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Biological Aspects of Roughhead Grenadier (*Macrourus berglax*) from Longline Catches in the Eastern Grand Bank Area, 1982

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Abstract

The distribution and relative abundance of roughhead grenadier (*Macrourus berglax*) and the length, age and sex composition of catches from depths of 300–1,000 m are described, based on a longlining experiment in the eastern Grand Bank area off Newfoundland during May–July 1982. The average catch per 1,000 hooks, consisting predominantly of females at all depths, increased from 35 specimens at 301–400 m to 65 at 401–500 m and then declined rapidly to <5 at 901–1,000 m. The feeding spectrum was quite diverse and changed with growth of fish, bottom organisms being the main food components with fish being significant in the diet of larger individuals. Fatness varied greatly with fish size, but was, on the average, higher in the northern than in the southern part of the surveyed area. Specimens in the length range of 36–87 cm were 6–23 years old. Notable variations in weight of fish of the same length and age were observed, and females evidently grew faster than males. The long life-cycle, slow growth and late maturation of roughhead grenadier in the Newfoundland area are typical of populations in other parts of the North Atlantic.

Introduction

Roughhead grenadier (*Macrourus berglax*) are found in deep water on the continental slope from New York to Davis Strait and West Greenland in the Northwest Atlantic, and in the Northeast Atlantic they have been taken off East Greenland, Iceland, northern Norway, Spitzbergen and in the Barents Sea as far north as 82° 10′N (Leim and Scott, 1966; Savvatimsky, MS 1969). In the Newfoundland area, they are commonly found on the continental slope in 200–800 m but not in dense commercial concentrations (Parsons, 1976; Pinhorn, 1976). By-catches of roughhead grenadier during bottom-trawling by USSR research and commercial vessels for Greenland halibut (*Reinhardtius hippoglossoides*), Atlantic redfishes (*Sebastes* sp.) and Atlantic cod (*Gadus morhua*) often contained up to a few hundred specimens. Maucorps and Fontaine (1979) reported that the research vessel *Thalassa* caught as much as 540 kg of roughhead grenadier per half-hour trawling in the Northwest Atlantic. Parsons (1976), from an analysis of research vessel catches of grenadiers in the Northwest Atlantic from the Scotian Shelf northward to Davis Strait, noted that the largest catches of roughhead grenadier were made along the eastern slope of Grand Bank (NAFO Div. 3L and 3N) in 200–500 m. Longline fishing for roughhead grenadier was shown to be promising from experiments off the coasts of Norway and Great Britain (Bakken *et al.*, MS 1975) and off Iceland (Magnusson, MS 1978). However, this species is seldom used for food or fishmeal because of the very hard and thick scales.

Relatively little is known about the ecology and biology of roughhead grenadier, and the information available in the literature is quite fragmentary. The aim of this paper is to elaborate on the biology of this species from material collected off Newfoundland in 1982.

Materials and Methods

During 26 May–28 July 1982, the USSR trawler *Langust* carried out 20 longline sets on bottom in 310–1,000 m along the eastern and southern slopes of Grand Bank and on Flemish Cap (Fig. 1). Squid was

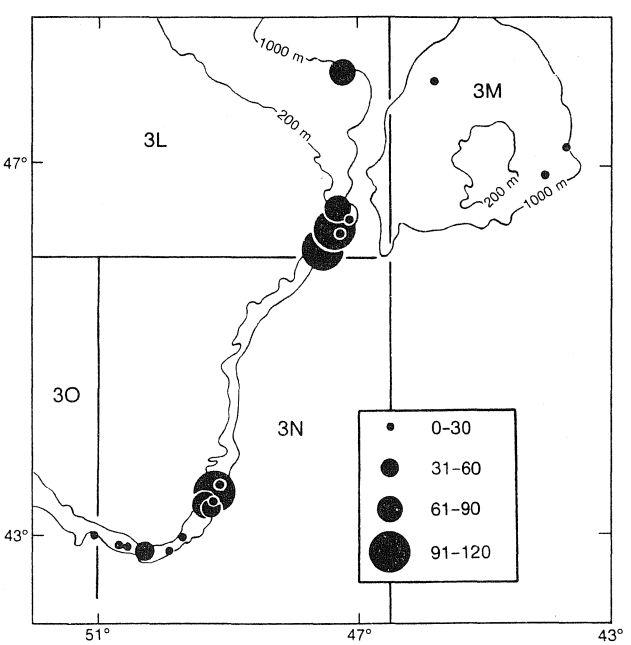

Fig. 1. Distribution of longline catches of roughhead grenadier (number per 1,000 hooks) in the eastern Grand Bank area, May–July 1982.

used as bait most frequently, but chunks of fish (grenadier, Atlantic cod, wolffishes, white hake and skates) were sometimes used. Three of the 20 sets were deeper than 700 m. The catches were sorted by species, which were enumerated and weighed, and samples taken for analysis.

The roughhead grenadier were measured from the tip of the snout to the end of the tail (total length) to the nearest centimeter and whole weights were recorded to the nearest 10 g. The sex of each specimen was recorded, and the maturity stage was determined by the 6-point scale developed by Sorokin (1957, 1960) for Atlantic cod. The liver was weighted to the nearest 5 g. The degree of stomach fullness was estimated visually by the 5-point scale: 0 = empty, 1 = quarter full, 2 = about half full, 3 = full or nearly full, and 4 = extended stomach, and the incidence of different food items was recorded.

In view of the problems associated with age determination of roughead grenadier from otoliths (Savvatimsky *et al.*, 1977), ages were determined from scales with the use of polarized light (Savvatimsky, 1971). The scales were taken from the body region between the dorsal fins just above the lateral line. The exponential function $y = ax^b$ was used to calculate the length-weight, age-length and age-weight relationships. Length frequencies and fatness curves were smoothed by the formula $B = (a + 2b + c)/4$, where a, b and c are three consecutive values of the frequency involved.

Results and Discussion

Catch composition

The largest catches of roughhead grenadier (>90 per 1,000 hooks) were taken in three sets on the eastern slope of Grand Bank (Fig. 1). Catches were negligible (≤30 specimens per 1,000 hooks) in three sets on Flemish Cap and in five of six sets on the southern slope of Grand Bank. As indicated in Table 1, the average catch (in numbers) was composed mainly of roughhead grenadier (65.1%) and five other species (31.1%): thorny skate (*Raja radiata*), northern wolffish (*Anarhichas denticulatus*), Greenland halibut (*R. hippoglossoides*), Atlantic halibut (*Hippoglossus hippoglossus*), and white hake (*Urophycis tenuis*). The remainder of the catch (3.8% by number) was composed of Atlantic cod (*G. morhua*), spotted wolffish (*Anarhichas minor*), barndoor skate (*Raja laevis*), beaked redfish (*Sebastes mentella*), cusk (*Brosme brosme*), ocean pout (*Macrozoarces americanus*), blue antimora (*Antimora rostrata*), deepwater chimaera (*Hydrolagus affinis*), and black dogfish (*Centroscyllium fabricii*).

Distribution by depth and area

Roughhead grenadier were found in all depth intervals from 300 to 1,000 m, the average catch declining rapidly from a peak value at 401–500 m to very low values at depths greater than 700 m (Table 2). There was little change in average weight of fish taken in 301–700 m, the mean for the four depth intervals being 1.36 kg. However, the mean weight increased to 1.59 kg at 701–800 m and to about 1.84 kg at 801–1,000 m.

Females constituted about 94% of the total number of grenadiers caught (Table 3), and their average length (63.0 cm) was considerably greater than that for males (49.8 cm). Specimens caught in 701–1,000 m were on the average larger than those from 301 to 700 m, and fish caught in the southern divisions were slightly larger than those from the northern divisions. However, the similarity of the length distributions of both males and females in the two areas (Fig. 2) possibly indicates the existence of a single population of roughhead grenadier in the surveyed region.

TABLE 1. Species composition of longline catches from 20 sets in the Grand Bank area, May–July 1982.

Species	Catch per 1,000 hooks			
	No.	%	kg	%
Roughhead grenadier	34.7	65.1	48.5	27.8
Thorny skate	10.8	20.3	45.3	25.8
Northern wolffish	2.3	4.3	25.1	14.4
Greenland halibut	1.6	3.0	4.6	2.6
Atlantic halibut	1.4	2.6	38.4	22.0
White hake	0.5	0.9	5.4	3.1
Other fish	2.0	3.8	7.5	4.3
Total	53.3	100.0	174.8	100.0

TABLE 2. Average catch of roughhead grenadier and mean weight of fish by depth from longline catches in the Grand Bank area, May–July 1982.

Depth (m)	No. of sets	Number per 1,000 hooks	Mean wt. (kg)
301–400	6	34.8	1.35
401–500	6	64.7	1.35
501–600	3	19.0	1.42
601–700	2	11.5	1.33
701–800	1	6.0	1.59
801–900	1	7.0	1.84
901–1000	1	4.0	1.83
Weighted mean		34.7	1.40

TABLE 3. Number and average length of roughhead grenadier by sex, depth and area from longline catches in the Grand Bank area, May–July 1982.

Depth/area	Number of fish			Mean length (cm)		
	M	F	M+F	M	F	M+F
301–700 m	59	872	931	49.8	62.8	61.9
701–1,000 m	1	34	35	49.0	68.7	68.2
Div. 3L+3M	38	425	463	49.3	61.1	60.1
Div. 3N+3O	22	481	503	50.7	64.7	64.1
Total	60	906	966	49.8	63.0	62.2

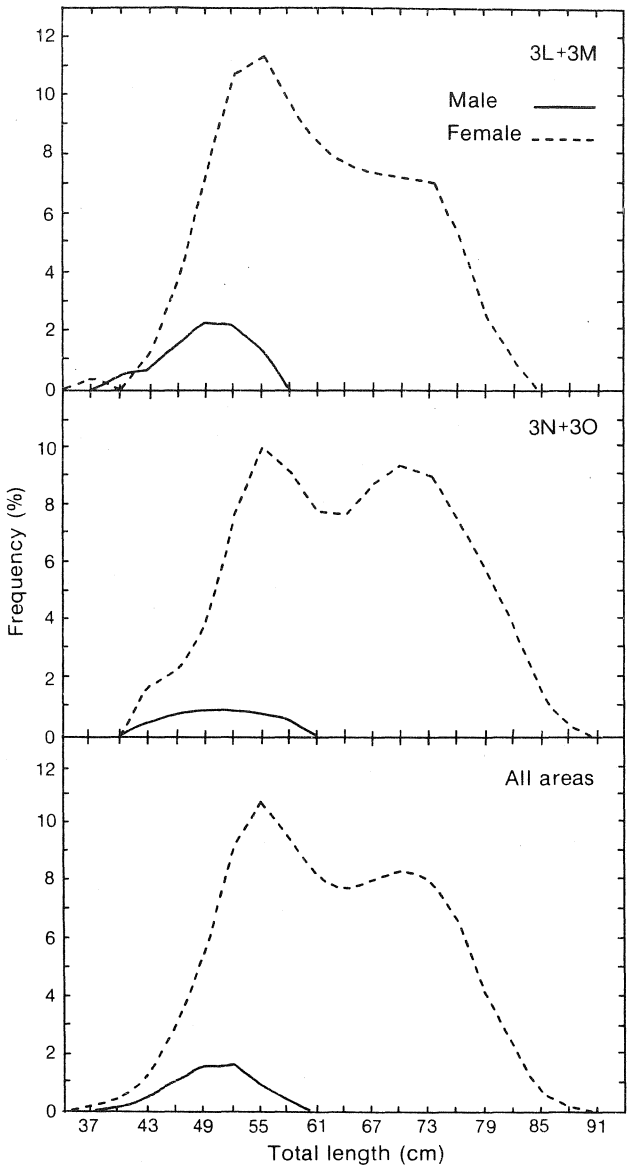

Fig. 2. Smoothed length compositions of male and female roughhead grenadier in the northern and southern divisions of the eastern Grand Bank area, May-July 1982.

Maturity

Maturity stages of roughhead grenadier were determined from 495 females for which both lengths and weights were available (Table 4). The samples from Div. 3N and 3O contained a significantly higher proportion of maturing and postspawning females (stages III and VI-II) and a lower proportion of immatures (stage II) than the samples from the northern divisions, implying that the major spawning ground of the Grand Bank population may be in the vicinity of the southern and southeastern slopes of the bank. The maturing and postspawning fish in the southern divisions were on the average larger than those in the northern area. The samples contained no spawning or prespawning fish. It is likely that spawning occurs in winter and early spring, as was observed for roughhead grenadier off Iceland (Magnusson, MS 1977).

TABLE 4. Number and average size of female roughhead grenadier by maturity stage and divisions from longline catches in the Grand Bank area, May-July 1982.

NAFO Div.	Maturity stage	Specimens No.	Specimens %	Mean length (cm)	Mean weight (kg)
3L+3M	II	182	60.9	54.9	0.94
	III	12	4.0	66.8	1.62
	VI-II	105	35.1	70.9	2.06
	Total	299	100.0	61.0	1.36
3N+3O	II	71	36.2	55.1	0.92
	III	10	5.1	69.9	1.87
	VI-II	115	58.7	75.4	2.45
	Total	196	100.0	67.8	1.86

Fatness

In roughhead grenadier, as in other grenadiers, fat accummulates in the liver. Because the flesh of the fish contains less than 1% fat, variation in fat content of individuals may be evaluated by the relative weight of the liver. The ratio of liver weight to total body weight, expressed as percent, is conventionally called "fatness", and values for this variable were calculated for 43 male and 495 female roughhead grenadier from the Grand Bank area (Table 5). Over the entire length ranges of the sampled fish, the fatness of males (mean length 49.5 cm) varied from 4.8 to 24.3% (average 11.3%), and the fatness of females (mean length 63.7 cm) varied from 1.7 to 23.5% (average 7.3%). The average fatness of females in the same length range as males was about 8.5%.

The average fatness of females was consistently higher in Div. 3L and 3M than in Div. 3N and 3O for all length groups except the smallest fish (Fig. 3). In both areas, fatness declined with increasing fish size from 8-9% in the smallest fish to an average of about 6.5% (7.2% in Div. 3L and 3M, and 5.8% in Div. 3N and 3O) in 70 cm fish and then increased rapidly to 9-10% in the largest specimens. The fatness of individuals within each length group varied greatly, the ranges being extreme for the 48-50 cm and 66-68 cm groups (4.0-23.5% and 1.7-21.2% respectively). These variations in fatness are indicative of the physiological condition of the fish and are probably related to their recovery from spawning in the case of adults and to the availability of food.

Stomach contents

The stomachs of all male roughhead grenadier were either empty or everted, and 38.2% of 495 females sampled had everted stomachs. Consequently, the information presented on food types and their frequency of occurrence in the stomachs is based on the

TABLE 5. Length, weight and fatness of roughhead grenadier from longline catches in the Grand Bank area, May-July 1982.

Sex	Div.	No. of fish	Length (cm) Mean	Length (cm) (range)	Weight (kg) Mean	Weight (kg) (range)	Fatness (%) Mean	Fatness (%) (range)
Male	3L+3M	33	49.1	(41-56)	0.63	(0.37-0.96)	11.4	(4.8-24.3)
	3N+3O	10	50.8	(46-58)	0.70	(0.43-1.12)	11.1	(7.0-19.6)
	Total	43	49.5	(41-58)	0.65	(0.37-1.12)	11.3	(4.8-24.3)
Female	3L+3M	299	61.0	(36-82)	1.36	(0.26-3.16)	7.8	(2.0-23.5)
	3N+3O	196	67.8	(42-87)	1.84	(0.34-4.06)	6.8	(1.7-23.5)
	Total	495	63.7	(36-87)	1.56	(0.26-4.06)	7.3	(1.7-23.5)

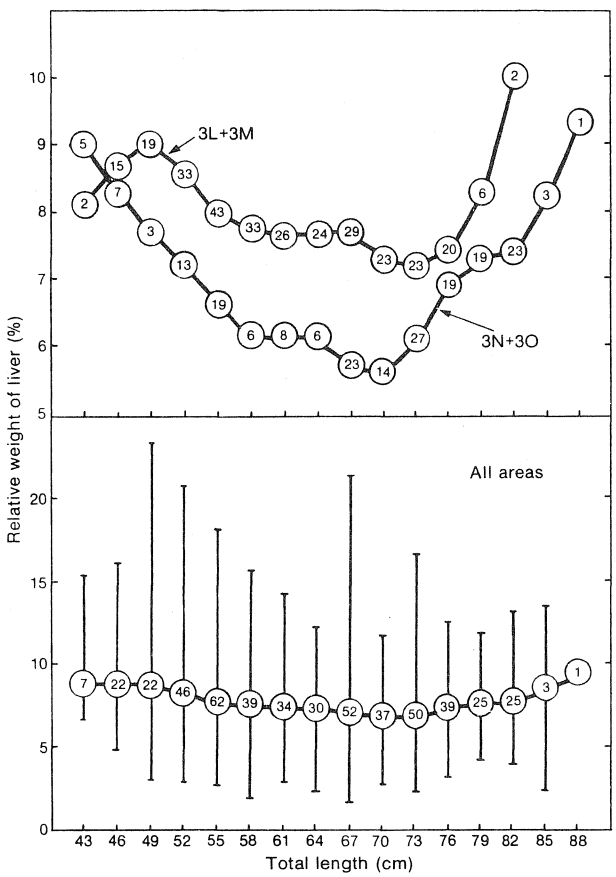

Fig. 3. Relative liver weights of female roughhead grenadier by length groups in the eastern Grand Bank Area, May-July 1982. (Circles contain numbers of fish.)

examination of 310 female specimens (Table 6), of which only 47.1% contained traces of food. The average degree of stomach fullness, based on a scale from 0 to 4, was only 0.72. This value is considered to be underestimated, because it is likely that some food was ejected from the stomachs as the longline catch was being retrieved from deep water. By size group, the relative number of stomachs containing food increased from 39-43% in 41-70 cm specimens to nearly 80% in the largest fish. Similarly, the average degree of stomach fullness was quite low (0.58-0.75) in 41-70 cm fish but increased to 1.36 in the 81-90 cm group.

From the scanty data available, it is evident that the roughhead grenadier prey on a diversity of benthic organisms and also some fishes (Table 6). Bivalve molluscs (13.4% occurrence), shrimp (12.4%), fish (11.1%) and starfishes (10.5%) were the major components of the diet in all size groups except the 41-50 cm group which contained no fish fragments. The larger grenadier preferred shrimps, bivalves and fish, whereas the smaller ones fed mainly on small bivalves and starfishes, with shrimps and polychaetes also being important.

Length-weight relation

No obvious differences were observed in the weights of male and female roughhead grenadier of the same length, and, in view of the small number of males in the sample (43 males and 495 females), the available data for both sexes were used in calculating the length-weight relationship (Fig. 4). Over the length range of 41-84 cm, with average weight range of 370-3,330 g, weight increased with length at a rate only slightly faster than the cube of the length. A notable feature of the data is the variation in weight-at-length, which increased with increasing length of fish.

Age composition of catches

Age determination of grenadiers which live in deep water along the continental slopes, including roughhead grenadier, is very difficult by the usual methods of microscopy applicable to fish from the shallower parts of the continental shelf, because annual rings on scales and otoliths are barely visible and difficult to interpret. The rings on the scales of roughhead grenadier become more distinct under polarized light, but the annulus is often composed of two rings situated close together, one of which is usually narrower than the other. This characteristic must be taken into account when counting the annuli and determining the age of the fish (Savvatimsky, 1971).

Ages of roughhead grenadier from the Grand Bank region were estimated by means of polarized light from the scales of 341 specimens (29 males and 312 females) with an overall length range of 36-87 cm.

TABLE 6. Frequency of occurrence of various food types in the stomachs of female roughhead grenadier from longline catches in the eastern Grand Bank area, May-July 1982.

Major group	Food type	Percent occurrence by length group (cm)					
		41-50	51-60	61-70	71-80	81-90	41-90
Mollusca	Bivalves	21.9	12.2	3.9	16.5	35.7	13.4
Crustacea	Shrimps	9.4	6.5	6.5	25.3	21.4	12.4
	Crabs	—	0.9	—	—	—	0.3
	Amphipods	—	0.9	1.3	—	—	0.6
Annelida	Polychaetes	9.4	4.7	3.9	2.5	—	4.2
Echinodermata	Starfishes	12.5	14.0	7.8	7.6	7.1	10.5
	Sea cucumbers	—	—	—	3.8	—	0.1
	Sea urchins	—	—	1.3	—	—	0.3
Pisces	Redfish	—	—	—	—	7.1	0.3
	Grenadier	—	—	—	1.3	—	0.3
	Sand lance	—	—	1.3	—	—	0.3
	Skate	—	—	—	1.3	—	0.3
	Digested fish	—	7.5	14.3	16.4	14.3	11.1
Other	Digested food	—	4.7	9.1	8.9	14.3	6.9
	Detritus	3.1	1.9	—	1.3	—	1.3
No. of stomachs examined		33	107	77	79	14	310
Stomachs containing food (%)		42.4	39.3	42.9	63.3	78.6	47.1
Degree of stomach fullness		0.75	0.58	0.61	1.04	1.36	0.72

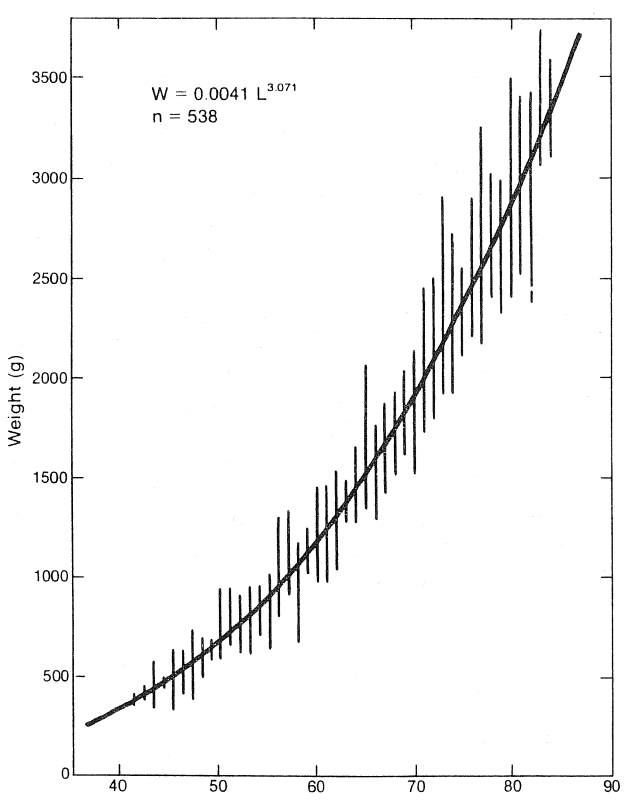

Fig. 4. Weight-length relationship for roughhead grenadier in the eastern Grand Bank area, May-July 1982.

Application of age-length keys to the length compositions of males and females in the overall catch from the longlining experiment yielded age compositions with ranges of 7-13 years for males and 6-23 years for females, and corresponding ranges in mean length-at-age values of 43-58 cm and 40-87 cm respectively (Table 7). The average ages of males and females were 9.7 and 12.9 years respectively. The female component of the catch was composed of many year-classes, with age-groups 10-12 being the dominant ones. Age-group 10 was the dominant one in the very small male component of the catch. Because the bulk of the longline catches was composed of fish which undoubtedly has spawned more than once, a longline fishery is considered the most reasonable one for preserving the

TABLE 7. Age composition and mean length of roughhead grenadier from long-line catches in the Grand Bank area, May-July 1982.

Age (yr)	No. of fish		Mean length (cm)	
	Male	Female	Male	Female
6	—	2	—	40.0
7	7	12	43.0	44.0
8	10	36	46.6	48.0
9	9	62	49.0	50.4
10	14	124	51.2	54.3
11	9	117	50.7	57.4
12	9	126	54.4	59.9
13	2	71	58.0	65.1
14	—	73	—	67.5
15	—	66	—	70.0
16	—	69	—	72.4
17	—	51	—	74.9
18	—	38	—	76.6
19	—	38	—	78.8
20	—	11	—	81.0
21	—	7	—	80.8
22	—	2	—	83.5
23	—	1	—	87.0
Total	60	906	49.8	63.0

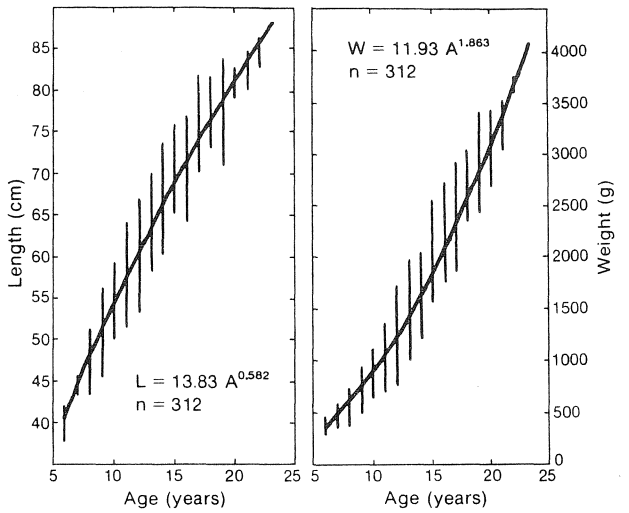

Fig. 5. Exponential growth curves by length and weight for roughhead grenadier in the eastern Grand Bank area, May-July 1982.

recruitment and reproductive potential of the population.

Growth

The number of aged males was inadequate to elaborate their growth over a range of ages comparable to that for females. Consequently, only the length-at-age and weight-at-age curves for females, as computed for 312 aged specimens by the exponential formula $y = ax^b$, are illustrated in Fig. 5. Appropriate statistical tests indicated a high degree of correlation of the estimated and empirical values for both relationships ($P<0.01$). It must be emphasized that these relationships reflect the growth patterns only over the range of known age-groups and cannot be used to interpolate the growth of younger or older fish. Over the range of age-groups considered (6-23), increase in average length from 40 to 87 cm corresponds approximately to increase in average weight from 0.34 to 4.10 kg. Considerable variation in length and weight is evident at each age. For example, at age 15, the length range was 65-76 cm, with a weight range of 1.56-2.54 kg. The ranges of these parameters tend to expand for fish older than about 10 years. This may be an important adaptive feature, as it implies a widening of the food spectrum and, consequently, the nutritive base of the year-classes, as the fish grow older.

To determine if the growth of male and female roughhead grenadier was different, only the data for age-groups 7-13 were used (Table 8), due to the absence of older males in the sample. Comparison of the mean lengths and mean weights indicate that the females grew faster than the males, at least for age 7 and older fish, and the differences increased with age. For example, the mean length of females increased by 16.2 cm and the mean weight increased by 0.74 kg from age 7 to 12, whereas the corresponding increases for males were 9.7 cm and 0.45 kg.

TABLE 8. Comparison of growth data for male and female roughhead grenadier from longline catches in the Grand Bank area, May-July 1982.

Age (yr)	No. of fish	Length (cm) Mean	Length (cm) (range)	Weight (kg) Mean	Weight (kg) (range)
		Males			
7	5	42.8	(41-45)	0.42	(0.37-0.50)
8	5	46.6	(46-48)	0.47	(0.38-0.54)
9	6	48.7	(47-51)	0.58	(0.47-0.74)
10	6	51.0	(49-53)	0.67	(0.60-0.73)
11	4	50.3	(49-52)	0.72	(0.61-0.84)
12	2	52.5	(51-54)	0.87	(0.77-0.96)
13	1	58.0		1.12	
		Females			
7	7	44.0	(43-45)	0.46	(0.34-0.58)
8	14	47.6	(43-51)	0.55	(0.32-0.72)
9	20	49.6	(45-50)	0.67	(0.46-0.91)
10	33	54.1	(50-59)	0.82	(0.64-1.10)
11	30	57.1	(51-64)	0.99	(0.66-1.35)
12	34	60.2	(53-68)	1.20	(0.74-1.71)
13	23	65.3	(58-70)	1.51	(0.96-1.97)

Only fragmentary data on the growth of roughhead grenadier are available in the literature. Some females caught off Iceland in 1967 were 67-89 cm long and 17-25 years old (Savvatimsky, 1971). A 70.5 cm female from the north coast of Norway was reported to be 16 years old (Yanulov, 1962), but the method of ageing was not stated. Applying the method of scale impregnation with silver, Kosswig (MS 1979) estimated the ages of a small number of roughhead grenadier caught on Dohrn Bank off East Greenland. He reported an abundance of 41-86 cm fish (aged 8-18 years) in the catches, with the dominant age-groups (12-15 years) being represented by 62-75 cm fish, but, unfortunately, he did not separate the fish by sex. On the basis of these scanty observations, it appears that growth of roughhead grenadier in the Northeast Atlantic is similar to that demonstrated in this paper for the eastern Grand Bank area of the Northwest Atlantic.

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