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"Diving observations on Barents Sea capelin at its spawning grounds off the coast of northern Norway"

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INTRODUCTION

The aim of this paper is to report observational studies done by divers concerning the nature of the spawning grounds of the Barents Sea capelin, the fishes behaviour on these grounds and the egg mortality. The observations were made during the Norwegian capelin investigations in the spring 1971 in cooperation with Dragesund, Gjøsæter and Mønstad (DRAGESUND, GJØSÆTER and MONSTAD 1971).

Previous investigations. Spawning behaviour and spawning grounds of the New-Foundland capelin have been described by many authors. TEMPLEMAN (1968) refers to observations of beachspawning as well as spawning down to at least 35 to 55 m in the Northwest Atlantic. Fine gravel from 0,25 to 1,50 cm diameter is especially favourable for heavy capelin spawning (TEMPLEMAN 1948). On the offshore spawning grounds the bottom substrate is somewhat finer, from 0.5 to 2.2 mm in diameter (PITT 1958).

Spawning behaviour and spawning-grounds of the capelin in the Northeast Atlantic have not been well investigated. PROKHOROV (1965) refers to Russian authors who unanimously write that spawning takes place on sandy grounds with admixture of fine shellstone. PROKHOROV

(1965) finds that the data of T. S. Rass which shows a depthrange of 50 to 100 m at the spawning places to be the most convincing, while MØLLER and OLSEN (1962) suggests spawning at depths of 10 to 100 meters.

Materials and methods. The diving work at the spawning grounds of capelin was carried out from the R/V "Johan Hjort" during a cruise from 15/3 to 29/4-71. The diving was done from a 20' small-boat by the authors with a crew of 3 men. The diving suits were constant volume suits made from neoprene and air was supplied from 20 l. scuba-tanks. There were some problems with the valves due to freezing, as the air temperature varied from 0°-10°C, and the water temperature varied from + 1.5-3.2°C. A diver-to-surface underwater communication system proved useful when mapping the extension of the main spawning grounds. The sampling gear included a stainless steel box designed by the authors to take 0.1 m^2 samples from sand and gravel bottoms, and two frames of 1.0 m^2 and 0.1 m^2 for sampling algae and stones from a specific area. Plastic bags of various sizes were used for holding the samples. At each diving locality at least two bottom samples were taken. A thermometer for bottom and sediment temperature measurements and a "Aanderå current meter" for finding current speed, direction, and water temperature were used.

Snapshots were taken with a "Rolleiflex" and films with a "Bolex" film camera. Both cameras were contained in underwaterhouses.

Diving localities. To find localities with high probability of spawning, information on areas with high fishing intensity close to the shore was gathered. In addition, grab samples were taken at various localities along the coast to check on the persence of eggs. Dives were made at the following localities (Fig. 1).

Arnøy	2	dives -	20-30 m
Loppa	2	-"- -	20-35 m
Hasvik	8	-"-	5-30 m
Tarhalsen	2	-"-	20-30 m
Trollsund	4	-"-	8-34 m
Nordkapp	2	-"-	20-30 m
Kamøyfjord	2	-"-	5-35 m
Nordvågen	24	-"-	10-50 m

RESULTS

Bottom substrate. The samples of the substrate are not yet analyzed, but a general view of situation can be stated.

At 2 localities, Loppa and Nordvågen, there was a distinct sorting of the bottom material from shallow water, and downwards, with rocks and boulders just below water level and successively finer material down to fine sand in deeper waters. Loppa is much more exposed to wave action than Nordvågen, the result being longer stretches of coarser material. Sandy bottom is thus found deeper at Loppa, 70 m, than at Nordvågen, 20 m. At one locality at Hasvik and also at Trollsund the picture was somewhat different, as the rocky bottom sloped directly into wavemarked sand. At a more sheltered bay near Hasvik, the shallowest part (0-10 m) was covered with sand, the next 10 m with a mixture of sand and stones, and the final 10 m observed, with fine sand with wave marks. At Arnøya and Tarhalsen, a wide plateau covered with a mixture of sand and stone was observed at 20 - 30 m, below the boulder zone. At Nordkapp and Kamøyfjord the areas were not sufficiently investigated to give a complete picture, but we observed a rocky bottom sloping directly into sand at about 30 m depth.

Wherever rock and stone were present, there were various types of algae attached, including crusting types.

Observations on capelin schools. Using the echo-sounder on board the R/V "Johan Hjort", we made contact with capelin schools all along the coast of Finnmark, and then, by using another echo-sounder in the small boat, we located the specific schools along which we dived and made our observations.

We dived into capelin schools at 3 different localities: Hasvik, Trollsund and Nordvågen. In each of these areas we took pictures and films of the fish at distances up to 0.4 m.

Two different behaviours of the schools could be distinguised. Most commonly the school formation was extensively long, while very narrow in width and breadth. The fish swam slowly at depths ranging from 5-20 m, well above the bottom. In these schools the capelins

were well spaced, the distance between them varying from 40-80 cm. Initially, they reacted simultaneously to movement by the divers, but this reaction eventually ceased as they became accustomed to our presence. The swimming was nondirectional, as the schools changed course several times during our observations. Very often they seemed to show a wide circular movement. Whether this is natural or caused by the presence of a diver is unknown. The other, and most facinating sight was seeing the schools close to the bottom in a very dense formation, the space between the capelins being less than 10 cm. Vertically the shools extended less than 2 m. They were sharply limited in all other directions as well. Just above the bottom (20 m) the school was most dense with the fish packed head to tail, and their sides nearly touching. The movement of the school was still somewhat circular, but within a very small radius. It appeared that the school reacted less to the presence of divers during these occasions, since we could take pictures from as near as 0.4 m, with the school, in effect, circulating around the divers. The pictures taken indicate that these schools consisted mainly of males.

Very frequently we observed capelins which were no longer able to follow the schools. They were in bad condition and seemed to have trouble with their buoyancy, since they were found both close to the bottom and near the surface. Sometimes they even swam upside down. We seldom observed any external sign of abnormality of these dead and dying fish, other than the frequent bloodshot nature of the swollen area below the male anal fin. Without exception the dying capelins observed were males.

At Nordvågen, large masses of dead capelins were seen on the bottom, but as it was on a spawning ground which was intensively fished by trawlers, we cannot be certain that the mass mortality was from natural causes. There were scattered dead fish at all localities where we dived, and because no fishing occurred at Hasvik, we are certain that those capelins died a natural death. The samples consisted of spent individuals.

The dead capelins were preyed upon by starfish, most commonly by Asterias rubens L. In later dives at the end of April, only the head and backbones of the dead capelins remained.

Observations on the spawning grounds.— We succeeded in finding the main spawning grounds only at Nordvågen and Loppa. At the other 6 localities we found areas with only sparse numbers of eggs attached to algae and stones. The main spawning grounds at Loppa were much more exposed to wave action than were the grounds found at Nordvågen. The upper limit of the spawning bed at Loppa was at 35 m depth, at the same level that the coarse gravel was succeeded by finer gravel of grain size 0.5 - 1.5 cm. Grab samples revealed that the gravel and egg mixture reached down to at least 70 m water depth.

At Loppa, the concentration of eggs was by far the highest observed; there seemed to be too little gravel surface for the eggs to stick to, thus accounting for the numerous lumps of eggs sticking together. The bottom was completely white with the eggs. The thickness of the gravel and egg mixture was ca. 5 cm.

The other, and more closely observed main spawning ground, was found just outside of Nordvågen. This area was more sheltered than the ground at Loppa, and the fine gravel was at 12 m to 18 m depth with coarse gravel at lesser and sand at greater depths. Using the underwater-telephone and marker buoys, divers circum navigated the spawning ground and found the area to be 180,000 m^2. The ground consisted of fine black gravel and was limited at the edge by either coarser gravel with stones or by sand. (Fig. 2). These observations were later confirmed by a series of grab samples which covered a greater area and showed that the bulk of the main spawning ground lay within the fine gravel. (DRAGESUND, GJØSÆTER and MONSTAD 1971). The thickness of the egg/gravel layer was ca. 4 cm in the center of the main spawning ground, and decreased towards the borders. Samples from the middle contained ca. $3X10^6$ eggs m^2.

Although the divers did not observe this, 400,000 eggs m^2 were found in one sample from fine sand at greater depths, ca. 100 m away from the main spawning ground.

Capelin eggs were not found closer to the shore than 250 m.

We observed the ground at Nordvågen 3 times, 29 - 31 March, 14 - 16 April, and 25 April. During this period, the sea temperature raised from 1.5°C to 3.2°C. During dives on April 13, we checked

the temperature across the egg bed at intervals of 40 m, both just above the egg surface and ca. 5 cm down into the bottom substrate. The water temperature varied from 3.25°C to 2.81°C inwards across the bed, and was slightly lower in the bottom substrate, probably due to a delay in heating.

Over a 29 hour period, the current direction was mainly N.N.E. and the current speed varied from 13 to 46 cm/sec.

On 14 - 16 April and 25 April we observed brown patches along the egg beds. This was caused by a filamentous alga that settled on the surface layer, both on the stones and the eggs. It seemed to have no ill affect on the eggs, as egg samples kept in jars did not show higher mortality than eggs without attached algae (DRAGESUND, GJØSÆTER and MONSTAD, 1971). The algae was not found in waters deeper than 16 m. Otherwise, the flora and fauna at the spawning ground was sparse, as only a few Laminarians and starfish were observed. Capelin was the only fishspecies noted at the spawning grounds.

After March 29 and until our last observations on April 25, we noted a distinct reduction in the number of eggs on the surface stratum. Although this surface egg layer changed from a blanket of eggs to a sparse distribution during this period, the concentration of eggs under the top layer remained high during the entire investigation. We observed drifting eggs at both the Nordvågen and Loppa grounds on almost every dive except during calm weather. The total egg reduction at Nordvågen is difficult to estimate, but it is probably between 100,000 to 400,000 eggs/m^2.

Damage to capelin eggs done by trawlers. Among Norwegian fishermen it has been argued that the lower doors of pelagic trawls would damage the capelin eggs if dragged along the spawning beds. BURD and VALLACE (1968) have discussed the effect of trawling on the spawning beds of herring. Their results from laboratory experiments concerning herring larvae viability suggest that observations at sea of apparent reduction in viability among herring larvae might be related to the effects of a disturbance of eggs on the spawning grounds.

At the spawning grounds in Nordvågen we observed tracks made by the

lower doors of pelagic trawls. The tracks were about 0.5 m broad and usually more than 40 m in length. Because the doors had pushed aside nearly all the mixture of eggs and gravel, ridges about 10 cm high were formed on one side of each of the tracks. In total, less than 1 % of the spawning area was covered with trawling tracks. During the time of the investigations, fishermen caught about 7300 tons of capelin at this locality.

In each of the three diving periods several samples were taken by divers from the middle of the tracks and from the top and bottom of the ridges, but mechanical destruction caused by the trawl doors could not be proved since the mortality was the same as in samples of eggs brought up by the grab and other samples taken by divers, where 2,5 - 5,0 % were crushed. It is not known whether this was a result of the sampling or a natural phenomenon. (DRAGESUND, GJØSÆTER and MONSTAD, 1971).

To study the effects of mechanical disturbance of the eggs, an experiment was carried out in Nordvågen. Three trawl bobbins were hauled along the spawning beds by the research vessel while a diver observed from below. The bobbins whirled up the eggs and bottom substrate and made a track on the bottom similar to those made by trawldoors. Egg samples were taken from the tracks and outside, and a plankton-net, placed behind and above the bobbins, sampled the egg which were whirled up. There was no difference in mechanical distruction of the eggs from the tracks and those which were undisturbed. When kept in glass jars for 12 days, the mortality among eggs whirled up from the bottom was between 6.0 - 10.2 % and the mortality among undisturbed eggs and eggs from the bobbintrack was from 0 - 2.1 % (DRAGESUND, GJØSÆTER and MONSTAD, 1971).

DISCUSSION

Spawning grounds. The gravel size (0.5 - 1.5 cm diameter) observed at Loppa and Nordvågen agrees with observations of main spawning grounds in Canada. (TEMPLEMAN 1948).

Only once, at Nordvågen, were large masses of eggs, 400,000/m^2, found in fine sand close to the main spawning ground. Although sand is assumed to be a less favourable substrate for mass-spawning, it

is possible that such spawning can occur when the most favourable grounds are occupied or when the spawning pressure is great (TEMPLEMAN, 1948). Grab samples along the coast of Finnmark confirmed this, as greater numbers of eggs were found only in connection with fine gravel. (DRAGESUND, GJØSÆTER and MONSTAD, 1971).

In Canada, fine gravel from 0.25 - 1.50 cm diameter is especially favourable for heavy capelin spawning. Here the spawning movements can somewhat bury the eggs, but most of the burying, down to 1 foot, is accomplished by wave action (TEMPLEMAN 1948, SLEGGS 1933). Most likely such burying does not occur at the spawning grounds we observed since the depth at Loppa, 35 - 70 m, and the sheltered nature of Nordvågen probably prevent strong wave action. In these areas the maximum thickness of the egg and gravel mixture was 5 cm. When this maximum is reached, as we observed at Loppa, lumps of eggs are formed when new spawning on the already saturated 5 cm of substrate occurs.

At both spawning grounds, the mixture of eggs and gravel had a foamy appearance, and it whirled up from the samllest wave movement of the hand. This is probably due to a greater buoyancy of grains with eggs stuck to them, thus making it easier for the capelins to bury their eggs.

Fish behaviour at the spawning grounds. Of the two types of behaviour observed, the observations of fish swimming in small circles close to the bottom were the most interesting. In Canada, similar behaviour has been observed by SLEGGS (1933) in connection with spawning activity, and often immediately before the spawning act. TEMPLEMAN (1948) writes that male capelin are mature when they approach the shore for spawning, and that they are in constant attendence at the beaches. Schools of unripe females remain in a few fathoms of water, away from the immediate neighbourhood of the beach and groups go to the beach to spawn as they ripen.

Since no females could be seen in the schools observed at Nordvågen and Hasvik, these shools were probably what Templeman calls "males in constant attendence".

Egg mortality. According to DRAGESUND, GJØSÆTER and MONSTAD (1971) natural egg mortality at the spawning ground seems to be low.

Although capelin eggs were found in stomachs of haddock and capelin at some localities (DRAGESUND, GJØSÆTER and MONSTAD 1971) no predation could be observed at Nordvågen.

DRAGESUND, GJØSÆTER and MONSTAD (1971) found neither increased egg mortality among the eggs from trawl tracks, nor among the eggs sampled during the bobbin experiment. After a 10 day incubation period, increased egg mortality (6.0 - 10.2 %) could be shown among the eggs whirled up by the bobbins, but not among the eggs sampled from the bobbin tracks. Even though the eggs were not crushed, it thus seems that the degree of mechanical disturbance influences the egg mortality. BURD and WALLACE (1968) found that mechanical disturbance of herring eggs at certain stages of development could reduce the viability of the hatched larvae. The increased mortality among incubated capelin eggs which were heavily disturbed by the bobbins, might indicate that the same is true for the capelin larvae. The degree to which trawling on the spawning grounds reduces capelin recruitment depends on the amount of trawling and the egg- and larval mortality of the disturbed eggs. During the time of investigations at Nordvågen a total of 7300 tons of capelin were caught, mainly by trawlers. However less than 1 % of the spawning grounds was disturbed. Even if there was a 100 % mortality of the disturbed eggs, less than 1 % of the eggs at Nordvågen would be lost.

On the spawning grounds, the egg reduction due to wave action over a 4 week period was relatively large, probably between 5 and 10 %. It is assumed that the mortality of these disturbed eggs is higher than for those remaining on the grounds. If the viability of the loosened eggs is small, this drift of eggs from the spawning grounds can largely reduce the recruitment.

SUMMARY

1) During the Norwegian capelin investigation in the spring 1971, observational studies on the spawning grounds of the Barents Sea capelin were carried out by divers.

2) Large masses of capelin eggs were found at two localities; Loppa (35 - 70 m depth) and Nordvågen (12 - 18 m depth). The eggs were buried down to 5 cm in fine gravel (0.5 - 1.5 cm diameter), a phenomenon corresponding to observations made in Canada.

3) Two types of fish behaviour were observed; well spaced schools in the upper layers and dense circulating schools close to the bottom. The latter is believed to be "males in constant attendence", waiting for ripe females.

4) Egg mortality caused by trawlers was experimentally investigated by dragging trawl-bobbins along the egg beds. Only the eggs whirled up by the bobbins showed higher mortality (up to 10.2 % after 10 days incubation) than undisturbed eggs and eggs from the bobbin tracks (up to 2.5 % mortality after 10 days incubation). Less than 1 % of the eggs on the specific area investigated is believed to be damaged by trawlers.

5) The reduction in the number of eggs on the spawning grounds during a 4 week period is estimated to be from 5 to 10 %, and is caused by convection and watercurrents. No predation on the capelin eggs was detected.

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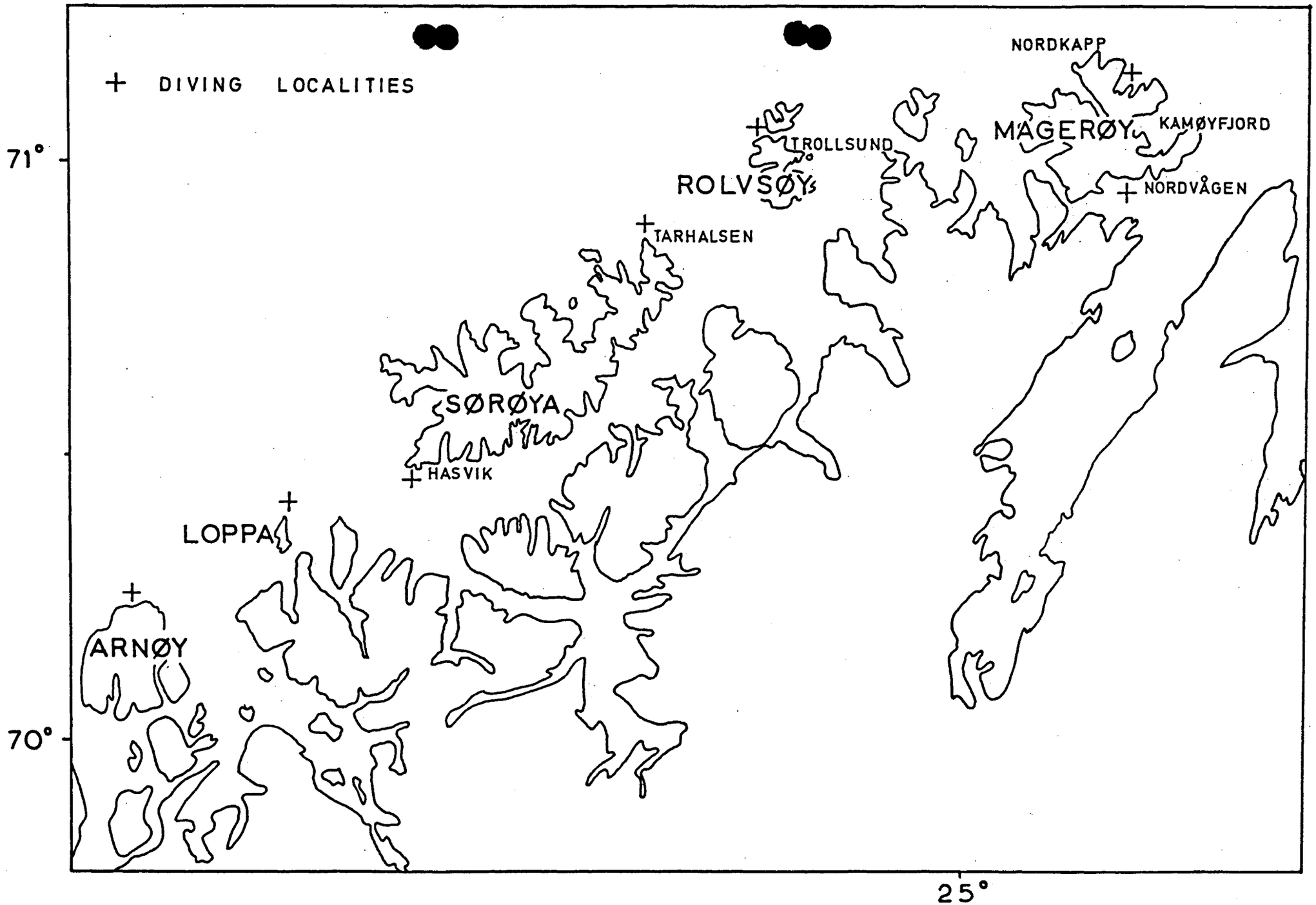

FIG. 1 THE AREAS INVESTIGATED BY DIVERS

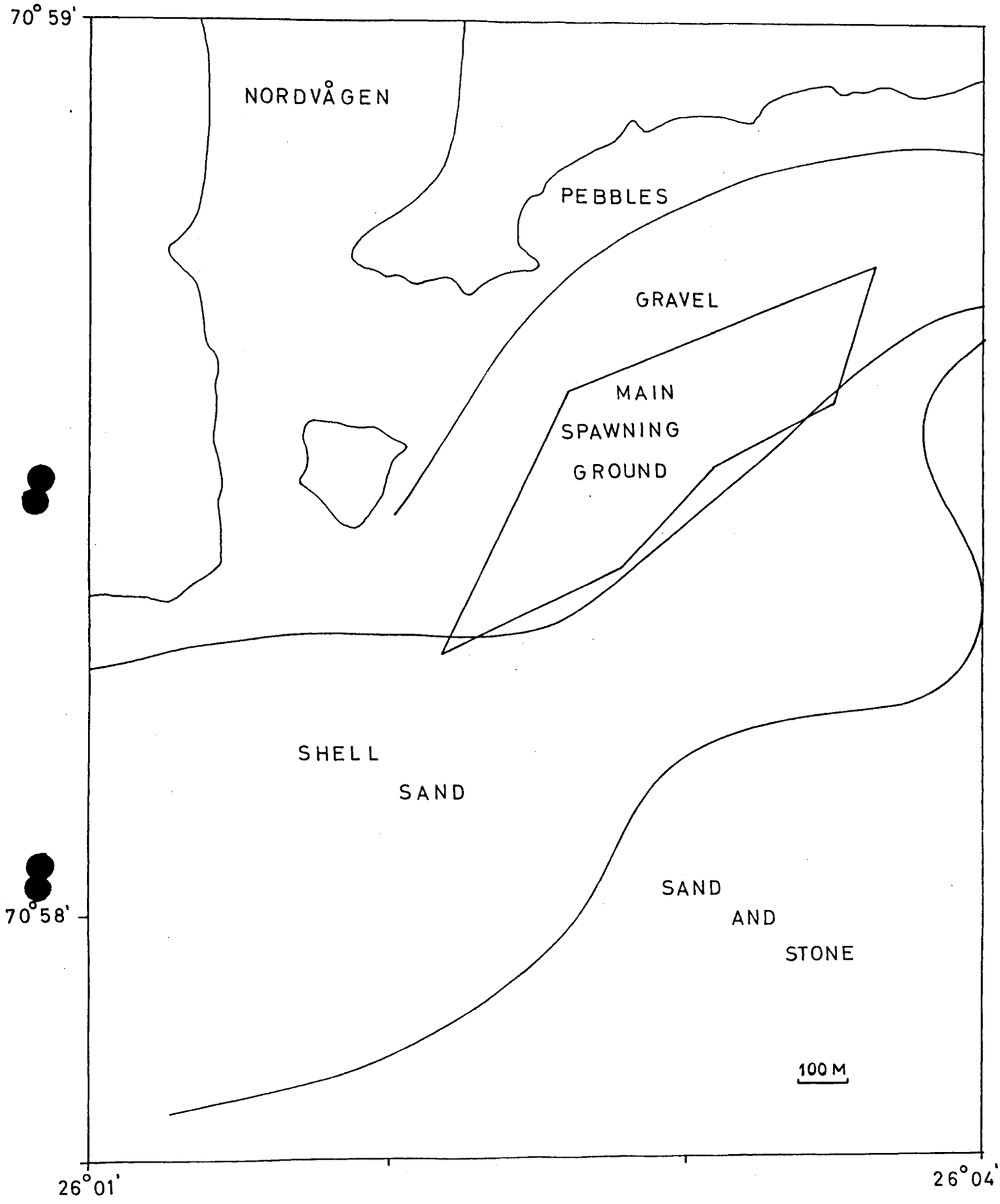

FIG. 2 THE AREA AT NORDVÅGEN AS DETERMINED BY DIVERS AND GRAB SAMPLERS