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HAVFORSKNINGSINSTITUTTETS EGG- OG LARVEPROGRAM (HELP)

SPAWNING AREAS AND SPAWNING PERIOD OF THE NORTH-EAST ARCTIC HADDOCK *(MELANOGRAMMUS AEGLEFINUS* L.*)*.

by

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ABSTRACT

Spawning of North-East Artic haddock occurs on the Norwegian continental slope. The location of the spawning grounds is, however, diffuse. This is mainly due to difficulties in identifying haddock eggs. In this work this problem is solved by using the biochemical genetical approach of electrophoresis. The results from haddock egg and trawl surveys in April -May 1987 and 1988 are analysed in relation to previous knowledge of haddock egg distribution and mature fish. Gonad maturity is compared to the distribution of egg developmental stages in different regions. Both horizontal and vertical gradients in gonad maturity of haddock are revealed. Most of the Tromsøflaket area from Nordkapp to near the shelf edge bordering the Norwegian Sea (Norskehavet) are inhabited by immature haddock. An increase in abundance of mature fish takes place in the western part of the shelf. The main spawning areas of North-East Arctic haddock seems to be the southeastern part of the continental slope of Tromsøflaket at depths from 300 to 600 m and temperatures between 4 and 6^0 C. Other spawning areas are found in Vestfjorden and over the continental slope from Tromsøflaket south to Røsttunga. The spawning in Vestfjorden seems to

take place at depths shallower than 200 m, but within the same temperature limits. Spawning seems to start at the beginning of April, reaches its maximum at the end of the month and ends during the first half of May. Very little spawning is recorded on the shelf and the continental slope from Røsttunga to 64^0 N. Spawning in the area 62-64^0 N (Møre) is supposed to origin from a local stock. The onset of this spawning seems to take place a week or two earlier than what was observed further north. A distinct bimodal distribution of larvae sampled in July 1987 indicate a possible influx of haddock larvae to the Norwegian coast which might originate from a population different from the North-East Arctic haddock.

INTRODUCTION.

The Norwegian shelf constitute important spawning grounds for fish of considerable economical interest, such as North-East Artic cod, saithe, capelin and Norwegian spring spawning herring (Anon., 1979). The continental shelf is also described as a spawning area for North-East Artic haddock although the location of the spawning grounds are rather diffus (Anon., 1979, Bergstad, Jørgensen and Dragesund, 1987). Fish eggs and larvae of these species are transported northwards and eastwards by the residual currents (Sætre and Ljøen, 1971).

Sonina (1969) describes the distribution of the North-East Arctic haddock in the Barents Sea (Barentshavet). In warm years the haddock is distributed more easterly, in cold years more to the west. Information on changes in the spawning area due to the geographical distribution of the mature stock is apparently lacking in the literature.

It is difficult to assess the maturing population in the Barents Sea, since the maturation takes place during the west and southern spawning migration (Sonina, 1981).

Soviet and Norwegian scientists have different opinions concerning the spawning area of the haddock. Based on their investigations on the sampling of planktonic eggs, Baranenkova and Khoklina (1967) demonstrated spawning from Røst to the western continental slope of

Tromsøflaket, up to 74° N. Maximum egg concentrations were found during April. These results were later confirmed by Mukhina (1983) and especially by Mukhina and Dvinina (1986), using the same grid system as Baranenkova and Khoklina (1967).

Sætersdal (1952) and Wiborg (1956) suggested that the spawning area covered the continental slope from Røst to about 65° N, and even south of this area. They based their assumptions on the results from tagging experiments and maturity statistics (Sætersdal, 1954), and the planktonic egg distribution (Wiborg, 1950). Comparing Soviet and Norwegian research on the spawning area of haddock, Bergstad et al. (1987) conclude that the main spawning of haddock occurs south of Røst.

The main weakness in all the investigations based upon planktonic egg-sampling is the difficulty in separating haddock and cod eggs (Solemdal, 1987). This problem was solved by using the biochemical, genetical approach of electrophoresis by Mork et al. (1983).

MATERIALS AND METHODS

The materials in this report were sampled during the following cruises: R/V "Odin Finder" April 1-17 1987, R/V "Johan Ruud" March 31 - April 8 1987, R/V "G.O. Sars" April 21 - May 15 1987, R/V "G.O. Sars" April 27- May 12, May 1-23 1988 and R/V "Eldjarn" May 1-23 1988.

Plankton was sampled by vertical hauls with modified WP 2 nets (0.1, 0.5 or 2.0 m^2), 375 µm mesh size (Anon., 1967), from 200 to 0 m. The nets were equipped with a TSK flowmeter and a Scanmar depth recorder. Eggs ranging from approximately 1.25 to 1.70 mm in diameter were removed immediately upon sampling. This includes practically all cod and haddock eggs according to Solemdal and Sundby (1981) and Moksness and Selvik (1987). After measuring the egg diameter and the egg developmental stage according to Solemdal (unpubl.), a sample of eggs, usually between 20 and 50, were stored at -90° C. The electrophoresis was carried out on board. The eggs sampled with R/V "G. O. Sars" and R/V "Eldjarn" in 1988 were removed from the plankton, measured and frozen to -20° C. Within one week they were identified.

The maturity stage of haddock females was recorded according to a scale developed for cod at the Institute of Marine Research, Bergen (Table I). Haddock is a batch spawner, spawning up to 24 batches within 5 weeks (Hislop, Robb and Gauld, 1978). Kjesbu (pers. comm.) found that spawning of cod occurred from maturity stage 1 to stage 3 as well as in stage 4, which is defined as the spawning stage (Table I). He also found that 50 % spawning corresponds to maturity stage about 3.5. Since cod and haddock are two closely related species and the haddock spawning migration (Sonina, 1969) is partly similar to that of cod (Bergstad et al., 1987), this figure is also used for haddock. The term Mi, later referred to as the maturity index, is simply the mean value of the different maturity stages.

Trawling was performed with the standard "Norwegian bottom research trawl for sampling bottom fish and shrimp, Campelen 1800", usually for 30 minutes. Total weight of all specimens was recorded. Length, otoliths and maturity stage were recorded for samples of cod and haddock. All haddock specimens were investigated for size and maturity stage.

The acoustic data were processed and evaluated according to Blindheim, Eide, Knutsen and Vestnes (1982). A more detailed description of the acoustic and catch sampling and processing procedures is given by Dalen and Nakken (1983). The procedure used in the present work did not estimate the abundance of fish deeper than 580 m.

The spawning intensity curve at Tromsøflaket (Fig. 9), were based on vertical net hauls along the continental slope from 70^0 20' N to 71^0 20' N (Fig. 1 and 2) on four different dates : 5 April, 13-14 April, 28-29 April and 5 May. The spawning intensity curve at Hølla (Fig. 10) in Vestfjorden, covers the following dates : 7 April, 9 April, 21 April and 9 May.

RESULTS

Figure 1 shows the location of the trawl stations, the different subareas and areas for spawning intensity investigations. The

subareas are : Røsttunga (I), the continental slope from Røst to Tromsøflaket (II), the continental shelf from Røst to Langøy (III), the Vestfjorden area (IV), the western continental slope of Tromsøflaket (V) and Nygrunnen (VI). Area V is subdivided into 3 regions, A - C, while area D is identical to area I but is used in connection with fish data while area I is used for egg data. Names referred to in text are shown in Fig. 2.

In Fig. 3 the distribution and concentration of haddock eggs in the period 21 April - 14 May 1987 are shown as numbers per square metre surface. The numbers include all egg developmental stages. The distribution of haddock eggs sampled in 1988 is shown in Fig. 4 - 6.

Fig. 7 shows the percentage distribution of the different egg developmental stages from the different subareas I-VI, while the percentage distribution of egg developmental stages in the main areas A - C is presented in Fig. 8.

The concentration and percentage of cod and haddock eggs in the areas I - VI are shown in Table II. The highest concentration of haddock eggs was found at the continental slope of Tromsøflaket and in Vestfjorden. Cod eggs were most abundant in Vestfjorden and on the continental shelf outside the Lofoten area.

The percentage of immature males and females and the sex ratio are shown in Table III. The trawl stations are arranged from east (top of the table) to west (bottom of the table), as can be seen from Fig. 1.

Total number of haddock from the acoustic survey, number of mature haddock, number of haddock caught per trawl hour, and the percentage of mature females from areas A - D are shown in Table IV.

In Table V the distribution of the maturity stages, in percent, from the areas A - D in 1987 and A - C in 1988 is shown. There is a significant increase in the proportion of running haddock females, maturity stage 4, from area A to areas C and D in 1987. In 1988 the samples in areas A - C where taken nearly one month later and the maturity index show that peak spawning is over.

In Table VI the abundance of haddock in each maturity stage is arranged in an east - west direction for each subarea, which corresponds to a depth gradient from shallow to deep water. The abundance of running haddock females increased towards deeper water in areas B and C, while at depths larger than 550 m the numbers are reduced.

The spawning intensity curve at Tromsøflaket shown in Fig. 9 are based on egg stage 1 and pooled stage 2 - 6 eggs. The curve from Hølla in Fig. 10 is based on all egg stages. Maximum egg concentrations in both areas are observed at the end of April.

A temperature section from the western bank area and the continental slope of Tromsøflaket in area B is shown in Fig. 11. The length distribution and the proportion of mature/immature female haddock from trawl station 190 (see Fig. 1), are also included in the figure.

A similar temperature transect from area C is found in Fig. 12. This figure includes the length distribution and the proportion of mature/immature female haddock from trawl stations 184, 185, 191, 192, and 193 (see Fig. 1). Note the great increase in mature haddock from the bank area towards the deeper part of the continental slope.

The temperature section from area C', Fig. 13, includes the trawl stations 199, 200, and 201 (see Fig. 1), which were sampled one week later. The highest density of fish is below 350 m depth, and all females are mature (Fig. 13).

The temperature profile in subarea D, the length distribution and proportion of mature/immature female haddock from trawl stations 196, 197, and 198 are shown in Fig. 14. As in area C' all females are mature while the peak in haddock abundance is close to 400 m depth.

DISCUSSION

Spawning north of Røst

The spawning haddock, distribution and number

The proportion of immature female haddock decreased from 98% in the eastern part of the investigated area (trawl station 181, see Fig. 1) to 81% in the western part of the bank area in region A (trawl station 187) and 17% in region C (trawl station 191) (see Table III). According to Sonina (1981) the immature haddock are mainly found in southern Barents Sea and in the Bear island (Bjørnøya) - Spitsbergen area. During maturation the haddock migrate to the spawning areas in the Norwegian Sea, along the continental slope from Tromsøflaket (the Kopytov bank) to Røst.

Both temperature and year class strength influence the distribution in the Barents Sea (Shevelev, Tereshchenko and Yaragina, 1987), but changes in spawning areas similar to North-East Arctic cod (Godø, 1984) have not been described. Such changes could be the reason for the earlier mentioned discrepancies between Soviet and Norwegian scientists concerning the spawning area of North-East Arctic haddock. During a cold period in the Barents Sea mature haddock were tagged off Varanger (Sætersdal, 1952; 1954) and recaptured from the Malangsgrunnen bank to the Røstbanken area during the period of late March - April. Assuming that the spawning starts at a later maturity stage and that the haddock have a certain cruising speed, the authour suggested the main spawning area to be located at least as far south as 65^0 N. However, the author concludes: "There is, however, still some doubt as to the exact location of the spawning ground" (Sætersdal, 1954). Bergstad et al. (1987), believe that the main spawning occurs south of Røst, obviously based on Sæterdal's suggestions from the 1950's. The present knowledge of the batch-spawning of haddock (Hislop et al., 1978) and the relation between the maturity stages and actual stage of spawning in the closely related species of North-east Arctic cod (Kjesbu, unpublished), indicate that the recaptured haddock were already spawning.

The vertical distribution of spawning haddock along the continental slope showed a maximum at about 400 m depth close to the bottom and at temperatures of 4 - 6^0 C. This is within the depth range of 350 - 600 m on the continental slope as reported by Sonina (1981). Compared to the North-East Arctic cod, the temperature range for spawning is similar, but the cod prefer more shallow water and often spawn pelagically (Ellertsen et al., 1981). Contrasted to this observation is the spawning of haddock in Vestfjorden which seems to take place at a much shallower depth. This was confirmed April 30 1988 when 26 female haddock with running roe were caugth by longline at 90 m depth near Hølla in Vestfjorden (Hylen, pers. comm.)

The total number of mature haddock in 1987 was calculated to be 269 millions (Anon., 1988). In the area of Malangsgrunnen to Vestfjorden, 8.5 million mature haddock were reported in March 1987 (Godø et al., 1987). In the present study the population of mature haddock at the end of April and beginning of May 1987 along the continental slope from 70^0 10' N to 72^0 50' N was estimated to be 14 million specimens (Table IV). Summing these figures only amounts to one tenth of the spawning stock, according to Anon. (1988).

Parts of the gap between estimated number (Anon., 1988), acoustic abundance estimate (Godø et al., 1987) and present results might be influenced by :

1) Spawning south of Røst
2) Pelagic spawning in the Norwegian Sea (Wiborg, 1957)
3) Spawning deeper than 580 meters.
4) Overestimation of the older year classes in the VPA-analyses.
5) Bias in the age/maturation keys (Sunnanå, pers. comm.).

Norwegian trawlers reported concentrations of spawning haddock down to 600 - 700 m at about 3^0 C (Fig. 12), along the continental slope of Tromsøflaket. Since the acoustic equipement only worked down to 580 meters the estimate of the spawning population given above is an underestimate.

The spawning period of the North-East Arctic haddock.

Based on the concentrations of planktonic haddock eggs in the period from the beginning of April to the beginning of May 1987 it appears that the maximum of stage 1 eggs occurs at the end of April, both on the continental slope of Tromsøflaket and in Vestfjorden (Fig. 9 and Fig. 10). Table VII presenting data from the Vestfjorden area in 1988, shows that the majority of haddock eggs must have been spawned during the last week of April. This is supported by the catch of spawning female haddock (N=130) by longline and Danish seine, near Hølla in Vestfjorden between April 25 -30 1988 (Hylen, pers. comm.). These haddock showed a gonad maturity index of 4.0, indicating that the population of female haddock had just passed maximum spawning. Data from Baranenkova and Khoklina (1967) indicate maximum egg concentration in the same period, though minor yearly fluctuations occur.

The index of gonad maturity of female haddock caught at the end of April along the continental slope of Tromsøflaket and at Røsttunga showed the same figure of 3.8 (Table V). According to Kjesbu (unpubl.) this value corresponds to half-spent cod females. The marked increase in the maturity index from 3.8 to 4.3 in the period from April 29 to May 6 in region C (Table V), together with a drastic reduction in number of haddock (Table IV), clearly demonstrate that the maximum spawning is over and that spent fish leave the spawning area.

This is confirmed by the investigation in 1988 by a mean gonad maturity index of 4.6 (N=94) in the last week of May (Table V). A low abundance of haddock eggs found in subareas A -C during an investigation in mid May 1988 (Fossum pers. comm.) verifies this. The spawning migrations of these related species are very similar. The North-East Arctic cod migrate from the Barents Sea to the Norwegian coast seeking a temperature gradient for spawning (Sund, 1927), while haddock migrate to the Norwegian coastal area and the slope of the Tromsøflaket area where they consentrate on a temperature gradient from 4 -6^{0} C. We therefore conclude, on the basis of the maturation index and the development of pelagic eggs, that peak spawning of

North-East Arctic haddock at Røsttunga, the Vestfjorden area and the continental slope of Tromsøflaket occurs at the end of April.

Combining the information obtained from planktonic eggs, maturation stages and changes in abundance of haddock at the spawning sites, we conclude that the spawning of North-East Arctic haddock in the region 65^0 N - Vestfjorden - Røsttunga - continental slope of Tromsøflaket starts at the beginning of April, reach its maximum at the end of April and ends during the first half of May. This is in contrast to the North-East Arctic cod, which starts spawning at the beginning of March, with the maximum at the beginning of April and end at the beginning of May (Solemdal, 1982; Pedersen, 1984).

Distribution of eggs

The distribution of haddock eggs found in 1987 is shown in Fig. 3 and fits well with the distribution maps given by Shmit (1936, 1937), Baranenkova and Khoklina (1967), Mukhina (1983), and especially with those of Mukhina and Dvinina (1986). Along the continental slope from Røst to about 74^0 N, the Soviet scientists have demonstrated spawning of haddock every year since the investigations started in 1959. The egg distributions given by these authors are not given in strictly quantitative terms, the actual sampling period is unknown, and there is also some uncertainty about the identification of haddock eggs. This is also the case for the egg distribution given by Wiborg (1950, 1952, 1956, 1960). Early egg stages of cod and haddock cannot be separated by visual means. However, the distribution map given by Mukhina and Dvinina (1986) is based on the last pigmented egg stage which can be identified. They found that egg concentrations along the continental slope from Røst to about 70^0 N was low, with increasing concentrations further north. The concentration of haddock eggs over the shelf from Røst northwards was also higher than along the slope.

The distribution of egg developmental stages in Vestfjorden (Fig. 7) is dominated by eggs in stage 5, indicating retention of eggs during the developement. This is also observed for cod eggs in the same area (Ellertsen et al., 1987).

The distribution (Fig. 3) and age composition of the haddock eggs on the shelf off Lofoten and in Vestfjorden (Fig. 7), also indicate a drift from Vestfjorden similar to the drift of cod eggs and larvae (Ellertsen et al., 1981). Haddock egg concentration in Vestfjorden is at the same level as along the continental slope of Tromsøflaket (Table II), but data from earlier years are lacking. The distribution pattern of haddock eggs in Vestfjorden (Fig. 3) is also similar to that of cod eggs (Ellertsen et al., 1981). Data from the shelf area Røst to Langøy from the beginning of May during the years 1981 - 1985 show a percentage of haddock eggs varying from 2 to 21, with no increase in the abundance of eggs towards the slope (Solemdal, 1987). This is supported by the decrease in egg abundance towards the slope in the present investigation (Table II), also indicating a drift from the Vestfjord. The significant haddock spawning in Vestfjorden, therefore seems to be a regular phenomenon. Findings of haddock eggs in stage 3 and older in 1988 support this (Table VII).

Concerning the western limit of haddock-spawning, Wiborg (1957) reports both planktonic haddock and running haddock females from the weather station M (66^0 N, 2^0 E) in the Norwegian Sea. North of Røst Baranenkova and Khoklina (1967) report haddock eggs as far west as 5^0 E at a latitude of about 68^0 N.

The maturation process, spawning and distribution of eggs at the central spawning area.

The main haddock spawning area north of Røst is shown in Fig. 3. The distance from the center in area A to the center of area C is about 100 n.m. (see Fig. 1). There is a clear tendency towards more advanced maturation stages of the haddock from region A to region C (Table V), probably indicating a southward migration along the continental slope. The number of mature haddock increases from about 0.7 million in region A, through 5.4 million in region B and 7.0 million in region C . The proportion of mature haddock increases from 27% in region A to 69 % in region B and 96 % in region C (Table IV). The gonad maturation index shows that the population of female haddock is in maximum spawning in region C (Table V).

The number of haddock found in the western bank area is low and less mature compared to the haddock from the deeper part of the continental slope (Fig. 11 - Fig. 14). This indicates that the migration from the east is completed or is of minor importance.

The distribution of planktonic eggs in the area reflects the distribution of spawning haddock. Above the easternmost trawl station in region B, only 4 stage 1 eggs per m^2 was found, while 24 stage 1 eggs per m^2 were found above the deep westernmost trawl station. Above the easternmost trawl station in region C no planktonic eggs were found, while 24 stage 1 eggs were found above the trawl stations at 300 - 500 m depth.

The eggs drift both to the north and to the east. Stage 1 cod eggs is from 0-2 days old at the prevailing temperatures (Solemdal unpubl.). The mean ascending velocity of cod eggs is about 1 mm/s (Solemdal and Sundby, 1981; Sundby, 1983). Using the same figure for haddock eggs, and a spawning depth of 350 m, they will use about 4 days to reach the surface current. To transport the stage 1 eggs from area C to reflect the peak of stage 3 eggs (5-6 days old) in region A (Fig. 8) indicates a horisontal transport velocity of 35 cm/s. This seems to be reasonable compared to the measured current speed of around 50 cm/s along the shelf edge (Sundby, pers. comm.). The drift of haddock eggs eastward from region C is in accordance with Baranenkova and Khoklina (1967).

Haddock spawning from 62^0 N to Røst

Figs. 4 and 5 show the distribution of haddock eggs younger than 4 days recorded during two subsequent cruises in 1988. South of Røst eggs younger than 4 days were recorded between 62 and 64^0 N (Fig. 4) and between 65 and 66^0 10' N (Fig. 5). In the same areas haddock eggs were found during the first half of April in 1987 (Bjørke, Bakkeplass and Hansen, 1988a and Table VIII). Also during investigations in April in the period 1976-1982 were identifiable haddock eggs in late stages of development recorded here (Bjørke, 1984). The distribution of haddock eggs indicate that the spawning area between 62 and 64^0 N (off

Møre) is isolated from that between 65^0 and 66^0 10' N and west of 10^0 E, since no eggs were recorded between these areas. Bergstad et al. (1987) suggests that it is possible that local stocks of haddock can be found along the coast. It is thus conceivable that recordings of eggs younger than 4 days between 62 and 64^0 N (Fig. 4) originate from a local stock of haddock. Some of the eggs sampled in this area April 1-3, 1987 were 10-18 days old (Table VIII). No haddock eggs were found during a coverage in March 18-20, 1987 (Bjørke et al., 1988a). Eggs younger than 2 days were recorded May 5 1988 (Table VIII). This shows that spawning has been recorded off Møre from the last third of March to the first week of May. It is, however, not possible to make any conclusion about the spawning period of haddock from the present investigation, although it indicates that spawning may start a week or two earlier than spawning further north. All the eggs younger than 2 days recorded in this area (Fig. 4), were sampled over depths shallower than 200 m. Most probably the eggs have been spawned over these depths, allthough it can not be overlooked that the eggs could have been spawned over a small 450 m deep basin in the area. In the North Sea most of the haddock eggs are spawned over depths shallower than 200 m (Anon., 1981).

The eggs found between 64 and 65^0 N near the coast in 1988 (Fig. 6), were older than 10 days when sampled April 30. A few eggs were also recorded in this area April 5, 1987 (Bjørke et al., 1988a and Table VIII). An Argos buoy drouged at 60 m and released April 4, 1988 (Fig. 6), shows a rather strong north-east going current in this area. The eggs recorded between 64 and 65^{0}N near the coast in 1987 were younger than 4 days. This indicate that haddock eggs in this area might originate from a local stock further south.

Haddock eggs were also found between 65^0 and 67^0 N (Fig. 6) over the continental slope. One Argos buoy drogued at 60 m and released at 63^0 45' N and 6^0 21' E March 29, 1988 indicate a drift towards the continetal slope from this area (Fig. 6). This buoy, however, passed 65^0 N May 3, i.e. it used at least 36 days to drift from the released area to the area were the eggs were recorded. Thus the possibility of a drift of eggs from the spawning area between 62 and 64^0 N to the continental slope between 65 and 67^0 N before hatching are rather

small. Lack of eggs in the area between these two regions both in 1987 (Bjørke et al., 1988a) and 1988 indicate that the eggs represents two different spawning areas. The eggs between 65 and 67° N were sampled May 4-7 and May 17, 1988. Table VIII shows that some of these eggs were near hatching i.e. 18-20 days old, while others were less than 4 days old when sampled May 4-7. The oldest eggs sampled in this area April 4-7, 1987 were 4-5 days old and the youngest less than two days (Bjørke et al., 1988a and Table VIII). Thus spawning of haddock in this area have been recorded from the beginning of April to the beginning of May. It is, however, not possible to make any conclusion about the spawning period of haddock in this area from the present data, although the start of the spawning seems to be reasonable documented. The start of the spawning in this area seems thus to coincide with that found for the haddock further north on the continental slope.

The eggs younger than 4 days recorded between 65 and 67° N (Fig. 5) were all sampled over depths between 370 and 762 m. The residual current in this region runs parallel with the continental slope (Sætre and Ljøen, 1971), and a bathymetric map over the area and the drift of the Argos buoys (Fig. 6) show that none of these eggs could have drifted from grounds shallower than 300 m. This indicate that the spawning of haddock in this area takes place over depths similar to those found on the continental slope further north.

Rather few haddock eggs were recorded between 64 and 67° N in 1988 over the continental slope (Fig. 6). Assuming that the spawning intensity in this area is similar to that of the haddock further north, the number of eggs should be much higher during the sampling at the beginning of May 1988 if this was a spawning area of any importance (conf. Fig. 3). R/V "G.O. Sars" made 5 bottom trawl hauls on the shelf between 64 and 66° N in the period April 30 - May 5 1988 (Fig. 6), and found haddock at one station at a depth of 468 m. Of a total of 19 haddock pr. trawlhour 9 were females with a gonad maturity index of 2.3, indicating an early stage of spawning. This low abundance of spawning haddock is in great contrast to figures given for the spawning area on the slope of Tromsøflaket in 1987 (Table VI). Bearing in mind the low number of eggs recorded in this area at the

beginning of April 1987 (Bjørke et al., 1988a and Table VIII) there are reasons to believe that only a small fraction of the North-East Arctic haddock spawn between 64°N and Røst both over the slope and over the continental shelf.

The presented view of the spawning and egg and larval distribution of the North-East Artic haddock received a new dimension from a larval survey in July 1987 from 62 to 74° N (Bjørke et al., 1988b). Haddock larvae larger than 50 mm were mainly found south of Røst, and larvae smaller than 20 mm mainly far north of this area. A westerly consentration between 64 and 65° N of the former arise question about the origin of these larvae. If they were hatched between 62 and 64° N in April the drift of the Argos buoy (Fig. 6) indicate that these larvae would have been found much further north when sampled at the end of July (Sætre, pers. comm.). During the same cruise in July, whiting larvae were found to have the same westerly distribution (Bjørke et al., 1988b). Information on the location of spawning grounds of whiting is limited, but spawning has been recorded in the English Channel, in the sentral part of the North Sea, in the area west and east of Scotland and near the Faroe Islands. The spawning season is long; beginning in January in the south and August/September in the north (Anon 1981). Along the Norwegian coast spawning has been recorded north to 64° N, from March to May (Dannevig, 1960). The similar westerly distribution of these two species and the fact that both species spawn in the North Sea, near the Hebridies and around the Faroe Islands indicate that these haddock larvae might originate from other stocks which spawn in the northern North Sea and west of the Orkneys from March to mid-May and around the Faroe Islands from late February to mid May (Anon., 1981). Similar length distributions of haddock larvae have also been recorded in earlier years.

Conclusions

- Most of the Tromsøflaket area from Nordkapp to near the shelf edge bordering the Norwegian Sea are inhabited by immature haddock in late April and early May 1987.

- An increase in abundance of mature fish takes place in the western

part of the shelf. Gonad maturity increases with increasing depth at the continental slope of Tromsøflaket, and from north to south along the shelf.

- The main spawning areas of North-East Arctic haddock seems to be the southeastern part of the continental slope of Tromsøflaket at depths from 300 to 600 m and temperatures between 4 and 6^0 C.

- Other spawning areas are found in Vestfjorden and over the continental slope from Trømsøflaket south to Røsttunga. The spawning in Vestfjorden seems to take place at depths shallower than 200 m but within the same temperature limits.

- Spawning seems to start at the beginning of April, reaches its maximum at the end of the month and ends during the first half of May.

- Very little spawning is recorded on the shelf and the continental slope from Røsttunga to 64^0 N.

- Spawning in the area 62-64^0 N (Møre) is supposed to originate from a local stock. The onset of this spawning seems to take place a week or two earlier than what was observed further north.

- A distinct bimodal distribution of larvae sampled in July 1987 indicate a possible influx of haddock larvae to the Norwegian coast which might belong to a population different from the North-East Arctic haddock.

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TABLE I

Maturity scale of gonads used for cod and haddock at the Institute of Marine Research, Bergen.

Stage 0 : Immature, small reddish transparent gonad.
Stage 1 : Maturing, only small ova, no hydrated eggs. All size groups.
Stage 2 : Maturing, some hydrated eggs.
Stage 3 : Many or most hydrated eggs.
Stage 4 : Spawning, all eggs hydrated.
Stage 5 : Spent. Faint blue appearance. Large blood vessels.
Stage 6 : Spent, maturing.
Stage 7 : Uncertain.

TABLE II

Percentage and concentration of haddock and cod eggs from six areas continental shelf and slope in north Norway 21 April - 15 May 1987 (see Fig. 1).

	Cod		Haddock	
	%	N/m^2	%	N/m^2
I Røsttunga	20.0	0.9	80.0	3.4
II Continental slope Røst - Tromsøflaket	83.9	13.3	16.1	2.5
III Continental shelf Røst - Langøy	70.8	15.4	29.2	6.4
IV Lofoten / Vestfjord area	79.8	109.9	20.2	27.8
V Continental slope of Tromsøflaket	10.6	3.2	89.4	27.3
VI Nygrunnen	64.5	1.1	35.5	0.6

TABLE III

The percentage of immature haddock in bottom trawl catches at Tromsøflaket (T and A-C) and Røsttunga (D) 21 April - 15 May 1987. The stations are on a gradient from east to west. M : Males. F : Females. See Fig. 1 for the area code. - : Not possible to calculate. N : Number of fish caugth. C' : Area C sampled one week later.

Area	Station	Depth(m)	Position	Sexratio	% M	% F	N
T	181	340	71°30'N,27°10'Ø	1.25	96.0	98.3	680
	182	270	71°41'N,25°05'Ø	1.07	96.7	99.1	471
	180	350	71°10'N,23°43'Ø	.82	86.5	96.9	768
	183	140	70°55'N,21°06'Ø	.85	94.7	97.4	289
	184	320	72°00'N,18°46'Ø	.84	65.9	89.8	90
	185	240	71°16'N,17°54'Ø	.92	63.6	75.0	23
A	187	430	72°32'N,15°36'Ø	1.15	64.4	81.4	404
	188	500	72°42'N,15°05'Ø	.88	57.1	87.5	15
C	191	250	71°05'N,17°30'Ø	.42	20.0	16.7	17
	192	302	71°01'N,17°12'Ø	2.34	3.6	5.9	397
	193	560-500	70°51'N,17°07'Ø	3.37	1.1	3.8	463
B	186	350	71°47'N,17°00'Ø	1.26	35.8	57.1	190
	190	500	71°57'N,15°51'Ø	4.85	7.1	23.1	152
	198	220	67°47'N,10°06'Ø	-	-	0.0	1
D	197	403	67°39'N,09°42'Ø	1.45	0.0	0.0	81
	196	600	67°36'N,09°30'Ø	4.00	0.0	0.0	15
	201	300	71°01'N,17°10'Ø	2.50	0.0	0.0	7
C'	200	400	71°00'N,17°06'Ø	.17	0.0	0.0	27
	199	500-550	71°00'N,17°03'Ø	2.33	0.0	0.0	20

TABLE IV

Stock estimates and percentage mature haddock in four regions on the shelf Tromsøflaket (A-C) and Røsttunga (D) 21 April - 15 May 1987. The edge at Tromsøflaket and Røsttunga. I : No. of fish based on acoustic estimates II : No. of fish per trawl hour and catch. * : Pelagic trawl stations used only for acoustic estimates. N : Number of fish caught. - : Not possible to calculate. See Fig. 1 for area code. C' : Area C sampled one week later. Areas are presented on a gradient from north to south.

Area	Station no.	Total stock No. of fish I (million)	II	Spawning stock (million)	% maturity of stock Total	Females	N
A	188,187	2.5	450.3	0.7	27.6	23.2	4
B	186,189*,190	7.9	316.7	5.4	68.9	49.8	3
C	191,192,193	7.3	584.0	7.0	96.0	94.4	8
C'	199,200,201	-	36.0	-	100.0	100.0	1
D	195*,196,197,198	0.6	32.2	0.6	100.0	100.0	

TABLE V

Maturity of female haddock in areas A (April 26), B (April 26-27), C (April 28-29) and D (May 2) at Tromsøflaket and Røsttunga in 1987 and 1988 (May 20-22). C' : Area C sampled (May 5-6). Mi : Maturity index. See Fig. 1 for area code.

			Degree of maturity (%)					
	Area	Station	1	2	3	4	5	Mi
1987	A	188,187	100.0	0.0	0.0	0.0	0.0	1.0
	B	186,190	68.3	1.6	3.2	14.2	12.7	2.0
	C	191,192,193	1.8	12.2	21.8	37.4	26.8	3.8
	C'	199,200,201	0.0	0.0	3.2	64.5	32.3	4.3
	D	196,197,198	0.0	2.7	21.6	70.3	5.4	3.8
1988	A	266	0.0	3.3	0.0	26.7	70.0	4.6
	B	265	0.0	0.0	0.0	33.3	66.7	4.7
	C	262,263,264	0.0	0.0	5.2	37.9	56.9	4.5

TABLE VI

Number of haddock per trawlhour and maturity stage across the continental slope of Tromsøflaket in 1987. Area A - C : April 24 -April 29th. Area D : May 2nd. Area C' : May 5th - May 6th. St.no Station number for bottom trawl. C' : Area C sampled one week later. See Fig. 1 for area code.

Area	St.no.	Immature	1	2	3	4	5	6	7	Depth (m
A	187	584.0	224.0	0.0	0.0	0.0	0.0	0.0	0.0	430
	188	68.0	24.7	0.0	0.0	0.0	0.0	0.0	0.0	500
B	186	172.0	208.0	0.0	0.0	0.0	0.0	0.0	0.0	350
	190	25.0	11.7	80.0	53.3	66.7	16.7	0.0	0.0	500
	184	142.0	4.0	24.0	8.0	0.0	0.0	0.0	2.0	320
	185	32.0	0.0	10.0	0.0	2.0	2.0	0.0	0.0	240
	191	5.6	0.0	15.0	7.5	0.0	3.8	0.0	0.0	250
C	192	34.0	42.0	164.0	190.0	254.0	100.0	0.0	4.0	302
	193	16.0	38.0	244.0	276.0	280.0	68.0	0.0	8.0	500
	198	0.0	0.0	0.0	0.0	1.2	0.0	0.0	0.0	220
D	197	0.0	0.0	2.0	17.0	60.0	2.0	0.0	0.0	403
	196	0.0	0.0	0.0	7.7	6.8	0.0	0.0	0.0	600
	201	0.0	0.0	0.0	2.0	12.0	0.0	0.0	0.0	300
C'	200	0.0	0.0	0.0	0.0	34.0	20.0	0.0	0.0	400
	199	0.0	0.0	2.0	6.0	28.0	4.0	0.0	0.0	500-550

TABLE VII

Developmental stages and number of haddock eggs from Vestfjorden, May 10-12, 1988. Stage and age after Solemdal (unpubl.).

Stage	1	2	3	4	5	6
Age (days)	0-2	3-4	5-6	6-10	10-18	18-20
Percent	0.0	0.0	30.8	4.1	48.2	16.9
Total Nos/m^2	0	0	69	9	108	38
Mean Nos/m^2	0	0	4.3	0.6	6.8	2.4

TABLE VIII

Stages of development of haddock eggs sampled between 62° N and Røst in 1987 and 1988. The figures show the total number of haddock eggs sampled. Unit: number per m^2 surface. Stage and age, in brackets, after Solemdal (unpubl.).

YEAR	AREA	DATE	STAGES (DAYS)						
			TOT	1 (0-2)	2 (3-4)	3 (5-6)	4 (6-10)	5 (10-18	6 (18-20)
1987	62-64°N	APRIL 1-3	92	34	34	20	0	4	0
	64-65°N	APRIL 5	2	0	2	0	0	0	0
	65-67°N	APRIL 4-7	6	2	0	4	0	0	0
1988	62-64°N	MAY 5-6	74	20	30	14	8	2	0
	64-65°N	APRIL 30	4	0	0	0	0	4	0
	65-67°N	MAY 4-7	38	0	13	5	2	12	6
		17	4	0	0	0	0	2	2

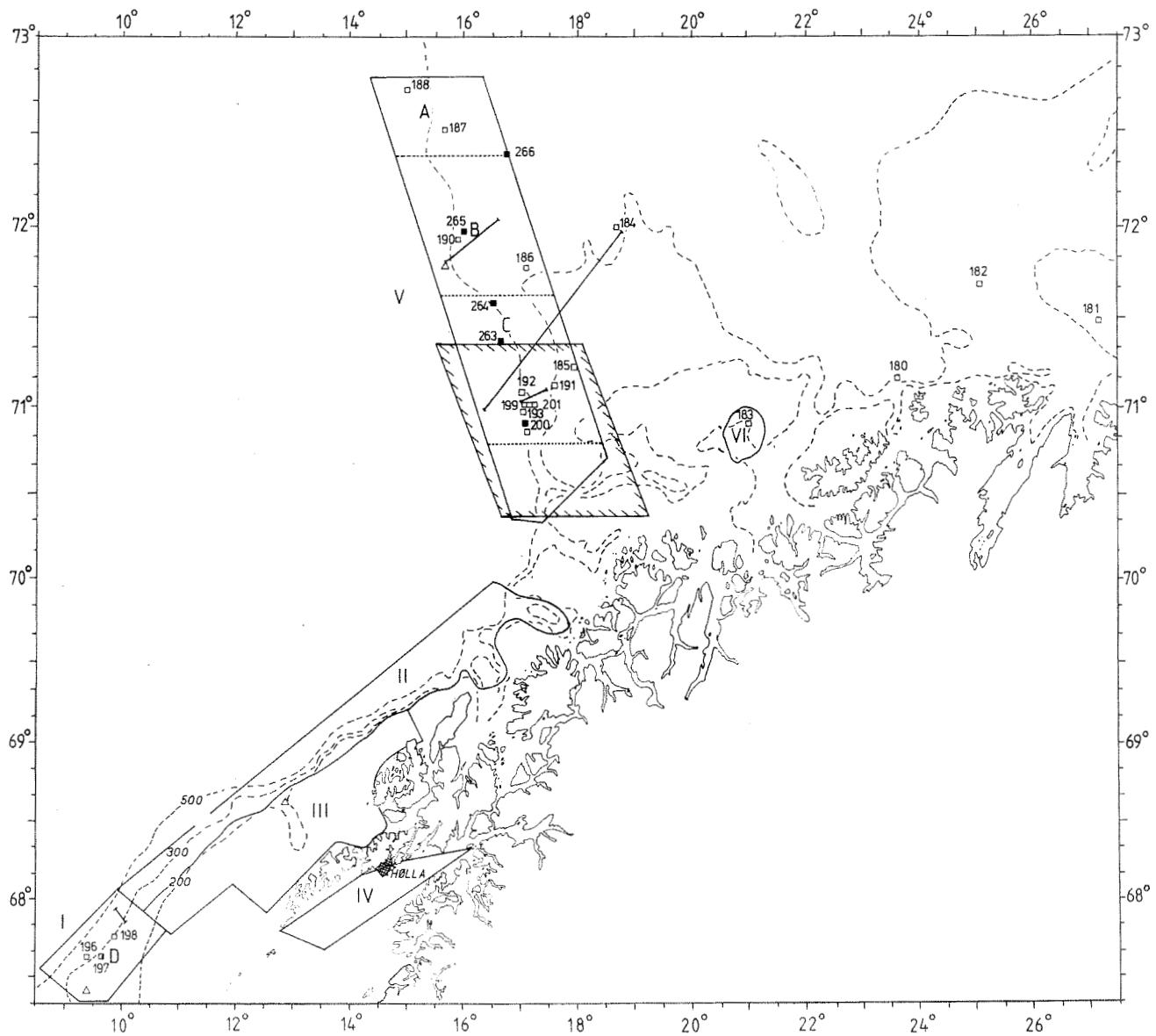

Fig. 1. Area of investigation north of Røst in 1987 and 1988. Hatched and cross hatched area of spawning intensity investigation at Tromsøflaket and Hølla respectively. □ : Bottomtrawl stations. △ : Pelagic trawlstations. Areas I - VI was investigated for egg developmental stages. Subareas A, B, C and D was a.o. investigated for acoustic estimates of stock size and egg developmental stages. ⟷ : Hydrographical sections presented in Figs 11- 14.

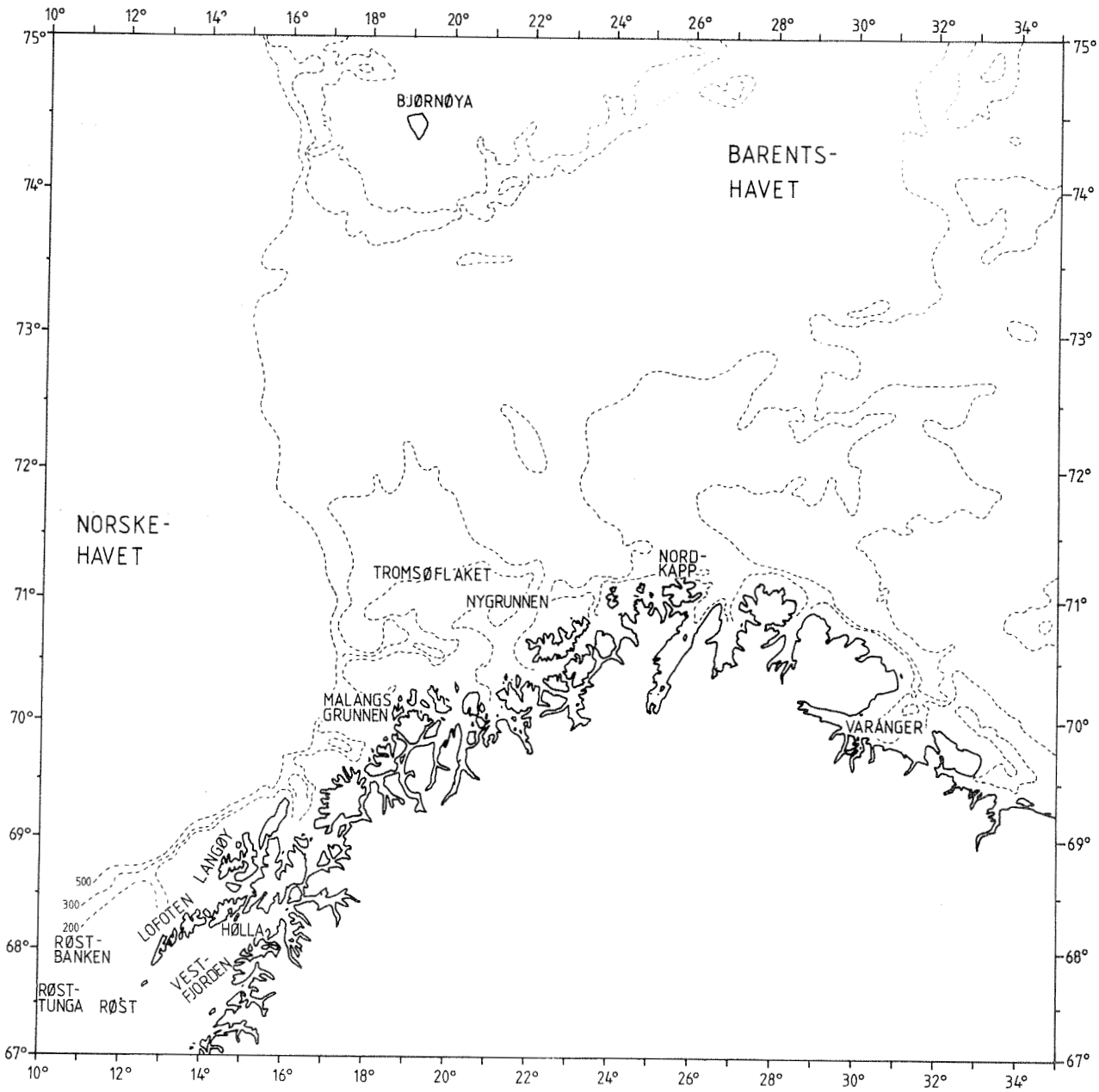

Fig. 2. Names used in the text.

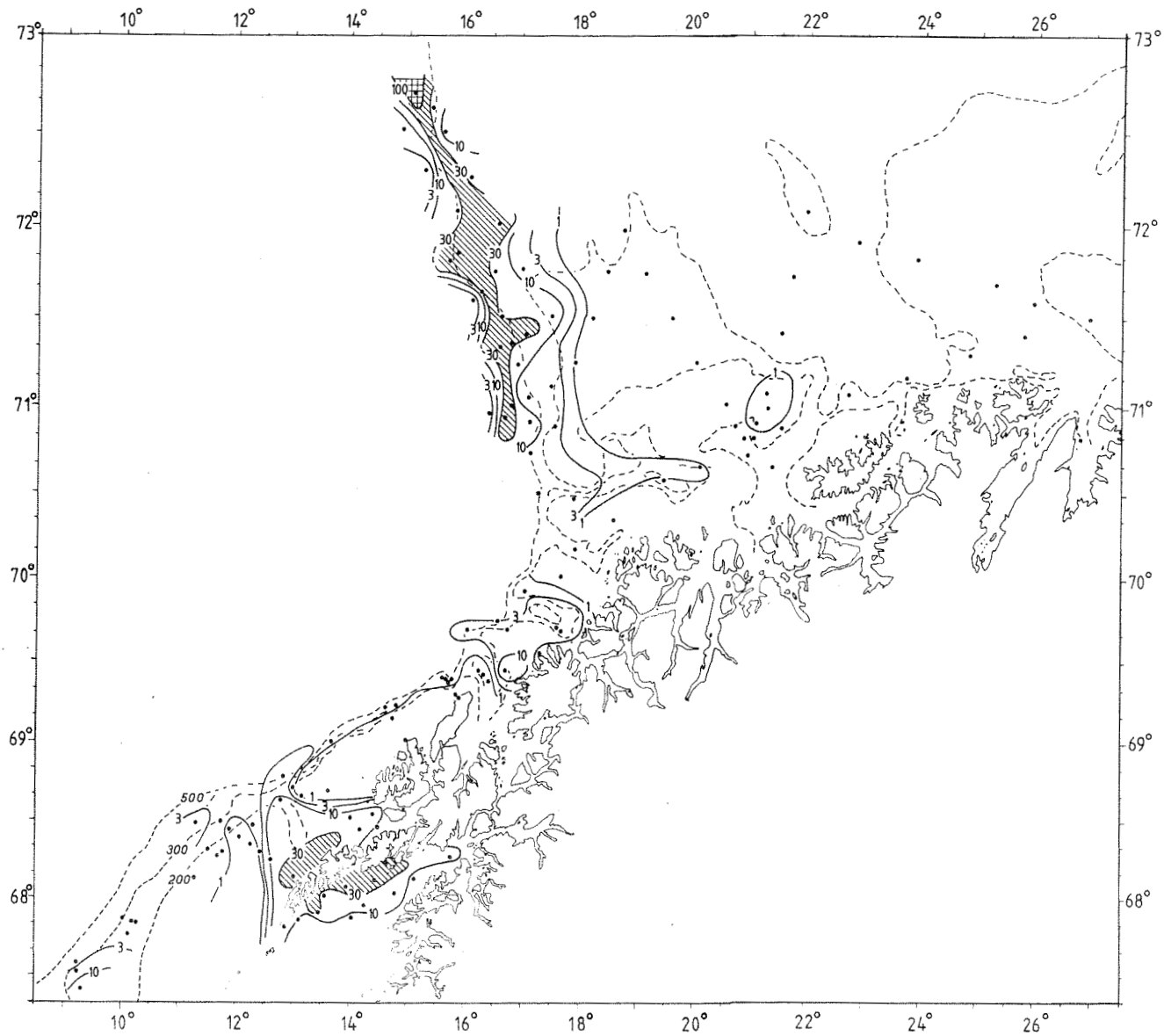

Fig. 3. Distribution of haddock eggs in nubers per m^2 surface. All developmental stages included. April 22 - May 14, 1987.

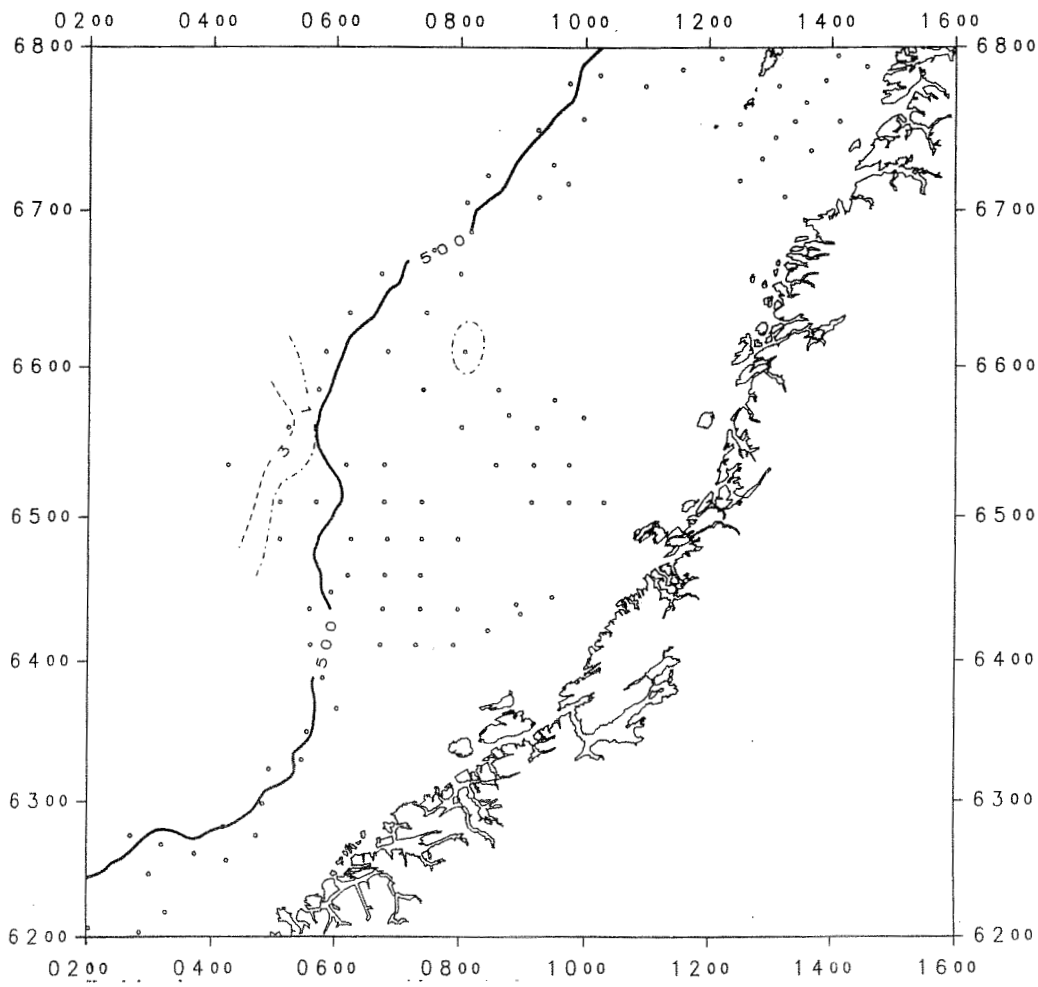

Fig. 4. Distribution of haddock eggs younger than 4 days. April 27 - May 12, 1988. Numbers per m^2 surface.

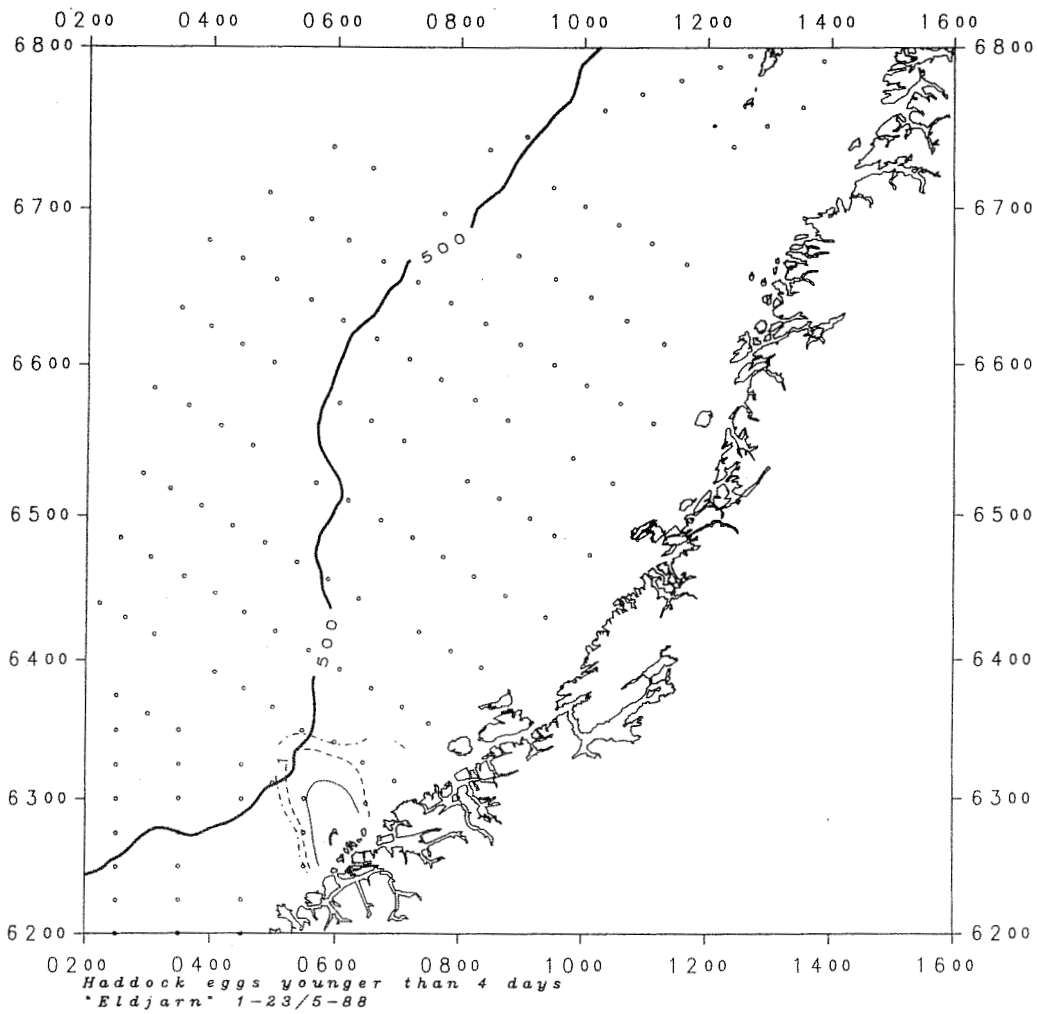

Fig. 5. Distribution of haddock eggs younger than 4 days. May 1 - May 23. 1988. Numbers per m^2 surface.

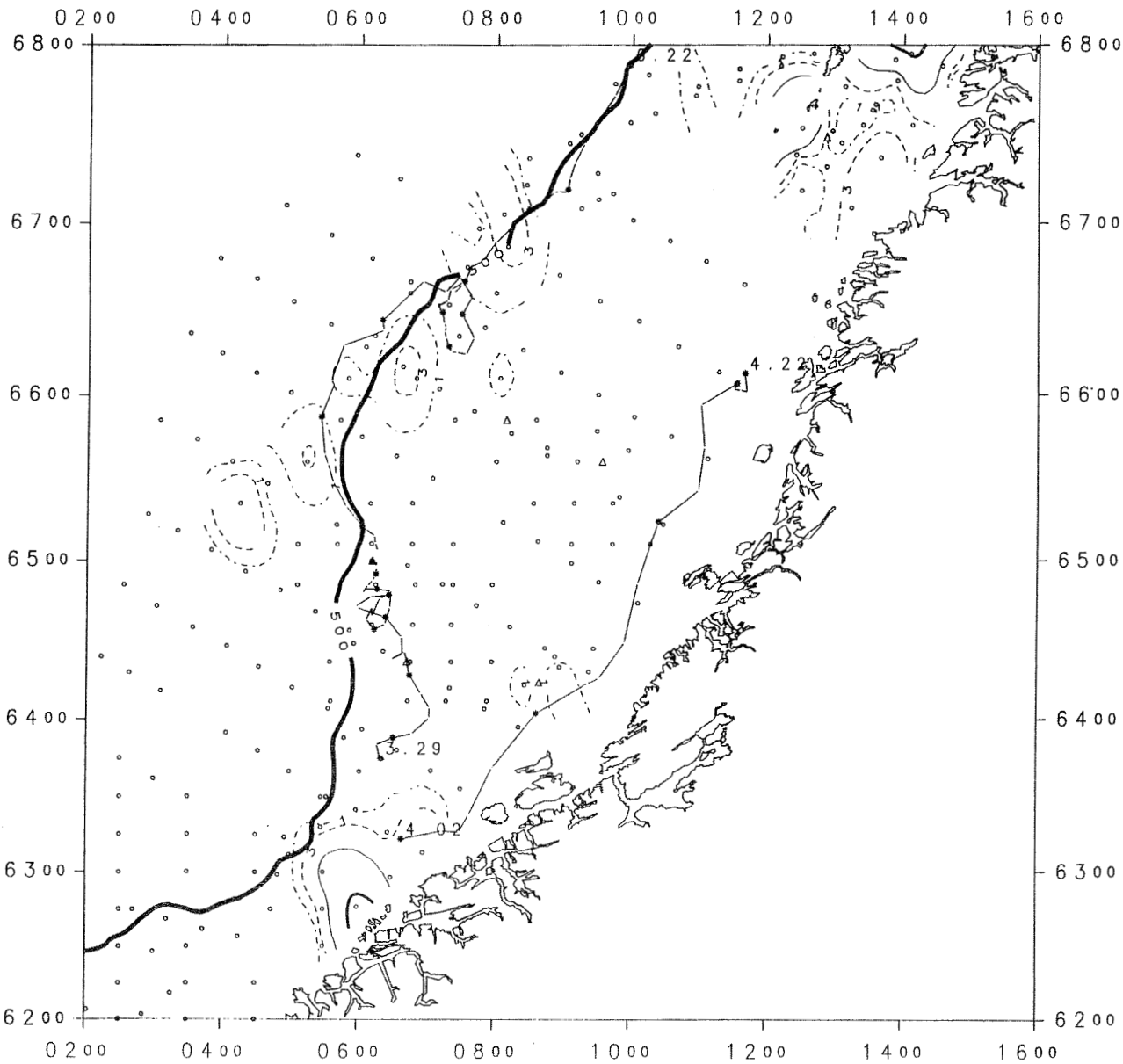

Fig. 6. Distribution of haddock eggs in numbers per m^2 surface. April 27- May 23, 1988. Data from coverages shown on Fig. 4 and Fig. 5. All developmental stages included. △ :Bottom trawl stations. ▲ :Bottom trawl stations with catch of haddock. Lines with crosses show drift of Argos buoys. Crosses every fifth day. Dates of deployment and recovery indicated.

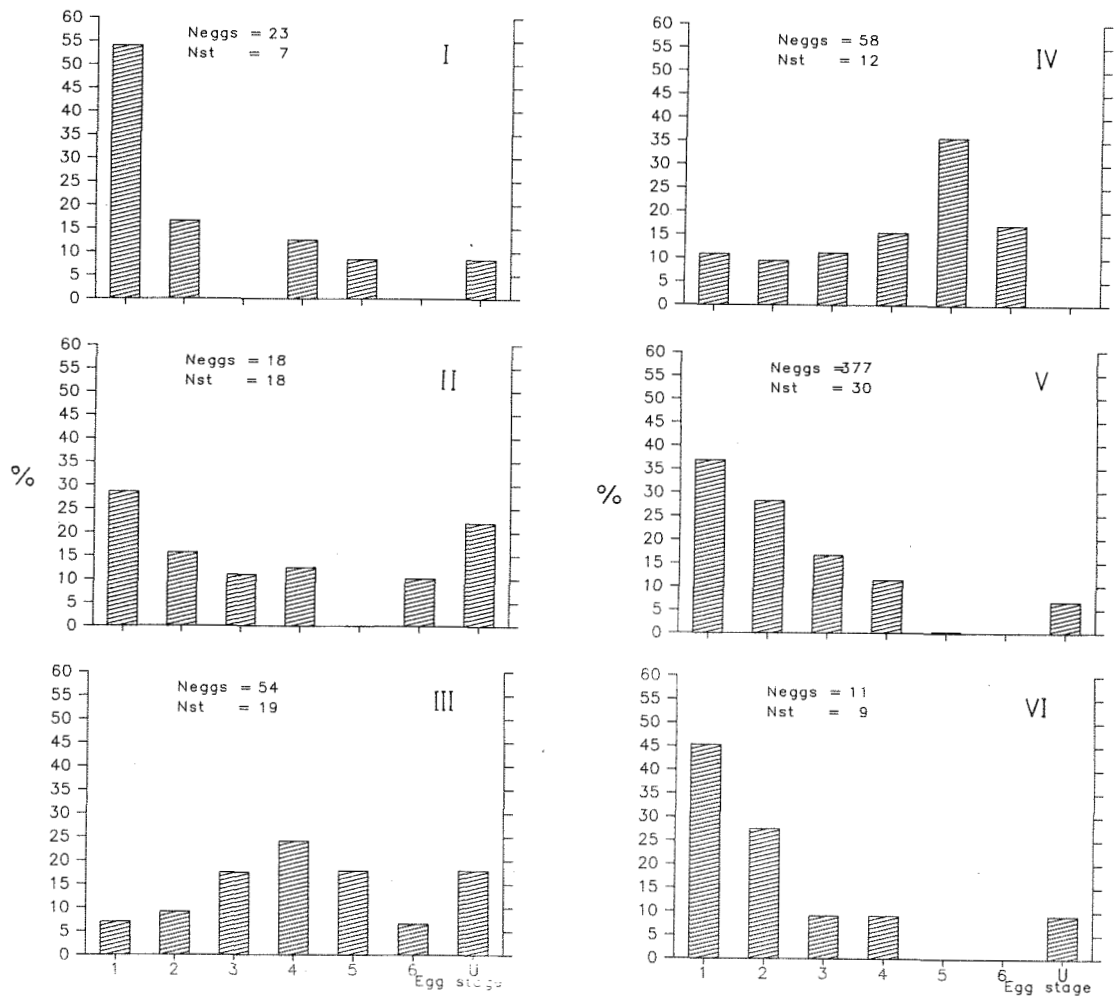

Fig. 7. Distribution of egg developmental stages in areas I-VI. I) Røstunga, II) the continental slope from Røst to Tromsøflaket, III) the continental shelf from Røst to Langøy, IV) the Vestfjord area, V) the western continental shelf of Tromsøflaket and VI) Nygrunnen. U = Unidentified. Neggs= Number of eggs. Nst= Number of stations.

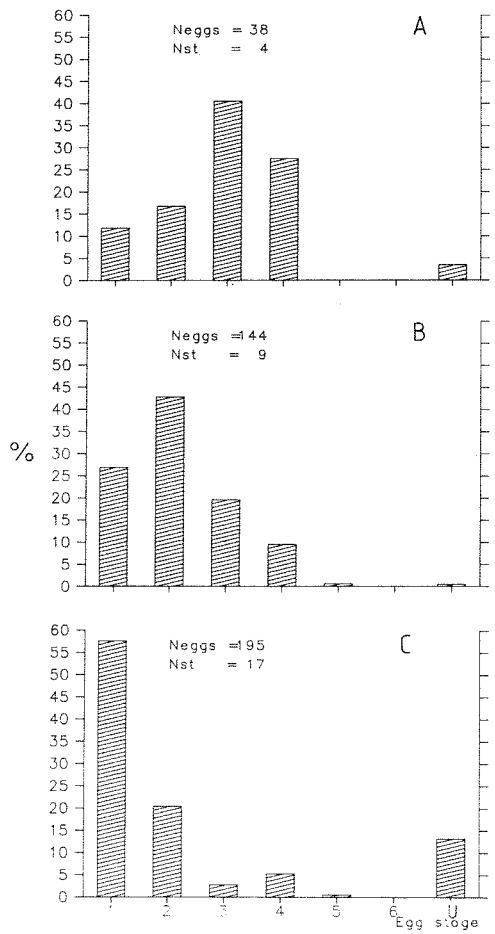

Fig. 8. Distribution of egg developmental stages in subareas A-C. U = Unidentified. Neggs= Number of eggs. Nst= Number of stations. (See Fig. 1 for investigated area).

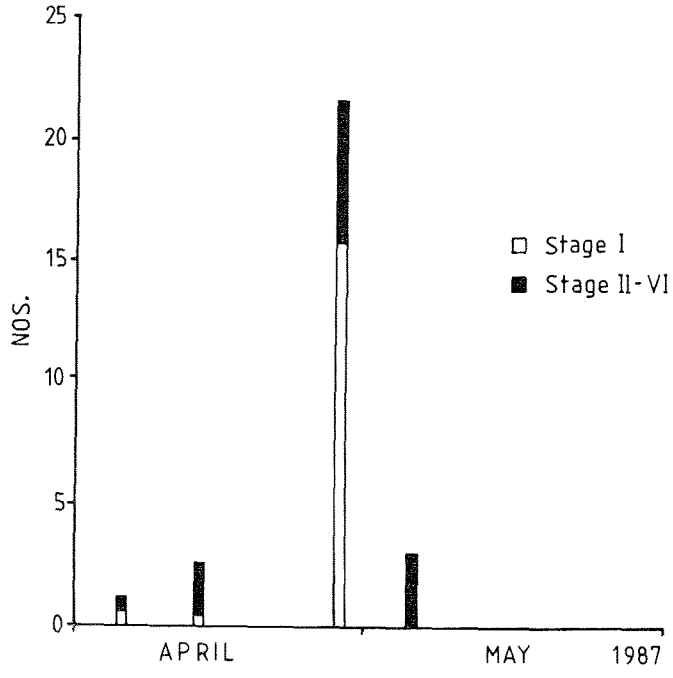

Fig. 9. Number of haddock eggs per m^2 surface at Tromsøflaket. Developmental stages I and II-VI are shown separately. (See Fig. 1 for investigated area).

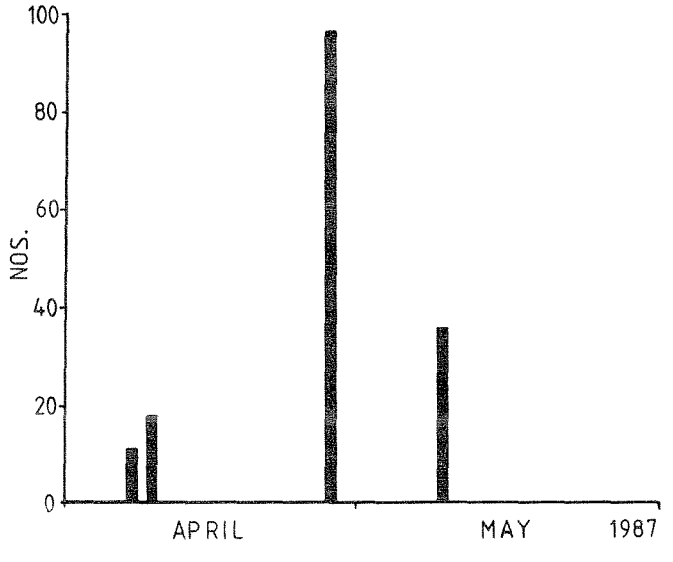

Fig. 10. Number of haddock eggs per m^2 surface at Hølla. Numbers represent stages I-VI. (See Fig. 1 for investigated area).

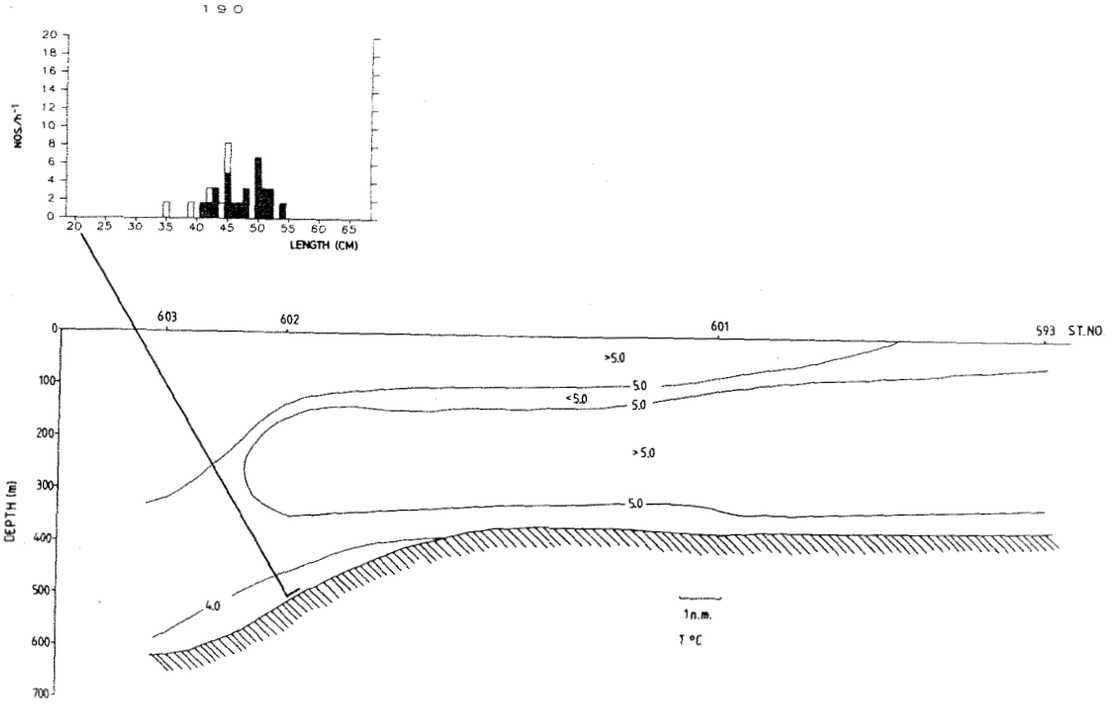

Fig. 11. Maturity, length distribution and number per trawl hour of female haddock. Temperature distribution (^{0}C) on a section from the western bank area and the continental slope of Tromsøflaket in area B. ▮ - Mature haddock females. ▯ - Immature haddock females.

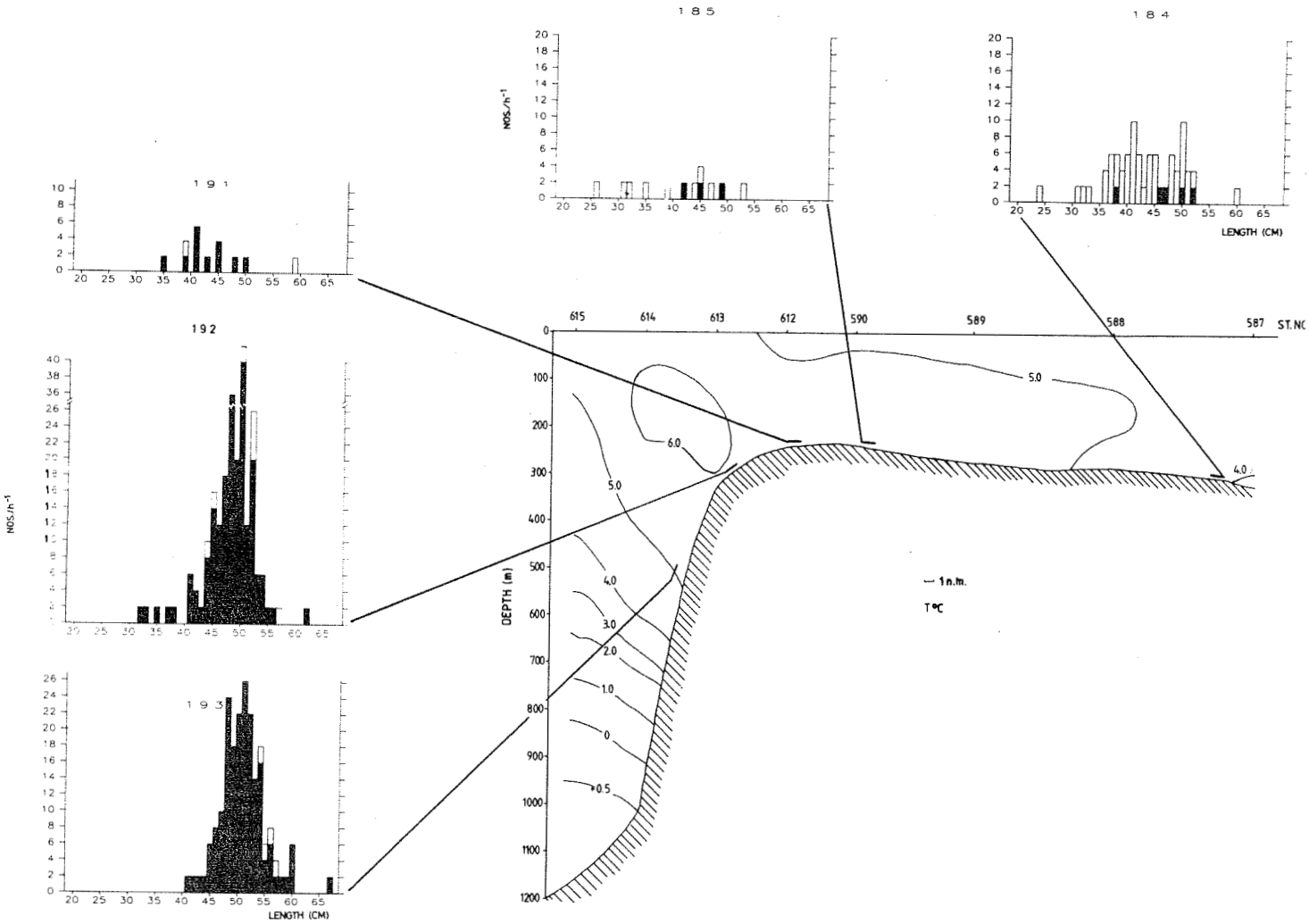

Fig. 12. Maturity, length distribution and number per trawl hour of female haddock. Temperature distribution (^{0}C) on a section from the western bank area and the continental slope of Tromsøflaket in area C. ▮ - Mature haddock females. ▯ - Immature haddock females.

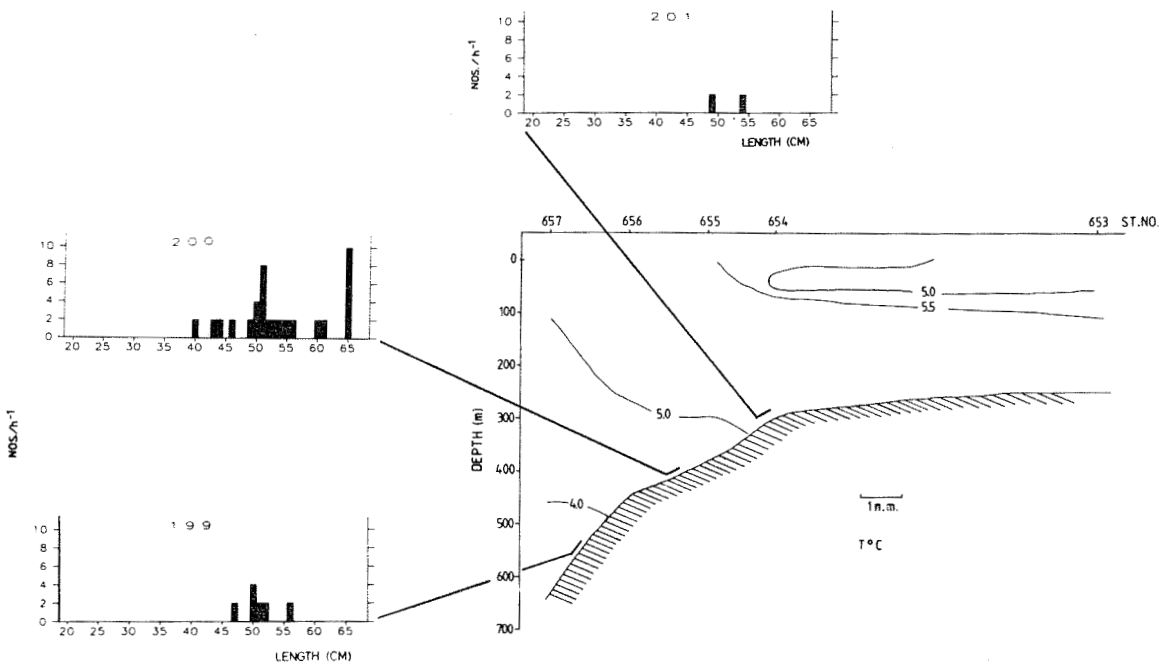

Fig. 13. Maturity, length distribution and number per trawl hour of female haddock. Temperature distribution (^{0}C) on a section from the western bank area and the continental slope of Tromsøflaket in area C'. ■ - Mature haddock females. □ - Immature haddock females.

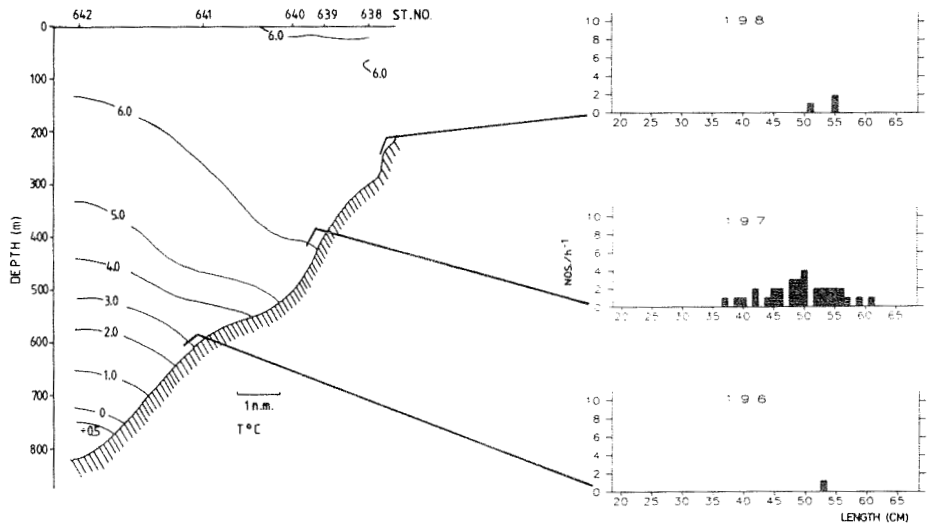

Fig. 14. Maturity, length distribution and number per trawl hour of female haddock. Temperature distribution (^{0}C) on a section from the western bank area and the continental slope of Røsttunga in area D. ■ - Mature haddock females. □ - Immature haddock females.

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