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

P. I. Savvatimsky

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

Abstract

The distribution of catches by area and depth, in relation to water temperature are described for the roughhead grenadier (*Macrourus berglax* L.). Biological data on sex and length compositions, feeding and fatness characteristics are described based on the materials of the bottom trawl surveys in 1972-83 and catches from research vessels in 1967-83. Grenadier concentrate along the continental slope and in deepwater troughs of the shelf. Catches increased with trawl depth (100-1,300 m) and were higher in the day-time at water temperatures of -2.0° to 3.0° C. The large grenadier were distributed in shallower waters. Females were larger than males. The differences in the length-weight relation between males and females were negligible. The feeding spectrum was wide where ophiura, polychaets, crustaceans, molluscs 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. Intermittent spawning occurred in winter and early spring and fecundity averaged 38.2 thousand eggs. Roughhead grenadier have a long life cycle and exhibit a many-aged population structure. They can serve as an additional fish supply for the trawl and long-line fishery.

Introduction

The roughhead grenadier (*Macrourus berglax* Lacépède) is an abundant and widespread fish species (Andriyashev, 1954; Leim and Scott, 1966). Grenadier have been captured near the coast of the USA and Canada from New York to the Davis Strait in Baffin Bay. They are distributed along the continental slope of the West and East Greenland and around Iceland (Magnusson, 1979), off the northwestern Norwegian coast, along the western boundary of the Barents Sea and northward up to 82° 10'N, around Spitsbergen and southward as far as Bergen (Fig. 1).

The Soviet research vessels have fished for grenadier in the area between northeastern Atlantic and Franz Josef Lands up to 40° 20'E. The fish are predominant in depths ranging from 400 to 1,200 m, while they are known to be caught as deep as 2,740 m (Wheeler, 1969). Grenadier are often taken as a large by-catch in bottom trawl fisheries for traditional fish such as cod, redfish and Greenland halibut, and also in the longline fishery for demersal fishes off the northern coast of Norway (Bakken *et al.*, MS 1975), west and northwest of Iceland (Magnusson, MS 1978) and in the Newfoundland area (Savvatimsky, MS 1983, 1984).

Data on grenadier catches around Norway are included in the Norwegian fishery statistics. The bottom trawl catches of this species have reached 1.5 tons-per-hour trawling near the Norwegian coast (Savvatimsky, MS 1985, 1986b) where they have accounted for as much as 73% of commercial catches (Eliassen, MS 1983a), and are captured in a wide depth range (Eliassen, MS 1983b). The catches of the Federal

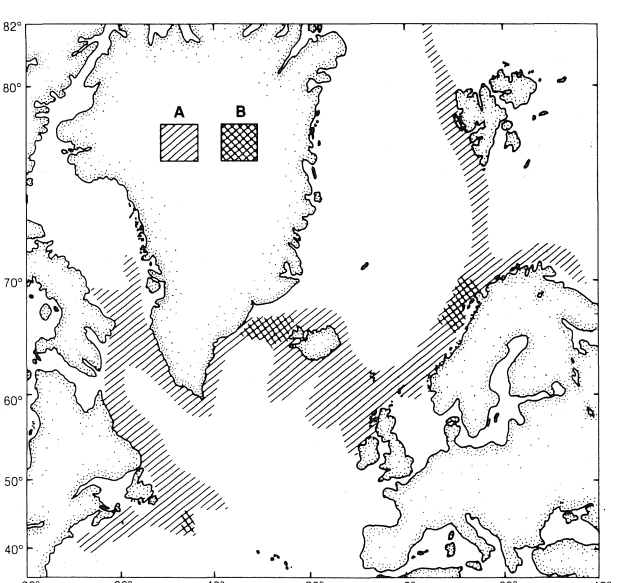

Fig. 1. Distribution of roughhead grenadier (**A**) and areas of the largest aggregations (**B**).

Republic of Germany (FRG) research vessel on the Dohrn Bank (East Greenland) reached 0.9 tons-per-30-min trawling (Sahrhage, 1986). A great demand for grenadier in recent years has increased FRG catches. In East Greenland area alone FRG catches in separate years have been more than 3,000 tons of grenadier, chiefly roughhead grenadier (Sahrhage, 1986).

Roughhead grenadier, similar to the related species common grenadier (*Nezumia bairdii*) is abundant in the Newfoundland area (Houston, MS 1983). Bottom trawl catches there have been as high as 2 tons (Yanulov, 1962). The highest catches-per-trawl (up to 540 kg-per-30-min trawling) were taken with a research trawl from July to September in comparatively shallow water (down to 500 m) along the eastern and northern slopes of the Grand Banks in NAFO Div. 3L and 3N (Parsons, 1976a, 1976b). Despite the occasional high catches in many areas and the existence of a fishery in separate areas of the North Atlantic, the life cycle of this fish has been poorly understood until now. There is only limited information in literature based on fragmentary observations.

The aim of this paper was to study the abundance, mechanisms of distribution and the biology of roughhead grenadier in the Northwest Atlantic using data collected over a long term. The observations are presented in view of the feasibility of commercial utilization of the resource.

Materials and Methods

In 1967–83 Soviet research and scouting vessels carried out the bottom trawl fishery for roughhead grenadier on the shelf and continental slope of West Greenland, Baffin Island, Labrador and Newfoundland. In all, 19,507 specimens were measured from 1967 to 1978 including measurements without sex determination. Materials were collected by research vessels from 1967 to 1983, mainly in the Newfoundland area. Further information was also gathered in the areas of Labrador and Baffin Island. To study the grenadier distribution, data from the annual trawl surveys for the assessment of the common demersal fish abundance were used. These surveys were carried out in summer from 1972 to 1983 using a grid of stations enveloping the shelf and part of the continental slope of the Grand Bank and southern Labrador. The trawl was modified with a 19 m long, fine-meshed (mesh size 10–12 mm) insertion in the codend. Duration of valid hauls was 1 hr. The mean catches were calculated within rectangles 20′ in latitude and 30′ by longitude. The catches were distributed within 100-m depth ranges taking into account the near-bottom water temperature and time of day. The area of the rectangles was considered only where the roughhead grenadier catches were taken. The absolute abundance (N) was determined by the formula:

$$N = \frac{1}{k} \cdot \frac{S \cdot n}{s}$$

where k is fishing efficiency as the ratio of the number of fish caught to the number present in the area fished, s is area fished per 1 hr, S is total area surveyed with grenadier catches, and n is mean catch-per-trawling hour from the trawl survey data.

The analysis of catches consisted of the following: the total (zoological) length by sex was measured to the nearest centimeter, and the measurements were classified into three cm groups (e.g. 21–23, 24–26 etc.). To study feeding patterns, only non-everted stomachs were studied right after catch retrieval.

The food components (except for those entirely digested) found in the fish stomachs were identified where possible to the genus or more rarely to the species level for fish and only to family, order or class for invertebrates.

The occurrence frequency of separate components in stomachs was estimated as the ratio of the number of stomachs (%) containing any food component, to the total number of stomachs analyzed (excluding empty ones). The procedure allowed to have only a relative feeding pattern since it overestimated small but numerous or frequently occurring organisms. The 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 – small amount of food, 2 – partially full, 3 – full stomach, and 4 – extended stomach. The mean degree of stomach fullness was found as the arithmetic average from the scale of fullness of stomachs analyzed. The coefficient of food similarity (K) was derived from the formula suggested by Yanulov (1963):

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

where N = sum of the highest values, and n = sum of the lowest values of occurrence frequency of all food components in fishes of compared length groups. With absolute diversity of food, K = 0, and with absolute similarity K = 100.

The maturity stage of fish gonads was determined by a 6-point scale (Sorokin, 1957, 1960). When determining fecundity of females caught on 26 November 1980 at 800–1,060 m in the Baffin Island area (61°40′N, 60°40′W), only large eggs 2.0–2.7 mm in diameter were considered. Three batches of eggs, 2 g each, were taken from each ovary and fecundity was

determined by multiplying the total number of eggs in the three batches by net weight of eggs (without membrane) and dividing by the total weight of batches. The coefficient of sexual maturity was determined as the ratio of gonad weight of fish body weight expressed as a percentage.

The length-weight relationship was expressed by the formula $W = aL^b$, where W = grenadier weight (g), L = total length (cm) and a and b are constants. Fulton's condition factors (K_F) were calculated by the formula:

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

in cases where the length groups contained less than 10 fishes, condition factors were not considered. Length and weight frequencies, relative liver weight (fatness) curves and occurrence of food components plotted against length were smoothed. The smoothing was made by the formula:

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

where a, b and c are preceding, average and subsequent members respectively of the frequency, B = the estimated value.

Results and Discussion

Distribution, abundance and biomass of grenadier

Roughhead grenadier are usually found in 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 Labrador areas showed that roughhead grenadier concentrated along the continental slope and in deepwater troughs of the shelf. In the shallows of the Grand Bank and Flemish Cap, catches did not include even sporadic specimens of this species (Fig. 2).

In the Northwest Atlantic they inhabit the Arctic (polar) waters, occupying the shelf and part of continental slope, and concentrating at the near-bottom water temperatures of -2° to +2° C. In the Northeast Atlantic the fish also dwell in Arctic waters at about 0° C (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 near-bottom temperatures of -0.4° to -0.5° C, while an Icelandic vessel caught them west of Iceland at 3° to 5° C (Magnusson, MS 1977).

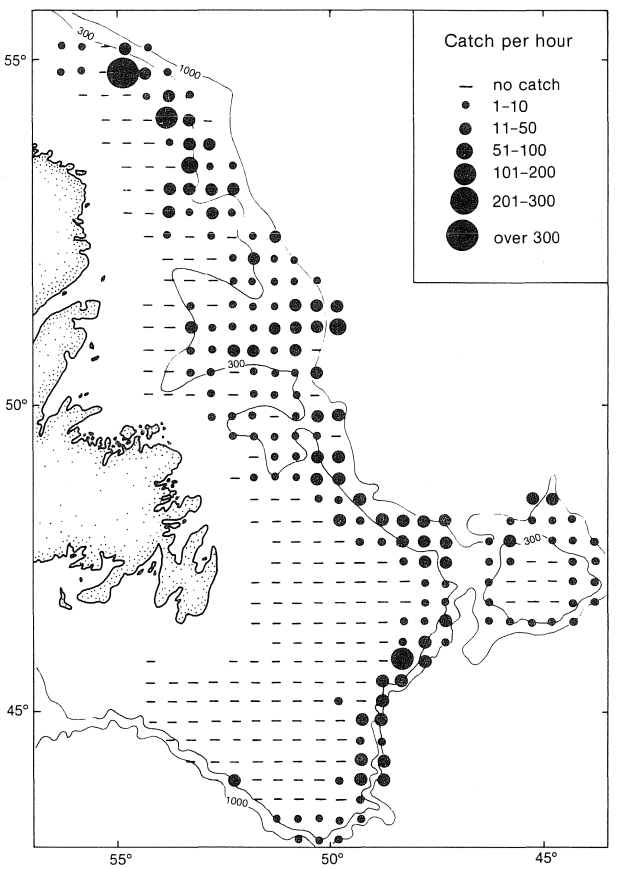

Fig. 2. Roughhead grenadier mean catches during trawl surveys aimed at asessing the bottom fish abundance, 1971–83.

This stenobathic distribution is typical of Macrouridae which occupy depths of some hundreds of metres, but some other species, for instance *Coryphaenoides bucephalus*, which are found from 245 to 2,878 m (Makushok, 1968), are characterized by a very wide vertical distribution. According to data from our trawl surveys roughhead grenadier were caught at 100–1,300 m (no trawling was made deeper). The catches taken down to 600 m were insignificant and then they increased with trawling depth (Fig. 3). Although in this study it is uncertain whether fish concentrations are found at 1,500 m and deeper, the capture of 10 large fishes with a bottom trawl at 1,470–1,520 m reported from Central Labrador in October 1969 (Savvatimsky, MS 1985) allows us to make this assumption. The species is known to occur as deep as 2,740 m which is indicative of its eurybathic distribution.

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 of -2° to +8° C, the highest catches were recorded at -2° to +3° C (Fig. 3). The catches taken in the daytime were higher

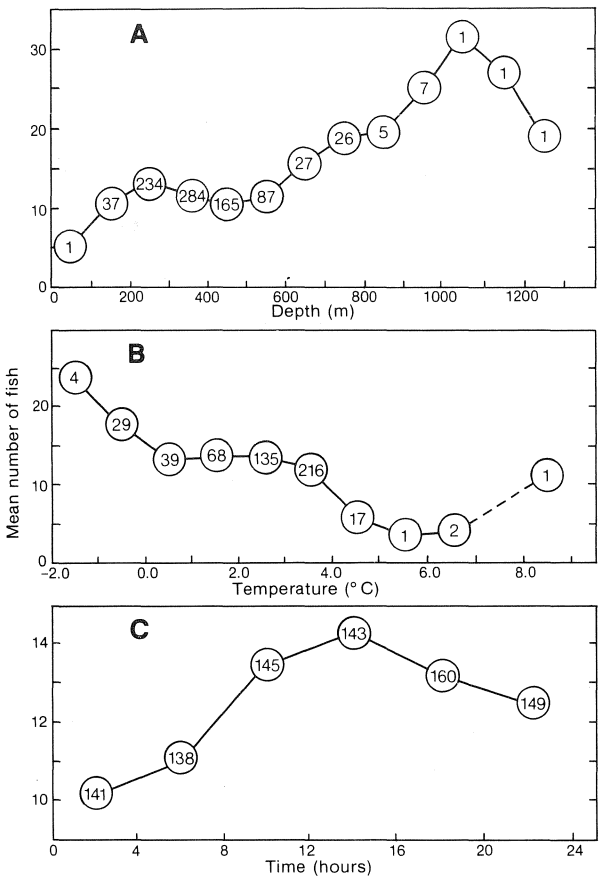

Fig. 3. Roughhead grenadier mean catches taken with a bottom trawl per hour trawling by (**A**) depth, (**B**) near-bottom water temperature, and (**C**) time of day, 1972-83 (smoothed curves, figures in circles = number of catches).

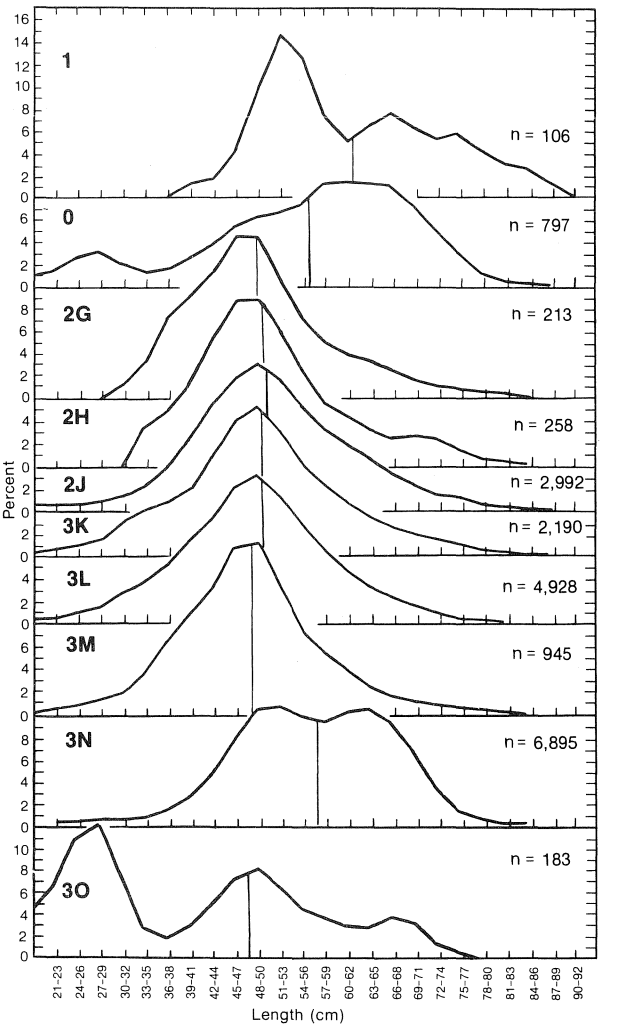

Fig. 4. Length composition of roughhead grenadier catches taken in NAFO Subareas 0 and 1 and Div. 2G-3O, 1967-83 (smoothed curves, mean fish length is shown by vertical lines).

than those fished at night, the largest ones were from 1200 to 1600 hr.

The trawl survey data were used to estimate abundance and biomass for the area shown in Fig. 1. The fishing efficiency of the trawl (k) was assumed to be 0.5. The ship's speed was 3.5 nm-per-hr and distance between the trawl wings was 14.3 m which was equivalent to 0.027 sq miles per trawl. The total area surveyed with grenadier catches (S) was approximately 66,000 sq miles. The mean catch-per-trawling hour (n) equalled 14.28 specimens. The absolute abundance was estimated to be 69.9 million specimens. Using the mean length of fish (51.75 cm) and mean weight of fish (700 g) the total biomass was assessed at 48.9 thousand tons. Thus, the roughhead grenadier stock can be an additional fish supply for the trawl fishery.

Length and sex composition of catches

The length composition of catches in NAFO Divisions was not the same (Fig. 4). Highest catches were taken in Div. 3K, 3L and 3N, and these were studied to determine frequency patterns (Fig. 5). Females averaged 62.5% of the catches and were much larger than males.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. The overall Div. 3KLN mean length of males was 47.0 cm and that of females, 54.6 cm. In general males were predominant 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.

Unsexed grenadier in Div. 3N were observed to vary in mean length dependent on various trawling depths (from less than 200 m to more than 1,000 m). Large grenadier were mainly caught at shallower depths (Table 1). The decrease in fish mean length with increasing trawling depth did not depend on the male and female distribution. Samples from 1979-83 showed mean length of both males and females decreased with increasing depth (Table 2).

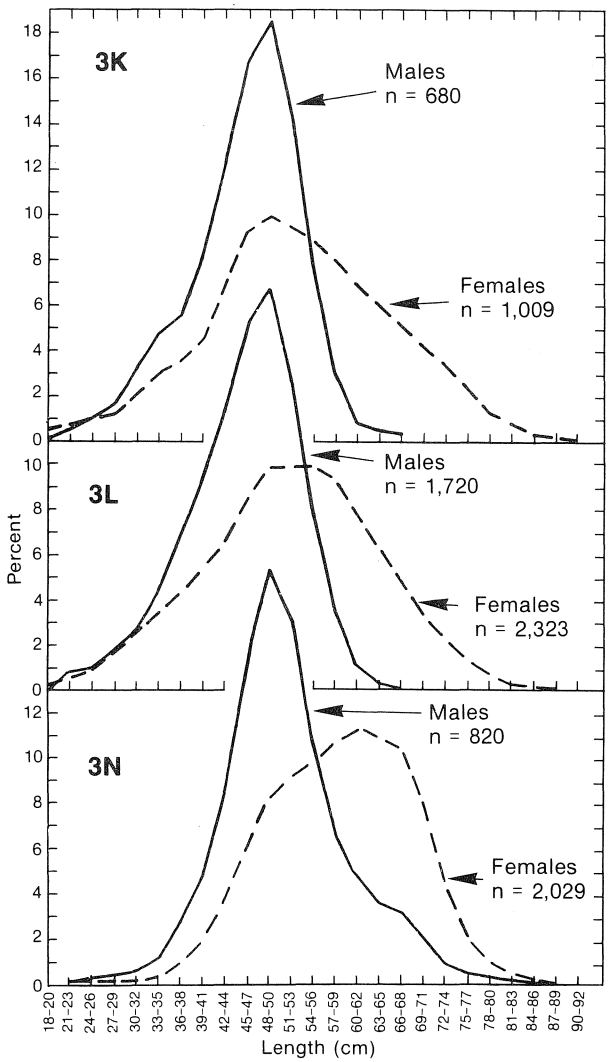

Fig. 5. Length composition of male and female roughhead grenadier in Div. 3K, 3L, 3N, 1967-83 (smoothed curves).

In Div. 3K and 3N both males and females were somewhat larger in the catches taken at night (from 2000 to 0800 hr) than those caught in the daytime (from 0800 to 2000 hr) (Table 3). However, in Div. 3L the length composition of catches taken at night and in the daytime did not differ.

Length-weight relation

Roughhead grenadier is a non-commercial species, consequently age samples were only collected occasionally with length and weight data. The 5,060 specimens analyzed from 1969 to 1983 did not allow a comparison of the length-weight relationships by year or season within the same Divisions. The largest number of samples were collected in Div. 3N. Here, the comparison of mean weight-by-years did not show any differences for the area.

TABLE 1. Mean length of roughhead grenadier in catches taken with a bottom trawl at different depths in Div. 3N, 1969-83.

Depth (m)	Mean length (cm)	No. of fish
<200	56.48	3,459
201-300	55.59	2,488
301-400	54.01	451
401-500	51.07	414
501-600	45.01	73
601-700	49.00	7

TABLE 2. Mean length of male and female roughhead grenadier in catches taken with a bottom trawl at different depths in Div. 3N, 1979-83.

	Males		Females		Males & Females	
Depth (m)	Mean length (cm)	No. of fish	Mean length (cm)	No. of fish	Mean length (cm)	No. of fish
<200	52.3	33	65.8	109	62.7	142
201-300	48.2	195	55.7	348	53.2	543
301-400	46.7	27	57.3	84	54.7	111
401-500	46.9	40	56.5	151	54.5	191
501-600	43.6	14	53.7	14	48.7	28

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. In contrast 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). The length-weight relationship (without separating by sex) on the basis of all available data (Fig. 6), is expressed quite precisely in the formula:

$$W = 0.00259L^{3.177}$$

The fish which occurred most commonly in bottom trawl catches were 45-47 cm long and weighed 550 g. Grenadier 80 cm long weighed 3,000 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 increase in grenadier length from 27 to 82 cm and weight from 80 to 3,250 g, Fulton's condition factor varied from 0.35 to 0.46% (Fig. 7). It should be stressed that the length-weight relation varies unequally with the growth of different grenadier species. For instance, according to our data for roundnose grenadier (*Coryphaenoides rupestris* Gunn) from 21 to 92 cm, Fulton's condition factor decreased from 0.34 to 0.18%, with values being lower for males.

Age and growth

A slow growth is characteristic of deepwater fishes including grenadiers, compared to fishes of the upper

TABLE 3. Day and night patterns of mean length in cm (numerator) against number of roughhead grenadier measured (denominator) in bottom trawl catches taken in Div. 3K and 3N, 1967-83.

NAFO Div.	Males		Females		Males & females	
	Day	Night	Day	Night	Day	Night
3K	45.4±0.4	46.1±0.4	52.0±0.6	54.3±0.6	49.2±0.4	51.2±0.4
	365	315	498	511	863	826
3N	48.9±0.3	54.1±0.5	58.3±0.3	59.0±0.4	55.8±0.2	57.4±0.3
	470	350	1,320	709	1,790	1,059
Overall	47.4±0.3	50.3±0.4	56.6±0.3	57.1±0.3	53.7±0.2	54.7±0.3
	835	665	1,818	1,220	2,653	1,885

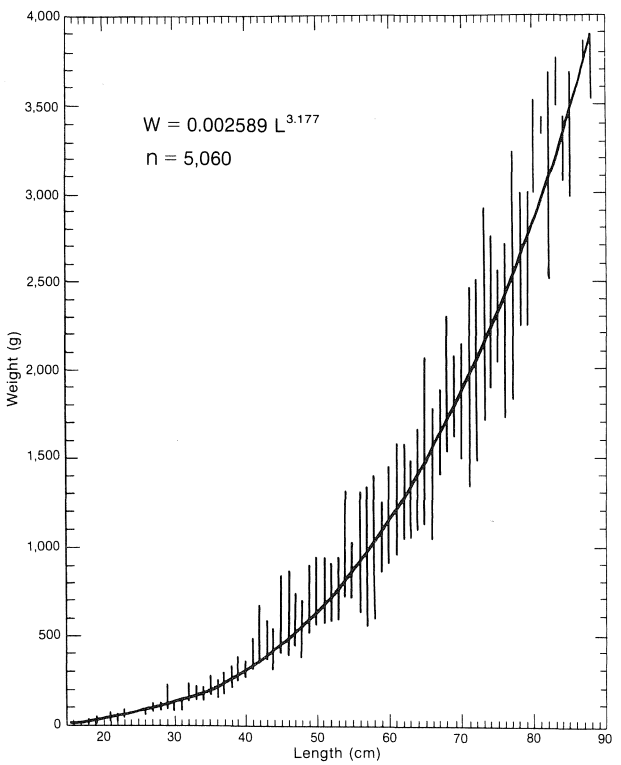

Fig. 6. Weight-length relationship for roughhead grenadier in the Northwest Atlantic, 1969-83.

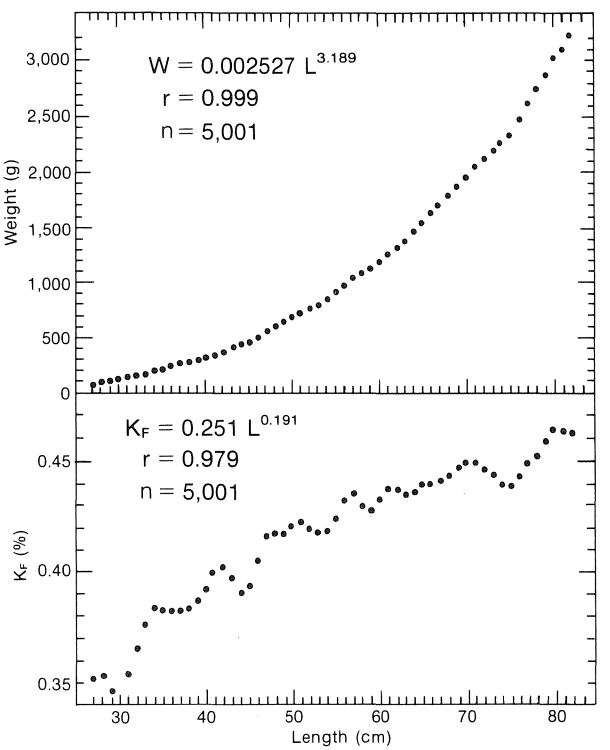

Fig. 7. Weight-length relationship and Fulton's condition factor (K_F) for roughhead grenadier taken in the Northwest Atlantic, 1969-83 (smoothed curves; L = length (cm); W = weight (g); r = correlation coefficient; n = number of fish).

oceanic layers (Hureau *et al.*, 1979). According to data of different sources roughhead grenadier and the other grenadiers of the North Atlantic have a long life cycle and a many-aged population structure. However, the data on the roughhead grenadier age and peculiarities of growth are scanty. Yanulov (1962) reported that a 70.5 cm female caught near the north coast of Norway was 16 years old while Norwegian authors presented evidence of fishes of 25 years (Eliassen, MS 1983a) and 30 years (Bakken *et al.*, MS 1975). The catches taken on the Dohrn Bank off East Greenland consisted of 41-86 cm fish aged from 8 to 18 years with the dominant age-groups from 12 to 15 years represented by 62-75 cm specimens (Kosswig, 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, 1986a). Females of this species from Iceland waters being 67-89 cm long and weighing 1,950-4,700 g were 17-25 years old. The fishes caught with a bottom trawl on the northeastern slope of Grand Bank at an age of 3-16 years were 26-66 cm long (Savvatimsky, 1971). Grenadier captured with a longline in summer 1982 on the Grand Bank were larger. Their length and age ranges were 40-87 cm and 6-23 years respectively (Savvatimsky, 1984).

Reproduction

Little is known about reproduction of roughhead grenadier. They seem to have a long spawning period since the prespawning and spawning fishes are observed at different times of the year. Yanulov (1962) reported the capture of a female near Norwegian coast in January 1958, which had ripe ovaries ready to spend. He proposed winter and early spring to be the reproductive period for the species. On the basis of egg size grouping in the ovaries, he assumed the existence of intermittent spawning. The mature eggs were described at 3.4–3.85 mm in diameter (average 3.62 mm) and fecundity was estimated at 25,000 eggs. In the same area, prespawning and spawning fishes were caught by Soviet research vessels in May 1968 (Savvatimsky, 1969), in April and December 1982, in January, March and December 1983, and in January 1984 (Savvatimsky, MS 1985, 1986a, 1986b). Accordingly we estimate that spawning lasted from December to May or later. The Norwegian investigators showed that the female gonads developed from May to December (Eliassen, MS 1983a; Eliassen and Falk-Petersen, 1985). During this period the ovaries of fishes above 80 cm gained in weight from 100 to 500 g and the most intensive spawning was described to occur in January. Roughhead grenadier 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 spawning was observed in May (Magnusson, 1975) and West Iceland area where they spawned in winter and early spring (Magnusson, MS 1977; MS 1978). Magnusson (MS 1977) also reported the capture of spawning roughhead grenadier and also larvae and eggs, west of Iceland in May and March 1976. The eggs were 3.48–4.02 mm in diameter with a yolk diameter of 0.80–1.01 mm. The eggs taken from spawning females were approximately of the same diameter (3.08–4.56 mm) but of two distinct size groups, which corroborated with the hypothesis of intermittent spawning. In the opinion of Magnusson (MS 1977), spawning probably occur year round but its peak is in the November–February period. The capture of free drifting bathypelagic eggs in the West Iceland waters in March 1977 support this hypothesis.

Jensen (1948) also assumed that 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 timing of spawning was different, from late spring to early summer (Geistdoerfer, 1979). The same spawning period was proposed for the Northwest Atlantic (Div. 3KL and 2J) based on prespawning fishes caught sporadically in July at 400 m depth, along with 90% of adult fishes which had already spent (Geistdoerfer, 1979). In general the different times of roughhead grenadier spawning can be accounted for by the prolonged spawning period of the species. The roughhead grenadier spawning on the Grand Bank is described to occur in winter and early spring (Savvatimsky, 1984). In this study, this was supported 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 analyzed 39 were females 45–80 cm long, 14 of which were prespawning females 65–80 cm long. All the males 51–65 cm long were immature. In other years, the Soviet investigations of the Newfoundland and Labrador Area were mainly carried out in summer and autumn when no spawning roughhead grenadier were found in the catches. The ovaries of four females caught in November 1980 in the Baffin Island area contained eggs of two sizes (Fig. 8). In these, single eggs 3.3–3.4

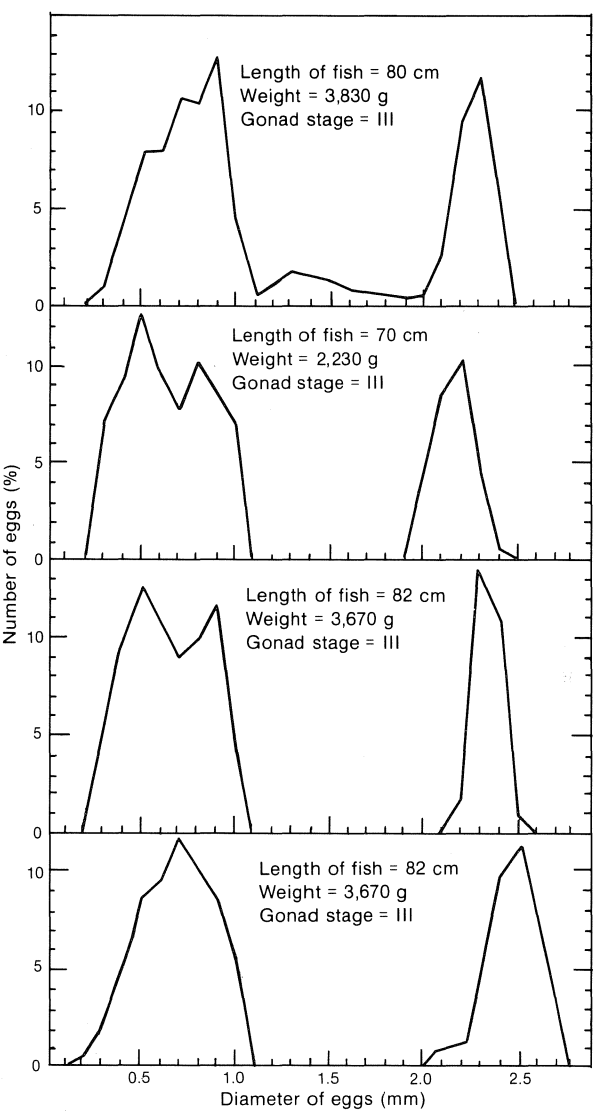

Fig. 8. Size composition of roughhead grenadier eggs taken from four females caught in the Baffin Island area, 26 November 1980.

mm in diameter were also found apparently remaining after intermittent spawning had occurred. The fecundity was estimated to average 38.2 thousand eggs (2.0–2.7 mm in diameter) (Table 4). Despite the fact that these fishes differed little in size, the maturity coefficient and fecundity were higher in larger females. These data support the findings of Norwegian scientists (Eliassen and Falk-Petersen, 1985) who state that fecundity increases from 2,000 to 71,000 eggs as grenadier grow in size.

TABLE 4. Biological parameters of four female roughhead grenadier caught in the Baffin Island area, November 1980.

Length (cm)	Fish weight (g)	Gonad weight (g)	Maturity coefficient (%)	Egg diameter (mm)	Fecundity (000 eggs)
80	3,830	332.4	8.7	2.0–2.5	43.0
70	2,230	141.7	6.4	2.0–2.4	23.1
82	3,670	395.9	10.8	2.2–2.5	54.4
82	3,020	363.5	12.0	2.1–2.7	32.2

Feeding

Roughhead grenadier is categorized as a species in which the major diet consists of benthic organisms (Podrazhanskaya, 1982; Hureau *et al.*, 1979; Geistdoerfer, 1976, 1979). Andriyashev (1954) reported that benthic organisms found in stomach contents were ophiura (*Ophiacantha abyssicola*), molluscs (*Buccinum* sp., *Fusus* sp.) and amphipods, however there were exceptions such as capelin and shrimp (*Pandalus borealis*, *Hymenodora glacialis*). Benthic animals accounted for 91.6% of food of this grenadier species caught on the Grand Bank (Houston, MS 1983). Investigations carried out by the USSR Polar Institute in October 1967 showed that grenadier from South Labrador and the northeastern slope of the Grand Bank fed on bottom and near-bottom animals, mainly ophiura. The basic food items of grenadier from other areas of the Northwest Atlantic and also Greenland and Iceland were also benthic animals (Savvatimsky, 1969). In August 1967 some prespawning females ranging from 53 to 59 cm, were caught with a bottom trawl in the research vessel *Novorossiysk* north of Iceland (67°50'N, 20°00'W) at the depth about 800 m. Their stomach contents were chiefly shrimp, along with squid and other molluscs and amphipods. In Greenland fjords roughhead grenadier fed on large shrimp (*Pandalus*), capelin and other small fishes, polychaets, ascidians and bivalves (Jensen, 1948). The food preference of this grenadier species with reference to body and gill structure was exhaustively studied by Konstantinov and Podrazhanskaya (1972) and Konstantinov (1976). According to their data grenadier inhabiting the Greenland-Canadian Ridge and North Labrador fed mainly on shrimps, ophiura and squid in August-December 1969. The authors recognized the feeding spectra of grenadier and spinax shark (*Centroscyllium fabricii*) were similar.

The seasonal and age specificity of feeding patterns are analyzed only in a small number of publications. Geistdoerfer (1979) pointed out five major groups of animals in grenadier diet: gammarids, ophiura, polychaets, shrimps and fishes. As grenadier grew the proportion of shrimps and fishes in the diet increased. Grenadier caught off the northern coast of Norway contained 30 different food components attributed to six basic groups: polychaets, molluscs, crustaceans, echinoderms, ascidians and fishes (Eliassen and Jobling, 1985) and the authors relate the variation of food composition to growth of the fish.

Food composition of grenadier and the great variations in food in relation to fish growth were confirmed by the results of our surveys. From 1969 to 1983, 738 males and 1,692 females from bottom-trawl catches taken in the Newfoundland, South Labrador and Baffin Island areas were analyzed for feeding. The stomachs of 36.7% of males and 37.1% of females average, 37% were found to be everted and these fish were not considered.

The feeding spectrum was wide with more than 20 food items belonging to different groups found in the stomachs (Tables 5, 6 and 7). The occurrence of ophiura (26%) was the highest, polychaets (19%) were the second, and gastropods and bivalves (11.7%, with bivalves occurring more often) were the third, followed by different crustaceans. The large grenadier preferred capelin and sand eel, and the occurrence of fish in the stomachs was 25.3% in the 71–80 cm grenadier and only 3.3% in the 31–40 cm specimens. The smaller grenadier fed mainly on calanus, amphipods, polychaets and small ophiura. Houston (MS 1983) may not have found any fish in the stomachs of grenadier from the Grand Bank because the specimens analyzed were very small (7.0–32.0 cm long).

Immature and postspawning grenadier were the most intensive feeders (the mean degree of stomach fullness was 1.0–1.2). The intensity of feeding decreased in prespawning fishes (the mean degree was 0.0–0.8). The decrease in intensity of feeding during spawning was also typical of grenadier 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 was 81.8% (Savvatimsky, MS 1985).

Small pelagic and near-bottom crustaceans (copepods, amphipods, euphausiids, cumacea) were of great importance in the food of grenadier below 30 cm. With their growth the occurrence of these crustaceans decreased sharply and the importance of pandalids, pagurids, molluscs and fishes increased (Fig. 9). Roughhead grenadier females were larger than males and accounted for some difference in their food com-

TABLE 5. Frequency of occurrence (%) of various food components in the stomachs of male roughhead grenadier from catches in the Baffin Island, Labrador and Newfoundland areas, 1969-83.

Food composition	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
Other 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
Other 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
Other 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
Other 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

position. The feeding spectrum of females which was much wider than that of males included fishes, shrimps, crabs, actinians and mysids. The fishes being found in female stomachs included those with body shapes inconvenient for swallowing (redfish, American plaice).

The coefficient of food similarity between males and females analyzed for feeding appeared to be not high (65.4). This was due to different sizes of fishes of two sexes. The mean length of 503 males was 45.5 cm while that of 1,056 females was 54 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 fish groups grew, thus comparing the 31-40 cm and 41-50 cm length groups, and the 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 8).

Fatness

There is little information in literature about roughhead grenadier fatness. The fatness of grenadier analyzed by Minder (1967) averaged 8.6%. According to the Polish data (Nordzynski and Zukowski, 1971) the fatness constituted 8.8-14.9% (average 12.1%). Grenadier forming spawning concentrations near the northern coast of Norway showed fatness was low in winter 1983-84 at an average of 7.5% (Savvatimsky, MS 1985). Eliassen and Falk-Petersen (1985) reported that near the Norwegian coast fatness increased in summer and

TABLE 6. Frequency of occurrence (%) of different food components in the stomachs of female roughhead grenadier from catches in the Baffin Island, Labrador and Newfoundland areas, 1969-83.

Food composition	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
Other 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
Other 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
Other 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
Other 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	1,056
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

decreased in autumn signifying they were feeding in preparation for spawning.

According to our data the mean fatness of grenadier caught at different times of the year through 1969-83 in the Baffin Island, Labrador and Newfoundland areas ranged from 4.7 to 12.4% (Table 9) and averaged 8.3%. In view of the small number of samples, patterns in fatness during the course of a year could not be observed. Geographically, however, fatness from the Baffin Island and Labrador areas was much higher than that in the Newfoundland area (Fig. 10, Tables 10, 11), suggesting that mean fatness decrease progressively southward.

Fatness of males and females which changed unequally with length (Fig. 10) was attributed to maturation patterns. Males began to mature at about 35 cm (stage III of gonad maturity) but matured and spawned at 50-55 cm (Table 12). Their relative liver weight was highest then and averaged 14%. However, as the male length continued to increase the liver weight decreased sharply. Grenadier females matured and spawned at about 70 cm (Table 12). Their fatness increased gradually before they attained this length and decreased at about 80 cm.

General Discussion

Throughout its range, the roughhead grenadier in the North Atlantic inhabits near-bottom shelf and adjacent waters of the continental slope. The length composition of trawl catches differed greatly by area but this probably related directly to trawling depth. In the present study with the increase in trawling depth from 200 to 600 m, the mean length of males and females in Div. 3N decreased. This concurs with the results

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

Food composition	Length (cm)								
	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90	11-90
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
Other 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
Other 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
Other 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	13.4	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
Other 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	1,559
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 8. Coefficients of food similarity between different length groups of roughhead grenadier (503 males and 1,056 females) caught in the Baffin Island, Labrador and Newfoundland areas, 1969-83.

Length groups (cm)	21-30	31-40	41-50	51-60	61-70	71-80	81-90
11-20	36.5	20.4	17.4	12.5	5.5	3.3	0.0
21-30	—	57.5	44.3	28.9	19.9	14.2	8.0
31-40	—	—	70.7	49.0	34.0	24.0	16.7
41-50	—	—	—	66.8	44.9	28.4	18.8
51-60	—	—	—	—	53.6	32.9	24.4
61-70	—	—	—	—	—	51.0	31.8
71-80	—	—	—	—	—	—	37.7

obtained by Parsons (1976a). In longline catches in Div. 3N the length of roughhead grenadier increased with depth from 300 to 1,000 m (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 groups and males within the lower range,

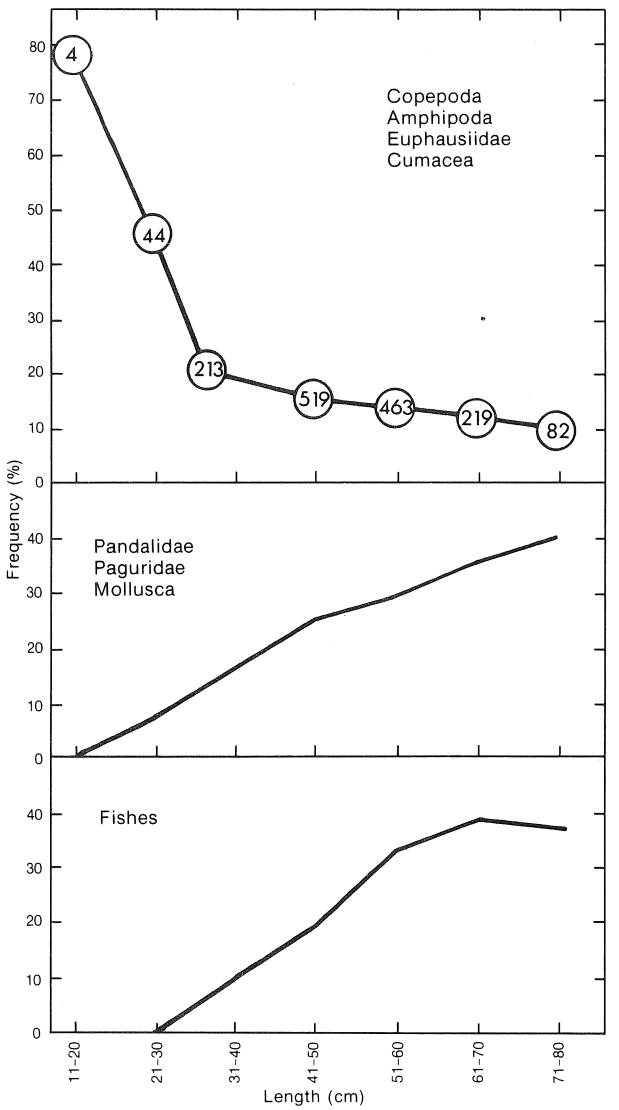

Fig. 9. Frequency of occurrence of small and large food items in the stomachs of roughhead grenadier taken in the Labrador, Newfoundland and Baffin Island areas, 1969-83 (smoothed curves; circles contain numbers of stomachs with food).

however, the mean length of fish increased with increasing depth from 400 to 900 m (Savvatimsky, MS 1985). According to information collected in September 1982 and April 1983 large grenadier were mainly caught at great depths but the relative number of females also increased with depth. If mixed concentrations of males and females were then found in the upper layers, large fishes, mainly females, were prevalent at depths more than 1,000 m. The 10 large specimens caught at 1,470–1,520 m in Central Labrador in 1969 were females. The increase in length with depth has also been described for other grenadier species: for instance *Coryphaenoides rupestris* (Savvatimsky, 1982; 1986b; MS 1986c and *Trachyrhynchus* (Ibanez, 1977). Grenadiers found in the near-bottom 750–

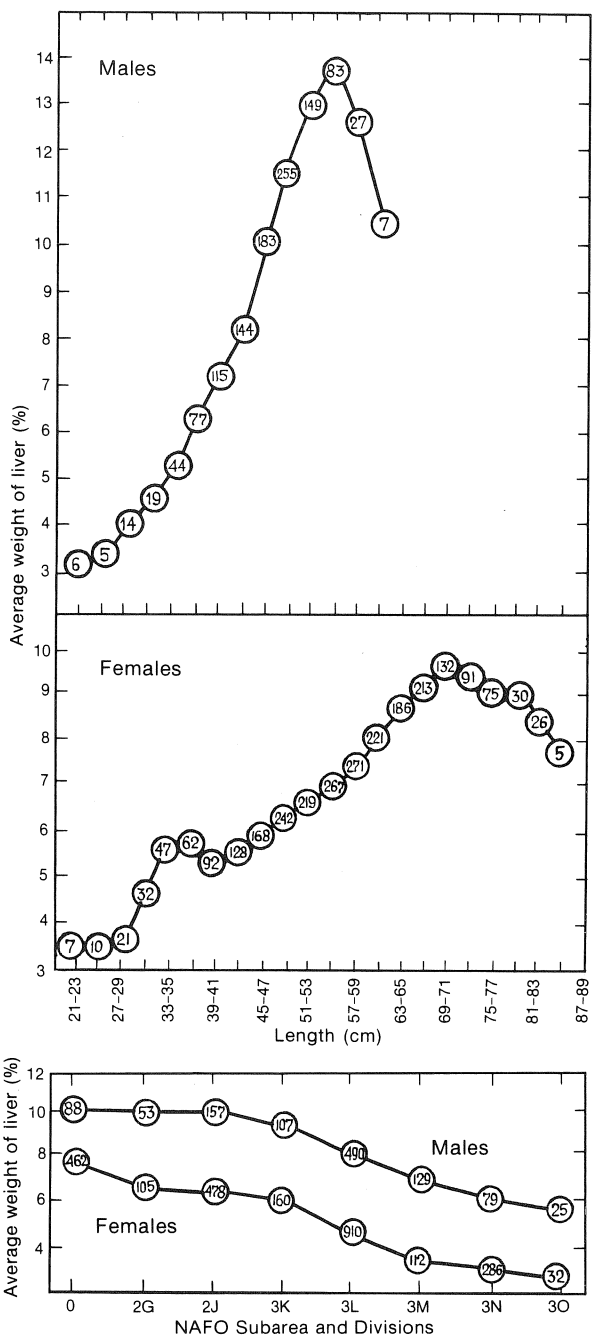

Fig. 10. Mean fatness of male and female roughhead grenadier taken in NAFO Subarea 0, Div. 2G and 2J-3O, 1969-83 (smoothed curves; circles contain numbers of fish, length groups with less than five fishes are not considered).

6,000 m layer in the Pacific, Atlantic and Indian Oceans were as a rule, large mature fishes (Isaacs and Schwartzlose, 1975). In these cases the increase in fish length with depth is probably related to adaptation to the environment with relatively poor nutritive base in deep oceanic layers and from more efficient consumption of food by large grenadier.

TABLE 9. Fatness (%) (numerator) and number of fish (denominator) of roughhead grenadier caught in different months between 1969 and 1983 in Subarea 0 and NAFO Div. 2G-30.

Month	Year	Subarea 0	Division 2G	2J	3K	3L	3M	3N	3O	In all areas
Feb	1978						5.2/181			5.2/181
Mar	1976					12.4/99				12.4/99
May	1974				11.0/99					11.0/99
May	1977					7.9/73		5.1/35		7.0/108
May-Jul	1982					7.5/308				7.5/308
Jun	1971							6.8/189		6.8/189
Jun	1977					7.6/74				7.6/74
Jun	1981					7.1/81				7.1/81
Jul	1977				6.9/21					6.9/21
Jul	1978			11.1/70						11.1/70
Jul	1981			10.1/98		9.6/77				9.9/175
Aug	1978							8.2/50		8.2/50
Sep	1969					5.8/197	8.0/63	4.7/93		5.9/353
Oct	1969								5.2/57	5.2/57
Oct	1983					7.8/397				7.8/397
Nov	1969			12.2/71						12.2/71
Nov	1975					8.6/100				8.6/100
Nov	1979			6.7/149						6.7/149
Nov	1980	10.5/100								10.5/100
Nov	1982	11.4/342								11.4/342
Dec	1981	9.5/112	8.0/158							8.6/270
Dec	1983			9.0/400						9.0/400
Feb-Dec	1969-83	10.8/554	8.0/158	9.7/639	8.3/269	7.9/1,406	5.9/244	6.3/367	5.2/57	8.3/3,694

The long growth period, many-aged population structure and late maturation are characteristic of roughhead grenadier. Spawning appears to occur in winter and early spring. The spawned eggs may be distributed at great depths, as they have been caught with plankton nets at 985-1,200 m (Magnusson, 1975). This distribution is known to prevent mass mortality and the transfer of eggs to great distances with surface

TABLE 10. Fatness (%) of male roughhead grenadier of different length groups caught in Subarea 0 and NAFO Div. 2G-3O, summarized for 1969-83.

Length (cm)	Subarea 0	Division 2G	2J	3K	3L	3M	3N	3O	Mean	No. of fish
21-23	—	—	—	3.3	3.8	—	1.7	—	3.4	6
24-26	—	—	6.2	2.1	2.3	—	2.3	—	2.8	5
27-29	6.4	—	6.6	4.9	3.9	2.7	4.5	—	4.6	14
30-32	—	—	—	4.9	4.1	3.7	—	4.2	4.3	19
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
39-41	8.8	8.0	10.6	6.0	6.8	5.2	4.9	—	6.9	115
42-44	10.5	8.7	10.8	7.1	8.1	6.9	6.4	6.6	8.1	144
45-47	12.8	11.1	12.2	5.0	9.6	6.9	7.4	—	10.0	183
48-50	14.1	12.3	13.7	10.6	2.5	8.2	9.2	8.6	11.8	255
51-53	12.3	9.2	15.6	12.6	3.1	9.9	10.6	3.5	13.0	149
54-56	16.7	15.2	15.0	14.2	4.1	11.7	12.2	6.4	14.1	83
57-59	13.3	11.0	11.8	—	3.4	15.2	17.8	—	13.5	27
60-62	9.1	4.1	20.5	—	—	9.2	2.7	—	9.3	7
63-65	—	—	—	15.0	—	—	6.6	—	9.6	3
66-68	15.2	—	—	—	—	—	—	—	15.2	2
69-71	—	—	10.3	—	—	3.0	—	—	5.0	3
72-74	—	—	—	—	—	—	—	—	—	—
74-77	—	—	—	—	—	—	—	—	—	—
78-80	—	—	—	—	6.3	—	—	—	6.3	1
81-83	—	—	—	—	—	—	—	—	—	—
84-86	—	—	—	—	—	7.4	—	—	7.4	1
21-86	12.6	10.4	13.7	10.3	11.2	7.9	8.9	7.2	11.0	
No. of fish	90	53	158	108	491	132	81	25		1,138

TABLE 11. Fatness (%) of female roughhead grenadier of different length groups caught in Subarea 0 and NAFO Div. 2G-3O, summarized for 1969-83.

Length (cm)	Subarea 0	Division 2G	2J	3K	3L	3M	3N	3O	Mean	No. of fish
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		2,556

TABLE 12. Length and relative number of male and female roughhead grenadier at different gonad maturity stages, caught in the Northwest Atlantic, 1969-83.

Gonad maturity stages	Male length (cm) range	mean	No. of males	Female length (cm) range	mean	No. of females
I	21-44	32.7	32	15-47	29.2	21
II	21-78	45.6	1,167	18-80	54.0	2,757
III	34-86	50.7	136	45-99	70.4	133
IV	45-65	56.4	6	63-80	72.4	8
V	39-59	51.8	26	—	—	—
VI	37-59	49.1	35	74-89	74.7	3
VI-II				39-91	69.6	330
Total	21-86	46.1	1,402	15-99	56.2	3,252

oceanic currents. The fecundity determined for grenadier from Baffin Island (average 38.2 thousand eggs) was similar to values obtained by Yanulov (1962) and by Eliassen and Falk-Petersen (1985). Similar to other deepwater fishes, this low fecundity can be attributed to adaptation to the relatively stable environment. At these depths living conditions are relatively steady and predator pressure is small, and thus the survival of progeny increased.

In roughhead grenadier, like in other grenadiers, fat is accumulated in the liver in relation to the relative weight of the fish. However, the general pattern is that fat content increases with fish growth before they mature, then decreases since part of it is utilized for gonad development. The pattern was also found to be related to the geographic distribution of the fish. The degree of fatness was observed to decrease as the average size of grenadier increased from the north to the south. This distribution, coupled with the capture of mature fish on the southeastern slope of Grand Bank, permits the interpretation that this area is a spawning ground.

The roughhead grenadier is a typical demersal species. But this active predator feeds on various food ranging from pelagic crustaceans and fishes to different bottom and near-bottom animals. The great variety of food and the wide feeding spectrum are essential features in the feeding patterns between early and late ontogeny. They are important adaptations for deepwater species since they widen the nutritive base, favour the decrease of intraspecific food competition and provide for more complete use of food resources at great depths. However, the diversity of food types, long life cycle and schooling behaviour are also believed to be factors which support the diverse parasitic fauna carried by the roughhead grenadier (Zubchenko, 1975; MS 1981; Campbell *et al.*, 1980; Houston, MS 1983; Moser and Noble, 1977).

The distribution in the water column and daily vertical migrations of bottom and near-bottom fishes depend, in general, on their feeding behaviour. Although, the diet consists of quite a number of various bottom dwelling animals, the major food components of large grenadier are the more active benthopelagic species (Eliassen and Jobling, 1985). The related feeding migrations, perhaps accounts for different size of landings and also different length composition of catches of the grenadier taken at night and in the daytime. The larger mean length of grenadier caught with a bottom trawl at night may be attributed to the pelagic migrations of chiefly small fishes following the small prey types. There are no data in literature on daily vertical migrations of roughhead grenadier, nevertheless, it is known that many of these fish stay for long periods in the middle water layers and quite often are observed near the sea surface (Konstantinov and Shestopal, 1976).

In this study an approximate estimate of total abundance and biomass was made (with many assumptions) using the long-term mean catch in the trawl survey area and an arbitrary value of the trawl fishing efficiency. Year-to-year abundance fluctuations were not known or considered. Even though it is tentative, the 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 will increase and result in the increase of the total abundance and biomass estimate.

The abundance and biomass indices were determined only in a limited shelf 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 Island where they account for a large by-catch in the Greenland halibut bottom fishery, especially when trawling at depths above 1,000 m.

Roughhead grenadier do not form dense concentrations unlike the similar species, roundnose grenadier (*Coryphaenoides rupestris*), therefore a directed trawl fishery is not advisable. The longline fishery in

which roughhead grenadier, wolffishes and skates make up a considerable portion of catches may be an efficient method of utilizing the resource in the Northwest Atlantic (Savvatimsky, MS 1983; 1984).

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