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LONG ROUGH DAB (*HIPPOGLOSSOIDES PLATESSOIDES*) OF THE BARENTS SEA AND SVALBARD AREA: ECOLOGY AND RESOURCE EVALUATION.

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Abstract

Based on data from Norwegian and Russian bottom trawl surveys in the years 1988-1993, the paper considers distribution, population structure, growth and reproduction of long rough dab (*Hippoglossoides platessoides*) of the Barents Sea. Based on effort statistics from the commercial fleet and data from commercial trawlers hired or inspected by Norwegian authorities, the paper also gives a preliminary evaluation of the resource potential.

Long rough dab was the most abundant flatfish at moderate depth in the Barents Sea and the abundance increased during the period 1988-1993, particularly in the outer part of the distribution area. This increase in abundance and distribution area was probably largely caused by the very strong 1986 year class. Eastern, northern and shallow areas were dominated by relatively small fish. Spawning occurred over wide areas, but the fishes in the northern part may to some extent have migrated to spawning grounds further south. Males reached 50 % maturation at age 5 and females at age 10. The growth rates of males and females were almost linear and not very different for age groups less than 10. Mortality was higher for males and nearly all fish older than 10 years were female. The results indicated that growth rate for the very strong 1986 year class was density dependent. The estimated total biomass of long rough dab in the Barents Sea increased from 70 000 metric tons in 1988 to more than 200 000 tons in 1993. The bycatch of long rough dab in the Norwegian fisheries was estimated to less than 1000 tons. The total catch of long rough dab in the Barents Sea was probably less than 0.2 % of the standing biomass. Although the precision of these estimates are low, there seems to be a considerable potential for biologically safe exploitation of this resource.

1. Introduction

The Barents Sea is a shelf sea extending from Norwegian and Russian coasts in south and east to the continental slopes of the Norwegian Sea in west and of the Arctic Ocean in north (Figure 1). The hydrography is characterised by three distinct water masses, Arctic water with temperatures at or below 0 °C and Atlantic and Norwegian Coastal waters, both with temperatures above 2 °C (Loeng, 1989). Between the Atlantic and the Arctic waters is the Polar Front, the position of which varies seasonally, annually and in periods of a few years dependent on the strength of the Atlantic inflow (Dragesund and Gjøsæter, 1988; Loeng, 1989).

Long rough dab (*Hippoglossoides platessoides*, Fabricius, 1730) is an Arctic-Boreal flatfish (Ekman, 1967) distributed on both sides of the north Atlantic (Andriyashev, 1954; Pitt, 1966; Isaksen, 1977; Bergstad, 1990). Although it is found within a wide temperature range, the distribution of a population may change with changes in temperature (Morgan and Brodie, 1991). In the Barents Sea, the species is recorded in temperatures between -1.3 and 5 °C (Milinsky, 1944), but is most abundant between -0.5 and 3.5 °C (Isaksen, 1977), i.e. both in Atlantic and Arctic waters and along the Polar Front (Walsh and Mokeeva, 1993).

The growth patterns of long rough dab varies extensively between areas and is assumed largely to be caused by differences in temperature (Powles, 1965; Pitt, 1967). Thus, the populations along the Canadian coasts grow much faster and become much larger than the Barents Sea population (Isaksen, 1977). Accordingly, in the north-west Atlantic, the species has supported a commercially important fishery (Brodie *et al*, 1990; Morgan and Brodie, 1991). This is presumably the reason why studies on the biology and ecology of long rough dab is much more comprehensive for the western populations than for the Barents Sea population.

In the Barents Sea, there exist at present no directed fishery for long rough dab. Commercial trawlers from several countries fish with bottom trawls in the area and certainly exert some fishing pressure on the species, but this bycatch is normally discarded at sea. However, the regular and widespread abundance of long rough dab in the area has led fishermen and managers to ask for the potential for exploitation of this resource. To answer this question we need more information on the biology and ecology of this species in the Barents Sea. Walsh and Mokeeva (1993) started this work with an analysis of changes in distribution and abundance during the years 1980-1992. The present paper follow up with a more detailed analysis of the most recent years.

The purpose of this report is thus to give a preliminary describe the ecology, the stock size and the fishery for long rough dab in the Barents Sea. The paper considers distribution and abundance, population structure, growth, maturation and exploitation.

2. Material and Methods

2.1. Data from research cruises

Data for this paper were gathered from five different series of yearly research cruises covering five time periods of the year. In January to March each year, the Norwegian Institute of Marine Research (IMR) carried out a survey for demersal fish in the Barents Sea. These surveys covered the area between the Norwegian and Russian coasts in south and east, the continental slope in west and Bear Island in north. In April and May, the Norwegian Institute of Fisheries and Aquaculture Ltd. (Fiskeriforskning) covered most of this area, yet concentrated on the deeper parts in the Norwegian sector of the sea and also the northern areas east of Svalbard. In May and June (July and August until 1991), another series of surveys was made by Fiskeriforskning to the west and north of Svalbard. Both of these yearly surveys were designed for research on shrimps (Pandalus borealis) and were formerly (until 1991) carried out by IMR. In September and October each year, IMR made a survey for demersal fish in the areas north, east, south and west of Svalbard. The fifth series of research cruises was made by the Russian Polar Research Institute of Marine Fisheries and Oceanography (PINRO). These were demersal fish surveys covering both the Barents Sea and The Svalbard region during the period September to November.

Long time series exists for each of the five surveys. Yet, this preliminary report mainly considers the years 1988-1993. In addition, some data from Fiskeriforsknings cruises in 1994 were also included. In this period all the Norwegian trawl hauls were made using the Campelen 1800 bottom trawl with a "rockhopper" ground gear (Engås & Godø, 1989). In the Russian surveys another type of bottom trawl and gear were used (Shevelev *et al.*, 1990). Differences in catching efficiency of trawl, with respect to long rough dab, between the Norwegian and Russian trawl type is not known. In the Norwegian surveys, trawls were made using a towing speed of 3 knots and the duration of the haul was usually 20 min. The Russian trawls were usually towed over 3 nautical miles.

The catch of long rough dab in terms of weight and numbers was recorded for each trawl catch. The total length was measured in 10 mm units in the Norwegian surveys and 20 mm units in the Russian surveys and a length frequency distribution was compiled for each trawl. In the Russian surveys, separate catch figures and length distributions were recorded for each sex. In the surveys made by Fiskeriforskning and PINRO, an additional length stratified sample were taken from selected catches for determination of individual length and weight, sex, maturity stage and age. Definition of maturity stages used in the Norwegian surveys is given in Table 1. These definitions are somewhat subjective and it was often difficult to distinguish between "immature" and "spent" (stage 1 and 4) and sometimes also between "immature" and "ripening". There may have been cases when the maturity stage was misinterpreted.

Age was determined by counting the zones in the otoliths (sagitta). The Norwegian otoliths were grind with emery, submerged in glycerol and read using a black background and reflected light. The Russian otoliths were stored in a 1:1:1 solution of glycerine, ethanol and ammonium hydroxide and read using reflected light. Comparisons of Norwegian and Russian readings showed good agreement for ages up to about 10 years, while for older fish the Norwegian reading were often 1-3 years higher than the Russian.

2.2. Analyses

Different stratification procedures were used in the different surveys. In order to analyse geographical patterns in the data, the survey area were divided into 11 subareas (Figure 1). The definition of subareas were based on the bottom topography, the general pattern of distribution of water masses and some prior knowledge of the distribution and length composition of long rough dab (Isaksen, 1977; Walsh & Mokeeva, 1993). The Russian data were not available in a suitable format for analysing together with the Norwegian data. Separate analyses were thus performed for the two data sets. The Russian data were divided into two subareas: the Barents Sea and the Svalbard area, which correspond to ICES' statistical areas I and IIb respectively.

Before further analyses, Norwegian and Russian catches were standardised to 1 nautical mile and 1 hour trawling (approx. 3 nm) respectively. In this preliminary report, data were mainly analysed graphically.

Data on individual age, length and sex were only available from Fiskeriforsknings cruises in 92 and 93. For these cruises, length at age and catch in terms of numbers at age were calculated for each sex using age-sex-length keys. These are matrices were the total number of sexed and aged fish in each 1 cm length group were distributed among all combinations of sex and age. The number in each combination was expressed as the proportion of the total number in that length group. Multiplication of these proportions with corresponding frequencies in the length frequency distribution of the random sample give estimated length frequency distributions for each age group and age frequency distribution of the catches (Kimura, 1977).

The standing biomass of long rough dab (B) in an area was calculated from the equation:

$$B = E \cdot C \cdot A/W,$$

where E is the proportion of long rough dab before the trawl that is actually retained in the catch (the catch efficiency of the trawl), C is the mean catch rate of long rough dab in terms of weight per nautical mile (kg/nm), A is the size of the area (measured in nm^2) and W is the effective width of the trawl (measured in nm). The catch efficiency was set to 1 and the effective width to 25 m (0.0135 nm), i.e. greater than the distance between the trawl wings (approx. 15 m) and less than the distance between the doors (approx. 45 m).

2.3. Data from commercial vessels

There exist no reliable Norwegian or Russian fishery statistics from the Barents Sea that include bycatch of long rough dab. The only way to get an estimate of the bycatch was to calculate catch rates in commercial trawlers hired or inspected by the Norwegian Directorate of Fisheries, and then multiply these catch rates by the total fishing effort in each of the Norwegian fleets. The bycatch of long rough dab is usually discarded at sea and it was assumed that all discarded fish subsequently died and that the bycatch thus reflect the fishing mortality.

Catch rates of long rough dab in the commercial fisheries were collected from two sources. Firstly, from commercial vessels hired by the Norwegian Directorate of Fisheries. The trawl and gear used by these vessels were presumably representative for the fleets, whereas the areas sampled were selected by other criteria than used in the fleets. Secondly, from commercial vessels inspected by the Directorate of Fisheries during fishing. These vessels were selected at the main fishing grounds used by each fleet. Thus, within limited areas the mean bycatch rates from both of these sources may be considered as representing the mean bycatch rate in the fishery. Both sources of data include catch of long rough dab by number and weight, duration of the haul, position, depth and trawl type. Data were available for the years 1988-1992.

Fishing effort in each fleet were available by the statistical squares used by the Directorate of Fisheries (Figure 2). The squares were combined to cover the subareas, restricted by the 100 and 500 m isobaths. There were no information about the trawl distance or the size of the trawl used. Therefor, fishing effort was estimated as the number of hours that each fleet were trawling in the given area and year. Accordingly, catch rates were calculated as mean catch per hour trawling. Fishing effort was available from 1980 onwards and the bycatch rates for the years 1980-1987 were set to the mean value for the years 1988-1992.

The Norwegian trawlers that may catch long rough dab may be grouped in two fleets, the shrimp trawlers, using trawls of variable size with 35 mm mesh size, and those trawling for demersal fish, mainly cod and haddock, using trawls with 135 mm mesh size. In the Norwegian shrimp trawl fishery, a 19 mm sorting grid was introduced during the period considered. The grid was mounted inside the trawl beneath an opening in the net panel. The purpose of the grid was to sort larger fish out through this opening. The sorting grid was obligatory in the shrimp fishery from 1993 onwards but was commonly used from 1991. It was assumed that all shrimp trawlers were using the grid from 1991 and that no one was using it before this year. Catch rates were thus calculated separately for shrimp trawls with sorting grid, shrimp trawls without grid and for the trawls used in the fishery for cod and haddock.

3. Results

3.1 Distribution and abundance

3.1.1 Overall distribution

In all the research cruises included in this work, long rough dab was the most abundant flatfish in bottom trawl catches within the depth range 100-400 m. Below this depth, catches of Greenland halibut may be larger. Long rough dab was distributed continuously from the Goose Bank in south-eastern Barents Sea to the continental slope of the Norwegian Sea and from Norwegian and Russian coastal areas to north of Svalbard. The south-eastern, southern, western and northern distribution limits seems thus reasonably well defined, whereas the north-eastern range of distribution remains poorly described due to ice coverage. Some records of the species north of Novaya Zemlya exist though (unpublished Russian data) and it seems reasonable that it may occur over most of the continental shelf between the Norwegian Sea, the Arctic Ocean and the Russian and Norwegian coasts.

The overall distribution pattern of long rough dab in the Barents Sea area seems quite consistent over years (Figures 3 and 4). Major concentrations were found along the south-eastern slope of the Svalbard Bank (extending from Bear Island to Hopen), in the South Cape Deep (between Spitsbergen and Bear Island) and along the Thor Iversen and Tiddly Banks south to the slopes of the Murman Bank (i.e. extending from Subarea 4 to Subarea 6).

3.1.2 Spatial and temporal variation

Long rough dab was recorded in trawl catches from 35 to 743 m sounding, while the main range of bathymetric distribution was from 100 to 500 m (Figure 5). Within this range, some variations in abundance with year, season and subarea were found though (Figure 6). There were overall relatively small catches in the south-western and north-western areas (subareas 1,10 and 11), the northern Subarea 8, and in the beginning of the time period also in the eastern subareas 5 and 6. No major and consistent seasonal changes were apparent though.

There was a general and gradual increase in catch rate during the period 1988-1993 (Figure 6). This increase was seen in all three seasons and was most pronounced in the eastern and northern subareas (4-9). This general increase was also found in the Russian surveys (Table 2).

Figure 7 shows how the catch rates of selected size groups varied between years, seasons and subareas. In the smallest size group (0-9 cm), catch rates increased from winter 1988 until autumn 1990 and decreased afterwards. The next two size groups (10-19 cm and 20-29 cm) also increased from 1988 to 1990, but they did not decrease afterwards. The 30-39 cm group increased throughout the time period 1988-1993, whereas the largest size group (40-59 cm) increased from 1991 to 1993. This delay in increased abundance with size may indicate that the increase was caused by one or a few strong year classes rather than by changes in distribution.

No one of the size groups were particularly abundant in the south-western subarea. Within the other subareas, the different size groups had somewhat different distribution patterns. The smaller fish (less than 20 cm) had a clearly easterly and north-easterly distribution. They were particular abundant in the Russian subareas (5 and 6) and east and south of Svalbard (7,8 and 9). Intermediate sized fish were more evenly distributed among the subareas. The 30-39 cm group showed reduced abundance in the most northerly subareas (8 and 11), whereas the largest fish were found primarily in the central subareas (2,3 and 4).

There were no major seasonal changes in abundance for any of the size groups. An exception might be the two largest size groups in Subarea 7, which were consistently more abundant in July-October than in April-June (Figure 7). This difference was much less pronounced for the smaller length groups. This may indicate some emigration of larger long rough dab from this subarea during or prior to the spawning season.

3.2 Population structure

3.2.1 Overall length, age and sex composition

There was a marked sexual difference in the size composition of long rough dab. Figure 8 shows the length distributions by sex and year for the Russian surveys in the Barents Sea and Svalbard area respectively (ICES areas I and IIb). In both subareas, the female part of the population was on average 6-8 cm larger than the males. The distributions were typically unimodal and included several age groups. The corresponding age distributions are shown in Figure 9.

Nearly all fish larger than 38 cm or older than 10 years were female. On the other side, few fish smaller than 12 cm or younger than 4 years were recorded in the Russian trawls, and this lower limit was approximately the same for both sexes. Thus, sampling of the younger age groups were apparently not representative of their abundance. This may be due to both age specific distribution patterns and to gear selection.

The proportion of larger long rough dab increased during the time period considered. This was particularly apparent for males larger than 30 cm and females larger than 40 cm (Figure 8). A corresponding increase in the proportion of older age groups (10-12 years) appears in Figure 9.

3.2.2 Spatial and temporal variation

The population structure of long rough dab varied throughout the survey area. Figures 10 and 11 shows how the length distributions from the Norwegian surveys changed with depth and subarea respectively. All lengths groups showed a rather wide bathymetric distribution, but the proportion of the smaller fish decreased, while larger fish increased with increasing depth.

This gradual change in size distribution with depth appeared in all the three time periods of the year, but was particularly pronounced in January-March.

The pattern of geographical and bathymetric distribution might be influenced by an interaction effect between subarea and depth. All stations below 400 m were for instance taken in the western subareas. Thus, the geographical variation were analysed within each of three depth intervals (Figure 11). In all subareas, small fish dominated at the shallower stations (50-200 m) whereas between-area differences were more pronounced at intermediate (201-350 m) and larger (351-600 m) depth. At those depth, small fish dominated in the eastern subareas (5 and 6), and particularly in those east of Svalbard (7 and 8), while larger fish were found in the southern subareas (1, 2, 3 and partly 4). In the western areas, the proportion of large fish decreased with increased latitude.

There were no pronounced differences between seasons. Even in Subarea 7, where some emigration may have occurred during winter, were the length distributions not significantly different in April-May and July-October.

Figure 12 shows between-years differences in length frequency distribution of long rough dab from subarea 5 and 7, two of the subareas where the increase in abundance were especially high. It appears that in Subarea 7 a single year class may be traced throughout the time period. It grows from 5-6 cm in 1988 to 10-15 cm in 1993. In 1988 this single year class contributed only 2 % to the catches in Subarea 7. This proportion increased gradually and in 1993 it was more than 45 %. It seems reasonably to assume that this strong year class is the 1986 year class that was found to be extraordinary large in the 0-group surveys (Anon., 1992). Although the length distributions from Subarea 5 were based on fewer observations, it seems that the same year class may be traced in this area too.

3.3 Growth and maturation

3.3.1 Growth in length

The age-sex-length keys consisted of more than 30 combinations of sex and age and more than 30 1-cm length groups. There were made one key for the southern area (Subareas 1, 2, 3 and 4) and one for the northern area (Subareas 7, 8, 9, 10 and 11). The northern key was based on data from 1992, whereas data from 92 and 93 had to be combined in order to make a key with reasonable precision for the southern area. The southern and northern keys were based on 1033 and 913 observations respectively.

Figure 13 shows estimated length at age of male and female long rough dab in April-June 1992. Recorded age ranged from 1 to 21 years, but there were too few 1-3 years old fish in the sample to make estimates for these age groups. The growth in length seemed to be almost linear, at least up to age group 10 for males and 12 for females. There were no significant sex difference in length at age for the younger age groups. From age group 10 onwards, females were largest though. Mean length at age was consistently larger in the southern area. The difference was especially large for younger males and intermediate females. However, any spawning migration that may occur between the two areas in this period of the year would influence the interpretation of these results.

If we compare the growth curve in Figure 13 with the length distribution of the large 1986 year class that appeared in Figure 12, it appears that this year class had a comparatively low growth rate. Although mesh selection might be important in the first few years of the time series, the mean length at age 7 (in 1993) was 8 cm less than the mean length of age group 7 in Figure 13. The length of age group 7 in Figure 13 was based on data from the 1992 survey and thus represented the 1985 year class.

3.3.2 Maturation

Table 3 shows the percentage of each sex and age group that were classified as sexually mature in autumn and thus were going to spawn the following spring. The data were from the Russian cruises and show that the male long rough dab matured at a younger age than the females.

Maturity stage was also determined at the Norwegian cruises in April-June 1992-1994. This period of the year is when peak spawning of long rough dab occurs in the Barents Sea (Isaksen, 1977). In this season, sexually mature specimens were caught in all subareas sampled (Figure 14). The proportion of mature fish were higher in the southern (2-4) than in northern (7-11) subareas though. Further, very few actually running individuals were recorded in the northern subareas and if some immature fish were misinterpreted as maturing or spawned (see chapter 2), the actual subarea differences may have been greater than indicated in the figure.

Figure 15 shows how the distribution of maturity stage varied between age groups in April-June 1992. The southern and northern areas were defined as in Figure 13 (i.e. Subarea 1-4 and 7-11 respectively). In the southern area, maturation of females started about age 7 and 50% maturation were reached at age group 10. Few males matured at age group 4, while more than 50% were mature at age group 5.

In the northern subareas, females reached 50% maturation at age 13, while males did not reach more than 20% maturation at any age. It may be that maturation was delayed in the northern subareas, but an alternative explanation is that mature specimens migrated southwards in the spawning season. If the latter was true one would expect that the migration included a higher proportion of the males than of the females, at least for age group 4-10. This is consistent with Figure 16, which shows that the proportion of females was much higher in the northern than in the southern area.

3.4 Resource evaluation

3.4.1 Standing biomass

The bathymetric distribution of major concentrations of long rough dab was approximately defined by the 100 and 500 m isobaths (Figure 5). When calculating the biomass of long rough dab in each subarea, the mean catch rates in the Norwegian surveys were calculated within this depth range and integrated over the area defined by the subareas and these two isobaths. Estimated biomass in each subarea and in all subareas combined are shown in Figure 17. Estimated total biomass increased from about 70 000 tons in 1988 to more than 200 000 tons in 92 and 93. The decrease in 1994 is uncertain, particularly in subarea 5, because it is based on data from the April-June cruises only.

The increase in biomass was particularly pronounced in the eastern and northern subareas 5 and 7, and was also apparent in subareas 2, 3, 4 and 6. In the south-western and north-western subareas 1, 9, 10 and 11, there were no clear increasing trend in biomass during the period. The proportion of the total stock found in Subarea 5 and 7 increased from about 20 % in 1988 to about 50 % in 1991-1992.

The surveys in January-March included a few trawls north of subarea 5, south of latitude 75°N and west of longitude 44°E. Catch rates in these trawls also showed a steep increase during the period 1988-1993. However, available data in this area were considered too sparse to allow estimation of biomass. It may be though, that estimated total biomass in the Barents Sea should be increased with a few 10 000 tons.

There is obviously a large biomass of long rough dab in the Barents Sea, but the precision of the biomass estimates is not known. We don't know how efficient the trawl and gear is in catching this species, or how large the area is where the trawl is actually fishing. Although the values that were used for efficiency and trawl width are reasonable guesses that are often used in this type of resource evaluation, the biomass estimates are thus not much more than indices of relative biomass.

3.4.2 Exploitation

The catch rates of long rough dab in each fishery/trawl type are shown in Figure 18. Catch rates were approximately the same in the demersal fish trawl and in the shrimp trawls without sorting grid. The sorting grid significantly reduced catch rates, especially in terms of weight per hour. Mean weight of individual fish was also much smaller in trawls using grid than in other shrimp or fish trawls (Figure 18). This was probably because the grid was more effective for larger fish and because smaller fish were retained in the small meshed shrimp trawls.

Not considering shrimp trawls with grid, there were generally both higher catch rates and mean individual fish weight in the southern area (Subarea 1-4) than in the northern area (Subarea 7-11). The exception was in 1992, when both catch rates and individual fish weights were larger in north. Catch rates in the shrimp trawls without grid increased in the period considered.

The fishing effort of each fleet, in terms of number of hours trawling, are given in Table 4. In both fisheries, the proportion of the activity that was carried out in the northern area increased clearly throughout the 1980's. Still, most of the activity in the fishery for demersal fish was carried out in the southern area, whereas the shrimp trawlers were operating nearly as much in the northern area.

The estimated total bycatch of long rough dab in the Norwegian fisheries was less than 1000 metric tons (Table 4). This catch represented 0.1-0.9 % and 0.1-0.3 % of the estimated standing biomass in the southern and northern area respectively.

4. Discussion

Long rough dab was the most abundant flatfish at moderate depth in the Barents Sea. The abundance increased during the period 1988-1993. The increase was particularly pronounced in the outer part of the distribution area, i.e. in the Russian part of the sea and in the area east of Spitsbergen.

Both in the Russian and Norwegian surveys a few relatively strong year classes may be traced throughout this period. Although data on individual age were limited, these year classes seemed to be 10-12 years in 92-93. If so, they were thus the first few year classes in the 1980's. As 0-group the year classes 1980-1982 were 40-100 % larger than the three preceding year classes and also larger than the three following year classes (Anon., 1992). The only of the 30 latest year classes that was outstanding in the 0-group surveys was the 1986 year class (Anon., 1992) which was at least 5 times more abundant than the 1980-1982 year classes. The increase in abundance and distribution area of long rough dab during the period considered was probably largely caused by the 1986 year class. Also the increase in Atlantic inflow in the latest years may have had influence though.

The eastern and northern part of the distribution and areas of less than 150 m sounding were dominated by relatively small fish. The largest fishes were mostly found in the southern and central areas of the sea. Spawning occurred over wide areas, but the fishes in the northern part of the distribution area may to some extent have migrated to spawning grounds further south. Based on seasonal differences in length distributions, Millinsky (1944) argued that long rough dab undertake extensive spawning migrations in the Barents Sea. The present study indicate that if such migrations occur they include only minor proportions of the individuals within a subarea.

Males matured earlier than females, 50 % maturation was reached at age 5 for males and age 10 for females. The growth rates of males and females were almost linear and not very different for the younger age groups. From age group 10 onwards, females were larger than males. Mortality was higher for males than for females however, and nearly all the fish larger than 38 cm or older than 10 years were female. Although data on individual age were limited, there were indications of reduced growth rate for the very strong 1986 year class. The increase in distribution area by this year class may also indicate that growth was density dependent.

The estimated total biomass of long rough dab in the Barents Sea increased from 70 000 metric tons in 1988 to more than 200 000 tons in 1993. In 1988, 20 per cent of that biomass was found in the Russian area and in the area east of Spitsbergen combined. In 1993, this percentage had increased to 50.

The bycatch of long rough dab in the Norwegian fisheries was estimated to less than 1000 tons. Walsh and Mokeeva (1993) reported the corresponding Russian catch to be less than 2000 tons. The total catch of was thus probably less than 0.2 % of the standing biomass. Although the precision of these estimates are low, there seems to be a considerable potential for biologically safe exploitation of this resource.

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Figure legends

Figure 1. Bathymetric map of the Barents Sea. The subareas 1-11 were defined for the purpose of this report.

Figure 2. Distribution of small (< 20 cm) long rough dab in the area covered by the Russian surveys in 1991-1993.

Figure 3. Distribution of larger (Distribution of small (≥ 20 cm) long rough dab in the area covered by the Russian surveys in 1991-1993.

Figure 4. Mean catch rate (with standard deviation) of long rough dab in different depth intervals. Data from the Norwegian cruises, years, seasons and subareas pooled.

Figure 5. Mean catch rate (with standard error) of long rough dab from different years, seasons and subareas. Data from the Norwegian cruises, restricted to the depth range 100-500 m.

Figure 6. Mean logarithmic catch rate (with standard error) of different length groups of long rough dab from different years, seasons and subareas. Data from the Norwegian cruises, restricted to the depth range 100-500 m.

Figure 7. Percentage frequency distribution of 2-cm length groups of each sex of long rough dab from the Russian surveys in the Barents Sea and Svalbard area (ICES-area I and IIb) in 1988-1993.

Figure 8. Percentage age distribution of each sex of long rough dab from the Russian surveys in the Barents Sea and Svalbard area (ICES-area I and IIb) in 1988-1993.

Figure 9. Percentage frequency distribution of 1-cm length groups of long rough dab from different seasons and depth intervals. Data from the Norwegian surveys.

Figure 10 a-c. Percentage frequency distribution of 1-cm length groups of long rough dab from different seasons and subareas within the depth intervals 50-200m (a), 201-350m (b) and 351-600m (c) respectively. Data from the Norwegian surveys.

Figure 11. Mean length at age (with standard deviation) of male and female long rough dab from the Barents Sea in April-June 1992. The age-length key for the southern area was computed using age-readings from both 1992 and 1993. The southern and northern areas correspond to Subarea 1-4 and 7-11 respectively.

Figure 12. Percentage length frequency distributions of long rough dab from Subarea 5 and 7 in each of the years 1988 to 1993. Data from all Norwegian surveys.

Figure 13. Percentage frequency distribution of maturity stages of each sex and selected length groups of long rough dab from different subareas of the Barents Sea. Only bars representing more than 5 observations are shown. Data from April-June 1992-1994.

Figure 14. Percentage frequency distribution of maturity stages of each sex and age group of long rough dab. The southern and northern areas correspond to Subarea 1-4 and 7-11 respectively. Bars representing less than 5 observations are marked with a triangle.

Figure 15. Percentage of each age group that were classified as females. The southern and northern areas correspond to Subarea 1-4 and 7-11 respectively. Data from April-June 1992-1993.

Figure 16. Estimated standing biomass of long rough dab in each subarea and in subareas combined. Data from all Norwegian surveys in the period 1988-1994. For 1994, only data from April-June were included.

Figure 17. Statistical squares used by the Norwegian Directorate of Fisheries to record fishery statistics. Data from the hatched squares were used in this report. This correspond approximately to the area between the 100 and 500 m isobaths that are covered by the subareas 1-11. See Figure 1 for definition of subareas.

Figure 18. Estimated bycatch rate and mean size of long rough dab in the commercial Norwegian trawl fisheries for shrimp and for cod and haddock in the Barents Sea. Missing bars represent missing values (no observations).

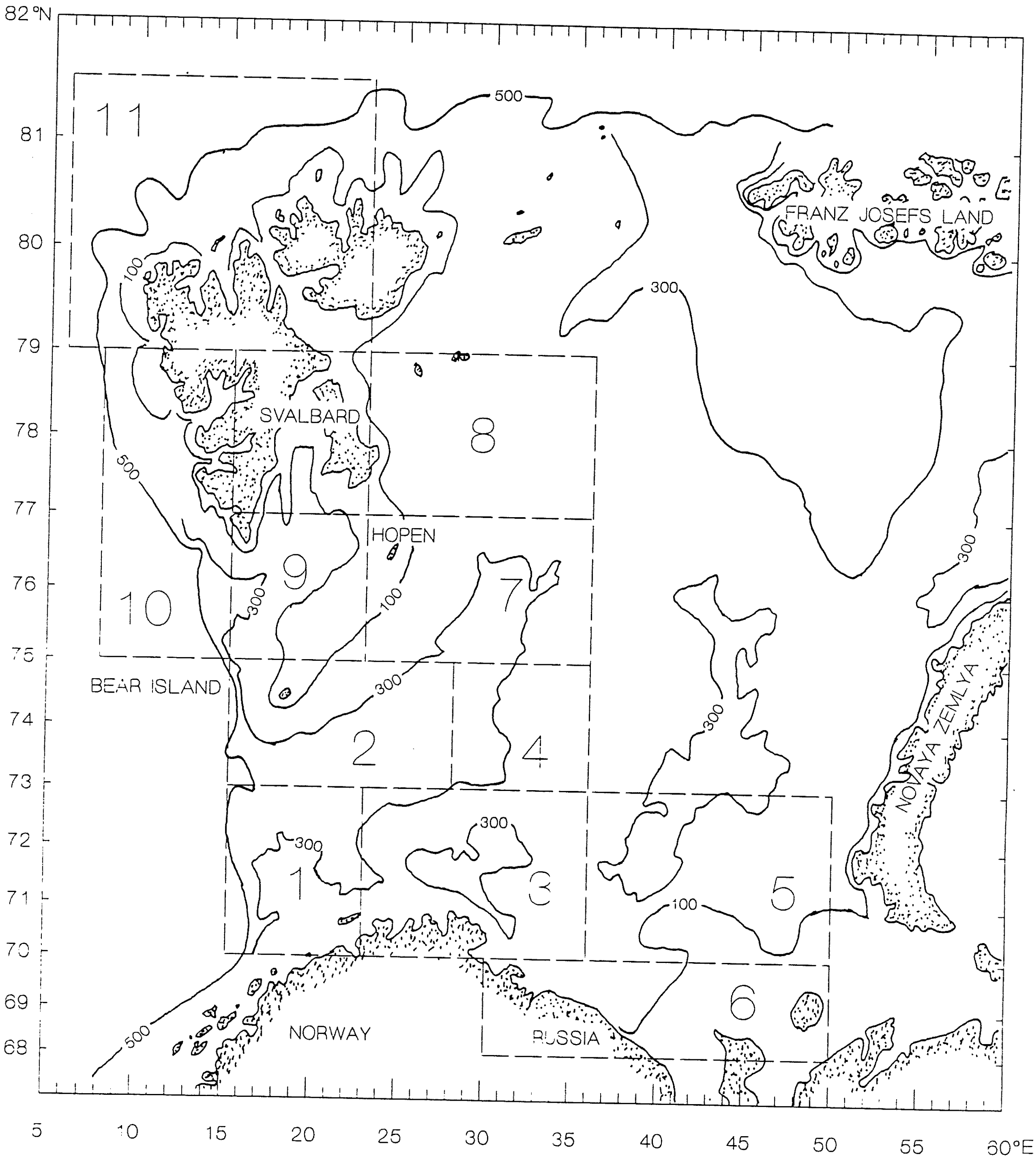

82°N
81
80
79
78
77
76
75
74
73
72
71
70
69
68
5
10
15
20
25
30
35
40
45
50
55
60°E
11
8
9
10
7
2
4
1
3
5
6
500
300
100
SVALBARD
HOPEN
BEAR ISLAND
FRANZ JOSEFS LAND
NOVAYA ZEMLYA
NORWAY
RUSSIA

Fig. 1

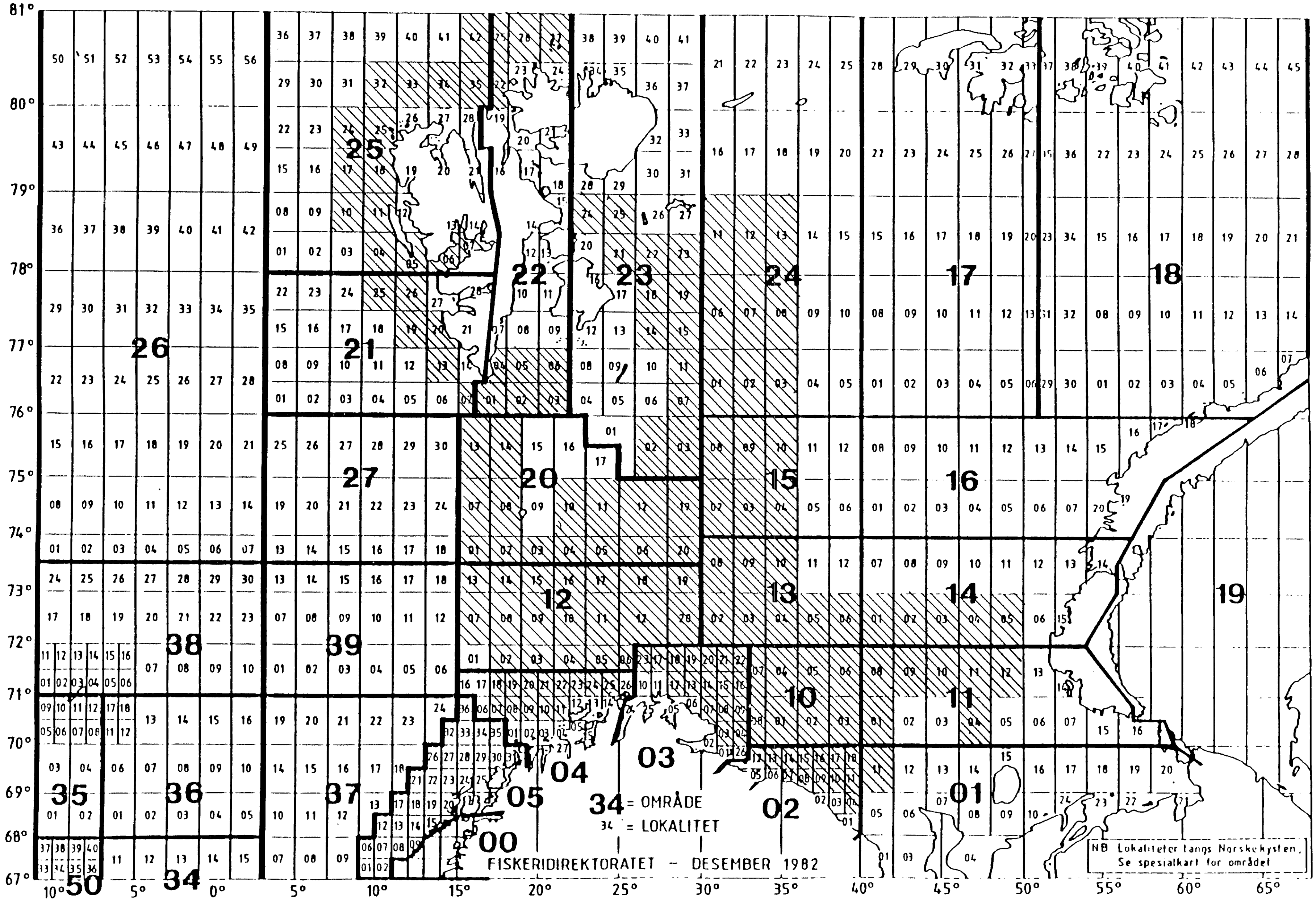
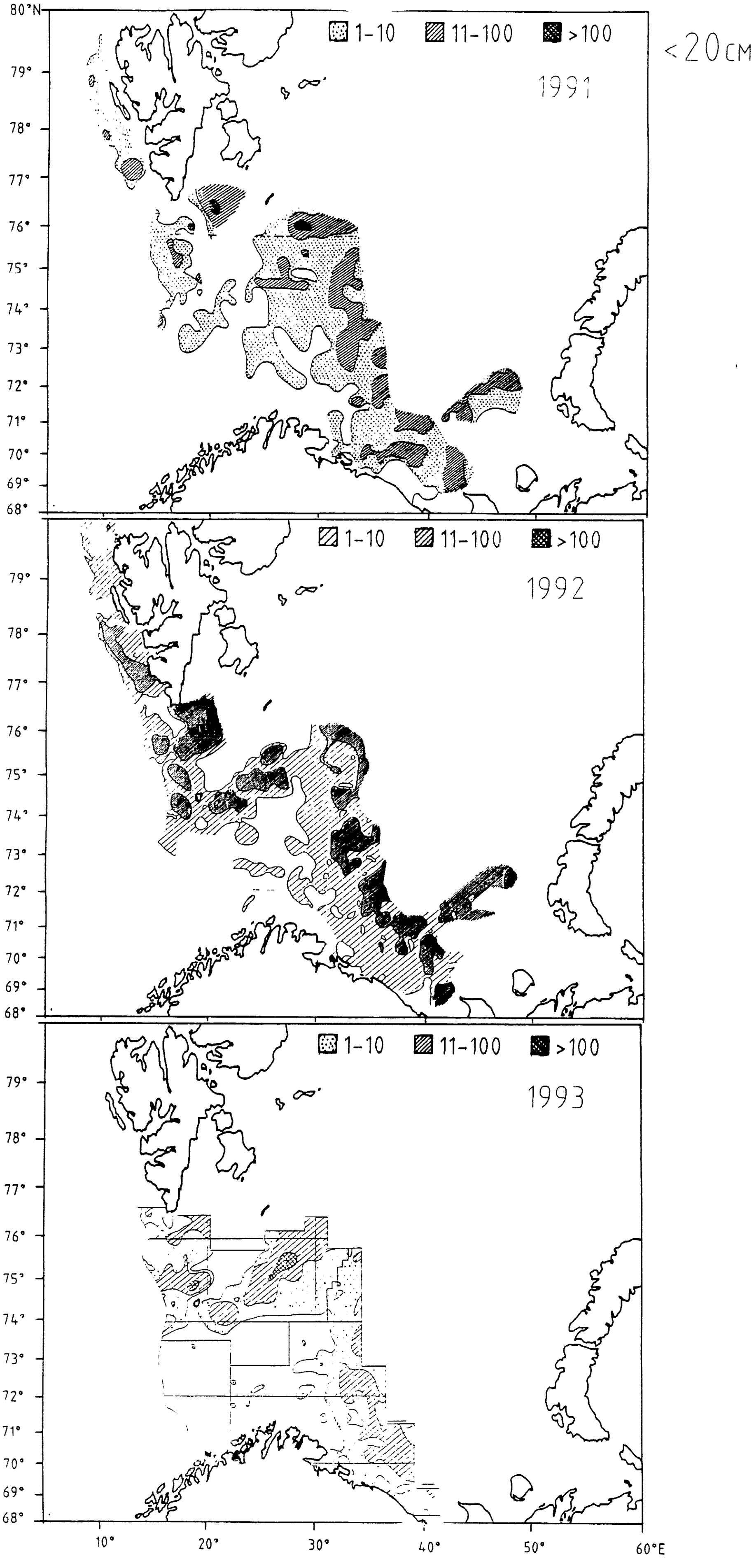

34 = OMRÅDE
34 = LOKALITET
FISKERIDIREKTORATET – DESEMBER 1982
NB Lokaliteter langs Norskekysten.
Se spesialkart for områdel

Fig. 2



<20CM
1-10
11-100
>100
1991
1992
1993
80°N
79°
78°
77°
76°
75°
74°
73°
72°
71°
70°
69°
68°
10°
20°
30°
40°
50°
60°E

Fig. 3.

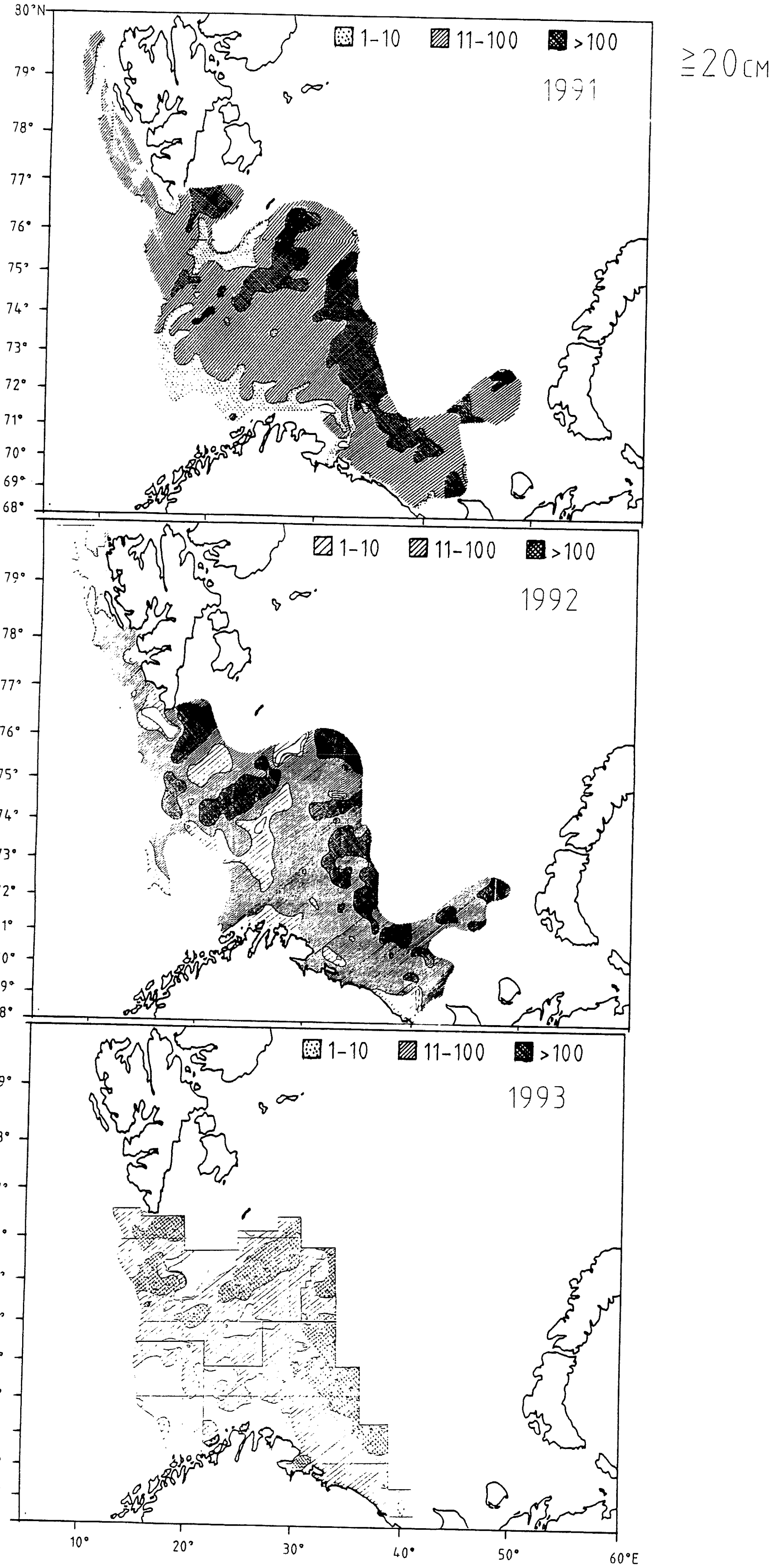

≧20cm
1-10
11-100
>100
1991
1992
1993
80°N
79°
78°
77°
76°
75°
74°
73°
72°
71°
70°
69°
68°
10°
20°
30°
40°
50°
60°E

Fig. 4.

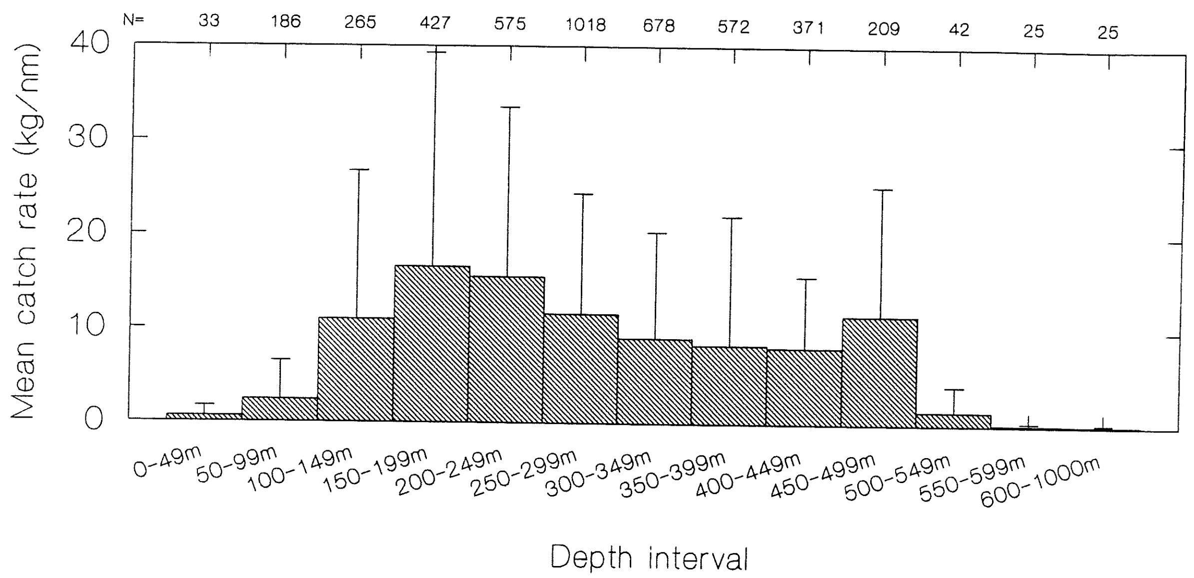
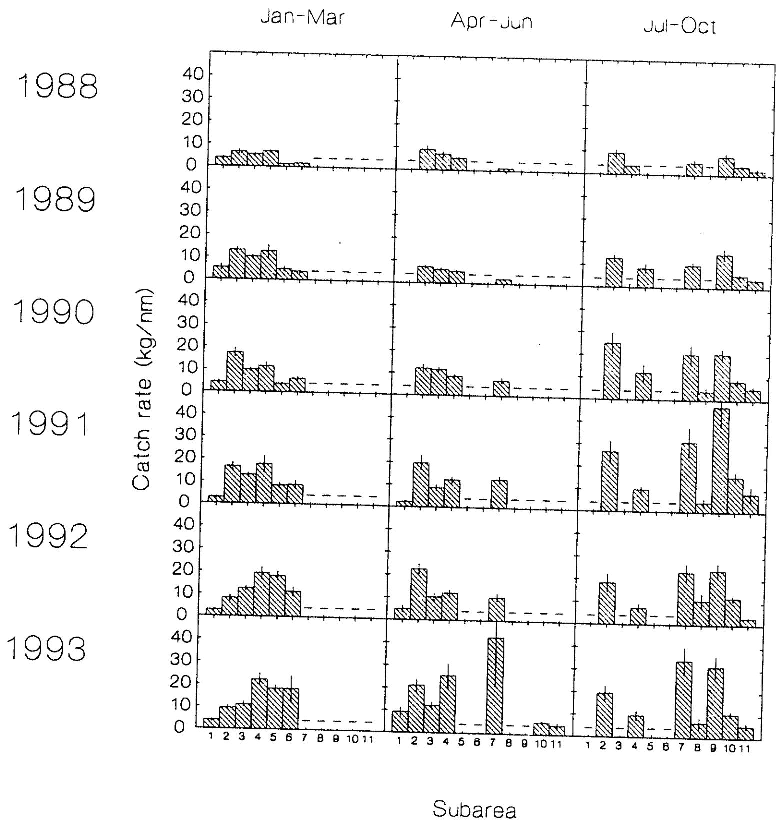
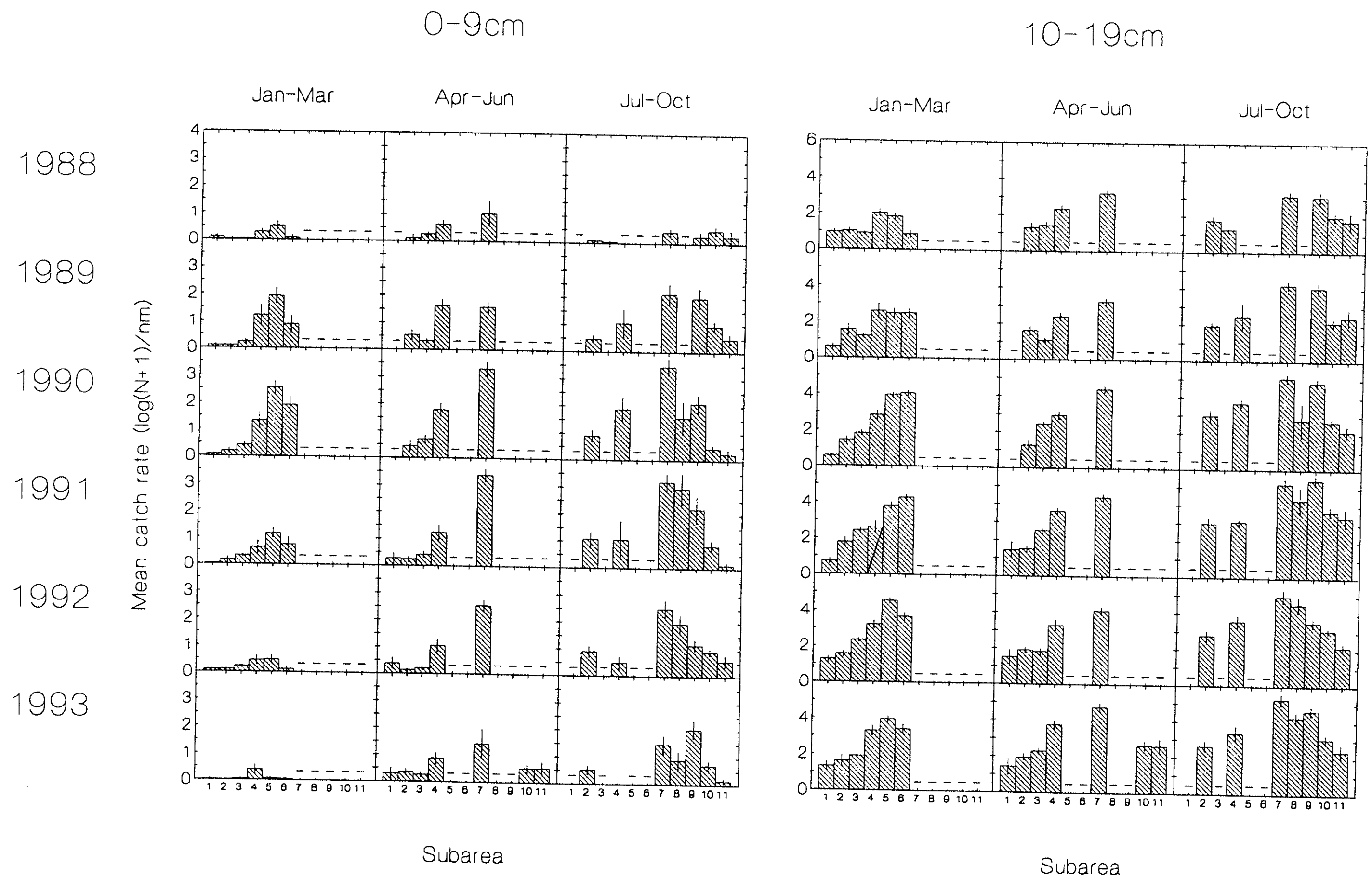

N=
33
186
265
427
575
1018
678
572
371
209
42
25
25
Mean catch rate (kg/nm)
40
30
20
10
0
0-49m
50-99m
100-149m
150-199m
200-249m
250-299m
300-349m
350-399m
400-449m
450-499m
500-549m
550-599m
600-1000m
Depth interval

Fig. 5.



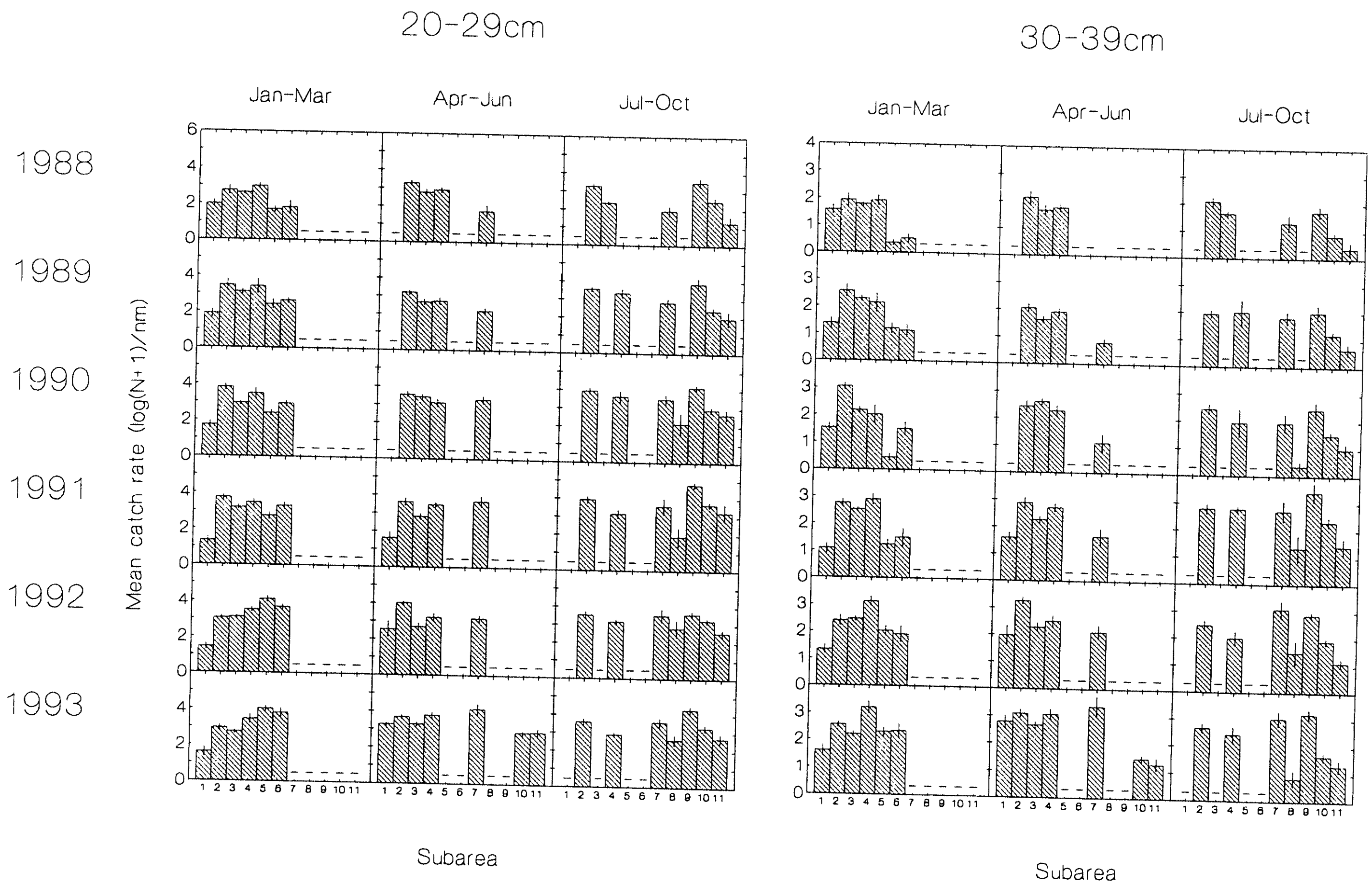
Jan-Mar
Apr-Jun
Jul-Oct
1988
1989
1990
1991
1992
1993
Catch rate (kg/nm)
0
10
20
30
40
1 2 3 4 5 6 7 8 9 10 11
Subarea

Fig. 6



0-9cm
10-19cm
Jan-Mar
Apr-Jun
Jul-Oct
1988
1989
1990
1991
1992
1993
Mean catch rate (log(N+1)/nm)
Subarea

Fig.7.



20-29cm
30-39cm
Jan-Mar
Apr-Jun
Jul-Oct
1988
1989
1990
1991
1992
1993
Mean catch rate (log(N+1)/nm)
Subarea

Fig. 7. cont.

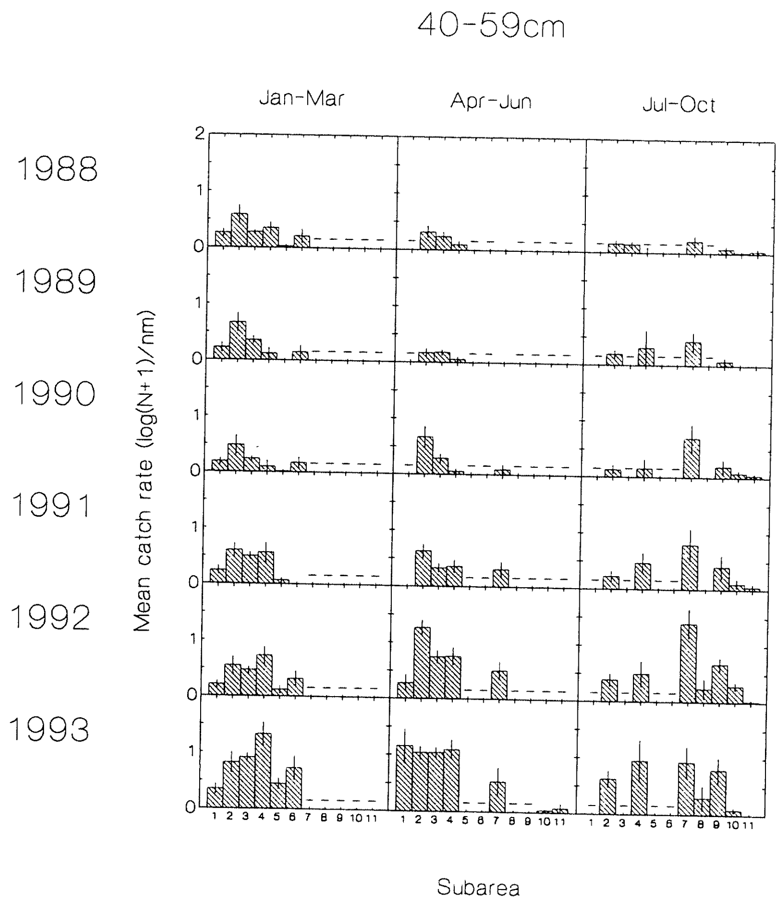
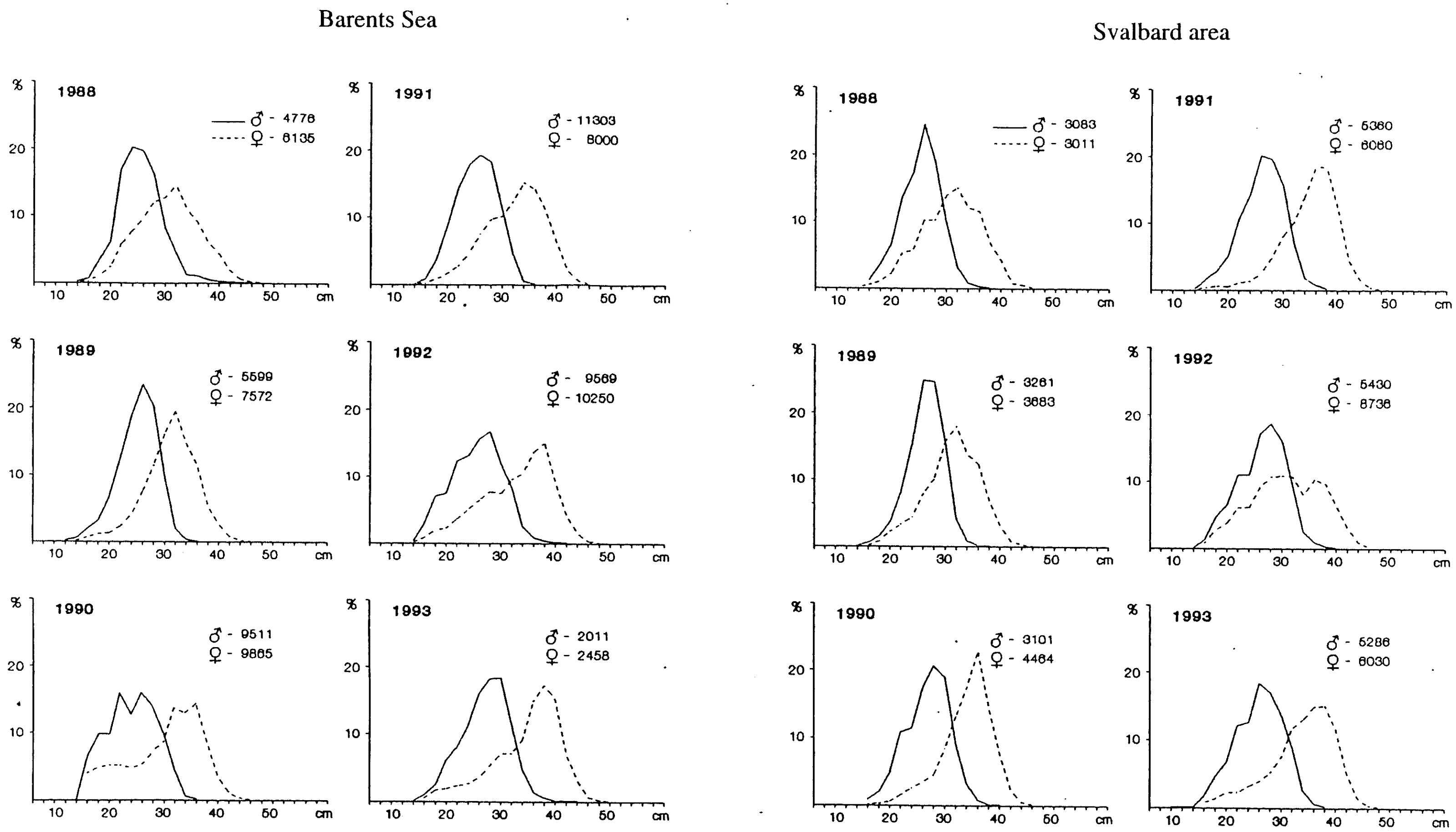

40-59cm
Jan-Mar
Apr-Jun
Jul-Oct
1988
1989
1990
1991
1992
1993
Mean catch rate (log(N+1)/nm)
Subarea

Fig. 7. cont.



Barents Sea
Svalbard area
1988
♂ - 4776
♀ - 6135
1991
♂ - 11303
♀ - 8000
1988
♂ - 3083
♀ - 3011
1991
♂ - 5360
♀ - 6060
1989
♂ - 5599
♀ - 7572
1992
♂ - 9569
♀ - 10250
1989
♂ - 3261
♀ - 3683
1992
♂ - 5430
♀ - 8736
1990
♂ - 9511
♀ - 9865
1993
♂ - 2011
♀ - 2458
1990
♂ - 3101
♀ - 4464
1993
♂ - 5286
♀ - 6030
%
cm

Fig. 8.

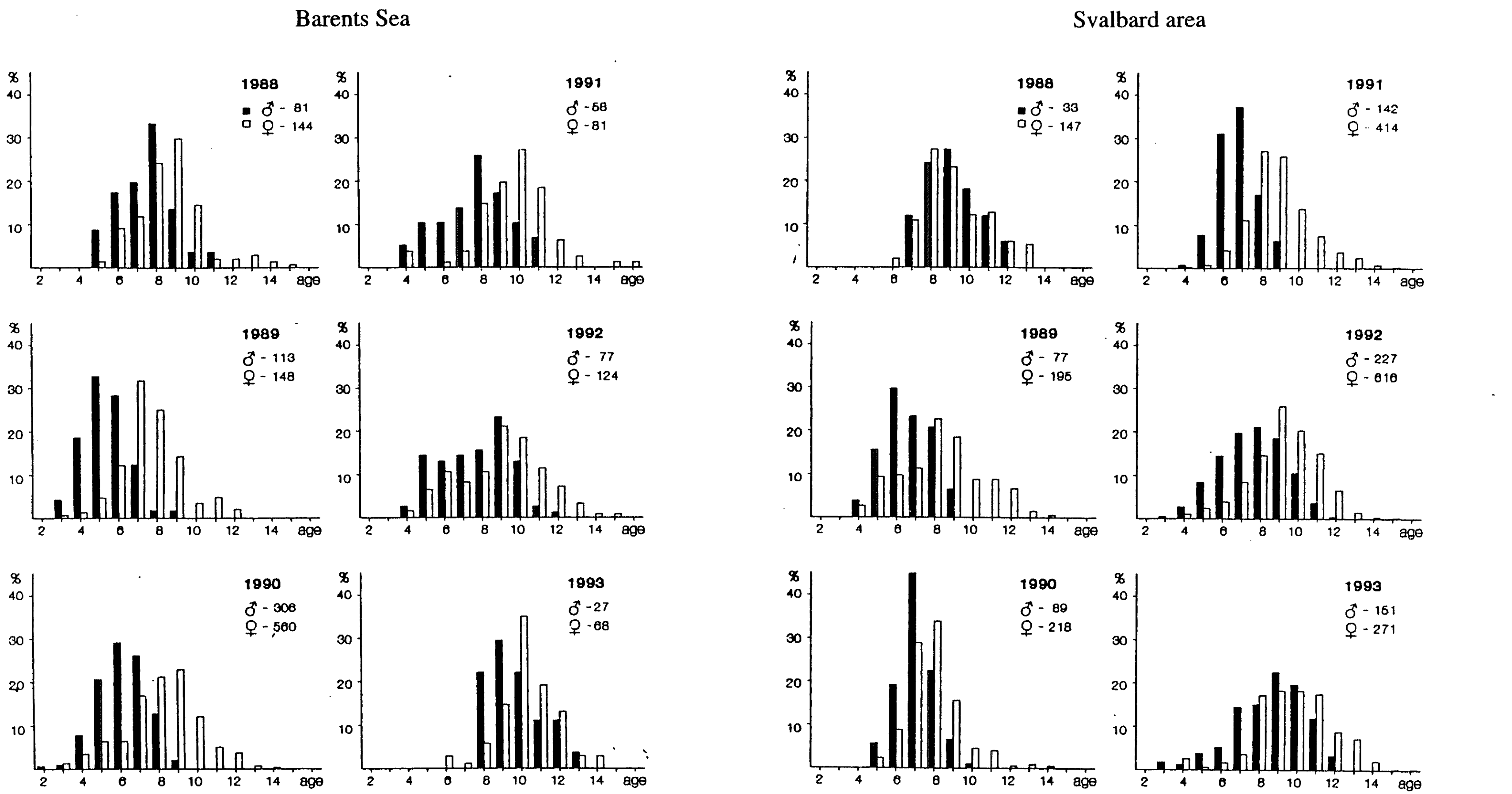

Barents Sea
Svalbard area
1988
♂ - 81
♀ - 144
1991
♂ - 58
♀ - 81
1989
♂ - 113
♀ - 148
1992
♂ - 77
♀ - 124
1990
♂ - 306
♀ - 560
1993
♂ - 27
♀ - 68
1988
♂ - 33
♀ - 147
1991
♂ - 142
♀ - 414
1989
♂ - 77
♀ - 195
1992
♂ - 227
♀ - 616
1990
♂ - 89
♀ - 218
1993
♂ - 161
♀ - 271
%
age

Fig. 9.

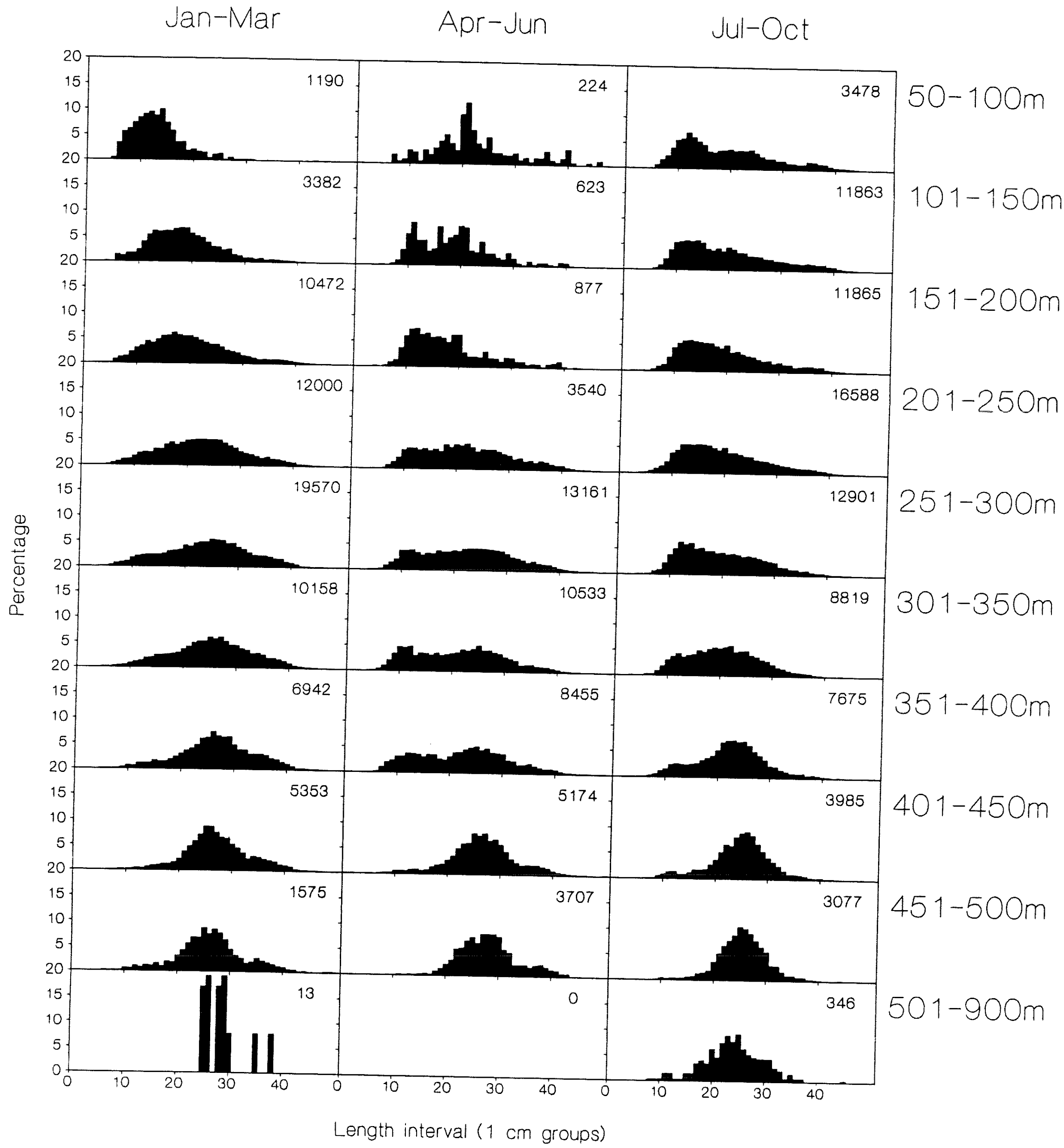
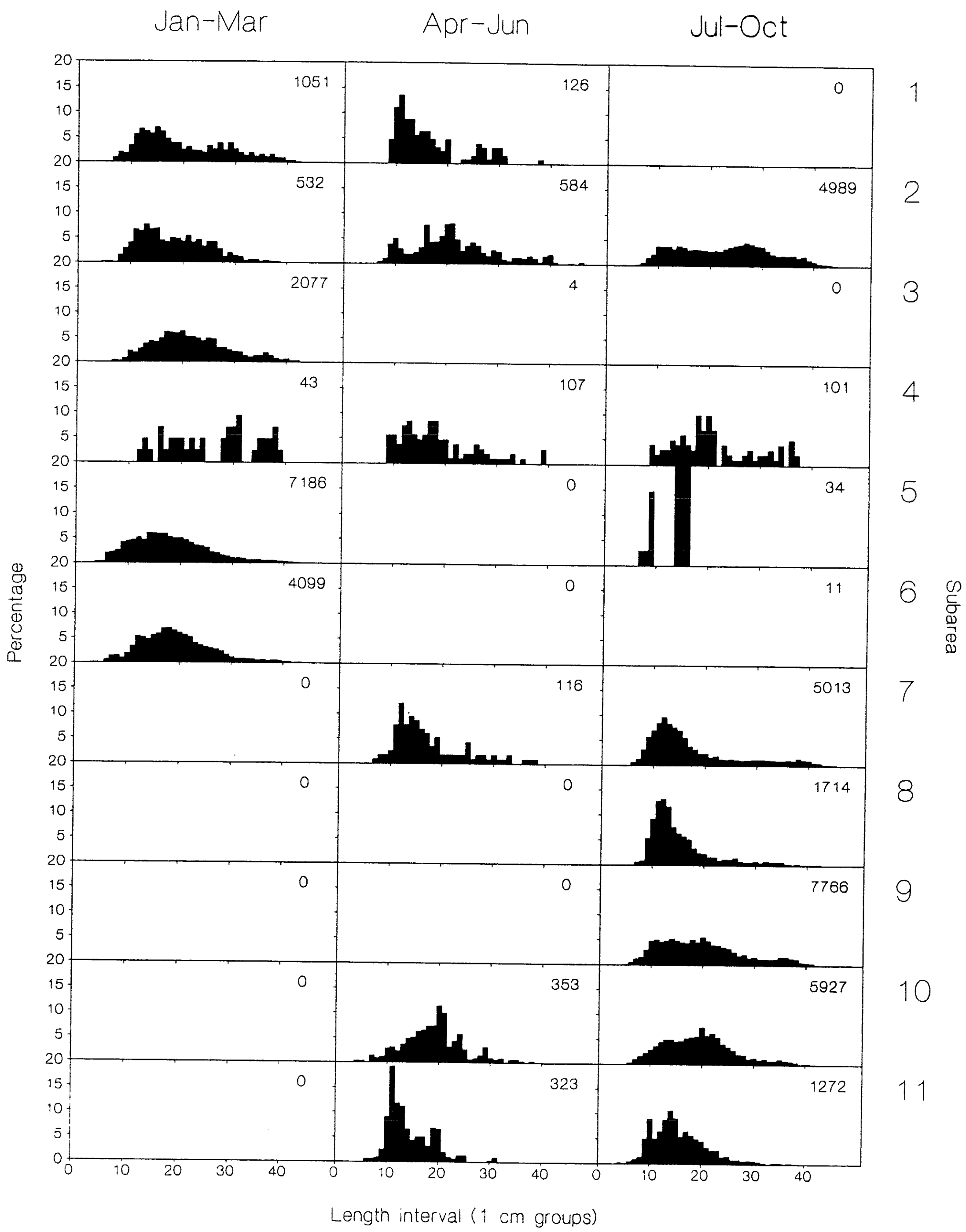
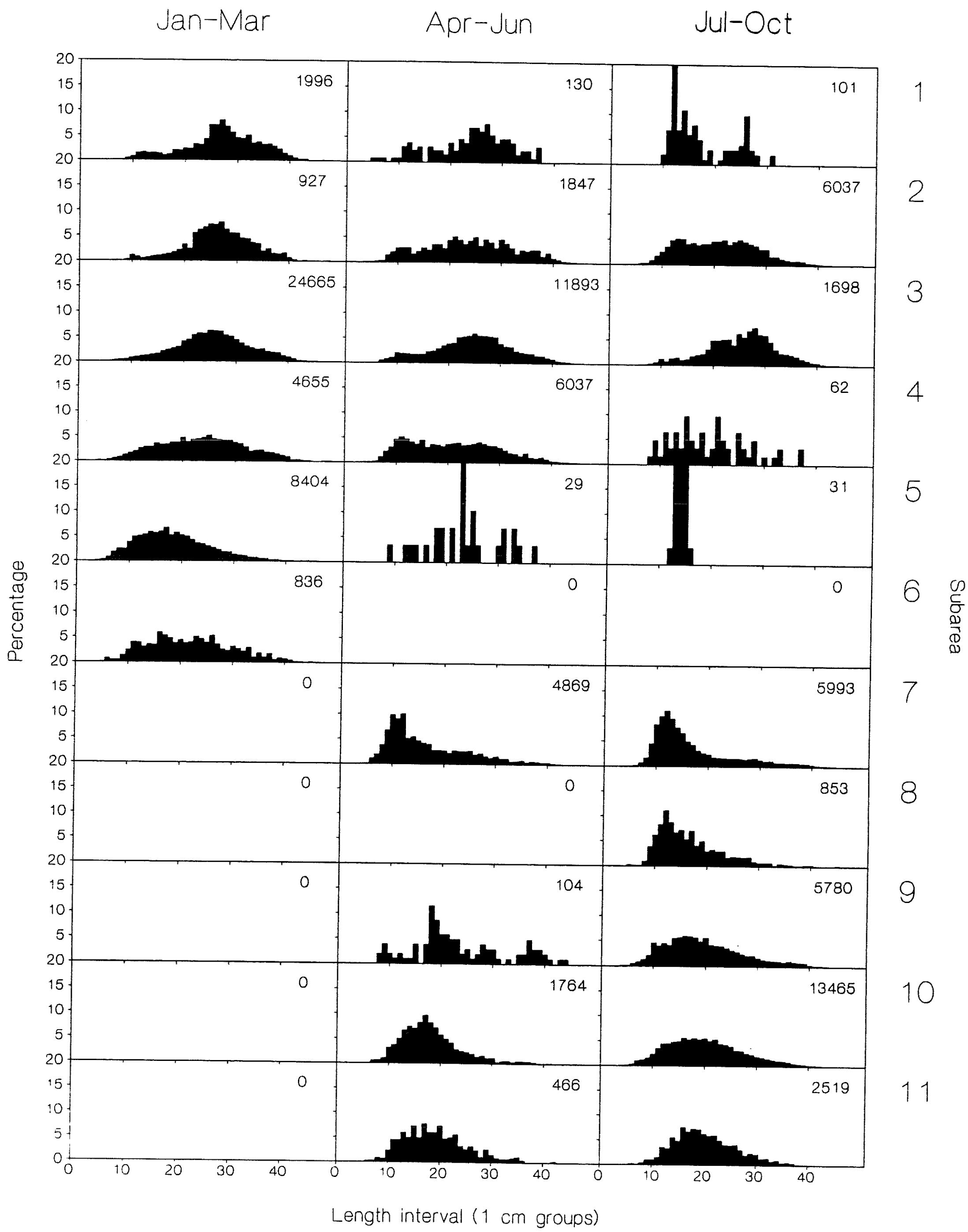

Jan-Mar
Apr-Jun
Jul-Oct
Percentage
1190
224
3478
50-100m
3382
623
11863
101-150m
10472
877
11865
151-200m
12000
3540
16588
201-250m
19570
13161
12901
251-300m
10158
10533
8819
301-350m
6942
8455
7675
351-400m
5353
5174
3985
401-450m
1575
3707
3077
451-500m
13
0
346
501-900m
Length interval (1 cm groups)

Fig. 10.



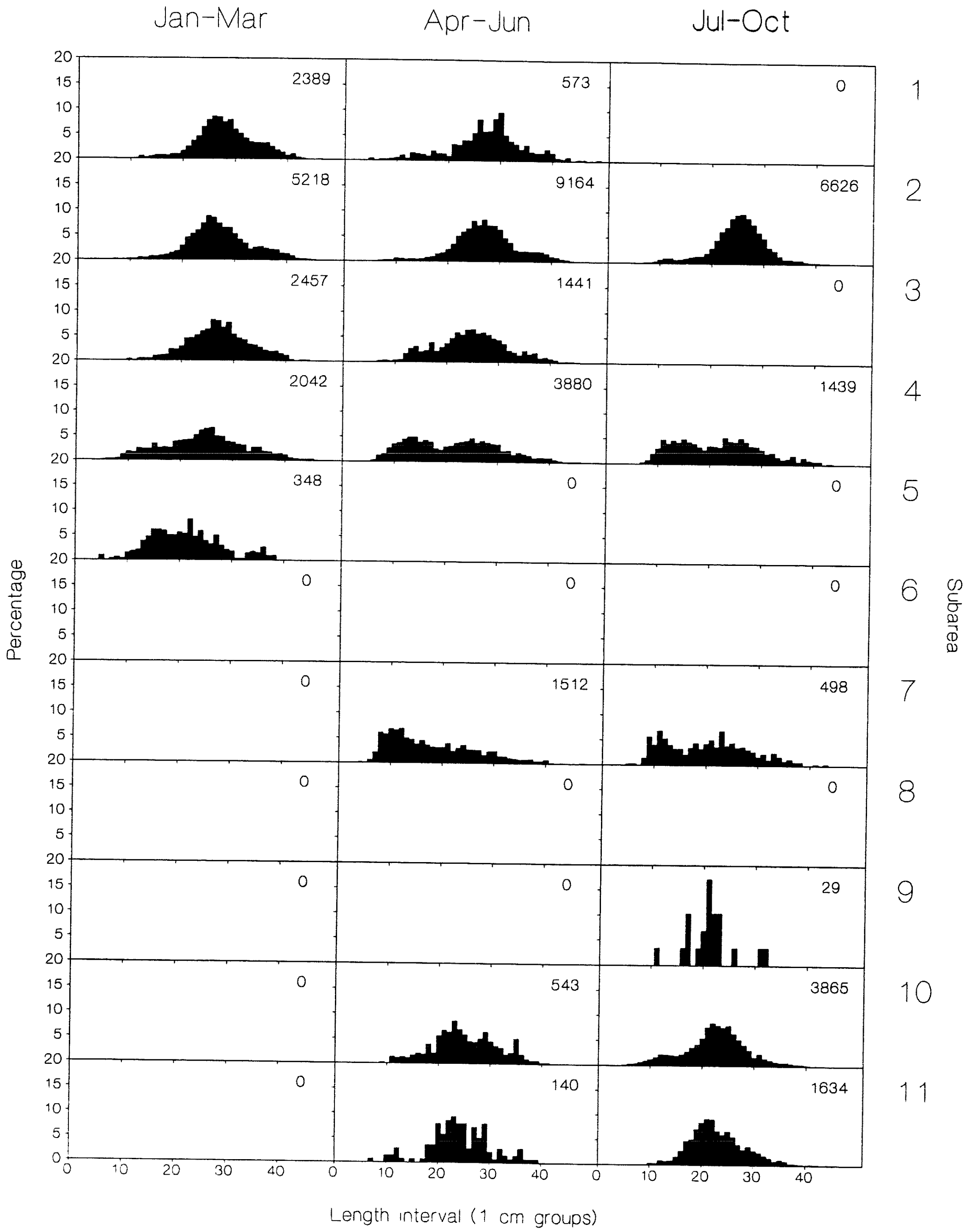
Jan-Mar
Apr-Jun
Jul-Oct
Percentage
Subarea
Length interval (1 cm groups)
1051
126
0
532
584
4989
2077
4
0
43
107
101
7186
0
34
4099
0
11
0
116
5013
0
0
1714
0
0
7766
0
353
5927
0
323
1272

Fig. 11a.



Jan-Mar
Apr-Jun
Jul-Oct
Percentage
Subarea
Length interval (1 cm groups)
1996
130
101
927
1847
6037
24665
11893
1698
4655
6037
62
8404
29
31
836
0
0
0
4869
5993
0
0
853
0
104
5780
0
1764
13465
0
466
2519
1
2
3
4
5
6
7
8
9
10
11

Fig. 11 b



Jan-Mar
Apr-Jun
Jul-Oct
Percentage
Subarea
1
2
3
4
5
6
7
8
9
10
11
2389
573
0
5218
9164
6626
2457
1441
0
2042
3880
1439
348
0
0
0
0
0
0
1512
498
0
0
0
0
0
29
0
543
3865
0
140
1634
Length interval (1 cm groups)

Fig. 11c

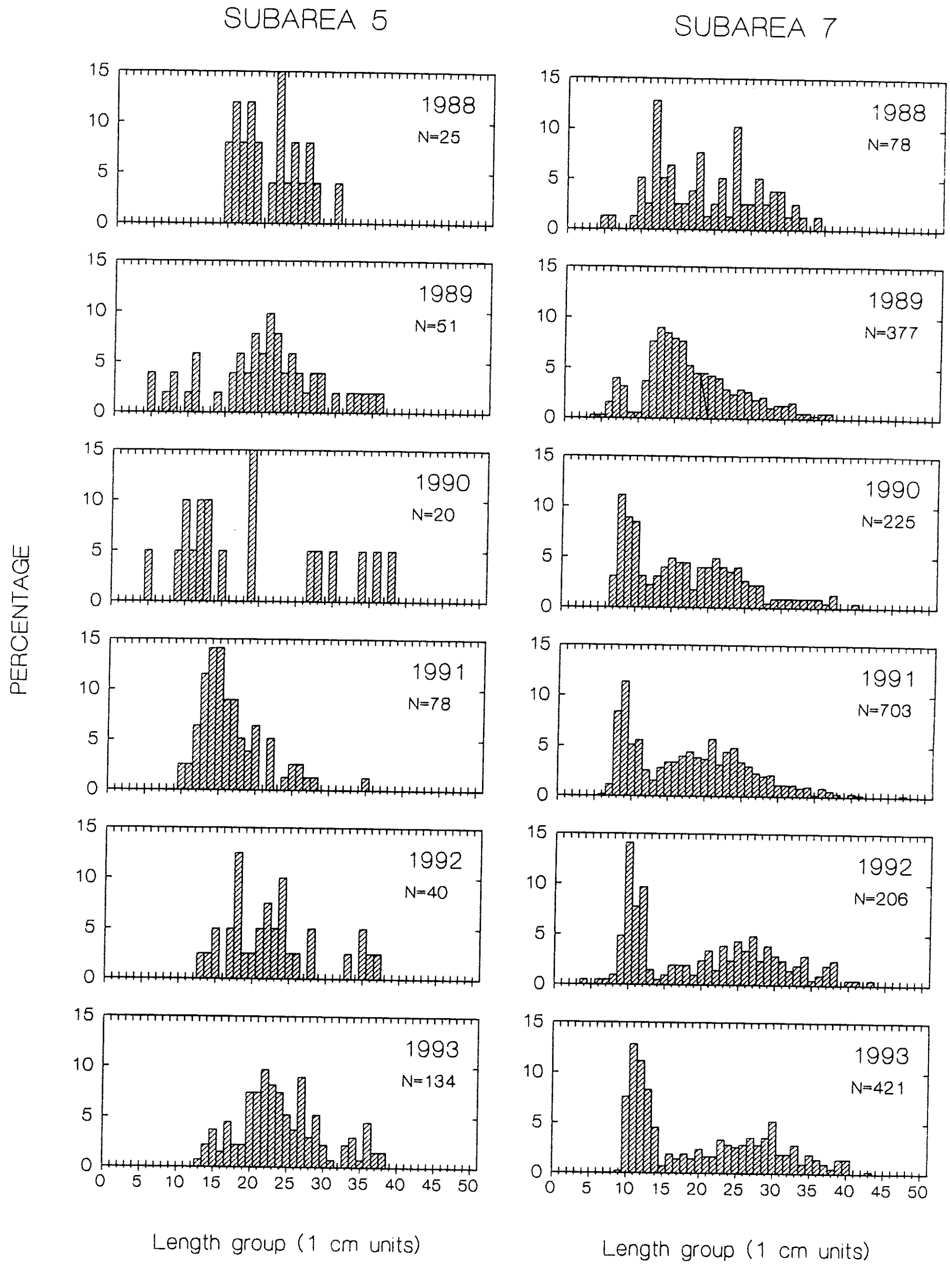

SUBAREA 5
SUBAREA 7
PERCENTAGE
1988
N=25
1989
N=51
1990
N=20
1991
N=78
1992
N=40
1993
N=134
1988
N=78
1989
N=377
1990
N=225
1991
N=703
1992
N=206
1993
N=421
Length group (1 cm units)
Length group (1 cm units)

Fig. 12.

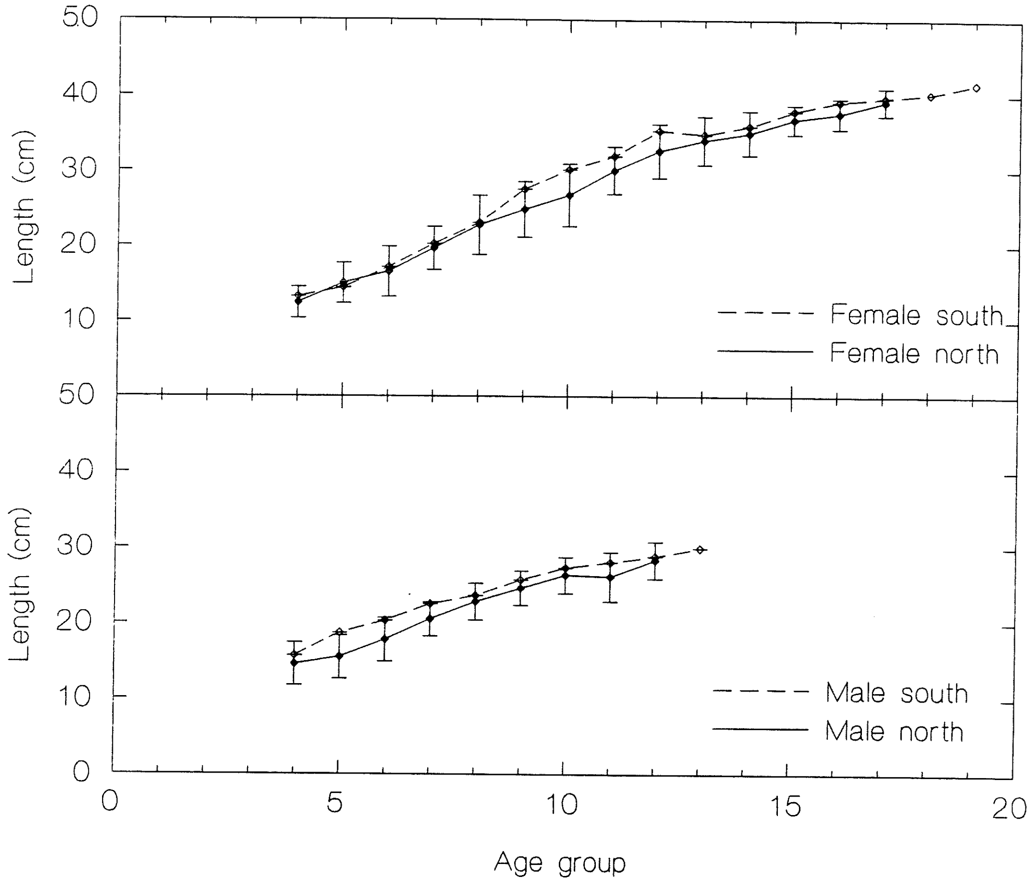
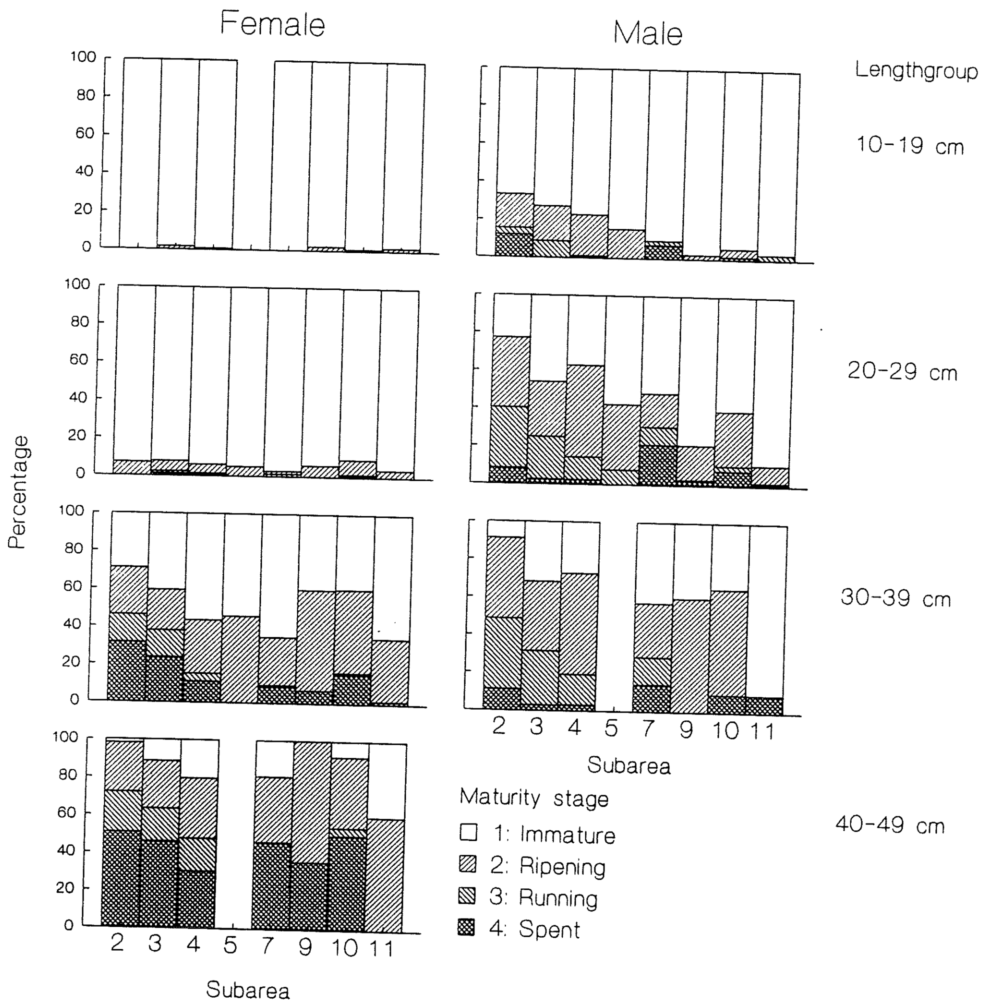

50
40
30
20
10
Length (cm)
Female south
Female north
50
40
30
20
10
0
Length (cm)
Male south
Male north
0
5
10
15
20
Age group

Fig. 13



Female
Male
Lengthgroup
10-19 cm
20-29 cm
30-39 cm
40-49 cm
Percentage
100
80
60
40
20
0
2 3 4 5 7 9 10 11
Subarea
Maturity stage
1: Immature
2: Ripening
3: Running
4: Spent

Fig. 14.

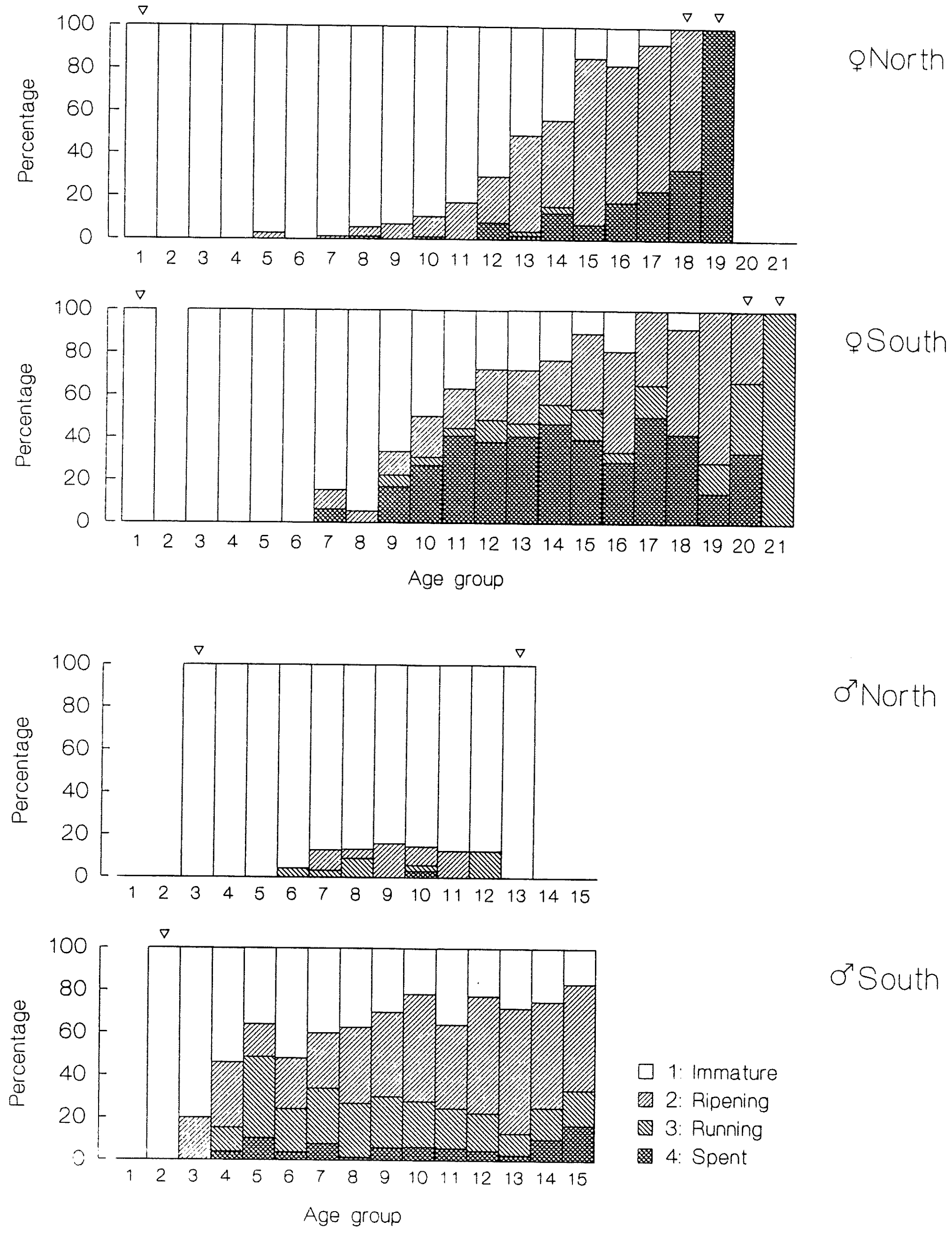

♀North
♀South
♂North
♂South
Percentage
Age group
1: Immature
2: Ripening
3: Running
4: Spent

Fig. 15

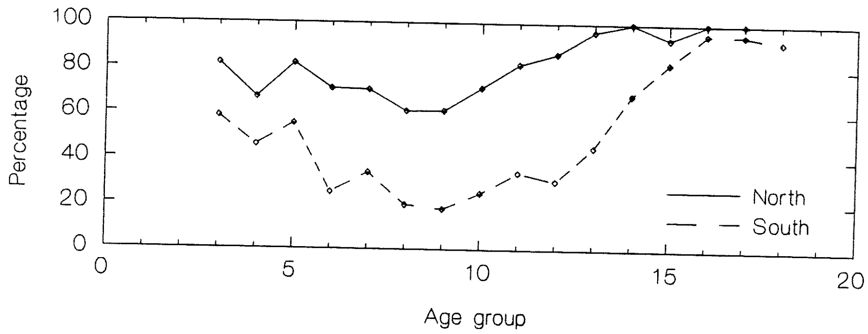
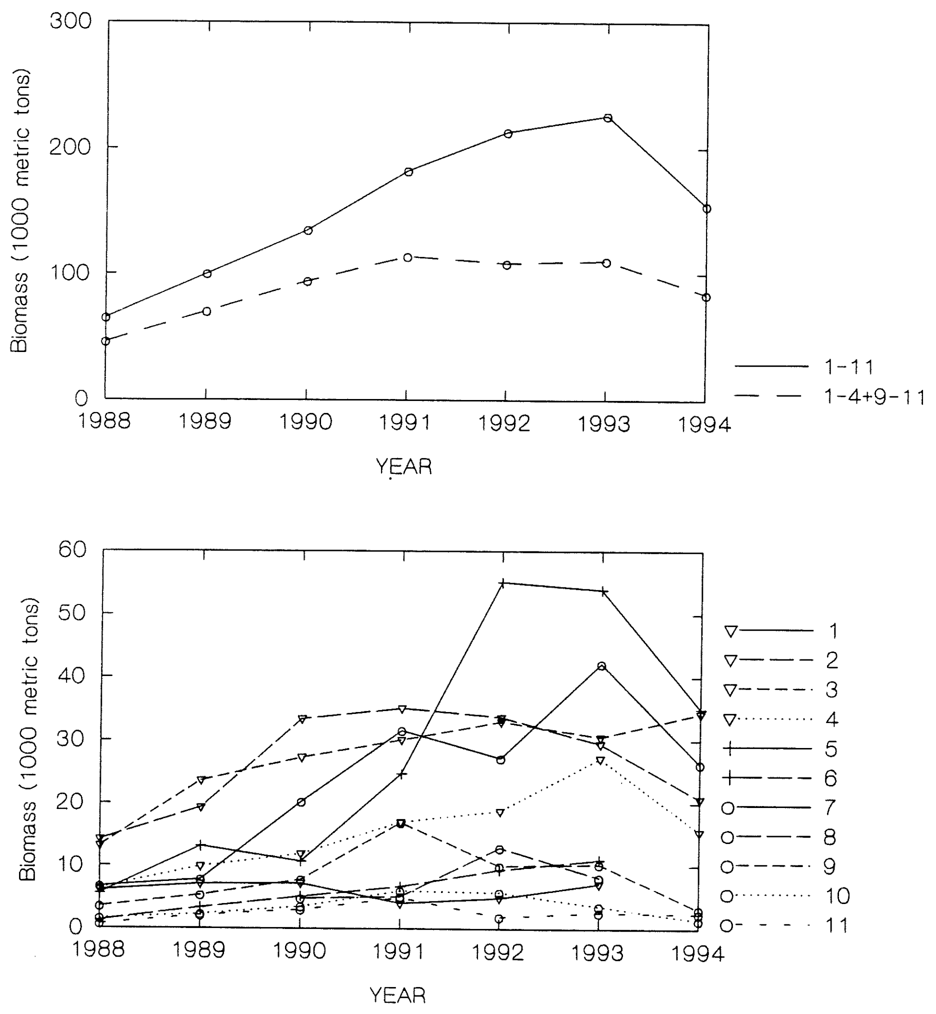


Fig. 16



300
200
100
0
Biomass (1000 metric tons)
1988
1989
1990
1991
1992
1993
1994
YEAR
1-11
1-4+9-11
60
50
40
30
20
10
0
Biomass (1000 metric tons)
1988
1989
1990
1991
1992
1993
1994
YEAR
1
2
3
4
5
6
7
8
9
10
11

Fig. 17.

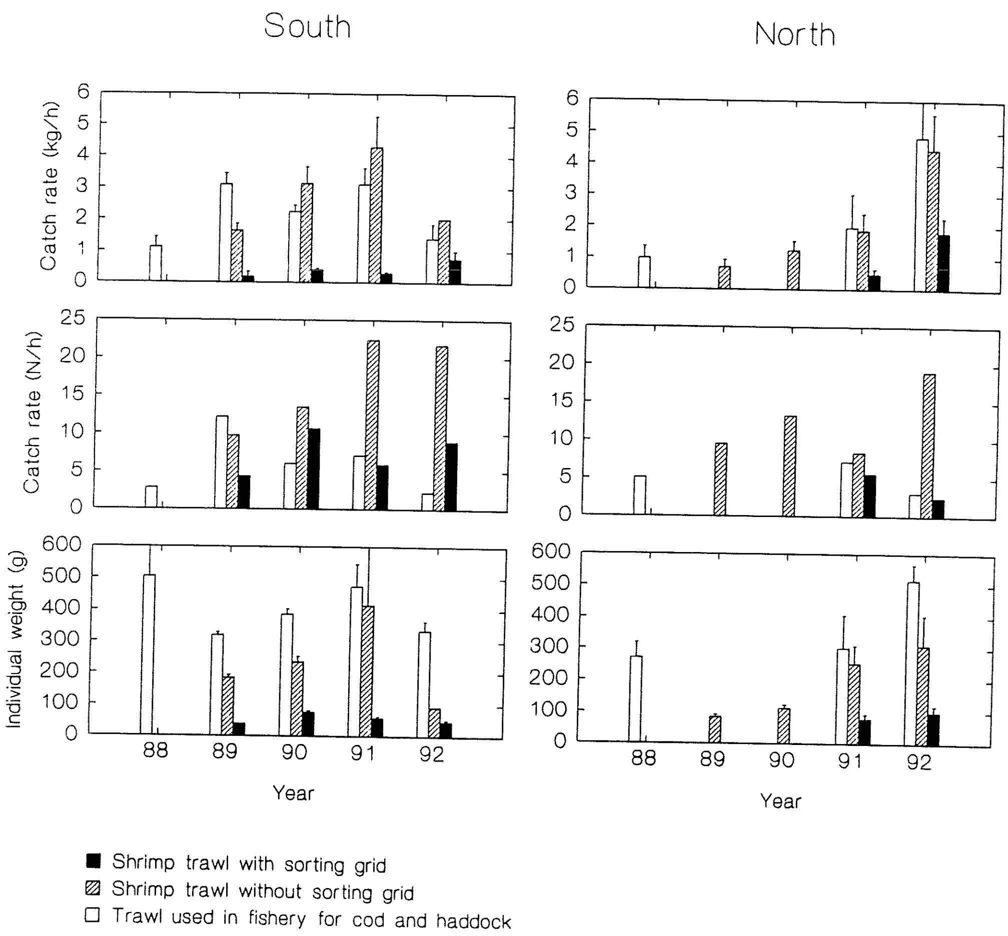

South
North
Catch rate (kg/h)
Catch rate (N/h)
Individual weight (g)
88
89
90
91
92
Year
Shrimp trawl with sorting grid
Shrimp trawl without sorting grid
Trawl used in fishery for cod and haddock

Fig. 18.

Table 1. Classification of maturity stages used in the Norwegian surveys.

MATURITY STAGE	DEFINITION
1: Immature	Small gonads; eggs not visible to the naked eye.
2: Ripening	Larger gonads; eggs are visible.
3: Running	Roe and milt run with slight pressure .
4: Spent / resting / recovering	Testes and ovaries are small, deflated and with blood capillaries. If recovering, gonads are larger than in stage 1.

Table 2. Catch statistics of long rough dab from the Russian surveys in the Barents Sea and Svalbard area: Catch rates in terms of weight and numbers per nautical mile and frequency of occurrence in bottom trawls.

		Barents Sea				Svalbard area			
		NUMBER OF STATIONS		CATCH RATES		NUMBER OF STATIONS		CATCH RATES	
Depth	Year	Total	With long rough dab	N/nm	kg/nm	Total	With long rough dab	N/nm	kg/nm
0 -150m	1988	47	47	10,3	2,8	36	36	18,0	4,4
	1989	58	56	9,9	2,2	2	2	45,6	12,5
	1990	81	73	22,7	6,3	43	43	10,1	3,7
	1991	42	37	16,1	6,0	62	54	26,5	10,8
	1992	30	30	25,7	7,8	30	30	18,8	6,8
	1993	2	2	6,3	2,9	19	19	17,9	6,7
151 -300m	1988	160	156	15,0	4,0	38	38	22,2	5,4
	1989	106	92	18,9	4,3	16	16	47,8	13,0
	1990	251	223	31,8	8,8	64	59	29,5	8,2
	1991	158	152	33,1	12,2	17	85	32,4	13,2
	1992	149	140	30,0	9,1	48	45	56,2	20,3
	1993	63	63	18,5	8,4	37	37	51,7	19,3
301 -450m	1988	16	16	7,9	2,1	27	27	13,2	3,2
	1989	12	12	13,8	3,1	16	15	16,8	4,6
	1990	23	23	12,7	3,5	31	29	8,9	2,5
	1991	35	28	19,3	7,1	28	28	14,1	5,8
	1992	33	19	21,7	6,6	28	26	15,9	5,7
	1993	12	12	24,6	11,2	33	33	18,6	6,9
451 -600	1988					7	7	8,3	2,0
	1989					6	6	9,4	2,6
	1990	1	1	2,2	0,6	11	11	5,3	1,5
	1991					10	10	8,8	3,6
	1992					12	12	8,9	3,2
	1993					14	14	10,7	4,0

Table 3. Maturation of long rough dab: Percentage of each sex and age group that were classified as sexually mature on the Russian surveys. Data from both areas (Barents Sea and Svalbard area) were pooled.

	Males						Females					
AGE	1988	1989	1990	1991	1992	1993	1988	1989	1990	1991	1992	1993
3	100,0	80,0	0,0		100,0	33,3	0,0	0,0	0,0			
4	80,0	79,2	20,8	80,0	100,0	50,0	0,0	0,0	0,0	0,0	0,0	0,0
5	84,2	67,3	45,6	38,9	93,3	66,7	0,0	3,0	2,5	0,0	4,3	0,0
6	90,5	50,9	78,3	48,2	81,1	50,0	11,7	0,0	0,0	0,0	8,1	0,0
7	100,0	50,0	83,3	85,1	83,9	63,6	60,7	11,6	7,0	22,0	8,1	9,1
8	90,0	97,8	93,2	94,4	86,7	89,7	81,4	24,7	26,6	50,0	26,2	29,4
9	100,0	92,9	100,0	87,5	96,7	85,7	92,0	47,4	61,7	65,0	53,5	65,0
10	95,0		100,0	93,6	100,0	98,9	100,0	50,0	75,6	77,3	75,7	86,7
11	99,0			99,0	100,0	99,2	100,0	66,7	89,2	90,6	85,0	78,7
12					100,0	100,0	66,7	100,0	100,0	87,5	95,9	81,8
13						100,0	100,0	100,0	100,0	100,0	92,3	81,8
14							100,0	100,0	100,0	100,0	100,0	87,5
15							100,0			100,0	100,0	100,0
N	108	108	287	184	275	147	142	103	286	321	400	220

Table 4. Effort in terms of hours of trawling and estimated bycatch of long rough dab in the Norwegian shrimp trawl fishery and the trawl fishery for cod and haddock in the Barents Sea. The southern and northern areas correspond to subareas 1-4 and 7-11 respectively.

Shrimp trawl fishery

	HOURS		CATCH RATE (kg/h)		BYCATCH (metric tons)		
YEAR	SOUTH	NORTH	SOUTH	NORTH	SOUTH	NORTH	TOTAL
80	85578	21008	2,13	1,93	182,3	40,5	222,8
81	70130	20264	2,13	1,93	149,4	39,1	188,5
82	109177	34162	2,13	1,93	232,5	65,9	298,5
83	152781	70557	2,13	1,93	325,4	136,2	461,6
84	132823	77973	2,13	1,93	282,9	150,5	433,4
85	105176	126030	2,13	1,93	224,0	243,2	467,3
86	30779	185476	2,13	1,93	65,6	358,0	423,5
87	102617	99631	2,13	1,93	218,6	192,3	410,9
88			2,13	1,93			
89	147517	84714	1,63	0,70	240,5	59,3	299,8
90	173051	60800	3,13	1,23	541,6	74,8	616,4
91	132189	59686	0,28	0,47	37,0	28,1	65,1
92	79080	85861	0,74	1,80	58,5	154,5	213,1

Fishery for cod and haddock

	HOURS		CATCH RATE (kg/h)		BYCATCH (metric tons)		
YEAR	SOUTH	NORTH	SOUTH	NORTH	SOUTH	NORTH	TOTAL
80	136196	8	2,12	2,44	288,7	0,0	288,8
81	89794	93	2,12	2,44	190,4	0,2	190,6
82	87423	0	2,12	2,44	185,3	0,0	185,3
83	85648	0	2,12	2,44	181,6	0,0	181,6
84	82940	499	2,12	2,44	175,8	1,2	177,1
85	67674	577	2,12	2,44	143,5	1,4	144,9
86	100071	459	2,12	2,44	212,2	1,1	213,3
87	174353	13960	2,12	2,44	369,6	34,1	403,7
88	185730	11139	1,11	0,97	206,2	10,8	217,0
89	97141	2434	3,10	2,44	301,1	5,9	307,1
90	53548	8492	2,23	2,44	119,4	20,7	140,1
91	61655	15989	3,11	1,96	191,7	31,3	223,1
92	39369	5132	1,39	4,84	54,7	24,8	79,6