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Distribution and Length of Roughhead Grenadier by depth in NAFO Divisions 3KLMNO Based on Data from Russian Surveys in 1981-2006

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Abstract

Data from Russian investigations conducted onboard research and fishing vessels were used to describe length composition of the roughhead grenadier by depth and distribution of their catches in Divs. 3KLMNO in 1981-2006. Catches of the roughhead grenadier were taken in a depth range of 100 to 1500 m. A trend to decrease in catches and to distribution at lesser depths from the northern areas towards southern ones was noted. The deepest distribution of the main concentrations was observed in Div. 3K. Along the northern and southern slopes of the Grand Bank the roughhead grenadier occurred in smaller number, mostly in a 200-800 m depth range. On the southwestern slope they were least abundant and encountered only in waters less than 700 m deep. From 1981 to 1995, the proportion of the roughhead grenadier increased with depth. Catches of fishing vessels did not reveal a trend to redistribution. Size composition was described using length of the body from the tip of the snout to the base of the first anal fin ray converted from the total length. The largest individuals of 44 cm in length were caught in the Flemish Pass area in a depth range of 1000-1300 m. A general length increase with depth was noted in Divs. 3K and 3M. In Divs. 3L and 3N, the mean length showed a downward trend or did not vary substantially. Size composition of the roughhead grenadier from commercial catches in Div. 3L in 1996-2006, Divs. 3MN in 1996-2000 and Div. 3O in 2001-2006 was very stable with modal group of 14-15 cm long individuals being predominant at all distribution depths.

Introduction

In the area of the Canadian Atlantic, nine species of the *Macrouridae* family are identified (Scott and Scott, 1988). The largest and the most common species of this family are of commercial importance, and the roughhead grenadier (*Macrourus berglax* Lacépède, 1801) is among them. There is no directed fishery for the roughhead grenadier, and NAFO does not regulate its catches. Among *Macrouridae*, the roughhead grenadier is the most frequent in bycatches in Subarea 3, mainly during Greenland halibut, some other demersal and bathypelagic fish and shrimp fisheries.

Information on the roughhead grenadier catches has been known since the second half of 1980's. In some years their catches were quite sizeable. NAFO statistics show that from 1987 to 2005 in Subarea 3 total catch of the roughhead grenadier by all countries made up about 60 000 metric tons with the largest catch (7000-9000 tons) being registered in 1998-2000 (Table 1).

The size of the roughhead grenadier catch depends primarily on their abundance and biomass as well as on the exploitation rate of the Greenland halibut stock (Savvatimsky and Gorchinsky, MS 2001). Stock assessment and research into biology of the roughhead grenadier are difficult due to their deepsea habitation. The roughhead grenadier is distributed at depth between 100 and 2740 m (Wheeler, 1969). Fishing and survey gears encompass only the upper part of its distribution range by depth, therefore trawl surveys for the stock are insufficiently informative and some aspects of biology remain unclear.

The objective of this paper is to describe length composition of the roughhead grenadier by depth and distribution of their catches in the Newfoundland area in 1981-2006.

Methods

Russian bottom trawl surveys in Divs. 3KLMNO were conducted regularly in 1981-1993 at a depth down to 730 m, except for Div. 3K, where survey tows were made down to 1300 m deep and sometimes down to 1500 m. Later on, the research also covered areas beyond the 200-mile EEZ of Canada, the Flemish Cap and Flemish Pass. In 1994-1995, 1997-2000 and 2004-2006 no surveys were conducted.

Prior to 1984, duration of survey tows was 1 hour, and in subsequent years it was limited to 30 minutes. To reach data comparability all catches were converted based on 1-hour tow duration. In all cases, only trouble-free tows that comprised roughhead grenadier were taken into account.

Timing of the surveys was determined in dependence on formation of seasonal prespawning and spawning concentrations of demersal fishes and usually embraced the period from March to July. All the surveys used 31.2/27.3 m bottom trawl with fishing height of 4.0 m and fishing spread between the wings of 14.3 m. To retain small individuals in trawl, the codend had a small-mesh insertion with a mesh size of 8-12 mm. All the fish caught were counted; large catches were weighed and divided into portions to determine the number of the roughhead grenadier in one portion and to convert it to the whole catch.

Before 1996, scientific information on the roughhead grenadier from Russian commercial catches was received occasionally. Further, according to the international NAFO observer program their presence onboard all fishing vessels became mandatory. In large quantity biological samples from commercial catches have become available since 1998. The fisheries used different bottom trawls, the minimum mesh size of which was not less than 130 mm. Commercial catches of the roughhead grenadier were taken only beyond the 200-mile Exclusive Economic Zone of Canada.

In Russian research the normal approach to measure grenadiers was the use of total length (TL). To convert historic data to anal-fin length (AFL), in 2006 both types of length were measured and a length key was constructed using 1384 individuals of the roughhead grenadier caught in the Flemish Pass area. Total length of individuals was measured in the range of 25 to 101 cm, length to the anal fin was determined within 8-44 cm range. A regression line obtained on the basis of combined data on males and females (Fig. 1) showed a high significant correlation between both types of length with a narrow 95% confidence interval of the projected estimates of AFL at the given mean values of TL ($r=0.99$, $P<0.01$). This permitted us to use in the present paper only length to the anal fin.

Data on catches and size composition were analyzed separately by years, Divisions and 100-m depth intervals.

Results

Distribution of catches by depth

Catches of the roughhead grenadier were taken in a depth range of 100 to 1500 m (Fig. 2). Data from surveys in 1981-1985 showed that most catches were taken at depths between 200-500 m. In 1986-1990, a shift of concentrations towards 1000 m depth contour was noted and in the subsequent five years it was observed closer to 1500 m depth. As a rule, in this period there were no catches of the roughhead grenadier in waters less than 500 m deep.

Before the beginning of 1990's in Div. 3M the roughhead grenadier distributed within a relatively short depth range of 350 to 700 m. After 2000, their catches were registered over a more extensive area of the bank down to a depth of 1500 m.

The use of one and the same type of trawl during surveys made it possible to compare catches quantitatively. On the whole, catches showed a trend to decrease and to be distributed at lesser depths from the northern to southern areas (Fig. 3). The largest catch per 1-hour tow (90.3 kg) was registered in Div. 3K in 1986-1990. In this area, distribution of the main concentrations was the deepest (900-1200 m, maximum down to 1500 m). In Divs. 3L and 3N the roughhead grenadier occurred in less numbers, predominantly at depths between 200 and 800 meters. Along the

southwestern slope of the Grand Bank (Div. 3O) compared to the other areas, they were the least in numbers (up to 10 kg per 1-hour tow) and occurred only in shallow waters at a depth above 700 m.

From 1981 to 1995, the proportion of the roughhead grenadier increased with depth. On the shelf areas of Divs. 3K, 3N and 3M at a depth less than 500 m no roughhead grenadier were found after 1991. At the same time, their proportion increased greatly in waters more than 500 m deep. In other words, along with general decrease in catches by weight, there was a gradual shift of the roughhead grenadier from lesser depths to deeper waters.

Tow tracks of fishing vessels were chosen so that they could ensure primarily a capture of target species with minimal bycatch of other fishes, therefore these data were not representative to describe distribution of the roughhead grenadier (Fig. 4). From 1985 to 2006 their catches were taken in a depth range of 100 to 1500 m without showing any prominent trend to redistribution.

Distribution of length composition by depth

Data from research vessels showed that in Div. 3K in 1981-1985 catches comprised the roughhead grenadier of 8-37 cm long. Modal length increased from 15-16 cm at a depth of 200-300 m to 26-27 cm at a depth of 500-600 m with 3-4 cm increment in mean length (Fig. 5). A dramatic change in the length composition was noted at the boundary with the 600-700 m depth range where modal length having decreased down to 15 cm then increased again up to 21 cm in a depth range of 1300-1400 m where catches included large individuals of 21 cm in length. In 1986-1990, all depths, except for waters 900-1000 m deep, were dominated by individuals of 14-15 cm in modal length. Due to an increase of relative number of large individuals 25-29 cm long with depth, the mean length increased from 17 to 19-22 cm.

In 1981-1985, in Div. 3L a relative number of individuals of 20 cm modal group decreased with depth. However, the proportion of individuals of 14 cm long increased down to a depth of 700 m that was followed by a respective decrease in the mean length (Fig. 6). Size composition of the roughhead grenadier in a 700-800 m depth range was more uniform; an increase in the proportion of individuals of 24-29 cm long resulted in an increase of the mean length up to 22 cm. In 1986-1990, in a depth range of 200 to 700 m the size composition was relatively stable. All the depths surveyed were dominated by individuals of 14-15 cm in length.

A considerable number of individuals of 10-15 cm in length determined the lowest mean length (less than 17 cm) in waters 400-500 m deep in Div. 3M in 1981-1985 (Fig. 7). The proportion of large individuals 19-20 cm long at a depth less than 800 m went up that led to an increase of the mean length to 19 cm. In 1986-1990, as with Div. 3L, the size group of 14-15 cm was prominent; the mean length increased with depth.

A characteristic feature of the size composition of the roughhead grenadier in Div. 3N was the presence of large individuals of 20-22 cm in mean length found in shallow depths (Fig. 8). An increase in length with depth was not pronounced.

Size composition of the roughhead grenadier from commercial catches in the area of usual fishery for Greenland halibut, redfish, skates and shrimp in Div. 3L in 1996-2006, Div. 3MN in 1996-2000 and in Div. 3O in 2001-2006 was very stable and was distinguished by predominant modal group of individuals 14-15 cm long through all depths (Fig. 9-12). The largest individuals up to 44 cm in length were caught in the Flemish Pass area in a depth range of 1000 to 1300 m. Variation in the size composition and increase of the mean length was noted in Divs. 3M and 3N in 2001-2006.

Discussion

The roughhead grenadier in the Northwest Atlantic is a widespread species with a relatively stable distribution on the shelf and slope, most frequently occurred in the Greenland halibut fishery (Duran et al., MS 1996; Alpoim, MS 1997). Due to depletion of some fish stocks in the Northwest Atlantic the importance and catch of the roughhead grenadier is expected to increase during the ensuing years. In particular circumstances, most likely related to specific features of physiological state of individuals and environmental conditions of their habitat, the roughhead grenadier form concentrations suitable for directed fishery. Relatively big catches were taken by Russian trawlers in Divs. 3LN at a depth of about 1000 meters. The proportion of the roughhead grenadier in some commercial catches reached 50-90%. Catches of the roughhead greanadier were registered to be 1750 kg against the total catch of 2912

kg; 2898 kg when the total catch was 2960 kg, and 3490 kg at the total catch of 5500 kg (Savvatimsky and Gorchinsky, MS 2001). The highest catches of the roughhead grenadier during trawl surveys (up to 540 kg per 30-min tow) were taken in July-September in waters deeper than 500 m along the eastern and northern slopes of the Grand Bank (Parsons, 1976).

It is worth noting that data were in a way misrepresented by international catch statistics in 1990's, since catches by Spain and Portugal, reported to NAFO as roundnose grenadier, corresponded to roughhead grenadier (Paz and Iglesias, MS 1994; Junquera et al., MS 1999). It was acknowledged that after 1990 catches of the roughhead grenadier became greater compared to the roundnose grenadier catches, but catch statistics combined both these species (Atkinson, MS 1996).

Distribution of the roughhead grenadier by depth and over the Newfoundland area is yet scantily known. The general pattern of spatial and temporal distribution of the roughhead grenadier described in this paper showed a gradual shift of their concentrations mainly towards the east, from the shallow waters of the shelf to greater depths along the continental slope. The most pronounced it was in Div. 3K, to a lesser extent it was observed in the other areas.

During the Russian trawl survey in Divs. 3LM, the proportion of the roughhead grenadier grew up from 9-13% in a depth range of 800-1200 m to 24-25% in waters 1200-1440 m deep (Gorchinsky and Savvatimsky, MS 1996). In the commercial fishery for the Greenland halibut the highest bycatch was taken from a depth of about 1000 m. Length composition was similar over the whole survey area during the year. The mean length increased with fishing depth from 800 to 1300 m (Savvatimsky and Gorchinsky, MS 2001).

Canadian surveys indicated that from the beginning of 1990's the roughhead grenadier shifted from Divs. 2GJ southwards to Divs. 3LN to a depth below 1000 m; their biomass was estimated to be the largest at a depth of 1000-1200 m (Atkinson et al., MS 1994; Bowering et al., MS 1995).

EU surveys on the Flemish Cap showed the roughhead grenadier to occupy the deepest survey areas. Their abundance and biomass increased with depth (Murua and Gonzalez, MS 2006).

The shift of the roughhead grenadier to greater depths was probably a response to anomalous water temperature lowering in the Northwest Atlantic in the early 1990's. Similar alterations were also found as regards capelin, silver hake, Greenland halibut and American plaice (Iglesias et al., 1994; Sigaev, 1994; Sigaev and Rikhter, 1994; Frank et al., 1996).

Tail breakage and its subsequent regeneration are characteristic of the grenadiers, therefore measurement of total length makes it impossible to get reliable and consistent data on size composition. It is known that percentage of the roundnose grenadier with injured tail exceeds 50% (Savvatimsky, MS 1981). A considerable number of the roughhead grenadier individuals have similar injuries. In this relation, in 1980 the NAFO Scientific Council recommended to measure the length of the roundnose grenadier and roughhead grenadier from the tip of the snout to the base of the first anal fin ray (Atkinson, 1981).

Formulae describing a relationship between anal fin length and total length were presented in a number of papers and were quite similar to one another (Atkinson, 1981, 1991; de Cardenas et al., MS 1996; Sainza, MS 1996).
Scientific publications present discrepant information on variation of the grenadiers' mean length in dependence on areas and depth of fishing. For instance, in Div. 3N both a decrease of the mean individual length with fishing depth (Parsons, 1976; Atkinson, Power, MS 1987) and an increase of it (Paz and Iglesias, MS 1994) are indicated. P. Savvatimsky (1989) reported that in scientific catches from 1967 to 1983 the roughhead grenadiers in Div. 3N were substantially larger than in Divs. 3KLMO.

Russian survey data showed that the largest individuals of the roughhead grenadier of the mean length of 23 cm were caught in Div. 3K at a depth of 500-600 m in 1981-1985, and the smallest individuals were taken in Div. 3M in a 400-500 m depth range in the same period. A general length increase with depth was noted in Divs. 3K and 3M; in Divs. 3L and 3N the mean individual length showed a downward trend or did not vary greatly. The whole picture suggested that in spring and summer small individuals were predominantly distributed on the shelf and large ones mostly resided on the slope.

There is still a little-understood phenomenon of variation in the size composition and increase of mean length of the roughhead grenadier from commercial catches in Divs. 3M and 3N in 2001-2006 compared to its stability in the other Divisions. A reduction in the Greenland halibut stock and adoption in 2004 of a 15-year International Rebuilding Plan raised an interest to the currently unregulated fishery for the roughhead grenadier. As was mentioned above, the roughhead grenadier forms local concentrations usable for the directed fishery. It may be assumed that an increase in length of the roughhead grenadier in catches during recent years is related to the change of the general fisheries strategy, the more full use of bycaught species, the choice of those fishing grounds and towing depths where the largest and valuable fish are caught.

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Table 1. Yield of roughhead grenadier in Subarea 3 NAFO (data for 2000-2005 are provisional).

Year	Division						Total
	3K	3L	3M	3N	3O	3P	
1987		912	7	82			1001
1988		907		52			959
1989	3	289	28	11			331
1990		2211	688	312			3211
1991	113	2543	497	1093	10		4256
1992	274	684	1022	471	125		2576
1993	193	174	812	1064	61	27	2331
1994	35	17	1940	271	28	9	2300
1995	16	115	970	292	20	4	1417
1996	103	1998	995	929	12	4	4041
1997	100	1777	922	1798	44	12	4653
1998	18	2690	2179	2229	83	2	7201
1999	61	2041	3130	1711	182		7125
2000	140	3211	3706	1762	73		8892
2001	97	911	419	463	23	1	1914
2002	147	769	336	389	23		1664
2003	91	838	382	461	15	1	1788
2004	58	703	197	678	35		1671
2005	91	689	180	311	10	0	1281
Total	1540	23479	18410	14379	744	60	58612

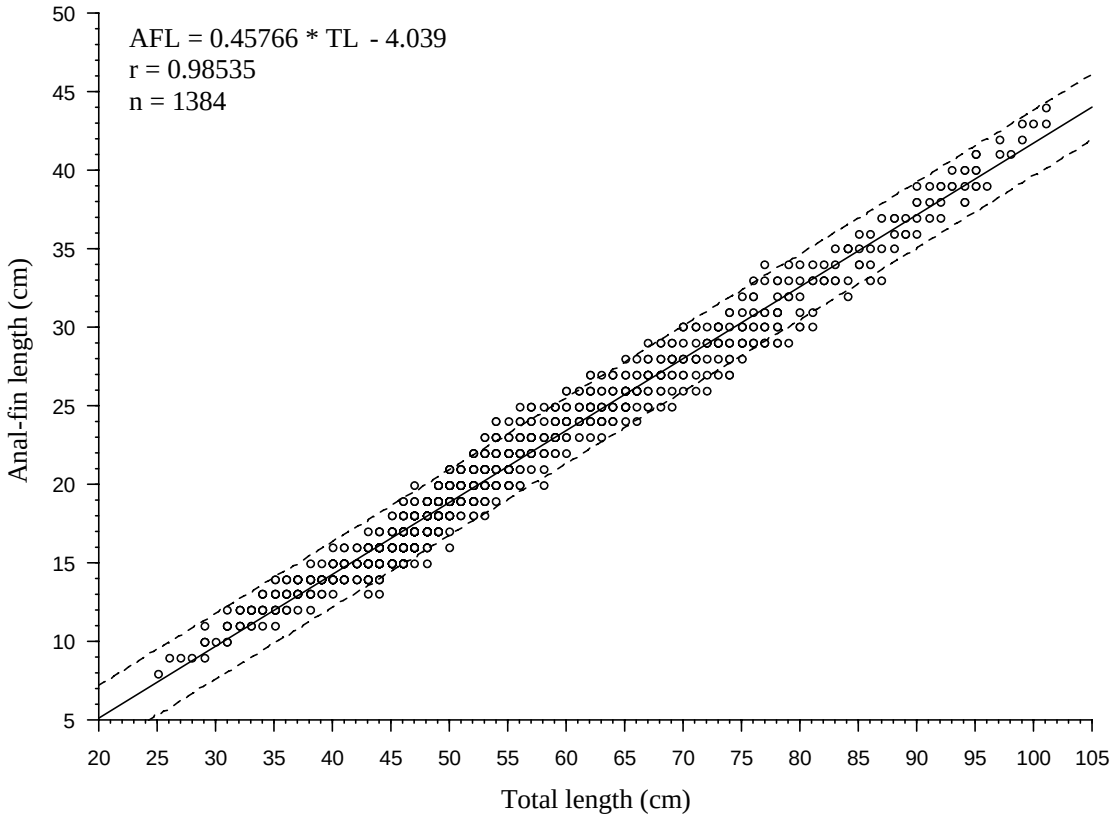

Fig. 1. Relationship between anal-fin length and total length for roughhead grenadier (sexes combined) in the Newfoundland area (dashed lines indicate 95 % prediction limits).

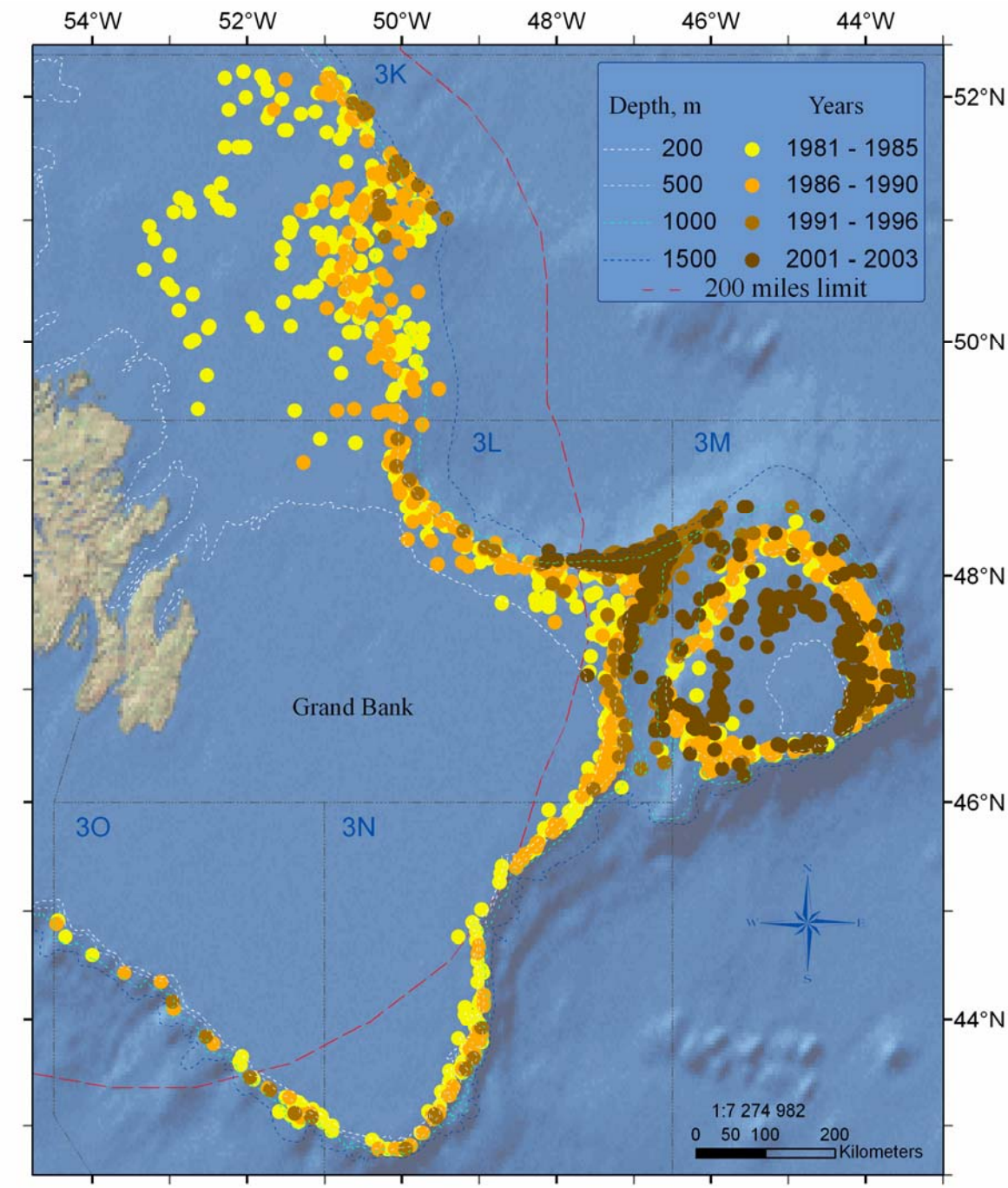

Fig. 2. Distribution of the roughhead grenadier catches in 1981-2005 based on research fleet data.

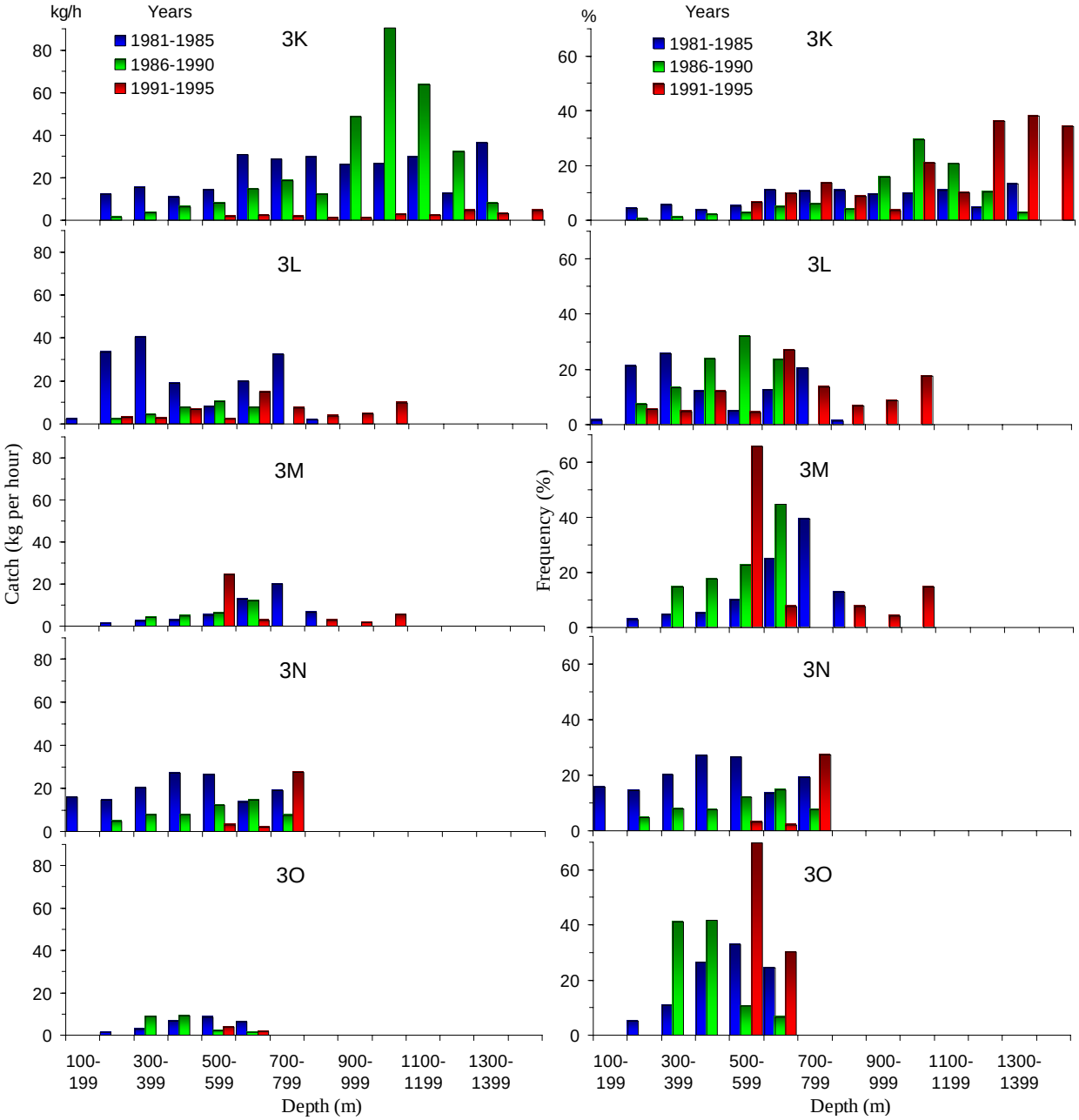

Fig. 3. Quantitative distribution of the roughhead grenadier in Subarea 3 NAFO in 1981-1995 based on research fleet data.

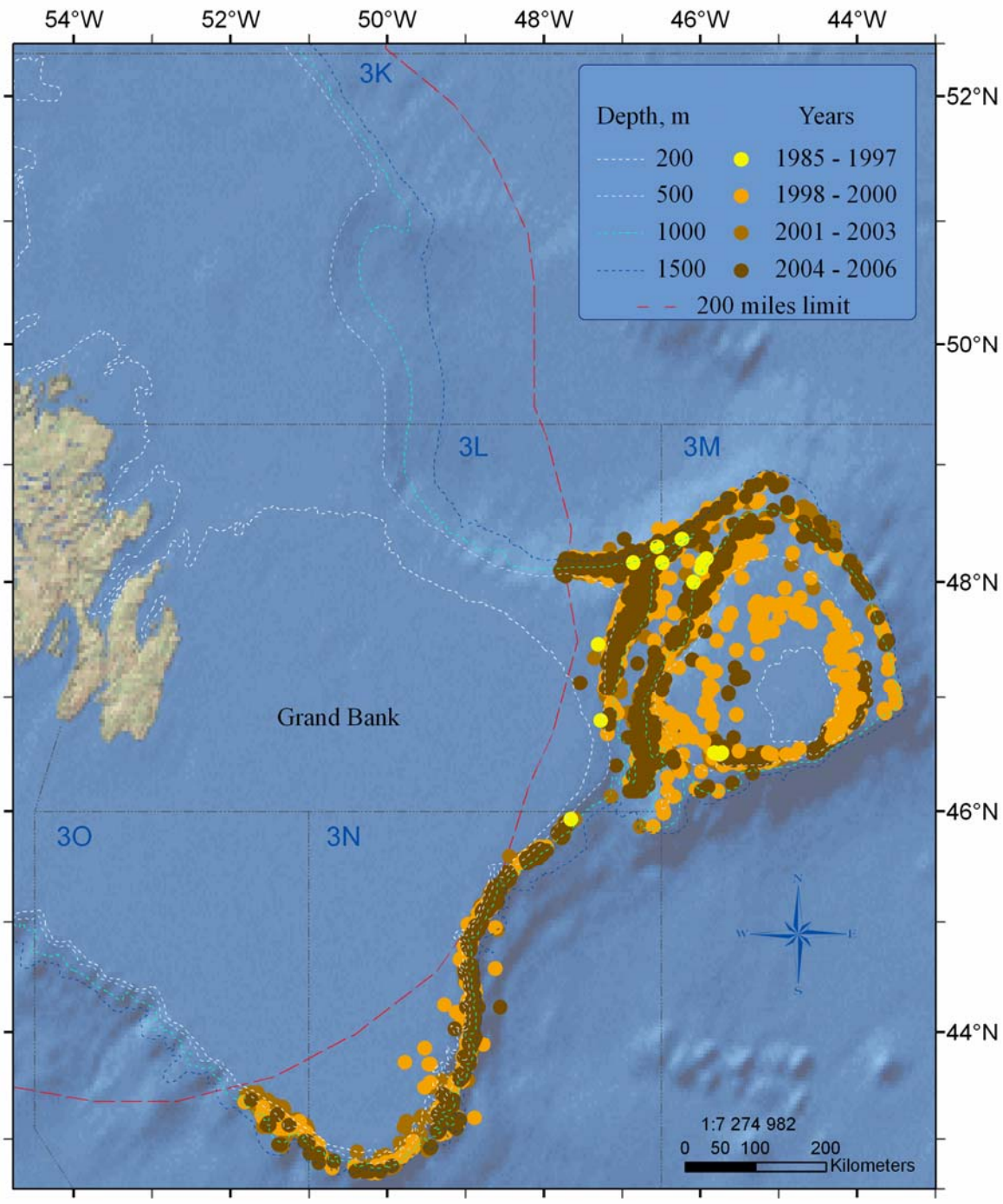

Fig. 4. Distribution of the roughhead grenadier catches in 1985-2006 based on fishing fleet data.

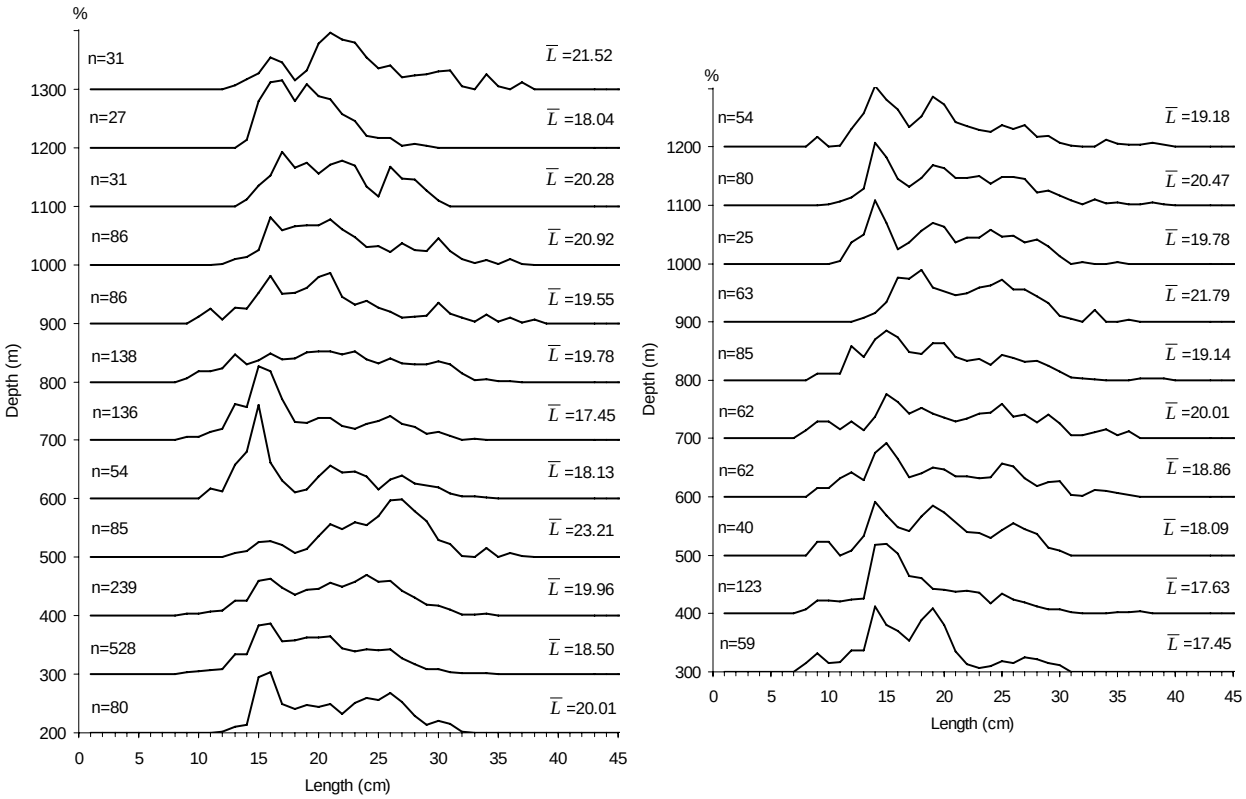

Fig. 5. Length composition of the roughhead grenadier in Division 3K based on research fleet data in 1981-1985 (left panel) and in 1986-1990 (right panel).

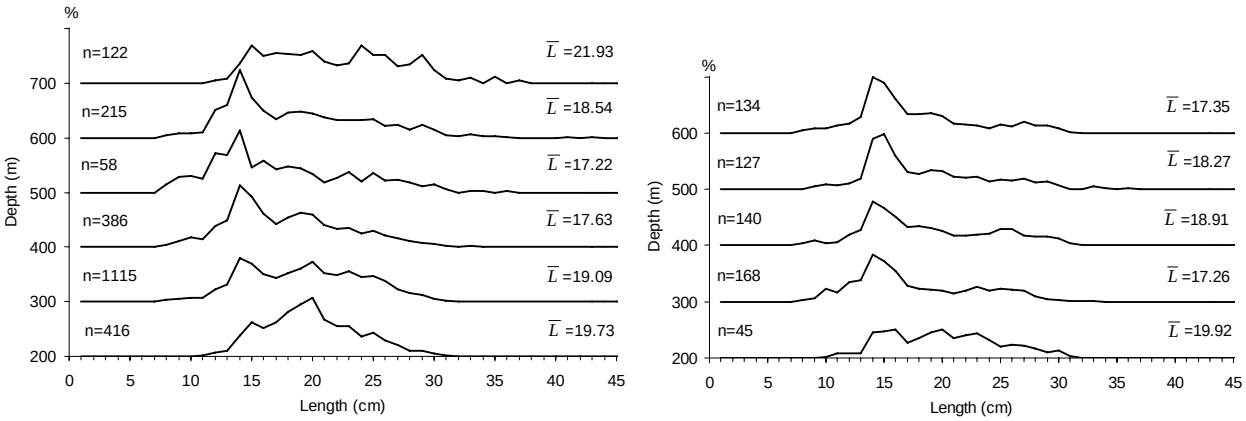

Fig. 6. Length composition of the roughhead grenadier in Division 3L based on research fleet data in 1981-1985 (left panel) and in 1986-1990 (right panel).

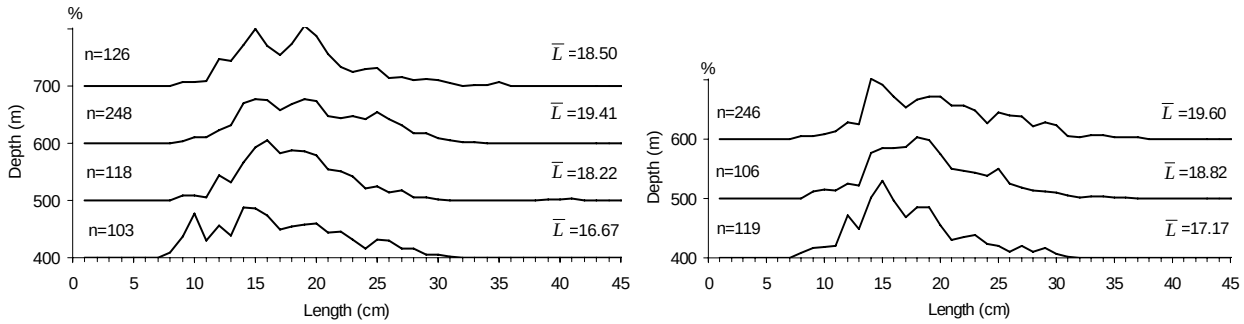

Fig. 7. Length composition of the roughhead grenadier in Division 3M based on research fleet data in 1981-1985 (left panel) and in 1986-1990 (right panel).

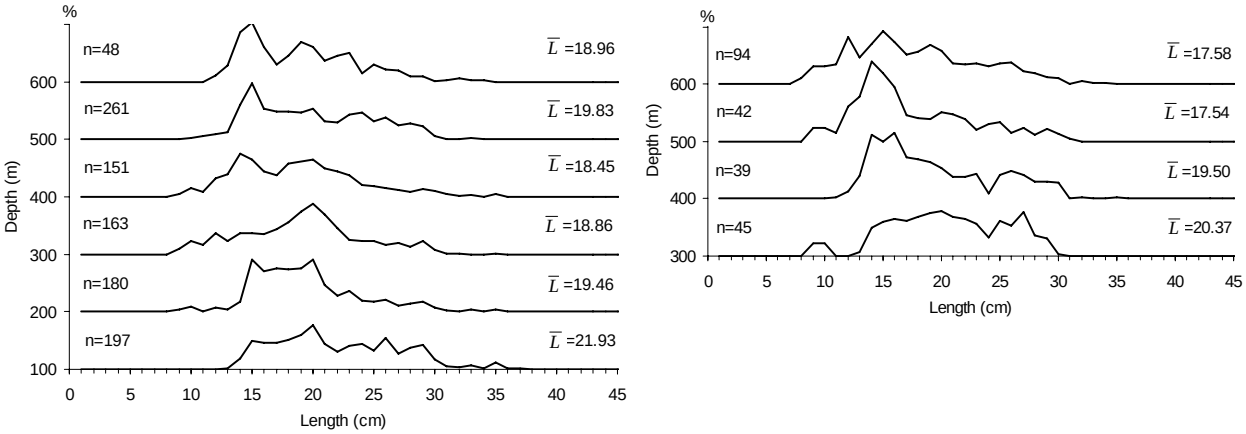

Fig. 8. Length composition of the roughhead grenadier in Division 3N based on research fleet data in 1981-1985 (left panel) and in 1986-1990 (right panel).

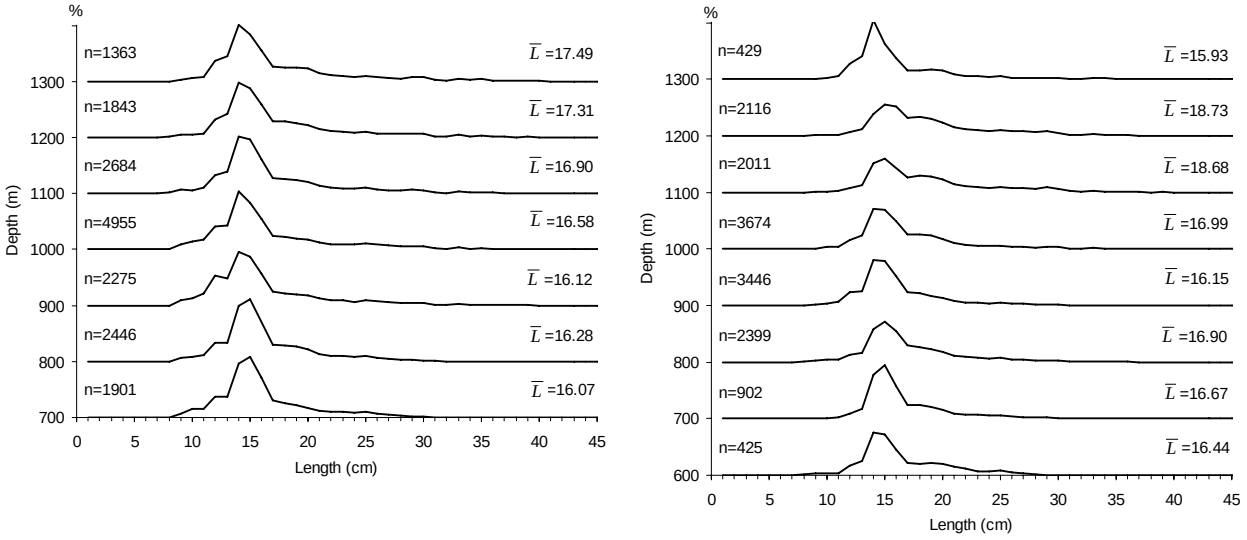

Fig. 9. Length composition of the roughhead grenadier in Division 3L based on fishing fleet data in 1996-2000 (left panel) and in 2001-2006 (right panel).

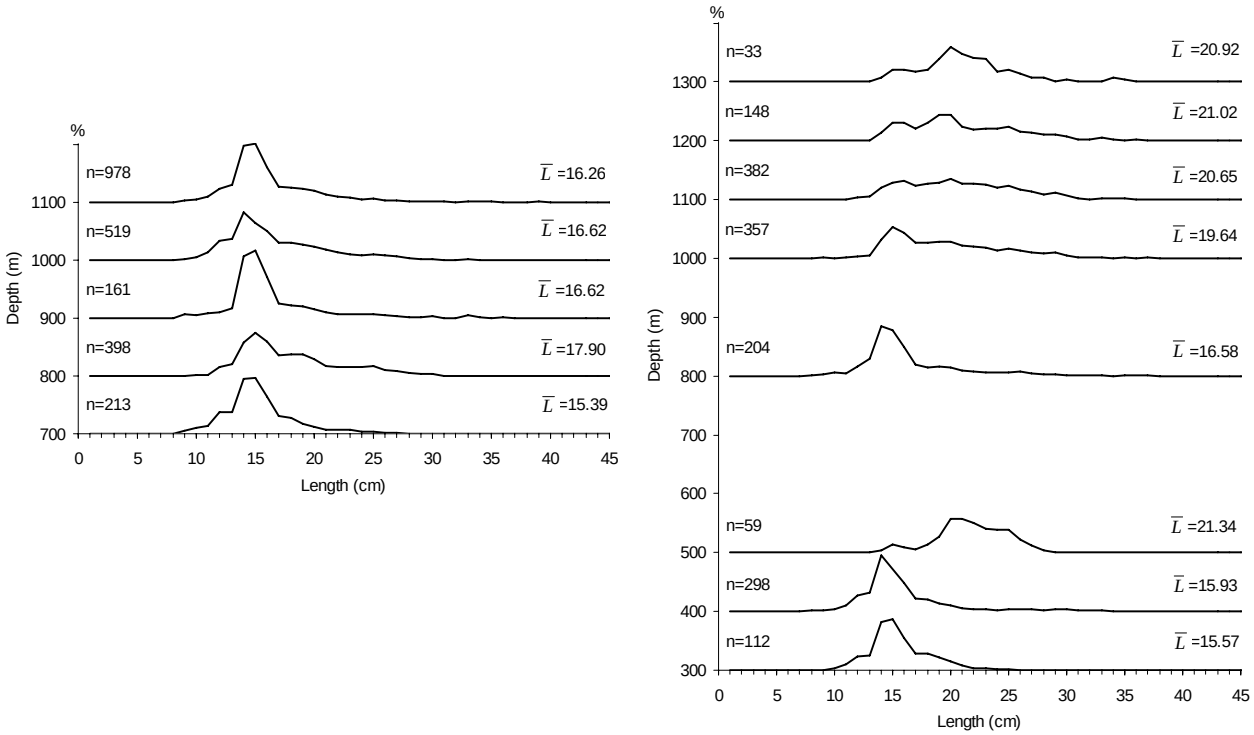

Fig. 10. Length composition of the roughhead grenadier in Division 3M based on fishing fleet data in 1996-2000 (left panel) and in 2001-2006 (right panel).

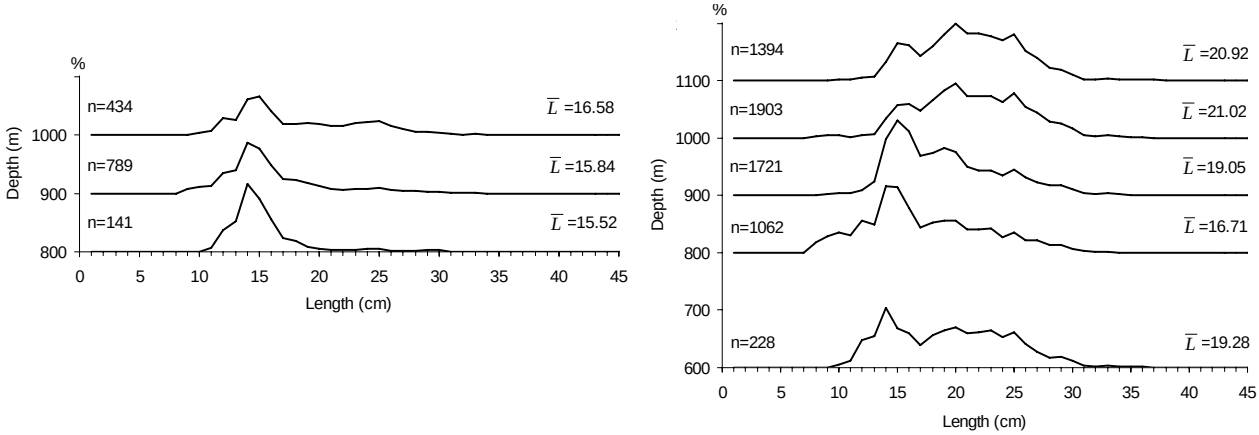

Fig. 11. Length composition of the roughhead grenadier in Division 3N based on fishing fleet data in 1996-2000 (left panel) and in 2001-2006 (right panel).

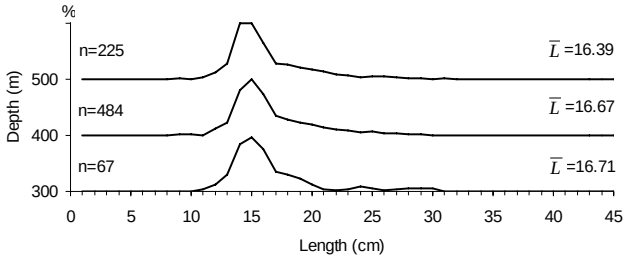

Fig. 12. Length composition of the roughhead grenadier in Division 3O based on fishing fleet data in 2001-2006.