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SURVIVAL OF TAGGED BARENTS SEA CAPELIN (*MALLOTUS VILLOSUS* MÜLLER) AND ESTIMATES OF THE 1973, 1974 AND 1975 SPAWNING STOCKS FROM TAG RETURNS

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ABSTRACT

DOMMASNES, A. 1978. Survival of tagged Barents Sea capelin *(Mallotus villosus,* Müller) and estimates of the 1973, 1974 and 1975 spawning stocks from tag returns. *FiskDir. Skr. Ser. HavUnders., 16* : 339—358.

Capelin tagged with internal stainless steel tags were kept in net enclosures for 8—9 days to obtain the survival factor. This was found to be 0.89 for males while additional information from routine tag recoveries indicated a survival factor of 0.51 for females.

The 1973 spawning stock was calculated separately from two different groups of tagged fish released at different times during the fishery. The resulting estimates were 2.2 and 4.1 million metric tonnes.

The 1974 spawning stock was calculated from three tagging experiments. The resulting estimates were 5.8, 1.1 and 1.9 million tonnes. The highest value is rejected as being obviously too high.

The 1975 spawning stock was calculated from two tagging experiments. Both gave an estimate of 1.1 million tonnes.

Some possible causes of error in the estimates are discussed.

INTRODUCTION

The Institute of Marine Research has carried out tagging of capelin with internal stainless steel tags since 1970, mostly during the winter fisheries on capelin migrating to the coast of Finnmark for spawning. The tags are recovered in fish meal factories by means of magnets in the production line and during cleaning of the machinery.

Tagging with internal metal tags and recovery by magnets was first described by ROUNSEFELL and DAHLGREN (1933). The method was later used successfully on herring (FRIDRIKSSON and AASEN 1950, 1952; AASEN 1958; DRAGESUND & HARALDSVIK 1966; ANON. 1975) and on mackerel (HAMRE 1975).

Abundance estimates of the 1971 and 1972 spawning stocks of Barents Sea capelin from tag returns have been published by DRAGESUND, GJØSÆTER and MONSTAD (1973).

Little knowledge is available on the survival of tagged capelin. DRAGESUND, GJØSÆTER and MONSTAD (1973) used 0.80 as an estimate of the survival factor for both females and males. Lack of information about survival has been one of the factors that seriously reduced the reliability of stock estimates based on tag returns. It was therefore decided to carry out a test experiment during the winter capelin fishery in 1974 to obtain more knowledge about the survival of tagged capelin.

THE SURVIVAL FACTOR

THEORY

The survival of tagged and untagged fish in the test can be expressed as follows:

$$S_1 = N_1 \cdot e^{-(M + T_1 + T_2 + L) \cdot t}$$

$$S_2 = N_2 \cdot e^{-(M + T_2) \cdot t}$$

or:

$$\frac{S_1}{S_2} = \frac{N_1}{N_2} \cdot e^{-(T_1 + L) \cdot t}$$

N_1 = number of tagged fish at the start of the test
N_2 = number of untagged fish at the start of the test
S_1 = number of tagged fish that survive without losing the tag
S_2 = number of untagged fish that survive
M = instantaneous natural mortality
T_1 = instantaneous mortality caused by the tagging operation
T_2 = instantaneous mortality caused by the handling apart from the tagging operation
L = instantaneous loss of tags (shedding)
t = time interval

Denoting $e^{-(T_1 + L) \cdot t}$ the tagging survival factor (s) we have:

$$s = \frac{S_1 \cdot N_2}{S_2 \cdot N_1} \qquad \text{(I)}$$

The estimate of s obtained in this way includes the mortality caused by the tagging operation and the loss of tags up to time t. The estimate according to (II) is thus to be regarded as an overestimate, partly due to eventual limitation in t, and partly due to mortality caused by the handling apart from the tagging operation.

MATERIAL AND METHODS

The test was carried out in Nordvågen, approximately 7 kilometers east of Honningsvåg, in February and March 1974.

The capelin used in the experiments were caught by purse seine approximately 60 nautical miles off the coast. After capture the fish were transferred to two tanks (each approx. 1.5 m^3) on the deck of the vessel. The tanks were continously supplied with seawater from a pump. Transport to the site of the experiment took 16 hours. The position of capture and of the test site are indicated in Fig. 3.

Tagging took place at the test site and was done according to the same procedure as in the open sea. The fish were taken one by one from the storage tanks with a dip net, and the tag was inserted by hand. No tagging gun, scalpel or other equipment was used, the tag being pressed into the body cavity without any sectioning in advance. This seems to cause the smallest wound. The tag was always inserted on the left side, slightly anterior to the anus (Fig. 1). After the tag had penetrated the body wall, it was turned so that it pointed straight forward, and then pushed completely into the abdominal cavity. Only fish larger than 15 cm were used. The tags, in lots of 50, were put into a jar of alcohol before use, and were picked out from there just before being inserted. As a result, both the tags and the fingers that came in contact with the wound were sterilized.

The tagged fish were collected in buckets and released into the net enclosures in batches of 10—25 fish.

The dimensions of the standard stainless steel capelin tags are 14 × 3 × 0.3 mm (Fig. 1).

The tagged fish and an equal number of untagged capelin were released into two net enclosures approximately 3.4 × 3.4 m at the surface and approximately 3.4 m deep. The surfaces of the enclosures were covered by nets. A 25 W electric lamp was placed in each enclosure to enable the fish to see the net wall. Into one enclosure 400 tagged and 400 untagged fish were released (Experiment 1), into the other 300 tagged and 300 untagged fish (Experiment 2). The surface temperature was 3.2°C where the fish were caught and 2.2°C at the experiment site.

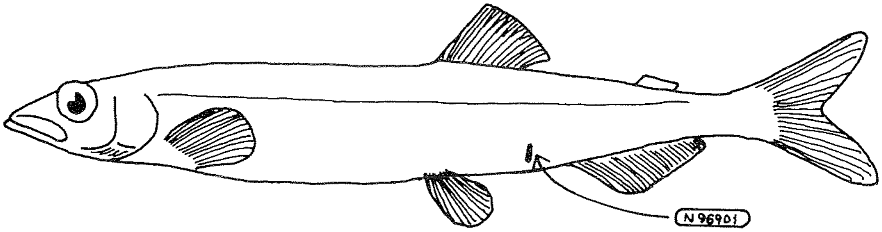

Fig. 1. A capelin. The position where the tag is pushed into the abdomen is indicated by an arrow. A tag is shown in correct relative size.

Dead fish were scooped up with a dip net twice on the first day after the experiment started and every morning on the other days. The dead fish were examined for tags, measured, and sex and maturity were noted. All tagged fish had the position of the tag noted if still present. Loss of the tag was also noted. At the end of the test all remaining fish were scooped up, and the same information recorded. The sex was not noted before the fish were released into the enclosures.

RESULTS AND DISCUSSION

At the end of the test some fish were missing: in «Experiment 1» 29 tagged and 5 untagged fish; in «Experiment 2» 79 tagged and 77 untagged fish. There seem to be several reasons for the loss of fish. Some fish were taken by kittywakes *(Rissa tridactyla)* as they were released into the enclosures, before the cover net was in position. According to observers ashore others were taken by eider ducks *(Somateria mollissima)*. On two occasions corners of the cover net were torn loose by waves and wind so that it may have been possible for the ducks to dive into the enclosures. There were often large flocks of eider ducks around the test site. At the end of the test it was also found that one corner of the second enclosure («Experiment 2») where an anchor rope was fastened had been pulled under the surface by the current. At the same time the cover net had been pulled loose. This is probably the main reason why so many fish disappeared from «Experiment 2».

The three first series (50 fish in each series) of tagged fish in «Experiment 1» had very high mortality the first 20 hours. Most of them seemed to die immediately after release into the enclosure. This was probably due to lack of oxygen in the bucket where the fish were kept between tagging and release.

For the first three series about 25 fish were put into the bucket before they were transferred to the net enclosure. Later no more than 10 fish were collected in the bucket before transfer. For untagged fish the transfer probably did not create problems as it was much quicker for them. For all calculations except the tag retainment factor the three first series in «Experiment 1» have been disregarded. The remaining tagged fish in «Experiment 1», together with the 400 untagged fish in that enclosure, will be referred to as «Experiment 1a».

The results (Tables 1 and 2) show a very high mortality for both tagged and untagged females, much higher than for males. It is not possible from these results to calculate any reasonable value of the survival factor for females. The results give reason to suspect that for females the mortality from other factors than the tagging operation is so large that it obscures the tagging mortality.

Table 1. Results of Experiment 1a.

Experiment 1a	Date	Time	Tagged			Untagged		
			♀	♂	♀+♂	♀	♂	♀+♂
Released into net enclosures	20 Feb.	13.05—14.35	58[1]	192[1]	250	104[1]	296[1]	400
Recovered dead	21 Feb.	09.00	32	12	44	49	9	58
» »	21 »	16.00	5	4	9	10	5	15
» »	22 »	09.00	2	5	7	8	4	12
» »	23 »	09.15	7	2	9	11	7	18
» »	24 »	09.30	1	3	4	4	2	6
» »	25 »	09.30	2	1	3	2	2	4
» »	26 »	10.15	2	3	5	4	3	7
» »	27 »	09.10	0	2	2	6	12	18
» »	28 »	08.50	2	3	5	3	1	4
Total number of dead during experiment			53	35	88	97	45	142
Surviving fish recovered at end of experiment.......	28 Feb.	09.10	1	145	146	6	247	253
Total number of fish recovered			54	180	234	103	292	395
Total number of fish lost			4[1]	12[1]	16	1[1]	4[1]	5
Tag retainment factor[2]			—	0.95				
Surviving fish recovered retaining the tags[3]			—	145				

[1]) The numbers have been estimated on the assumption that the sex ratio among fish released was the same as among those recovered.
[2]) The tag retainment factor has been calculated from the complete «Experiment 1».
[3]) This number has been calculated using the tag retainment factor.

Table 2. Results of Experiment 2.

Experiment 2	Date	Time	Tagged ♀	Tagged ♂	Tagged ♀+♂	Untagged ♀	Untagged ♂	Untagged ♀+♂
Released into net enclosures	20 Feb.	15.45—17.45	45[1]	255[1]	300	56[1]	244[1]	300
Recovered dead	21 Feb.	09.30	15	5	20	14	2	16
» »	21 »	16.00	3	6	9	11	1	12
» »	22 »	08.15	4	7	11	8	2	10
» »	23 »	09.00	3	2	5	4	3	7
» »	24 »	09.20	2	0	2	0	1	1
» »	25 »	09.00	2	4	6	2	2	4
» »	26 »	10.10	2	6	8	1	3	4
» »	27 »	09.00	1	5	6	1	3	4
» »	28 »	09.30	1	0	1	0	1	1
» »	1 March	08.30	0	4	4	0	2	2
Total number of dead during experiment			33	39	72	41	20	61
Surviving fish recovered at end of experiment	1 March		0	149	149	1	161	162
Total number of fish recovered			33	188	221	42	181	223
Total number of fish lost			12[1]	67[1]	79	14[1]	63[1]	77
Surviving fish recovered retaining the tags			0	145				
Tag retainment factor			--	0.97				

[1]) The numbers have been estimated on the assumption that the sex ratio among fish released was the same as among those recovered.

TAGGING SURVIVAL FACTOR FOR MALE CAPELIN, $s♂$.

In order to determine the numbers of each sex that were released into the net enclosures at the start of the experiment it was assumed that the sex ratio among the fish that were released was the same as for those recovered, and that mortality was the same among fish lost as among those recovered. The corresponding values of S_1, N_1, S_2 and N_2 are given in Table 3b, combination A. Using formula (I), «Experiment la» gives $s♂ = 0.91$ and «Experiment 2» gives $s♂ = 0.87$. The mean value is 0.89.

The most obvious sources of error in these estimates are the assumptions of the sex ratios of the fish originally released into the enclosures, and the theories of what happened to the lost fish. In Tables 3a and 3b are listed some other possible assumptions and the resulting values of S_1, N_1, S_2, N_2 and $s♂$. The lowest value of $s♂$, 0.85, is obtained from assumption E in «Experiment la». The highest value, 0.92, is obtained from several of the assumptions.

It is reasonable to assume that if all the fish that were released could have been accounted for, the test would still have given a value of $s♂$ somewhere between the above mentioned extremes. It is also probable that small variations in the handling and tagging technique, as are likely to occur if the tagging is done by different people, may cause the survival factor to change beyond the extremes calculated. This was demonstrated in the report from the ICES Working Group on the Bløden Tagging experiment 1969/70 (ANON. 1975) where two tagging teams were used, and it was found that the mean recapture rate of fish tagged by team 2 relative to team 1 was 0.73. It must be further remembered that $s♂$ only represents a maximum value for the tagging survival factor, because it does not take into account mortality due to stress from the catching procedure or the stay in the storage tanks.

Table 3a. Some possible combinations ot sex ratio and mortality of the lost fish.

A The sex ratios among the fish initially released into the enclosures was the same as among those recovered, and the ratio dead/survivors was the same among those lost as among those recovered in the groups «tagged» and «untagged», respectively.

B The sex ratios among the fish initially released into the enclosures was the same as among those recovered, and all lost fish are considered as survivors.

C The sex ratios among fish initially released into the enclosures was the same as among those recovered, and all lost fish are considered as dead.

D All lost fish are considered as surviving males.

E All lost fish are considered as dead males.

F All lost fish are considered as females.

Table 3b. Values of S_1, N_1, S_2, N_2 and $s♂$ for the combinations of sex ratio and mortality given in Table 3a. Loss of tags has been included in s, using the «Tag retainment» factors given in Tables 1 and 2.

	Experiment 1a					Experiment 2				
	N_1	S_1	N_2	S_2	$s♂$	N_1	S_1	N_2	S_2	$s♂$
A	192	147	296	250	0.91	255	197	244	217	0.87
B	192	149	296	251	0.92	255	210	244	218	0.92
C	192	138	296	247	0.86	255	145	244	161	0.86
D	196	153	297	252	0.92	267	222	258	238	0.90
E	196	138	297	247	0.85	267	145	258	161	0.87
F	180	138	292	247	0.91	188	145	181	161	0.87

THE SIZES OF THE SPAWNING STOCKS

THEORY

When calculating the size of the capelin population based on tagging, the Petersen method was used (RICKER 1975):

(II)
$$\hat{V} = \frac{C \cdot N \cdot s}{R} \qquad \text{(II)}$$

$\hat{V}$ = estimate of population at time of tagging,
C = size of catch after tagging in the same unit as $\hat{V}$,
N = number of fish tagged,
s = «tagging survival factor» which must also take into account loss of tags (shedding),
R = number of tags recovered.

When the sex of the tagged fish is known, the calculations are based on male fish only. If one assumes that the proportion of male capelin in the catches (k♂) is the same as in the spawning population, one can write:

$$\hat{V} \cdot k♂ = \frac{C \cdot k♂ \cdot N♂ \cdot s♂}{R♂}$$

$$\hat{V} = \frac{C \cdot N♂ \cdot s♂}{R♂} \qquad \text{(III)}$$

An estimate of the total spawning population ($\hat{P}$) disregarding natural mortality in the period concerned is found from the formula

$$\hat{P} = C_0 + \hat{V} \qquad \text{(IV)}$$

where C_0 is the catch taken before the tagged fish were released.

When the ratio $\frac{R}{C}$ is small, the standard deviation of the inverse value of V (RICKER 1975) is:

$$\text{St. dev.}\left(\frac{1}{V}\right) = \frac{\sqrt{R}}{C \cdot N \cdot s} \tag{V}$$

Using (II) and (V) one obtains the 95% limits of confidence for $\left(\frac{1}{V}\right)$:

$$\frac{R - 1.96 \cdot \sqrt{R}}{C \cdot N \cdot s} < \frac{1}{V} < \frac{R + 1.96 \cdot \sqrt{R}}{C \cdot N \cdot s}$$

Inverting the values and introducing (IV) gives the 95% confidence limits for P:

$$C_o + \frac{C \cdot N \cdot s}{R + 1.96 \cdot \sqrt{R}} < P < C_o + \frac{C \cdot N \cdot s}{R - 1.96 \cdot \sqrt{R}} \tag{VI}$$

or, adapted to (III):

$$C_o + \frac{C \cdot N♂ \cdot s♂}{R♂ + 1.96 \cdot \sqrt{R♂}} < P < C_o + \frac{C \cdot N♂ \cdot s♂}{R♂ - 1.96 \cdot \sqrt{R♂}} \tag{VII}$$

MATERIAL AND METHODS

In order to calculate the spawning population the fish tagged in 1973 were divided into two groups, and calculations were made for each group separately. In 1974 three groups were used, in 1975 two groups.

In 1973 no attempt was made to determine the sex of the tagged fish, and the first 1000 fish tagged in 1974 were not sexed either. Later, each series of 50 tags was used for one sex only. The sex was determined from external characters.

The time of release for each group of tagged fish and the number of fish released is shown in Tables 4, 5 and 6 for 1973, 1974 and 1975, respectively. The areas of release are shown in Figs. 2, 3 and 4.

The input data used in the calculations were obtained as follows:

C_o was obtained from the catch statistics as the total catch fished before the date when the first tagged fish in the group were released. R and the corresponding C were obtained from plants that had a magnet efficiency coefficient above 0.40 in 1973, and above 0.50 in 1974 and 1975.

Table 4. Release dates and numbers of tagged capelin released in 1973.

	Date	Numbers released (Sex not determined)
Group 1	27 Feb.	1 500
	1 March	1 400
	2 »	1 000
	6 »	950
	8 »	150
Group 2	21 »	2 000
	22 »	1 500

Table 5. Release dates and numbers of tagged capelin released of each sex in 1974.

	Date	Numbers released		
		Sex not determined	♀	♂
Group 1	19 Feb.	1 000		
Group 2	11 March		1 000	1 000
	12 »		1 000	1 000
	13 »		1 000	1 000
	14 »		500	500
	15 »		500	500
Group 3	19 March		250	250
	20 »		900	600
	21 »		700	300
	25 »		1 000	500

Table 6. Release dates and numbers of tagged capelin released of each sex in 1975.

	Date	Numbers released	
		♀	♂
Group 1	8 March	500	1 000
	9 »		1 500
Group 2	15 March		2 000
	16 »		1 500
	17 »		1 000
	18 »		500

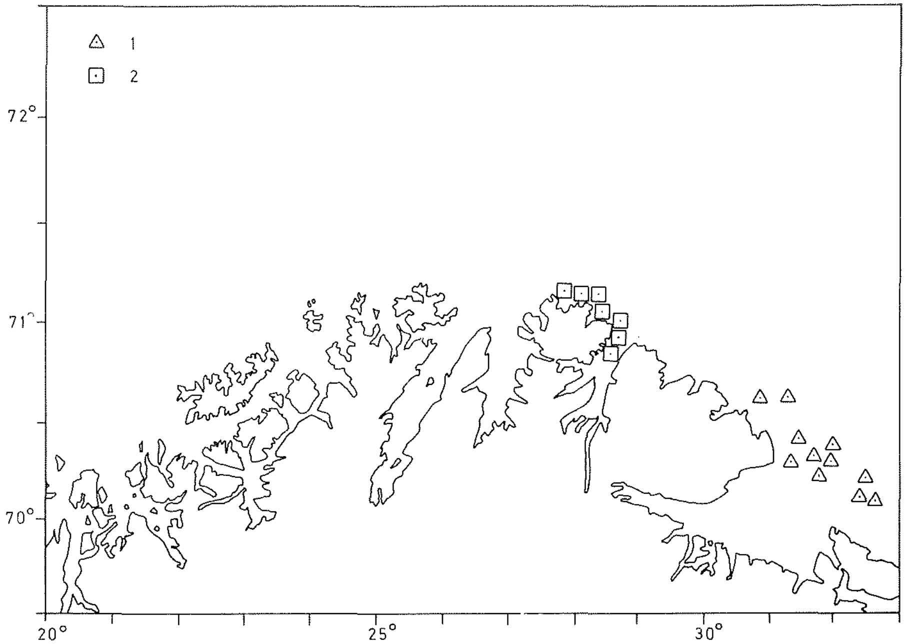

Fig. 2. Positions where tagged capelin were released in 1973.
1) Group 1, 2) Group 2.

The magnet efficiency coefficient, which is the proportion of retained tags to the number of tags in the catch produced, was determined by tagging in the usual way, but with unnumbered tags and «releasing» on the conveyor belt of the meal plant concerned. Of the 6 factories tested in 1973, 5 had magnet efficiency coefficients above 0.40. From one of these, however, no numbered tags were recovered and it too has been omitted from the calculations. In 1974, 12 factories were tested, and 7 had coefficients above 0.50. In 1975, 8 factories were tested, and 5 had coefficients above 0.50. The relevant values of R and the corresponding corrected catch C are shown in Tables 7, 8 and 9.

Where only tags from male capelin were used, the survival factor s♂ $= 0.89$ was employed. For the 1973 material, where the sex of the tagged fish is not known, samples from the same area and time period indicate a sex ratio of 62% females to 38% males. Assuming a survival factor for females s♀ $= 0.51$ (to be discussed later), a weighted value of $s = 0{,}65$ is obtained for the 1973 material. For group 1, 1974, samples indicate a sex ratio of 50 % females and 50% males, and a survival factor $s = 0.70$ has been used.

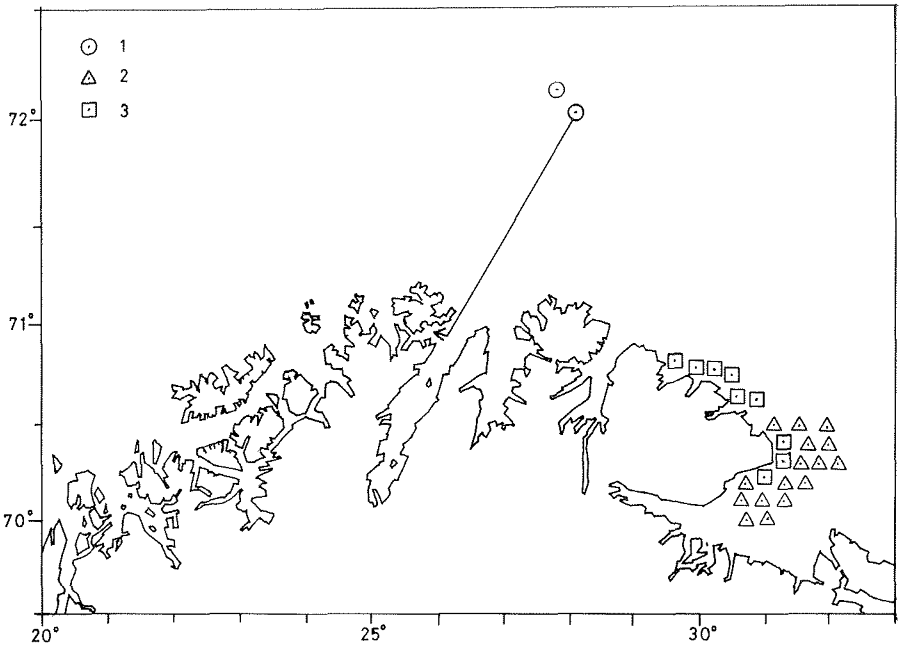

Fig. 3. Positions where tagged capelin were released in 1974.
1) Group 1, 2) Group 2, 3) Group 3. The line indicates the transport of live capelin that were used in the tagging survival experiment.

RESULTS AND DISCUSSION

1973

Equations (II) and (IV) were used for calculation of the spawning population, and the 95% confidence interval was calculated from (VI). The input data used in the formulas are summarized in Table 10 and give the following results:

Group 1

Population estimate: $\hat{P} = 2.18 \times 10^6$ tonnes

Confidence interval: 1.93×10^6 tonnes $< P < 2.52 \times 10^6$ tonnes

Group 2

Population estimate: $\hat{P} = 4.12 \times 10^6$ tonnes

Confidence interval: 3.12×10^6 tonnes $< P < 6.54 \times 10^6$ tonnes

Table 7. Tag return efficiencies for the factories in 1973, quantities delivered to the factories after the tags were released (in metric tonnes), corrected quantities, returned tags and returned tags per 10 000 tonnes corrected quantity. Note that the designations A, B, C, ... do not cover the same factories each year.

Factory	Tag return efficiency	Group 1				Group 2			
		Quantity tonnes	Corrected quantity	Returned tags Total	Returned tags per tonne $\times 10^4$	Quantity tonnes	Corrected quantity	Returned tags Total	Returned tags per tonne $\times 10^4$
A	.95	30 008	28 508	42	15	12 247	11 635	5	4
B	.74	20 100	14 873	41	28	9 240	6 837	12	18
C	.48	72 290	34 698	48	14	22 543	10 820	3	3
D	.41	18 390	7 540	22	29	8 253	3 384	2	6
Total ...			85 619	153			32 677	22	

1974

For 1974 the spawning population was calculated from (II) and (IV) for Group 1 and from (III) and (IV) for Groups 2 and 3. The 95% confidence interval was calculated from (VI) for Group 1 and from (VII) for Groups 2 and 3. The input data are summarized in Table 11:

Group 1
Population estimate: $\hat{P} = 5.78 \times 10^6$ tonnes
Confidence interval: 4.10×10^6 tonnes $< P < 9.89 \times 10^6$ tonnes

Group 2
Population estimate: $\hat{P} = 1.06 \times 10^6$ tonnes
Confidence interval: 1.00×10^6 tonnes $< P < 1.13 \times 10^6$ tonnes

Group 3
Population estimate: $\hat{P} = 1.96 \times 10^6$ tonnes
Confidence interval: 1.66×10^6 tonnes $< P < 2.45 \times 10^6$ tonnes

1975

For 1975 the spawning population was calculated from (III) and (IV) and the 95% confidence interval from (VII). The input data are summarized in Table 12:

Table 8. Tag return efficiencies for the factories in 1974, quantities delivered to the factories after the tags were released (in metric tonnes), corrected quantities, returned tags and returned tags per 10 000 tonnes corrected quantity. For Group 1 all tags returned from the factories in question have been used, for Groups 2 and 3 only tags from male fish. Note that the designations A, B, C, ... do not cover the same factories each year.

Factory	Tag return efficiency	Group 1				Group 2				Group 3			
		Quantity tonnes	Corrected quantity	Returned tags		Quantity tonnes	Corrected quantity	Returned tags		Quantity tonnes	Corrected quantity	Returned tags	
				Total	per tonne × 10^4			Total	per tonne × 10^4			Total	per tonne × 10^4
A	.90	16 664	14 998	0	0	11 794	10 615	32	30	6 789	6 110	7	11
B	.81	21 625	17 516	2	1.1	16 218	13 137	50	38	7 079	5 734	5	9
C	.79	22 932	18 116	6	3.3	20 164	15 930	71	45	10 964	8 662	9	10
D	.78	95 807	74 729	3	0.4	53 801	41 965	172	41	27 166	21 189	22	10
E	.74	42 243	31 260	2	0.6	32 242	23 859	134	56	17 339	12 831	8	6
F	.61	21 081	12 859	5	3.9	17 086	10 422	52	49	7 658	4 671	6	13
G	.55	19 013	10 457	4	3.8	15 520	8 536	30	35	6 476	3 562	5	14
Total			179 935	22			124 464	540			62 759	62	

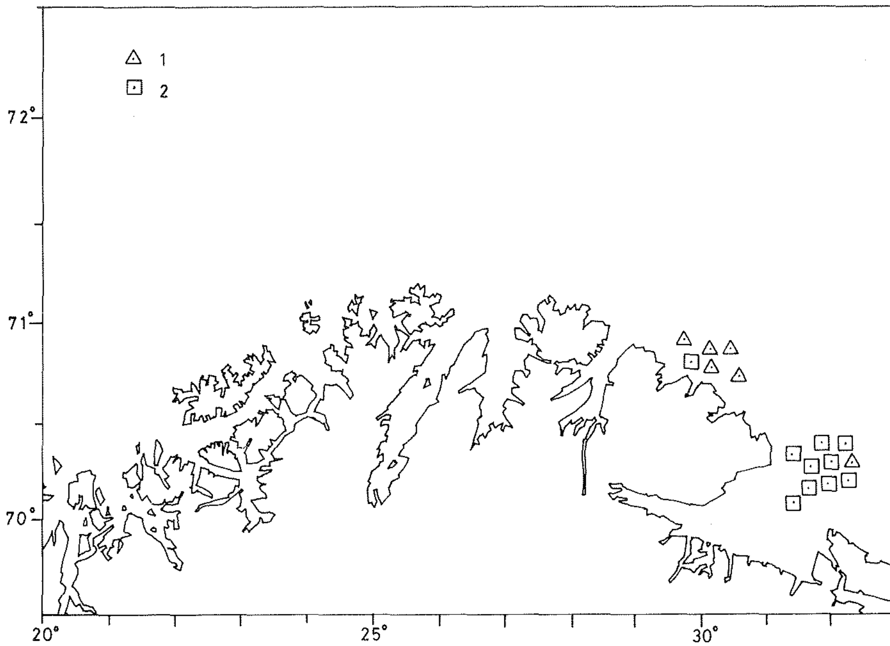

Fig. 4. Positions where tagged capelin were released in 1975.
1) Group 1, 2) Group 2.

Group 1
Population estimate: $\hat{P} = 1.14 \times 10^6$ tonnes
Confidence interval: 1.02×10^6 tonnes $< P < 1.29 \times 10^6$ tonnes

Group 2
Population estimate: $\hat{P} = 1.12 \times 10^6$ tonnes
Confidence interval: 1.04×10^6 tonnes $< P < 1.22 \times 10^6$ tonnes

A number of factors can have caused errors in the results. Some of these are discussed below.

The value used for the tagging survival factor is an obvious source of bias because it does not take into consideration the mortality caused by handling apart from the tagging operation. The actual tagging survival is therefore lower than indicated by s, and the population estimates given here must be regarded as overestimates.

A minimum requirement if a tagging experiment is to be used for calculating population sizes, is that the tagged fish must be randomly distributed in the population to be estimated or the fishing effort must be randomly distributed. If neither of these conditions is met, fishing mortality

Table 9. Tag return efficiencies for the factories in 1975, quantities delivered to the factories after the tags were released (in metric tonnes), corrected quantities, returned tags and returned tags per 10 000 tonnes corrected quantity. Only tags from male fish have been used. Note that the designations A, B, C, ... do not cover the same factories each year.

Factory	Tag return efficiency	Group 1				Group 2			
		Quantity tonnes	Corrected quantity	Returned tags		Quantity tonnes	Corrected quantity	Returned tags	
				Total	per tonne × 10^4			Total	per tonne × 10^4
A	.97	16 077	15 595	18	12	13 039	12 648	52	41
B	.78	10 076	7 849	12	15	9 358	7 299	100	137
C	.70	7 037	4 926	6	12	4 905	3 434	29	84
D	.69	69 385	47 876	143	30	47 237	32 594	128	39
E	.68	14 473	9 842	23	23	9 823	6 680	26	39
Total ...			86 098	202			62 655	335	

Table 10. Input data used to calculate the spawning stock in 1973.

	C_o (tonnes)	C (tonnes)	N	s	R
Group 1	362 033	85 619	5 000	.65	153
Group 2	739 426	32 677	3 500	.65	22

Table 11. Input data used to calculate the spawning stock in 1974.

	C_o (tonnes)	C (tonnes)	N, $N♂$	s, $s♂$	R, $R♂$
Group 1	58 433	179 935	1 000	.70	22
Group 2	238 495	124 464	4 000	.89	540
Group 3	469 246	62 759	1 650	.89	62

Table 12. Input data used to calculate the spawning stock in 1975.

	C_o (tonnes)	C (tonnes)	$N♂$	$s♂$	$R♂$
Group 1	190 609	86 098	2 500	.89	202
Group 2	283 672	62 655	5 000	.89	335

for the tagged fish is likely to be different from that of the whole population. In these experiments the tagged fish were released in batches in the areas where the fishing fleet was working. As a consequence, the first condition was probably not fulfilled. As to the second condition it is more difficult to say, but it was probably not fulfilled all the time.

The tag return efficiency was checked only once during the season for each factory. It is likely that efficiency is subject to some change during the season. This is indicated by the fact that there is considerable variation in the tag return efficiency for the same factory from year to year.

The two estimates for 1973 differ so much that their usefulness is seriously reduced, -- 2.2 and 4.1 million tonnes, respectively. It is not possible from our material to tell whether the difference is due to one or more of the possible causes discussed above. It is therefore not really possible either to tell which of the two estimates is most correct. However, the lowest estimate is based on a higher number of released tagged fish and a larger catch. It therefore seems reasonable to put most emphasis on the lowest figure. On the other hand, an acoustic survey carried out in August 1972 resulted in an estimate of 3.7 million tonnes for the 1973 spawning stock (NAKKEN and DOMMASNES 1975). This is closer to the highest estimate from the tagging experiments.

In the case of Group 1 1974, fishing mortality for the tagged fish must have been much lower than for the rest of the population. Immediately after the tagging a storm blew up and stopped the fishing almost completely for more than a week. After the storm this concentration of capelin could not be relocated, and fishing started in another area. Observations (ANON. 1974) also indicate that the capelin tagged in Group 1 1974 may have had very high natural mortality due to predation from cod. The extraordinarily high population estimate resulting from the tags in Group 1 should therefore be disregarded.

Having decided to disregard the population estimate from Group I 1974, one is left with the estimates from Groups 2 and 3. Again the estimates differ rather a lot -- 1.1 and 1.9 million tonnes, respectively. In this case it also seems most reasonable to accept the lower estimate as the best one. This agrees quite well with an acoustic survey in September–October 1973 which resulted in an estimate of 1.0 million tonnes for the 1974 spawning stock, with a possibility that the value might be as high as 1.5 million tonnes (NAKKEN and DOMMASNES 1975).

The estimates from Group 1 and Group 2 1975 both give a value of 1.1 million tonnes for the spawning stock. This does not exclude the possibility that both estimates may have been subject to error, but it still seems justifiable to put some confidence in the value. The acoustic survey in September–October 1974 resulted in an estimate of 0.8 million tonnes for the spawning stock in 1975 (NAKKEN and DOMMASNES 1975).

The widely differing estimates of the 1973 and 1974 stocks using different groups of tags and the possibilities of error pointed out in the discussion suggest that stock estimates for capelin based on tagging experiments should be used with caution. Even so, they are in the same size range as the acoustic estimates and are useful for checking those figures.

TAGGING SURVIVAL FACTOR FOR FEMALE CAPELIN, $s♀$.

For most of the capelin tagged in 1974 and all capelin tagged in 1975, each series of 50 tags was used for one sex only. It is thus possible to calculate the ratio between returned tags and released tagged fish separately for the sexes. If one assumes that fishing mortality is the same for both sexes, different values of this ratio must be due to mortalities from other causes than fishing. Of those other causes, natural mortality is likely to be small compared to tagging mortality so that any difference in the ratios between returned and released tags can be assigned to different tagging mortality alone:

$$\frac{R♀}{N♀ \cdot s♀} = \frac{R♂}{N♂ \cdot s♂}$$

$$s♀ = s♂ \cdot \frac{N♂ \cdot R♀}{N♀ \cdot R♂} \qquad \text{(VIII)}$$

Table 13 shows the releases and recaptures by sexes for 1974 and 1975. Using these values and $s♂ = 0.89$ in equation (VIII) we get $s♀ = 0{,}51$ from the 1974 material and $s♀ = 0.59$ from the 1975 material. The 1975 sample is relatively small, and the 1974 estimate is therefore regarded as the most reliable one. Both samples confirm, however, the high tagging mortality for female capelin observed in the test experiments.

Table 13. Total numbers of capelin of each sex released in 1974 and 1975, and total numbers of tags returned.
$N♀$, $N♂$: numbers tagged
$R♀$, $R♂$: numbers of tage recovered.

Year	$N♀$	$N♂$	$R♀$	$R♂$
1974	6 850	5 650	644	931
1975	500	7 500	12	271

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