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The Propagation of Cod *Gadus morhua* L.

SPAWNING GROUNDS OF THE ARCTO-NORWEGIAN COD OUTSIDE VESTFJORDEN

V.P. Serebryakov and V.K. Aldonov

VNIRO, 17 V. Krasnoselskaya,
Moscow B-140, 107140 USSR

ABSTRACT

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The spawning area of the Arcto-Norwegian cod is vast, extending from 62°N to 74°30'N in the area investigated.

Localities characterized by an intensive rate of spawning are in the Norwegian Sea over the Langgrunnen, Buagrunnen, Halten, Røst, Vesterålen, Andøy, Malangen and Fugløy Banks, in the shelf slope area and in the open sea over great depths. The position of spawning grounds and the intensity of spawning in the area vary from year to year.

Various positions of spawning grounds are grouped into three types: Type 1 - the main spawning grounds are only in the areas of banks near the shore; Type 2 - spawning grounds are both in the areas of banks and in the shelf slope area; Type 3 - spawning grounds are outside the Norwegian Sea shelf and over the Malangen Bank.

The position of spawning grounds in the survey area outside the Vestfjorden is not an indicator of the abundance of year classes of the Arcto-Norwegian cod.

INTRODUCTION

The fishery for spawning cod off the Norwegian coast and Kola Peninsula has been in existence since ancient times. The distribution of the spawning grounds in the area has been described by many scientists engaged in the study of the species

(Hjort, 1902; Damas, 1909; Schmidt, 1909, 1930; Tanasiichuk, 1932; Sund, 1938; Marty, 1939; Maslov, 1944; Rass, 1934, 1949, and others). Rass made a thorough investigation of the reproduction of cod in the Barents Sea where spawning grounds were found off Murman in the 1930's (Suvorov, 1932; Esipov, 1932; Tarasov, 1932). The spawning grounds in the Norwegian Sea in the Vestfjorden area were investigated thoroughly by Wiborg (1948, 1952, 1954, 1956, 1957) which, as Marty and Martinsen (1969) pointed out, had been the main spawning grounds of arctic cod since the 1930's. Our knowledge of the spawning grounds of cod has been, to a large extent, extended by ichthyoplanktonic investigations carried out by the Polar Research Institute of Marine Fisheries and Oceanography (PINRO) (Baranenkova, 1961; Baranenkova and Khokhlina, 1959, 1964; Baranenkova et al., 1972, 1973, 1976). They indicated that cod spawn intensively north and northeast of the Lofoten outside Vestfjorden. The spawning intensity in Vestfjorden fluctuated widely from year to year (Wiborg, 1952, 1960, 1978) which sometimes seemed to be associated with upwelling induced by southwesterly winds (Audunson et al., 1981, Ellertsen et. al. 1981). In some years, as Baranenkova and Khokhlina (1964) noted, the increase in the abundance of eggs and larvae of cod outside Vestfjorden corresponded to a decrease in the abundance of eggs and larvae inside Vestfjorden. Material from the standard ichthyoplanktonic surveys of PINRO in the east Norwegian Sea and in the south-western Barents Sea in 1959-1980 allows a detailed analyses of changes in the distribution pattern of localities characterized by an intensive rate of spawning.

MATERIALS AND METHODS

The ichthyoplanktonic surveys were regularly conducted in April-May from 1959 to 1980 (Fig. 1). At each of 200 stations a vertical haul was made from the bottom to 0 m if it was less than 500 m depth or 500-0 m, and horizontal hauls at depths of 0.25 and 50 m when the vessel was under way, moving with a speed of 2.5 knots. The fishing gear for eggs was a conical net

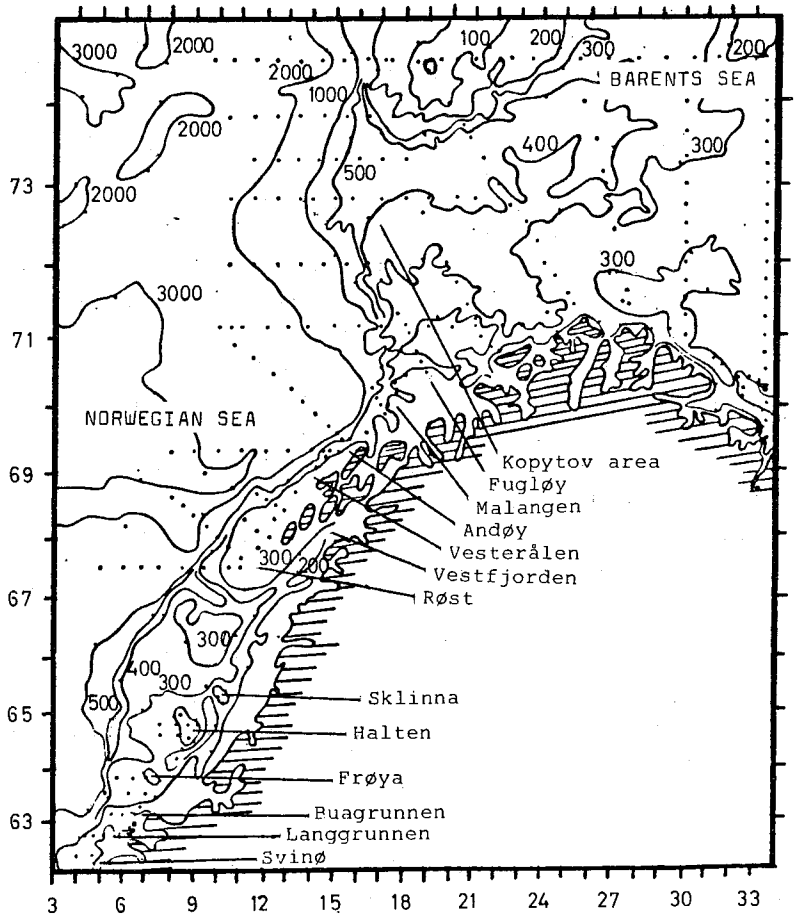

Fig. 1. Ichthyoplanktonic surveys in the Norwegian and south-west Barents Seas in 1959-1980. Dots indicate stations.

made of gauze, 0.505 mm mesh, with an 80 cm mouth opening. In addition, in 1969-1976 another series of ichthyoplanktonic surveys was made in the Norwegian shallows. The surveys started alternatively from the Malangen Bank on April 20 or from the Svinø area on April 2-5. The methods of the surveys have been described in detail (Baranenkova, 1961; Baranenkova and Khokhlina, 1959; Seliverstov 1972).

In order to compile egg distribution density maps, a special programme was worked out for a computer equipped with a graph-plotter. The maps of the distribution density of eggs are provided only for the northern part of the survey (north of 67°N) as the sampling method in the southern part (south of 67°N) was a little different and did not suit the computer programme. Data obtained during vertical hauls were compared with data characterizing horizontal hauls to compile the distribution density maps of eggs at stage I of development (according to the scale suggested by Rass in 1946). While comparing the maps, it was found that patches of highest egg densities were situated in the same areas on both types of maps, whereas patches of lowest densities were much more widely distributed on maps compiled on the basis of data obtained in horizontal hauls. Proceeding from this, the data from horizontal hauls were used for finding spawning areas, and the data from vertical hauls were used for the assessment of the total number of eggs in the area surveyed (this material is not available in the paper).

Stage I of development (from fertilization to embryonic shield formation, lasts not more than 5 days at the temperature of 5-6°C characteristic of the upper layer in the spawning season of cod and in the period of egg drift (Mukhin and Dvinina, 1983). Therefore, the maximum error in ascertaining the time of spawning does not seem to exceed 5 days, and the maximum error in finding the spawning area may not be more than 60 miles, according to the speeds of currents in the area investigated (Alekseev and Istoshin, 1956; Audunson et al., 1981).

Identification of cod eggs of stage I from haddock eggs of the same stage is always a confusing matter, while eggs of both

species are easily identifiable at stage II. Therefore the number of cod eggs at stage I was defined by the percentage ratio of cod eggs to haddock eggs at stage II in each sample.

Data on the abundance of three-year-old cod presented in the Report of the Arctic Fisheries Working Group (Anon., 1983) have been used to find a criterion for the size of yearclasses. When the numerical strength of 3-year-olds is over 1000.10^6 the yearclass is believed to be abundant, when it is less than 500.10^6 it is of low abundance. Intermediate values characterize an average yearclass.

RESULTS

Cod eggs at stage I were found practically over the whole area surveyed. They occurred in the south in the Svinø area, in the north off Bear Island up to $74^{o}30'N$ and in the east were encountered at the transect over the Kola meridian. The distribution density of eggs varied from year to year. The highest densities (over 1000 eggs per horizontal haul near the surface) were observed in 1959, 1963, 1965, 1969, 1970, 1974 and 1975. The largest area with the maximum density of eggs was observed in 1970 and the smallest area in 1974. The former was on the Vesterålen Bank, and the latter in the Kopytov area.

In 1960, 1961, 1962, 1968, 1972, 1976, 1978 and 1980 density did not exceed 1000 eggs per haul in any areas, but the largest areas with a lower density (300-1000 eggs) distribution were found in the Vesterålen and Andøy Banks areas in 1961.

Each year eggs at stage I were distributed over the Buagrunnen, Langgrunnen, Halten Banks, the east part of the Røst Bank, Vesterålen, Andøy, Malangen Banks, the west part of the Fugløy Bank and the southwestern part of the Kopytov area (Fig. 2-20). The maximum hauls of eggs at stage I occurred not only over banks and in coastal waters, i.e. in relatively shallow waters, but also far from the banks and coasts in water of 500 or even 1000 m depth near and in the Kopytov area. In 1975, such cases were registered over oceanic depths (over 1000 m) nearly 80

miles north of the Lofotens. Besides, eggs at stage I occurred annually in depths exceeding 400 m (Fig. 15).

The total area where eggs at stage I were distributed varied from year to year. The widest distribution patterns were observed in 1962, 1972, 1973, 1974 and 1975 (Fig. 2, 12, 14 and 15) and the narrowest patterns were registered in 1963 and 1965 (Fig. 6 and 7). No eggs at stage I occurred at northern stations of the surveys in 1959, 1963 and 1969 (Fig. 2, 6 and 9). In 1972 and 1974, many more eggs were found in the northeastern part of the area investigated than was usual (Fig. 12 and 14).

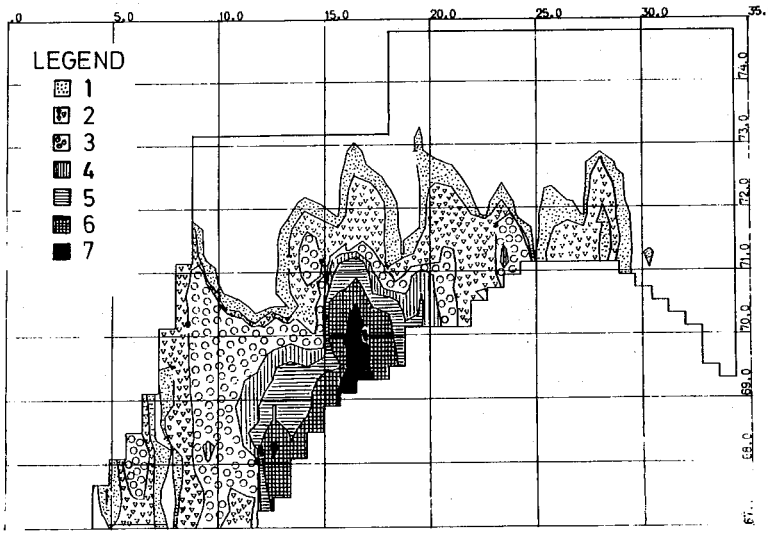

Fig. 2. Distribution of cod eggs at stage 1 in 1959. Legend: 1-7 density distribution of eggs per 15 min horizontal haul: 1 = less than 3 eggs, 2 = 4 - 10 eggs, 3 = 11 - 30 eggs, 4 = 31 - 80 eggs, 5 = 81 - 300 eggs, 6 = 300 - 1000 eggs, 7 = more than 1000 eggs.

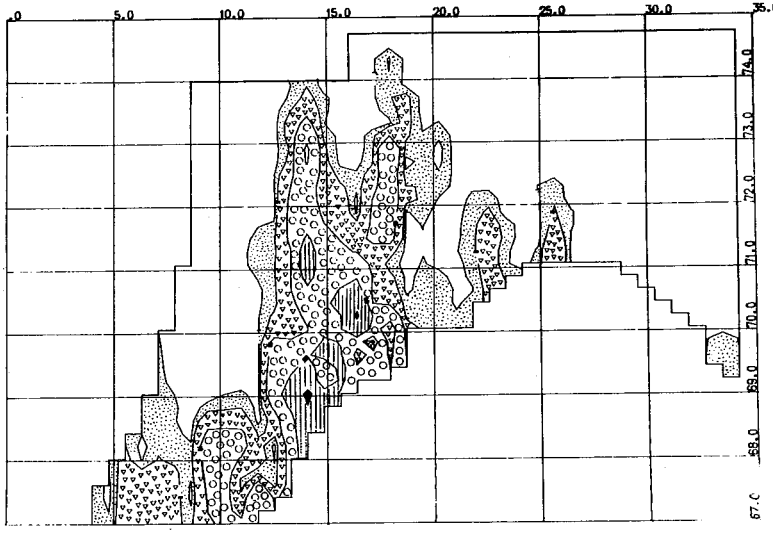

Fig. 3. Distribution of cod eggs at stage 1 in 1960. Legend as in Fig. 2.

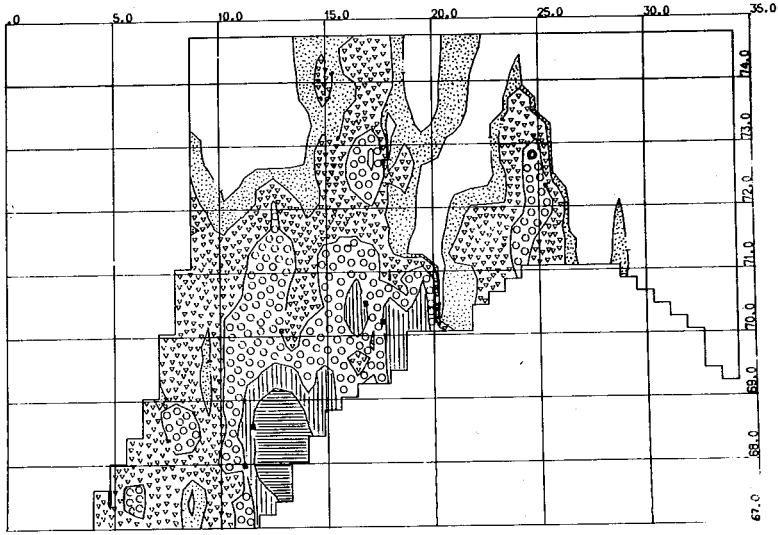

Fig. 4. Distribution of cod eggs at stage 1 in 1961. Legend as in Fig. 2.

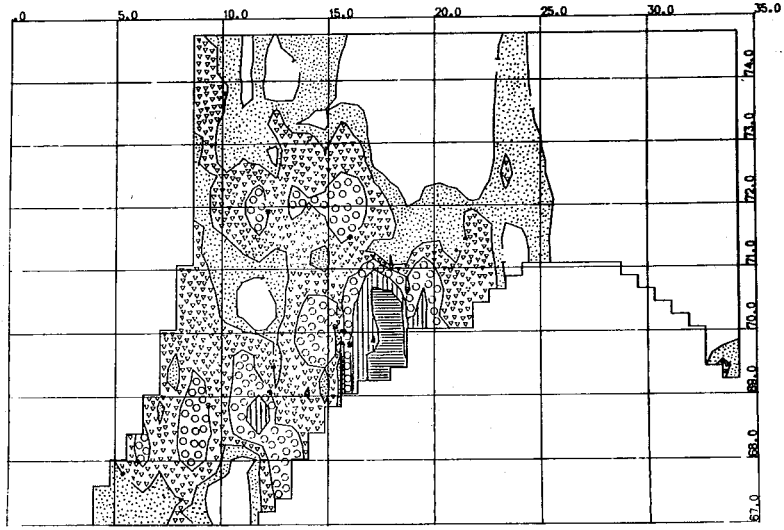

Fig. 5. Distribution of cod eggs at stage 1 in 1962. Legend as in Fig. 2.

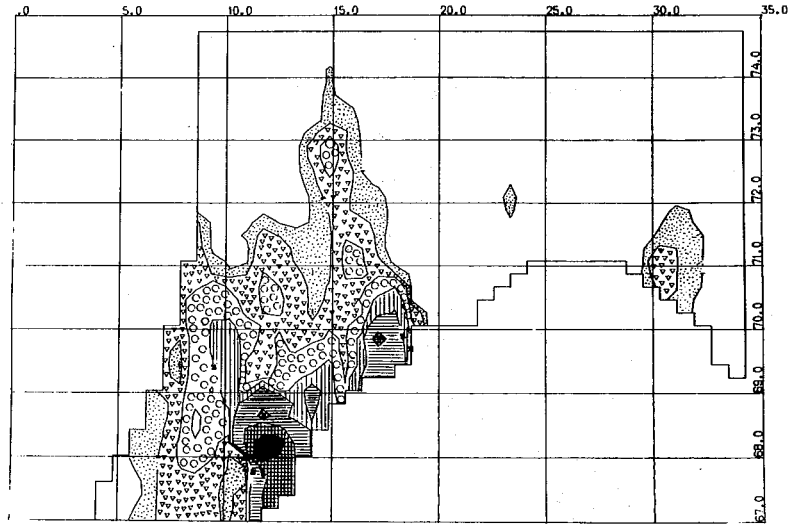

Fig. 6. Distribution of cod eggs at stage 1 in 1963. Legend as in Fig. 2.

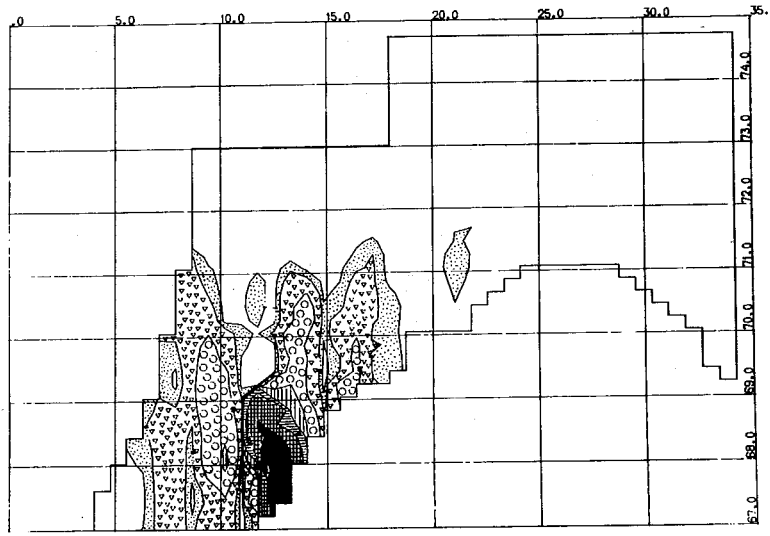

Fig. 7. Distribution of cod eggs at stage 1 in 1965. Legend as in Fig. 2.

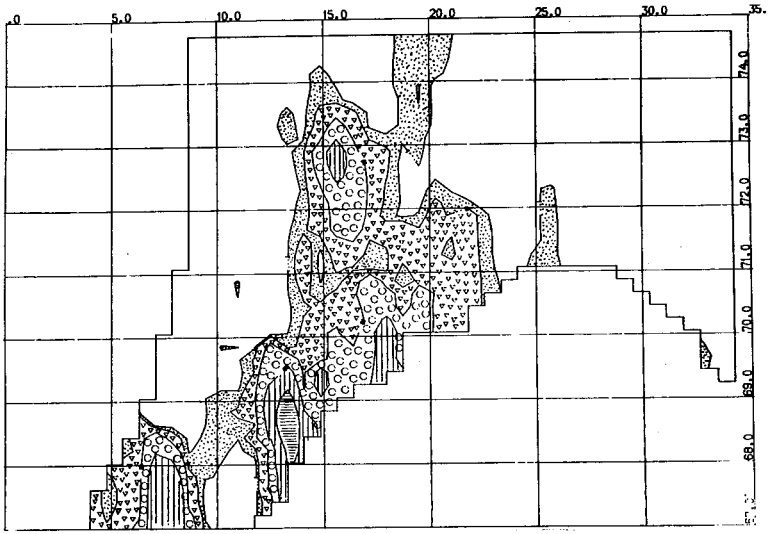

Fig. 8. Distribution of cod eggs at stage 1 in 1968. Legend as in Fig. 2.

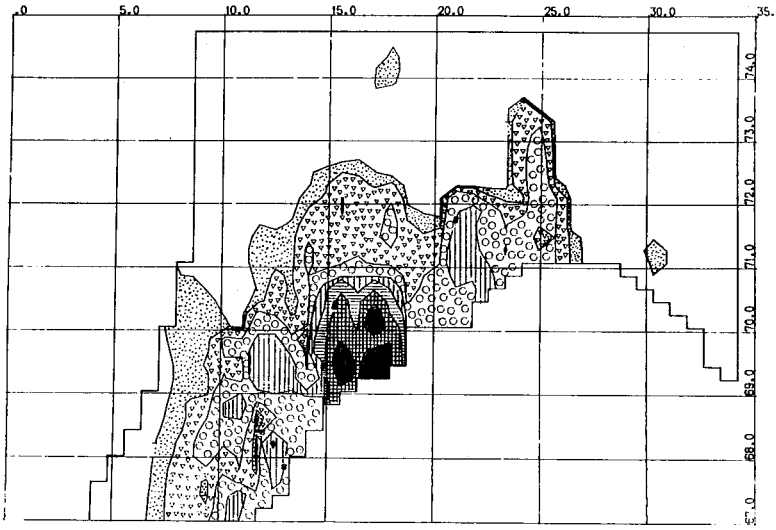

Fig. 9. Distribution of cod eggs at stage 1 in 1969. Legend as in Fig. 2.

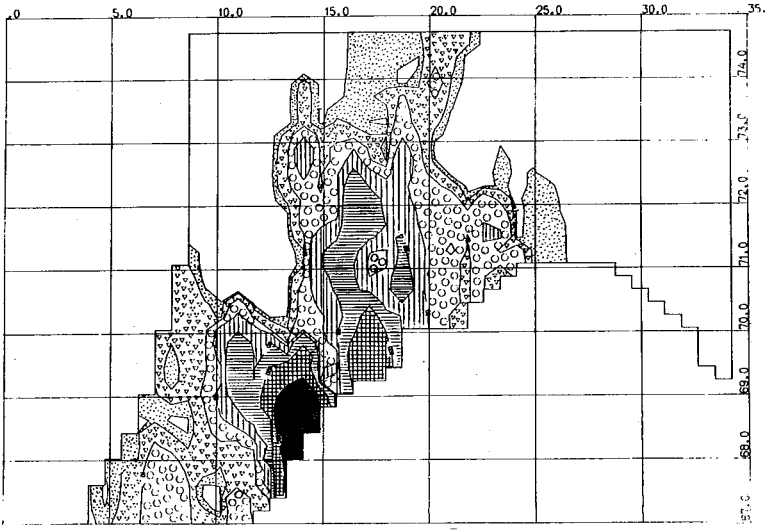

Fig. 10. Distribution of cod eggs at stage 1 in 1970. Legend as in Fig. 2.

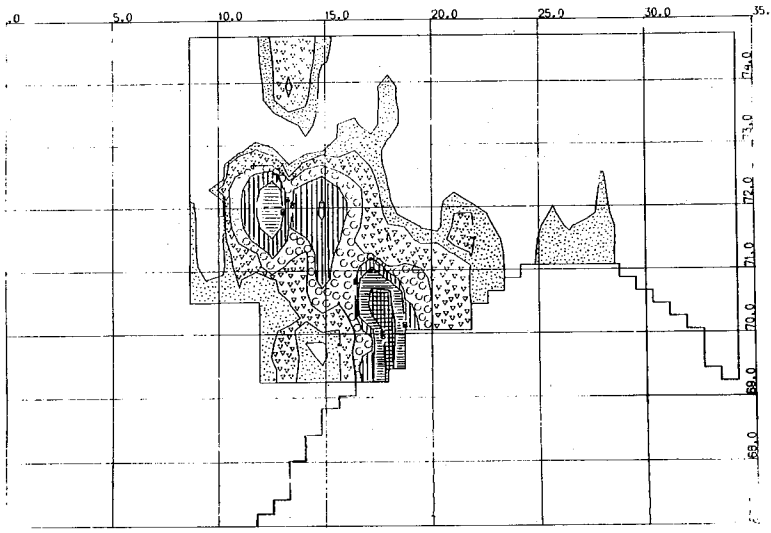

Fig. 11. Distribution of cod eggs at stage 1 in 1971. Legend as in Fig. 2.

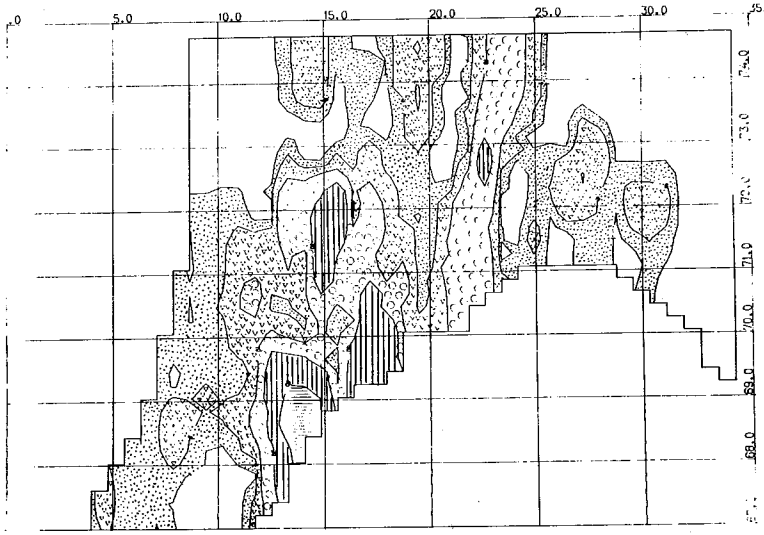

Fig. 12. Distribution of cod eggs at stage 1 in 1972. Legend as in Fig. 2.

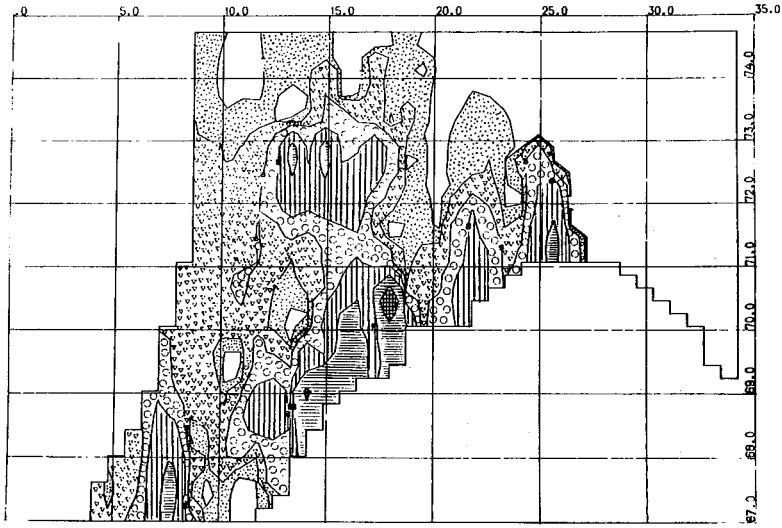

Fig. 13. Distribution of cod eggs at stage 1 in 1973. Legend as in Fig. 2.

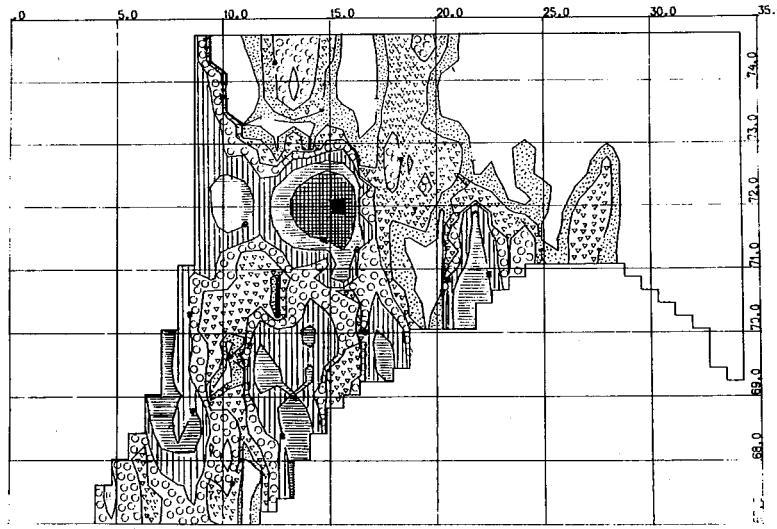

Fig. 14. Distribution of cod eggs at stage 1 in 1974. Legend as in Fig. 2.

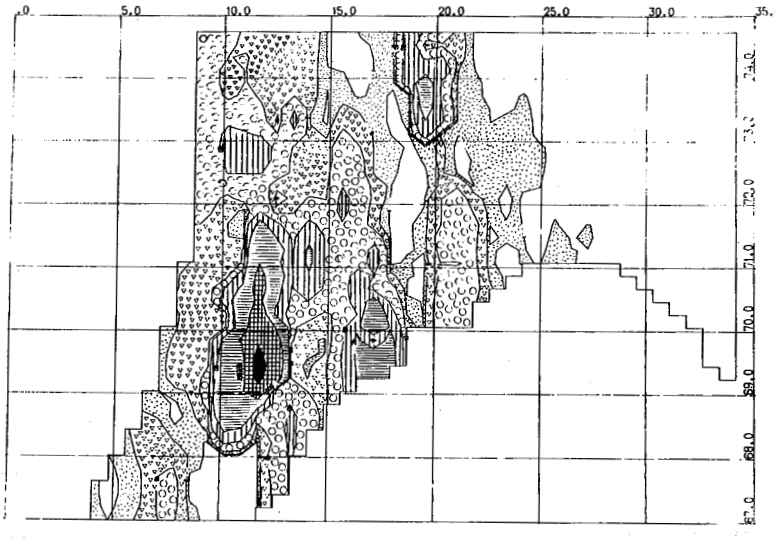

Fig. 15. Distribution of cod eggs at stage 1 in 1975. Legend as in Fig. 2.

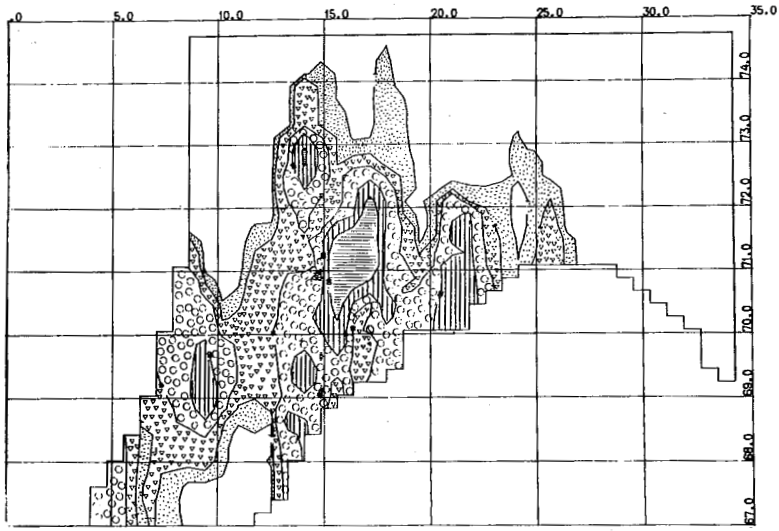

Fig. 16. Distribution of cod eggs at stage 1 in 1976. Legend as in Fig. 2.

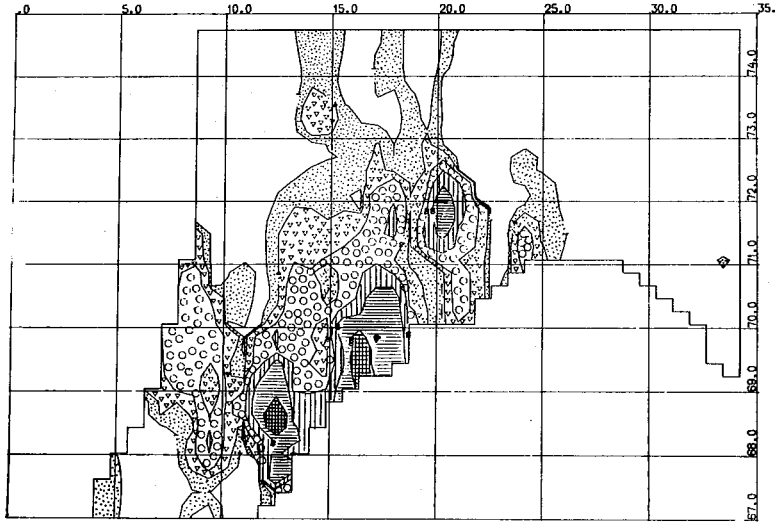

Fig. 17. Distribution of cod eggs at stage 1 in 1977. Legend as in Fig. 2.

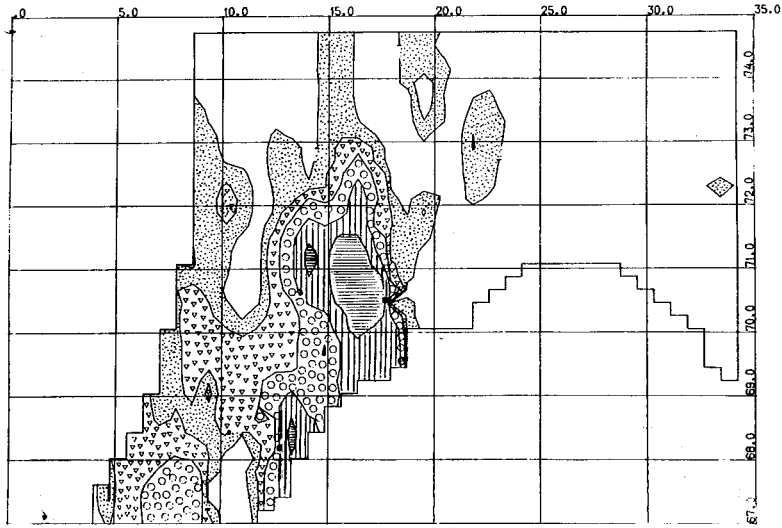

Fig. 18. Distribution of cod eggs at stage 1 in 1978. Legend as in Fig. 2.

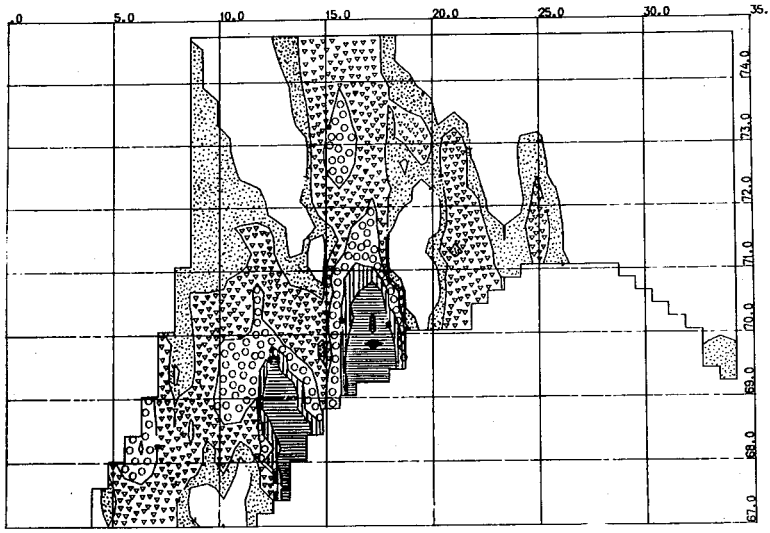

Fig. 19. Distribution of cod eggs at stage 1 in 1979. Legend as in Fig. 2.

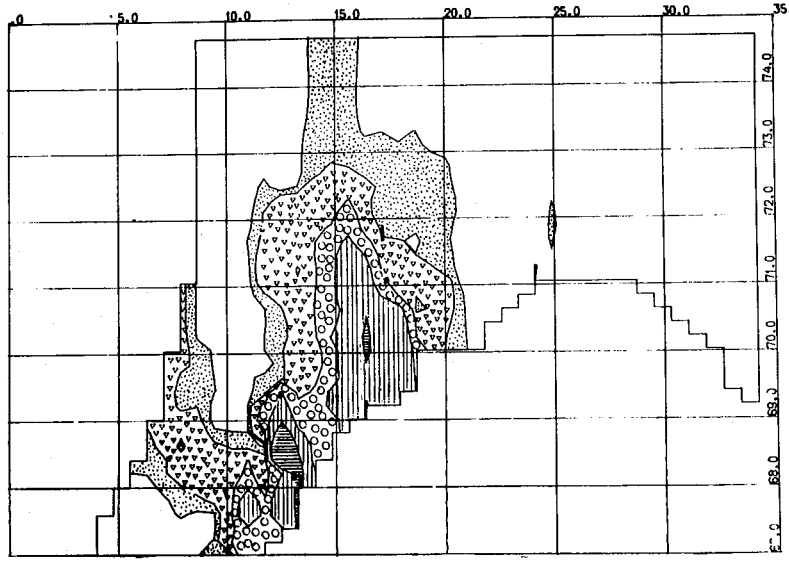

Fig. 20. Distribution of cod eggs at stage 1 in 1980. Legend as in Fig. 2.

DISCUSSION

Judging from the distribution pattern of eggs at stage I, it is evident that in all the years when the surveys were made the spawning area of the Arcto-Norwegian cod was extensive, from 74°30'N off Bear Island to 62°N off the Norwegian coast. Every year cod spawn intensively over Buagrunnen, Langgrunnen, Vesterålen, Andøy and Malangen Banks. In some years intensive spawning was observed over Svinøy, Frøya, Halten, Sklinna, Røst and Fugløy Banks, as well as in the open Barents Sea over depths of 300-500 m and in the open Norwegian Sea over depths of over 1000 m (Fig. 21).

The assumption that cod spawn over great depth was presented earlier (Rass, 1949; Baranenkova et al., 1972, 1973, 1976; Serebryakov, 1965, 1967), but the intensity of spawning was not discussed. In view of the fact that 2 of the 12 areas characterized by intense spawning were situated over great depths, it may be concluded that the spawning of cod over great depths is very important for the reproduction of the Arcto-Norwegian population in certain years. Particularly so, since the intensity of spawning on other spawning grounds over the banks and in the inshore water fluctuates greatly.

In the north part of the area investigated (north of 67°N) in 1959-1980, all the variety of the positions of spawning grounds can be grouped into three types of repeated situations.

Type 1: Cod spawn intensively only over banks close to the shore (Fig. 22). This situation is typical for 1959-1963, 1965, 1968, 1969, 1972, 1979 and 1980 when spawning occurred over the Røst, Vesterålen and Malangen Banks.

Type 2: Spawning grounds are situated not only in the bank area, but on the shelf slope, as if along the slope northward to the Kopytov area. This situation was observed in 1970, 1973, 1977 and 1978 (Fig. 23).

Type 3: Cod spawn mainly in the coastal zone, primarily on the Malangen Bank and in the open sea over great depths. This type was observed in 1971 and 1975 (Fig. 24).

Among the principal factors responsible for fluctuations in the abundance of yearclasses, Wiborg (1957) stressed the posi-

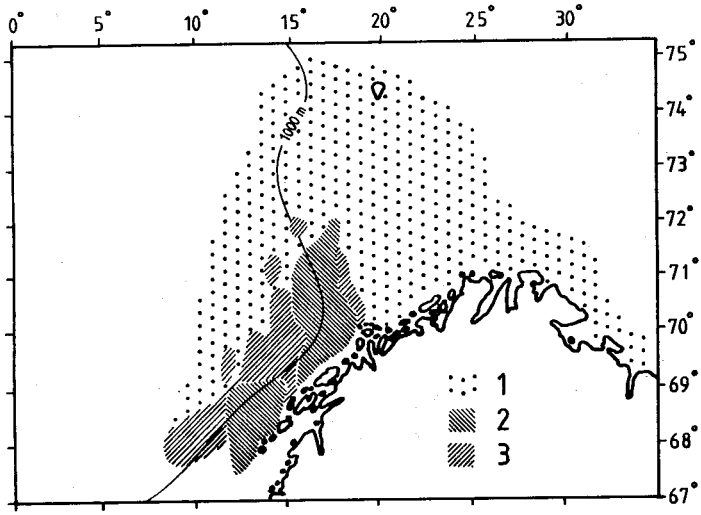

Fig. 21. Spawning grounds of cod outside the Vestfjorden. Legend: 1 - not intensive spawning, 2 - intensive spawning, occurred every year, 3 - intensive spawning occurred in some years. 1000 m isobath is shown.

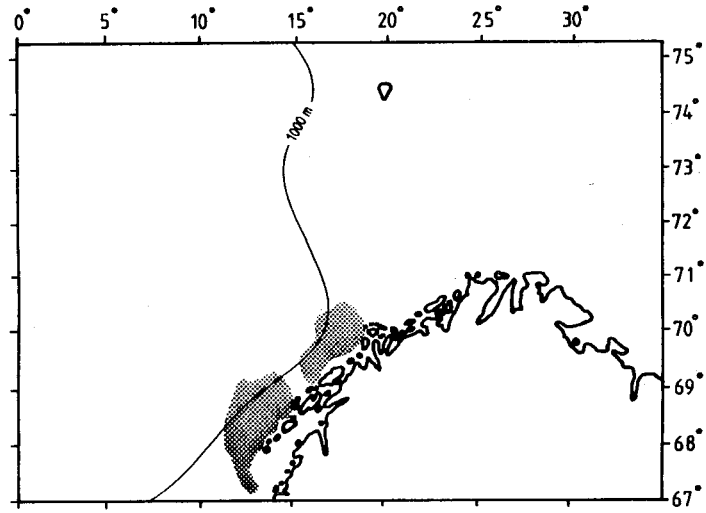

Fig. 22. Type 1 of spawning ground locations. Dotted areas indicate spawning grounds.

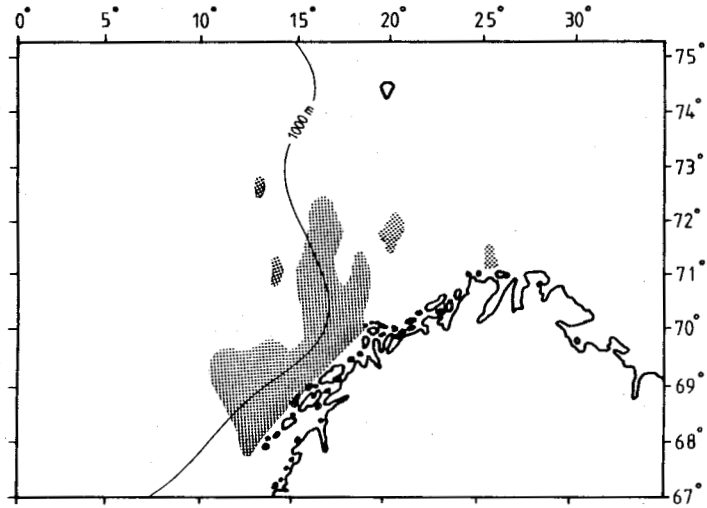

Fig. 23. Type 2 of spawning ground locations.

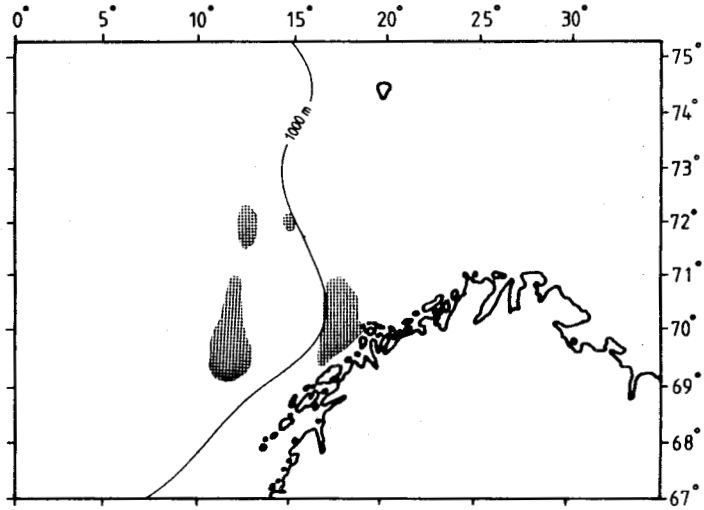

Fig. 24. Type 3 of spawning ground locations.

tion of spawning grounds. The significance of choosing a fortunate place for spawning eggs, their subsequent drift and, in the long run, their survival is quite evident and arouses no doubts. So, let us consider how the types of distribution of spawning grounds are associated with the abundance of yearclasses of the Arcto-Norwegian cod. Abundant yearclasses emerged in 1963, 1969 and 1970. The 1963 and 1969 yearclasses were typical of type 1, i.e.spawning over the banks (Fig. 22). The abundant 1970 yearclass emerged when principal spawning grounds were situated in the bank areas and on the shelf slope up to the Kopytov area, i.e. type 2. Thus, abundant yearclasses may arise from spawning distributions of types 1 and 2. Poor yearclasses, however, also appear in such years, e.g. the poor 1960, 1961, 1965, 1968, 1979 and 1980 yearclasses occurred when spawning distributions were of type 1 and the poor 1977 and 1978 yearclasses when they were of type 2. In other words, both abundant and poor yearclasses emerged when spawning distributions were of types 1 and 2. Although type 3 was only observed for the average 1971 and 1975 yearclasses, average yearclasses appeared also for type 1 (the 1959, 1962 and 1972 yearclasses) and type 2 (the 1973 yearclass). It is concluded that, as a result of a simple comparison of the abundance of yearclasses with the distribution of spawning grounds where cod spawned intensively using the data available on the distribution of eggs at stage 1, no causal relationship between the two phenomena can be established.

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