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ESTIMATES OF STOCK SIZE AND REPRODUCTION OF THE BARENTS SEA CAPELIN IN 1970—1972.

By

OLAV DRAGESUND, JAKOB GJØSÆTER and TERJE MONSTAD

Institute of Marine Research, Bergen

ABSTRACT

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The distribution and migration of young and maturing capelin during the period 1969—1972 have been investigated by combined acoustic surveys and fishing experiments.

The nursery area of the capelin is extensive, but the main grounds are in the central and eastern part of the Barents Sea. The two and three year old fish are distributed farther north and northeast than the younger capelin.

Previously, the main part of the spawning stock approached the western part of the Murman coast and the Varanger peninsula, and dispersed westward along the Norwegian coast. During recent years, a major part of the stock also reached the coast of West-Finnmark and migrated farther west and south along the coast for spawning.

The capelin mainly become sexually mature when they are four years old. A very heavy postspawning mortality is observed, and most likely very few capelin survive to spawn a second time.

At present the Barents Sea capelin is the most important fish resource for the Norwegian purse seine fleet, and Norway has been responsible for more than 90% of the total catch from this resource.

Preliminary spawning stock size estimates for 1971 and 1972 are available from acoustic surveys, egg and larval surveys, and tagging experiments.

It is tentatively concluded that the spawning stock size in 1971 was at a high level, being somewhat lower both in 1970 and 1972.

So far no sign of overfishing has been observed. The increase in catch during the last six years is due to a significantly increased fishing effort, but also for a larger part attributed to a raise in the stock size.

A more detailed analysis of the location and time of spawning during the 1971 season is given. Spawning took place along the coast from Vesterålen to Varangerfjord. The major spawning west of North Cape took place during March and off the coast of eastern Finnmark in April.

Fertilization and survival of eggs were studied. On the spawning beds the fertilization seemed to be almost 100%. Egg mortality seemed to be low. The distribution of capelin larvae, during the first month after hatching, was studied. The larvae were collected on five surveys in oblique hauls with Clarke Bumpus plankton samplers.

INTRODUCTION

The annual yields of the Norwegian capelin has gradually increased during the last two decades, and at present the Barents Sea capelin is the most important fish resource for the Norwegian purse seine fleet. Previously capelin were exploited commercially mainly during winter and spring when the mature stock enters coastal waters to spawn, but since 1968 an important fishery has also developed for capelin on the feeding grounds in the Barents Sea (Fig. 1). It is apparent from the history of the fisheries that great variations in spawning time and area have occurred, and that the stock strength has fluctuated widely (OLSEN 1965, 1968). These fluctuations strongly influence the fisheries, and in 1960 the Institute of Marine Research started a programme of capelin investigations with the aim of establishing the causes of these fluctuations and if possible, making prognoses for the fishery.

Each year in February—March, and in later summer and autumn, research vessel surveys have been carried out in the Barents Sea (MØLLER og OLSEN 1962, OLSEN 1968, MONSTAD 1969, LAHN-JOHANNESSEN og MONSTAD 1970). The work has included sonar and echo sounder searching, sampling with midwater and bottom trawls, and hydrographic observations. Since the 1961 season, sampling of the commercial landings has been carried out, and records of biological data for the last decade are available.

Due to the increasing fishing effort, great attention has recently been given to the question of regulating the fisheries for the Barents Sea capelin. Thus in 1970 the Norwegian government introduced a time regulation by closing the summer season from 1 June to 15 July. In 1971 it was prohibited to land catches of capelin from 15 May to 24 July and in 1972 from 1 May to 24 July. A minimum legal size of 12 cm was set in 1971. For the 1972 season it was recommended to increase the minimum size to 14 cm, in order to utilize the growth potential of the young fish (DRAGESUND, MONSTAD og ULLTANG 1973). However, the decision was taken by the Government to increase the legal minimum size by only 1 cm.

The need for regulatory measures during the spawning season has also been discussed. The question has arisen as to whether the intensified fishery during the years 1970—1972 has endangered the future reproduction of the stock. During the winter fishery of 1972 the season was closed for a short period from 19 to 26 March west of North Cape and from 27 March to 9 April east of North Cape.

In order to give more reliable prognoses for the fishery and to collect adequate material for regulatory measures to be taken, the Norwegian

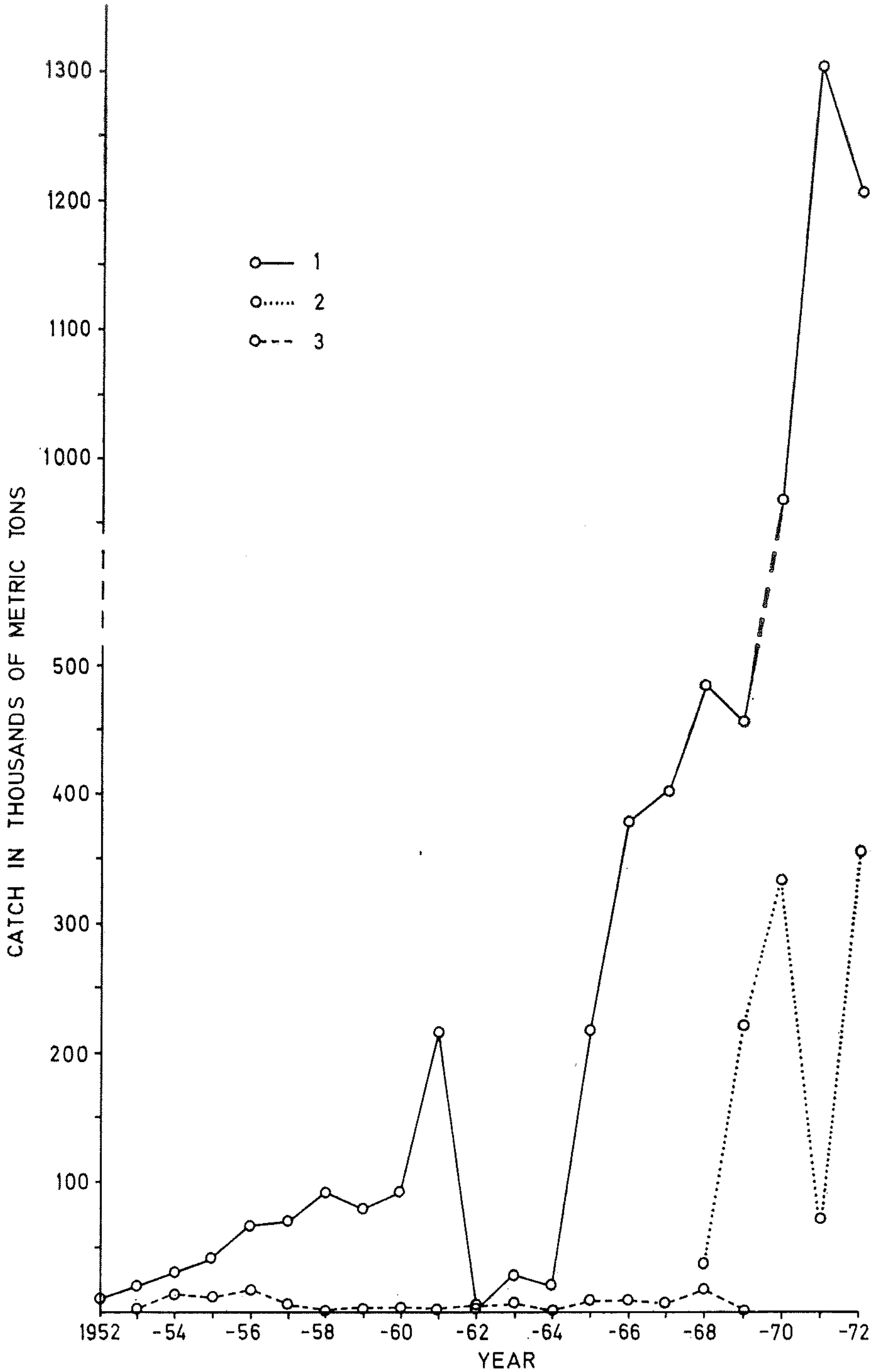

Fig. 1. Catches of Barents Sea capelin in 1950—1972. 1) Norwegian winter fishery, 2) Norwegian summer fishery, 3) Soviet winter- and summer fishery.

capelin investigations were considerably extended in 1971 by including more qualitative work on the Barents Sea capelin resource and its production of recruits.

The aim of the present paper is to report some results of the investigations carried out the last three years with emphasis on:

1) distribution and migration of capelin during autumn and winter;
2) structure and size of the spawning stock;
3) reproduction of the stock and the resulting year-class strength.

MATERIAL AND METHODS

Most of the material is obtained from investigations carried out during autumn and winter 1969—1970 to 1971—1972. It includes data from acoustic surveys, egg and larval surveys, tagging experiments, samples of capelin and catch statistics.

ACOUSTIC SURVEYS

Every autumn, during October to December, the distribution and abundance of adult capelin in the Barents Sea were studied from combined acoustic surveys and fishing experiments with pelagic trawl (MONSTAD 1971, JAKUPSSTOVU *et al.* 1972). Similar acoustic surveys were conducted from January to late February (LAHN-JOHANNESSEN og MONSTAD 1970, BLINDHEIM og MONSTAD 1972). In 1971 and 1972 investigations were also carried out during the spawning season from mid-March to the end of April. In order to give a more quantitative distribution of the capelin resource, special echo surveys were undertaken in August-September 1970 and 1971 (BLINDHEIM *et al.* 1971, DRAGESUND og NAKKEN 1972).

The research vessels used («Johan Hjort» and «G. O. Sars») were equipped with vertical echo sounders, echo integrators and horizontal ranging sonars, and during the surveys the acoustic instruments were operated continuously. The settings of the Simrad echo integrator and the EK 38 kHz echo sounder during the surveys in August-September 1970 and 1971 were: Output power 1/10 effect, time varied gain (TVG) 20 log R and receiver gain — 20 dB. The source level was 136 dB, receiving voltage response 7.8 and the beamwith 5° and 5.5° along and athwartship between the 3 dB points. In order to avoid saturation of the echo integrator the gain was adjusted when necessary. Three echo integrators with six echo integrator channels were used, each covering a depth interval of 50 m. Echo integrator readings were made each nautical mile, and average values of each five miles were plotted on maps.

When other fish species were recorded within the same depth interval, the echo abundance was divided between capelin and the other species. Both experimental fishing and analysis of the echo traces were used for diving the total echo abundance (Blindheim *et al.* 1971).

A method to estimate the stock size based on acoustic surveys, is developed by Midttun and Nakken (1971), Blindheim and Nakken (1971) and applied by Midttun and Nakken (1972).

The total echo abundace (T) was estimated from the equation

$$T = \int_A \varrho \, dA \qquad (1)$$

where A is the area of distribution and ϱ the number of fish or fish weight per unit area.

C is calculated from the relation of Midttun and Nakken (1971),

$$\varrho = C\,M \qquad (2)$$

where C is approximately constant for the same species in case ϱ is measured in fish weight per unit area. M is the integrated echo intensity. The procedure for calculating C is described by Blindheim and Nakken (1971).

Applying (1) and (2) $T = C \int_A MdA$ (3)

$$T = C_{T\ relative} \qquad (4)$$

where $T_{relative}$ has the dimension: mm echo integrator readings $\times$ unit surface area.

By integrating the area between the isolines on the map where the echo integrator readings are plotted, $T_{relative}$ can be found.

EGG AND LARVAL SURVEYS

During surveys carried out in winter of 1971 and 1972, capelin eggs were collected by Pettersen grab, but were also sampled by diving and from the stomach content of haddock, cod and saithe caught by bottom trawl. A more detailed description of the diving technique used is given by Bakke and Bjørke (1973).

The larvae were collected in oblique hauls with Clarke—Bumpus plankton samplers (CBPS). The length of the nylon net used was 60 cm with a mesh size of 0.5 mm. The CBPS were equipped with flowmeters, and three samplers were towed simultaneously at different depths and raised in 5 m steps.

The sampling depths were 25—5, 50—30 and 75—55 m. The total towing time was 20 minutes. A weight of 28 kg was attached at the end of the 4 mm thick wire which was kept as close as possible to an angle of 50° from the surface by keeping the towing speed between 1.5 and 2.0 knots. Because of difficulties in operating the closing mechanism of the CBPS in bad weather, this was permanently kept in open position. The number of larvae collected was converted to numbers below 1 m^2 sea surface.

In order to evaluate the size of the spawning stock, the total number of eggs in a locality near North Cape (Nordvågen) was estimated in 1971. One week after hatching commenced, a detailed larval survey was carried out in the area where larvae from Nordvågen were distributed. Probably some larvae had drifted out of the area, and some larvae from other spawning grounds may have drifted into it; though it is belived that the estimated number is reasonably close to the real one. The ratio, between eggs spawned in Nordvågen and the number of larvae derived from these eggs and available to the plankton gears during the given period of time, was calculated. This ratio between eggs and larvae can be applied to the whole spawning area, provided that:

1) the plankton samplers are taken at the same time in relation to the hatching sequence;
2) that hatching success and mortality of the implied larval stages are the same in all areas, or that the area selected for the detail study has conditions corresponding to an average for the other areas;
3) the larvae sampled are equally representative in all areas.

By this method number of eggs spawned can be computed from number of larvae taken during a larval survey, and when fecundity is known, number of fish which have spawned can be found. A more detailed discussion of this method is given by GJØSÆTER and SÆTRE (1973).

TAGGING EXPERIMENTS

During the winter seasons of 1971 and 1972 tagging experiments were carried out from the scouting vessel «M. Ytterstad», which on this occasion was equipped with purse seine. The capelin were tagged with internal steel tags measuring 14 × 3 × 0.5 mm. A tagging device, especially developed for inserting this tag, was used. After being carefully brought from the purse seine into the tank on deck, the capelin were taken out indicidually, imidiately tagged, and were released in batches of approximately 20 individuals into the sea by means of a bucket.

Nearly all tags recovered were found at Norwegian reduction plants where magnets are installed for detecting the tags. The efficiency of the magnets was tested during the winter seasons of 1971 and 1972. The procedure for testing the magnets, and the routine for collecting data on the catches and tags recovered at Norwegian reduction plants, are described by AASEN (1958) and by DRAGESUND and HARALDSVIK (1968).

The spawning stock (S) was estimated from the relation

$$S = \frac{S_1 \cdot N_1 + S_2 \cdot N_2 + \text{-----------} S_n \cdot N_n}{N} \tag{5}$$

where S_1, S_2 - - - - - - - S_n are the stock sizes estimated from each release and N_1, N_2 - - - - - - - N_n the number of tagged fish. N is the total number of tagged fish. S_1, S_2 - - - - - - - S_n are estimated from the relation

$$S_n = \frac{N_n \cdot C_n \cdot s}{R_n} \tag{6}$$

where C_n is the catch subesequent to the n^{th} release and R_n the number of recaptures from this release.

s is the tagging survival, taking into account both tagging mortality and shedding of tags. No decisive experiments on capelin have been carried out on tagging survival with internal steel tags. This factor certainly plays an important role in the calculations of the stock strength and has to be adjusted for. Tentatively s is set to 0.80.

CAPELIN SAMPLES AND CATCH STATISTICS

During the acoustic surveys capelin were caught with a Norwegian capelin trawl with an opening of 12 × 12 fathomes, mesh size (stretched) ranging from 200 mm (wings and squares) graded down to 22 mm (cod end). An ordinary Granton bottom trawl with cover net equipped with bobbins was also available.

In addition to samples collected during the acoustic surveys, capelin samples were collected throughout the winter seasons of 1970—1972 from commercial catches. The capelin were examined fresh or from frozen material.

Total length was measured to the nearest mm and grouped in half cm class intervals (GJØSÆTER and MONSTAD 1973). Otoliths, mainly taken stratified, were used for age determination, and age-length keys were established. The maturity stages were classified according to a scale used by MONSTAD (1971). The weigth in g was recorded.

During surveys the volume of individual fish was measured by the displacement method, and from this the weight was estimated.

Catch statistics of the Norwegian landings were obtained from the official fishery statistics. Statistical information, on the geographical distribution of commercial catches of spawning and spent capelin in winter 1971, was supplied from the fishermen's sales organization, Feitsildfiskernes Salgslag. Statistics of landings by USSR were derived from «Bulletin Statistique des Peches Maritimes».

DISTRIBUTION AND MIGRATION

The distribution of capelin in August—September 1970 and 1971 is illustrated in Fig. 2, 3 and 4. The survey in 1970 did not cover the area east of 40°E and north of 77°N. In the western part of the investigated area the abundance was significantly higher in 1970 (Fig. 2) than in 1971 (Fig. 3). During the second survey in 1971 (Fig. 4) the capelin were recorded somewhat farther west and north. The summer fishery on two and three years old capelin in 1969—1971 took place in this area, i. e. between 74°—78°N and 25°—45°E.

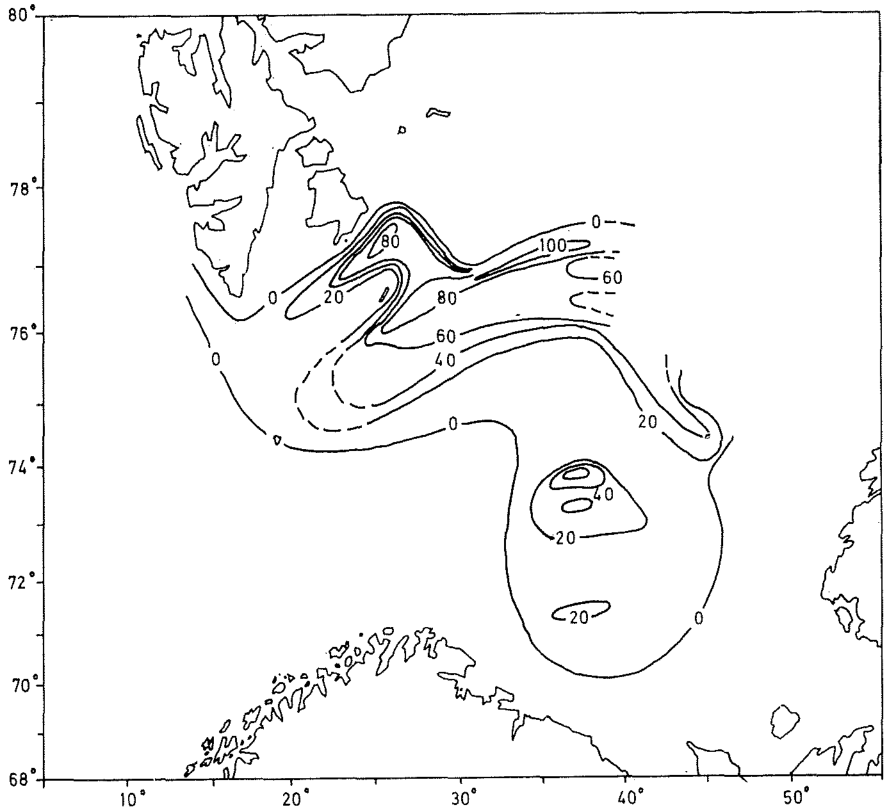

Fig. 2. Distribution of capelin 28 August—11 September 1970. Isolines and numbers are fish density as echo integtorar recordings in mm.

Fig. 5—7 show the distribution and migration during the prespawning period in 1969—1970, 1970—1971 and 1971—1972. In late autumn the maturing capelin segregate from the immature stock and gradually start their migration southward along the front between the cold and warmer water in the area from the Central Bank (75°N, 35°E) towards the Thor Iversen Bank (73°N, 35°E). From this region part of the stock moves farther south and southeast, whereas another component start migrating westward.

In previous years the main part of the spawning stock usully aproached the western part of the Murman coast and the Varanger peninsula and dispersed westward along the Norwegian coast (PROKHOROV 1965, MØLLER og OLSEN 1962). During the spawning seasons in 1970—1972

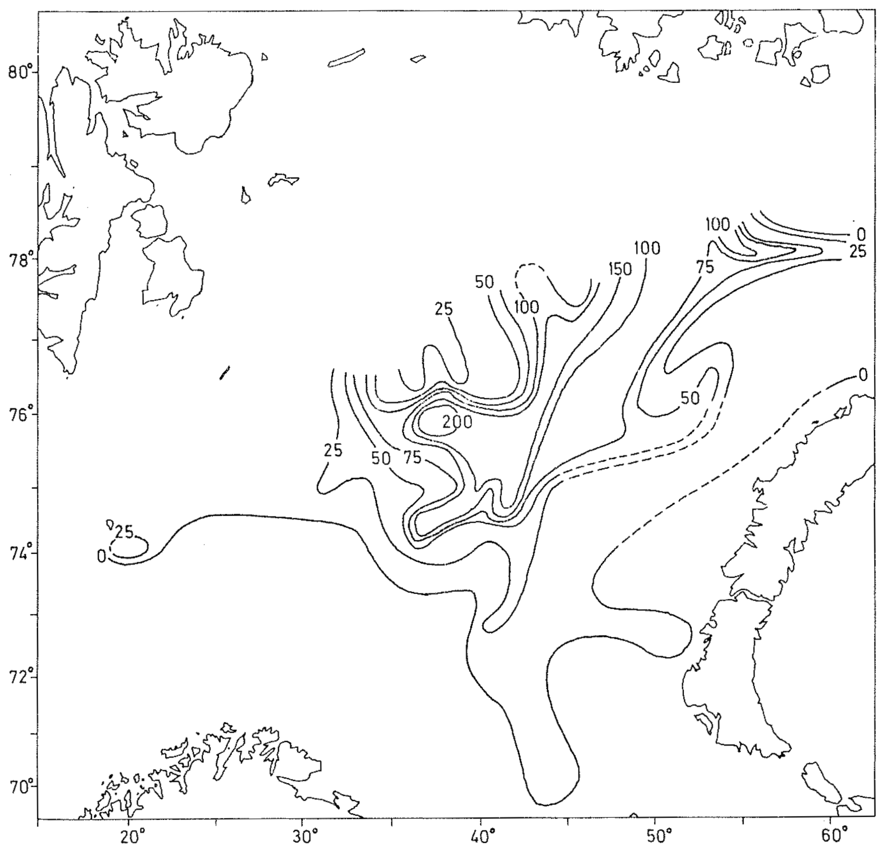

Fig. 3. Distribution of capelin 23 August—9 September 1971. Isolines and numbers are fish density as echo integrator recordings in mm.

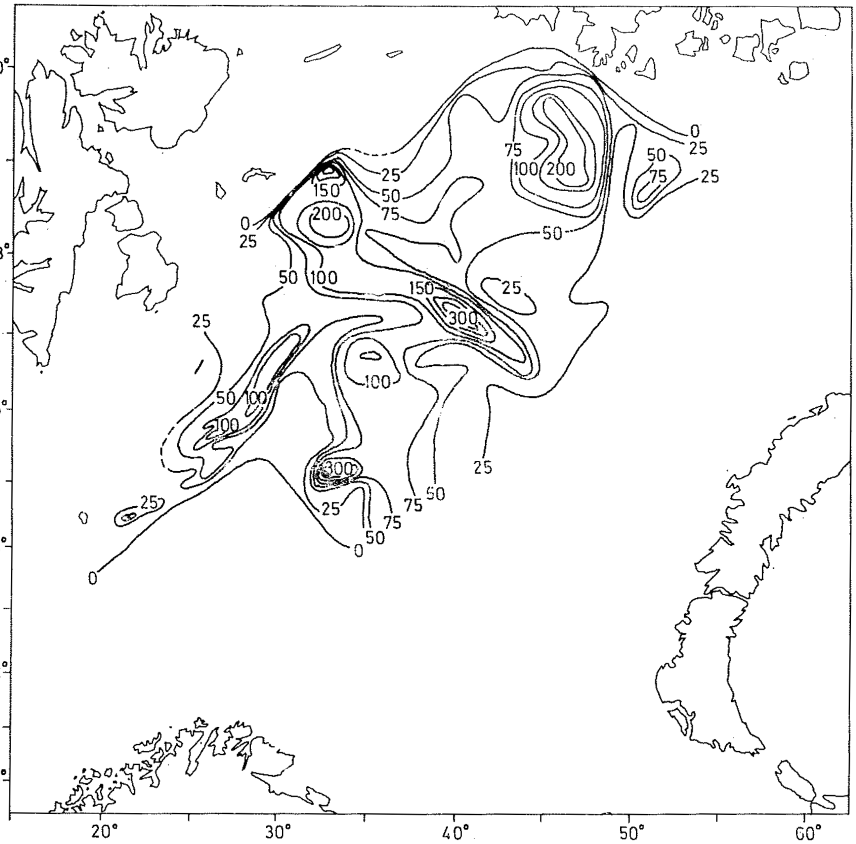

Fig. 4. Distribution of capelin 12—29 September 1971. Isolines and numbers are fish density as echo integrator recordings in mm.

as well as in 1968 and 1969 (Olsen 1968, Lahn-Johannessen og Monstad 1970) part of the stock also migrated from the open sea towards the coast of West-Finnmark (west of North Cape). The main part of the western stock component approached the coast between Sørøya and the North Cape during February. In 1970 the main part of the spawning stock was distributed east of North Cape where the most important fishery took place (Table 1). However, in 1971 mature capelin continuously approached the coast west of North Cape during February and March and dispersed farther west and south along the coast. In March concentrations of capelin were located off Senja and in March—April off Vesterålen. This is the most southern area of capelin catches recorded in Norwegian waters during the last two decades. Components of the stock also reached the Finnmark coast east of North Cape, but in contrast to previous years no great concentrations were observed along the coast of eastern Finnmark in 1971, although the larval surveys indicated heavy spawning also in this area. The most important fishing took place west of North Cape, but profitable catches were also obtained east of North Cape. Also in 1972 most of the fishing took place west of North Cape, but the capelin did not move to the spawning grounds off Senja and Vesterålen.

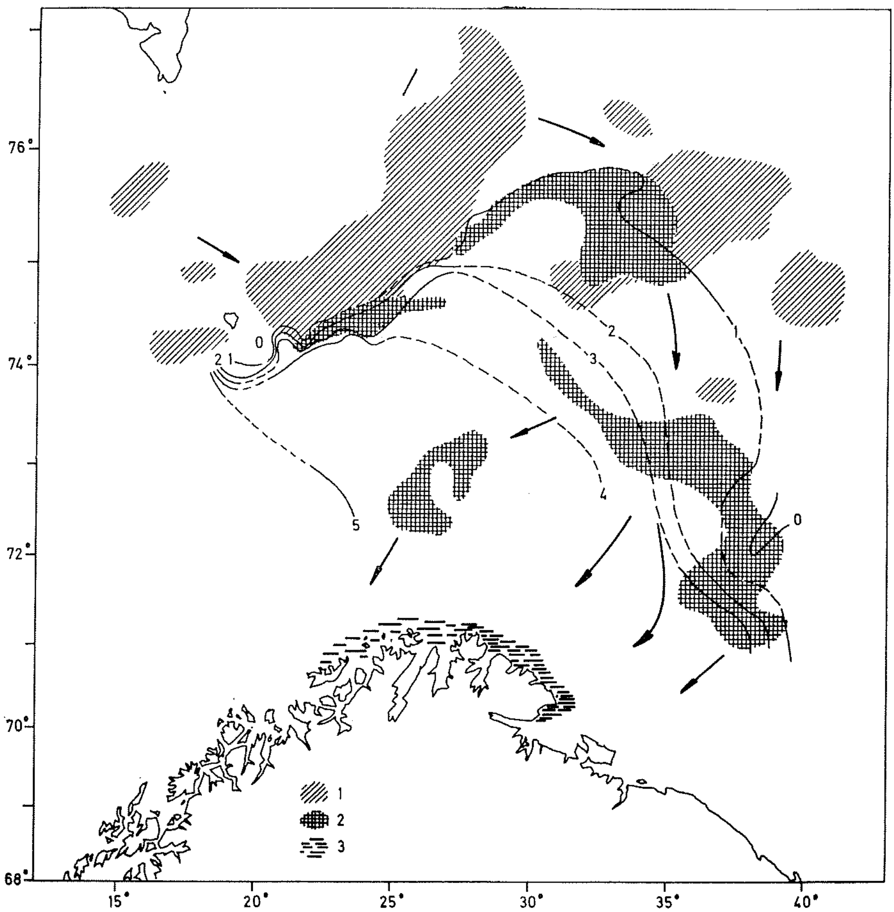

Fig. 5. Distribution of capelin during autumn and winter of 1969—1970. The temperature (°C) at 50 m depth in January 1970 is also indicated. Arrows denote the main migration routes. 1) October—November 1969, 2) January 1970, 3) March—April 1970.

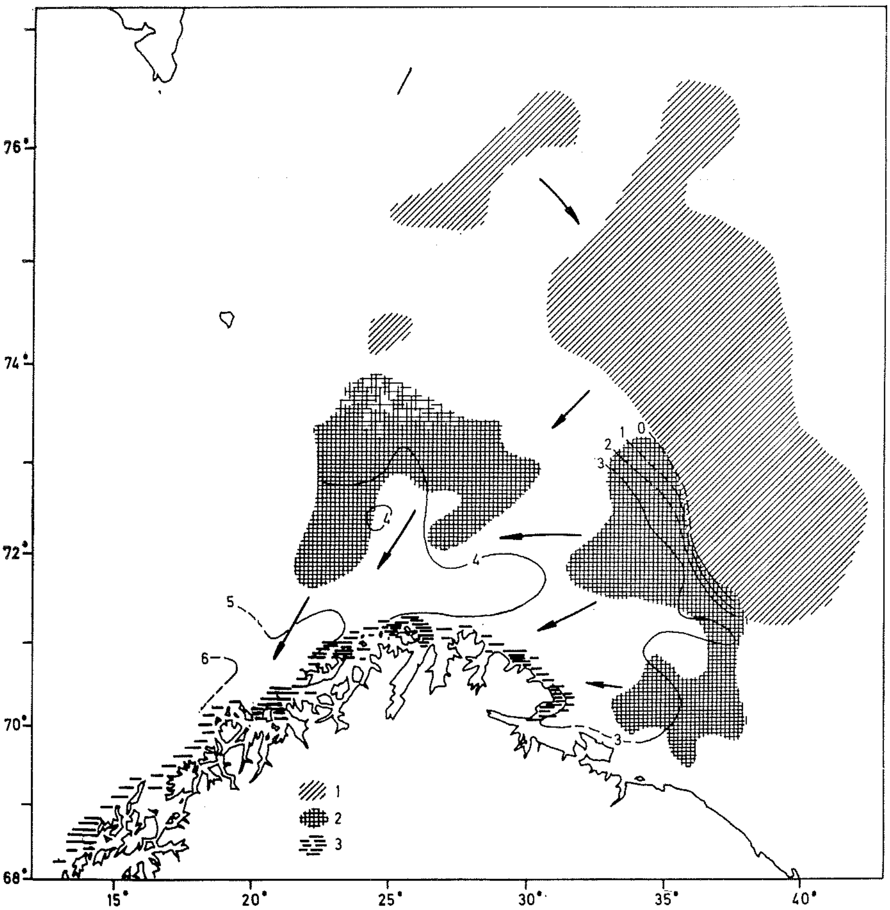

Fig. 6. Distribution of capelin during autumn and winter of 1970—1971. The temperature (°C) at 50 m depth in January—February 1971 is also indicated. Arrows denote the main migration routes. 1) November—December 1970, 2) January—February 1971, 3) March—April 1971.

Table 1. Catch of capelin (in thousand tons) during the winter seasons 1970—1972, west and east of North Cape respectively.

Month	Week no.	1970 West	1970 East	1971 West	1971 East	1972 West	1972 East
January	3			7.035		71.630	
	4		1.451	47.193	1.410	130.600	
	5	8.859	11.167	58.647		85.565	
February	6	0.198	0.042	6.604	22.390	158.065	
	7	23.632	14.043	100.573	39.340	126.220	
	8	88.283	10.210	101.555	42.909	69.931	
	9	95.381	35.295	127.950		52.607	0.100
March	10	6.286	114.983	124.365	2.000	206.167	2.817
	11	31.065	95.023	117.710	19.010	147.240	
	12	7.949	89.701	115.100	9.100	65.316	18.546
	13	2.558	67.702	142.508	20.636		105.330
	14	0.999	96.772	112.877	22.022	1.545	
April	15		116.072	32.867	0.307		
	16		31.070	5.649	31.925		
	17		7.255		5.060		
	18		0.131				
May	19	0.023	0.544				
	20		0.136				
	21						
	22		0.013				
Total		265.233	691.610	1 100.633	216.109	1 114.886	126.793

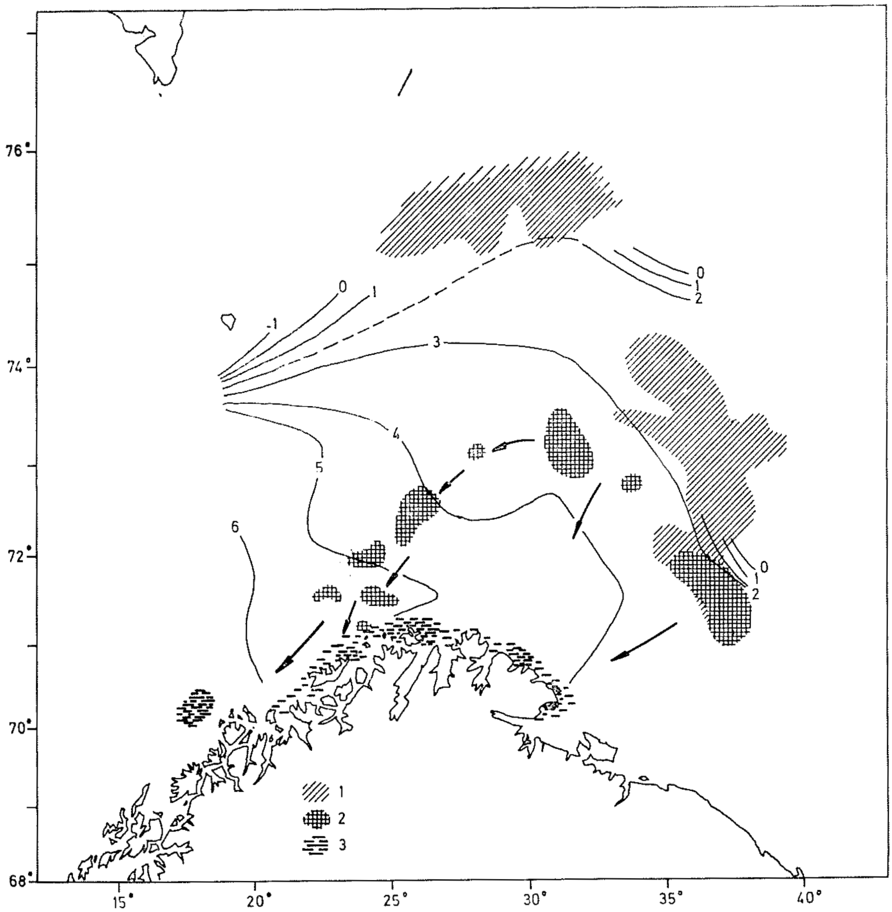

Fig. 7. Distribution of capelin during autumn and winter of 1971—1972. The temperature (°C) at 50 m depth in January—February 1972 is also indicated. Arrows denote the main migration routes. 1) November—December 1971, 2) January—February 1972, 3) March—April 1972.

STRUCTURE AND SIZE OF SPAWNING STOCK

The Barents Sea capelin spawn mainly when three and four years old, and the lack of older fish strongly supports the theory of a very heavy postspawning mortality. At the end of the spawning season dead and dying capelin were observed over wide areas. Possibly some capelin do survive to spawn a second time (TEMPLEMAN 1948, PROKHOROV 1965, VILHJÁLMSSON 1968, WINTERS 1971), but it is suggested that most of them die after spawning.

According to previous investigations, the major part of a year-class spawn at an age of four years (OLSEN 1965, 1968, PROKHOROV 1965). During the winter fishery in 1970 the rich 1966 year-class dominated the catches (Fig. 8), followed by the 1967 year-class.

Investigations carried out during the summer of 1970 (BLINDHEIM *et al.* 1971) indicated that the 1967 year-class was rich, and during the winter season of 1971 this year-class showed to be very abundant and strongly dominated the catches (Fig. 9).

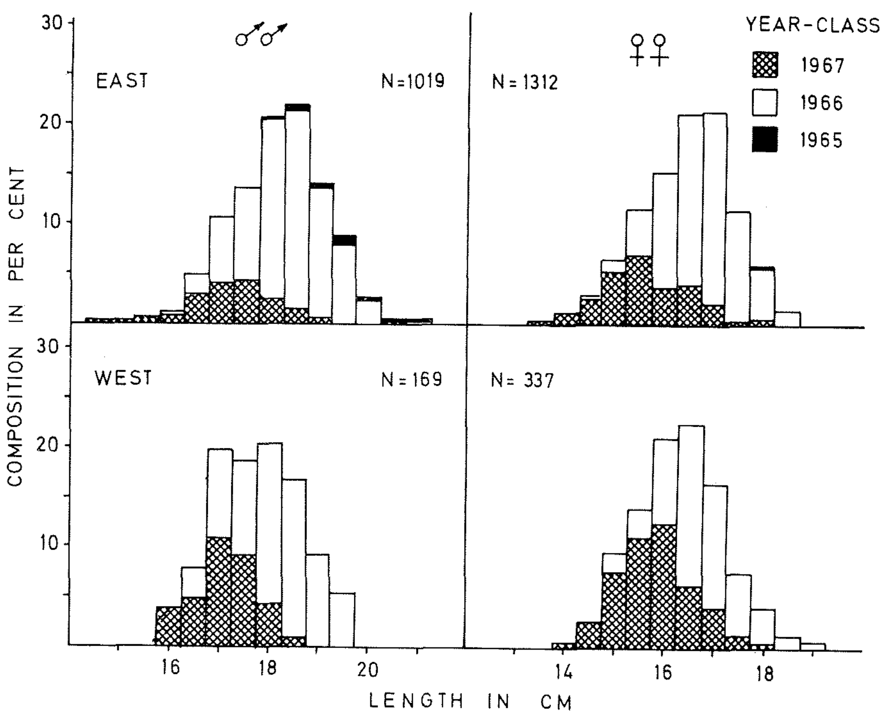

Fig. 8. Age and length composition of capelin during the winter season 1970 off eastern (East) and western (West) Finnmark.

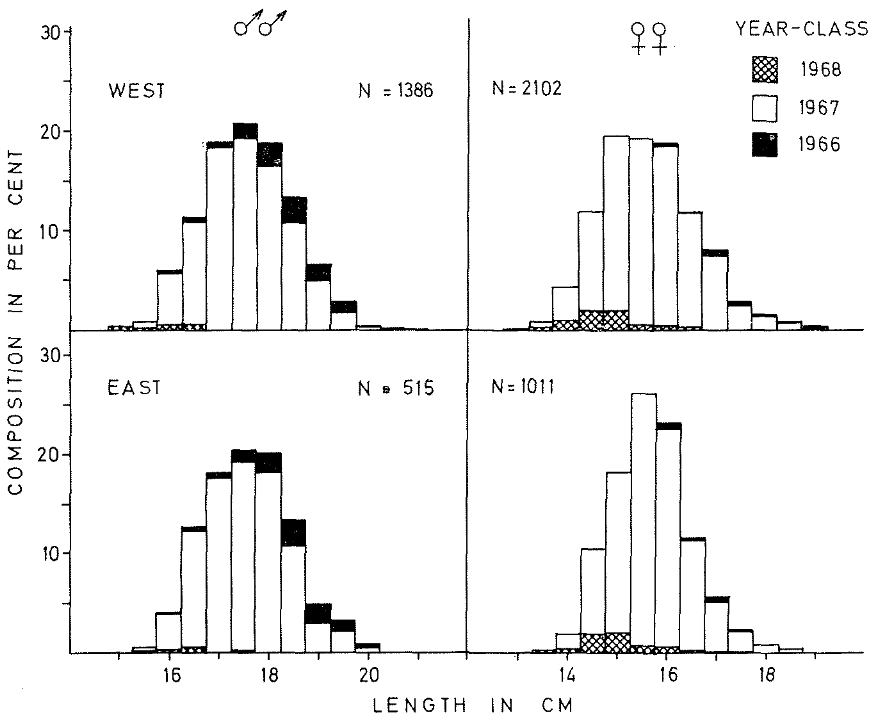

Fig. 9. Age and length composition of capelin during the winter season 1971 off western (West) and eastern (East) Finnmark.

Also, in the winter season of 1972 the four year old fish (1968 year-class) predominated (Fig. 10).

Estimates of the spawning stock size in 1971 are available from tag returns and data on egg and larval abundance and distribution, and for the 1972 season from tagging experiments and acoustic surveys. the different methods used are subject to great errors and will only give some indication of the order of magnitude of the stock size.

The tagging experiments both in 1971 and 1972 were carried out at the beginning of the winter season. The within season returns are listed in Table 2 and 3. The effective quantities of capelin processed during the season, at reduction plants equipped with tested magnets, are also given in Table 2 and 3. The effective quantity processed, subsequent to each release, was estimated according to date on weekly landings during the season (Table 1).

Applying relations (5) and (6), the stock size in 1971 was estimated to be about 5.9 mill. tons, and in 1972 to about 4.8 mill. tons. The figures obtained from this method are overestimated and must be interpreted with caution. An estimate of the stock strength based on these data is only tentative due to lack of information on tagging survival, and because the number of returns are too low and probably not evenly distributed in the catches.

A preliminary estimate of the spawning stock size for the season of 1971 is also obtained from egg and larval surveys. On 7—9 May a detailed larval survey was carried out in the area where larvae from Nordvågen were distributed. Approximately 4×10^{10} larvae were present. Number of eggs spawned in Nordvågen was 7.5×10^{11}. Number of larvae in this period was therefore approximately 1/20 of the number of eggs.

The survey of the whole area and the detail survey should be conducted at the same time in relation to the hatching curve. This requirement is best solved if the survey between 2 and 17 June is selected (Fig. 18). This survey indicate that 1.5×10^{13} larvae were present, and

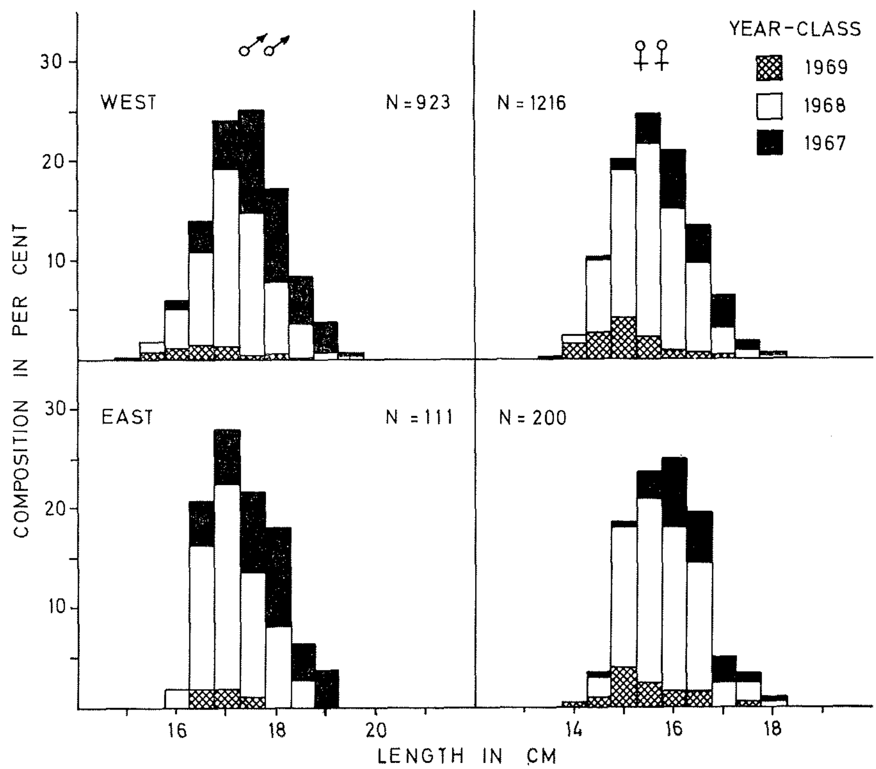

Fig. 10. Age and length composition of capelin during the winter season 1972 off western (West) and eastern (East) Finnmark.

Table 2. Quantity of processed capelin (tons) and number of returns from tagging experiments off the Finnmark coast during the winter season 1971.

Factory no.	Efficiency (e)	Quantity processed (p)	Corrected quantity (e . p)	Date and number of released capelin			
				16—18 February 3000	24 February 500	11—12 March 1500	Total
79.......	0.53	104 305	55 281	4	3	25	32
70.......	0.65	38 150	24 797	4		2	6
69.......	0.62	36 000	22 320	5			5
95.......	0.89	47 363	42 153	10	2	3	15
66.......	0.64	21 753	13 922	7		3	10
55.......	0.94	28 774	27 047	5		6	11
45.......	0.76	28 037	21 308	10			10
43.......	0.77	34 828	26 817	4		2	6
40.......	0.50	21 340	10 670	6			6
42.......	0.90	53 948	48 553	15		1	16
37.......	0.67	32 000	21 440	31			31
24.......	0.66	35 978	23 745	10	2	2	14
31.......	0.88	25 449	22 395	4			4
68.......	0.89	59 510	52 963	36	4	3	43
73.......	0.41	36 642	15 023			7	7
			428 434	151	11	54	216

accordingly that 3×10^{14} eggs had been laid. Assuming a mean fecundity of 10 000 eggs pr. female (GJØSÆTER and MONSTAD 1973), that males and females were present in equal proportions and that there are 3000 capelin in one hl, this corresponds to about 2.0 mill. tons of spawning capelin. Most of the capelin caught during the winter season were in the prespawning stage, and only between one and two hundred thousand tons of the total landings were spent capelin. The stock size at the beginning of the season, estimated from this method, should at least be in the order of 3.2 mill. tons.

A slightly different method, considering only number of young larvae, was applied by GJØSÆTER and SÆTRE (1973). This method indicated a spawning stock size in 1971 of 4.0 mill. tons.

The total echo abundance of capelin during the autumn of 1971 was estimated on the basis of the echo survey carried out 12—29 September (Fig. 4). Both immature and maturing capelin were distributed within the area surveyed (Fig. 11). The mean weight in the samples collected, showed that the maturing capelin made up 36% (weight) of the total stock. The total stock in the area surveyed was estimated from relations (3) and (4).

Table 3. Quantity of processed capelin (tons) and number of returns from tagging experiments off the Finnmark coast during the winter season 1972.

Factory no.	Efficiency (e)	Quantity (p)	Corrected quantity (e . p)	Date and number of released capelin				Total
				2 February 1200	3 February 1100	6 February 1500	7 February 300	
79	0.86	126 833	109 077	2	13	15	3	33
70	0.65	37 506	24 379	1	2	7		10
69	0.79	38 796	30 649	3	5	1		9
95	0.85	43 753	37 190	8	5	13	4	30
66	0.97	22 923	22 235	3	6	5		14
55	0.94	30 312	28 493	7	9	4	2	22
45	0.82	30 047	24 638	3	12	9	1	25
43	0.60	24 828	20 896		4	1	1	6
40	0.81	17 591	14 249	2	10	4		16
42	0.56	55 319	30 978	3	13	4	2	22
37	0.50	19 145	9 573	1	2			3
24	0.93	28 823	26 806	1	2	6	1	10
68	0.86	53 231	45 779	7	8	4	2	22
35	0.58	24 577	14 255	2		1	4	7
47	0.58	28 192	16 351	2	5	1	1	9
52	0.92	22 372	20 583	2	4	9	2	17
53	0.90	18 550	16 695	1	3	2	1	7
49	0.86	14 949	12 856	1	2	5	1	9
59	0.53	16 632	8 815		4			4
63	0.74	19 258	14 251			3	1	4
			528 748	49	109	94	26	278

$$T_{relative} = 479 \cdot 10^4 \text{ mm} \cdot (\text{nautical miles})^2$$

$$C = 2.1 \text{ tons/mm} \cdot (\text{nautical miles})^2.$$

The total stock of capelin (T) in the area was estimated to

$$T = 10.1 \cdot 10^6 \text{ tons}$$

Assuming that all the maturing capelin migrated towards the coast for spawning in 1972, the size of the maturing stock was estimated to be between 2 and 3.6 mill. tons. This is a significantly lower figure than that obtained from tag returns (4.8 mill. tons). It is tentatively concluded that the figure estimated on the basis of the acoustic surveys is the most reliable of the two. It should be noted that the C probably is too high, and consequently this will result in an overestimation of the stock size (MIDTTUN and NAKKEN 1972).

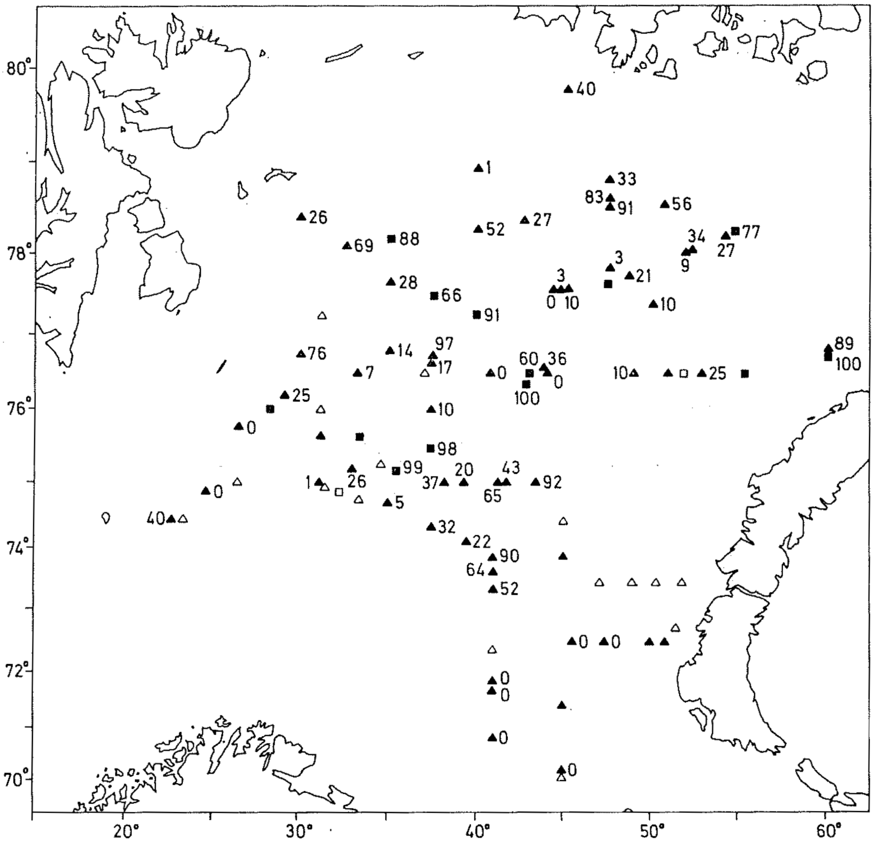

Fig. 11. Weight percentage of capelin $\geq$ 14 cm at each trawl station August—September 1971. Open symbols indicate no catch. At stations where the symbols are filled and no figure is given, only a few fish were caught, and no percentage is given. Triangles indicate pelagic — and squares bottom trawl stations.

REPRODUCTION AND RESULTING YEAR-CLASS STRENGTH

LOCATION AND TIME SPAWNING

To locate spawning concentrations of capelin in 1971 an echo survey was carried out during the second half of March (Fig. 12). The geographical distribution of commercial catches of spawning and spent capelin were compared with the echo integrator readings, and from these data a series of possible spawning places were found.

To verify the spawning, a grab station survey was carried out. Most of the stations were made in areas where capelin had been recorded. In some cases, divers were also used to locate spawning places (Bakke and Bjørke 1973). Eggs were found at 55 out of 227 grab stations. At 33 of these, eggs only occurred in numbers between 1 and 10 in each sample, indicating that the main spawning beds were surrounded by relatively large areas with small concentrations of eggs. This feature was also confirmed by the divers.

It is therefore suggested that, in areas where concentrations of eggs were sparse, mass spawning had taken place in a nearby area. The spawning places, found by grab or divers or both, are shown in Fig. 12.

The bottom substratum and number of eggs in the grab samples are shown in Table 4. Gravel was by far the most preferred substratum, and only few eggs were found on other substrata. The gravel on most spawning grounds had a grain size between 0.5 and 1.5 cm. Depth distribution of the eggs is shown in Table 5. Great concentrations of eggs were found to a depth of 65 m, while small numbers were observed

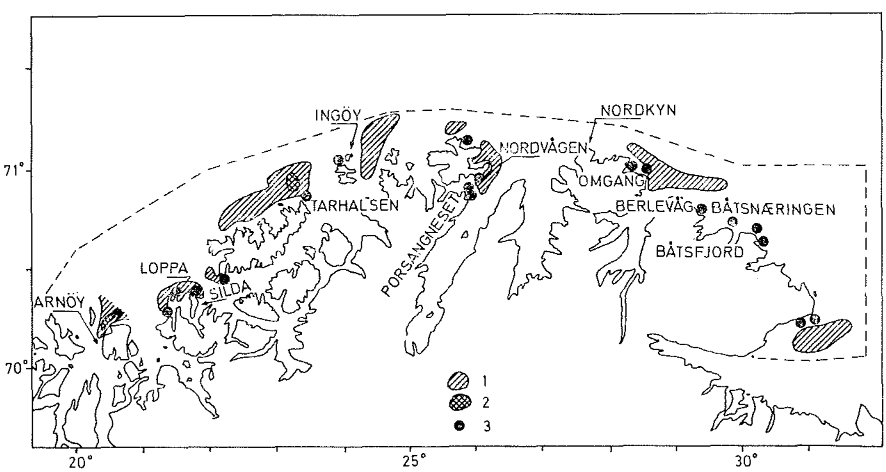

Fig. 12. Distribution of capelin 19—31 March 1971 and observed spawning places. 1) 1—10 integrator units, 2) > 10 integrator units, 3) spawning places.

Table 4. Substratum and egg density on the grab stations.

Substratum	Number of stations	No eggs	Scattered	Dense	Very dense
Gravel	28	11	2	10	5
Shell sand, shell fragments.............	44	29	10	4	1
Mineral sand	33	21	11	1	
Rocks, algae	117	106	10	1	
Silt, clay	5	5			

Table 5. Depth (in m) and egg density on the grab stations.

Depth	Number of stations	No eggs	Scattered	Dense	Very dense
10—19..............	36	19	5	9	3
20—29..............	45	34	9	2	
30—39..............	60	50	7	2	1
40—49..............	33	22	8	2	1
50—59..............	19	16	3		
60—69..............	9	8			1
70—79..............	9	7	1	1	
80—89..............	3	3			
90—99..............	4	4			
> 100..............	9	9			

to 75 m depth. The most shallow spawning beds were found at 12—15 m depth. Probably the bottom substratum is a more important factor for the location of spawning than the depth.

Both direct observations and study of the character of the substrtaum indicate a strong current at most of the spawning grounds.

The greatest concentrations of eggs were found at Loppa, Nordvågen and Båtsnæringen (Fig. 12). At Nordvågen egg densities of up to 8 mill. per m^2 were recorded in a local patch. However, most samples indicated egg densities between 1 and 3 mill. eggs per m^2. Similar great densities might also have been situated in other areas where only samples from the fringe or the surroundings of the spawning beds were taken.

Nordvågen was selected for a more detailed study. For this area a Decca map in scale 1 : 10 000 was made by reading the values of the decca meters. Simultaneously the position was determined by taking the bearing of selected land points (Fig. 13). The area was surveyed by grabbing, and all stations were plotted on the map. These stations were

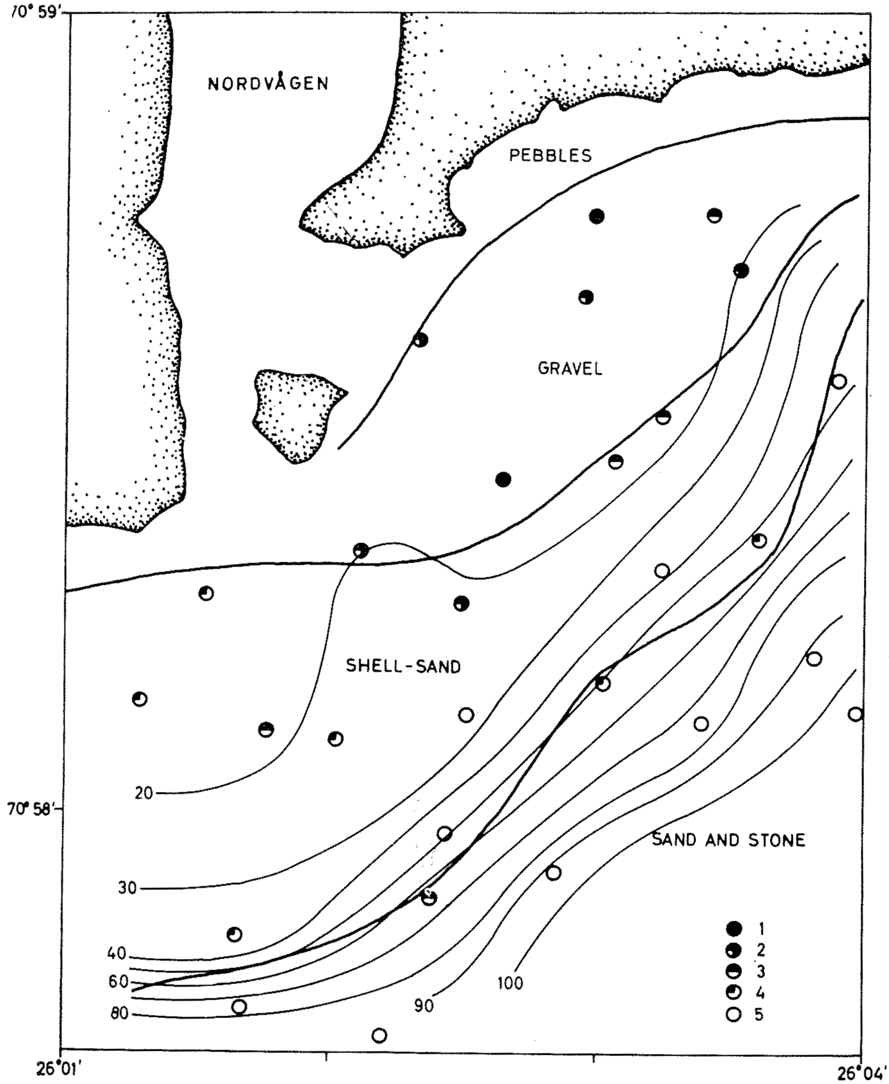

Fig. 13. Depth, bottom substratum and distribution of capelin eggs in Nordvågen 26 April 1971. 1) very dense, 2) dense, 3) scattered, 4) very scattered, 5) none.

later used for determining the area of the spawning bed. Divers were also used in this surveying.

The extension of the spawning bed in Nordvågen was about 0.2 km^2. This turned out to be very similar to the extension of the area with gravel bottom. Within this area a mean egg density of 2.5 mill. per m^2 was observed. A total of 7.5×10^{11} eggs had therefore been spawned

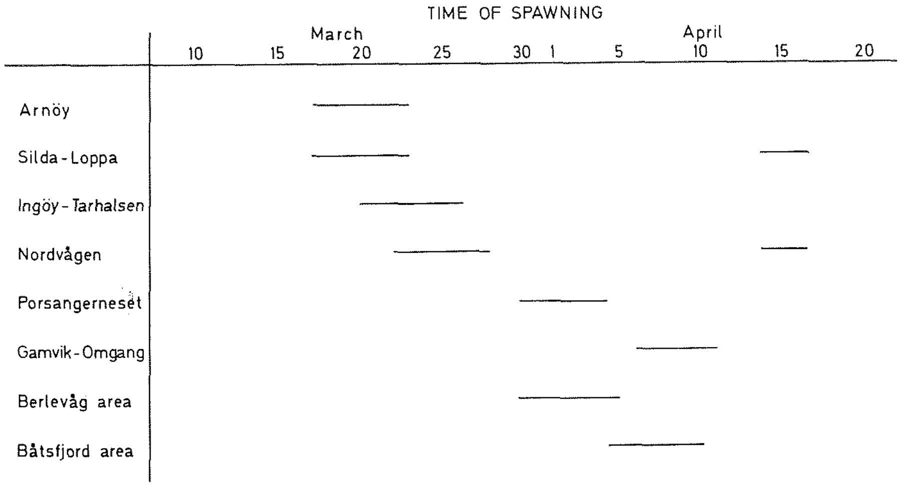

Fig.14. Time of main spawning in different areas, 1971.

Table 6. Maturing of capelin (%) in weekly samples from northern Norway during the spawning season 1971.

Date	West of Nordkyn				East of Nordkyn			
	Maturing	Spawning	Spent	Number in samples	Maturing	Spawning	Spent	Number in samples
17 — 23 January	100.0	—	—	97	—	—	—	—
24 — 30 January	100.0	—	—	248	100.0	—	—	119
31 Jan. — 6 February	100.0	—	—	125	100.0	—	—	146
7 — 13 February	100.0	—	—	123	100.0	—	—	273
14 — 20 February	100.0	—	—	119	100.0	—	—	195
21 — 27 February	100.0	—	—	245	100.0	—	—	110
28 Febr. — 6 March	99.0	1.0	—	103	100.0	—	—	131
7 — 13 March	—	—	—	—	100.0	—	—	99
14 — 20 March	32.9	32.9	34.2	365	—	—	—	—
21 — 27 March	—	27.8	72.2	36	57.5	42.0	0.5	200
28 March — 3 April	2.8	45.8	51.4	216	—	—	—	—
4 — 10 April	—	—	—	—	42.9	30.0	27.1	140

in Nordvågen. If it is presumed that males and females were present in equal numbers, this implies that approximately 5000 tons of capelin had spawned.

From the grab samples, the developmental stages of eggs were designated, by comparison with artificially fertilized eggs kept in the laboratory. Thus, approximate dates of spawning were found for the different areas (Fig. 14). At Arnøy, Loppa, Silda, Ingøy and Tarhalsen spawning probably took place between the 15 and 25 March. Spawning at Nordvågen occurred between the 20 and 30 March. At Porsangneset and in the Berlevåg areas spawning most likely occurred about 1 April, in Omgang and Båtsfjord areas one week later. At Loppa and in Nordvågen a new spawning occurred in the middle of April, but in Nordvågen this spawning was of little significance compared to the first one. These spawning times are in accordance with the development of the gonad condition of the capelin (Table 6).

The exact temperature at the time of spawning is not known. In Nordvågen temperature at the bottom was measured on 30 March and 14 April, and was then 1.5° and 3.0° C respectively. An other spawning grounds which were visited two or three weeks after spawning, the temperature varied between 2° and 3°C.

Spawning in 1972 was studied by BJØRKE, GJØSÆTER and SÆTRE (1972). Both spawning area and spawning time differed from the conditions in 1971. Spawning depth also showed some difference, especially in the western part of the area. In 1972 the most extensive spawning took place off East Finnmark. Farther to the west, spawning was observed at Magerøy, Hjelmøy, Tarhalsen and Malangsgrunnen—Fugløybanken. At all these localities the spawning depth was greater and the temperature considerably higher than in 1971. At Malangsgrunnen spawning took place at about a 150 m where the temperature was about 6°C. Spawning in 1972 started about 1 March and lasted until the end of March.

In the eastern part of the spawning area, spawning was later than in the western part.

FERTILIZATION AND SURVIVAL OF EGGS

On the spawning beds the fertilization seemed to be almost 100 per cent, while fertilization rates down to about 50 per cent were sometimes observed among eggs brought up by grab or divers. Between 2.5 and 5.0 per cent were mechanically destroyed. It is not known whether this was a result of the sampling or a natural phenomenon. Apart from this, mortality seemed to be very low. Generally, greater mortality was observed where only a few eggs were found than on the proper spawning

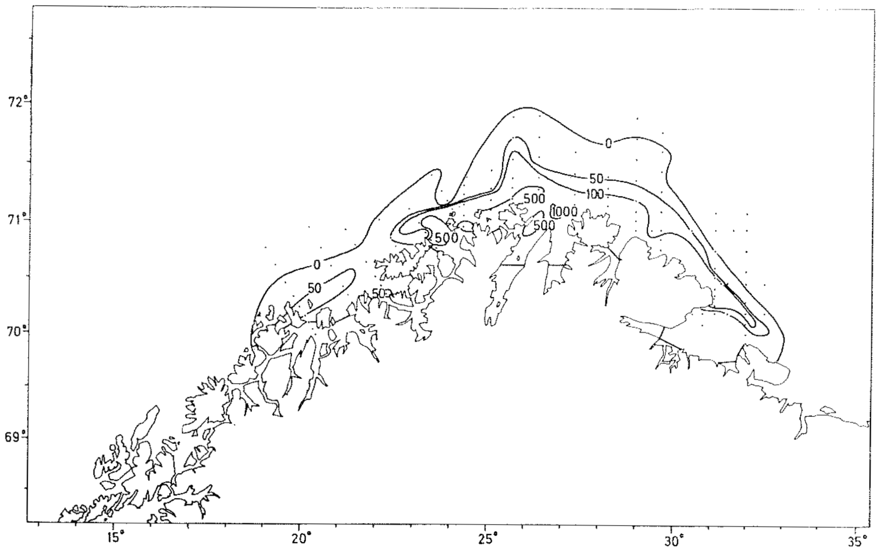

Fig. 15. Distribution of capelin larvae 1—15 May 1971. Isolines indicate the number of larvae below 1 square m surface. Stations are plotted as dots.

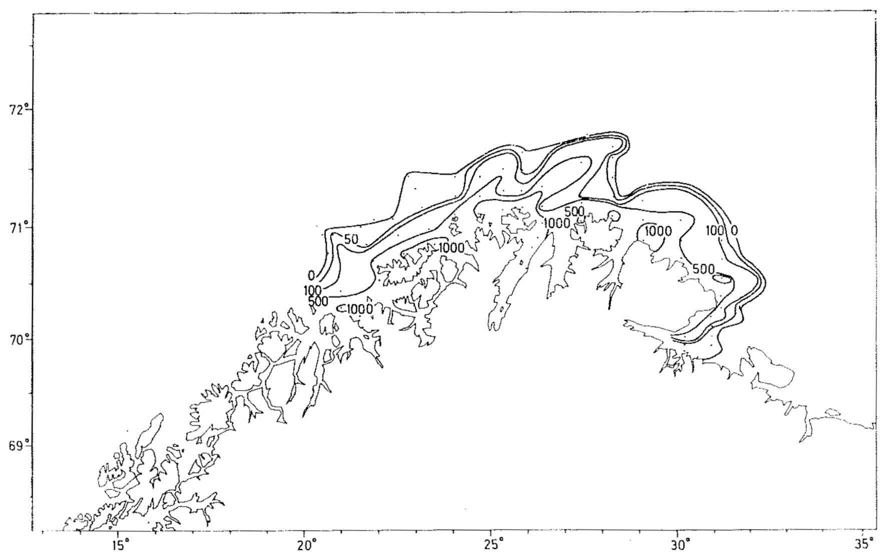

Fig. 16. Distribution of capelin larvae 19—25 May 1971. Isolines indicate the number of larvae below 1 square m surface. Stations are plotted as dots.

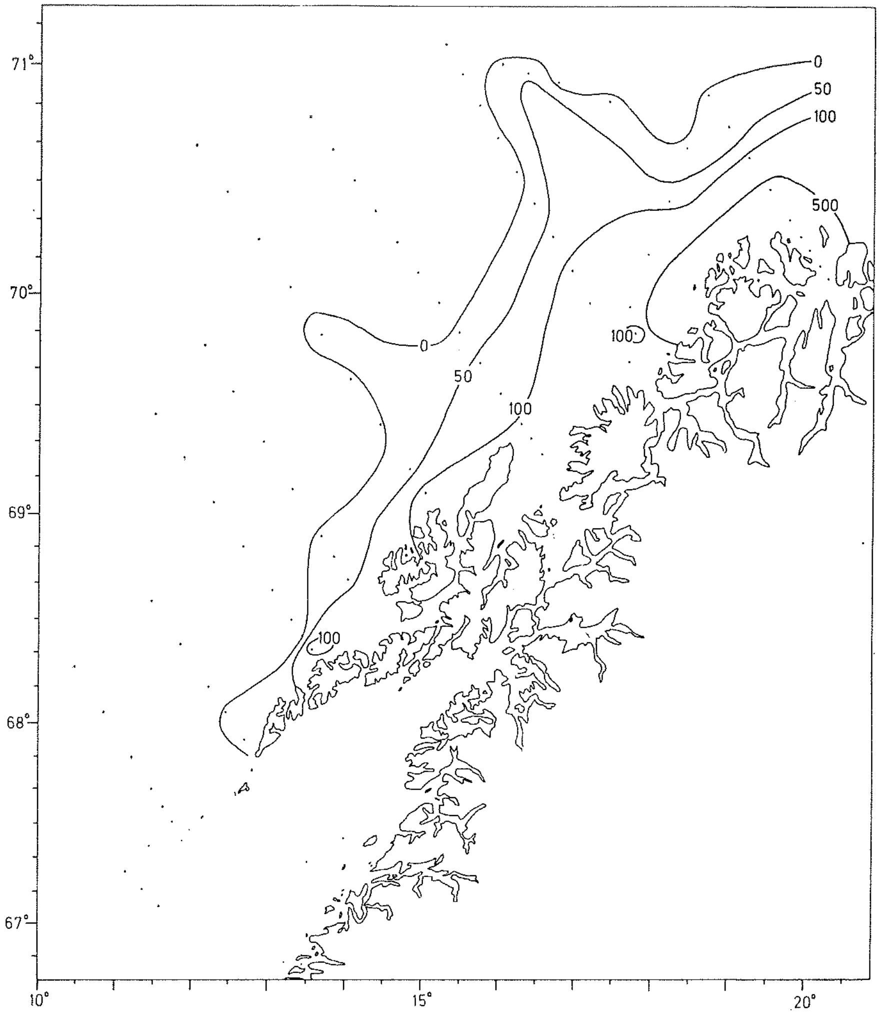

Fig. 17. Distribution of capelin larvae 20—28 May 1971. Isolines indicate the number of larvae below 1 square m surface. Stations are plotted as dots.

beds. An exception was observed at Loppa, where mortalities up to 19 per cent were found in samples with very dense concentrations of eggs. On some of the spawning grounds many eggs were overgrown with small filamentous algae, but this did not seem to cause any retardation of the development or any increase in the mortality rate.

Eggs, together with bottom sediment, were found in the stomachs of capelin and haddock. At the spawning beds investigated, few haddocks were present. Therefore the predation on eggs was not very intensive and had no serious effect. In 1972 an extensively larger predation by haddock was observed, but only at spawning grounds deeper than 150 m (BJØRKE, GJØSÆTER og SÆTRE 1972). According to ZENKEVITCH (1963) capelin eggs form an important part of the haddock's diet.

Predation on eggs by ducks (*Somateria spectabilis, S. mollissima* and *Clangula hyemalis*) was observed at shallow spawning grounds (GJØSÆTER, SÆTRE og BJØRKE 1972), but the quantities consumed are probably of little significance.

Eggs from the upper bottom strata showed a faster development than those laying deeper in the substratum. No difference in mortality was observed at the egg stage, but preliminary results indicate a higher hatching success among eggs from the upper strata.

To evaluate the effects of using fishing gears on the spawning beds, trawl bobbins were towed through one of them (BJØRKE and BAKKE 1973). No increase in mechanical destruction could be observed, but eggs whirled up from the bottom showed mortalities between 6.0 and 10.2 per cent after being kept in glass jars in the laboratory, while eggs taken from the bottom of untouched spawning beds showed mortalities between 0 and 2.1 per cent when kept in a similar way. This experiment was carried out when the eggs had finished about 2/3 of the developmental time.Studies of eggs in the laboratory suggest that susceptibility to mortality is higher in earlier stages of development and possibly also in the latest. These results, therefore, might not be representative for eggs in other stages.

LARVAL DISTRIBUTION

Five larval surveys were carried out during 1 May to 22 June 1971. The distribution of larvae in each survey is shown in Fig. 15—19. In the first surveys the larvae were distributed close to the shore. During the surveys in June smaller quantities of larvae had drifted from land. Near the shore both newly hatched and older larvae were found, while offshore only older larvae were found. This indicates that spawning in 1971 only occurred in the near shore area.

During the first surveys highest larval concentrations were observed off Troms and West Finnmark, while the latest surveys showed highest concentrations at the coast of eastern Finnmark. This is due to later spawning and lower temperatures in the eastern area.

Number of larvae was determined for each survey by means of an area integration. The following results were obtained:

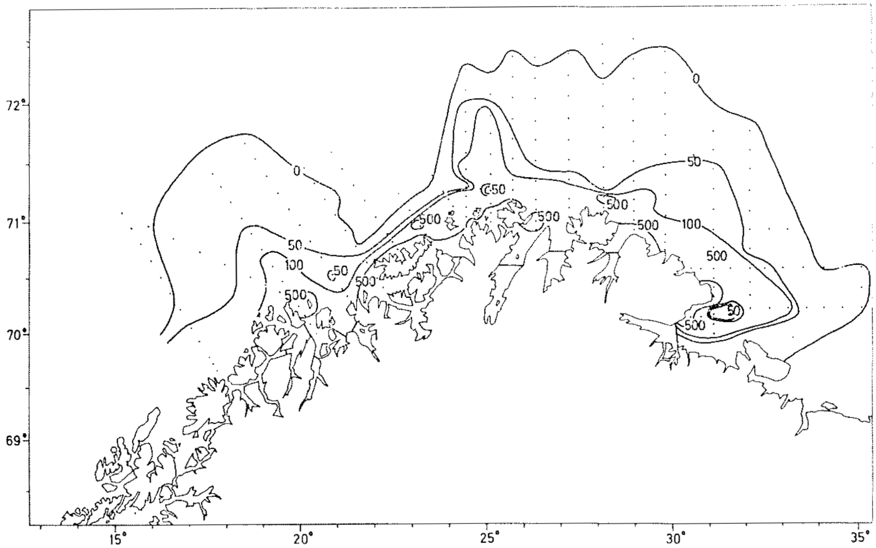

Fig. 18. Distribution of capelin larvae 2—17 June 1971. Isolines indicate the number of larvae below 1 square m surface. Stations are plotted as dots.

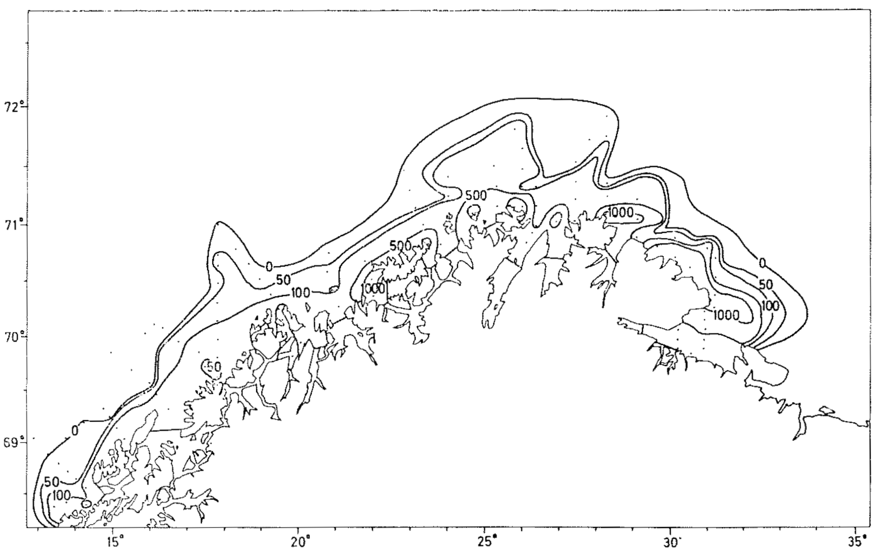

Fig. 19. Distribution of capelin larvae 7—22 June 1971. Isolines indicate the number of larvae below 1 square m surface. Stations are plotted as dots.

1—15 May: 2.8 · 10^{12}
19—25 May: 1.4 · 10^{13}
2—17 June: 1.5 · 10^{13}
7—22 June: 1.6 · 10^{13}

Although the larval material for 1972 is not completed, preliminary results seem to indicate a more eastern distribution than in 1971.

0-AND I-GROUP ABUNDANCE

During the larval and postlarval stages a drift migration takes place into the central part of the Barents Sea. The younger capelin (0- and I-group fish) are distributed farther south than the two and three year olds. The nursery area of the capelin is extensive, but the main grounds are in the central and eastern part of the Barents Sea. The abundance indices of 0-group fish, obtained from acoustic surveys, give a fairly good estimate of year-class strength (DRAGESUND 1971).

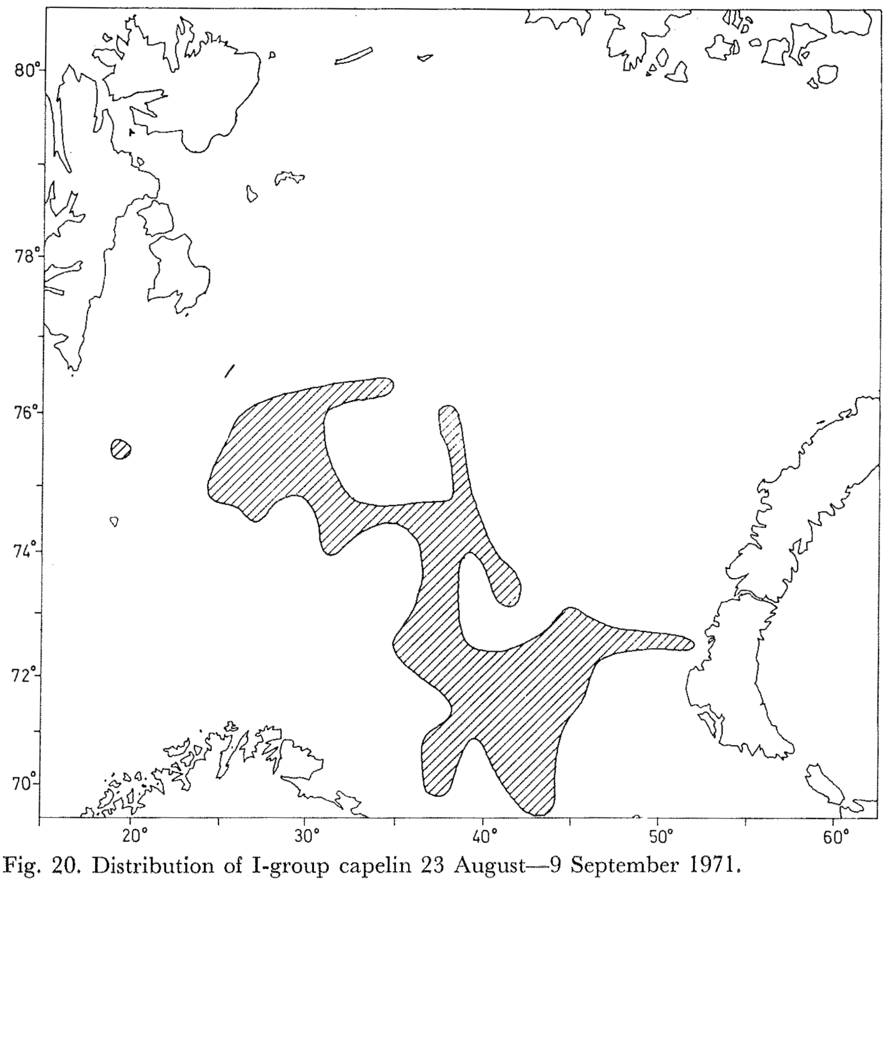

Fig. 20. Distribution of I-group capelin 23 August—9 September 1971.

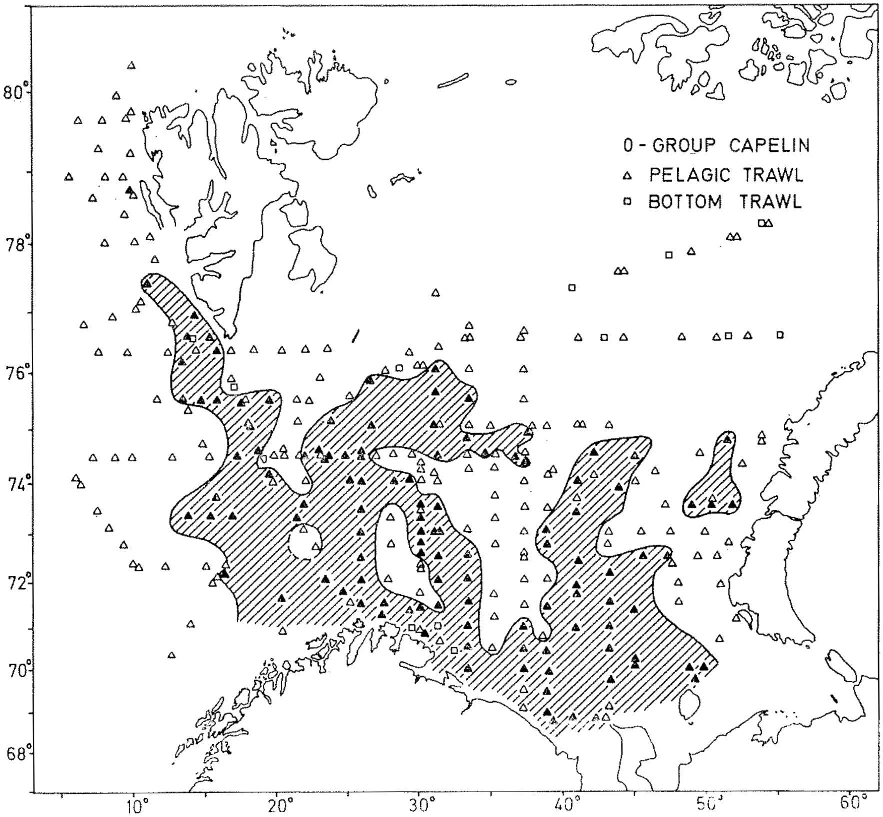

Fig. 21. Distribution of 0-group capelin 23 August—9 September 1971.

In 1970, 0-group capelin were limited to a small area, mainly along the Finnmark and Murman coast and in the eastern Barents Sea (ANON. 1970). The concentrations were rather low, indicating a week 1970 year-class. However, later investigations showed that the I-group capelin were distributed over a fairly wide area (Fig. 20), and, although the 1970 year-class is relatively weak, it is suggested that the year-class is somewhat stronger than indicated from the 0-group survey. In 1971 the abundance of 0-group capelin was not so high as that observed in the years 1967 and 1969 (BENKO *et al.* 1970), but was considerably higher than in 1970 (Fig. 21), and the indication is that the 1971 year-class is abundant. The 1972 year-class also seem to be strong (Fig. 22), probably of the same order as that of 1971.

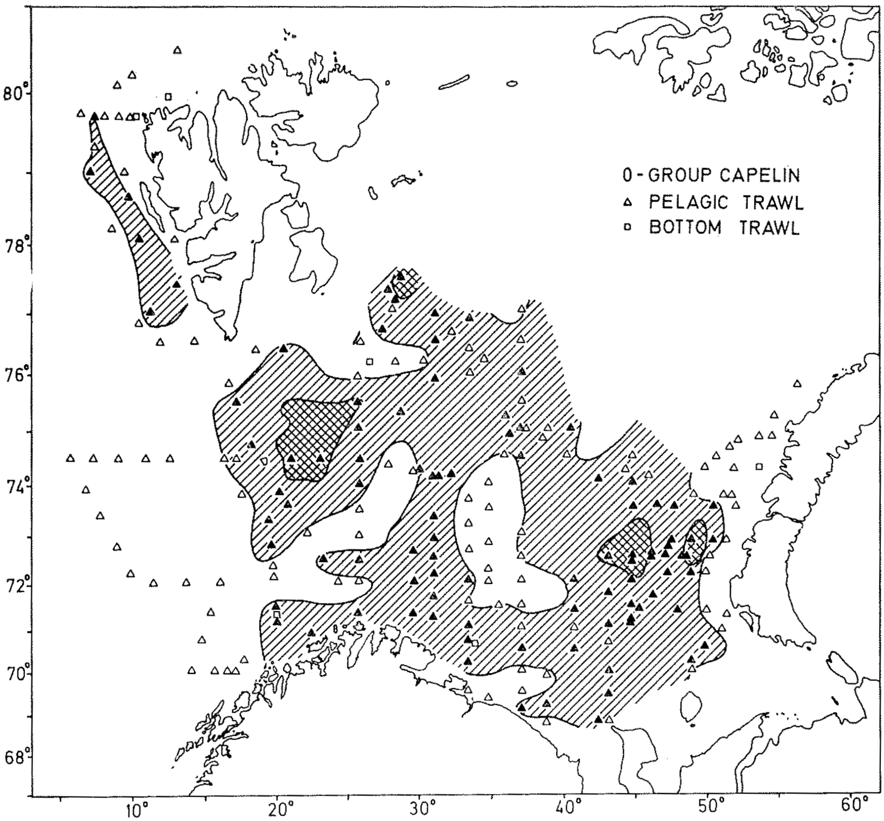

Fig. 22. Distribution of 0-group capelin 27 August—11 September 1972.

DISCUSSION

The availability of capelin was good during the winter seasons 1970—1972. Capelin were distributed over wide areas, the seasons lasted relatively long, and the weather conditions were good. A relatively small part of the stock reached the Murman coast for spawning (Seliverstov, verbal information), and most of the capelin spawned in Norwegian territorial waters in 1971 and 1972.

Table 7. Summary of results of stock size estimates (mill. tons) in 1971 and 1972.

Year	Method		
	Tagging experiments	Egg and larval surveys	Acoustic surveys
1971	5.8	3.2	—
1972	4.8	—	2-3.6

The steady increase in the total catch of capelin since 1965 is due to a significantly increased fishing effort (Bakken and Dragesund 1971), but is also for a large part attributed to a raise in stock size. Some indication of the relative variation in the size of the spawning stock in 1969—1972 might be obtained from year-class strength estimates at the 0-group stage (Anon. 1969, Benko *et al.* 1970).

These estimates indicated that the 1966, 1967 and 1968 year-classes exceeded the year-class of 1965. The ranking of the 1966, 1967 and 1968 year-classes were difficult to assess from the 0-group fish surveys. However, later information from catch statistics and echo surveys, suggests that the 1967 year-class was significantly stronger than those of 1966 and 1968. Since four year old fish predominated in the spawning stocks in 1969—1972, it is likely that the spawning stock was higher in 1970 than in 1969, and again the stock strength was greater in 1971 than in 1970 and 1972.

Although the stock size estimates for 1971 and 1972 must be interpreted with caution, they indicate that the spawning stock in 1971 was greater than in 1972 (Table 7).

With the fragmentary knowledge of stock size and of the relationship between stock size and reproduction of capelin, it is difficult to state that the exploitation rate is too high. A study of capelin reproduction during the period 1951 to 1961 indicated, however, that although the stock size probably was much lower than now, there were no clear correlation between parent stock size and subsequent recruitment (Gjøsæter 1972). This, and the investigations carried out during the last two years, indicate that no immidiate further steps are needed to secure a high spawning potential. On the other hand, it is possible that the intensive fishing during the prespawning and spawning period may have unfortunate influence on spawning behaviour.

The spawning stock was at a very high level in 1971 and fairly high in 1972. The resulting year-classes measured at the 0-group stage seemed to be abundant. The 1969 year-class is also estimated to be strong (Anon. 1969). The relatively low production in 1970 was most likely due to environmental factors and not to small spawning stock, and so far no sign of overfishing has been observed.

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