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PRELIMINARY RESULTS OF THE NORWEGIAN CAPELIN INVESTIGATIONS DURING WINTER AND SPRING 1971

By

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INTRODUCTION

The annual yield of the Norwegian capelin fishery 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 the 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 the Institute of Marine Research started a programme of capelin investigations in 1960 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 late summer and autumn research vessel surveys have been carried out in the Barents Sea (Møller and Olsen 1962, Olsen 1968, Monstad 1969, Lahn-Johannessen and Monstad 1970). The work has included sonar and echo-sounder searching, sampling with mid-water 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 during the summer of 1970 and 1971 the Norwegian Government introduced a

time regulation closing the season from 1 June to 15 July in 1970 and from 15 May to 24 July in 1971. The need for regulatory measures during the spawning season has also been discussed. The question has arisen whether the intensified fishery during the last two years has endangered the future reproduction of the stock. In order to examine whether any reduction of the fishery need be recommended, the Norwegian capelin investigations were considerably extended in 1971 by including more qualitative and quantitative work on the adult stock and its production of recruits.

The aim of the present paper is to report some preliminary results of the investigations carried out during the winter and spring of 1971 with emphasis on:

1) distribution and migration of capelin during the winter fishery;
2) spawning characteristics, i.e. structure and size of the spawning stock, spawning behaviour, location and time of spawning;
3) fertilization and survival of eggs during the incubation period.

MATERIAL AND METHODS

Most of the material is obtained from the investigations carried out during the winter and spring of 1971 and it includes data from acoustic surveys, in situ observations of the spawning behaviour of capelin, samples of capelin, catch statistics and tagging experiments. Where it is important to include information from other years, data from the literature and unpublished data from records of the Institute of Marine Research, Bergen, are used.

Surveys

During the periods 20 January to 28 February and 15 March to 1 May, the distribution and migration of capelin were studied by combined acoustic surveys and fishing experiments with a pelagic trawl. The surveys were carried out by one research vessel and one scouting vessel. The vessels were equipped with vertical echo sounders and horizontal ranging sonars. During the surveys the acoustic instruments were operated continuously. Onboard the research vessel "Johan Hjort" a Simrad echo integrator was linked to a Simrad Ek 38 kHz echo sounder. The setting of the EK echo sounder was: output power 8,9 kw, receiver amplification 20 log R-20db, with the amplification on the echo integrator varying from 30 to 40 db. The threshold on the integrator was constantly set at 3. Echo integrator readin

were made each nautical mile and average values for each two nautical miles were plotted on maps. The two integrator channels covered the depth intervals from 5 to 50 m and from 50 m to bottom.

When fish species other than capelin were recorded within the same echo integrator interval, the total echo abundance was divided between capelin and other species. Both experimental fishing and analysis of the echo traces were used for dividing the total echo abundance.

In situ observations on the spawning behaviour of capelin were recorded by divers. Capelin eggs were collected by Pettersen grab but were also obtained 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 (1971).

Where capelin concentrations were found, samples were taken for analysis of the maturity stages of the gonads. The maturity stages were classified according to a scale modified from Nikolsky (1963).

Capelin samples and catch statistics

In addition to samples collected during the acoustic surveys, capelin samples were collected throughout the winter season from commercial catches. The capelin were examined fresh or from frozen material brought to the laboratory for examination. The total length was measured to the nearest mm and grouped in half cm class intervals. Otoliths were used for age determination.

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 were supplied from the fishermen's sales organization, Feitsildfiskernes Salgslag. Statistics of landings by the USSR were derived from Bulletin Statistique.

Tagging experiments

Tagging experiments were carried out on the scouting vessel M/S "Ytterstad", which on this occasion was equipped with a purse seine. The capelin were tagged with internal tags measuring 15 x 2 x 0,5 mm. A tagging device especially developed for inserting this tag was used. The capelin were carefully brought from the purse seine into a tank on deck, from which the fish were taken individually and released into the open sea immediately after tagging by means of a bucket in batches of approximately 2o individuals.

Nearly all tags were recovered at Norwegian reduction plants where magnets are installed for detecting the tags. The efficiency of the magnets was tested during winter 1971 (table 2). 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 Dragesund and Haraldsvik (1968).

DISTRIBUTION AND MIGRATION

The main part of the spawning stock usually approaches the western part of the Murman coast and the Varanger peninsula, and disperses westward along the Norwegian coast (Prokhorov 1965, Møller and Olsen 1962). During the spawning seasons 1968, 1969 and 1970, part of the stock also reached the coast of West-Finnmark (Olsen 1968, Lahn-Johannessen and Monstad 1970). The first recordings of adult capelin in winter 1971 were made in the middle of January northwest of the North Cape Bank, where the winter fishery also commenced. The distribution during January is illustrated in Fig. 2. The main part of the stock approached the coast between Sørøya and the North Cape during February and March. No distinct influxes towards the coast could be defined in 1971. Mature capelin approached the coast west of the North Cape continuously 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 the North Cape, but in contrast to previous years no great concentrations were observed along the coast of eastern Finnmark.

The main part of the spawning stock this season had an extremely westerly distribution compared to previous years. The most important fishery took place between the North Cape and Arnøya, but profitable catches were also obtained farther south along the coast, especially off Vesterålen as well as farther north and east of the North Cape-Arnøya region mainly off Tana. The total landings of the Norwegian winter fishery amounted to 1,3 mill. tons (Fig. 1).

SPAWNING CHARACTERISTICS

Spawning stock

The Barents Sea capelin spawn mainly when 3 and 4 years old and the lack of older fish strongly supports the theory of a very heavy post-spawning mortality. At the end of the spawning season dead and dying capelin were observed over wide areas. It might be that some capelin do survive to spawn a second time (Templeman 1948, Prokhorov 1965, Vilhjamson 1968), 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 4 years (Olsen 1965, 1968, Prokhorov 1965). During the winter fishery in 1970 the rich 1966 year-class dominated the catches (Lahn-Johannessen and Monstad 1970), but in 1971 this year-class was of minor importance. The age composition of capelin caught during the 1970 summer season clearly demonstrated that the 1967 year-class was rich, and during the winter season of 1971 this year-class strongly dominated the catches (Table 1).

Some indication of the relative variation in the size of the spawning stock during the last three years might be obtained from year-class strength estimates at the O-group stage (Benko et al. 1970). These estimates indicated that the 1966 and 1967 year-classes exceeded the year-class of 1965. The ranking of the 1966 and 1967 year-classes were difficult to assess from the O-group fish survey, but later information from catch statistics and echo surveys suggests that the 1967 year-class was significantly stronger than that of 1966. Since four year old fish predominated in the spawning stock in 1969 - 1971, 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.

In order to get estimate of the size of the spawning stock, tagging experiments were carried out during the spawning season 1971. Returns during the same season are listed in Table 2. An estimate of the stock strength based on these data is not advicable due to lack of information on tagging mortality, and because the number of returns are too low. However, the experiments indicate that the tagging technique can be used also for capelin for stock strength estimates.

Location and time of spawning

To locate spawning concentrations of capelin, an echo survey was carried out during the second half of March (Fig. 3). 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 was 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 (Bjørke and Bakke 1971). 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 wide areas with small concentrations of eggs. This feature was also confirmed by the divers. It is suggested, therefore, that in areas where concentrations of eggs were sparse mass spawning had taken place in nearby area. The spawning places found by grab and or divers are shown in Fig. 3.

The greatest concentrations of eggs (ca 3 000 000 per m^2) were found at Loppa, Nordvågen and Båtsnæringen. Similar dense patches might, however, have been situated in other areas where only samples from the fringe or the surroundings of the spawning beds were taken. In Nordvågen 28 grab stations were taken to estimate the extension of the spawning bed (Fig. 4). This turned out to be very similar to the extension of an area with gravel bottom. At Båtsnæringen where several grab stations were also taken, the same feature was observed.

The bottom substratum and number of eggs in the grab samples, are shown in Table 3. The gravel was by far the most prefered substratum, and only few eggs were found on other substrata. The substratum on the spawning grounds are more thoroughly discussed by Bakke and Bjørke (1971). The depth distribution of eggs is shown in Table 4. Great concentration of eggs were found down to a depth of 65 m, while small numbers were observed 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.

The development stages of eggs from the grab samples were designated by comparison with artificially fertilized eggs kept in the laboratory. Thus

approximate dates of spawning were found for the different areas. At Arnøy-Loppa, Silda, Hånebben, Trollsundet and Vestfjorden (Magerøy) spawning probably took place between 15 and 20 March (Fig. 3). Spawning at Nordvågen occurred between 20 and 30 March. At Porsangerneset and in the Berlevåg area spawning most likely occurred about 1 April, and in the Omgang and Båtsfjord areas one week later. At Loppa and in Nordvågen a new spawning occurred in the middle of April. This is in accordance with the development of the gonad condition of the capelin (Tab. 5).

The exact temperature at the time of spawning is not known. In Nordvågen where spawning probably occured about 25 March and 10 April, temperature at the bottom was measured on 30 March and 14 April, and was then 1,5° and ca 3,0°C respectively. At other spawning grounds which were visited two to three weeks after spawning, the temperatures varied between 2° and 3°C.

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 which were found outside the proper spawning beds. In samples of eggs brought up by grab or divers 2,5 - 5,0 per cent were mechanically destroyed. But 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 beds. 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. The material is not yet worked up, but predation of eggs did not seem to be very intensive on the spawning beds investigated, and will not have a serious effect similar to that observed on the herring spawning grounds (Dragesund and Nakken 1970). Eggs from the upper strata of the bottom showed a faster development than those laying deeper in the substratum, but no difference in mortality was observed. The hatching success in nature is not yet determined, but among artificially fertilized eggs it was high.

To evaluate the effects of use of fishing gears on the spawning beds, trawl bobbins were towed through one of them. Samples of eggs from the track and from eggs whirled up were taken by divers. 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 for 12 days while eggs taken from the bottom of untouched spawning beds showed mortalities between 0,0 and 2,1 per cent when kept in a similar way.

CONCLUDING REMARKS

The steady increase in the total catch of capelin during the last six years is due to a significantly increased fishing effort, but is also for a large part attributed to a raise in stock size. The availability of the spawning stock for the Norwegian fishing fleet in winter 1971 was especially good, since the capelin approached the coast at western Finnmark and dispersed over a wide area from Vesterålen to the Varangerfjord. According to Russian investigations (SELIVERSTOV, personal communication) a relatively small part of the stock reached the Murman coast for spawning, and it is therefore tentatively concluded that the major part of the capelin stock spawned in Norwegian territorial waters in 1971.

Although the efficiency of the fleet to some extent is reduced due to long transport distances of their catches, the danger exists that the exploitation rate is too high. With our fragmentary knowledge of the stock strength of capelin and its reproduction it is difficult to recommend any strict regulation, but the more intensive investigations initiated will probably give data of value for further assessment. The tagging experiments as well as investigations on spawning conditions and larval abundance distribution will continue next year and abundance estimates from acoustic surveys will also be carried out in order to get other independent estimates of the stock strength. A study of egg parametres and their relationship to the parent fish and to the progeny started this year, will also be continued.

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Table 1. Mean lengths ($\bar{l}$, in cm) and age composition (in %) of spawning capelin in Norwegian waters 1970 and 1971

Year	Sex	Total number	Age group 3		4		5	
			$\bar{l}$	%	$\bar{l}$	%	$\bar{l}$	%
1970	♂	2553	17.4	25.0	18.4	73.9	19.7	1.1
	♀	2751	15.6	33.2	16.9	66.8	18.7	0.1
	♂ + ♀	5304	16.3	29.2	17.2	70.2	19.7	0.6
1971	♂	2381	16.8	1.3	17.7	89.0	18.5	9.7
	♀	3834	15.0	6.3	15.9	92.4	17.2	1.5
	♂ + ♀	6215	15.2	4.3	16.6	91.1	18.3	4.7

Table 2. Quantity of processed capelin (hl) and number of returns from tagging experiments off the Finnmark Coast in the spawning season 1971. 500 liberated in each experiment.

Factory no.	Efficiency (e)	Quantity (p) hl	Corrected quantity (e·p) hl	Returns Date of liberation and exp. no 16.2 1	17.2 2	17.2 3	17.2 4	18.2 5	18.2 6	24.2 7	11.3 8	12.3 9	12.3 10	Total
1	0,53	1 043 055	552 819				2	2		3	14	2	9	32
2	0,65	381 500	247 975			1		2	1				2	6
3	0,62	360 000	223 200			2	1	2						5
4	0,89	473 635	421 535	1		1	3	5		2			3	15
5	0,64	217 534	139 222	1	3	2	1				1	1	1	10
6	0,94	287 740	270 476			2	1	2			1	1	4	11
7	0,76	280 378	213 087	3		1	4		2					10
8	0,77	348 281	268 176	2	2						1	1		6
9	0,50	213 408	106 704	3	2				1					6
10	0,90	539 480	485 532	2	8	3	4	1	2			1		21
11	0,67	320 000	214 400	10	6	11	2	1	1					31
12	0,66	359 786	237 459	1	2	2		3	2	2	1	1		14
13	0,88	254 495	223 956	2			2							4
14	0,89	595 100	529 639		28	5		2	1	4	1	2		43
15	0,41	366 426	150 235								2	1	4	7
			4 284 415	25	51	30	20	20	10	11	21	10	23	221

Source 1977

Table 3. 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 4. 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			

Table 5. Maturing of capelin (%) in weekly samples from North-Norway during the spawning season 1971.

Date	West of Nordkyn				East of Nordkyn			
	Maturing	Spawning	Spent	N	Maturing	Spawning	Spent	N
17.1-23.1	100.0	-	-	97	-	-	-	-
24.1-30.1	100.0	-	-	248	100.0	-	-	119
31.1- 6.2	100.0	-	-	125	100.0	-	-	146
7.2-13.2	100.0	-	-	123	100.0	-	-	273
14.2-20.2	100.0	-	-	119	100.0	-	-	195
21.2-27.2	100.0	-	-	245	100.0	-	-	110
28.2- 6.3	99.0	1.0	-	103	100.0	-	-	131
7.3-13.3	-	-	-	-	100.0	-	-	99
14.3-20.3	32.9	32.9	34.2	365	-	-	-	-
21.3-27.3	-	27.8	72.2	36	57.5	42.0	0.5	200
28.3- 3.4	2.8	45.8	51.4	216	-	-	-	-
4.4-10.4	-	-	-	-	42.9	30.0	27.1	140

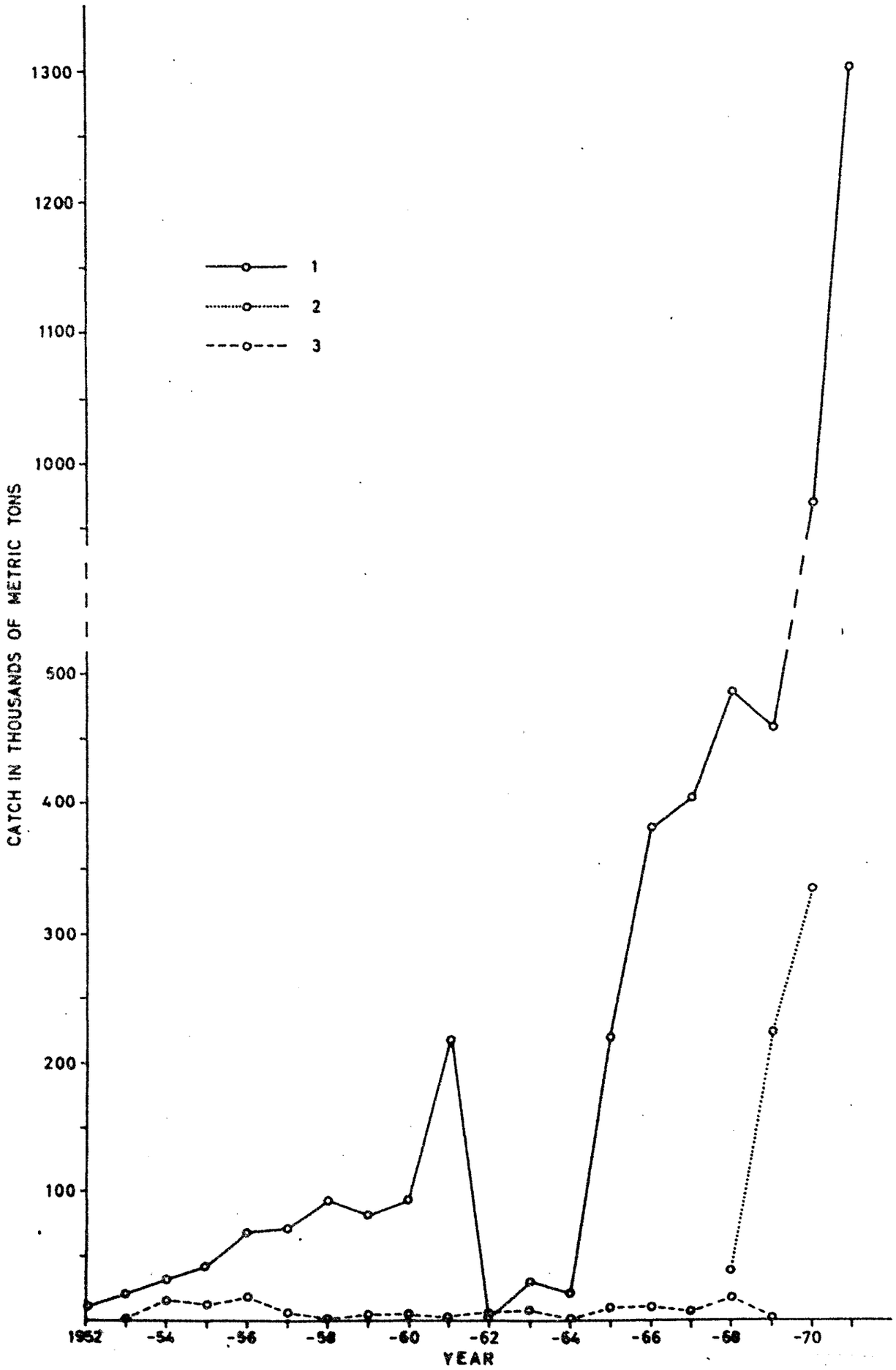

Fig. 1. Catches of the Barents Sea capelin in 1950-1971.
1) Norwegian winter fishery 2) Norwegian summer fishery and
3) Soviet winter and summer fishery.

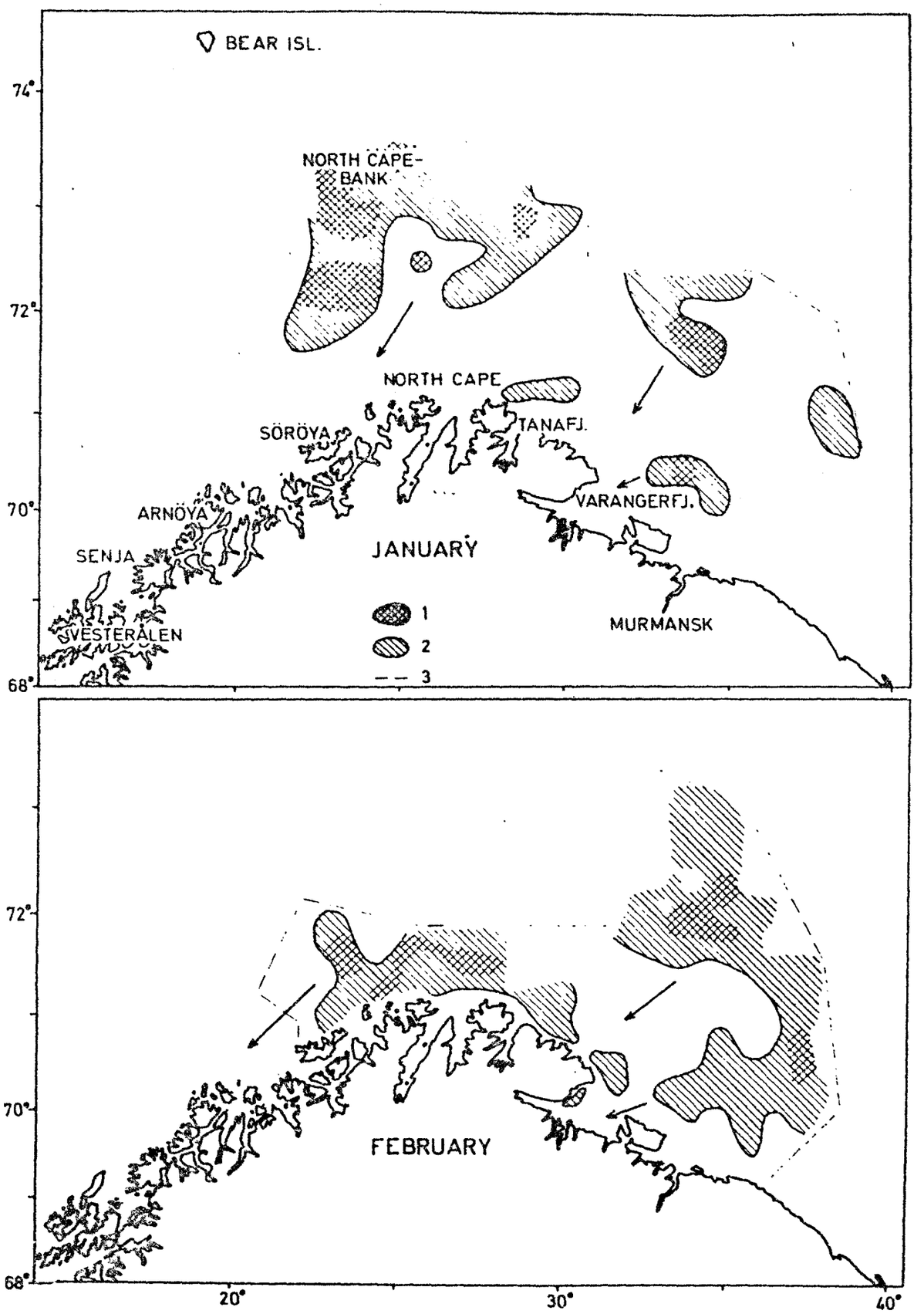

Fig. 2. Distribution of capelin in January and February 1971.
1) dense, 2) scattered, 3) limits of the area investigated.

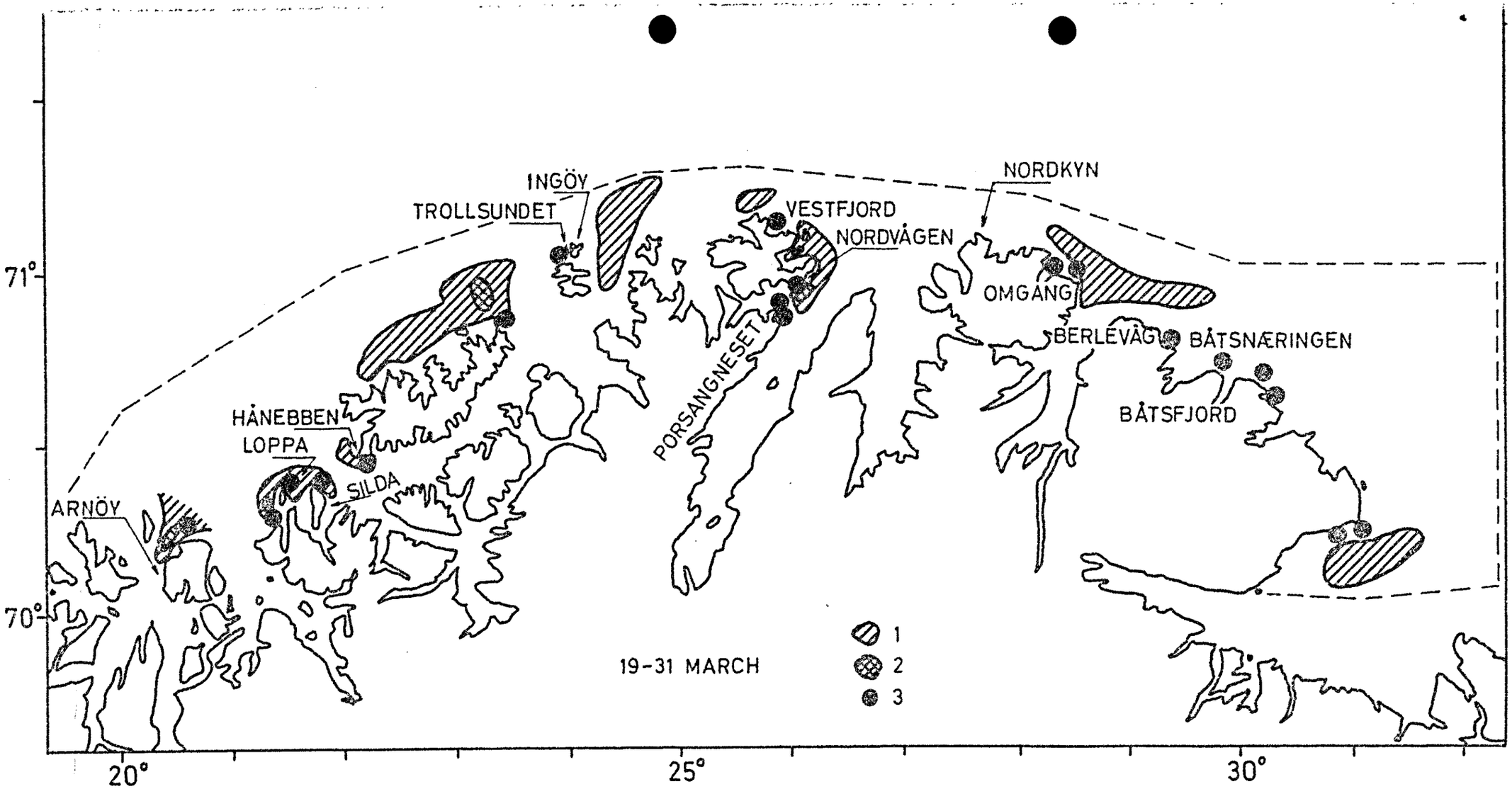

Fig. 3. Distribution of capelin 19 - 31 March 1971 and observed spawning places. 1) 1-10 integrator units. 2) 10 integrator units, 3) spawning places.

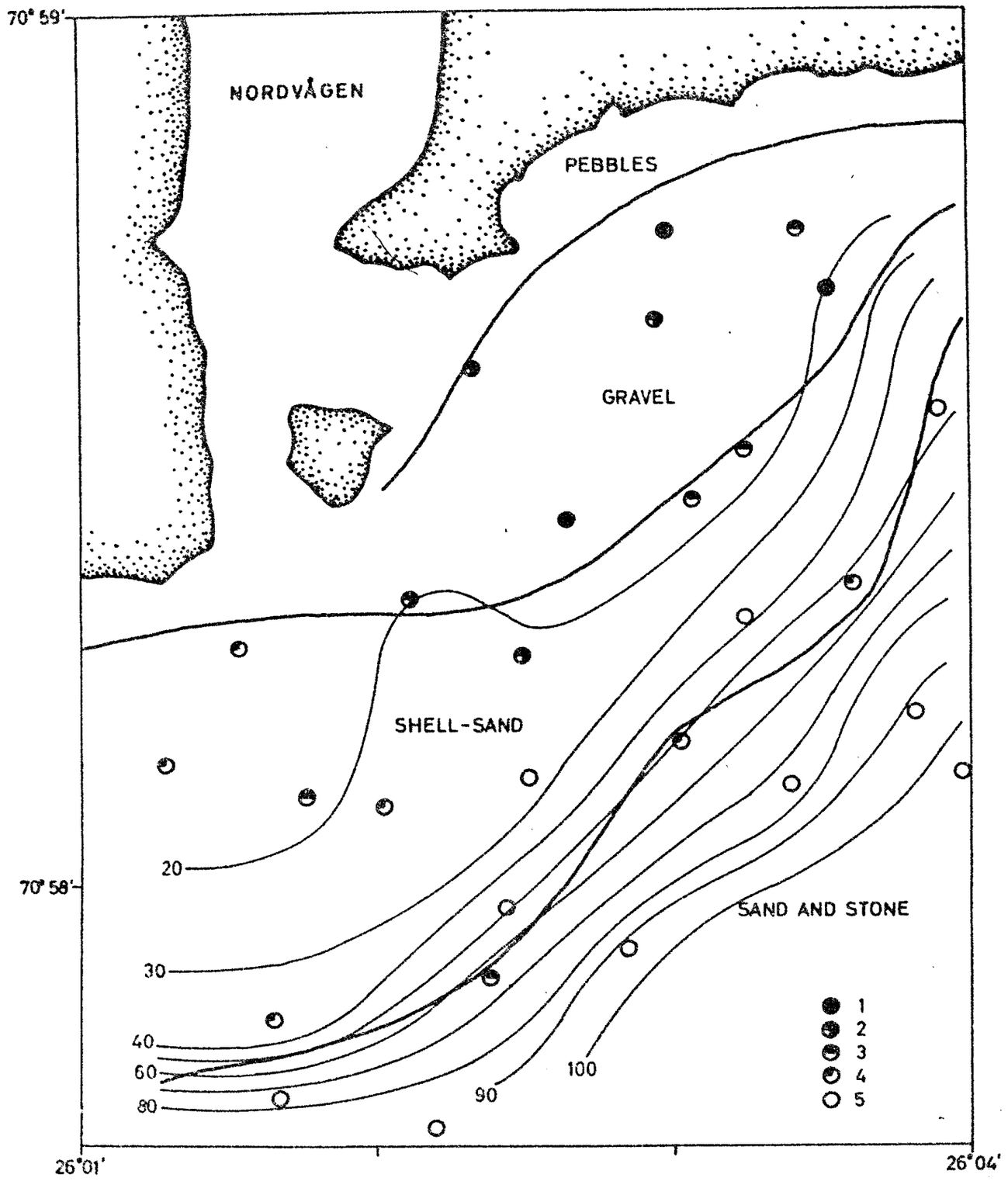

Fig. 4. Depth, bottom substratum and distribution of capelin eggs in Nordvågen 26 April 1971. 1) very dense, 2) dense, 3) scattered, 4) very scattered 5) none.