Northwest Atlantic Fisheries Organization

Serial No. N1453

NAFO SCR Doc. 88/17

SCIENTIFIC COUNCIL MEETING - JUNE 1988

Investigations of Roughhead Grenadier (*Macrourus berglax* L.) in the Northwest Atlantic in 1967-83

by

P. I. Savvatimsky

Polar Research Institute of Marine Fisheries and Oceanography (PINRO)
6 Knipovich Street, 183763, Murmansk, USSR

ABSTRACT

The distribution of the roughhead grenadier catches by area, depth, in relation to water temperature, the length and sex compositions, feeding and fatness characteristics are described based on the materials of the bottom fish trawl surveys in 1972-83 and catches of research vessels in 1967-83. Grenadier concentrate along the continental slope and in deepwater troughs of the shelf. The catches increased with the trawling depth (100-1300 m). They were higher in the day-time at the water temperature of -2.0° to +3.0°C. The large grenadier were distributed in shallow waters. Females were larger than males. The differences in the length-weight relation between males and females were negligible. The feeding spectrum was wide: Ophiura, Polychaeta, different Crustacea, Mollusca and fishes were the main food items. As the grenadier grew their food composition changed sharply and the liver weight increased relative to body weight before they matured. The intermittent spawning occurred in winter and early spring. The fecundity averaged 38.2 thou. eggs. Roughhead grenadier have a long life cycle and many-aged population structure. They can serve as an additional fish supply for the trawl and long-line fishery.

INTRODUCTION

Roughhead grenadier - Macrourus berglax Lacépède, 1802 -

is an abundant and widespread fish species (Andriyashev, 1954; Leim and Scott, 1966). Fig.1 shows its range. Grenadier were captured near the coast of the North America and Canada from New York to the Davis Strait, in the Baffin Bay. They are distributed along the continental slope of the West and East Greenland, around Iceland (Magnusson, 1979), off the north-western Norwegian coast, along the western boundary of the Barents Sea northward up to 82°10'N, around Spitsbergen, southward as far as Bergen. The Soviet research vessels fished for grenadier in the area between the North-eastern and Franz Josef Lands up to 40°20'E. The fish prefer the 400-1200 m depths, they are known to be caught at depth to 2740 m (Wheeler, 1969). Grenadier are often taken as a large by-catch when carrying on the bottom trawl fishery for traditional objects - cod, redfish and Greenland halibut, and also the long-line fishery for bottom fishes off the northern coast of Norway (Bakken et al., MS 1975), west and north-west of Iceland (Magnusson, MS 1978), in the Newfoundland area (Savvatimsky, MS 1983, 1984). The bottom trawl catches of this grenadier species reached 1.5 t near the Norwegian coast (Savvatimsky, MS 1985, 1986). Sometimes the fish account for 73% of commercial catches (Eliassen, MS 1983), they are captured in a wide depth range (Eliassen, MS 1983a) and data on their catches are included in the Norwegian fishery statistics. The catches of the FRG research vessel on the Dohrn Bank (East Greenland) reached 0.9 t per 30-minute trawling (Sahrhage, 1986). In recent years the grenadier catches of FRG increased and were in great demand. Just in the East Greenland area FRG caught in separate years more than 3000 t of grenadiers, chiefly roughhead grenadier (Sahrhage, 1986).

Roughhead grenadier as the other related species - Nezumia bairdii, is very abundant in the Newfoundland area (Houston, MS 1983). Its bottom trawl catches mounted to two tons (Yanulov, 1962). The highest catches (up to 540 kg per 30-minute trawling) were taken with a research trawl from July to September in comparatively shallow waters (down to 500 m) along the eastern and northern slopes of Grand Bank, in NAFO Divisions 3L and 3N (Parsons, MS 1975, 1976a). Despite the occasional high catches in many areas and existing fishery in separate areas of the North Atlantic, the fish

life cycle has been poorly studied until now, there is only few information in literature based on fragmentary observations.

The aim of the paper was to study the abundance, mechanisms of distribution and general problems of roughhead grenadier biology in the Northwest Atlantic using the data of the long-term observations for the purpose of its feasible commercial utilization.

MATERIAL AND METHODS

Materials were collected by research vessels from 1967 to 1983 mainly in the Newfoundland area; another information was also gathered in the areas of Labrador and Baffin Land. To study the grenadier distribution we used the data of the yearly trawl survey concerning the assessment of the bottom fish abundance which was carried out in summer 1972-83 by a grid of stations enveloping the shelf and part of continental slope in the areas of Grand Bank and South Labrador. A 19 m long fine-meshed (mesh size 10-12 mm) net was inserted in the codend of the trawl. Duration of valid hauls was 1 hour. The mean catches were calculated by rectangles 20' in latitude and 30' by longitude. The catches were distributed within the 100-meter depth ranges with regard for the near-bottom water temperature and time of a day. The area of the rectangles was considered where the roughhead grenadier catches were taken. The absolute abundance was determined by the formula:

$$N = \frac{I}{k} \cdot \frac{S \cdot n}{s},$$

where k - fishing efficiency - the ratio of the number of fish caught to the number present in the area fished;

s - area fished per 1 hour;

S - total area surveyed with grenadier catches;

n - mean catch per trawling hour from the trawl survey data.

The analysis of catches consisted in the following. The full (zoological) length was measured with an accuracy of 1 cm, the results of measurements were classified into 3-centimetre groups (21-23, 24-26 etc.). To study the fish feeding the analysis of non-everted stomachs was made right away after the catch retrieval.

The food objects (except for those entirely digested) found in the fish stomachs were identified and registered. The swallowed fishes were determined accurate to genus, more rarely to species; the invertebrate animals - only to family, order or class.

The occurrence frequency of separate components in stomachs, i.e. the ratio of the number of stomachs (%) containing any food component to the total number of stomachs analysed (excluded empty ones) was estimated. The procedure allowed to have only a relative feeding pattern since it overestimated small but numerous or frequently occurring organisms. The obtained frequency value helped to study relative changes in the diet of fishes as they grew.

The degree of stomach fullness was estimated visually by the 5-point scale: 0 - empty, 1 - availability of food, 2 - weak fullness, 3 - full stomach, and 4 - extended stomach. The mean degree was found as the arithmetical average from points of fullness of stomachs analysed.

The coefficient of food similarity (K) was derived from the formula suggested by K.P.Yanulov (1963):

$$K = \frac{n \cdot 100}{N},$$

where N - sum of the highest, and n - sum of the lowest values of occurrence frequency of all food objects in fishes of compared length groups. With absolute diversity of food K = 0 while with absolute similarity K = 100. The maturity of fish gonads was determined by the 6-point scale (Sorokin, 1957, 1960). When determining fecundity of females caught on 26 November 1980 at 800 - 1060 m in the Baffin Land area (61°40'N, 60°40'W) only large eggs 2.0-2.7 mm in diameter were considered. The three 2-gram batches of eggs were taken from each ovary. The fecundity was determined by multiplying the total number of eggs in three batches by net (without membrane) weight of eggs and dividing by the total weight of batches. The coefficient of sexual maturity was determined as the ratio of the gonad weight to the fish body weight expressed in per cent.

The length-weight relationship is formulated in $W = aL^b$, where W - grenadier weight in g, L - length in cm. Fulton's condition factors were calculated by the formula:

$$K_F = \frac{W \cdot 100}{L^3},$$

in this case the length groups including less than 10 fishes were not considered. Length and weight frequencies, relative liver weight (fatness) curves and occurrence of food objects plotted against length were given in the smoothed form. The smoothing was made with the use of the formula:

$$B = \frac{a + 2B + c}{4},$$

where a, b, c - preceding, average and subsequent members of the frequency; B - the estimated one.

DISTRIBUTION, ANALYSIS OF CATCHES, ABUNDANCE AND BIOMASS OF GRENADIER

In the Northwest Atlantic roughhead grenadier inhabit the arctic (polar) waters occupying the shelf and part of continental slope, and concentrate at the near-bottom water temperature of -2° to +2°C. In the Northeast Atlantic the fish also dwell in arctic waters at about 0° (Bakken et al., MS 1975). In August 1967 the Soviet research vessel "Novorossiysk" caught roughhead grenadier north of Iceland in small quantities at 630-720 m at the near-bottom temperature of -0.4° to -0.5° while the Icelandic vessel - west of Iceland at 3° to 5° (Magnusson, MS 1977).

Roughhead grenadier are usually found in the catches both on the shelf and continental slope. This typical benthophage and predator (Konstantinov and Podrazhanskaya, 1972; Konstantinov, 1976; Geistdoerfer, 1976) is captured exclusively with the bottom fishing gears. Materials of the total trawl survey carried out in the Newfoundland and South Labredor areas showed that roughhead grenadier concentrated along the continental slope and in deepwater troughs of the shelf. In shallows of the Grand and Flemish Cap Banks the catches did not include even sporadic specimens of this species (Fig.2).

The stenobathic distribution is rather typical of Macrouridae which occupy by depth some hundreds of metres but separate species, for instance Coryphaenoides bucephalus, are characterized by a very wide vertical distribution - from 245 to 2878 m (Makushok, 1968). According to data from our trawl surveys roughhead grenadier were caught at 100 to 1300 m (no trawling was made deeper). The catches taken down to 600 m were insignificant and they increased with trawling depth (Fig.3). The species is known to be spread as deep as 2740 m which is indicative of its eurybathic distribution. So far it is uncertain whether the fish concentrations are found at 1500 m and deeper though the capture of 10 large fishes with a bottom trawl at 1470-1520 m reported from Central Labrador in October 1969 (Savvatimsky, 1985) allows to make this assumption.

Most Macrouridae are notable for stenothermy, yet some of them are eurythermal (Makushok, 1968). During the trawl surveys roughhead grenadier were caught within a wide near-bottom temperature range from -2° to +8°, the highest catches were recorded at -2.0° to +3.0° (Fig.3). The catches taken in the day-time were higher than those fished at night, the largest ones - from 12 to 16 hours.

The trawl survey permits to have an estimate of roughhead grenadier abundance and biomass for the area shown in Fig.1. The fishing efficiency of the trawl (k) was assumed to be 0.5. Provided that the ship's speed is 3.5 miles per hour and distance between the trawl wings is 14.3 m s = 0.027 sq. miles. The total area surveyed with grenadier catches (S) was about 66000 sq. miles. The mean catch per trawling hour (n) equalled 14.28 specimens. The absolute abundance was estimated to be 69.9 mill. spec. Using the mean length of fish (51.75 cm) and mean weight of one specimen (700 g) the total biomass was assessed at 48.9 thou. t. Thus, the roughhead grenadier stock can be an additional fish supply for the trawl fishery.

LENGTH AND SEX COMPOSITION OF CATCHES

In 1967-83 the research and scouting vessels carried out the bottom trawl fishery for roughhead grenadier on the shelf

and continental slope of West Greenland, Baffin Land, Labrador and Newfoundland, the highest catches being taken in Divs. 3K, 3L and 3N.

Males averaged 37.5% of the catches, females - 62.5%, the latters were by far larger than the formers (Table 1, Fig.4).

In Div. 3N roughhead grenadier were the largest (the mean length of males was 50.8 cm, that of females - 58.6 cm), the relative number of females (71.2%) was higher than in other Divisions. Throughout Divs.3K, 3L, 3N the mean length of males was 47.0 cm, that of females - 54.6 cm.

In the length frequency as a whole males prevailed among fishes below 53 cm while among those above 53 cm females constituted more than 50% of the total number of fish in each length group.

In all 19507 specimens were measured from 1967 to 1978 including measurements without sex determination. The length composition of catches in different NAFO Subareas and Divisions is not the same (Fig.5) which is explained by different sex composition dependent on various trawling depth (from less than 200 m to more than 1000 m). Large grenadier were mainly caught at small depth (Table 2).

The decrease of the fish mean length in the catches with increasing trawling depth did not depend on the male and female distribution. The mean length of both males and females decreased (Table 3).

In Divs. 3K and 3N both males and females were somewhat larger in the catches taken at night (from 20 to 8 hours) than those caught in the day-time (from 8 to 20 hours) (Table 4).

In Div. 3L the length composition of catches taken at night and in the day-time did not differ.

LENGTH-WEIGHT RELATION

Roughhead grenadier is a non-commercial species, that is why the materials, especially age samples, were collected occasionally with the length measuring and weighing of fish in the latter case. A small number of age samples (only 5060 specimens were analysed from 1969 to 1983) does not allow to compare the length-

weight relation by years or seasons between the same Divisions.

The highest number of samples was collected in Div. 3N. The comparison of the mean grenadier weight by years did not show any differences for the area. The same result was obtained when comparing the fish weight by Divisions.

In the Northwest Atlantic the roughhead grenadier weight did not differ between males and females below 60 cm while in fishes above 60 cm the mean weight of females was slightly greater than that of males. It is interesting to note that the mean weight of females was much higher than that of males in fishes of the same length caught in winter 1982 and 1983 near the Norwegian coast (Savvatimsky, MS 1985). Fig.6 gives the length-weight relation (without dividing by sex) on the basis of all available data. This relation is expressed rather precisely in the formula: $W = 0.00259L^{3.177}$. The fishes which occurred most commonly in bottom trawl catches were 45-47 cm long and weighed 550 g. Grenadier 80 cm long weighed 3000 g. The largest specimen caught off Greenland was 109 cm long and weighed 10 kg (Jensen, 1948). Fulton's condition factor increased with the fish growth. With the increase in grenadier length from 27 to 82 cm and weight from 80 to 3250 g Fulton's condition factors varied from 0.35 to 0.46% (Fig.7). It should be stressed that the length-weight relation varied unequally with the growth of grenadiers of different species. Thus, according to our data, with the increase in length, for instance, of roundnose grenadier (Coryphaenoides rupestris Gunn) from 21 to 92 cm Fulton's condition factors decreased from 0.34 to 0.18%, these values being lower for males.

AGE AND GROWTH

A slow growth is characteristic of deepwater fishes including grenadiers compared to fishes of the upper oceanic layers (Hureau et al., 1979). The data on the roughhead grenadier age and peculiarities of growth are scanty. K.P.Yanulov (1962) reported that a 70.5 cm female caught near the north coast of Norway was 16 years old. The catches taken on the Dohrn Bank off East Greenland consisted of 41-86 cm fish (aged 8-18 years) with the dominant

age-groups (12-15 years) represented by 62-75 cm specimens (Koswig, MS 1979). According to our data grenadier 48-70 cm long caught with a bottom trawl in December 1982 in the area of Lofoten Islands were 8-17 years old (Savvatimsky, 1986). Females of this species from Iceland waters being 67-89 cm long and weighing 1950-4700 g were 17-25 years old. The fishes caught with a bottom trawl on the northeastern slope of Grand Bank at an age of 3 to 16 years were 26-66 cm long (Savvatimsky, 1971). Grenadier captured with a long-line in summer 1982 on the Grand Bank were larger. Their length and age were 40-87 cm and 6-23 years (Savvatimsky, 1984). By evidence of the Norwegian authors the fishes were of 25 (Eliassen, MS 1983) and 30 (Bakken et al., MS 1975) years.

Thus, according to data of different scientists roughhead grenadier as the other grenadiers of the North Atlantic have a long life cycle and many-aged population structure.

REPRODUCTION

Little is known about reproduction of roughhead grenadier. They seem to have a long spawning period, the prespawning and spawning fishes are observed at different time of a year. K.P.Yanulov (1962) reported about the capture of a female near Norwegian coast in January 1958, the one which ovaries contained eggs ready to be spent. He pointed out winter and early spring to be the reproductive period of the species. On the basis of the egg grouping size in the ovaries he assumed the existence of intermittent spawning. By his evidence the mature eggs were 3.4-3.85 mm (on the average 3.62 mm) in diameter and fecundity - 25 thou. eggs. In that very area prespawning and spawning fishes were caught by the Soviet research vessels in May 1968 (Savvatimsky, 1969), in April and December 1982, in January, March, December 1983 and in January 1984 (Savvatimsky, MS 1985, 1986, 1986a). So, the spawning lasted here from December to May and, perhaps, later. The Norwegian investigators showed that the female gonads developed from May to December. During this period the ovaries of fishes above 80 cm gained in weight from 100 to 500 g (Eliassen, MS 1983; Eliassen and Falk-Petersen, 1985), the most intensive spawning

occurred in January. Roughhead grenadier dwelling off the Norwegian coast and northward, along the continental slope, seemed to have the same spawning period as the grenadier from both the East Greenland area where the spawning was observed in May (Magnusson, 1975) and West Iceland area where the fish spawned in winter and early spring (Magnusson, MS 1977; MS 1978). Magnusson (MS 1977) reported about the capture of spawning roughhead grenadier and also larvae and eggs of this species west of Iceland in May and March 1976. The eggs caught were 3.48-4.02 mm in diameter with a fat ball diameter of 0.80-1.01 mm. The eggs taken in spawning females were approximately of the same diameter (3.08-4.56 mm) and of two sizes which corroborated the hypothesis of intermittent spawning. In the opinion of Magnusson the fish spawning occurred probably round the year but its peak fell on November-February, the capture of freely drifting bathypelagic eggs in the West Iceland waters in March 1977 proved it.

Jensen (1948) assumed as well that the spawning off West Greenland took place in winter and early spring since he found very small eggs in females caught in the area in July.

In the Faroe-Iceland Ridge area the terms of the fish spawning were different, i.e. late spring - early summer (Geistdoerfer, 1979). The same spawning period was recorded for the Northwest Atlantic (NAFO Divs. 3KL and 2J) based on the fact that prespawning fishes were caught sporadically in July at 400 m depth and 90% of adult fishes were already spent (Geistdoerfer, 1979). Different terms of roughhead grenadier spawning are accounted for by a lingering spawning period of the species, fragmentary observations or various ecologic conditions of the fish habitat.

In our opinion the roughhead grenadier spawning on the Grand Bank occurred in winter and early spring (Savvatimsky, 1984) which was confirmed by the capture of prespawning females by the research vessel "Rossiya" using a bottom trawl in NAFO Div. 3N (45°22'N, 48°50'W) at 150-200 m depth on 5 May 1968. Of 45 fishes analysed 39 turned to be females 45-80 cm long. 14 prespawning females were 65-80 cm long. All the males 51-65 cm long were immature. In other years the Soviet investigations of Newfoundland and Labrador were

mainly carried out in summer and autumn when, as a rule, there was no spawning roughhead grenadier in the catches. The ovaries of four females caught in November 1980 in the Baffin Land area contained eggs of two sizes (Fig.8). Besides, single eggs 3.3 - 3.4 mm in diameter remained apparently after intermittent spawning were found. The fecundity was on the average 38.2 thou. eggs (2.0-2.7 mm in diameter) (Table 5).

Despite the fact that fishes differed little in size the maturity coefficient and fecundity were higher in larger females. It supported the findings of Norwegian scientists (Eliassen and Falk-Petersen, 1985) which stated the increase in fecundity from 2 to 71 thou. eggs with the growth of grenadier.

FEEDING

Roughhead grenadier is a bottom-feeding predator. Except for shrimp (Pandalus borealis, Hymenodora glacialis), the benthic organisms were found in its stomachs: Ophiura (Ophiacantha abyssicola), Mollusca (Buccinum, Fusus), Amphipoda and also capelin (Andriyashev, 1954). Roughhead grenadier is classified as a species the major diet of which consists of benthic organisms (Podrazhanskaya, 1982; Hureau et al., 1979; Geistdoerfer, 1976, 1979). Benthic animals accounted for 91.6% of food of this grenadier species caught on the Grand Bank (Houston, MS 1983). The investigations carried out by the Polar Institute in October 1967 showed that grenadier from South Labrador and north-eastern slope of Grand Bank fed on bottom and near-bottom animals, mainly on Ophiura. The basic food items of grenadier from other areas of the Northwest Atlantic and also Greenland and Iceland were benthic animals too (Savvatimsky, 1969). In August 1967 some tens of prespawning females 53-89 cm long were caught with a bottom trawl in the cruise of research vessel "Novorossiysk" north of Iceland (67°50'N, 20°00'W) at the depth about 800 m. In the stomachs of the fishes we found chiefly shrimp and also squids, molluscs and amphipods. In Greenland fjords roughhead grenadier fed on large shrimp (Pandalus), capelin and other small fishes, polychaetes, ascidians and bivalves (Jensen, 1948). The feeding of this grenadier species

with reference to peculiarities of the body and gill structure was exhaustively studied by K.G.Konstantinov and S.G.Podrazhanskaya (1972) and Konstantinov (1976). According to their data grenadier inhabiting the Greenland-Canadian Ridge and North Labrador fed mainly on shrimps, Ophiura and squids in August-December 1969. The authors recognized the feeding spectra of grenadier and spinax shark (Centroscyllium fabricii) to be similar.

The seasonal and age peculiarities of roughhead grenadier feeding are analysed only in some of a small number of publications dedicated to studying of this problem. Geistdoerfer (1979) pointed out 5 major groups of animals in grenadier diet: Gammaridae, Ophiura, Polychaeta, shrimps and fishes. As grenadier grew the portion of shrimps and fishes in the food increased. The stomachs of grenadier caught off the northern coast of Norway contained 30 different food objects attributed to 6 basic groups: Polychaeta, Mollusca, Crustacea, Echinodermata, Ascidiacea and fishes (Eliassen and Jobling, 1985). The authors concentrated upon the variation of food composition with the fish growth.

A various food composition of grenadier and great variations in food ration with the fish growth were confirmed by the results of our surveys. From 1969 to 1983 738 males and 1692 females from the bottom trawl catches taken in the Newfoundland, South Labrador and Baffin Land areas were analysed for feeding. The stomachs of 36.7% of males and 37.1% of females (37.0% on the average) turned to be everted and these fishes were not considered. To study general rules of grenadier feeding the data were summarized.

Immature and postspawning grenadier fed most intensively (the mean degree of stomach fullness was 1.0-1.2), the intensity of feeding decreased in prespawning fishes (the mean degree - 0-0.8). The decrease in intensity of feeding during spawning was also typical of grenadier dwelling near the coast of Norway in winter 1982-84 when the mean degree of stomach fullness was 0.3 and the number of empty stomachs - 81.8% (Savvatimsky, MS 1985).

The feeding spectrum of grenadier from the Newfoundland area was rather wide, more than 20 food items belonging to different zoological groups were found in its stomachs (Tables 6, 7, 8).

The occurrence of Ophiura (26%) was the highest, Polychaeta (19.0%) were the second in food composition, Gastropoda and Bivalvia (11.7% with prevalence of the latters) were the third. Then followed different Crustacea: Amphipoda, Isopoda, shrimps and others. Roughhead grenadier , mainly large, preferred capelin and sand eel of fishes. So, the occurrence of fish in the stomachs was 25.3% in 71-80 cm grenadier and only 3.3% in 31-40 cm specimens. The smaller grenadier fed mainly on Calanus, Amphipoda, Polychaeta, small Ophiura. Houston (MS 1983) must not have found any fish in the stomachs of grenadier from the Grand Bank because the specimens analysed were very small (77.7-324.0 mm long and weighing on the average 316.1 g).

Small pelagic and near-bottom crustaceans (Copepoda, Amphipoda, Euphausiidae, Cumacea) were of great importance in the feeding of grenadier below 30 cm, with their growth the occurrence of crustaceans decreased sharply and the importance of Pandalidae, Paguridae, Mollusca and also fishes increased (Fig.9).

Roughhead grenadier females were larger than males. It accounted for some difference in their food composition. The feeding spectrum of females was much wider than that of males. It included fishes, shrimps, crabs, actinians, mysids, the fishes being found in female stomachs with body shape inconvenient for swallowing by predators (redfish, American plaice). The coefficient of food similarity between males and females analysed for feeding appeared to be not high (65.4) which was due to different sizes of fishes of two sexes. The mean length of 503 males was 45.5 cm while that of 1056 females - 54.0 cm. The comparison of coefficient of food similarity between males and females in the 41-60 cm group gave the value 75.2. The analysis of food similarity of grenadier (data summarized for males and females) between the 10 cm size groups indicated great variations in the feeding of this fish with its growth. Coefficients of food similarity differed little between the nearest length groups. They increased as the length of compared fish groups grew. So, comparing the 31-40 cm and 41-50 cm length groups, and also 41-50 cm and 51-60 cm groups we obtained high and similar coefficients - 70.7 and 66.8 respectively. When

comparing the 21-30 cm and 81-90 cm length groups the coefficient was small - 8.0 which was indicative of the different feeding spectrum of fish in compared groups (Table 9).

FATNESS

There is but little information in literature about roughhead grenadier fatness. The fatness of grenadier analysed by L.P.Minder (1967) was 16% (8.6% on the average). In accordance with the Polish data (Nordzynski and Zukowski, 1971) the fatness of this fish constituted 8.76-14.89% (12.1% on the average). Fatness of grenadier forming spawning concentrations near the northern coast of Norway turned to be rather low in winter 1983 and 1984 - 7.5% on the average (Savvatimsky, MS 1985).

According to our data the mean fatness of grenadier caught in 1969-83 in the Labrador, Newfoundland and Baffin Land areas ranged from 4.7 to 12.4% (Table 10). Fatness of all fish samples (3694 specimens) averaged 8.3%. In view of the small number of samples no regular changes were observed in fatness during a year. The fatness of grenadier caught near Norwegian coast increased in summer and decreased in autumn signifying the fish getting ready for spawning (Eliassen and Falk-Petersen, 1985).

Fatness of grenadier from the Baffin Land and Labrador areas was much higher than that in southern part of Newfoundland (Fig.10, Tables 11, 12). It may be said that mean fatness decreased gradually in NAFO Divisions toward south.

The mean fatness of males in all samples was 11.0%, that of females - 8.2%. Fatness of males and females changed unequally with the length variations (Fig.10) which was due to fish feeding and maturing. Males got first mature being about 35 cm long (stage III of gonad maturity) though the bulk of them matured and spawned at the length of 50-55 cm (Table 13). By that time their relative liver weight was the highest (14% on the average). As the male length continued to increase the liver weight decreased sharply. Grenadier females got mature much more later and spawned being about 70 cm long (Table 13). Their fatness increased gradually before the fish attained this length and decreased in fish above 80 cm.

DISCUSSION

The range of roughhead grenadier in the North Atlantic is vast and deep, the fish inhabit near-bottom shelfy waters and adjacent parts of continental slope. The length composition of trawl catches differed greatly by areas depending, perhaps, on various trawling depth. As it has been already mentioned with the increase of trawling depth from 200 to 600 m the mean length of males and females in Div. 3N decreased which coincided with the results of observations obtained by Parsons (1976). The grenadier length increased in long-line catches with increasing depth from 300 to 1000 m in above area (Savvatimsky, MS 1983, 1984).

The Soviet investigations carried out in winter 1982-84 off Lofoten Islands showed that females were mainly distributed within the upper depth range of spawning grounds and males - within the lower one, the mean length of fish in the catches increasing with the increasing trawling depth from 400 to 900 m (Savvatimsky, MS 1985). According to different information in September 1982 and April 1983 large grenadier were mainly caught at great depths but as the trawling depth grew the relative number of females increased in the area. If the mixed concentrations of males and females were usually found in the upper layers, large fishes, females in the main, prevailed at the depth more than 1000 m. So, the 10 large specimens caught with a bottom trawl at 1470-1520 m in Central Labrador in 1969 turned to be females. The increase of length with trawling depth was also peculiar to other grenadier species, for instance Coryphaenoides rupestris (Savvatimsky, 1982; 1986a; MS 1986b), Trachyrhynchus trachyrhynchus (Ibanez, 1977). Grenadiers found by American scientists in the near-bottom 750-6000 m layer in the Pacific, Atlantic and Indian Oceans were, as a rule, large mature fishes (Isaacs and Schwartzlose, 1975). The increase of the fish length with the depth resulted, probably, from adaptation to the environment with a relatively poor nutritive base in deep oceanic layers and from more efficient consumption of food by large grenadier.

The long growth period, many-aged population structure and

late maturation are characteristic of roughhead grenadier. The spawning occurred to all appearances in winter and early spring. The spawned eggs may be distributed at a great depth since they were caught with plankton nets in the 985-1200 m layer (Magnusson, 1975). It prevented from mass mortality and transfer of eggs to great distances with the surface oceanic currents. The fecundity determined for grenadier from Baffin Land (on the average 38.2 thou. eggs) was similar to values obtained by Yanulov (1962) and by Eliassen and Falk-Petersen (1985), and was rather low like in other deepwater fishes which was attributed to adaptation to the environment. At the great depth the living conditions were relatively invariable, predator pressure was small, thus, the survival of progeny increased, especially at early developmental stages.

In roughhead grenadier, like in other grenadiers, fat is accumulated in the liver by the relative weight of which the fat depot of organism is determined as a whole. Its content increased with fish growth before they got mature, then decreased since part of it was spent on gonads to ripen. The tendency toward decrease of fatness and the increase of grenadier sizes by NAFO Divisions from the north to the south concurrent with the capture of mature fishes on the southeastern slope of Grand Bank permit to regard the area as the spawning ground.

Roughhead grenadier is a typical demersal species, the active predator eating various food - from pelagic crustaceans and fishes to different bottom and near-bottom animals. A great variety of food, wide feeding spectrum, essential distinctions in the feeding between early and late ontogeny are undoubtedly of adaptive importance since they widen the nutritive base of the species, favour the decrease of intraspecific food competition and more complete use of food resources at great depths.

The diversity of food objects, long life cycle, schooled mode of life determine a rich parasitic fauna of roughhead grenadier (Zubchenko, 1975; MS 1981; Campbell et al., 1980; Houston, MS 1983; Moser and Noble, 1977).

The distribution in water column and daily vertical migra-

tions of bottom and near-bottom fishes depend, in general, on their feeding behaviour and consumption of food organisms performing the above migrations. The diet consists of quite a number of various bottom animals but the major food components of large grenadier are more active benthopelagic species (Eliassen and Jobling, 1985). This accounts, perhaps, for different size of landings and also different length composition of catches taken at night and in the day-time. The increase in the mean length of grenadier caught with a bottom trawl at night was, obviously, due to pelagic migrations of chiefly small fishes following the minor food objects. There are no data in literature on daily vertical migrations of roughhead grenadier, nevertheless, it is known that many bottom fishes stay for long in the middle water layers and quite often are observed near the sea surface (Konstantinov and Shestopal, 1976).

The approximate (with many assumptions) total abundance and biomass estimate was made by the long-term mean catch in the trawl survey area. The arbitrary value of the trawl fishing efficiency was taken, year-to-year abundance fluctuations were not known and considered though even tentative estimate showed a high potential grenadier catch. During the trawl surveys most hauls were performed at depths under 600 m where the catches were small. Provided that the fishing is carried out at depths above 600 m the mean catch per trawling hour increases which will result in the increase of the total abundance and biomass estimate.

The abundance and biomass indices are just determined in a limited shelfy area of Newfoundland and South Labrador. It should be taken into consideration that roughhead grenadier are also abundant in the areas of North and Central Labrador and Baffin Land accounting for a large by-catch in the Greenland halibut bottom fishery especially when trawling at depths above 1000 m.

Roughhead grenadier do not form so dense concentrations as the similar species - roundnose grenadier (Coryphaenoides rupestris), therefore, its directed trawl fishery is hardly advisable.

The long-line fishery in which roughhead grenadier together with wolffishes and skates make up a considerable portion of catches may be efficient in the Northwest Atlantic (Savvatimsky, MS 1983; 1984).

REFERENCES

ANDRIYASHEV, A.P. 1954. Fishes of the northern seas of the USSR. USSR A.S. Press, Moscow-Leningrad, 566 p. (in Russian).

BAKKEN, E., J. GJØSAETER, and J. LAHN-JOHANNESSEN. MS 1975. Demersal fish on the continental slope off Norway. ICES CM 1975/F:29, 15 p.

CAMPBELL, R.A., R.L. HAEDRICH, and T.A. MUNROE. 1980. Parasitism and ecological relationships among deep-sea benthic fishes. Mar. Biol., 57(4): 301-313.

ELIASSEN, J.E. MS 1983. Occurrence, gonad development and age distribution of the roughhead grenadier (Macrourus berglax Lacépède) (Gadiformes, Macrouridae) along the continental slope of Northern Norway. ICES CM 1983/G:41, 19 p.

ELIASSEN, J.E. MS 1983a. Depth distribution of roughhead grenadier (Macrourus berglax Lacépède) in relation to hydrographical conditions along the continental slope of northern Norway. ICES CM 1983/G:42, 17 p.

ELIASSEN, J.E, and I.B. FALK-PETERSEN. 1985. Reproductive biology of the roughhead grenadier (Macrourus berglax Lacépède) (Pisces, Gadiformes) from the continental slope of northern Norway. Sarsia, 70(1): 59-67.

ELIASSEN, J.E., and M. JOBLING. 1985. Food of the roughhead grenadier (Macrourus berglax Lacépède) in North Norwegian waters. J. Fish. Biol., 26(3): 367-376.

GEISTDOERFER, P. 1976. Alimentation de deux Macrouridae de l'Atlantique nord: Macrourus berglax et Coryphaenoides rupestris (Teleosteens, Gadiformes). Rev. trav.Inst. pêches mar., 40(3-4): 579-580.

GEISTDOERFER, P. 1979. Recherches sur l'alimentation de Macrourus berglax L.) (Macrouridae, Gadiformes). Ann.Inst.oceanogr., 55(2): 135-144.

HOUSTON, K.A. MS 1983. Food sources for deep-sea fishes of the Newfoundland continental slope. NAFO SCR Doc., No.89, Serial No.N755, 19 p.

HUREAU, J.C., P. GEISTDOERFER, and M. RANNOU. 1979. The ecology of deep-sea benthic fish. Sarsia, 64(1-2): 103-108.

IBANEZ, M. 1977. Contribucion al estudio de la biologia y crecimiento de un pez batibentico Trechyrhynchus trachyrhynchus (Risso) en el Mediterraneo y Atlantico N.E. Notas ictiologicas IV. Minibe Sociedad de Ciencias Aranzadi, San Sebastian, 29(3-4): 213-230.

ISAACS, J.D., and R.A. SCHWARTZLOSE. 1975. Active animals of the deep-sea floor. Sci.Amer., 233(4):85-91.

JENSEN, A.S. 1948. Contributions to the ichthyofauna of Greenland. Spolia zool. Mus. Hanniensis, Copenhagen, IX, 182 p.

KONSTANTINOV, K.G. 1976. Morpho-functional peculiarities of Greenland halibut and grenadiers associated with movement and feeding. Trudy PINRO, Murmansk, 37: 26-34 (in Russian).

KONSTANTINOV, K.G., and S.G. PODRAZHANSKAYA. 1972. Feeding and food interrelations of grenadier (Macrurus rupestris) and other deep-water fishes of Northwest Atlantic. Trudy PINRO, 28: 96-106 (in Russian).

KONSTANTINOV, K.G., and I.P. SHESTOPAL. 1976. On the capture of bottom fishes off the sea surface. Trudy PINRO, Murmansk, 37: 77-82 (in Russian).

KOSSWIG, K. MS 1979. A note on the age and growth of the roughhead grenadier (Macrourus berglax Lacépède) at East Greenland (Dohrn Bank) in 1978. ICES CM 1979/G:59, 4 p.

LEIM, A.H., and W.B. SCOTT. 1966. Fishes of the Atlantic coast of Canada. Bull.Fish.Res.Bd.Canada, 155: 485 p.

MAGNUSSON, J.V. 1975. Notes on the rock grenadier (Coryphaenoides rupestris) and the roughhead grenadier (Macrourus berglax) at Iceland in 1975. Annls biol., Copenh., 32: 178 p.

MAGNUSSON, J.V. MS 1977. Some notes on the spawning habits of Macrouridae at Iceland. ICES CM 1977/F:49, 9 p.

MAGNUSSON, J.V. MS 1978. On the distribution and spawning grounds of the roughhead grenadier (Macrourus berglax Lacépède) west of Iceland. ICES CM 1978/G:36, 10 p.

MAGNUSSON, J.V. 1979. Icelandic investigations on grenadier fish (Coryphaenoides rupestris Gunnerus and Macrourus berglax Lacépède) in 1977. Annls biol., Copenh., 34:223-225.

MAKUSHOK, V.M. 1968. Grenadiers (fam. Macrouridae or Coryphaenoididae auct.). In: The Pacific Ocean, Nauka Press, Moscow, p p.200-227 (in Russian).

MINDER, L.P. 1967. Weight and chemical composition of grenadier, Macrurus berglax. Trudy PINRO, 22: 127-132 (in Russian).

MOSER, M., and E.R. NOBLE. 1977. Myxosporidian genera Auerbachia, Spherospora, Davisia and Chloromyxum in macrourid fishes and the Sablefish, Anoplopoma fimbria. Zeitschrift fur Parasitenkunde, 51(2): 159-163.

NODZYNSKI, J., and Cz. ZUKOWSKI. 1971. Biologiczna i technologiczna charakteristyka ryb bulawikowatych z Polnocno-Zachodniego Atlantyku. Studia i Materialy, M.I.R. Gdynia, seria D, 5:45 s.

PARSONS, L.S. MS 1975. Distribution and relative abundance of roundnose, roughhead and common grenadiers in the Northwest Atlantic. ICNAF Res.Doc., No.26, 19 p.

PARSONS, L.S. 1976. Distribution and relative abundance of roundnose, roughhead and common grenadiers in the Northwest Atlantic. ICNAF Sel. Papers, 1: 73-88.

PARSONS, L.S. 1976a. Grenadiers. Living marine resources of Newfoundland-Labrador: Status and Potential. Bull.Res.Board Canada, 194: 19-23.

PODRAZHANSKAYA, S.G. 1982. Feeding and food interrelations of different commercial fishes of Northwest Atlantic. Abundance and mode of life of commercial fishes of Northwest Atlantic. Sbornik nauchnych trudov PINRO, Murmansk, p.112-123 (in Russian).

SAHRHAGE, D. 1986. Wirtschaftlich wichtige Grenadierfische des Nordatlantiks. Mitteilungen aus dem Institut für Seefischerei der BFA für Fischerei, Hamburg, 37:81.

SAVVATIMSKY, P.I. 1969. Grenadier of the North Atlantic. Murmansk, 72 p. (in Russian).

SAVVATIMSKY, P.I. 1971. On age reading in grenadiers (Macruriformes). Vopr.Ikhtiol., 11(3): 495-501 (in Russian).

SAVVATIMSKY, P.I. 1982. Fatness of grenadiers of the North Atlantic. Abundance and mode of life of commercial fishes of the Northwest Atlantic. Sbornik nauchnych trudov PINRO, Murmansk, p.97-111 (in Russian).

SAVVATIMSKY, P.I. MS 1983. Distribution, biological characteristics and percentage of roughhead grenadier in the catches from the Grand Newfoundland area in May-July 1982. NAFO SCR Doc., No.45, Serial No.N702, 21 p.

SAVVATIMSKY, P.I. 1984. Biological aspects of roughhead grenadier (Macrourus berglax) from long-line catches in the eastern Grand Bank area, 1982. NAFO Sci.Coun.Studies, 7:45-51.

SAVVATIMSKY, P.I. MS 1985. Features of spawning concentrations of roughhead grenadier Macrourus berglax L. at the Norwegian coast. ICES CM 1985/G:6, 34 p.

SAVVATIMSKY, P.I. 1986. Distribution, length-age composition, food, and fat content of roughhead grenadier (Macrourus berglax) off Lofoten. Annls biol., Copenh., 40: 177-179.

SAVVATIMSKY, P.I. 1986a. Investigations on roughhead grenadier Macrourus berglax off the Norwegian coast in the winter of 1983/1984. Annls biol., Copenh., 41: 151-153.

SAVVATIMSKY, P.I. MS 1986b. Changes in composition of the bottom fish catches at different depths along the continental slope in NAFO Subareas 0, 2 and 3 in 1970-85. NAFO SCR Doc., No.67, Serial No.N1184, 26 p.

SOROKIN, V.P. 1957. Ovogenesis and annual development of the ovaries of cod (Gadus morhua morhua L.). Trudy PINRO, 10: 125-144 (in Russian).

SOROKIN, V.P. 1960. Cod sexual cycle and spermatogenesis. Trudy PINRO, 12: 71-87 (in Russian).

WHEELER, A. 1969. Anacanthini. The fishes of the British Isles and Northwest Europe. London-Melbourne-Toronto, pp.255-259.

YANULOV, K.P. 1962. On the reproduction of the roughhead grenadier (Macrurus berglax Lacépède). Zoologicheskii Zhurnal, 41(8): 1259-1262 (in Russian).

YANULOV, K.P. 1963. Feeding of the Sebastes mentella Travin in the waters of Newfoundland and Labrador. Vopr.Ikhtiol., 3(4): 708-725 (in Russian).

ZUBCHENKO, A.V. 1975. On the fauna of Macruridae parasites in North Atlantic. Trudy PINRO, 35:234-238 (in Russian).

ZUBCHENKO, A.V. MS 1981. Ecological-faunistic review of parasitic fauna of some Macrouridae in the Northwest Atlantic. NAFO SCR Doc., No.46, Serial No.N328, 12 p.

Table 1. The mean length and sex composition of roughhead grenadier in the catches from Divs.3K, 3L, 3N in 1967-83.

Division	Males			Females		
	Mean length, cm	%	No.of spec.	Mean length, cm	%	No.of spec.
3K	45.7	40.3	680	53.2	59.7	I009
3L	45.5	42.5	I720	5I.9	57.5	2323
3N	50.8	28.8	820	58.6	7I.2	2029
In all Divisions	47.0	37.5	3220	54.6	62.5	536I

Table 2. Mean length of roughhead grenadier in the catches taken with a bottom trawl at different depths in Div.3N in 1969-83.

D e p t h, m	Mean length, cm	No. of spec.
Less than 200	56.48	3459
20I-300	55.59	2488
30I-400	54.0I	45I
40I-500	5I.07	4I4
50I-600	45.0I	73
60I-700	49.00	7

Table 3. Mean length of male and female roughhead grenadier in the catches taken with a bottom trawl at different depths in Div.3N in 1979-83.

Depth, m	Males		Females		Males & females	
	Mean length, cm	No. of spec.	Mean length, cm	No. of spec.	Mean length, cm	No.of spec.
Less than 200	52.3	33	65.8	I09	62.7	I42
20I-300	48.2	I95	55.7	348	53.2	543
30I-400	46.7	27	57.3	84	54,7	III
40I-500	46.9	40	56.5	I5I	54.5	I9I
50I-600	43.6	I4	53.7	I4	48.7	28

Table 4. Mean length in cm (numerator) and number of roughhead grenadier measured (denominator) in bottom trawl catches taken at night and in the day-time in Divs. 3K, 3N in 1967-83.

Division	Males		Females		Males & females	
	Day	Night	Day	Night	Day	Night
	45.4±0.4 365	46.I±0.4 3I5	52.0±0.6 498	54.3±0.6 5II	49.2±0.4 863	5I.2±0.4 826
	48.9±0.3 470	54.I±0.5 350	58.3±0.3 I320	59.0±0.4 709	55.8±0.2 I790	57.4±0.3 I059
Total	47.4±0.3 835	50.3±0.4 665	56.6±0.3 I8I8	57.I±0.3 I220	53.7±0.2 2653	54.7±0.3 I885

Table 5. Parameters of female roughhead grenadier caught in the Baffin Land area in November 1980.

Fish length, cm	Fish weight, g	Gonad weight, g	Maturity coefficient, %	Egg diameter, mm	Fecundity, thou. eggs
80	3830	332.4	8.7	2.0-2.5	43.0
70	2230	I4I.7	6.4	2.0-2.4	23.I
82	3670	395.9	I0.8	2.2-2.5	54.4
82	3020	363.5	I2.0	2.I-2.7	32.2

Table 6. Frequency of occurrence (%) of various food components in the stomachs of male roughhead grenadier from the catches in the Baffin Land, Labrador and Newfoundland areas, 1969-83.

Food composition	Fish length, cm						
	21-30	31-40	41-50	51-60	61-70	71-80	21-80
Medusa			0.4				0.2
Ctenophora			0.7	0.8			0.6
Spongia			0.4				0.2
Polychaeta	26.3	28.7	22.9	21.8			23.6
oth Vermes	5.3	5.7	3.3	0.8	50.0		3.4
Calanus			2.5	0.8			1.6
Amphipoda	21.0	8.0	10.2	12.6	50.0		10.9
Euphausiacea		1.1	2.9	1.7			2.2
Isopoda		4.6	3.6	5.9			4.2
Cumacea		1.1	1.4	0.8			1.2
Shrimp		4.6	7.3	6.7			6.4
Crabs		1.1	1.1	1.7			1.2
oth Crustacea		3.4	1.4	0.8			1.6
Cephalopoda			1.4				0.8
Ophiura	52.6	44.8	35.6	31.1			36.6
oth Echinodermata			0.7	5.9			1.8
Actiniaria			1.1	1.7			1.0
Mollusca	5.3	13.8	10.2	12.6			11.1
Mysidacea		2.3	0.7	1.7			1.2
Myctophidae			1.4	3.4			1.6
Capelin		1.1	12.4	13.4		100.0	10.3
Sand eel			0.4	6.7			1.8
Grenadier			0.4				0.2
Digested fish		3.4	9.1	5.0			6.7
Digested food	5.3	23.0	10.5	6.7	50.0		11.7
oth fishes				0.8			0.2
ground		2.3	0.7				0.8
No.of stomachs excluding empty ones	19	87	275	119	2	1	503
No.of empty stomachs	9	50	118	55	3		235
Mean degree of stomach fullness	1.0	0.9	1.2	1.2	0.6	3.0	1.1

Table 8. Frequency of occurrence (%) of different food components in the stomachs of male and female roughhead grenadier from the catches in the Baffin Land, Labrador and Newfoundland areas, 1969-83.

Food composition	Fish length, cm								
	II-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90	II-90
Medusa				0.6	0.9	3.6	6.1		1.3
Ctenophora				0.6	2.1	2.3	1.2	6.7	1.3
Spongia			0.5	0.4	1.1	3.2	7.3		1.3
Polychaeta		27.3	23.0	24.3	16.8	12.8	3.6	-	19.0
oth Vermes		2.3	4.2	3.5	3.0	0.9	1.2		2.9
Calanus		2.3	2.8	2.1	0.4	0.4			1.3
Amphipoda	100.0	27.3	10.3	10.0	9.1	6.4	4.9		9.6
Euphausiacea			1.9	2.7	2.8	6.4	1.2		2.9
Isopoda			2.3	2.9	3.7	4.1		6.7	3.0
Cumacea		4.5	0.9	1.0	0.6	1.4			1.0
Shrimp			3.3	8.5	8.4	11.9	21.9	33.3	8.9
Crabs			0.5	1.3	1.9	1.8			1.3
oth Crustacea			2.3	1.1	0.6	0.4			1.0
Cephalopoda				1.5	1.3	4.6	6.1		1.9
Ophiura	50.0	52.3	35.7	33.1	23.1	9.6	4.9		26.0
oth Echinodermata			0.5	2.3	5.4	10.0	12.2	13.3	4.6
Actiniaria				1.1	2.4	4.6	-	-	1.7
Mollusca		2.3	9.8	13.3	9.5	14.1	18.4	40.0	11.7
Mysidacea			1.4	1.5	1.9	2.7			1.7
Myctophidae				1.0	1.3				0.7
Capelin			2.3	9.4	17.3	5.9	3.6		9.6
Sand eel				0.8	5.8	17.3	6.1		4.7
American plaice						0.4			0.1
Redfish					0.4	1.8	1.2	6.7	0.5
Grenadier				0.2		0.9			0.2
Digested fish			3.3	6.9	10.1	15.1	23.2	13.3	9.2
Digested food		18.2	18.8	10.0	7.1	14.6	17.1	20.0	11.7
oth fishes					1.1	0.5	1.2		0.4
ground		2.3	1.4	0.8	0.6	0.9	17.1		1.7
No.of stomachs excluding empty ones	4	44	213	519	463	219	82	15	1559
No.of empty stomachs	3	22	105	252	264	164	55	6	871
Mean degree of stomach fullness	1.0	1.0	1.0	1.1	1.1	1.1	1.1	1.2	1.1

Table 7. Frequency of occurrence (%) of different food components in the stomachs of female roughhead grenadier from the catches in the Baffin Land, Labrador and Newfoundland areas, 1969-83.

Food composition	Fish length, cm								
	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90	11-90
Medusa				0.8	1.2	3.7	6.2		1.8
Ctenophora				0.4	2.6	2.3	1.2	6.7	1.6
Spongia			0.8	0.4	1.4	3.2	7.4		1.9
Polychaeta		28.0	19.0	25.8	15.1	12.9	3.7		16.8
oth Vermes			3.2	3.7	3.8	0.5	1.2		2.6
Calanus		4.0	4.8	1.6	0.3	0.5			1.2
Amphipoda	100.0	32.0	11.9	9.8	7.8	6.0	4.9		9.0
Euphausiacea			2.4	2.4	3.2	6.4	1.2		3.3
Isopoda			0.8	2.0	2.9	4.1		6.7	2.5
Cumacea		8.0	0.8	0.4	0.6	1.4			0.8
Shrimp			2.4	9.8	9.0	12.0	22.2	33.3	10.1
Crabs				1.6	2.0	1.8			1.4
oth Crustacea			1.6	0.8	0.6	0.5			0.7
Cephalopoda				1.6	1.7	4.6	6.2		2.4
Ophiura	50.0	52.0	29.4	10.3	20.3	9.7	4.9		20.9
oth Echinodermata			0.8	4.1	5.2	10.1	12.3	13.3	6.0
Actiniaria				1.2	2.6	4.6			2.1
Mollusca			7.1	16.8	8.4	14.3	13.6	40.0	12.0
Mysidacea			0.8	2.4	2.0	2.8			1.9
Myctophidae				0.4	0.6				0.3
Capelin			3.2	6.1	18.6	6.0	2.5		9.3
Sand eel				1.2	5.5	17.5	6.2		6.1
American plaice						0.5			0.1
Redfish					0.6	1.8	1.2	6.7	0.7
Grenadier						0.9			0.2
Digested fish			3.2	4.5	11.9	15.2	23.4	13.3	10.4
Digested food		28.0	15.9	9.4	7.3	14.3	17.3	20.0	11.6
oth fishes					1.2	0.5	1.2		0.6
ground		4.0	0.8	0.8	0.9	0.9	17.3		2.2
No.of stomachs excluding empty ones	4	25	126	244	344	217	81	15	1056
No.of empty stomachs	3	13	55	134	209	161	55	6	636
Mean degree of stomach fullness	1.0	1.0	1.0	1.1	1.1	1.1	1.1	1.2	1.1

Table 9. Coefficients of food similarity between different length groups of roughhead grenadier (503 males and 1056 females) caught in the Baffin Land, Labrador and Newfoundland areas, 1969-83.

Length groups, cm	2I-30	3I-40	4I-50	5I-60	6I-70	7I-80	8I-90
II-20	36.5	20.4	I7.4	I2.5	5.5	3.3	0.0
2I-30	-	57.5	44.3	28.9	I9.9	I4.2	8.0
3I-40	-	-	70.7	49.0	34.0	24.0	I6.7
4I-50	-	-	-	66.8	44.9	28.4	I8.8
5I-60	-	-	-	-	53.6	32.9	24.4
6I-70	-	-	-	-	-	5I.0	3I.8
7I-80	-	-	-	-	-	-	37.7

Table 10. Fatness (%) of roughhead grenadier caught in separate months of 1969-83 in different NAFO Divisions (numerator) and number of fish (denominator).

Month, year		Divisions								In all Divs.
		0	2G	2J	3K	3L	3M	3N	3O	
February	I978						5.2 I8I			5.2 I8I
March	I976					I2.4 99				I2.4 99
May	I974				II.0 99					II.0 99
May	I977					7.9 73		5.I 35		7.0 I08
May-July	I982					7.5 308				7.5 308
June	I97I							6.8 I89		6.8 I89
June	I977					7.6 74				7.6 74
June	I98I					7.I 8I				7.I 8I
July	I977				6.9 2I					6.9 2I
July	I978			II.I 70						II.I 70
July	I98I			I0.I 98		9.6 77				9.9 I75
August	I978							8.2 50		8.2 50
September	I969					5.8 I97	8.0 63	4.7 93		5.9 353
October	I969								5.2 57	5.2 57
October	I983					7.8 397				7.8 397
November	I969			I2.2 7I						I2.2 7I
November	I975					8.6 I00				8.6 I00
November	I979				6.7 I49					6.7 I49
November	I980	I0.5 I00								I0.5 I00
November	I982	II.4 342								II.4 342
December	I98I	9.5 II2	8.0 I58							8.6 270
December	I983			9.0 400						9.0 400
February-December	I969-I983	I0.8 554	8.0 I58	9.7 639	8.3 269	7.9 I406	5.9 244	6.3 367	5.2 57	8.3 3694

Table 11. Fatness (%) of male roughhead grenadier of different length in the Northwest Atlantic summarized for 1969-83.

Length cm	NAFO Subarea and Divisions								Mean	No. of fish
	0	2G	2J	3K	3L	3M	3N	3O		
21-23	-	-	-	3.3	3.8	-	I.7	-	3.4	6
24-26	-	-	6.2	2.I	2.3	-	2.3	-	2.8	5
27-29	6.4	-	6.6	4.9	3.9	2.7	4.5	-	4.6	I4
30-32	-	-	-	4.9	4.I	3.7	-	4.2	4.3	I9
33-35	4.4	8.8	7.4	4.5	4.6	4.2	-	4.8	5.0	44
36-38	8.2	9.4	9.9	3.8	6.9	4.6	8.4	3.6	6.7	77
39-4I	8.8	8.0	I0.6	6.0	6.8	5.2	4.9	-	6.9	II5
42-44	I0.5	8.7	I0.8	7.I	8.I	6.9	6.4	6.6	8.I	I44
45-47	I2.8	II.I	I2.2	5.0	9.6	6.9	7.4	-	I0.0	I83
48-50	I4.I	I2.3	I3.7	I0.6	I2.5	8.2	9.2	8.6	II.8	255
5I-53	I2.3	9.2	I5.6	I2.6	I3.I	9.9	I0.6	3.5	I3.0	I49
54-56	I6.7	I5.2	I5.0	I4.2	I4.I	II.7	I2.2	6.4	I4.I	83
57-59	I3.3	II.0	II.8	-	I3.4	I5.2	I7.8	-	I3.5	27
60-62	9.I	4.I	20.5	-	-	9.2	2.7	-	9.3	7
63-65	-	-	-	I5.0	-	-	6.6	-	9.6	3
66-68	I5.2	-	-	-	-	-	-	-	I5.2	2
69-7I	-	-	I0.3	-	-	3.0	-	-	5.0	3
72-74	-	-	-	-	-	-	-	-	-	-
75-77	-	-	-	-	-	-	-	-	-	-
78-80	-	-	-	-	6.3	-	-	-	6.3	I
8I-83	-	-	-	-	-	-	-	-	-	-
84-86	-	-	-	-	-	7.4	-	-	7.4	I
2I-86	I2.6	I0.4	I3.7	I0.3	II.2	7.9	8.9	7.2	II.0	
No. of fish	90	53	I58	I08	49I	I32	8I	25		II38

Table 12. Fatness (%) of female roughhead grenadier of different length in the Northwest Atlantic summarized for 1969-83.

Length, cm	NAFO Subares and Divisions								Mean	No. of fish
	0	2G	2J	3K	3L	3M	3N	3O		
15-17	-	-	-	-	3.0	-	-	-	3.0	1
18-20	-	-	6.0	4.6	1.7	-	-	-	3.3	3
21-23	4.3	-	-	-	3.4	-	3.9	-	3.7	7
24-26	-	-	-	3.9	2.6	3.6	4.3	-	3.4	10
27-29	-	-	6.6	3.5	3.0	2.4	5.5	-	3.4	21
30-32	7.6	13.1	5.4	3.9	4.0	2.9	4.2	-	4.5	32
33-35	3.6	6.8	6.8	4.4	7.7	3.9	3.7	3.3	6.8	47
36-38	7.1	7.4	7.5	4.6	4.8	3.6	5.4	2.0	5.4	62
39-41	5.7	6.6	6.1	5.2	4.6	3.8	4.0	4.3	5.1	92
42-44	7.2	6.9	8.0	4.6	5.9	4.0	3.5	2.7	5.6	128
45-47	6.9	5.1	7.1	6.6	6.0	5.9	4.5	3.2	6.0	168
48-50	7.3	5.8	7.7	7.0	6.2	3.2	6.4	3.0	6.5	242
51-53	8.1	6.0	8.3	6.4	6.7	4.4	5.5	6.5	6.8	219
54-56	8.2	7.6	8.2	8.0	6.4	2.8	4.8	4.2	6.9	267
57-59	8.6	7.6	8.6	9.4	6.8	3.5	5.3	2.9	7.4	271
60-62	10.5	7.8	9.2	8.2	7.2	5.6	6.8	4.2	8.3	221
63-65	10.5	11.3	9.7	10.1	7.5	4.3	6.1	-	8.8	186
66-68	11.8	8.0	10.1	8.6	8.3	3.6	6.9	2.8	9.2	213
69-71	12.8	6.4	9.9	9.6	6.7	6.9	8.4	-	10.0	132
72-74	13.6	5.9	9.5	8.9	7.5	-	4.0	-	9.1	91
75-77	11.6	5.1	10.0	1.6	8.8	-	5.8	-	9.1	75
78-80	12.3	-	11.0	1.8	7.8	3.1	8.8	-	9.3	30
81-83	15.2	-	9.5	12.1	7.5	5.4	-	-	8.6	26
84-86	-	12.2	-	-	6.3	-	-	-	7.4	5
87-89	11.9	-	2.6	-	10.6	-	-	-	9.4	5
90-92	12.2	-	8.1	-	-	-	-	-	10.8	2
15-92	11.0	7.2	9.0	8.2	7.2	4.1	6.3	3.9	8.2	
No. of fish	464	105	481	161	915	112	286	32		2556

Table 13. Length (cm) and relative number of male and female roughhead grenadier at different gonad maturity stages in the Northwest Atlantic, 1969-83.

Gonad maturity stages	Male length, cm		No. of males, spec.	Female length, cm		No. of females, spec.
	range	mean		range	mean	
I	2I-44	32.7	32	I5-47	29.2	2I
II	2I-78	45.6	II67	I8-80	54.0	2757
III	34-86	50.7	I36	45-99	70.4	I33
IУ	45-65	56.4	6	63-80	72,4	8
У	39-59	5I.8	26	-	-	-
УI	37-59	49.I	35	74-89	74.7	3
УI-II				39-9I	69.6	330
Total	2I-86	46.I	I402	I5-99	56.2	3252

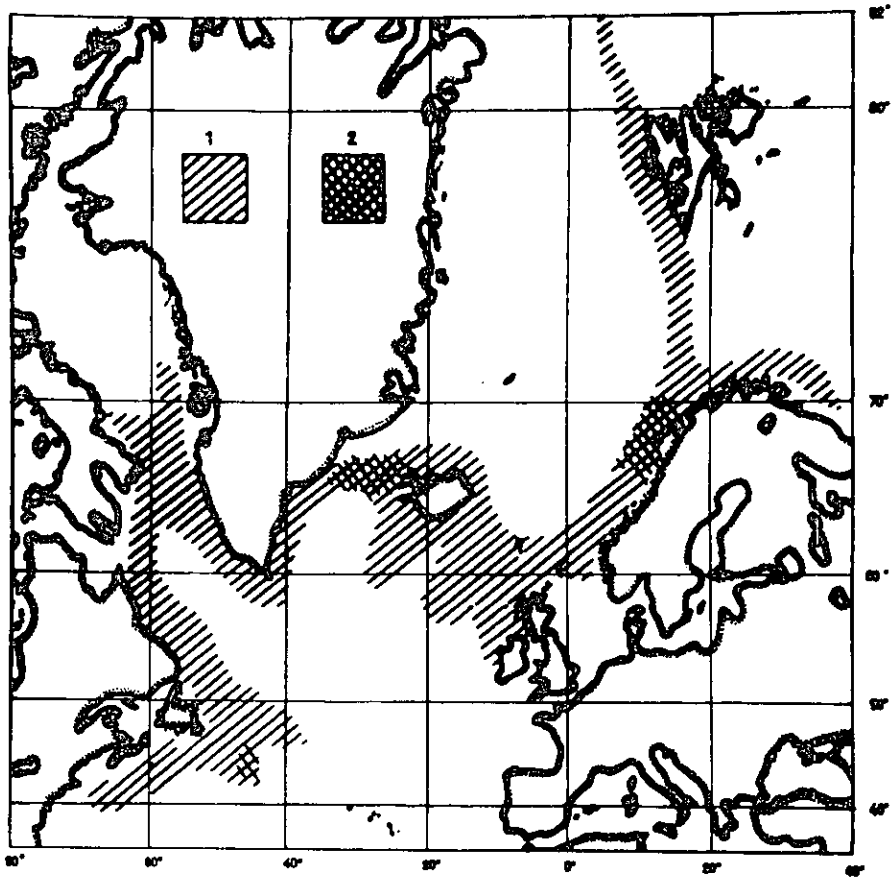

Fig.1 Distribution of roughhead grenadier (1) and areas of the largest aggregations (2).

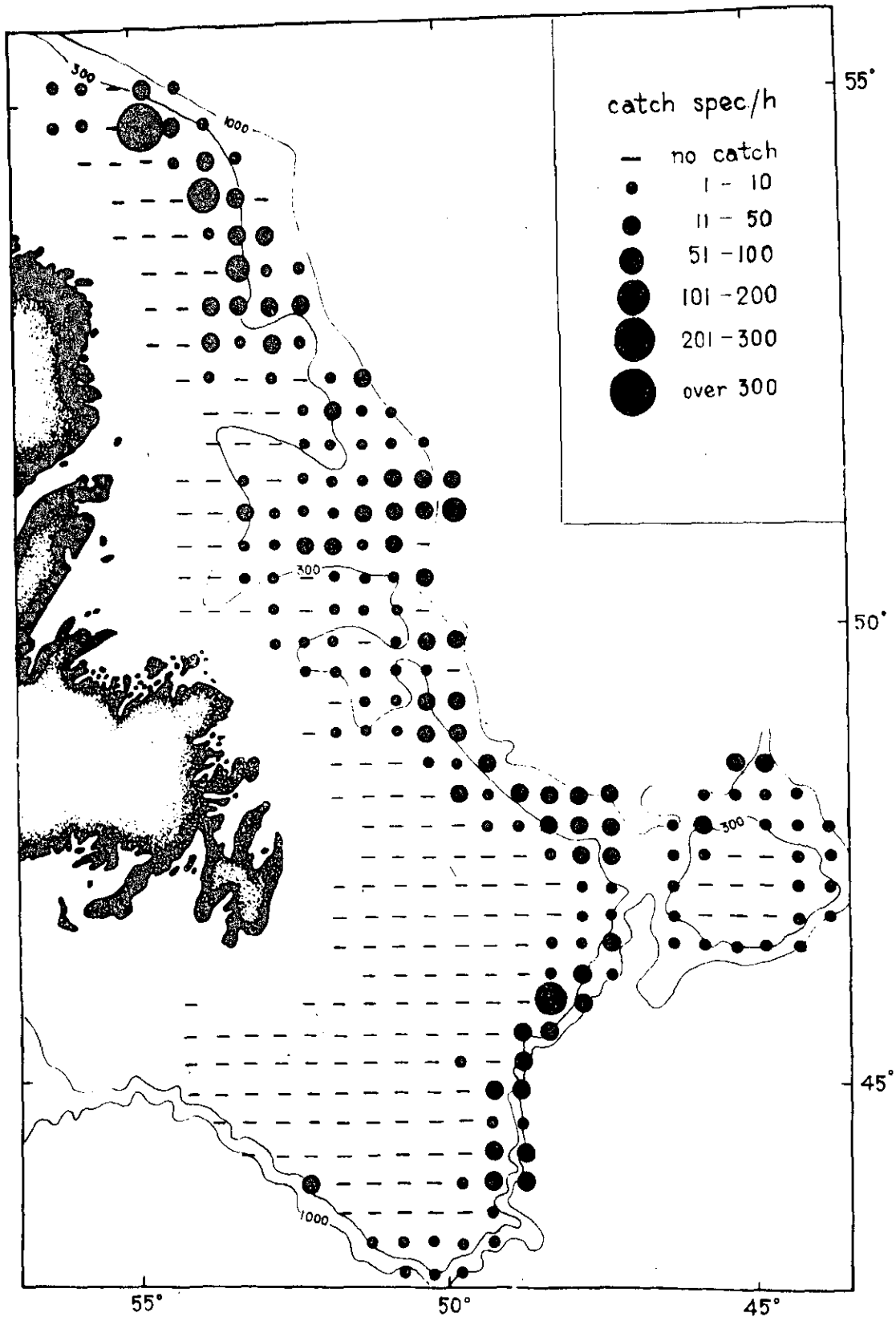

Fig.2 Roughhead grenadier mean catches during trawl surveys aimed at assessing the bottom fish abundance in 1971-83.

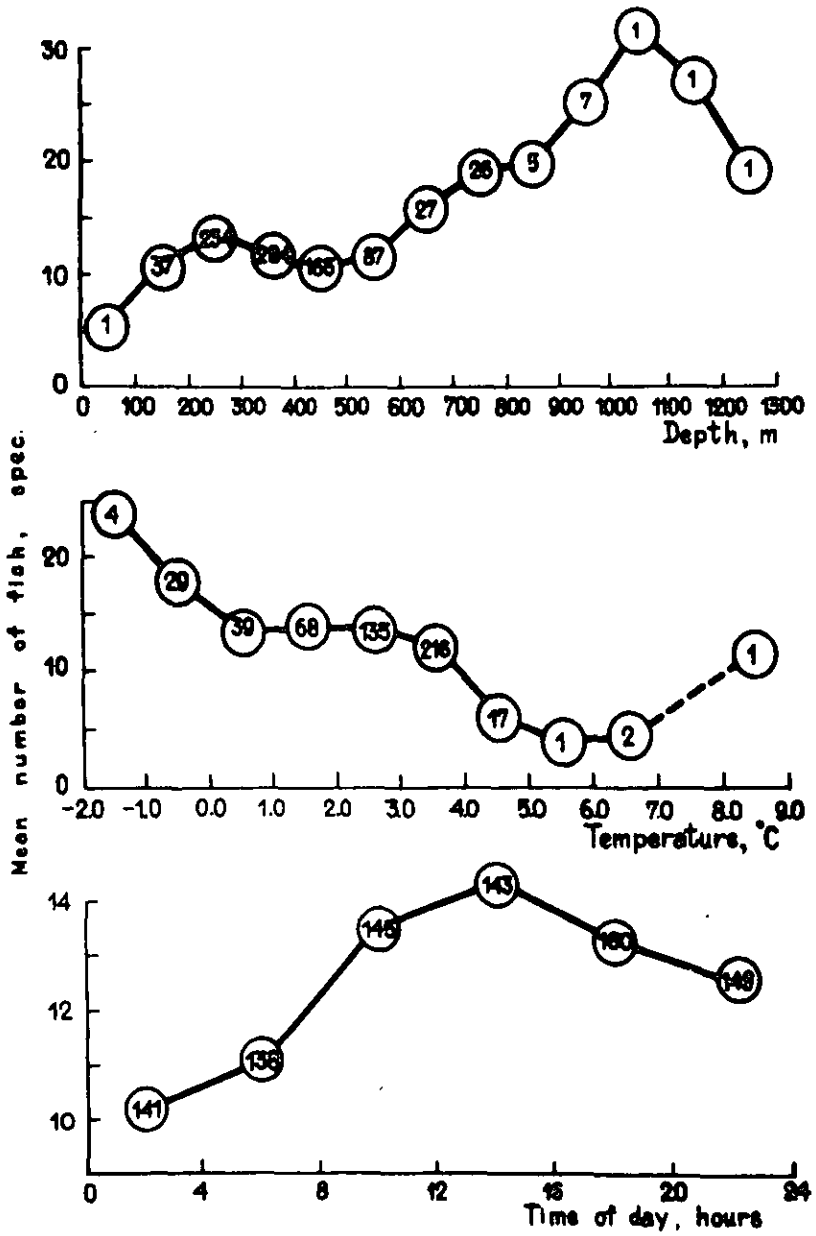

Fig.3 Roughhead grenadier mean catches taken with a bottom trawl per hour trawling by depth, time of a day and in relation to near-bottom water temperature in 1972-83 (smoothed curves, figures in circles - number of catches).

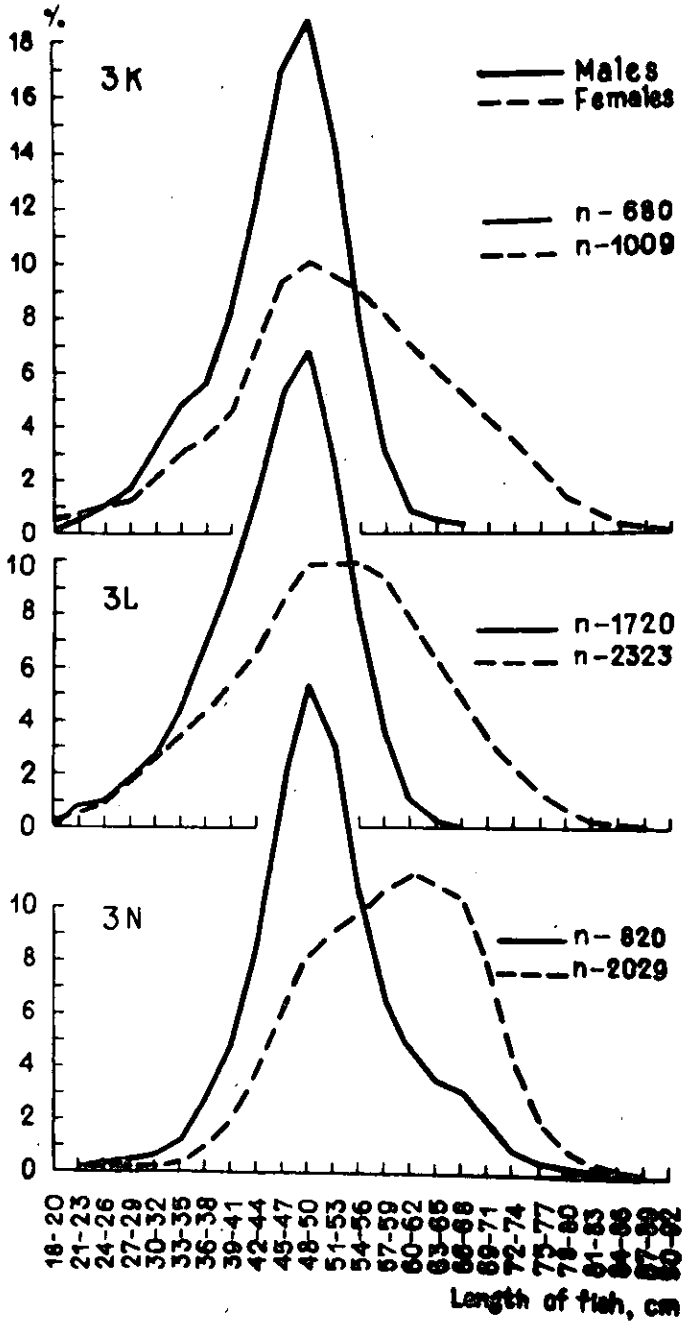

Fig.4 Length composition of male and female roughhead grenadier in Divs.3K, 3L, 3N in 1967-83 (smoothed curves).

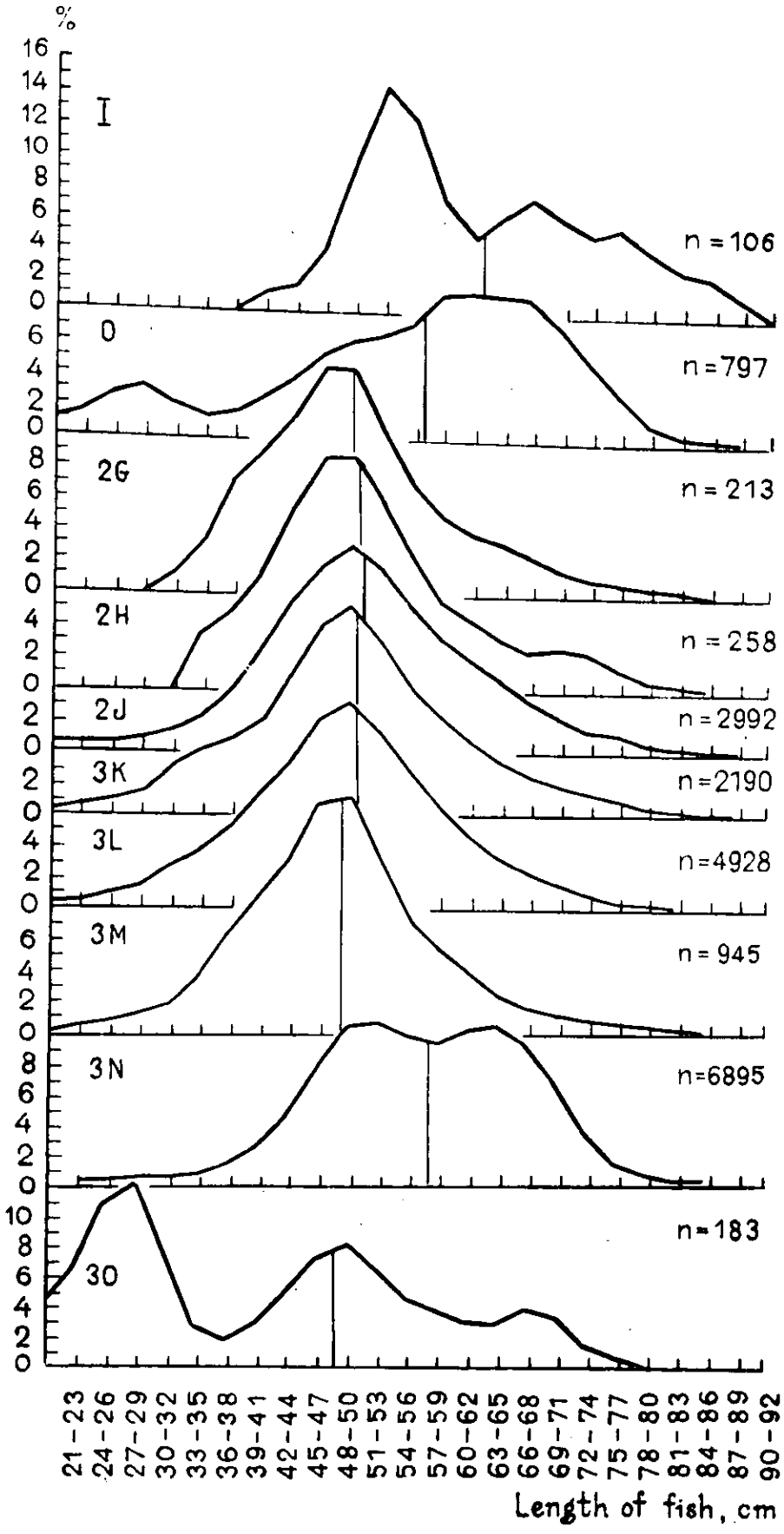

Fig.5 Length composition of roughhead grenadier catches taken in the Northwest Atlantic in 1967-83 (smoothed curves).

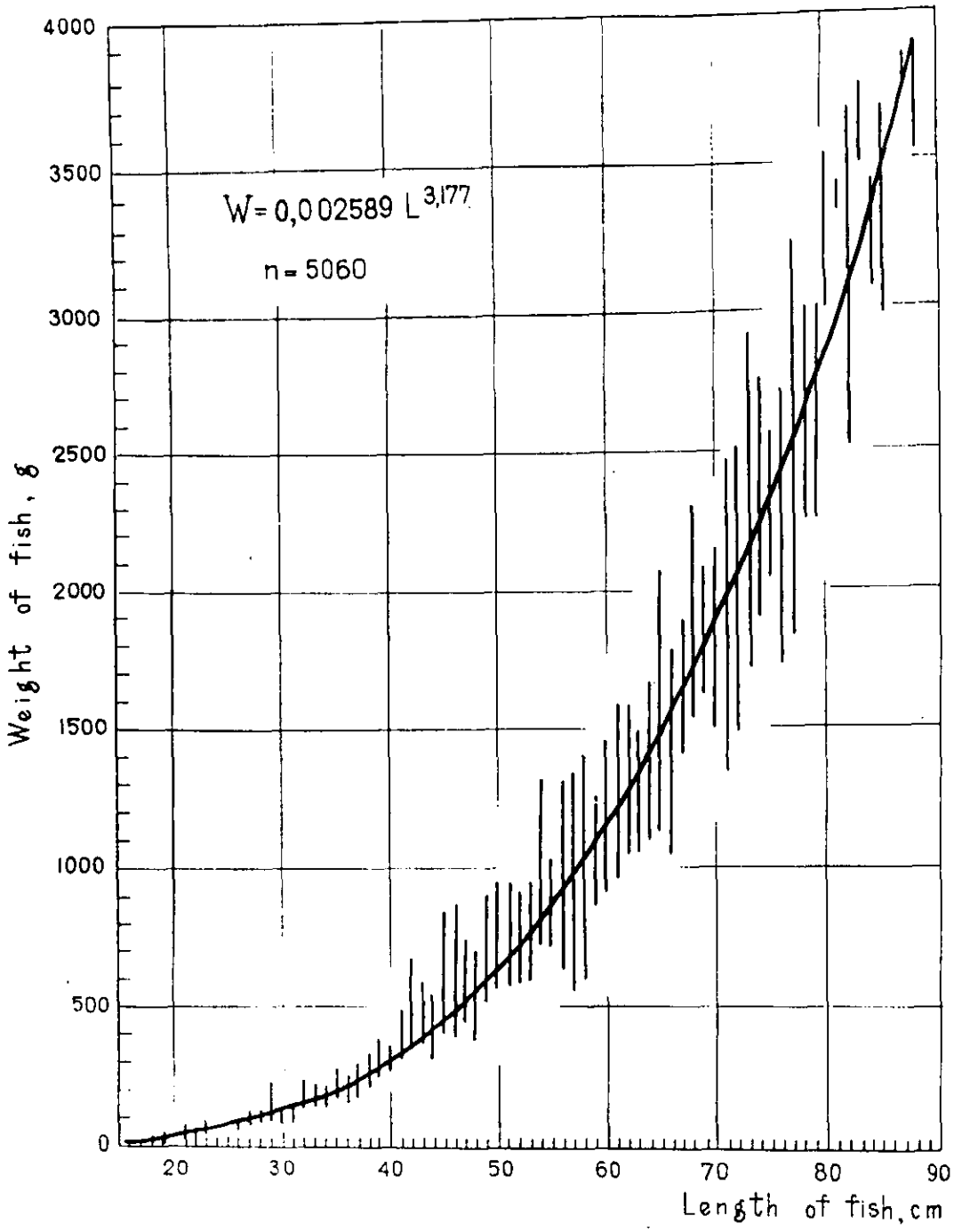

Fig.6 Weight-length relationship for roughhead grenadier in the Northwest Atlantic, 1969-83.

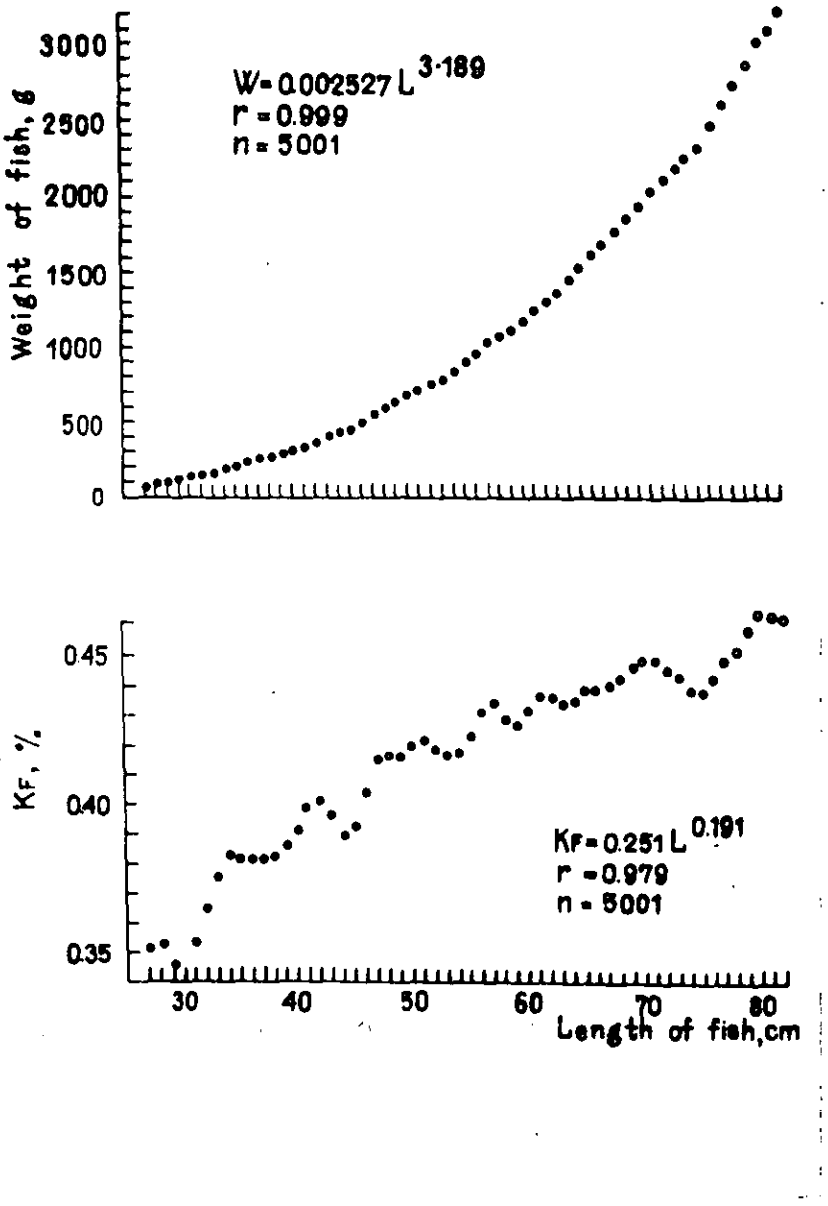

Fig.7 Weight-length relationship and Fulton's condition factors (K_F) for roughhead grenadier of different length in the Northwest Atlantic, 1969-83 (smoothed curves; L - length, cm; W - weight, g; r - correlation coefficient; n - number of fish, spec.).

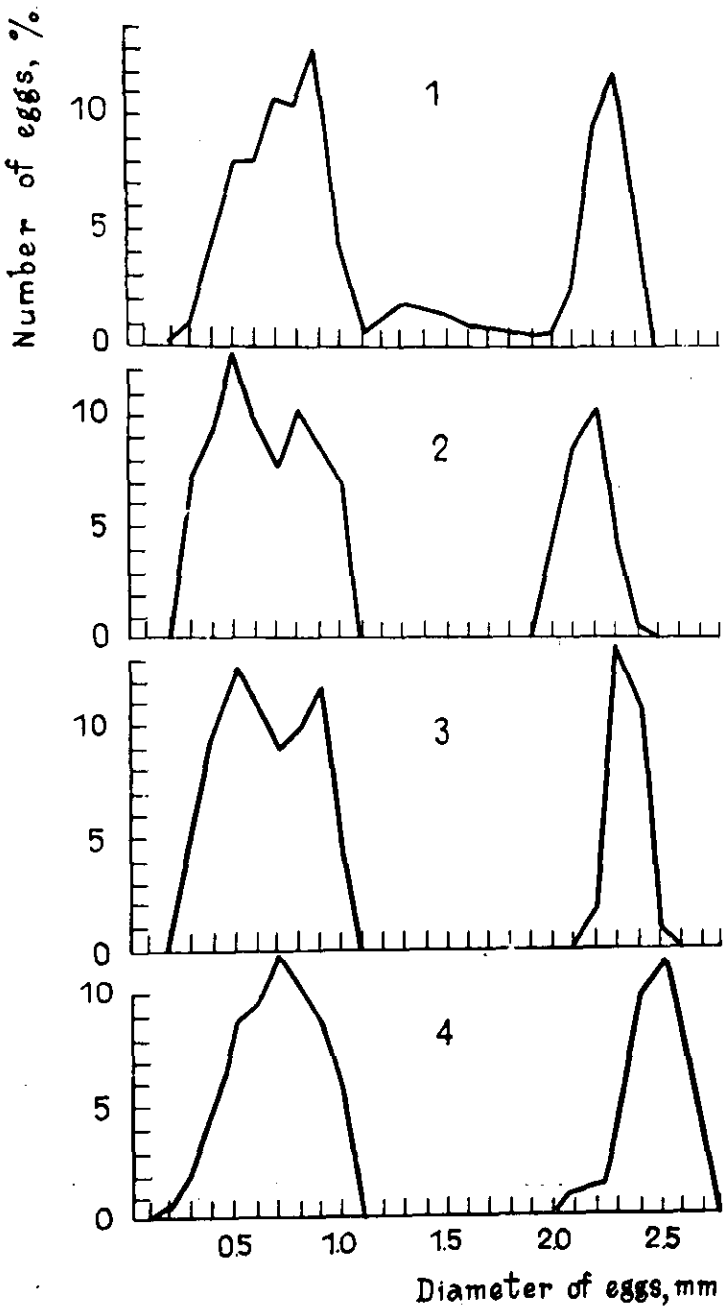

Fig.8 Length composition of roughhead grenadier eggs caught in the Baffin Land area on 26 November 1980
1 - female III, 80 cm long, weighing 3830 g;
2 - female III, 70 cm long, weighing 2230 g;
3 - female III, 82 cm long, weighing 3670 g;
4 - female III, 82 cm long, weighing 3020 g.

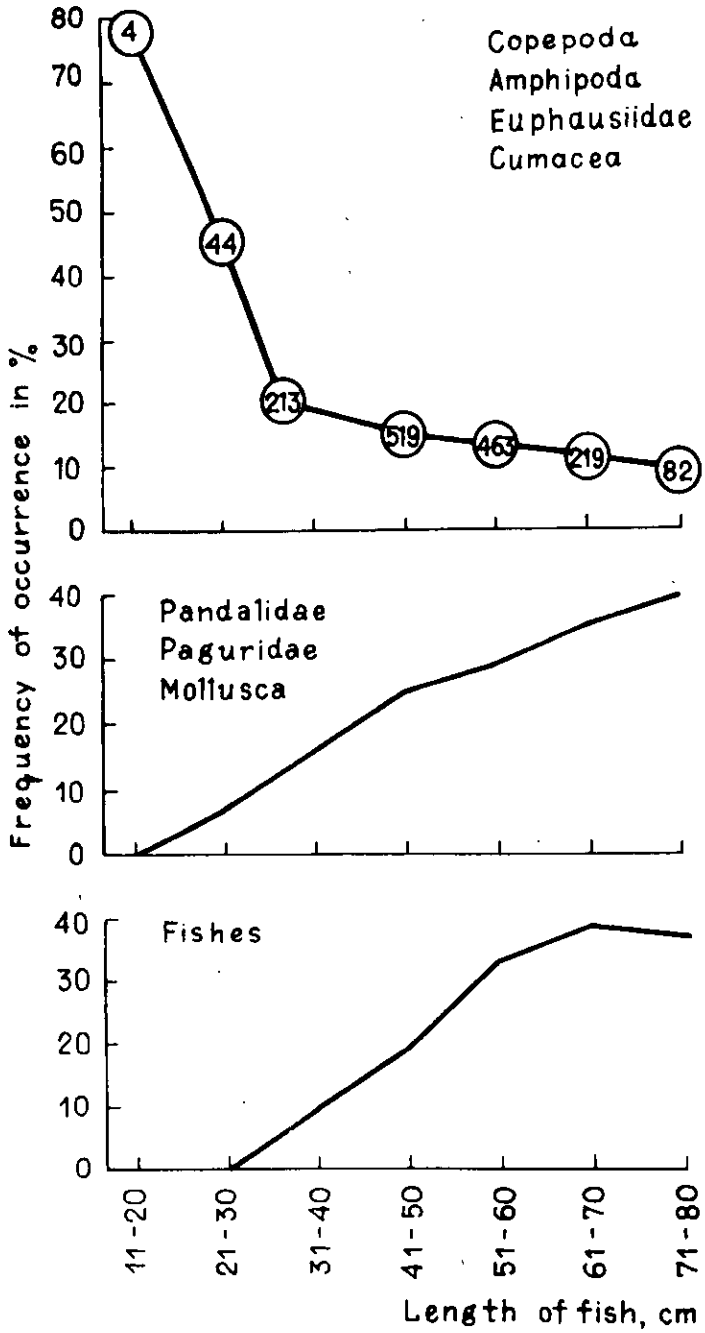

Fig.9 Frequency of occurrence of small and large food objects in the stomachs of roughhead grenadier of different length in Labrador, Newfoundland and Baffin Land, 1969-83 (smoothed curves, circles contain numbers of stomachs with food).

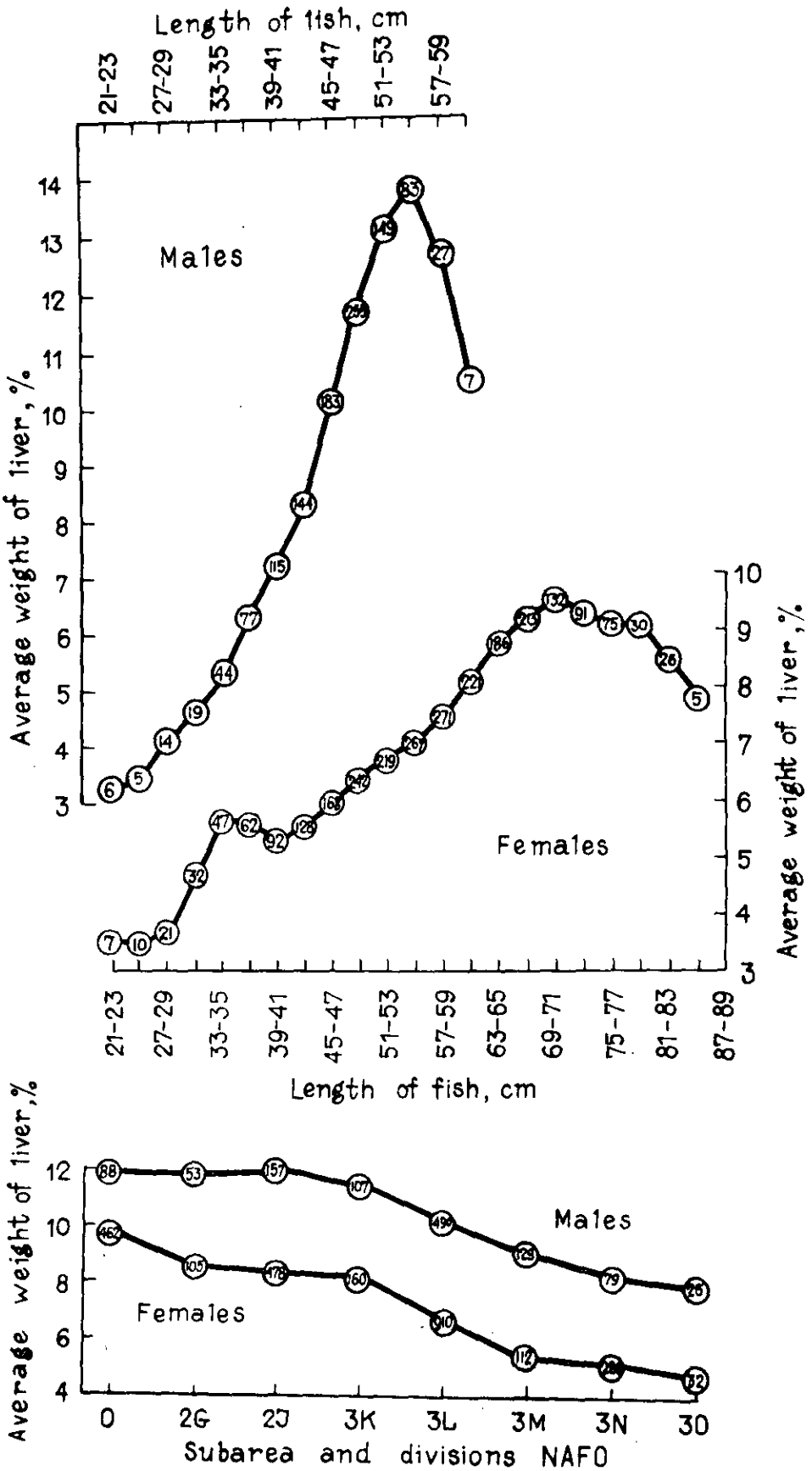

Fig.10 Mean fatness of male and female roughhead grenadier in the Northwest Atlantic, 1969-83 (smoothed curves, circles contain numbers of fish, length groups including less than 5 fishes are not considered).