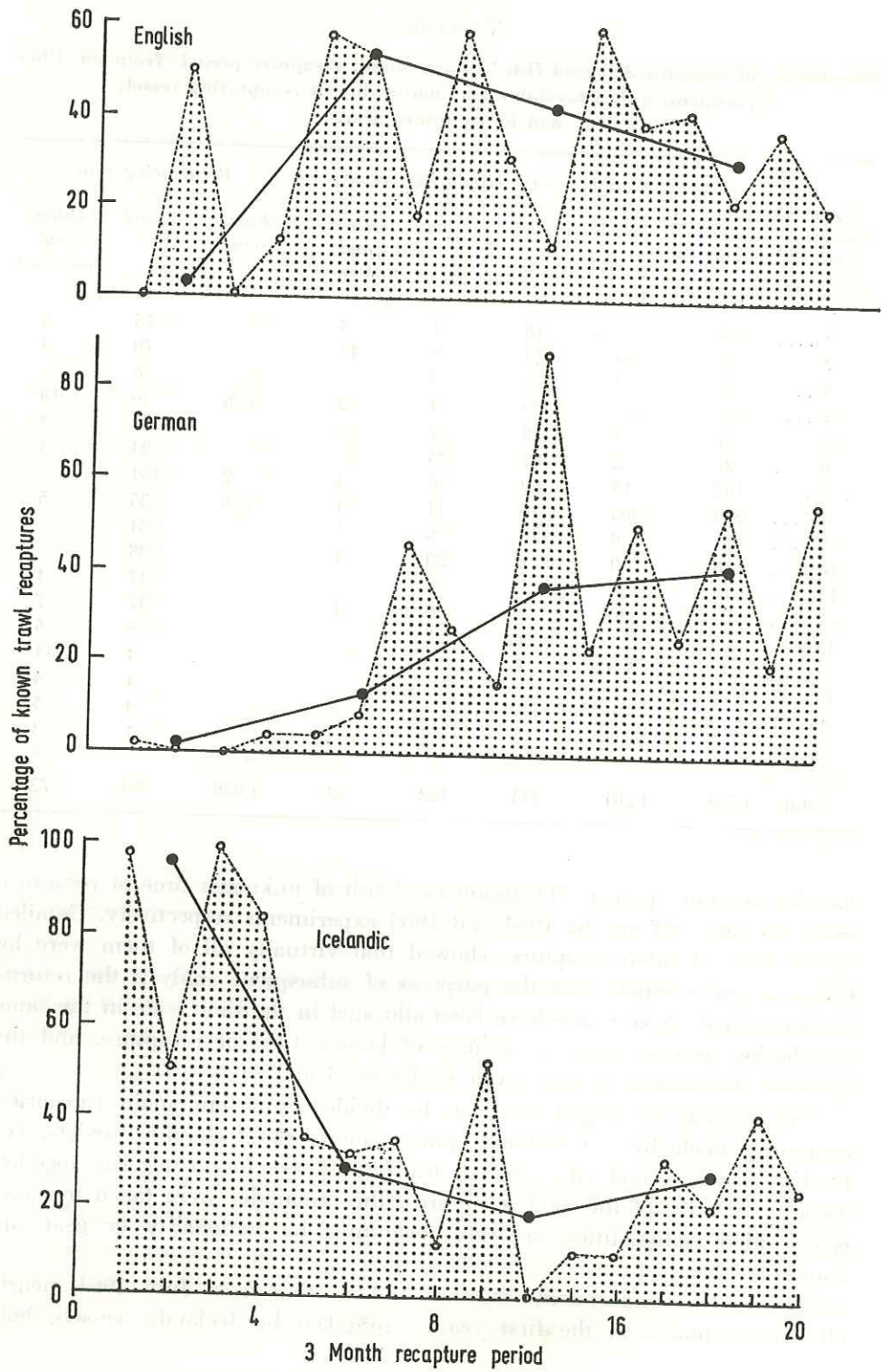
Distribution of recaptured tagged fish in three-month recapture periods from the 1965 experiment, with a breakdown by nationality of recapturing vessel, and by recapture gear.

3-month recapture period	Total recap- tures	Nationality of recapturing vessel				Recapturing gear		
		Icelandic	English	German	Others and unknown	Purse seine	Trawl	Others and unknown
1	29	5	18	1	5		25	4
2	82	23	44	2	13		79	3
3	8	3	2	3			8	
4	832	803	23	4	2	778	36	18
5	61	34	18	7	2		58	3
6	27	2	2	23			24	3
7	103	14	69	16	4	2	101	
8	296	265	16	14	1	256	35	5
9	31	9	15	6	1		31	
10	38	9	8	20	1		38	
11	18	8	7	3			17	1
12	24	10	4	9	1		17	7
13	9	1	1	7			4	5
14	12	6	1	5			1	11
15	5	4	1				1	4
16	9	2	3	2	2		4	5
17	4	3	1				1	3
Total	1 588	1 201	233	122	32	1 036	480	72

specific recapture period. The numbers of fish of unknown time of recapture were 387 and 570 for the 1964 and 1965 experiments respectively. Detailed examination of these recaptures showed that virtually all of them were by Icelandic purse-seiners. For the purposes of subsequent analysis the returns of unknown recapture time have been allocated in the time scale in the same distribution as purse-seine recaptures of known time of recapture, and the resultant distribution is that given in Tables 3 and 4.

The returns of tagged fish can be divided into four main categories: recaptures made by (a) Icelandic purse-seiners, (b) Icelandic trawlers, (c) English trawlers, and (d) German trawlers. These four categories together account for 96% of the total recaptures; the remainder were taken by other gears, other nationalities, or were recaptures by nationality or gear unknown.

Taking both experiments together and starting from July 1964, nearly all the recaptures in the first year were taken by Icelandic vessels, both



trawlers and purse-seiners. The temporal distribution of purse-seine recaptures shows a strictly seasonal pattern with sharp peaks of recaptures in the summers of 1964 to 1967, but after 1967 the tagged population did not return to the summer purse-seine fishery. The pattern of trawl recaptures shows that in the first year following July 1964 virtually all were taken by Icelandic trawlers (Fig. 6). Subsequently, the proportion of the total trawl recaptures taken by Icelandic vessels declined while that taken by English vessels increased, reaching its highest level in the second year. This subsequently declined as the proportion of recaptures by German trawlers increased.

Thus, taken with the pattern of geographical distribution described in the previous section, it can be seen that during the first year at liberty the tagged population remained in the inshore areas of the north coast of Iceland where it was subject to exploitation by Icelandic vessels, both purse-seiners and trawlers. As the fish grow larger and an increasing proportion attain maturity, the seasonal migration pattern is accompanied by a more offshore distribution when the fish become available to English trawlers and later to German trawlers. Up to 1967, however, the fish returned each summer to the seasonal purse-seine fishery. The English fleet at Iceland tends to catch a larger proportion of small coalfish than the German fleet and this would be consistent with the observed pattern of recaptured tagged fish, showing recruitment to the English trawl fishery before recruitment to the German fishery.

4. Mortality rates.

The total mortality rate (Z) has been estimated by two methods. From a linear regression fitted to a plot of the logarithm of numbers recaptured in annual time periods (Fig. 7) an estimate of the total mortality rate is given by the slope of the line. Individually the two experiments give estimates of $Z = 1.15$ and 1.14 , the regression lines for the two experiments being virtually identical. The fitted line shown in Figure 7 is that for the two experiments combined, from which $Z = 1.15$. As the same number of fish was tagged in both experiments, an alternative method is to calculate Z for a given time period from the logarithm of the ratio of recaptures from the 1965 experiment to the recaptures from the 1964 experiment, and this gives the following result:

FIGURE 6. Percentages of known trawl recaptures taken by (a) English, (b) German and (c) Icelandic trawlers in each three month recapture period. The bold lines join annual averages.

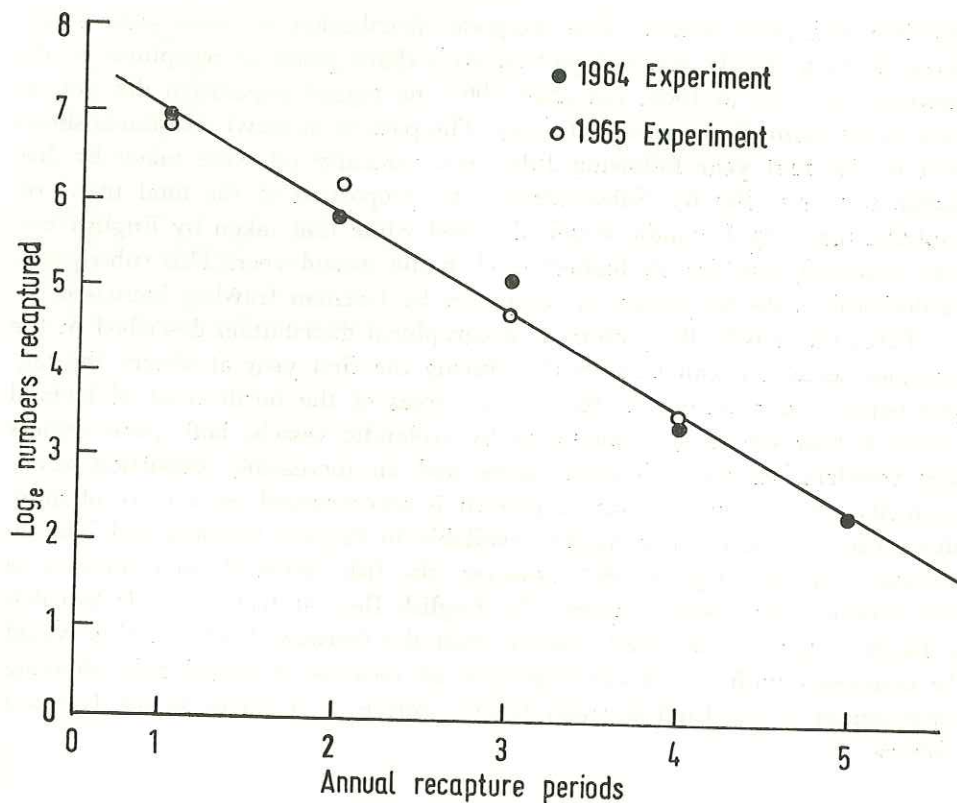


FIGURE 7. Log_e numbers of tagged fish recaptured in annual recapture periods for the two experiments. The line shown is fitted to the points of both experiments.

Annual period	Recaptures from 1964 experiment	Recaptures from 1965 experiment	Z
1. 1964-5	1 054		
2. 1965-6	353	951	0.99
3. 1966-7	166	487	1.08
4. 1967-8	32	111	1.24
5. 1968-9	11	35	1.16

The results from the two methods of calculation are in good agreement.

In order to estimate the magnitude of the fishing mortality coefficient, F , the recaptured tagged fish were analysed by the method of virtual populations (Gulland, 1965). For the purposes of the analysis, recaptures were grouped into recapture periods of three months' duration. To initiate the calculation, an initial value of the quarterly fishing mortality coefficient (F_t) has to be assumed for the last recapture period and a value of $F_t = 0.25$ was used. The value of the "other loss" coefficient, X , was fixed for the whole period over which recaptures were taken. Trial values of X_t were used to

TABLE 5.

Estimates of the quarterly fishing mortality coefficient, F_t , and the tagged fish population size by recapture period, calculated by the method of virtual populations for the two experiments.

Recapture period, t (3 months)	1964 experiment		1965 experiment	
	Tagged population at liberty	F_t	Tagged population at liberty	F_t
1	2 971	0.076		
2	2 468	0.001		
3	2 209	0.173		
4	1 665	0.394		
5	1 006	0.100	2 985	0.010
6	815	0.167	2 647	0.033
7	618	0.017	2 294	0.004
8	544	0.298	2 047	0.557
9	362	0.092	1 051	0.063
10	296	0.113	884	0.033
11	237	0.263	766	0.153
12	163	0.428	589	0.749
13	95	0.156	249	0.140
14	73	0.139	194	0.231
15	57	0.038	138	0.148
16	49	0.189	107	0.270
17	36	0.091	73	0.139
18	30	0.112	57	0.252
19	24	(0.250)	40	0.143
20			31	0.368
21			19	(0.250)
\bar{F}_t		0.158		0.206
Mean annual F		0.63		0.82
Assumed annual X		0.44		0.44
Z		1.07		1.26

obtain a value of X_t which on back calculation gave an initial population of 3 000 fish, which was the number of tagged fish liberated in each experiment. Quarterly values of $X_t = 0.11$ gave initial tagged populations of 2 971 and 2 985 for the 1964 and 1965 experiments respectively. The virtual population analysis gives estimates of the tagged population size and the fishing mortality rate for each recapture period, and the results are set out in Table 5. Average values of F_t were 0.16 and 0.21 and were obtained from the two experiments with corresponding annual values of $F = 0.63$ and 0.82. Conspicuous in the pattern of F_t are the seasonal peak values corresponding with the intensive exploitation in the summer purse-seine fishery (Fig. 8).

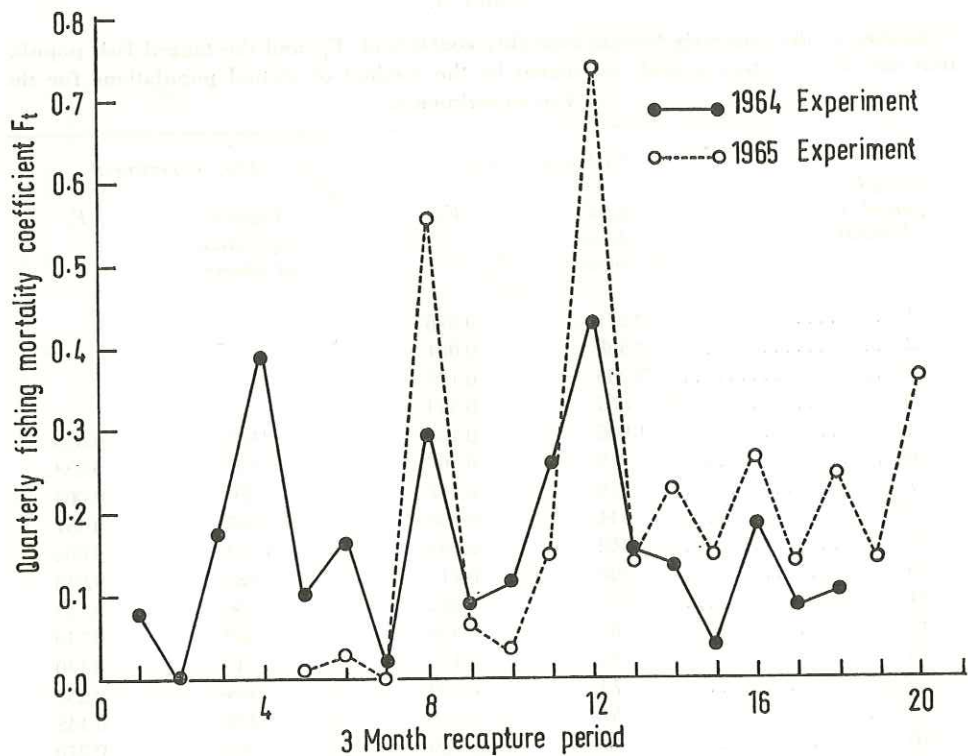


FIGURE 8. Temporal trend of the estimated quarterly fishing mortality coefficient F_t , for the two experiments shown separately.

For each recapture period the calculated values of F_t have been averaged for the two experiments and the average values have been subdivided (Table 6) in the ratio of tags recaptured by the different fisheries: Icelandic purse-seine, Icelandic trawl, English trawl and German trawl. Over the five years that the tagged fish have been recaptured the major source of fishing mortality has been the Icelandic purse-seine fishery, which has been responsible for 30% of the fishing mortality. As was noted in an earlier section, the tagged fish did not return to the purse-seine fishery after the fourth summer (1967) and so the fishing mortality component due to this fishery did not continue after that year. However, the trawl fisheries will be expected to continue to catch tagged fish after the five-year recapture period studied, but by the end of this period the tagged population had been depleted to only a very small fraction (about 0.8%) of the original population (Table 5). It should be noted that during the last four quarterly recapture periods the "unknown and others" category of returns accounts for a large proportion of total recaptures and so the estimates of F_t for the individual fisheries are probably unreliable.

TABLE 6.
Average quarterly fishing mortality coefficient, F_t , for the two experiments,
broken down by individual fisheries.

Recapture period	Fishing mortality coefficient, F_t					
	Average total value	Purse seine	Icelandic trawlers	English trawlers	German trawlers	Unknown and others
1	0.076	0.057	0.019			
2	0.001		0.001	0.001		
3	0.173		0.167	0.002		0.004
4	0.394	0.329	0.052	0.008	0.002	0.003
5	0.055		0.018	0.031	0.002	0.004
6	0.100		0.031	0.052	0.008	0.008
7	0.011		0.004	0.002	0.005	0.001
8	0.428	0.386	0.004	0.020	0.009	0.008
9	0.077	0.005	0.036	0.021	0.011	0.004
10	0.073			0.008	0.060	0.005
11	0.208	0.003	0.023	0.122	0.047	0.013
12	0.589	0.466	0.012	0.044	0.057	0.010
13	0.148		0.047	0.061	0.037	0.003
14	0.185		0.039	0.039	0.102	0.004
15	0.093		0.037	0.033	0.019	0.005
16	0.230		0.043	0.036	0.101	0.050
17	0.115			0.010	0.086	0.019
18	0.182			0.012	0.073	0.097
19	0.143			0.014	0.014	0.114
20	0.368			0.123	0.082	0.164
Total	3.649	1.246	0.533	0.639	0.715	0.516

The mortality estimates have been made with no correction for errors. The fish were in perfect condition at the time of tagging and tagging mortality would be expected to be small enough to be negligible. Another potential source of error is non-reporting of recaptured tags. This certainly occurs to some degree, but no quantitative estimates are available of the extent to which it occurs in the fisheries involved here. Non-reporting of recaptured tags would not affect the estimates of total mortality, but would result in underestimation of fishing mortality. The other main sources of error in tagging experiments are due to factors which result in overestimation of the total mortality rate: tag shedding, tags resulting in additional mortality to the tagged fish, or emigration. These latter sources of error are considered to be minimal in the present study. Over the experimental period, with the type of tag used, tag shedding would not be expected and there is no evidence that tagging makes the tagged fish more vulnerable. Recaptures of tags from

TABLE 7.

Comparison of mean length at age of year-classes 1960—63 estimated (a) from the tagging experiments and (b) from English commercial landings.

Year-class	Age group						
	II	III	IV	V	VI	VII	VIII
1963	(a) 35.9 (b) 43.0						
1962	(a) 34.8 (b) 42.5	43.2 49.5	54.0 60.8	58.7 67.4	69.8 73.5		
1961	(a) (b)	43.8 49.6	57.6 56.2	61.0 65.2	67.6 74.0	76.3 81.7	
1960	(a) (b)		53.9 54.0	60.9 63.8	68.9 73.8	77.2 80.5	84.5 86.0
Average	(a) 35.4 (b) 42.8	43.5 49.6	55.2 57.0	60.2 65.5	68.8 73.8	76.9 81.1	84.5 86.0

outside the Iceland area have been very few and emigration does not appear to be a serious problem. As explained above, the value of the "other loss" coefficient X giving the best fit to the data was X (annual) = 0.44. It is likely that this coefficient contains a component other than natural mortality and because of non-reporting of tags fishing mortality could have been underestimated. From experience with similar gadoid stocks a natural mortality coefficient of 0.3 would probably be more realistic. However, it is reasonable to assume that the true value of the annual fishing mortality coefficient for Icelandic coalfish from the north coast nursery ground over the age range three to ten years lies in the range $F = 0.70$ to 0.85 , indicating intensive exploitation.

5. Age validation and growth rate.

Recaptures of tagged fish provide data on growth in length for known periods of time at liberty and these data can be used to validate age determinations. Coalfish age determinations are normally made from otoliths, where the rings seen in cross section are assumed to be annual. There has never been any serious doubt that the rings are deposited annually but no attempt at validation has been made within this species. The approach adopted here has been to make a comparison between Walford plot regressions for data of mean lengths for different age-groups and data of length of tagged fish before and after annual periods at liberty. The data for mean lengths of fish of different ages are shown in Table 7, and both the data from the

TABLE 8.

Mean length of age-groups caught in the purse-seine fishery at the time of tagging (shown bold) and subsequent mean lengths of the same year-classes calculated from recaptures of tagged fish at yearly intervals.

Year-class	Age group							
	I	II	III	IV	V	VI	VII	VIII
	1964 releases							
1962		34.8	41.5	53.8	57.8			
1961			43.8	60.2	59.6	63.8		
1960				53.9	60.1	69.9	79.2	85.9
	1965 releases							
1964	22.3							
1963		35.9						
1962			44.8	54.1	59.5	69.8		
1961				54.9	62.3	71.3	76.3	92.9
1960					61.7	67.9	75.1	83.1

tagging experiments (derived from averages of data, Table 8) and from the English commercial landings have been used. The incremental growth of tagged fish for periods at liberty of one, two and three years is shown in Table 9. The initial lengths of the fish at the time of tagging have been grouped in 5 cm length-groups and only fish which have been at liberty for 11–13 months (1 year), 23–25 months (2 years), and 35–37 months (3 years) have been used. Comparison of the regression lines of the Walford plot (l_t against l_{t+1}) gave no significant difference either of intercept or of slope (e^{-K} of the von Bertalanffy growth equation). The regression equations were:

- (a) from mean lengths of age-groups, $l_{t+1} = 0.951 l_t + 10.611$;
 (b) from annual length increments, $l_{t+1} = 1.022 l_t + 6.288$.

Significance of difference of slope $P > 0.10$, of intercept $P > 0.10$, 37 d.f. The results show that it is valid to assume that growth rings in coalfish otoliths are laid down annually.

A comparison of mean lengths of age-groups from the tagging data and similar data for the same year-classes estimated from English commercial landings (Table 7) show the former to be consistently smaller than the latter. This would be expected, since the largest numbers of recaptures, especially of the younger age-groups, are made by the Icelandic purse-seiners and trawlers fishing mainly in the inshore areas. As the fish grow they tend to have a more offshore distribution; thus the inshore fishery would tend to catch a higher proportion of slower growing fish, the faster growing ones moving

TABLE 9.

Summary of growth increments of tagged coalfish recaptured after one, two and three years at liberty.

The data have been grouped in 5 cm length groups at time of liberation.

Mean initial length (cm)	Months at liberty					
	11-13		23-25		35-37	
	Number	Mean growth increment	Number	Mean growth increment	Number	Mean growth increment
1964 experiment						
43	19	5.9	10	15.3	3	17.7
47	56	6.3	14	17.6	4	23.5
52	59	5.4	22	16.0	11	26.2
56	50	6.1	24	15.7	7	22.7
60	8	5.4				
1965 experiment						
43	109	9.6	34	14.9	2	23.5
46	137	9.0	48	16.1	3	26.0
52	32	7.4	11	14.9	1	21.0
57	61	7.4	13	12.2	7	21.4
62	21	6.1	4	12.5	1	23.0
66	8	4.8	3	15.3		

offshore where they would be recruited to the English and German commercial fisheries.

Growth data from the tagged fish do not give a satisfactory estimate of growth over the whole lifespan of the fish. The data cover the age-groups where growth is practically linear and the recruitment effects described in the previous paragraph tend to give an exaggerated apparent linearity. The result is that attempts to fit the von Bertalanffy growth equation give unrealistically high values of L_{∞} and low values of K . The best data for calculation of the growth parameters are those from English and German commercial landings. The German data of Schmidt (1959) have been used to calculate the growth curve shown in Figure 9. The calculated parameters of the von Bertalanffy growth equation were $L_{\infty} = 119.7$ cm, $K = 0.15$, $t_0 = -0.58$ years. Shown on the same figure are the points from the English commercial landings (average 1961-69) which are in very good agreement with the German data, the growth parameters calculated from the English data being $L_{\infty} = 127.7$ cm, $K = 0.13$, $t_0 = -0.90$ years. Also shown are the points for mean lengths of age-groups of the tagged population.

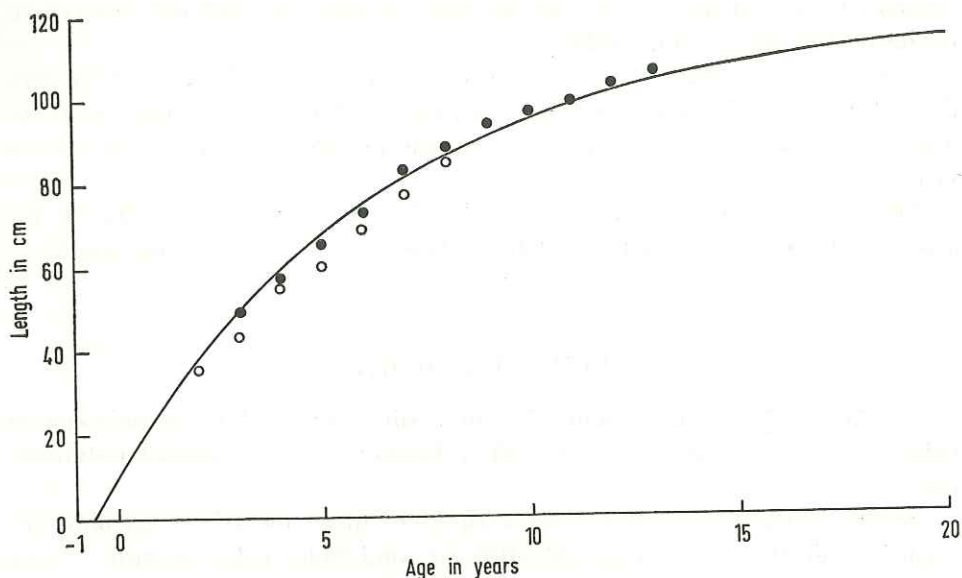


FIGURE 9. Growth curve for Icelandic coalfish. The line shown is that calculated from data of German commercial landings (Schmidt, 1959). Also shown are mean lengths of the age-groups in English commercial landings (average for 1961-1969) (solid points) and mean lengths of age-groups from the tagging experiments (open circles).

SUMMARY

Two batches of 3000 coalfish caught in the summer purse-seine fishery off the north coast of Iceland were tagged, one in the summer of 1964 and the other in the summer of 1965. They consisted of age-groups III to V.

Recaptures up to mid-1969 showed no evidence of any large-scale emigration from the Iceland area.

The pattern of recaptures within the Iceland area showed the tagged population to be relatively stationary during their first year at liberty (mid-1964 to mid-1965) in the inshore area on the north coast. Here they were exploited mainly by Icelandic trawlers and purse-seiners. In subsequent years, as the fish grew larger and an increasing proportion became sexually mature, an annual migration pattern developed. In the autumn and winter the fish left their summer grounds on the north coast and moved in an anti-clockwise direction to the west and south-west coasts. This was almost certainly a spawning migration to the main spawning grounds off the south-west of Iceland. There was a return migration to the north coast in the early summer. With increasing size the fish had a more offshore distribution when they became increasingly available to first the English and then the

German trawl fisheries. After the summer of 1967 the fish did not return to the north-coast summer fishery.

Estimates of mortality rates gave a total mortality coefficient of 1.15 with the fishing mortality coefficient in the range of 0.70 to 0.85, indicating intensive exploitation of the Icelandic coalfish in the age range three to ten years.

Growth data from recaptured tagged fish have been used to validate age determinations of coalfish from otoliths. The growth pattern is discussed.

ÍSLENZKT ÁGRIP

Merkingar þær á ufsa, sem hér um ræðir, voru gerðar sameiginlega af fiskirannsóknastofnuninni í Lowestoft á Englandi og Hafrannsóknastofnuninni.

Seinni hluta júlímánaðar 1964 voru 2999 ufsar merktir á svæðinu frá Siglufirði að Mánáreyjum og árið eftir var sami fjöldi fiska merktur á sama svæði og tíma (sjá mynd 1).

Merkingarnar voru framkvæmdar um borð í mótorbátum Auðbjörgu, sem þá var í þjónustu Hafrannsóknastofnunarinnar við síldarmerkingar við Norður- og Austurland. Var ufsinn fenginn hjá bátum, er stunduðu ufsaveiðar með hringnót og háfaður í sérstaka merkingarnót, en úr henni var hann merktur. Fiskurinn var því í mjög góðu ástandi og vel fallinn til merkingar.

Samtímis merkingunni voru teknar kvarnir úr öðrum fiski til aldursákvörðunar og var það ásamt lengdardreifingu merkta fisksins notað til þess að fá fram aldursdreifingu þess fisks, sem merktur var (sjá töflu 2).

Fyrri árið var 4 ára fiskur eða árgangurinn frá 1960 yfirgnæfandi í aflanum (88%) og árið eftir var einnig mikið af þessum árgangi, en mest var þó af 3 ára fiski frá árinu 1962.

Fjöldi endurheimta úr báðum þessum merkingum nam alls 3175 fiskum, en af þeim fengust einungis 20 utan Íslands. Þær endurheimtur komu frá Noregi, Færeyjum, norðanverðum Norðursjó, Skotlandi og Vestur-Grænlandi. Hér er um að ræða minna en 1% af heildarfjölda allra endurheimtra fiska.

Á 1. mynd eru sýndar allar endurheimtur frá tilraununum bæði árin og þar kemur greinilega í ljós, að fiskurinn hefur dreifzt umhverfis allt landið.

Skipting endurheimtanna eftir árstímum kemur vel fram á myndum 2–5, en þar eru sýndar allar endurheimtur á þriggja mánaða tímabilum. Þess ber þó að geta, að dreifing endurheimtanna hefur ekki verið leiðrétt með tilliti til mismunandi sóknar á hinum einstöku veiðisvæðum, en sóknin er samt nógu dreifð til þess að ætla má að endurheimturnar gefi nokkuð sanna mynd af göngum hins merkta fisks.

Fyrsta árið eftir merkingu fengust svo til allar endurheimtur við norðurströndina, aðallega í nágrenni við merkingarstaðinn. Ári síðar varð nokkur hluti merkta fisksins kynþroska og hélt suður í heita sjóinn til hrygningar (mynd 2, period 2 og 3). Þessi fiskur fór aftur norður að lokinni hrygningu, en eftir 1967 virðast göngurnar að sunnan hafa staðnæmzt við norðvesturströndina, en ekki haldið lengra austur með norðurströndinni, enda er það í samræmi við þá staðreynd, að sá ufsi, sem veiðist á sumrin fyrir Norðurlandi, er aðallega óþroska fiskur. Örfáar endurheimtur hafa fengizt við Suður- og Austurland og hefur sá fiskur trúlega haldið austur með suðurströndinni að lokinni hrygningu.

Endurheimturnar fyrsta árið koma svo til allar frá íslenskum veiðiskipum: hringnótatátum og togurum; eftir það minnkar hlutur íslenskra skipa í endurheimtunum, en endurheimtur frá brezkum skipum verða mest áberandi. Að síðustu koma endurheimturnar aðallega frá þýzkum togurum. Þetta er í samræmi við hegðun fisksins, því á fyrsta ári er hann mest á grunnslóð þar sem íslensk veiðiskip geta stundað veiðar. Síðan leggst hann meira frá landi, þar sem erlend veiðiskip halda sig.

Endurheimturnar voru notaðar til þess að reikna út álag veiðanna á stofninn og samkvæmt því er áætlað, að árleg dánartala í ufsastofninum fyrir Norðurlandi af völdum veiðanna sé yfir 70% á aldrinum 3–10 ára, og bendir það til þess, að mjög hart sé sótt í stofninn.

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