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AGEING OF ROUNDNOSE GRENADIER (*CORYPHAENOIDES RUPESTRIS* GUNN.) FROM OTOLITHS

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Abstract

Samples of grenadier were collected from the catches effected by two Polish vessels, which operated in the Northeastern Atlantic (ICES Fishing Area XII) from April to July 1997. The otoliths (sagitta) were used for age determination of 309 fish measuring from 25 to 100 cm (in total length). The readability of broken and burned otoliths proved to be unsatisfactory. To make the zones visible on fish otoliths more discernible the otoliths were embedded in the epoxy and their surface was polished, then treated with 5% EDTA. The final ageing was preceded by recurrent ageing of 30 roundnose grenadier otoliths sample by the six Institute experts. The exercise contributed to an improvement in the criteria selection for determination of the annual growth rings attributes. The age was determined from counts of hyaline and opaque zones visible in the reflected light. The estimated age of the examined fish ranged from 6 to 27 years. The fish belonging to age groups: 16 – 18 provided the bulk of the catches effected. The growth in length (sexes combined) is best described by

$$L_t = 137.5\ (1 - e^{-0.0543\ (t - 2.309)})$$

The estimated values for the total mortality coefficient of roundnose grenadier ranged from 0.52 to 0. 62 year^{-1}.

DÉTERMINATION DE L'ÂGE DU GRENADIER DE ROCHE (*CORYPHAENOIDES RUPESTRIS* GUNN.) À PARTIR DES OTOLITHES

Resumé

Les échantillons du grenadier de roche provenant des pêches effectuées par les deux navires polonais, qui avaient opperé dans les eaux de l'Atlantique du Nord-Est (XII Zone de pêche ICES) d'avril à juillet 1997). Les otolithes (sagitta) étaient utilisées pour la détermination de l'âge de 307 poissons de la longeur totale 25 à 100 cm. La lisibilité des otolithes détériorées n'était pas satisfaisante. Pour faire les zones visibles sur les otolithes plus distinctes, les otolithes étaient placées dans l'époxyde, leur surface était polie et traitée avec 5% EDTA. La détermination finale de l'âge était précédée par une évaluation repetée de 30 échantillons des otolithes du grenadier de roche effectuée par les six experts de l'Institut. Cet exercice avait contribué à l'amélioration de séléction des critères pour la détermination de la qualité de segments de la croissance annuelle. L'âge était déterminé de la quantité de zones hyaline et opaque visibles dans la lumière refletée. L'âge estimé des poissons examinés était placé entre 6 et 27 ans. Les poissons qualifiés au groupe: 16 - 18 avaient constitué la majorité des poissons pêchés. La croissance en longeur (tous les deux sexes) est le mieux décrite par:

$$L_t = 137.5\ (1 - e^{-0.0543\ (t - 2.309)})\ .$$

La valeur estimée pour l'indice de la mortalité totale du grenadier de roche était placée entre les limites de 0,52 à 0,62 an^{-1}.

AGEING OF ROUNDNOSE GRENADIER (CORYPHAENOIDES RUPESTRIS GUNN.) FROM OTOLITHS

1. Introduction.

Directed fishery of species belonging to *Macrouridae* family started relatively late. It has resulted from two factors:

- **the distribution area of the species within waters exceeding 700 m in depth,**
- **morphological characters of *Macrouridae* family uncommon to most other fish species; the club-shaped body and its elongated tail part without distinguished caudal fin, which make it harder to accept in the established markets of countries with long-term tradition of fish consumption.**

In the roundnose grenadier fishery on commercial scale were interested countries of insignificant tradition in marine fish consumption and of limited possibilities to supply their markets with animal protein and, at the same time, having at their disposal modern fishing fleets. In 1967, in the catch statistics of USSR and GDR the catch of 600 tones of the roundnose grenadier originated from the Northeastern Atlantic and 1,400 tones from the Northwestern Atlantic was recorded. Four years later the annual catch of that species by the USSR fleet amounted to 84,000 tons. The catch of that magnitude has never been reached in the next years, on the contrary the catches declined to 26,000 - 30,000 tons annually. In the meantime the directed fishery was joint by fleets from other countries including that of Federal Republic of Germany. FRG fishing vessels in 1978 and 1979 caught 9,000 and 10,000 tons of roundnose grenadier, respectively.

The legal limitation of access and a decrease in the c.p.u.e. on the traditional fishing grounds affected not only the Polish fishery. Countries like France, Germany, Spain, United Kingdom, Faroe Islands were also forced to re-direct part of their fishing effort into "deep-water" fish species distributed in the deepest zone of the continental slope and below.

Grenadiers, and mainly the roundnose grenadier (Coryphaenoides rupestris Gunn.) became an object of interest of fishing vessels which due to their technical characteristics are economically effective only providing the access to large and

homogenous aggregations of fish, with respect to their species composition and size structure.

In the meantime, a large number of publications was elaborated concerning the distribution of roundnose grenadier in the North Atlantic waters: Atkinson (1983, 1984), Atkinson and Power (1987, 1988), Jorgensen (1996, 1997), Chumakov and Savatimsky (1984, 1987), De Cardenas et al. (1996), Magnusson and Magnusson (1995), Bergstad (1990). Much smaler number of publications was devoted to Macruridae species ageing (*Coryphaenoides rupestris, Macrourus berglax*), however even in that case there is a large number of them. During the last years much more attention was devoted to roughhead grenadier: Rodriguez-Martin et al. (1998), Alpoim (1997), Bergstad (1995), Sainza (1995, 1996), Casas (1994).

From the available literature it appears that the bulk of catches in the roundnose grenadier fishery is comprised of 14 years old and older fish. A slow individual growth rate of fish and the fact that the fishery is based on population consisting of large numbers of age groups limit not only an opportunity to increase catches but put a question as to a chance of maintaining their present level taking into account the recorded c.p.u.e. Therefore to estimate the prospective of allocation of the excessive fishing effort it is not sufficient to find fishing grounds where the resources actually attractive for the fishery are distributed. Only on basis of comparison of research results on age structure of the exploited population with former results of other research teams one can draw conclusion as to the perspective of the fishery for the next few years.

2. Material and methods

The presented study was based on the roundnose grenadier samples collected during April - July 1997 from trawl catches conducted from onboard two Polish fishing vessels which operated in the area of the Atlantic Ridge (Pelczarski et al. 1997) (Fig. 1). The fish were measured with 3 cm below accuracy and grouped into 3 cm length classes. From each length class 3 - 5 specimen were chosen to determine their

individual mass, sex, degree of sexual maturity and to collect otoliths for subsequent age determination based on counting of the number of growth zones.

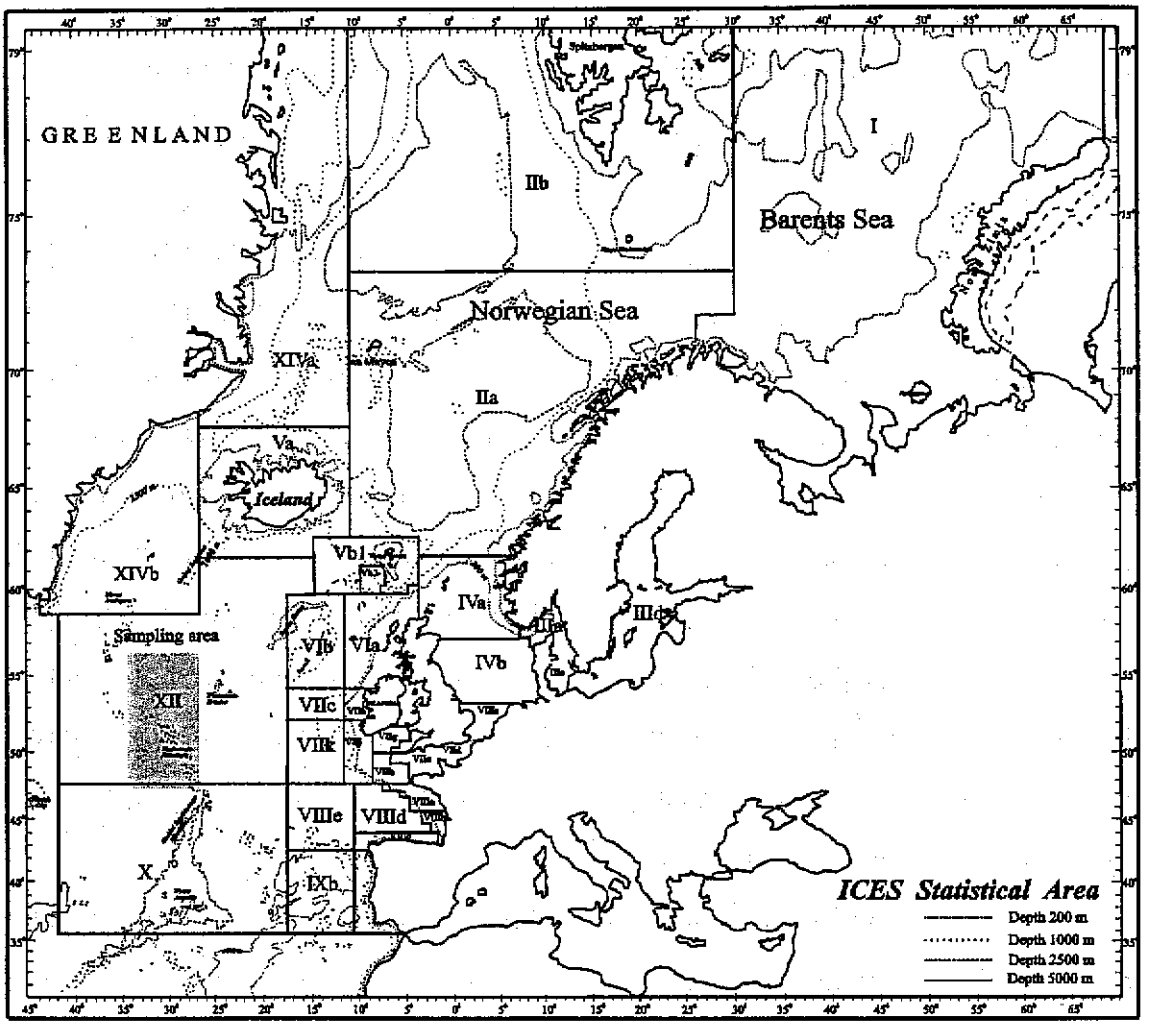


Fig. 1 Map showing the area where the roundnose grenadier samples were collected

A specific feature of the Macrouridae family is a long peduncle of the caudal fin. During the investigations very frequent losses of a considerable part of the tail appeared.

The losses took place partly during hauling the cod-end of the trawl up onto the deck and emptying it. The observations proved that 92 % of the fish caught were

subjected to such damage which caused that the total length of a part of fish collected for this study had to be approximately estimated.

The evaluation was conducted based on experience of research team members involved in the data collection. Judging from earlier observations on the body proportions of the whole fish, in cases when the lost of the total length of a fish has not exceeded 5%, its total length and thus the length of the lacking part was estimated by extrapolation accordingly with proportions of other parts of its body. Such procedure enabled to increase the proportion of the fish measured up to 56 % of all grenadiers taken in the haul.

The knowledge of a population age structure is a foundation of any estimates of its size in and changes in numbers. In case of roundnose grenadier the determination of age was considerably impeded by obliterated picture of the growth zone structures enabling identification of annual rings visible on otoliths. That problem was raised for the first time by Savvatimsky (1971a,b, 1972, 1987), Gordon et al. (1995) and Bergstad (1995) who emphasized the difficulties in the grenadier age group determination based on observation of otoliths structure. The up-to-date trials of the grenadier age determination from otoliths showed that in spite of application of many methods there are considerable differences in interpretation of the observed otoliths structure. They caused that estimates of the studied grenadier population in some cases ranged from 4 to 20 age groups and in other from 1 to 66 age groups.

In the age determination the following procedure was accepted. The size of otoliths of the studied grenadier specimens (as measured along the longer axis) was comprised in the range of 0.5 to 1.2 cm. Except otoliths originated from fish below 30 cm long and kept in the fresh water for 4 weeks before reading (Koch 1976) the structure of rings was not visible and was not revealed until the otolith was broken and burnt. Nevertheless the clearness of the opaque and hyaline growth zones enabled differentiation of up to 7 annual rings counting from the otolith center. The other, more "outside" zones, however, discernible within some parts of the otolith did not allow to identify the rings in accordance with the accepted standard. That has resulted in a very large age range estimates for the same specimen.

A comparison of consistence of the age determination between readers revealed that the maximum agreement reached 11 %. On that basis the results of the age reading from the grenadier otoliths prepared with the method described earlier were rejected.

A next approach applied was a procedure that included polishing up the inner surface of the otolith embeded in the epoxy and its treatment with 5 % EDTA during 5 - 30 minutes. The method was developed on the base of the one used by Vollestad et al. (1988) suggested by Nagięć (personal communication) from Technical Academy of Agriculture in Olsztyn (Poland) for age readings of eel otoliths. Such prepared otoliths were provisionally inspected in order to check whether they need to be further polished using fine-grained, water polishing paper. The age was determined by one reader viewing the otoliths under incident light at 16-fold magnification.

Analogously to the most of authors, it was assumed that a single hyaline zone followed by a single opaque zone are formed within the same calendar year and that they both consists jointly the annual ring. It is necessary to take into account that such obtained age readings are subjected to an error resulting from subjective criteria followed by the reader in rings differentiation, particularly in case of large sized fish (above 86 cm).

In order to elaborate a possibly explicit interpretation of growth zones visible on the cross-section of otoliths an inter-calibration by a group of 6 experts from the SFI very well experienced in ageing fish based on otoliths was conducted. The accepted procedure of inter-calibration consisted of two stages. During the first one using the magnified pictures of otoliths a preliminary rules of zones interpretation were agreed upon. During the second stage the age of 30 grenadier specimens ranging from 28 cm to 98 cm, based on otoliths, was determined by each reader. After the first reading the obtained results were discussed and the second trial of age determination was performed in such a way as the readers were not suggested by results of the preceding attempt. A comparison of readings agreement is collated in Table 1 and Figure 2.

Table 1. Agreement of age reading from otoliths of 30 roundnose grenadiers between 6 experts.

Reader	Reader					
	1	2	3	4	5	6
First reading						
1	100	-	7	4	4	11
2		100	-	-	7	-
3			100	11	7	-
4				100	4	7
5					100	4
6						100
Second reading						
1	100	32	26	42	29	24
2		100	26	42	26	26
3			100	24	24	50
4				100	29	29
5					100	24
6						100

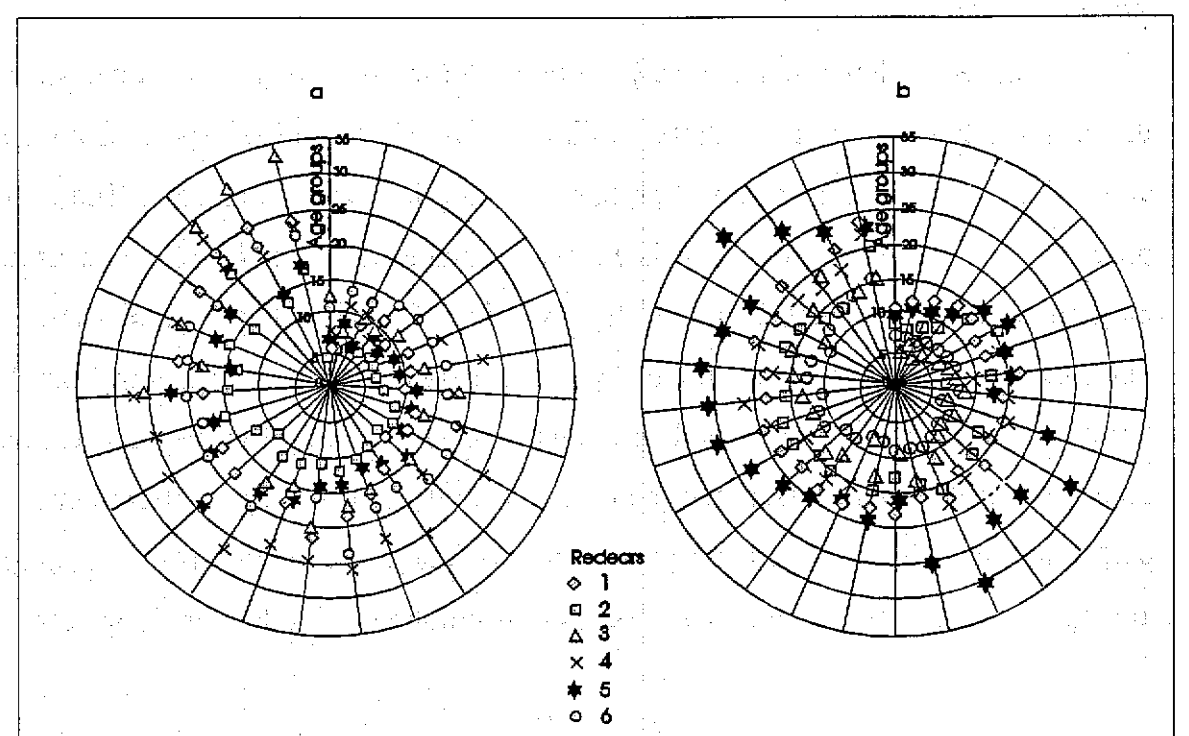


Fig. 2 Results of age reading of roundnose grenadier as determined by 6 readers.

a. First reading

b. Second reading

To enable an alternate use of the linear measurement and mass of a specimen the coefficients of the power equation relating both variables were determined.

$$W = a * L \wedge b \qquad [1]$$

Where: W - mass of a specimen (g), L - length of a specimen (cm), **a** and **b** are constant parameters estimated by curvilinear approximation of the empirical data.

Mean length of fish by age groups were applied as a basis to growth rate estimation with use of von Bertalanffy equation.

$$L_t = L_\infty (1 - e^{-K(t - t_0)}) \qquad [2]$$

Where:
L_t – total length of fish at age t;
L_∞ – theoretical maximum length according to the equation;
K – coefficient in the growth equation, equal to 1/3 of the catabolic coefficient;
t_0 – the age at which, in terms of the model, the fish would commence to grow from length = 0.

In 1997 36,000 fish were measured, 2,833 specimens were weighted and age of 309 specimens was determined. The investigations were continued in 1998, however, in the actual study only length measurements of 10,912 specimens are considered.

A crucial question of the research on the population age structure determined by recording annual growth zones discernible on fish otoliths is validation of results (Beamish and McFarlane 1983). Usefulness of most methods applied to fish species inhabiting shelf waters is limited or non with regard to deep-water or long life-span species (Bergstad 1995). Rodriguea-Marin et al. (1998) inform that results of length distribution analyses of the roughhead grenadier population on the modal progression of an exceptionally large year-class constitute a basis for validation of the interpretations of growth zones observed on otoliths. Wilson (1988) on basis of observations of daily growth zones on the grenadier otoliths arrived to similar conclusions. However, conclusions drawn by the cited authors were only right based on assumptions they accepted whose validity they themselves could not check.

A progress in age determination of fish belonging to Macrouridae family was noted on antipodes (Kalish et al. 1997, Fenton and Short 1995).

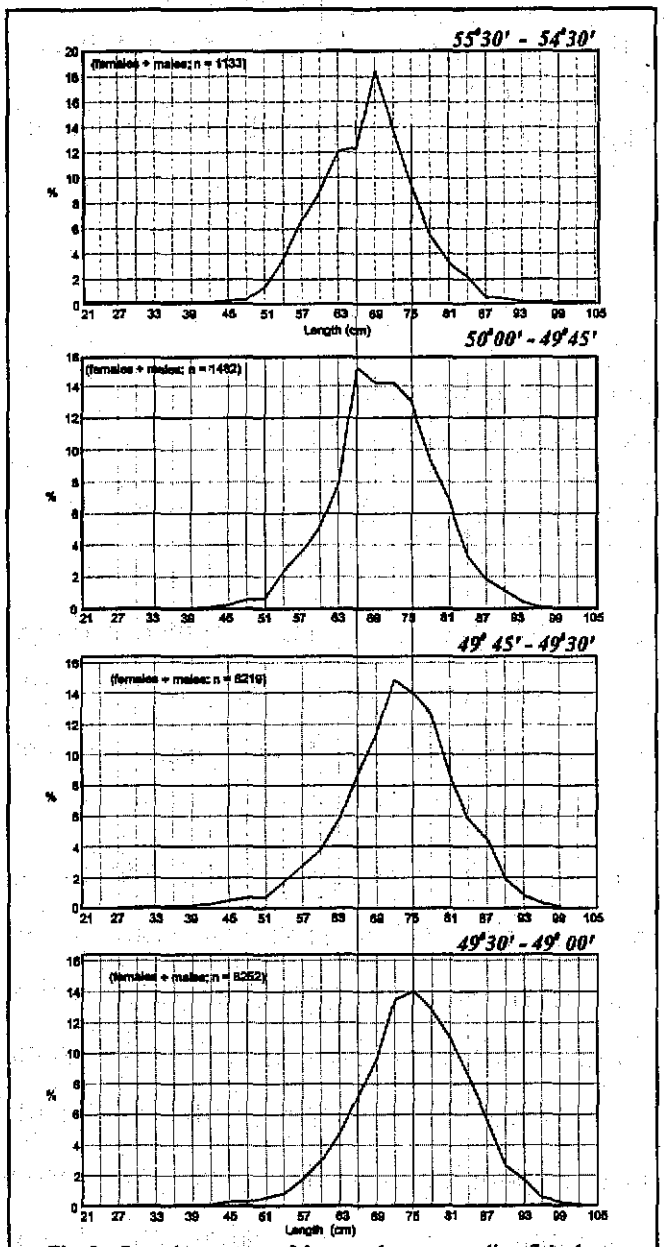


Fig. 3 Length structure of the roundnose grenadier fished on the Atlantic Ridge between 55° 30' and 48° 30' N in 1997.

Application of radiometric technology for validation of age readings from otoliths of blue grenadier (*Macrouronus novazelandiae*), the species of similar longevity as roundnose grenadier raises hopes that at least a unification of age readings within the group of experts from countries interested in the fishery will be possible.

3. Length composition of the roundnose grenadier fished on the Atlantic Ridge.

The population of roundnose grenadier exploited in the area of the Atlantic Ridge height situated between 57°30' and 48°30' N composed of fish 21 - 105 cm in total length. The analysis of the population length structure included measurement results of 36,000 specimens. The population fished on the northernmost part of the height in May was dominated by specimens 60 - 78 cm in length.

Along with a shift southward the share of larger fish increased (Fig. 3).

Including only these length classes which constituted not less than 2 % of the total exploited population by numbers, the length of such defined population part ranged between 63 and 90 cm. Independently of the location of samples collection and the proportion of males and females by numbers in samples, the mean length of males in a sample in all cases was smaller than the mean length of females. Consequently, the frequency curve of males by length-class was always shifted to the left compared to the curve of females. The shift becomes more evident when the mass of individual fish is used as the independent variable (Fig. 4a, b).

The longest 3-months period comprise measurements of the grenadier length in 1997. The length of fish during that time did not change to a greater extent (Fig. 5) if as a criterion the mean length of fish in a monthly sample is accepted; the mean from April to June equaled 69.1, 69.9 and 71.4 cm respectively.

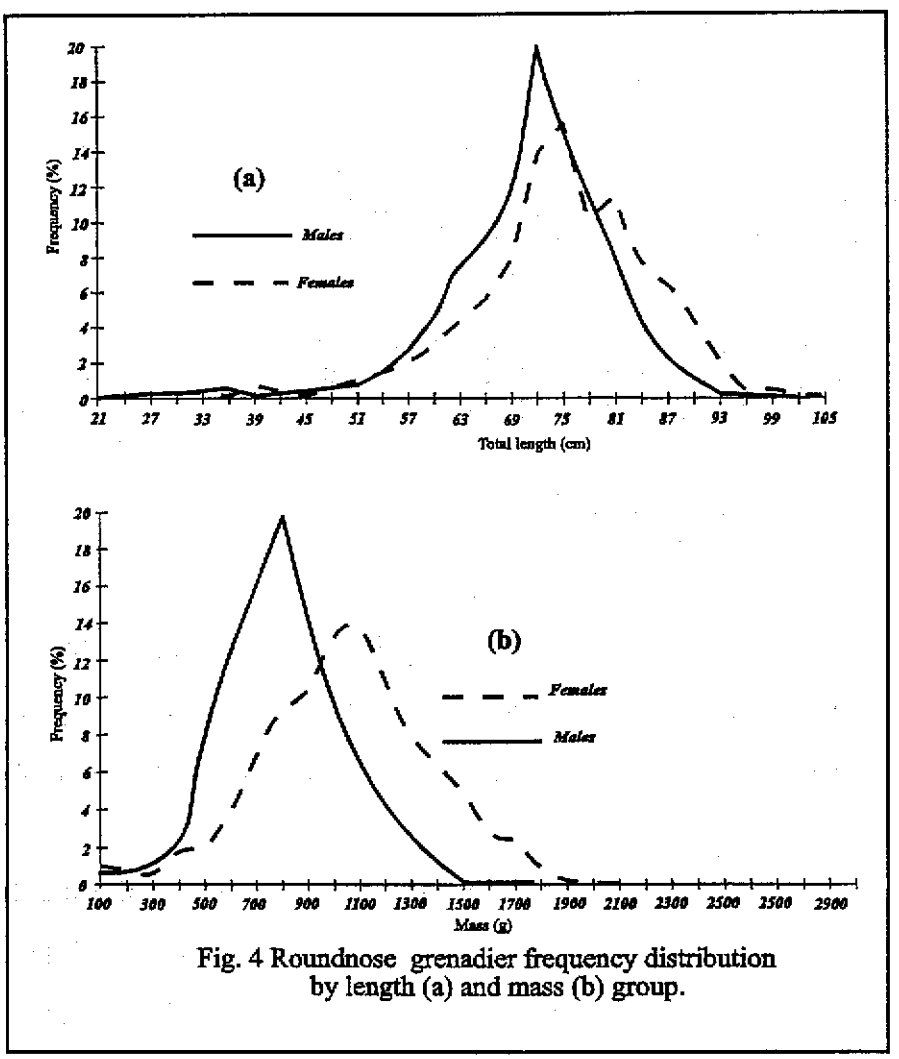


Fig. 4 Roundnose grenadier frequency distribution by length (a) and mass (b) group.

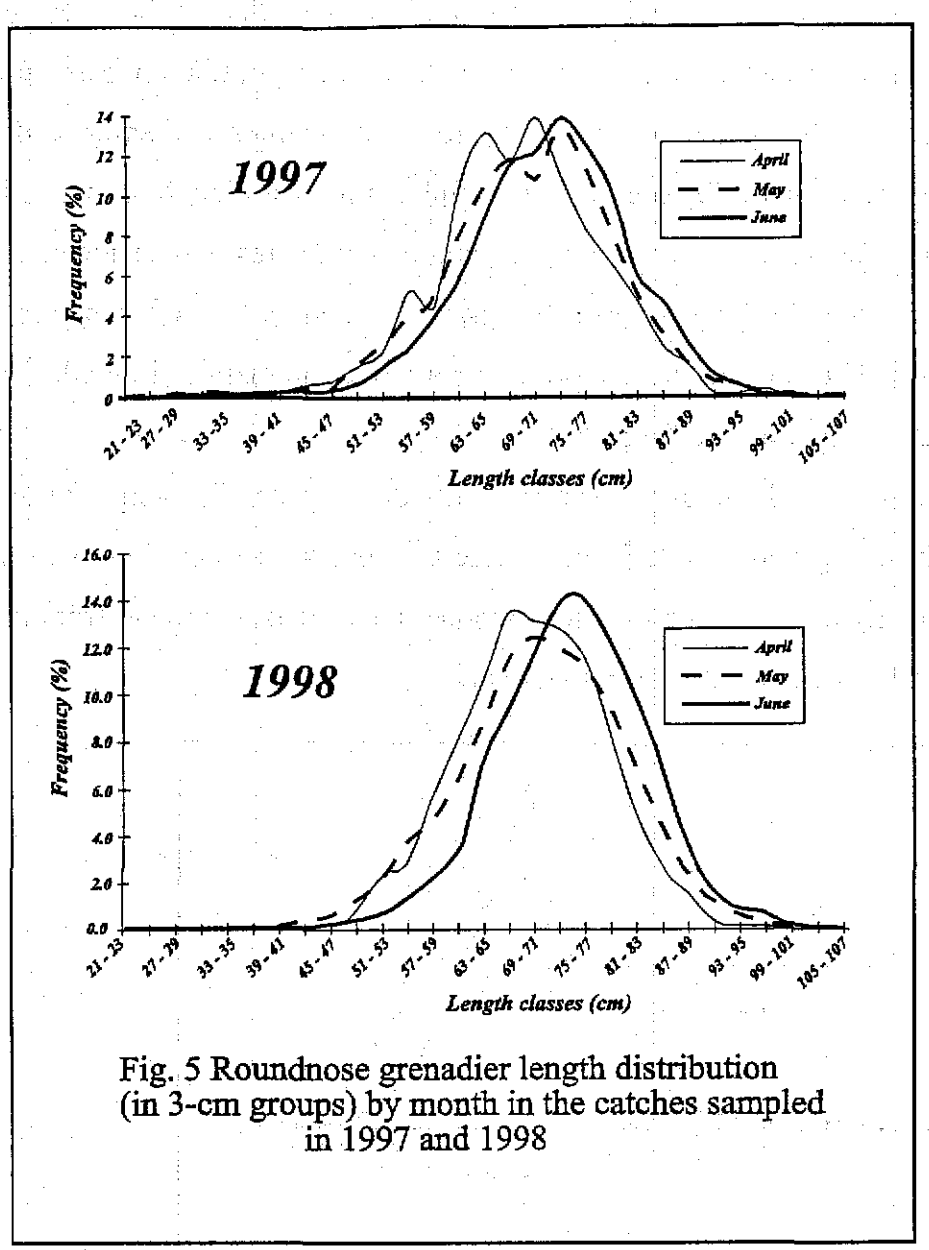


Fig. 5 Roundnose grenadier length distribution (in 3-cm groups) by month in the catches sampled in 1997 and 1998

The length distribution curve of grenadier in April and May was multi-modal with peaks that are visible to the left of the modal value. The multi-modality resulted from differences in numbers of males and females grouped into 3 cm length-classes ranging from 51 to 65 cm.

Exactly speaking, it was effected by domination of males in the length-classes 63 - 65 cm in April (11.3 %) and 66 - 68 cm in May and June (11.6 and 11.5 % respectively) as well as females in length-classes 69 - 71 and 72 - 74 in April (12.1 and 12.1 % respectively) and 72 - 74 in May and June (13.7 and 13.6 % respectively).

From April to May the mean length of males increased from 67.6 to 70.4 cm. In case of females that feature of the studied population was less conspicuous. The observed mean increased from 73.0 to 73.6 cm.

In 1998 the population structure of the roundnose grenadier was similar but mean length of fish (Fig. 5) recorded in April, May and June increased reaching values of 68.4, 70.8 and 74.2 cm respectively.

The observed characters of the population suggest that the area where the fishery was conducted is situated along the grenadier migration route.

4. Individual weight of the fish in the exploited population.

The analysis of the population structure with respect to linear size of individual specimens is connected to another characteristic variable - the individual mass. The parameter values of the grenadier length - weight relationship are shown in Table 2.

Table 2.

Parameter values for the exponential equation representing the relationship between length (cm) and weight (g) of the roundnose grenadier.

	a	b
Males	**0,02591**	**2,415622**
Females	**0,017244**	**2,545564**
Total	**0,02122**	**2,47576**

The curves drawn on basis of those equations are presented on Fig. 6 together with curves determined for grenadier fished in Icelandic and Newfoundland waters (Savvatimsky 1969, 1971a). The observed differences should not be interpreted as specific for the studied populations. They may be caused by differences in time period of the samples collection.

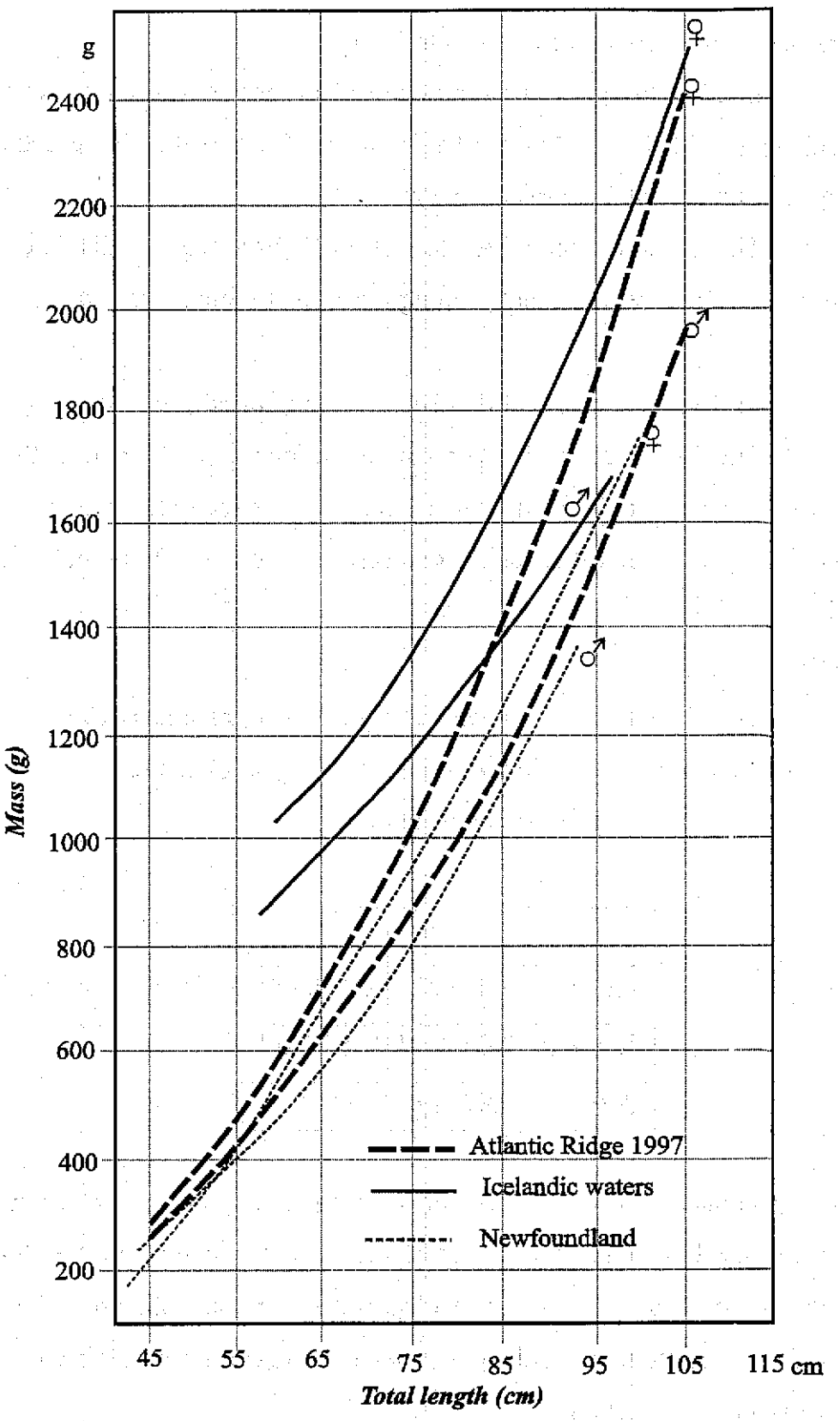


Fig. 6 Length-weight relationships for roundnose grenadier

5. Age and growth

5.1 Age structure of the roundnose grenadier

In the catches fish from age groups 6 - 27 were present (Fig.7). The share of fish from age groups 6 - 15 amounted to 28 % by numbers. The fishery was based mainly on fish belonging to 3 age groups (16 - 18) which constituted together 57 % of the catch. That part of the population supplied 59 % of the catch by weight (Tab. 3). It indicates that success of the fishery depends on the abundance of 3 year-classes. On the other hand, many year-classes (up to 11) which are not fully recruited to the exploited population are liable to fishing mortality. Along with the increasing amount of fishing the younger part of the population is reduced and only an insignificant share of it would reach the age of 16 - 18 years thus diminishing the chance of the fishing success.

Fig. 7 Age composition of the roundnose grenadier fished in 1997 on the Atlantic Ridge

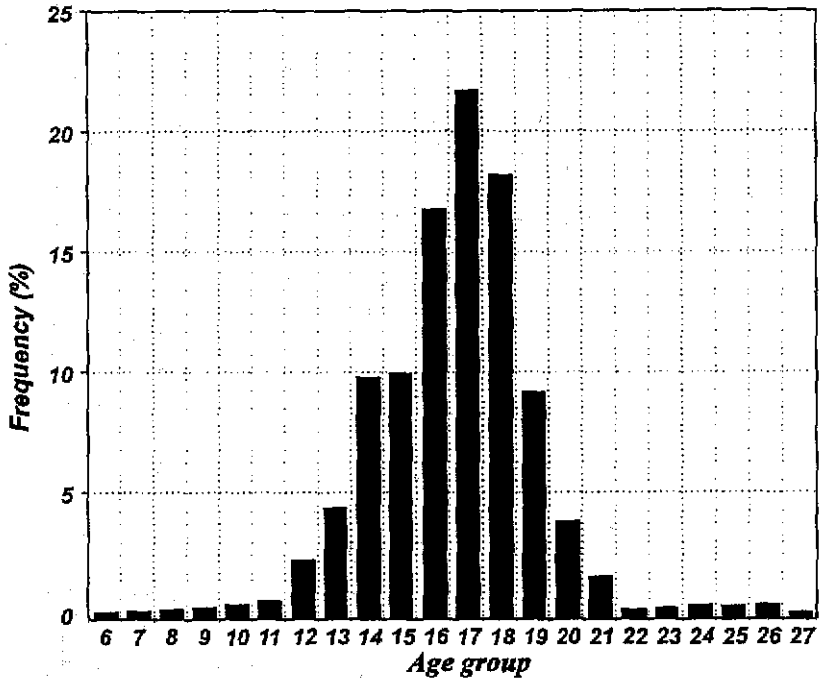


Table 3

Age composition of the studied roundnose grenadier.

	Age group																						
	6	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**Total**
No of fish aged	3	4	4	6	9	8	21	28	35	26	32	41	36	20	9	7	3	4	4	3	5	1	309
Age structure of the studied population (No. of fish in %)	0,06	0,10	0,14	0,25	0,37	0,52	2,19	4,33	9,77	9,93	16,76	21,68	18,17	9,16	3,77	1,51	0,16	0,20	0,31	0,27	0,34	0,02	100,00
Age structure of the studied population (Mass of fish in%)	0,01	0,01	0,02	0,07	0,10	0,21	1,07	2,55	7,19	8,35	15,58	22,26	21,24	11,47	5,05	2,37	0,31	0,38	0,57	0,50	0,64	0,05	100,00

Those facts explain fluctuations and the decline of grenadier catches on the fishing grounds of the North Atlantic. Even accepting assumption on an error in the age determination resulting from subjective criteria followed by the reader, the result of analysis of all materials indicates that effect of conceivable error would exert a negligible influence on the final conclusions.

Such conclusion is supported by changes of length and age structure of grenadier in catches taken by French vessels on the continental shelf westward of Scotland (Anon. 1996). During 1990 - 1993 the French vessels caught in these waters (FAO Statistical Subarea VI) 6,000 - 8,000 tons of black grenadier annualy. The shift of the length frequency curve towards the smaller sized fish along with the extention of the exploitation time reflects the influence of the fishing mortality.

A comparison of research results of different authors points out to the similarity of the age structure of the population available for the Polish fishery in the waters of the Atlantic Ridge to that exploited in the deep water fishing grounds west of Scotland. On the contrary, the population fished in the Northwest Atlantic waters is composed of younger fish belonging to age groups 9 - 14. It corroborate the formerly mentioned hypotesis that the population of roundnose grenadier exploited by Polish vessels in 1997 was the spawning one and that the c.p.u.e. on the fishing grounds situated along the migration route of that population does not depend on the locally directed fishing effort but on the actual abundance of the whole greandier population.

5.2 Linear growth of roundnose grenadier

The calculated values of von Bertalanffy equation parameters for the studied grenadier equaled:

$L_\infty = 137,5$ cm.

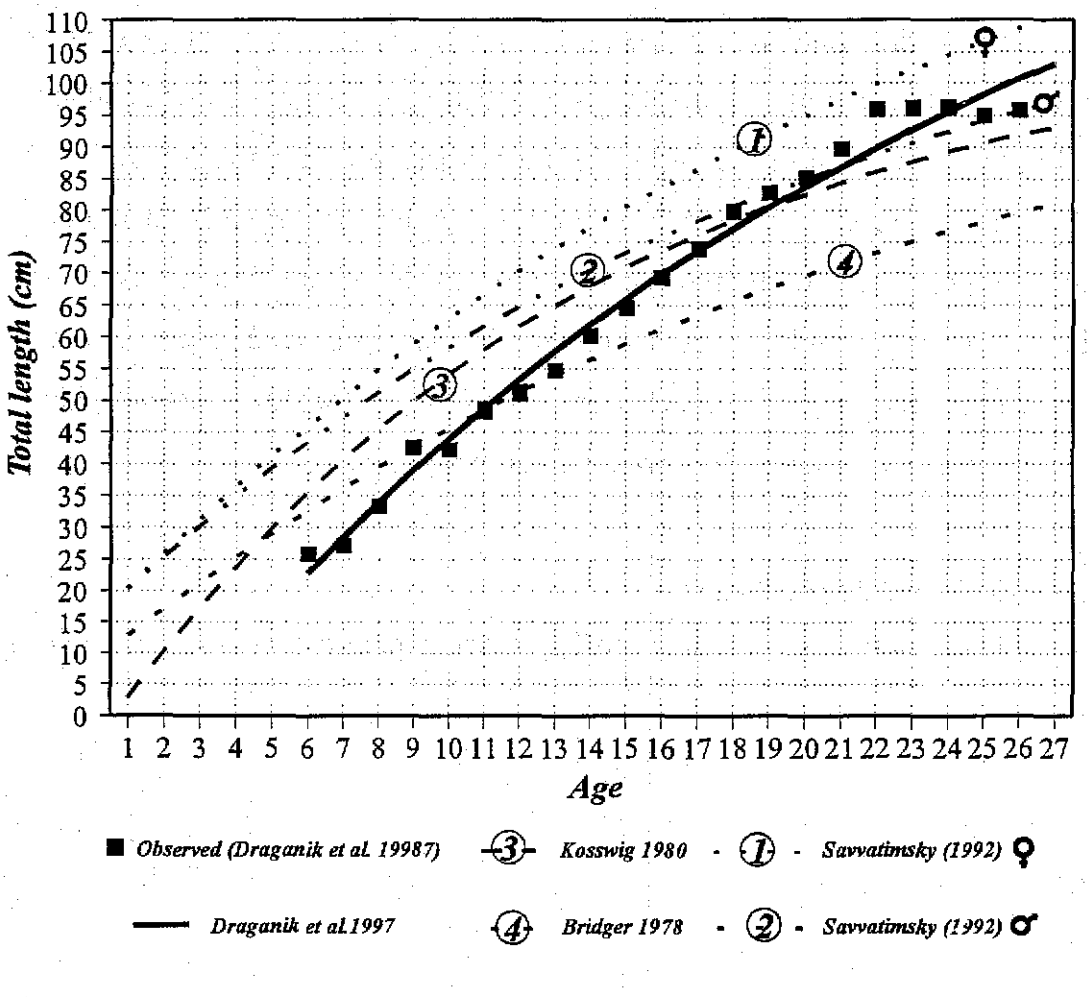
$K = 0,0543$

$t_0 = 2,309$

The obtained results allow to state in spite of difficulties in the age determination that the growth rate in the studied population exhibits a declining trend along with the age decrease in a similar manner as in case of the most other fish species.

The high value of L_{∞} and the low value of **K** testify about small changes in the annual growth increments of fish belonging to age groups 6 -25. Small deviations of the mean length of fish by age groups determined from direct otolith readings from those defined based on the growth equation (Fig. 8) indicate that a possible errors in age determination (age groups 6 - 23) are insignificant. It does not mean, however, that age of an individual fish is in agreement with its absolute age.

Fig. 8 Growth curve for roundnose grenadier



To confirm that it would be necessary to posses a comparable material originated from fish of known age from the moment of hatching or of age verified on basis of information independent on indirect methods of age determination. In practice it is impossible not only in case of grenadier but also in the instance of the most sea fish species. According to Savvatimsky (1992) the growth rate of females is considerably faster compared to the growth rate of males which is reflected by the values of the parameter L_∞ and **K.**

$L_t = 127\ (1 - e^{-0.047\ (t + 2.54)})$ ..... males

$L_t = 158.04\ (1 - e^{-0.041(t + 2.38)})$..... females

Mean length of roundnose grenadier by age group determined by Savvatimsky (1972), Kosswig (1980), Bridger (1978) were used by those authors to calculate values of von Bertalanffy growth equation parameters (Tab. 4) and to draw growth curves of the studied species (Fig. 8).

Table 4.

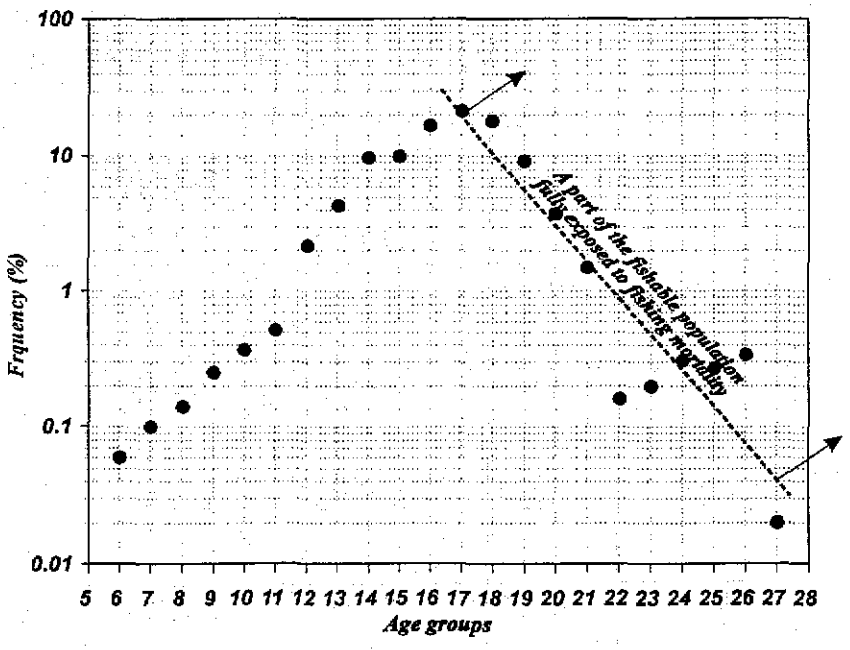
Values of the von Bertalanffy's. growth equation derived determined from the data presented by other authors.

	Savvatimsky (1972)		Kosswig (1981)	Bridger (1978)
	Females	**Males**		
L_∞	*139,2*	*137,0*	*108,8*	*112,8*
K	*0,0512*	*0,0456*	*0,0735*	*0,0442*
t_0	*- 2,238*	*- 2,117*	*0,638*	*- 1,736*

5.3 Mortality of the roundnose grenadier population fished on the Atlantic Ridge

The frequency curve of fish by age groups constitutes a basis for estimation of the total fishing mortality coefficient of the exploited part of the population which is fully available for a fishing gear viz. in case of the studied roundnose grenadier the fish belonging to age group 17 and older (Fig. 9). The slope of the right section of the curve represents an index of total mortality. The value of that coefficient equalled **0.62**; it means that during the year the abundance of the previously mentioned age groups is decreased by 46 % as a result of fishing and factors independent of the fishery.

Fig. 9 Catch curve for the roundnose grenadier fished on the Atlantic Ridge in 1997



The high value of the total mortality index may be affected by the fact that the age of fish which were fully vurnelable to fishing mortality was actually greater than that resulted from age readings.

The obtained values of the growth equation parameters may be mostly used to characterise exploitation features of the studied population including the index of total mortality. Growth coefficients in conjuction with such indices of the exploited population as mean length ($\hat{l}$) and length at which 50 % of fish is retained (l_c) allow estimation of total mortality (Gulland 1983).

$$Z = K(L_\infty - \hat{l})/(\hat{l} - l_c) \quad [3]$$

In case of the studied grenadier the most difficult task was estimating (l_c). Taking into account lack of any information on the selectivity of the fishing gear used with respect to the species, it was assumed that the value seeked corresponds to the mean length of fish at the moment when sexual maturity is attained viz. the mean length of fish whose gonads in May and June were in resting stage.
That length equals 65 cm (Draganik et al. 1997). The mean length of the studied grenadier population equalled 72.7 cm. After substitution of such determined values to the equation [3] the total fishing mortality amounts to **0.52** which corresponds to 40 % reduction of the population during 12 months.

Atkinson (1995) having reviewed the research results of the exploited population of the roundnose grenadier in the North Atlantic informs that the value of that the value of fishing mortality coefficient of fish fully available for fishing gears ranges from **0.2** to **0.8**. The estimated values of $F_{0.1}$ and F_{max} for that population equalled **0.3** and **0.65** respectively. Atkinson (1995) is of opinion that the value of the natural mortality coefficient **(0.2)** estimated by Bridger (1978) is too high if upper limit of the observed age of that species reaches 40 years.

Acknowledgement

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