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Results of the Joint Japan/Greenland Trawl Surveys at West Greenland During 1987-95, Roundnose Grenadier (*Coryphaenoides rupestris* Gunnerus)

by

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PLEASE NOTE NEW TITLE

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SHOULD READ

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Abstract

During the period 1987-1995 Japan Marine Fishery Resources Research Center and Greenland Institute of Natural Resources jointly conducted 12 bottom trawl surveys and 4 pelagic surveys at West Greenland. Roundnose grenadier (*Coryphaenoides rupestris*) was the second most common species and was recorded in 11 of the bottom trawl surveys and 2 of the pelagic surveys. The bottom trawl area has been restratified in 200 m depth intervals and the biomass and abundance of roundnose grenadier in all surveys have been recalculated. Further, information on length distributions by depth, age and sex distributions is given. The vertical distribution of roundnose grenadier is analysed based on 59 pelagic hauls covering the entire water column at all time of the day, and length distributions from pelagic trawl hauls are compared to those from bottom hauls.

Introduction

During the period 1987-1995 Japan Marine Fishery Resources Research Center (JAMARC) and Greenland Institute of Natural Resources (former Greenland Fisheries Research Institute) jointly conducted 12 bottom trawl surveys and 4 pelagic surveys (Jorgensen, 1997a) at West Greenland as part of a joint venture agreement on fisheries development and fisheries research in Greenland waters. The surveys were primarily aimed at Greenland halibut (*Reinhardtius hippoglossoides*) (Jorgensen, 1997b). Roundnose grenadier (*Coryphaenoides rupestris*) was the second most common species and was recorded in 11 of the bottom trawl surveys and 2 of the pelagic surveys. Some of the results have previously been reported to NAFO as a number of Research Documents. (Yamada *et al.*, MS 1988a; Yamada *et al.*, MS 1988b; Yatsu and Jorgensen, MS 1989a; Yatsu and Jorgensen, MS 1989b; Jorgensen and Akimoto, MS 1990; Jorgensen and Akimoto, MS 1991; Yano and Jorgensen, MS 1992; Satani *et al.*, MS 1993; Ogawa *et al.*, MS 1994; Yokawa *et al.*, MS 1995; Yokawa *et al.*, MS 1996).

The bottom trawl surveys were conducted as stratified random surveys (Jorgensen, MS 1997b). In the present paper the material from the surveys have been restratified to 200 m depth intervals in order to achieve a better description of the distribution of roundnose grenadier and hence more accurate estimates of biomass and abundance. Further, information on length, age and sex distribution and pelagic occurrence, not previously reported, is given.

Materials and Methods

Data and material were collected during 12 bottom trawl surveys which were directed mainly at Greenland halibut. The surveys were conducted from 1987 to 1995 at different times of the year between April and December and a total of 1036 trawl hauls were carried out. The surveys covered West Greenland from south of Cape Farewell (59°27'N) to Upernavik (72°51'N), between the 3-mile limit and the 200-mile limit or the midline Canada-Greenland, at depths from 34 to 1497 m. NAFO divisions 1C and 1D were covered by all surveys except one, while areas north of 69°57'N and south of 63°03'N, were only covered once. Roundnose grenadier was not encountered in one survey conducted in Div. 1A and 1B in November 1991 (51 hauls) and this survey is not included in the analyses.

In 1990 two pelagic surveys were conducted in the southern part of Div. 1C and in Div. 1D. The outline of the surveys is given in Table 1. Further, two other pelagic surveys conducted in Div. 1B revealed no roundnose grenadier and these surveys are not dealt with in the present paper (Jorgensen, 1997a).

All surveys were carried out by the Japanese research vessel SHINKAI MARU. In the bottom trawl surveys towing time was usually 30 min and average towing speed was 3.5 kn. Mesh size was 140 mm with a 30 mm mesh codend liner. Trawling was carried out in day time only. All catches were standardized to catch per km^2, calculated from the actual towing speed and estimated wing spread. Further description of vessel and gear is given in Jørgensen, MS 1997b. Biomass and abundance estimates were obtained by applying the swept area method taking the catchability coefficient as 1.0.

The bottom trawl survey area was stratified by NAFO Division. The NAFO Divisions 1A (south of 70°N) - 1E have been restratified to 200 m depth intervals, except depth stratum 1401 to 1500 m (Jorgensen, MS 1997b).

In the first pelagic survey, trawling took place within a defined area and the water column was divided into 6 depth strata. Towing time varied between 30 and 90 min. but catches were standardized to catch/hour. In the second pelagic survey fishing took place at three stations with good catches of Greenland halibut and roundnose grenadier in a preceding bottom trawl survey. The water column was divided into four depth strata, further, subdivided into three substrata. These were trawled for 20 min each giving a total fishing time per stratum of 60 min. Towing speed averaged 4.0 knots. The net opening was measured by net sonde and was approximately 30/70 high and 40/80 m wide, respectively, in the two nets (Table 1). In both net mesh size was 140 mm with a 30 mm mesh codend liner.

All catches were sorted by species and weighed to nearest 0.1 kg and the number of specimens recorded (only in a few hauls in 1987). The length was measured as preanal fin length (AFL) to 0.5 cm below. In cases of large catches subsamples of at least 200 specimens were measured. In the bottom trawl survey the length distributions were calculated by 1 cm groups for Div. 1C+1D in the depth intervals 401-800, 801-1000, 1001-1200 and 1201-1500 m, respectively.

Due to lack of time, bad weather, ice coverage and restratification some strata have not been covered in some surveys. In survey used for comparison between years (surveys conducted in July - October) the biomass and abundance in strata without hauls have been estimated by a three-way ANOVA, anticipating that the relative distribution was the same in all years, according to the following:

Ln(biomass or abundance= $\alpha + \beta 1Y + \beta 2Div + \beta 3Dep + \varepsilon$, where

Y=Year, Div=NAFO Division (1C and 1D) and Dep=depth stratum. The model was statistically significant (P> 0.01) and explained 71% of the variation in data. Biomass and abundance was primarely estimated by the ANOVA in depth strata > 1000 m in 1987, but also in some shallow strata in Div. 1D with low biomass and abundance (Table 2 and 3). In strata where biomass and abundance was estimated by the ANOVA and in strata with only on haul, the Standard Error (S.E.) was estimated from a regression between mean biomass or abundance and S.E.

In 1988 scales were collected for age determination (n= 366). The scales were taken between the dorsal fins above the lateral line.The age was determined using polarized light (Kosswig, MS 1979). Age distribution was estimated using age/length keys and survey length frequencies pooled in 1 cm groups.

In the second pelagic survey the temperatures were measured in the water column by CTD, (0.1 °C) two times at each of the three pelagic stations .

Results

Information on stomach contents, growth, spawning, total length distributions by survey, length-weight relations, relation between total length and preanal fin length, distribution in relation to bottom temperatures, and abundance per km^2 has previously been reported in Jorgensen, 1996.

Bottom trawl surveys.

1987

The survey was conducted between July 15 and August 13 and covered Div. 1AS to 1F at depths between 34 and 998 m. In total 117 successful hauls were made. Roundnose grenadier was found in Div. 1C and 1D, in four hauls, (< 250 kg per swept km^2), in the southern part of Div. 1B depth stratum 401-600 and 601-800 m, and in a single haul in Div. 1F (3 kg per swept km^2).

The biomass of roundnose grenadier in Div. 1C-1D, 401-1500 m, was estimated at 83778.2 tons (S.E. 35552.3) which is by far the highest estimate in the time series (Table 2, Fig. 1 and 2). However, the estimate was based on 23 hauls only, and the biomass at depths > 1000 m (47% of the total) was estimated by an ANOVA. The highest biomass was found in Div. 1C depth stratum 801-1000 m. Roundnose grenadier occurred only sporadic at depths < 400 m in Div. 1C, and the biomass was estimated to only 63.1 tons.

Due to incomplete sampling it was not possible to make estimates of abundance.

The lengths ranged between 2 and 16 cm (AFL) and the length distributions were dominated by modes around 9 and 10 in depth strata 401-800 and 801-1000 m (Fig. 3).

1988

The survey was conducted between September 12 and November 11 and covered Div. 1A (to 72°51'N) to 1D at depths between 422 and 1402 m. In total 109 successful hauls were made. Besides a single specimen caught at 70°44'N (Div. 1A) roundnose grenadier was found in Div. 1C and 1D, only (Fig 1).

The biomass in Div. 1C-1D, 401-1500 m, was estimated at 44235.1 tons (S.E. 14358.6) which was only about half the estimate in 1987 but the difference was not statistically significant (95 % level) due to large variation in data (Fig. 2, Table 2). The largest decrease in biomass was seen in Div. 1C, especially in depth stratum 801-1000 m where the biomass was reduced from about 29000 tons in 1987 to about 1500 tons in 1988. The highest biomass was found in Div. 1D depth stratum 1001-1200 m.

The abundance in Div. 1C-1D, 401-1500 m, was estimated at $168475.0*10^3$ (S.E. $68092.3*10^3$) and the distribution of the abundance resembled the distribution of the biomass, *i.e.* the highest abundance was found in Div. 1D depth stratum 1001-1200 m (Table 3).

The lengths ranged from 2 to 22 cm (AFL) and there was a clear increase in length by depth with modes at 6, 9, 9.5, and 14 cm in the four depth intervals (Fig. 3).

The ages ranged from 4 to 20 years and age 7 was the most dominant in both Div. 1C and 1D. Generally the fish seemed to be older in Div. 1D, probably reflecting that the size (age) was increasing by depth. The maximum depth in Div. 1C is about 1200 m and fish were sampled at depths down to 1500 m in Div. 1D. The smallest fish in the age/length key were 6 cm, which implies that fish in the length range 2-5 cm AFL, which constituted 18.5 % of the fish in Div. 1C and 3.7 % of the fish in Div. 1D, have not been included in the age composition.

1989

The survey was conducted between April 30 and May 17 and covered Div. 1C and 1D at depths between 494 and 1497 m. In total 61 successful hauls were made (Fig. 1). Div. 1AS, 1B and the western part of Div. 1C and 1D was not surveyed due to ice.

The biomass in Div. 1C-1D, 401-1500 m, was estimated at 8149.7 tons (S.E. 2900.0) which is a statistically significant (95 % level) drop in biomass on approximately 35000 tons compared to the estimate in 1988. The two surveys were, however, conducted at different time of the year which makes comparison difficult (Fig. 2, Table 2).

Roundnose grenadier was almost absent from Div. 1C and more than 60 % of the biomass was found in the small depth stratum 1401-1500 m in Div. 1D (3091 km^2), where the biomass increased compared to 1988.

The abundance in Div. 1C-1D, 401-1500, m was estimated at 36115.0*10^3 (S.E. 7136.8*10^3) which was a marked, but statistically insignificant, decrease compared to about 155000*10^3 in 1988. The highest abundance was found in Div. 1D depth stratum 1001-1200 m. (Fig 2, Table 3).

The lengths ranged from 2 to 19 cm (AFL) but the length distribution was dominated small fish with a mode around 4.5 cm (AFL) in all depth strata. A mode around 8-9 cm (AFL) was also seen in all depth strata except stratum 801-1000 m. Further, a broad mode at 12-15 cm (AFL) was seen in the deepest depth stratum (Fig. 3).

1990

In 1990 two surveys were conducted The first survey took place between June 9 and June 22 and covered Div. 1B to 1D at depths between 449 and 1482 m. In total 75 successful hauls were made. The second survey took place between August 27 and September 12 and covered Div. 1AS to 1D at depths between 422 and 1467 m. In total 87 successful hauls were made. In both surveys roundnose grenadier was found in Div. 1C and 1D only.

In the first survey the biomass of roundnose grenadier in Div. 1C-1D, 401-1500 m, was estimated at 9184.5 tons (S.E.5762.9) which was close to the 8149.7 tons estimated in the same area in 1989 where the survey took place approximately a month earlier. The bulk of the biomass was found in Div. 1D depth stratum 1401-1500 m as in 1989. The biomass in Div. 1C was very low but had increased slightly compared to 1989 (Table 2).

In the second survey the biomass in Div. 1C-1D, 401-1500 m, was estimated to 19162.0 tons (S.E. 6488.0), which was more than a doubling compared to the survey about two months earlier, but only about the half of the estimate in the comparable survey in 1988 (44235.1 tons). The highest biomass was found in Div. 1D depth stratum 1001-1200 m indicating that the fish have moved towards shallow water in the period since the first survey, where the highest biomass was found in depth stratum 1401-1500 m.

In the first survey the abundance in Div. 1C-1D, 401-1500 m, was estimated at 24810.5*10^3 (S.E. 14227.2*10^3) which is a little lower than in the same area in 1989 (36115.0*10^3), despite the increase in biomass. The distribution of the abundance resembled the distribution of the biomass, *i.e.* the main abundance was found in depth stratum 1401-1500 m (Table 3, Fig. 2).

In the second survey the abundance in Div. 1C-1D, 401-1500 m, was estimated at 76890.8*10^3 (S.E. 29707.2*10^3) which is about three times the estimate in the first survey (24810.5*10^3), although the biomass only was doubled, indicating an influx of small fish, which was also reflected in the length distribution (Fig. 3). The estimate in the second survey was about half the estimate in the comparable survey in 1988 (168475.0*10^3). The highest abundance was found in Div. 1D depth stratum 1001-1200 m.

In the first survey the lengths ranged between 3 and 22 cm (AFL) (Fig. 3). The increase in size by depth seen in most other surveys could not be observed in this survey, except that fish in the deepest depth stratum generally seemed to be the largest and the length distribution was dominated by a broad mode around 15 cm (AFL). The distributions in the three shallow strata were dominated by a number of modes without any clear trends.

In the second survey the lengths ranged from 2 to 21 cm (AFL) and the length distributions in the four depth strata were dominated by modes at 5, 8, 9 and 12 cm indicating a clear increase in size by depth as also seen in the comparable survey in 1988 (Fig. 3).

1991

In 1991 two surveys were conducted. The first survey took place between August 4 and August 30 and covered Div. 1AS to 1D at depths between 38 and 1490 m. In total 139 successful hauls were made. The second survey took place between November 12 and November 27 and covered Div. 1AS and 1B at depths between 38 and 774 m. In total 51 successful hauls were made. No roundnose grenadier were observed during this survey.

All the biomass in the first survey was found in Div. 1C-1D, 401-1500 m except a single specimen caught in depth stratum 601-800 m in Div. 1B. The biomass was estimated at 41890.8 tons (S.E. 16122.4), which was a doubling compared to the second survey the year before, but at the same level as the comparable survey in 1988. The increase in biomass compared to the survey in 1990 was mainly seen in Div. 1C depth stratum 801-1000 m, where also the largest biomass was found. A significant proportion of the biomass was also found in Div. 1D depth stratum 1001-1200 m (Fig 1 and 2, Table 2).

The abundance in Div. 1C-1D, 401-1500 m, was estimated at $240722.4*10^3$ (S.E. $109470.2*10^3$), which was a marked, although not statistically significant, increase compared to the year before ($76890.8*10^3$) (Fig 2, Table 3). The largest increase in abundance was seen in Div. 1C depth strata 601-800 and 801-1000 m, where the largest abundance was found, and in the two shallow strata in Div. 1D, indicating an influx of small fish, which was also reflected in the length distributions (Fig. 3).

The lengths ranged between 1 and 22 cm (AFL) and the length distribution in the four depth strata were dominated by modes around 5, 8, 9 and 12 cm as seen in the second survey in 1990.

1992

In 1992 two surveys were conducted. The first survey took place between August 11 and August 28 and covered Div. 1AS to 1D at depths between 417 and 1475 m. In total 90 successful hauls were made. The second survey was conducted between November 25 and December 7 and covered Div. 1C-1D at depths between 510 and 1400 m. In total 49 successful hauls were made. Due to severe damage of the trawl in the second survey, the trawl was replaced at haul 15. Although the two trawls were almost identical there was found a statistically significant difference in the catchability of Greenland halibut in the two trawls (Satani *et al.* MS 1993). The difference in the catchability of roundnose grenadier was a factor 3.1 but the difference was not statistically significant due to large variation in data. All catches after haul 15 were, however, multiplied by 2.4.

Roundnose grenadier was found in Div. 1C and 1D, only, in the two surveys. In the first survey the biomass was estimated at 43132.5 tons (S.E. 15192.5), which was at the same level as the survey in 1991 (41890.8 tons) and the distribution of the biomass in the two surveys was very much alike, *i.e.* with the highest biomass in Div. 1C depth stratum 801-1000 m closely followed by Div. 1D depth stratum 1001-1200 m. (Fig. 1 and 2, Table 2).

In the second survey the biomass dropped significantly (95% level) to only 1101.5 tons (S.E. 341.7) compared to the survey three month earlier (43132.5 tons) (Fig. 1, Table 2). The highest biomass was found in depth stratum 1201-1400 m. Depth stratum 1401- 1500 m was not covered in this survey. The biomass in this stratum was, however, estimated at 135 tons only in the first survey. On the other hand relative high biomasses have been recorded in the stratum in the spring in 1989 and 1990, when the overall biomasses were low.

In the first survey the abundance in Div. 1C-1D, 401-1500 m, was estimated at $311969.2*10^3$ (S.E. $12525.0*10^3$) which was a minor increase compared to about $240000*10^3$ in 1991. The highest abundance, $150859*10^3$, was found in Div. 1C, depth stratum 801-1000 m. (Fig 2, Table 3).

In the second survey the abundance in Div. 1C-1D, 401-1400 m, was estimated at $22256.7*10^3$ (S.E. $5557.0*10^3$) which is a statistically significant drop compared to the first survey ($311969.2*10^3$ S.E. $125525.0*10^3$). The highest abundance was found in the two deepest strata surveyed in Div. 1D (1001-1400 m) (Table 3).

In the first survey the lengths ranged between 1 and 19 cm (AFL) and the length distributions in the four depth strata were dominated by modes around 6, 9, 11 cm similar to what was seen in previous surveys conducted at the same time of the year (Fig 3).

In the second survey the lengths ranged between 1 and 15 cm (AFL). Clear modes were also seen in the four depth strata but they were now located around 4 and 6 cm (AFL) in the two shallow and the two deep strata, respectively (Fig. 3).

1993

The survey was conducted between August 20 and September 8 and covered Div. 1B to 1D at depths between 435 and 1418 m. In total 87 successful hauls were made.

Roundnose grenadier was found in Div. 1C-1D, only, and the biomass was estimated at 8029.3 tons (S.E. 1676.4), which is a marked, but statistically insignificant, decrease compared to 1992 (43132.5 tons S.E. 15192.5) (Fig. 1 and 2, Table 2). The reduction in biomass was seen in almost all depth strata but it was most pronounced in Div. 1C depth stratum 801-1000 m (statistically significant (95 % level)). The highest biomass was found in Div. 1D depth stratum 1001-1200 m.

The abundance in Div. 1C-1D, 401-1500 m, was reduced, statistically insignificantly, to $40208.8*10^3$ (S.E. $13820.7*10^3$) compared to $311969.2*10^3$ (S.E. $125525.0*10^3$) in 1992. The reduction in abundance was seen in all depth strata. The highest abundance was found in Div. 1D depth stratum 1001-1200 m, where it used to be located in Div. 1C depth stratum 8001-1000 m at this time of the year (Table 3, Fig. 2).

The lengths ranged from 2 to 19 cm (AFL) and the length distribution in the four depth strata resembled the distribution in the comparable surveys in having modes at 3.5, 6, 9 and around 11 cm, respectively, although the position of the modes are varying slightly between years. Further, minor modes were seen at 6 cm in depth stratum 401-800 m and a mode at 4 cm in depth stratum 1201-1500 m (Fig. 3).

1994
The survey was conducted between August 2 and August 19 and covered Div. 1B to 1D at depths between 439 and 1472 m. In total 80 successful hauls were made.

Roundnose grenadier was found in Div. 1C and 1D, only. The decrease in biomass seen since 1992 continued in 1994 and the biomass in Div.1C-1D, 401-1500, m was estimated at 3144.4 tons (S.E. 909.4), which was the lowest estimated biomass in comparable surveys in the time series, and statistically significant (95% level) lower than the estimate on 431325 tons in 1992. Compared to 1993, the reduction in biomass was seen in all depth strata. The highest biomass was found in Div. 1D depth stratum 1201-1400 m, where it was found in depth stratum 1001-1200 in 1993 (Fig. 1 and 2, Table 2).

The abundance was estimated to an all time low, $16682.0*10^3$ (S.E.$5985.6*10^3$), which was statistically significant lower (95 % level) than the estimate from 1992 ($311969.2*10^3$ S.E. $125525.0*10^3$), and less than half of the estimate in 1993 ($40208.8*10^3$) (S.E. $13820.7*10^3$). The reduction in abundance compared to 1993 was seen in almost all strata but was most pronounced in Div. 1D depth strata 1001-1200 m and 1200-1400 m. As in 1993, the highest abundance was seen in Div. 1D depth stratum 1001-1200 m (Table 3, Fig. 2).

The lengths ranged between 1 and 18 cm (AFL). As in the previous survey at this time of the year the length distribution in the four depth strata were dominated by modes at 4 cm, around 6 cm, 8 cm and, in the deepest stratum, a broad mode ranging from 8 to 12 cm. The position and width of the modes are, however, varying between years (Fig. 3).

1995
The survey was conducted between August 12 and September 1 and covered Div. 1AS to 1D at depths between 422 and 1463 m. In total 91 successful hauls were made.

Roundnose grenadier was found in Div. 1C and 1D, only. The decrease in biomass seen since 1992 seemed to have stopped and the estimated biomass in Div. 1C-1D, 401-1500 m, increased from 3144.4 tons (S.E. 909.4) in 1994 to 7187.2 tons (S.E. 2445.7) in 1995 (Fig. 1 and 2, Table 2). The increase in biomass was seen in almost all depth strata. The highest biomass was found in Div. 1D depth stratum 1001-1200 as in the year before.

The abundance also increased from $16682.0*10^3$ (S.E. $5985.6*10^3$) in 1994 to $31745.2*10^3$ (S.E. $13016.3*10^3$) in 1995. The increase in abundance was seen in almost all strata, but was most pronounced in Div. 1C depth stratum 601-800 m, where the highest abundance was observed as in the beginning of the time series (Table 3, Fig. 2).

The lengths ranged from 2 to 21 cm (AFL) and the length distribution in the two shallow strata were dominated by clear modes at 4.5 and 7 cm, respectively. In depth stratum 1001-1200 m were seen three modes at 4, 9 and 11 cm, respectively, and in depth stratum 1201-1500 m two modes at 4 and around 12 cm were seen. (Fig. 3).

<u>Sex ratio.</u>

Although varying between years the trends in the sex ratio was the same thoughtout the period in surveys conducted in the summer time (July-October). (There were to few observations in the spring and autumn surveys to draw any conclusions about the sex ratio). The percentage of males was gradually decreasing by depth from 70.3 % at depth stratum 801-1000 m to about 50 % at depths > 1400 m (Table 4). (The figure on 52.1 % males at depth stratum 601 - 800 m is based on 7 fish only). Overall 59.2 % of the sexed specimens were males in the summer surveys. If all surveys are included 56.1 % of the specimens were males. Atkinson and Power (MS 1987b) also found a dominance of males (64%) in Subarea 1, but without any trends in the distribution by depth.

Pelagic surveys.

In total 59 pelagic hauls were made in the two pelagic surveys (Table 1). In the first survey roundnose grenadier was caught in 4 of the 24 hauls. In the stratum closest to the bottom 2 (0.2 kg) and 6 (0.2 kg) specimens were taken at noon and sunset, respectively. In the stratum 420 - 550 m from the surface (approximately in the middle of the water column) 2676 (389.4 kg) and 1 specimen (0.3 kg) were taken at midnight and noon, respectively. The lengths ranged from 2 to 16 cm with a mode around 9 cm (n=352). The catches of roundnose grenadier at two bottom trawl stations in the pelagic survey area in the preceeding bottom trawl survey were rather poor, 4.7 and 53.2 kg per swept km^2, and the length distribution was bimodal with modes around 5 and 14 cm (n=44) (Fig. 5).

In the second survey roundnose grenadier was caught in 18 of the 35 hauls. The largest catch was 365 specimens (63.9 kg). Roundnose grenadier was taken in all four depth strata, but it was most common in the depth stratum closest to the bottom, where it was taken at all time of the day (Tables 5 and 6). It was also taken at all time of the day in depth stratum 550-800 m with the largest catch at midnight. The catches in two upper depth strata were all low and without any clear trend in the catch distribution by the time of the day. As the length distributions in all strata at all time of the day were very much alike the length frequency data have been pooled. The length ranged from 2 to 17 cm with a mode around 9 cm (n=1711), which resembled the length distribution at the three bottom trawl stations at the same position as the pelagic stations (n=934) (Fig. 5). The catches on the bottom at the three stations varied between 788.1 and 2259.6 kg per swept km^2. The temperature ranges were 2.5-5.2, 3.9-4.5, 3.7-4.5 and 3.2-3.9 °C in the four depth strata, respectively.

Discussion

Bottom trawl surveys

Roundnose grenadier was distributed from the southern part of Div. 1B and southward, apart from a single ocurrence in Div. 1A 70°44'N. It was usually found at depths > 400 m and most common at 1000-1200 m, but the depths with greatest abundance varied between years and by year. Roundnose grenadier was not found in Div. 1E and only sporadic in Div. 1F, but this is probably because the coverage of the relevant depths has been very poor.

The highest estimated biomass was observed in 1987 (84000 tons in Div. 1C-1D). The estimate was however based on 23 hauls only, and the biomass at depths > 1000 m (47% of the total) was estimated from on an ANOVA, in which 1987 was the first year in the time series. On the other hand was the biomass in the area (including the southern part of Div. 1B) estimated to about 100000 tons, by a Canadian survey in 1986 (Atkinson and Power MS 1987a). The biomass was almost halved to 44000, tons between 1987 and 1988 and the biomass remained at this level, with some fluctuations, until 1992. Since then the biomass has decreased to about 8000 tons in 1995. The reason for this decrease is not known. The bottom temperatures in the area have been stable throughout the period (Jorgensen MS 1997b). The trawl fishery for Greenland halibut in the area has been increasing during the period. The reported catches of roundnose grenadier have been very low (< 300 tons Anon. 1997). It can, however, not be excluded that the fishery for Greenland halibut has had a negative influence on the roundnose grenadier stock. Most of the roundnose grenadier in the area are small and will probably escape through the 140 mm net used in the Greenland halibut fishery, but roundnose grenadier is rather fragile and might be lethally injured in that process. The area off West Greenland seems to be a feeding area for roundnose grenadier, which to a large extend feeds on pelagic Crustacea (Jorgensen, 1996). Decrease in the primary and secondary production could, on the other hand, have changed the availability of food and hence caused the observed decrease in the abundance of roundnose grenadier.

The estimates of biomass and abundance was encumbered with great uncertainty due to large variations in the catches within the single stratum. This made it hard to make any firm conclusions about variations in biomass and abundance. From the biomass estimates from different times of the year, however, a certain movement pattern could be indicated. The biomass was low and found mainly at deep water, primarily in Div. 1D, in the spring (the survey in 1989 and the first survey in 1990). Roundnose grenadier then gradually moved to shallow water and towards Div. 1C, where it was found during the summer. In the autumn roundnose grenadier moved towards deeper water and left the survey area (the surveys in 1992). These movements were probably related to feeding.

In most of the surveys conducted during the summer a clear increase in length by depth is observed, but generally the fish are small with modes at 12-14 cm (AFL) in the deepest stratum. This increase by depth was also observed by Atkinson and Power (MS 1987a).

The age distribution in 1988 was dominated by age 7 which corresponds to an AFL length of 9 cm (Jorgensen, 1996) and idicates a rather slow growth. The age reading was based on scales but this method has never been validated. Savvatimsky *et al.* (1977) found a good agreement between age readings done by means of scales and otoliths, while Atkinson *et al.* (1982) found great discrepancies in the results of the two methods. The best study was made by Bergstad (1990), who found marked discrepancies in the results based on the two methods, when he compared age readings based on scales and otoliths from the same fish. The oldest age read from scales was 20 years, while the oldest age read from otoliths was 50 years. In an analysis of the age structure of roundnose grenadiers in Skagerrak by means of otoliths he found 72 years old fish, and ages on 40-50 years were not unusual. Bergstad recommended otoliths for age readings because he found it difficult to read scales from small fish and he often overestimated the age of small fish compared to what seemed to be reasonable in relation to the length of the fish. Fish older than 10-13 years were also difficult to read on scales, and there was a tendency to underestimate the age of older fish based on scales compared to the age obtained from otoliths, probably because the growth of the scales ceases when the somatic growth rate is reduced by age.

Pelagic surveys

The biomass estimate in the first bottom trawl survey in 1990 was low (9000 tons) and the catches in the following pelagic survey were also low except in a single haul. Due to the low catches it was not possible to deduce any pattern in the distribution in relation to depth and time of the day. The length distribution on the bottom differed from the distribution in the water column, the pelagic fish generally being larger compared to fish taken on the bottom. The number of fish taken on the bottom were, however, scarce. In the second bottom trawl survey the biomass had increased to 19000 tons (Table 2) and the pelagic net used in the first survey was replaced by a larger in the second survey (Table 1). The higher biomass (abundance) and the larger net in combination was probably the reason for the better catches in the second pelagic survey. Roundnose grenadier was caught all over the water column, but the best catches were made in the near bottom stratum and in the stratum above (Tables 5 and 6). There was a tendency towards better catches during the night, but the number of hauls and the variation in data did not allow any firm conclusions. The length distributions on the bottom and pelagic very much alike implying that the entire population makes migrations into the water column probably for feeding (Jorgensen, 1996)

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References

Anon. 1997. Scientific Councils Reports 1996. Northwest Atlantic Fisheries Organization.

Atkinson, D.B., W. R. Bowering, D.G. Parsons, Sv. Aa Horsted and J.P.Minet. 1982. A review of the biology and fishery for roundnose grenadier Greenland halibut and northern shrimp in Davis Strait. *NAFO Sci. Coun. Studies*, **3**: 7-27.

Atkinson, D.B. and D. Power. MS 1987a. An Evaluation of the Status of Roundnose Grenadier in Subarea 0+1 and 2+3. *NAFO SCR Doc.* No. 39, Serial No. N1324. 11 pp.

Atkinson, D.B. and D. Power. MS 1987b. Distribution of Roughead and Roundnose Grenadiers in the Northwest Atlantic. *NAFO SCR Doc.* No. 94, Serial No. N1398. 28 pp.

Bergstad O.A. 1990. Distribution, population structure, growth and reproduction of roundnose grenadier *Coryphaenoides rupestris* (Pisces:Macrouridae) in the deep waters of Skagerrak. *Marine Biology* **107**, 25-39.

Jorgensen, O A. 1996. Distribution and Biology of Grenadiers (Macrouridae) in West Greenland Waters, *J. Northw. Atl. Fish. Sci.*; **18**: 7-29.

Jorgensen, O. A. 1997a. Pelagic occurrence of Greenland halibut, *Reinhardtius hippoglossoides* (Walbaum) in West Greenland waters. *J. Northw. Atl. Fish. Sci.*; **21**, in press.

Jorgensen, O. A. MS 1997b. Results of the joint Japan Greenland trawl surveys at West Greenland during 1987-1995. Greenland halibut (*Reinhardtius hippoglossoides*, Walbaum). *NAFO SCR Doc.* This meeting.

Jorgensen, O. and K. Akimoto. MS 1990. Results of a Stratified Random Bottom Trawl Survey in NAFO Subarea 1 in 1989. *NAFO SCR Doc.* No. 39, Serial No. N1756, 14p.

Jorgensen, O. and K. Akimoto. MS 1991. Results of two Trawl Surveys in NAFO Subarea 1 in 1990. *NAFO SCR Doc.* No. 50, Serial No. N1933, 14p.

Kosswig, K. MS 1979. A note on the age and growth of the rough head grenadier (Macrourus berglax) at East Greenland (Dohrn Bank) in 1978. *ICES C.M. Doc.*, No. G:59, 4p.

Ogawa, M., K. Yokawa and O. Jorgensen. MS 1994. Results of a Stratified Random Bottom Trawl Survey off West Greenland in 1993. *NAFO SCR Doc.* No. 31, Serial No. N2399. 12p.

Satani, M., S. Kawahara and O. Jorgensen. MS 1993. Results of two Stratified Random Bottom Trawl Surveys off West Greenland in 1992. *NAFO SCR Doc.* No. 58, Serial No. N2241, 12p.

Savvatimsky, P.I., H. Koch and P. Ernst. 1977. On comparison of the methods of age determination of grenadiers (Macrouriformes, Pisces) of the North Atlantic. *Voprosy Ikhtiolgii*, 17:324-327.

Smidt, E.L.B. 1969. The Greenland halibut, *Reinhardtius hippoglossoides* (Walb.). Biology and Exploitation in Greenland Waters. *Medd. Danm. Fisk. og -Havunders. N.S.* **6**: 79-148.

Yamada, H., K. Okada and O. Jorgensen. MS 1988a. West Greenland Groundfish Biomasses Estimated from a Stratified-random trawl survey in 1987. *NAFO SCR Doc.* No. 31, Serial No. N1469, 6p.

Yamada, H., K. Okada and O. Jorgensen. MS 1988b. Distribution, Abundance, Size Composition of Greenland halibut Estimated from a Stratified-Random Trawl Survey off West Greenland in 1987. *NAFO SCR Doc.* No. 34, Serial No. N1473, 6p.

Yano, K. and O. Jorgensen. MS 1992. Results of two Stratified Random Bottom Trawl Surveys at West Greenland in 1991. *NAFO SCR Doc.* No. 48, Serial No. N2100, 14p.

Yatsu, A. and O. Jorgensen. MS 1989a. West Greenland Groundfish Biomasses Estimated from a Stratified-random trawl survey in 1988. *NAFO SCR Doc.* No. 30, Serial No. N1607, 7p.

Yatsu, A. and O. Jorgensen. MS 1989b. Distribution, Abundance, Size, Age, Gonad Index and Stomach Contents of Greenland halibut (*Reinhardtius hippoglossoides*) off West Greenland in September/October 1988. *NAFO SCR Doc.* No. 31, Serial No. N1606, 12p.

Yokawa, K., H. Shimizu, O. Jorgensen and H. Yamada. MS 1995. Results of a Stratified Random Bottom Trawl Survey off West Greenland in 1994. *NAFO SCR Doc.* No. 23, Serial No. N2531, 12p.

Yokawa, K., I. Kouya and O. Jorgensen. MS 1996. Results of a Stratified Random Bottom Trawl Survey off West Greenland in 1995. *NAFO SCR Doc.* No. 29, Serial No. N2702, 12p.

Table 1. Outline of pelagic trawl surveys conducted at West Greenland, 1990.

	Period	Area	Bottom depth (m)	No. of hauls	Netopening (m)	Strata (m)
Survey 1	22.6-27.6 1990	63°09'N - 63°49'N				50[*1)]-150 b.s
						220-350 b.s
		and	916-1563	24	30x40	420-550 b.s
						380-150 a.b.
		53°02'W - 53°51W				20 a.b
Survey 2	14.9-19.9 1990	64°04'N 54°37'W	1073	12		50[*1)]-300 b.s
						301-550 b.s
		63°35'N 54°29'W	1119	12	70x80	551-800 b.s.
						801-20 a.b.
		64°19'N 55°38'W	1079	11		

[*1)] position of head rope. All other strata limits are position of ground rope. b.s. below surface a.b. above sea bottom.

Table 2. Biomass (tons), number of hauls and Standard Error (S.E.) by NAFO Division, depth stratum, year and cruise number. Biomass figures in **bold** are estimated from an three-way ANOVA and S.E. in **bold** are estimated from a regression between biomass and S.E. (see text).

	Year	1987	1988	1989	1990	1990	1991	1992	1992	1993	1994	1995
Div	Depth (m)				1	2	1	1	2			
1C	0-200	0 10/0										
	201-400	63.1 6/44.0										
	401-600	2209.3 3/801.8	25.6 5/18.9	3.9 4/1.6	200.5 5/149.4	14.5 5/13.9	8.0 5/4.0	24.3 5/19.7	0 2/0	0 4/0	0 4/0	1.1 3/1.1
	601-800	835.0 8/499.7	333.0 18/185.6	0 10/0	55.7 13/36.6	188.2 16/76.0	1719.6 16/1059.4	181.6 20/151.6	26.7 14/11.3	19.0 22/13.5	32.3 16/17.4	30.4 16/11.3
	801-1000	29256.3 5/13118.3	1483.0 11/581.7	37.9 8/30.2	53.0 13/36.0	1288.0 11/614.5	12653.7 11/4529.7	14513.8 7/3911.9	151.9 8/34.0	851.0 9/532.4	294.6 10/139.0	1150.3 14/666.8
	1001-1200	**752.2** **-/331.0**	1745.4 2/1553.8	1.8 2/0.3	2.7 2/0.4	570.9 2/89.3	1813.4 2/650.7	517.9 2/94.4	25.4 2/3.0	252.8 2/164.1	200.8 2/70.1	81.3 2/50.8
1D	0-200	0.0 5/0										
	201-400	0 3/0										
	401-600	**37.1** **-/16.3**	**4.0** **-/1.8**	89.1 2/13.9	74.9 2/74.9	226.0 1/**99.4**	254.2 2/253.0	120.3 2/41.5	63.7 1/**28.0**	16.9 2/6.1	**0.4** **-/0.2**	**0.5** **-/0.2**
	601-800	1096.8 **-/482.6**	**13.8** **-/6.1**	4.4 1/**1.9**	0.4 3/0.4	21.8 1/**9.6**	1895.6 3/1814.9	3693.0 3/1920.2	10.0 2/6.6	**2.2** **-/1.0**	7.0 2/2.8	**1.8** **-/0.8**
	801-1000	10814.5 6/3240.7	6949.7 7/3754.4	99.0 3/83.5	319.3 4/304.6	1586.5 7/1498.6	5914.0 5/4533.1	5016.8 4/4893.8	26.2 3/3.7	169.9 7/90.7	22.7 4/11.2	66.3 8/20.1
	1001-1200	**27928.4** **-/12288.5**	23807.4 17/6356.6	1138.0 14/395.6	706.9 14/118.8	9605.6 20/2215.5	12186.1 15/2625.1	13810.3 16/2606.0	363.9 12/67.4	3549.0 19/576.2	890.5 14/218.9	1576.3 15/428.0
	1201-1400	**9348.3** **-/4113.3**	7006.8 11/638.5	1421.1 14/501.2	1389.1 9/879.7	3301.5 4/1019.9	3845.1 10/455.4	5119.1 11/1493.8	433.7 5/187.7	3153.7 11/285.9	1094.0 13/296.8	2453.7 13/435.1
	1400-1500	**1500.3** **-/660.1**	2866.4 1/**1261.2**	5354.5 3/1871.8	6382.0 3/4162.1	2359.0 2/851.3	1601.1 2/197.1	135.4 1/**59.6**		14.8 1/**6.5**	602.1 3/153.0	1825.5 2/831.5
	Sum 1C-1D 401-1500	83778.2 23/35552.3	44235.1 72/14358.6	8149.7 61/2900.0	9184.5 68/5762.9	19162.0 69/6488.0	41890.8 71/16122.4	43132.5 71/15192.5	1101.5 49/341.7	8029.3 77/1676.4	3144.4 68/909.4	7187.2 73/2445.7

Table 3. Abundance (.000) and Standard Error (S.E.) by NAFO Division, depth stratum, year and cruise number. Abundance figures in **bold** are estimated from an three-way ANOVA and S.E. in **bold** are estimated from a regression between abundance and S.E. (see text).

	Year	1988	1989	1990	1990	1991	1992	1992	1993	1994	1995
Div	Depth (m)			1	2	1	1	2			
1C	401-600	296.7 231.0	61.1 31.4	1403.1 1112.6	329.5 250.4	180.4 58.3	339.30 243.9	19.0 19.0	12.5 7.2	12.9 12.9	53.1 28.8
	601-800	3449.7 1579.8	41.5 41.5	535.8 243.2	4606.1 1833.9	27870.3 18085.3	3520.4 2612.9	1910.9 638.6	570.2 272.7	1400.4 701.5	954.5 322.6
	801-1000	15150.3 4785.3	2074.5 1583.7	624.0 407.2	12994.2 6098.5	88985.0 31332.9	150859.0 45218.9	5083.6 920.4	9503.6 4947.4	3553.1 1611.4	12264.1 6757.3
	1001-1200	11153.5 9952.4	83.3 16.7	46.2 6.7	2737.3 493.0	8697.4 2471.2	2469.2 454.3	791.2 38.8	1897.3 1258.9	1022.2 250.4	537.4 389.1
1D	401-600	**218.7** **113.7**	530.6 253.0	620.3 620.3	1335.6 **694.5**	3153.6 3136.6	882.5 525.1	418.8 **217.8**	**87.4** 24.1	**29.3** **15.2**	**46.0** **23.9**
	601-800	**1960.6** **1019.5**	220.1 **114.5**	31.7 12.8	163.3 **84.9**	22664.4 21553.5	44294.0 22110.7	533.1 98.8	**279.9** **145.5**	427.5 134.5	**400.8** **208.4**
	801-1000	42115.9 20512.5	1143.5 755.4	2729.5 2501.1	11885.3 11443.4	27018.3 18650.2	40225.6 39017.2	1224.2 219.1	1716.2 966.6	413.3 76.7	733.8 126.4
	1001-1200	78363.3 26692.0	12930.6 2864.5	4574.2 656.2	33304.4 6395.3	50037.0 11876.3	56056.8 11631.7	6788.8 1092.1	15939.5 3185.0	4442.6 1125.7	6823.2 1727.3
	1201-1400	11492.5 983.7	6800.5 1458.8	2950.9 1435.6	5844.7 1096.6	9479.5 1770.3	13135.0 3612.9	5487.1 2312.4	10181.0 3002.3	4215.7 1732.4	6637.1 1986.6
	1400-1500	4273.8 **2222.4**	12229.3 17.3	11294.8 7231.5	3690.4 1316.7	2636.5 535.6	187.4 **97.4**		21.2 **11.0**	1165.0 324.9	3295.2 1445.9
	Sum 1C-1D 401-1500	168475.0 68092.3	36115.0 7136.8	24810.5 14227.2	76890.8 29707.2	240722.4 109470.2	311969.2 125525.0	22256.7 5557.0	40208.8 13820.7	16682.0 5985.6	31745.2 13016.3

Table 4. Sex distribution (percent males) in surveys conducted in the period July-October combined. n=6255

Depth (m)	Percent males
601-800	52.1
801-1000	70.3
1001-1200	63.4
1201-1400	52.7
1401-1500	51.0
Over all	59.2

Table 5. Mean catches (kg/hour), Standard Deviation (STD) and number of hauls (n) distributed by depth stratum and time of day.

Time	Midnight			Sunrise			Noon			Sunset		
Depth (m)	kg/hr	STD	n	kg/hr	STD	n	kg/hr	STD	n	kg/hr	STD	n
50-300	0.3	0.3	3	0	0	2	0.1	0.1	3	0.6		1
301-550	0	0	3	2.9		1	0	0	3	0.2	0.3	2
551-800	20.8	29.4	2	0.8	1.1	2	0.6	1.1	3	0.2		1
801- bottom	38.3	36.3	2	29.4		1	36.2	16.1	3	17.2	10.7	3

Table 6. Mean catches (numbes/hour). Standard Deviation (STD) and number of hauls (n) distributed by debth tratum and time of day.

Time	Midnight			Sunrise			Noon			Sunset		
Depth (m)	no/hr	STD	n	no/hr	STD	n	no/hr	STD	n	no/hr	STD	n
50-300	30	2.6	3	0	0	2	0.3	0.6	3	1.0		1
301-550	0	0	3	13		1	0	0	3	1	1.4	2
551-800	109	154	2	3	4.2	2	4.7	8.1	3	1		1
801- bottom	2103	220	2	101		1	181	75.4	3	128	85.1	3

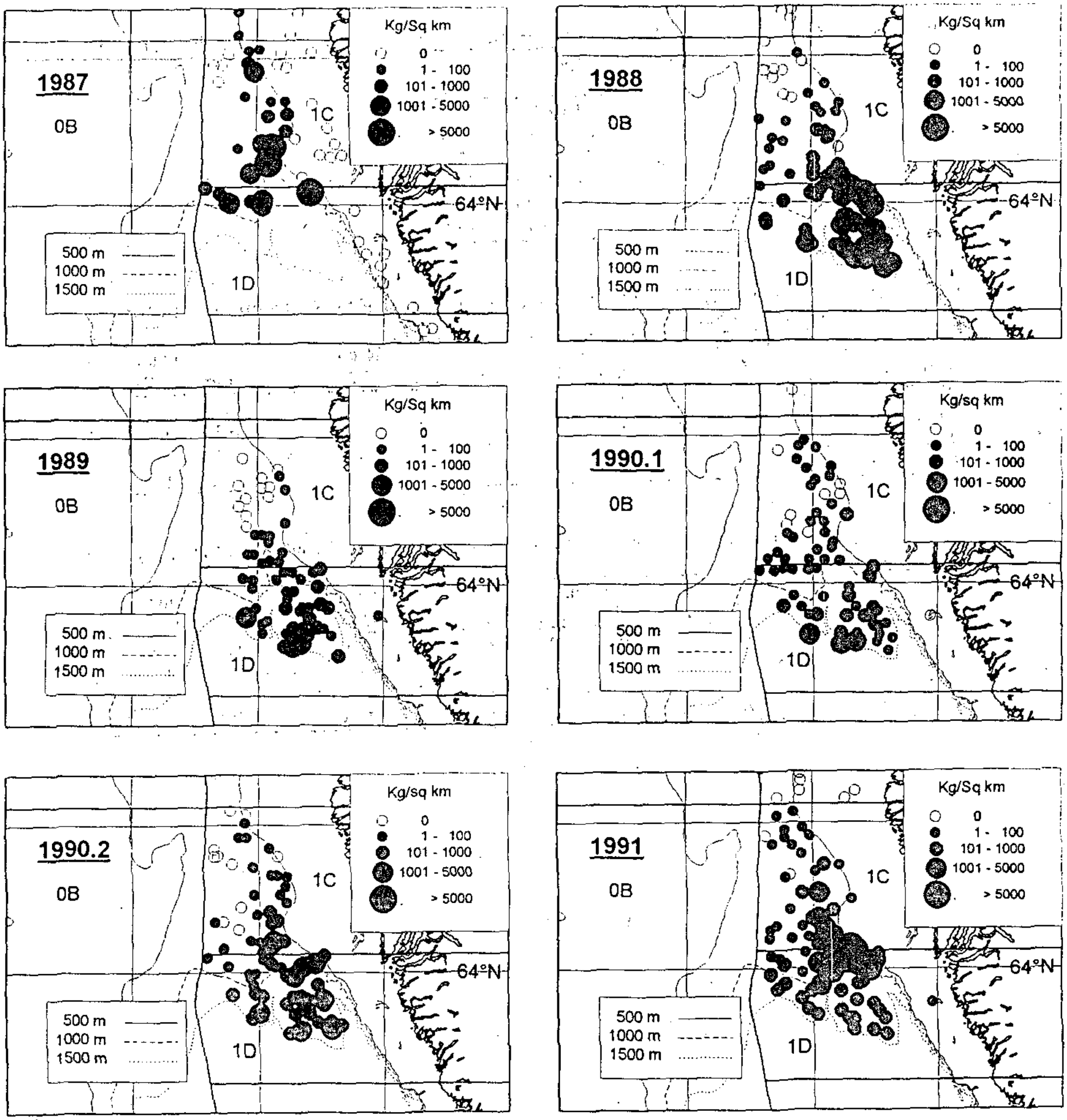

Fig. 1. Distribution of catches of roundnose grenadier in kg per km² swept in the joint Japan Greenland surveys conducted 1987-1995.

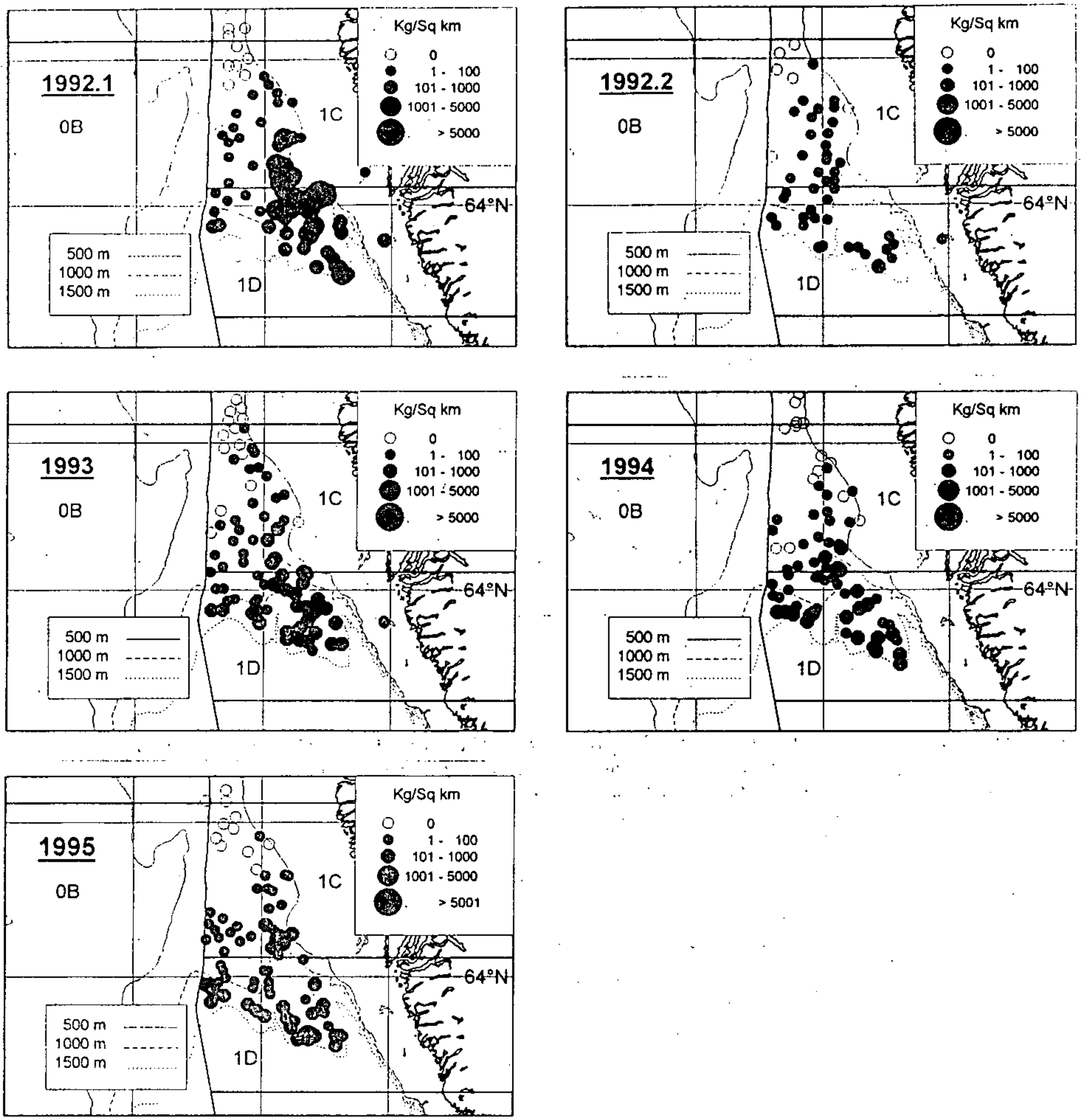

Fig. 1. Distribution of catches of roundnose grenadier in kg per km^2 swept in the joint Japan Greenland surveys conducted 1987-1995 (cont.).

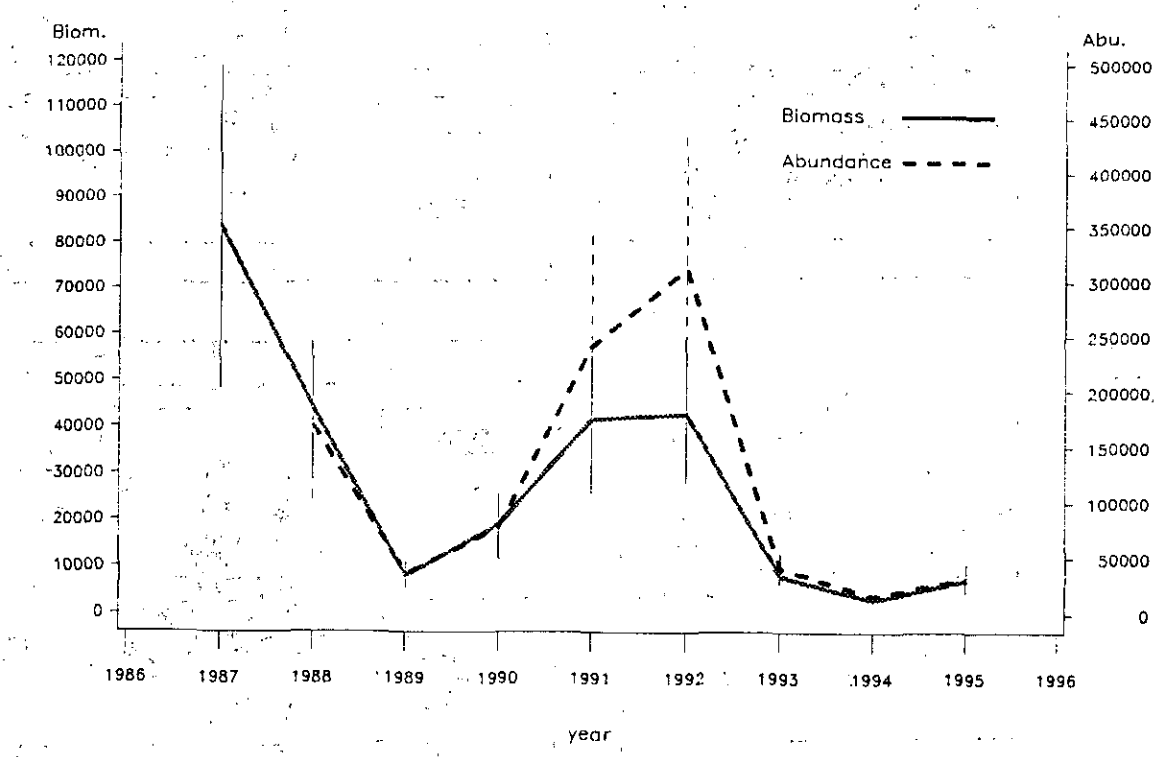

Fig. 2. Estimated biomass and abundance in Div. 1B-1D at depths between 401 and 1500 m in the period 1987-1995 with +/- Standard Error. The survey in 1989 covered 1C-1D only and was conducted in May, all other surveys were conducted in mid July - mid October. No abundance data from 1987.

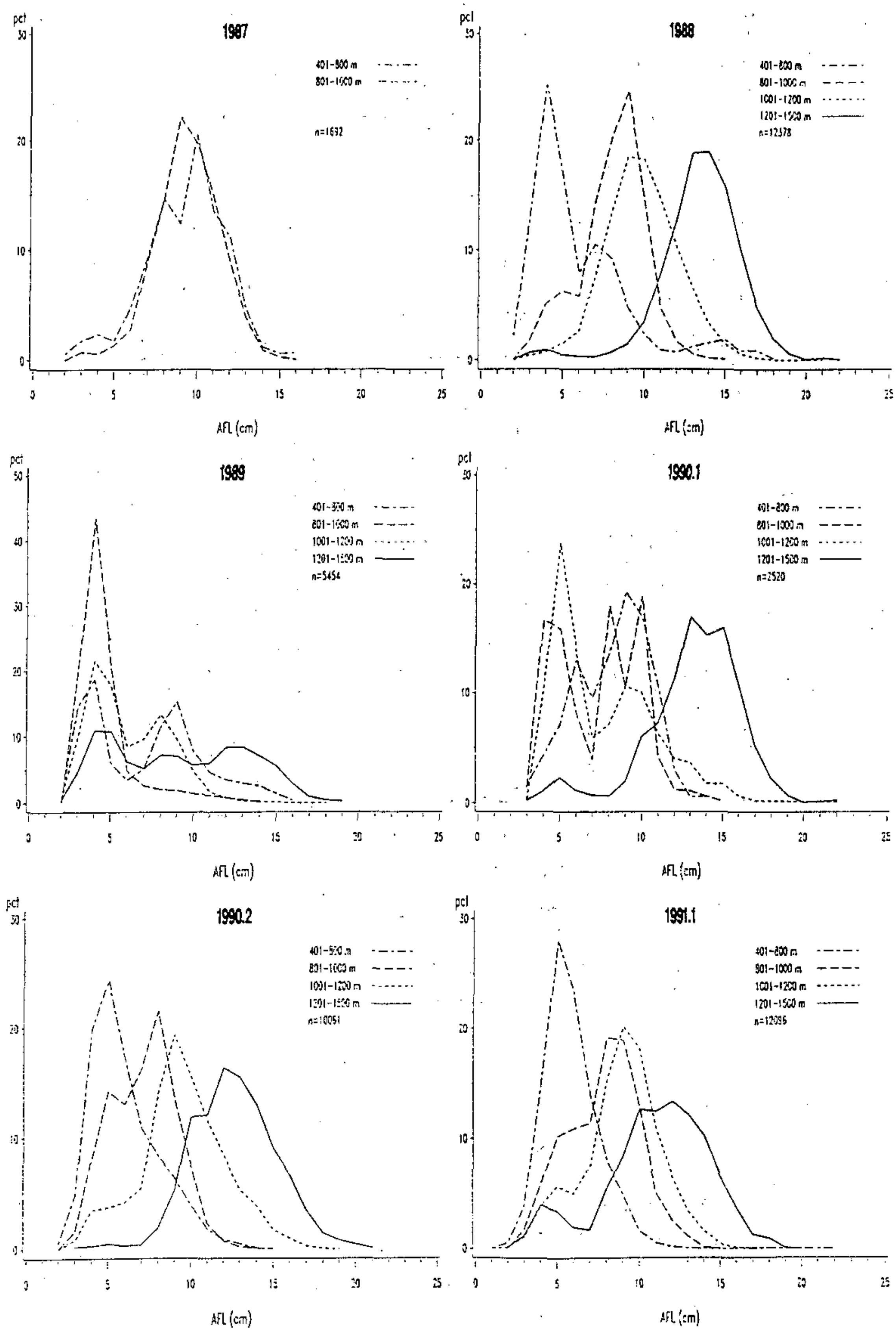

Fig. 3. Length frequencies by survey, NAFO Division and depth.

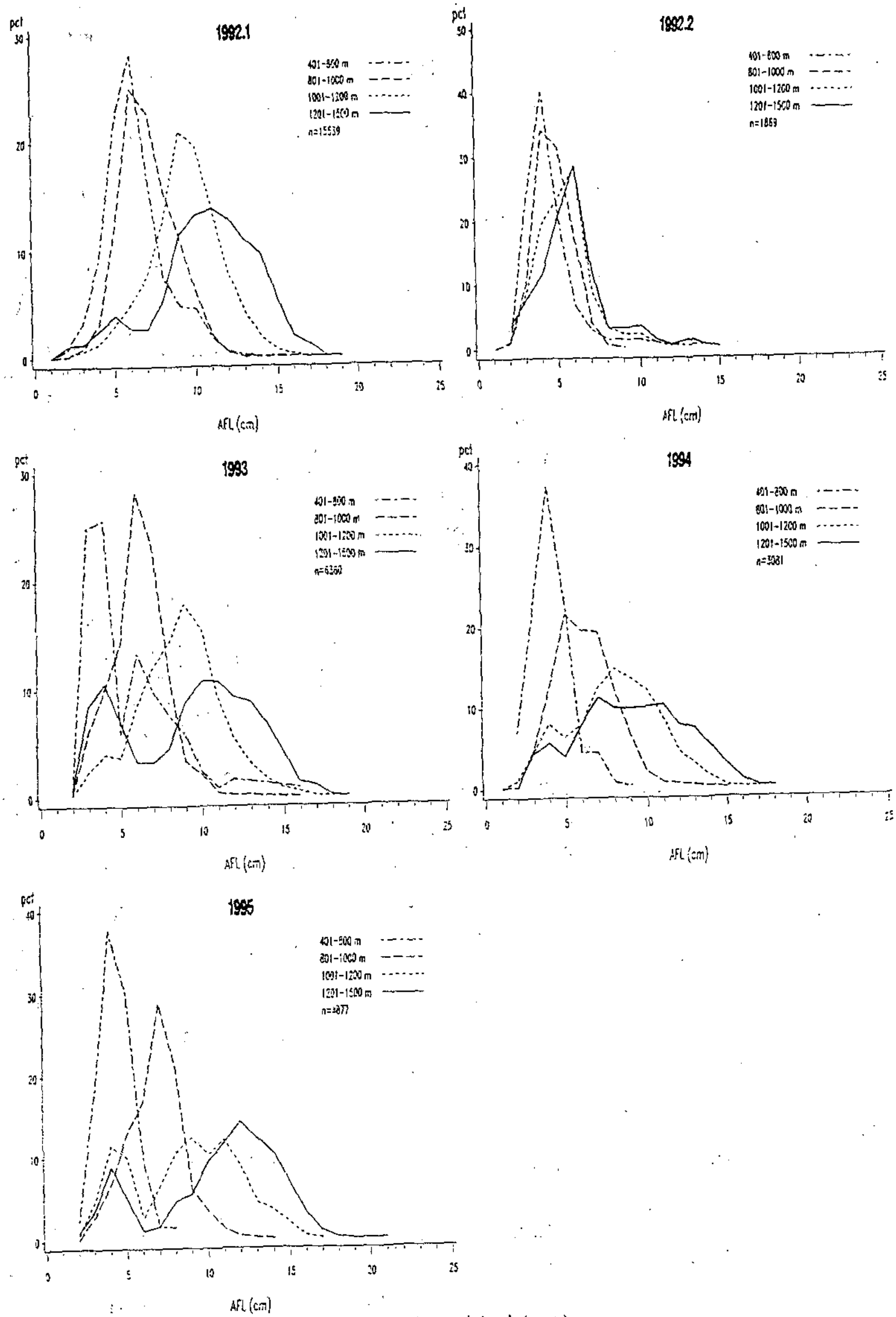

Fig. 3. Length frequencies by survey, NAFO Division and depth (cont.).

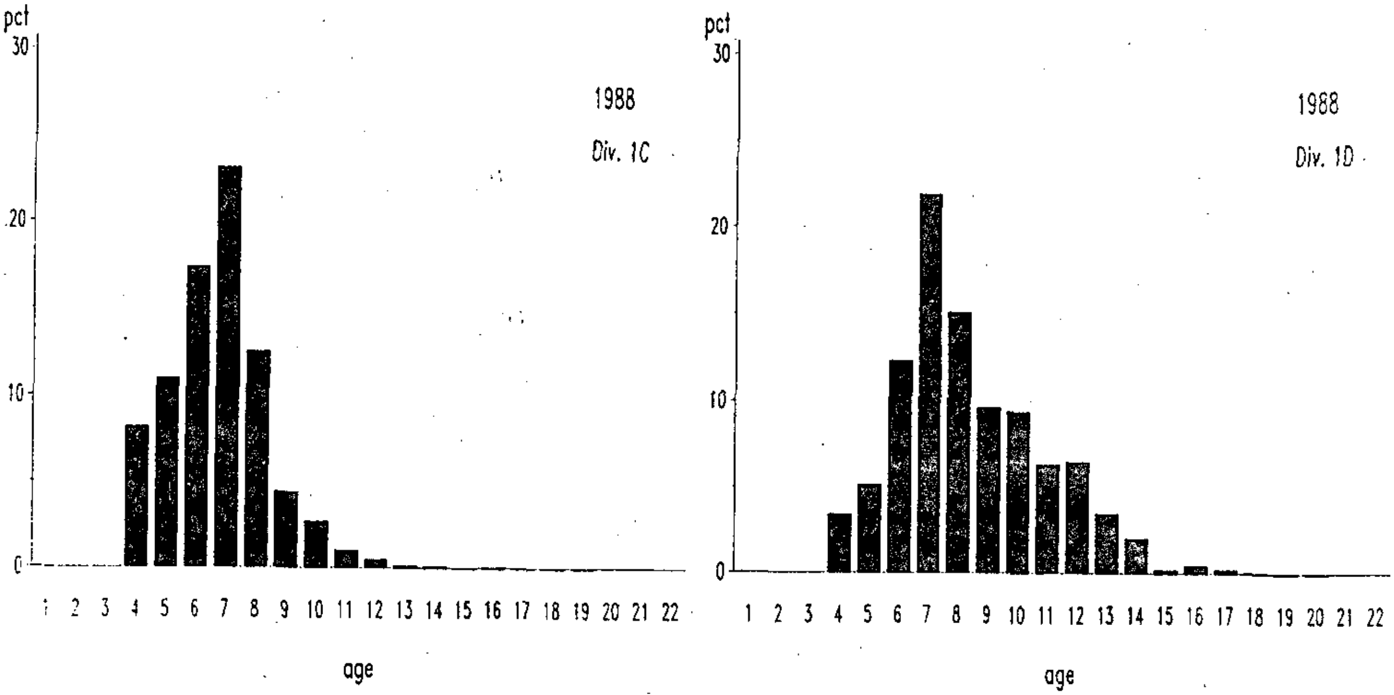

Fig. 4. Age distribution of roundnose grenadier 1988 in NAFO Division 1C and 1D.

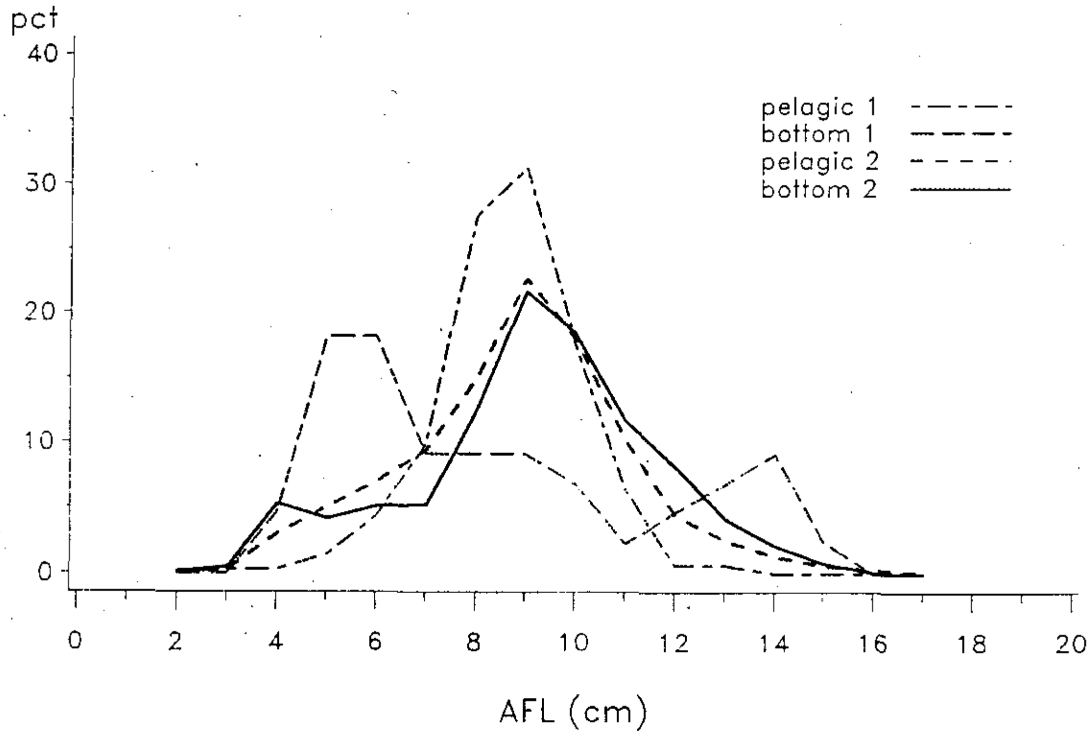

Fig. 5. Length distribution of roundnose grenadier in two pelagic surveys and on bottom trawl stations in the survey areas.