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SURVIVAL OF TAGGED CAPELIN (MALLOTUS VILLOSUS, MULLER) AND ESTIMATES OF THE 1974 SPAWNING POPULATION IN THE BARENTS SEA FROM TAG RETURNS

by

Are Dommasnes[x)]

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 coasts of Finnmark for spawning.

Most of the capelin caught by Norwegian vessels is processed into oil and fishmeal. The tags are recovered by magnets in the production system, and during cleaning of the machinery.

Estimates of the spawning stocks in 1970 - 72 from tag recoveries have been published by DRAGESUND, GJØSÆTER and MONSTAD, 1973.

Tagging during the winter capelin fishery is usually severely

x) Institute of Marine Research
Directorate of Fisheries
P.O. Box 2906 - 5011 BERGEN

hindered by the weather. The fishing has to be done with purse-seine to get fish in good condition. Neither the purse-seining nor the actual tagging procedure can be carried out in rough seas. In addition come the problems with finding capelin. During the spawning migration the capelin goes too deep to be reached by purse-seine most of the time before it reaches the spawning areas. Only occasionally will the schools come up to a depth where they can be fished successfully, and when such schools are discovered, a large part of the commercial fishing fleet is likely to be there as well as the purse-seiner that has been chartered for tagging operations. This results in two serious disadvantages in the tagging of capelin, as compared to ideal conditions: 1) It is possible only to a limited extent to choose time and place for the tagging operations, and 2) the tagged capelin have to be released fairly close to the commercial fishing fleet. The main consequence of this is that one gets a relatively poor mixing of tagged and untagged fish. In addition, it becomes difficult to time the tag releases in relation to the fishery in order to obtain the maximum amount of information from the recovered tags.

One has had little knowledge about the survival factor for tagged capelin. DRAGESUND, GJØSÆTER and MONSTAD (1973) used 0.80 as an estimate of the survival factor for both females and males. The lack of information about the survival factor 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 during the winter capelin fishery 1974 an experiment to get more knowledge about the survival of tagged capelin.

THE SURVIVAL FACTOR

MATERIAL AND METHODS

The experiments were carried out in Nordvågen, approximately 7 kilometers east of Honningsvåg (Fig. 1), in February and March 1974.

Two vessels were used for the experiment: the 70 feet research vessel "Asterias" chartered from the University of Tromsø, and the 130 feet purse seiner "M. Ytterstad", also chartered.

The capelin to be used in the experiments were caught with 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 continuously supplied with new seawater from a pump. The transport to the site of the experiment took 16 hours.

The tagging took place at the site of the experiment. After tagging, the tagged fish and the untagged controls were transferred to two net enclosures approximately 3.4 x 3.4 m at the surface and approximately 3.4 m deep. The surface of the enclosures was also covered by a net. In each enclosure a 25 W electric lamp was placed to enable the fish to see the net. Experience has shown that if no light is provided, the fish may suffer quite extensive skin damage due to collisions with the net (J. HAMRE, personal information). The surface temperature was 3.2°C where the fish were caught. At the experiment site it was 2.2°C.

The tags used were the same as those used during "normal" tagging, standard stainless steel "sprat tags", 14 x 3 x 0.3 mm (Fig. 2).

The tagging was done according to our normal tagging procedure. No tagging gun, scalpel or other equipment was used. The tags were pressed into the body cavity without any section having been made in advance. Our experience shows that this given the smallest wound. The tag was always pushed in on left side, a little in front of the anus (Fig. 2). After the tag had penetrated the body wall, it was turned so that it pointed straight foreward, and then pushed completely in. Hands and tags were washed in alcohol before tagging. Only fish large enough to be maturing were used.

400 tagged and 400 untagged fish were released into the first enclosure ("Experiment 1"), in such a way that each time 50 tagged

fish had been released, 50 untagged fish were also released.

In the second enclosure ("Experiment 2") 300 tagged and 300 untagged fish were released.

Dead fish were picked up with a dip-net twice the first day after the experiment started, and every morning the other days. All fish that died, were measured, and sex and maturity were noted. For the tagged fish we also noted the position of the tag, or whether it had been lost. At the end of the experiments all remaining fish were picked up, and the same information was recovered.

The fish were not sexed before they were released into the enclosures, as we expected to get the numbers of each sex as the fish were recovered. It was also considered important to reduce handling of the fish before release to a minimum.

RESULTS AND DISCUSSION

At the end of the experiments we found that some fish were missing: in experiment 1, 29 tagged and 5 untagged fish, and in experiment 2, 79 tagged and 77 untagged fish.

There may be several reasons for these losses:
1) Some fish were taken by kittywakes (Rissa tridactyla) at the release into the enclosures. These were fish that were dying, and lay at the surface, before we had put on a covernet. As far as we could see, only a few fish were lost in this way from each enclosure.

2) Some fish were probably taken by eider ducks (Somateria mollissima). We did not see this for ourselves, but people ashore said they had seen eider ducks take fish from the enclosures. How many they can have taken is not possible to say. On two occasions corners of the covernet were torn loose by the waves and the wind, so that it may have been possible for the ducks to dive into the enclosures. There were large flocks of eider ducks around the site of the experiments.

3) It is likely that some fish have managed to swim out of the enclosures. In some periods a strong local wind set up small waves, and under such conditions it may have been possible for fish to swim over the float-line when the covernet was torn loose. At the end of the experiments it was also found on one occasion that one corner of the second enclosure ("Experiment 2"), where an anchor rope was fastened, was pulled down under the surface by the current. At the same time the current had also torn loose the covernet. This is probably the main reason why so much 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 (Table 1). Most of them seemed to die immediately after the release into the enclosure. This was probably due to lack of oxygen in the buckets where the fish were kept between tagging and release into the enclosure. 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 has probably not created problems, as it was much quicker for them. For all calculations the first three series tagged in experiment 1 (Numbers N 98501 - N 98650) have been disregarded. The remaining tagged fish in experiment 1 (N 98651 - N 98900), together with the 400 untagged fish in that experiment, will be referred to as Experiment 1 a. Most of the fish recovered were in maturity stage III, some in maturity stage IV (stages as defined by NAIER, from LAEVASTU, 1965). In Tables 2, 3 and 4 are shown the courses of experiments 1, 1a and 2.

In calculating the size of the population from tagging results the following formula is used:

$$\hat{V} = \frac{N \cdot C \cdot s}{R} \qquad (1)$$

$\hat{V}$= the estimate of the population at the time of tagging

N= number of fish tagged

C= the size of the catch after tagging, in the same unit as V

R= number of tags recovered

s= the survival factor, which also takes into account the loss of tags.

Loss of tags must be included in the tagging mortality because tagged fish that have lost their tags will not be recognizable as such with out recovery system (collection of the tags by magnets at fish meal factories). In a "free" population fish that loose their tags will go back to the untagged population without any significant change in the proportion between tagged and untagged fish. But in experiments like this the number of fish that loose their tags is relatively large compared to the number of untagged fish, and those that loose their tags can not be added to the untagged ones, but must still be deducted from the tagged specimens.

The survival of tagged fish and untagged fish, respectively, can be expressed as follows:

$$S_1 = N_1 \cdot e^{-(M+T_1+T_2+L)} \cdot t \tag{2}$$

$$S_2 = N_2 \cdot e^{-(M+T_2)} \cdot t \tag{3}$$

N_1= number of fish tagged in the experiment

N_2= " " " untagged in the experiment

S_1= " " tagged fish that survive without loosing the tag

S_2= " " untagged fish that survive without loosing the tag

M = instantaneous natural mortality

T_1= " mortality caused by the tagging operation

T_2= " " " " " handling apart from the tagging operation

L = instantaneous loss of tags

t = the time interval

T_2, as we get it from these experiments, can not be expected to represent the "handling mortality" as it is during "normal" tagging, as the fish normally is not kept in a tank for more than 2 - 3 hours before tagging, and it is not kept in a net enclosure after tagging. Concequently, stress factors other than the actual tagging operation are probably much smaller during "normal" tagging operations. The survival factor to be calculated from these experiments should therefore only take into account the mortality caused by the actual tagging operation, and the loss of tags. It will then, of course, represent a slight overestimate:

$$s = e^{-(T_1 + L) \cdot t} = \frac{e^{-(T_1 + L + T_2 + M) \cdot t}}{e^{-(T_2 + M) \cdot t}} = \frac{\frac{S_1}{N_1}}{\frac{S_2}{N_2}} = \frac{S_1 \cdot N_2}{S_2 \cdot N_1}$$

$$(4) \qquad s = \frac{S_1 \cdot N_2}{S_2 \cdot N_1}$$

The results (Tables 3 and 4) show a very high mortality for both tagged and untagged females, and 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 is obscures the tagging mortality. It is therefore necessary to calculate the survival factor for males alone.

Survival factor for male capelin

To get an estimate of the numbers of each sex that were released into the net enclosures at the start of the experiment, I have assumed that the sex ratio was the same among the fish that were released as among those that were recovered, and that the mortality was the same among the fish that were lost as among those recovered in the groups "tagged" and "untagged", respectively. The corresponding values of S_1, S_2, N_1 and N_2 are given in Table 5, combination A. Using formula (4), the two experiments give the following values for $s_♂$:

Experiment 1a: $s_♂ = \frac{147 \cdot 296}{250 \cdot 192} = 0.91$

Experiment 2 : $s_♂ = \frac{197 \cdot 244}{217 \cdot 255} = 0.87$

Using a mean value of the two experiments, we get

$$s_♂ = \frac{0.91 + 0.87}{2} = \underline{0.89}$$

It is not possible with the present material to use statistical criteria to get an idea of the accuracy of the results, both becuase we have too few experiments and because of the large number of lost fish.

However, one can use a rough reasoning to find the possible extreme values of the survival factor. Much of the uncertainty is connected with the sex ratio among the fish originally released into the enclosures, and with what happened to the lost fish. In Table 5a are given some of the possible combinations, and in Table 5b are given the resulting values of S_1, N_1, S_2, N_2 and $s_♂$.

The extreme values of $s_♂$ from Experiment 1a and assumptions D and E, are 0.92 and 0.85 as the highest and lowest values, respectively. It is reasonable to assume that if all the fish that were released could have been accounted for, the experiments would still have given a value of $s_♂$ somewhere between those 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 persons, may cause the survival factor to change beyond the extremes found from these considerations.

It must be remembered, further, that $s_{♂}$ only represents a maximum value for the survival factor, because it does not take into account mortality due to stress from the catching procedure or the stay in the storage tanks.

Taking these qualifications into account, the accuracy obtained from the experiments should be considered satisfactory, and $s_{♂} = 0.89$ can be adopted as a maximum value for the survival factor for male capelin.

Survival factor for female capelin

For most of the capelin tagged during 1974, each series of 50 tags was used either for females only or males only. It is thus possible to calculate "tag recovery factors" (F) separately for tags applied to female and male capelin, respectively:

$$F' = \frac{\text{number of tagged fish recovered}}{\text{number of tagged fish released}}$$

If one assumes that fishing mortality is the same for male and female capelin, different values of the tag recovery factor must be due to different mortality. Natural mortality is probably small for both sexes compared to the tagging mortality so that the difference between tag recovery factors can be assigned to different tagging mortality alone. The tag recovery factor can then be assumed to be proportional with the tagging survival factor, and the relationship can be expressed as follows:

$$\frac{s_{♀}}{s_{♂}} = \frac{F_{♀}}{F_{♂}}$$

$$s_{♀} = s_{♂} \cdot \frac{F_{♀}}{F_{♂}}$$

Using $s_{♂} = 0.89$ and tagging data from 1974, we get:

$$s_{♀} = 0.89 \cdot \frac{\frac{644}{6850}}{\frac{931}{5650}} = \underline{0.51}$$

$\underline{s_{♀} = 0.51}$ can thus be adopted as a <u>maximum</u> <u>value</u> for the survival factor for female capelin.

THE SIZE OF THE 1974 SPAWNING POPULATION

MATERIAL AND METHODS

Altogether 13.500 tagged capelin were released during the winter fishery 1974. In Fig. 3 are shown the positions where tagged capelin were released.

For calculation of the results, the releases were divided into three groups according to time:

<u>Group 1</u>. The tags N 9701 - N 10000 and N 11101 - N 11800, altogether 1000 fish, were released Februar 19 on the North Cape Bank. The sexes were not tagged with different series of tags, and it is therefore not possible to know the sex ratio of the tagged fish that were released nor of those that were recovered.

<u>Group 2</u>. The tags N 11801 - N 14000 and N 15001 - N 20800, altogether 8000 fish, were released during the period March 11 - 14, in the outer part of the Varanger fjord and outside Vardø. For these tags and those released later each series of 50 tags was used either for males only or for females only. It is thus possible to know whether recovered tags are from male or female fish. 4000 of the tagged fish were males and 4000 were females.

<u>Group 3.</u> The tags N 20801 - N 25300, altogether 4500 tags (1650 male capelin and 2850 females) were released from March 19 to March 25 along the coast of eastern Finnmark, from the

outer part of the Varanger fjord to Berlevåg.

The spawning population (V) at the time of tagging can be estimated from formula (1):

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

For the tags in Group 1 this formula can be used directly.

For Group 2 and Group 3 we also have information about the numbers of each sex that were tagged. The most direct way to use this additional information is to calculate the populations separately for females and males, and then add the results to get the total population. However, with a survival factor of 0.51 for female capelin, the calculations based on females are likely to be unreliable. The calculations from tags in Group 2 and Group 3 were therefore based on male capelin only, and formula (1) was adapted for the purpose:

$$V = \frac{N_o' \cdot (C \cdot k_{♂}) \cdot s_{♂}}{R_{♂} \cdot k_{♂}}$$

$$(5) \qquad V = \frac{N_o \cdot C \cdot s_{♂}}{R_{♂}}$$

$k_{♂}$ = the proportion of the catch that is made up of male capelin.

The other symbols are as in (1) with the addition that the index ♂ signifies that the appropriate values for male capelin should be used.

The total spawning population, P, is estimated from the formula

$$(6) \qquad P = V + C_o$$

where C_o is the catch taken before the tags were released.

More interesting than the actual values of $\hat{V}$ obtained from the calculations are the limits of confidence for the results. BAILEY (1951) has given formulas for mean and standard deviations for $\left(\frac{1}{\hat{V}}\right)$. Although $\hat{V}$ is not normally distributed, $\left(\frac{\hat{1}}{V}\right)$ is, and the 95 % confidence interval is:

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

The corresponding "confidence interval" for $\hat{P}$ is:

$$(7) \qquad C_o + \frac{N \cdot C \cdot s}{R + 1.96 \cdot R} < P < C_o + \frac{N \cdot C \cdot s}{R - 1.96 \quad R}$$

Formula (7) was used directly for the calculations from Group 1. For Group 2 and Group 3 the formula was, according to (5):

$$(8) \qquad C_o + \frac{N_{\text{♂}} \cdot C \cdot s_{\text{♂}}}{R_{\text{♂}} + 1.96 \cdot \sqrt{R_{\text{♂}}}} < P < C_o + \frac{N_{\text{♂}} \cdot C \cdot s_{\text{♂}}}{R_{\text{♂}} - 1.96 \cdot \sqrt{R_{\text{♂}}}}$$

Number of fish tagged (N)

The numbers of fish tagged were known. Fro Group 1 we knew only the sum of females and males. For Group 2 and Group 3 both the number of females and the number of males were known.

Size of the catch after tagging (C)

The 12 factories that were considered most important were tested for "tag return efficiency". 100 capelin taken from the conveyor belt were tagged in the usual way, but with unnumbered tags. The tagged fish were then put back on the conveyor belt just before it entered the production machinery. The unnumbered test tags were collected together with the numbered tags from magnets in the production system and during cleaning. In Table 6 the tag return efficiencies (the proportion of the released test tags that were returned), and the numbers of recovered numbered tags per (hectolitre x 10^5) are given. Only factories with tag return efficiencies > 0.50 were used in further calculations.

All catches of capelin that are delivered, are sampled by statistics collectors, and among other information they also record the date the catch was taken, the size of the catch, the factory that takes delivery, and the length frequencies, based on one or two samples of approximately 100 fish from each catch.

From the above information we obtained the catch fished in any period of time that was delivered to each factory (Tables 7, 8 and 9).

C was then calculated from the formula:

$$C' = \sum^{f} e_f \cdot p_f$$

f signifies the factories A - G, that had tag return efficiencies > 0.50

e_f = tag return efficiency for factory f

p_f = catch of capelin from the date tagging started and out the season, delivered to factory f.

The calculations of C are shown in Tables 7, 8 and 9.

Catch taken before the tags were released (C_o)

C_o is the total catch fished before the date when the first tag in each group was released, and has been taken from the same statistics as C.

Group 1 C_o (fished Febr. 18 and earlier) $= 0.6 \cdot 10^6$ hl

Group 2 C_o (fished March 10 and earlier) $= 2.5 \cdot 10^6$ hl

Group 3 C_o (fished March 18 and earlier) $= 4.8 \cdot 10^6$ hl

Tagging survival factors (s)

The maximum values from the experiment were used:

$s_♀ = 0.51$ and $s_♂ = 0.89$. For Group 1 it was assumed that half the tagged fish were females and half males, and consequently $s = \frac{1}{2}(s_♀ + s_♂) = 0.70$.

Numbers of tags recovered (R)

Each tag that was returned was taped to a card with (among other) information about which factory the tag was returned from. Thus, it was easy to count the tags from different series that had been returned from the factories in question. As the correction for tag return efficiency has been incorporated into C, the values for returned tags can be used directly. The results are given in Tables 7, 8 and 9.

RESULTS AND DISCUSSION

Using the above information, the "95 % confidence intervals" for P can be calculated separately for the three groups of tags. A factor of 0.097 is used to transfer the results from hectolitres, as used in the catch statistics, to tons (for commercial purposes one reckons 97 kilos in 1 hectoliter of capelin).

$$\left(0.6 \cdot 10^6 + \frac{1{,}000 \cdot 1{,}883{,}265 \cdot 0.70}{22 + 1.96 \cdot \sqrt{22}}\right) \cdot 0.097 \text{ tons} < P <$$

$$\left(0.6 \cdot 10^6 + \frac{1{,}000 \cdot 1{,}883{,}265 \cdot 0.70}{22 - 1.96 \cdot \sqrt{22}}\right) \cdot 0.097 \text{ tons}$$

$$\underline{4.2 \cdot 10^6 \text{ tons} < P < 10.0 \cdot 10^6 \text{ tons}}$$

Group 2

$$\left(2.5 \cdot 10^6 + \frac{4{,}000 \cdot 1{,}283{,}129 \cdot 0.89}{538 + 1.96 \cdot \sqrt{538}}\right) \cdot 0.097 \text{ tons} < P <$$

$$\left(2.5 \cdot 10^6 + \frac{4{,}000 \cdot 1{,}283{,}129 \cdot 0.89}{538 - 1.96 \cdot \sqrt{538}}\right) \cdot 0.097 \text{ tons}$$

$$\underline{1.0 \cdot 10^6 \text{ tons} < P < 1.1 \cdot 10^6 \text{ tons}}$$

Group 3

$$\left(4.8 \cdot 10^6 + \frac{1{,}650 \cdot 646{,}999 \cdot 0.89}{65 + 1.96 \cdot \sqrt{65}}\right) \cdot 0.097 \text{ tons} < P <$$

$$\left(4.8 \cdot 10^6 + \frac{1{,}650 \cdot 646{,}999 \cdot 0.89}{65 - 1.96 \cdot \sqrt{65}}\right) \cdot 0.097 \text{ tons}$$

$$\underline{1.6 \cdot 10^6 \text{ tons} < P < 2.3 \cdot 10^6 \text{ tons}}$$

As can be seen, the estimates of the spawning population differ widely according to which group of tags has been used. This variation is much larger than what can be accepted if the population estimate is to be used for regulation of the fishery.

The obviously most important reason for this is that the tagged fish were not randomly distributed in the population. As a result of this, fishing mortality for the tagged fish may have been substantially different from the fishing mortality for the rest of the spawning population.

In the case of Group 1, there is also reason to believe that natural mortality has been much higher than for the rest of the population: Immediately after the tagging a storm blew up and stopped the fishing almost completely for a week. After the storm the concentration of capelin in which the tagged fish from Group 1 had been released could not be located. Information from our research vessels (ANON. 1974) indicate that a fairly heavy concentration of cod was found in the area where this capelin was lost. In any case, whether this concentration of capelin was decimated by predation or it just avoided the fishing vessels, there can be no doubt that fishing mortality for the capelin from Group 1 was much lower than for the rest of the spawning population. The extraordinarily high population estimates resulting from the tags in Group 1 should therefore be disregarded completely.

As for the capelin tagged in Group 2 and Group 3 there are few data to indicate, for the groups as a whole, whether fishing mortality for tagged fish was different from that for the whole population. However, release of the tagged fish occurred fairly close to the fishing fleet, and fishing mortality was at least likely to be very variable from batch to batch of the tagged fish.

There are also considerable possibilities of bias in the values used for the survival factors, the tag return efficiencies and the way the catch statistics have been used, but a discussion of that would carry too far here.

We are then left with two estimates of the spawning population. The calculations based on the tags in Group 2, with 4,000 tags released and 538 returned, indicate a spawning population of 1.0 - 1.1 million tons. The calculations based on the tags in Group 3, with 1,650 tags released and 65 returned, indicate a spawning population of 1.6 - 2.3 million tons.

The larger number of tags released in Group 2, and the fact that the tags were released earlier in the fishing season, might indicate that the results from Group 2 are less likely to be biased. This estimate also agrees well with an acoustic estimate carried out in September - October 1973 (DOMMASNES, NAKKEN, SÆTRE and FRØILAND, 1974), that indicated a spawning population of 1.0 million tons, with a possibility that the value might be as high as 1.5 million tons (NAKKEN and DOMMASNES, 1975).

The widely differing estimates of the same stock using three different groups of tags indicate that at present stock estimates for capelin based on tagging experiments should be treated with caution. However, even now the tagging experiments are useful as controls for the acoustic estimates, and efforts should be made to improve the reliability.

SUMMARY

1. Capelin tagged with internal stainless steel "sprat tags" have been kept in net enclosure for 9-10 days to get the survival factor.

The "maximum survival factor" was found to be 0.89 for males. Additional information from routine tag recoveries indicated a maximum survival factor of 0.51 for female capelin.

2. The 1974 capelin spawning population in the Barents Sea was calculated separately from three different groups of tags released at different times during the fishery.

The resulting estimate for the population size was 4.2-10.0 million tons, 1.0-1.1 million tons, and 1.6-2.3 million tons, respectively. The highest estimate is obviously too high, and the reason is believed to be that the part of the population into which those tags were released had lower fishing mortality than the rest of the population. As for the two remaining estimates, the reason for the difference probably is that the tagged fish was not randomly mixed into the population. The tagging experiments give little basis for choosing one or the other of those two estimates, except that the lowest one is based on the largest number of released tags.

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Table 1. Numbers of dead fish picked up each day from the different series of tags, plus the numbers of survivals picked up at the end of the experiments. Also given is the number of recovered tagged fish in experiments 1 and 2 that had lost their tags. The fish were released into the net enclosures February 20. February 21 dead fish were taken up in the morning and the afternoon, the other days in the morning. Experiments 1 and 1a were finished on February 28, and Experiment 2 was finished on March 1.

Experiment	Tag number \ Dates	February 21	21	22	23	24	25	26	27	28	March 1	End of Exp.	Total number recovered
Experiment 1	N 98501 - 550	36	1	-	-	-	-	-	1	-		-	38
Experiment 1	N 98551 - 600	38	3	1	3	-	-	-	-	-		2	47
Experiment 1	N 98601 - 650	28	3	3	1	1	-	1	-	--		7	44
Experiment 1a / Experiment 1	N 98651 - 700	11	2	-	3	1	2	1	1	-		26	47
Experiment 1a / Experiment 1	N 98701 - 750	11	3	2	-	-	-	2	1	2		23	44
Experiment 1a / Experiment 1	N 98751 - 800	12	3	2	2	-	1	-	-	-		26	46
Experiment 1a / Experiment 1	N 98801 - 850	5	-	1	1	-	-	1	-	1		39	48
Experiment 1a / Experiment 1	N 98851 - 900	8	1	2	2	2	-	1	-	2		25	43
Experiment 1a / Experiment 1	Fish that have lost the tag	5	-	-	1	-	-	-	-	-		8	14
Experiment 2	N 98901 - 950	4	-	3	-	1	-	2	2	1	1	25	39
Experiment 2	N 98951 - 000	-	-	1	-	-	1	1	1	-	-	29	33
Experiment 2	N 99001 - 050	2	3	-	1	-	2	3	1	-	1	23	36
Experiment 2	N 99051 - 100	6	4	3	3	-	-	-	1	-	1	17	34
Experiment 2	N 99101 - 150	5	-	3	1	-	-	-	-	-	-	28	37
Experiment 2	N 99151 - 200	2	2	1	-	1	3	2	2	-	1	23	37
Experiment 2	Fish that have lost the tag	1	-	-	-	-	-	-	-	-	-	4	5

Table 2. Tag retainment in Experiment 1 (tags N98501-N989[illegible])

	♀	♂
Surviving fish recovered at the end of the experiment	1	155
Surviving fish recovered that had kept the tags	1	147
Tag retainment factor	1.00	0.95

Table 3. Results of Experiment 1a (tags N98651-N98900)

Experiment 1a	Date	Time	Tagged ♀	Tagged ♂	Tagged ♀+♂	Untagged ♀	Untagged ♂	Untagged ♀+♂
Released into the net enclosures	Febr. 20	13.05-14.35	58*	192*	250	104*	296*	400
Recovered dead	Febr. 21	09.00	32	12	44	49	9	58
"	" "	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 recovered during experiment			53	35	88	97	45	142
Surviving fish recovered at the end of the experiment	Febr. 28	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*	12*	16	1*	4*	5
Surviving fish recovered that had kept the tags			1**	138**				

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

** The numbers have been estimated, using the "Tag retainment factor" calculated for Experiment 1 and given in Table 2.

Table 4. Results of Experiment 2 (tags N98901-N99200)

Experiment 2	Date	Time	Tagged ♀	Tagged ♂	Tagged ♀+♂	Untagged ♀	Untagged ♂	Untagged ♀+♂
Released into the net enclosures	Febr. 20	15.45-17.45	45*	255*	300	56*	244*	300
Recovered dead	Febr. 21	09.30	15	5	20	14	2	16
"	" "	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
"	March 1	08.00	0	4	4	0	2	2
Total number of dead recovered during experiment			33	39	72	41	20	61
Surviving fish recovered at the end of the experiment	March 1		0	149	149	1	161	162
Total number of fish recovered			33	188	221	42	181	223
Total number of fish lost			12*	67*	79	14*	63*	77
Surviving fish recovered that had kept the tags			0	145				
Tag retainment factor			-	0.97				

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

Table 5a. Some possible combinations of sex ratio and mortality for 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/survivals 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 survivals.
C	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 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 5b. Values of S_1, N_1, S_2, N_2 and s♂ for the combinations of sex ratio and mortality given in Table 5a. Loss of tags has been included in S_1, using the "Tag retainment factors" given in Tables 2 and 4.

	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

Table 6. Tag return efficiencies, and recovered tags per (hectolitre x 10^5) corrected for tag return efficiencies

Factory designation	Tag return efficiency (e)	Recovered tags per (hectolitre x 10^5) fished after the tags were released $\left(\frac{R \cdot 10^{5*}}{e \cdot p}\right)$				
		N 9701-10000 N 11101-11800	N 11801-14000 N 15001-20800		N 20801 - N 25300	
		♀ + ♂	♀	♂	♀	♂
A	0.90	0	47.9	50.3	30.2	19.1
B	0.81	1.1	89.8	59.8	12.1	14.7
C	0.79	3.2	72.4	74.5	18.6	17.4
D	0.78	0.4	51.7	68.6	17.4	17.4
E	0.74	0.6	88.1	93.3	30.7	10.3
F	0.61	3.8	84.3	81.9	74.1	21.6
G	0.55	3.7	59.5	58.8	51.9	23.4
H	0.44	1.5	76.9	135.3	56.9	13.8
I	0.39	4.5	244.8	187.9	47.9	46.4
J	0.21	3.6	90.5	172.4	38.3	46.4
K	0.17	0	344.3	303.1	0	91.7
L	0.10	0	0	0	0	0

* R and (e · p) taken from Tables 7, 8 and 9 for factories A - G, and calculated in the same way for factories H - L.

Table 7. Quantities of capelin fished after Febr. 18, delivered to the factories in question and corrected for tag return efficiency, together with the numbers of tags from Group 1 returned from those factories

Factory desination	Tag return efficiency (e)	Quantity received that had been fished after Febr. 18, in hectolitres (p)	Corrected quantity in hl (e · p)	Returned tags N 9701 - 10000 N 11101 - 11800
A	0.90	171 789	154 610	0
B	0.81	222 941	180 582	2
C	0.79	236 414	186 767	6
D	0.78	987 701	770 407	3
E	0.74	435 498	322 269	2
F	0.61	217 329	160 823	5
G	0.55	196 012	107 807	4
Sum of corrected quantities, C			1883 265	
Sum of returned tags, R				22

Table 8. Quantities of capelin fished after March 10, delivered to the factories in question and corrected for tag return efficiency together with the numbers of tags from Group 2 returned from those factories.

Factory designation	Tag return efficiency (e)	Quantity received that had been fished after March 10, in hectolitre (p)	Corrected quantity in hl (e . p)	Returned tags from male capelin, in the series N 11801-14000 N 15001-20800
A	0.90	121 591	109 432	32
B	0.81	167 193	135 426	47
C	0.79	207 876	164 222	72
D	0.78	554 652	432 629	172
E	0.74	332 393	245 971	134
F	0.61	176 148	107 450	51
G	0.55	159 999	87 999	30
Sum of corrected quantities, C			1283 129	
Sum of returned tags, $R_{♂}$				538

Table 9. Quantities of capelin fished after March 18, delivered to the factories in question and corrected for tag return efficiency together with the numbers of tags from Group 3 returned from those factories.

Factory designation	Tag return efficiency (e)	Quantity received that had been fished after March 18, in hectolitres (p)	Corrected quantity in hl (e · p)	Returned tags from male capelin, in the series N 20801-25300
A	0.90	69 987	62 988	7
B	0.81	72 979	59 113	5
C	0.79	113 036	89 298	9
D	0.78	280 057	218 444	22
E	0.74	178 748	132 274	8
F	0.61	78 953	48 161	6
G	0.55	66 766	36 721	8
Sum of corrected quantities, C			646 999	
Sum of returned tags, $R_{♂}$				65

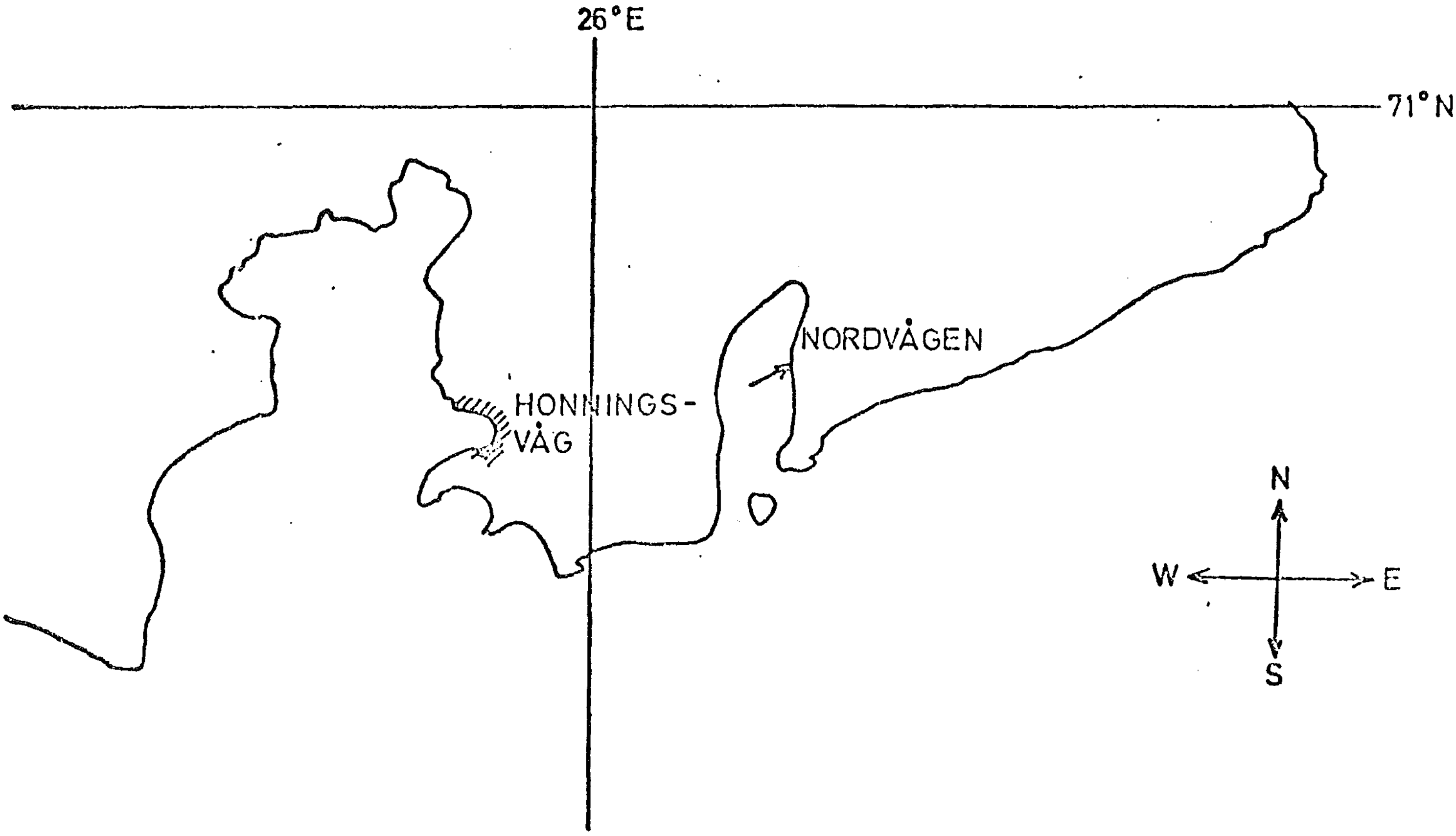

Fig. 1. The Honningsvåg - Nordvågen area. The experiment site in Nordvågen is indicated by an arrow.

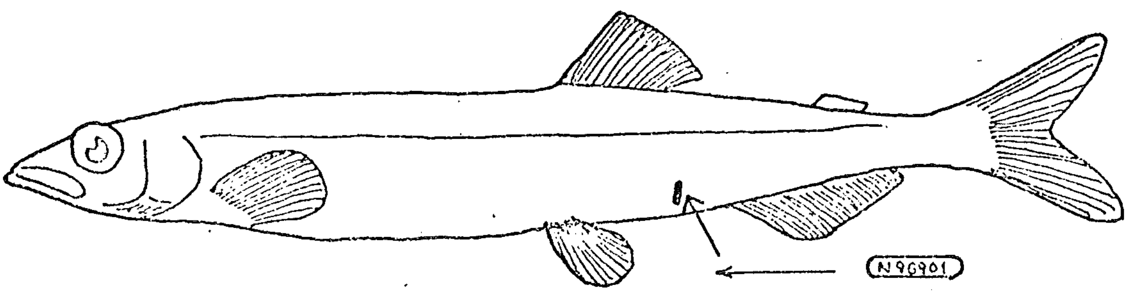

Fig. 2. A capelin. The position where the tag is pushed into the body cavity is indicated by the arrow. A tag is shown in correct relative size.

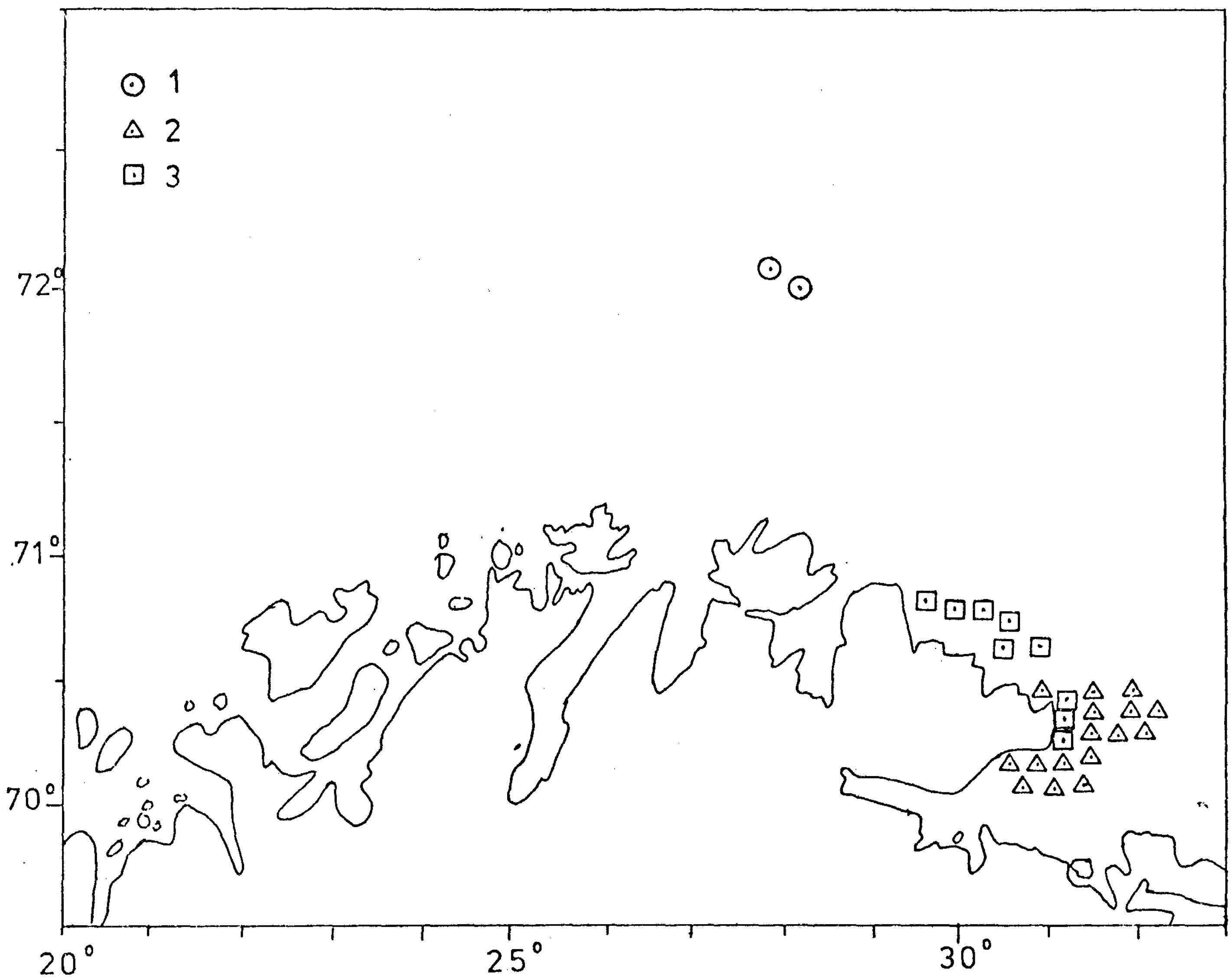

Fig. 3. Positions where tagged capelin were released. 1) Tags N 9701-10000 and N 11101-11800 (Group 1), 2) Tags N 11801-14000 and N 15001-20800 (Group 2), 3) Tags N 20801-25300 (Group 3).