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Fish Biology

ASSESSMENT OF THE LENGTH GROWTH RATE OF FIVE-BEARDED ROCKLING  
(*CILIATA MUSTELA* L.) OF THE WADDEN SEA ORIGIN

OKREŚLENIE TEMPA WZROSTU DŁUGOŚCI MOSTELKI (*CILIATA MUSTELA* L.)  
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The paper describes results of the otolith analysis of five-bearded rockling (*Ciliata mustela* L.) of the Wadden Sea origin. The length growth rate of five-bearded rockling was determined. Moreover the accurate method of mathematical characterization of this fish growth was found out by means of non-asymptotic growth model.

INTRODUCTION

In spite of its ecological importance in ecosystem of the North Sea the biology of the five-bearded rockling (*Ciliata mustela* L.) is still little known. There are data of embryonal and early larval stage of its development (Brook 1885), (Ehrenbaum 1905–09 by Russell 1976), (Demir, Dando and Southward, 1985).

Others available data concerning biology of five-bearded rockling are limited to general information in diverse guides or keys to fishes of the North Sea (Muus 1974), (Nijssen and de Groot 1987), (Rutkowicz 1982), (Wheeler 1978).

*Ciliata mustela*, mostly its juvenile stage called "mackerel-midge" which occurs in pelagic zone is eaten by numerous sea birds. It is an important ingredient of diet for nestlings birds as sterns and puffins (Wheeler 1969). Ornithologists research on birds of the southern part of the North Sea often find otoliths also belonging to five-bearded rockling in birds stomachs. Therefore the assessment of the relationship between length of radius of the otoliths and length of the body of fishes seems to have great practical importance. Tiews (1965) studied a frequency of occurrence of different fish species in a total industrial catch of the Wadden Sea. He classified five-bearded rockling as a "common species" of the Wadden Sea (26 specimens per 1000

square meters). For this reason, determination of the length growth rate is an important aspect of the biological characteristic of five-bearded rockling population. So far made studies on the growth rate of *Ciliata mustela* are restricted to data obtained by means of the measurements of mean lengths within age groups (Badsha and Sainsbury 1978) and comparisons with the use of Petersen method (Fonds 1978).

The present work was carried with the aim of finding the length growth rate of five-bearded rockling. In order to obtain the most accurate model describing the five-bearded rockling growth, the backwards reading method and mathematical models of fish growth were used.

### MATERIAL AND METHODS

(A sample of) 118 specimens of *Ciliata mustela* used in this study was captured in Western part of the Dutch Wadden Sea (Fig. 1) in November 1988. A fishing gear the fyke net was being used (the crib – mesh 1.25 x 1.25 cm). The total length (longitudo totalis) to 1 mm accuracy of each fish was measured, the sex determined and otoliths collected. The otoliths were taken washed with running fresh water, all remains of labyrinth and blood were moved off. Such prepared otoliths were read and measured to 0.01 mm accuracy. The readability of the otoliths was enhanced by immersing the otoliths in 10% solution of ethanol. The total length of radius (R) was assumed to be a distance between center and the most posterior point on the otolith margin (Fig. 2). The distances between the center of each otolith and subsequent hyaline zones (which reflected the growth of fish during subsequent years of its life) were measured too.

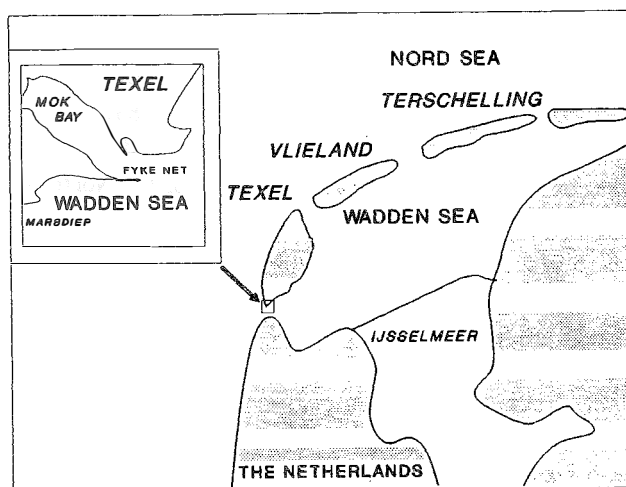


Fig. 1. Site from which Five-bearded Rockling sample was taken

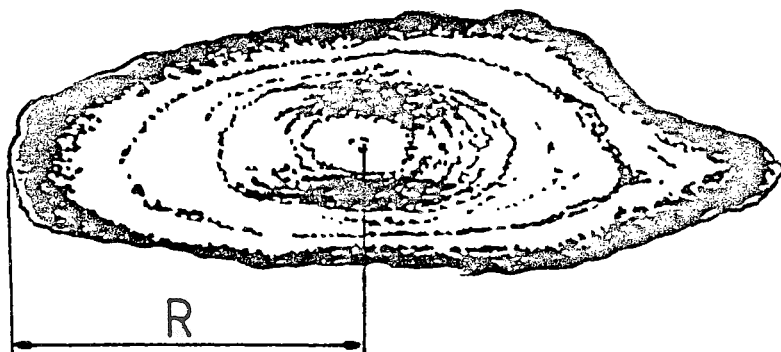


Fig. 2. Otolith of Five-bearded Rockling (3+ age group) R = the otolith radius that was measured

The assessment of the length growth rate was obtained by means of the measurements of mean lengths within age groups and the backwards reading method.

The length growth was determined using Wowk's method with regard to the consideration correction of the radius of otolith's radius (Szypuła, 1983). For data obtained, as stated above the mean length in subsequent years of fishes life ( $\bar{L}$ ) and a standard deviation ( $\bar{S}$ ) were calculated.

The results obtained using the backwards readings method were input data to express of the length growth of five-bearded rockling. The results obtained with the use of the backwards reading method were input data to express of the length growth of *Ciliata mustela* L. by means of the mathematical models of growth. Mathematical models describe the length growth of fishes as a relationship between the total length of fish ( $L_t$ ) and the time ( $t$ ) as follows:

1. Ford and Walford model (Rassefell and Everhart, 1955)

$$L_t = L_{\infty} \frac{1 - k^t}{1 - k}$$

2. Von Bertalanffy model (Beverton and Holt, 1957)

$$L_t = L_{\infty} (1 - e^{-k(t-t_0)})$$

3. Binomial (Szypuła, 1983)

$$L_t = a + bt + ct^2$$

The latter allows to obtain a coefficient of length growth ( $G_L$ ) which is described as follows:

$$G_L = \int_0^{t_{\max}} (a + bt + ct^2) dt = at + \frac{bt_{\max}}{2} + \frac{ct_{\max}^2}{3}$$

These calculations, as stated above were applied to all fishes together and as well as to separated sex groups.

Five-bearded Rockling (*Ciliata mustela*.)  
Fishes captured in 1988

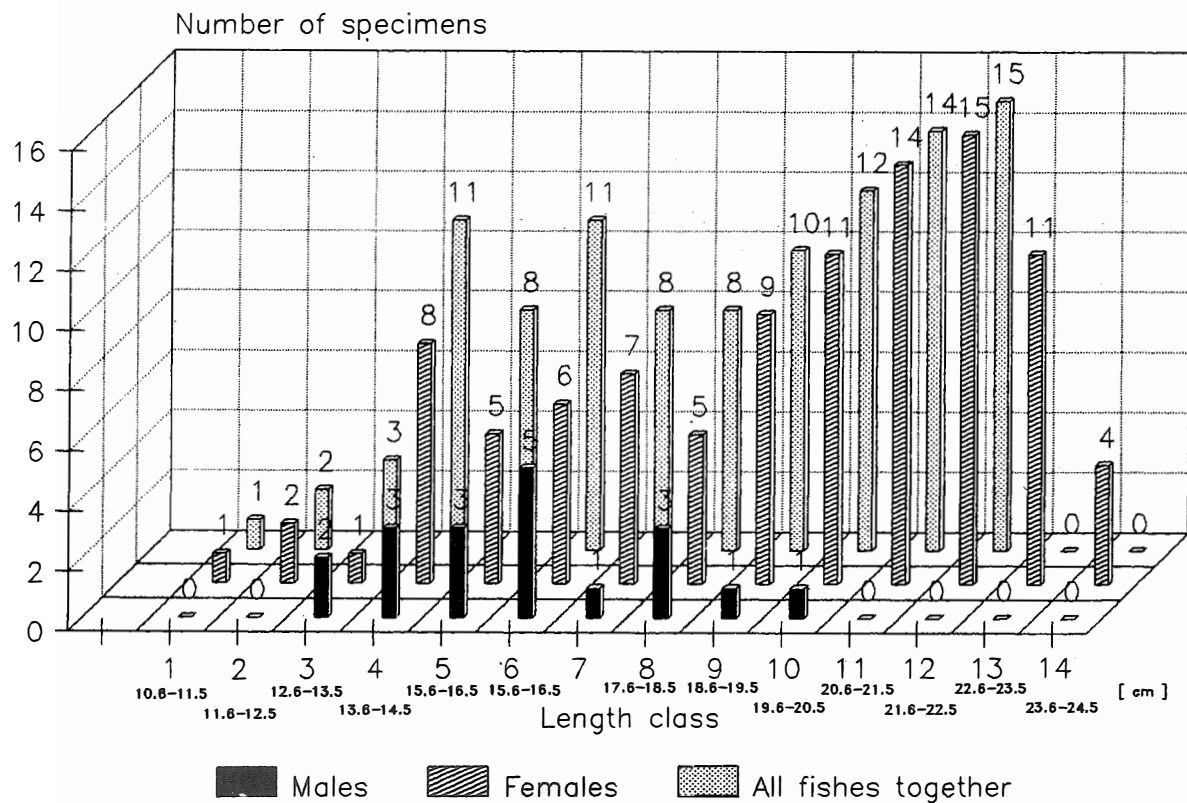


Fig. 3. Length distribution

## RESULTS

Material was collected during permanent catching period in 1988 using fyke net of The Netherlands Institute for Sea Research property. The Wadden Sea near by Texel island was the experiment area (Fig. 1). From 118 captured specimens of five-bearded rockling the same number of otoliths were removed. The sample consisted of 99 females and 19 males.

The range of the lengths of fish body varied from 11.5 cm to 24.5 cm.

Fishes were divided into 14 length classes, each of 1 centimeter range. Length distribution of fishes in the sample is showed in Figure 3. The most numerous was 21.6–22.5 cm length class – 15 specimens followed by 20.6–21.5 cm class – 14 specimens. All fishes within these classes were females. Captured fishes belonged to age groups from 0+ to 4+. The age distribution of every age group taking together and when separated into sex groups is showed in Figure 4. There is seen that the 2+ age group was predominant (53 specimens). The least numerous was 4+ age group (1 specimen) followed by 0+ age group (6 specimens).

The relationship between the radius of the otolith ( $R$ ) and the total length of body ( $L_t$ ) is presented in Figure 5. An analysis of points denoted lengths empirically showed curvilinear tendency of changes of the length of body with relationship to changes of otolith radius length.

The parameters of the curve were calculated by using the least squares method:

$$L_t = 0.630 + 14.474 R - 2.077 R^2.$$

The readability of hyaline zones on the otoliths of five-bearded rockling was defined as very. The determination of age of the older specimens was the most difficult because of blurred hyaline zones. An additional ring, clear to see was undoubtedly found on the otoliths of 53 fishes and defined as a pelagic ring. The origin of the pelagic ring should to be determined as a result of changes in environmental behaviour of *Ciliata mustela* L. (migration from pelagic to bottom zone). The pelagic ring was found on the otoliths of others fishes (*Gadiformes*) e.g. *Merluccius australis* too (Wyszyński, 1986).

The total length growth rate of five-bearded rockling obtained by application of the measurements of mean lengths within age groups is presented in Table 1. There is evidently to see the highest growth rate of the fishes during the first year of their life. (13.7 cm the gain in length). The length growth considerably decreases during subsequent years of five-bearded rockling life with tendency to leveling itself. There is to be necessary to mention about possibility of not precise determination of the mean length within 0+ age group because of the selective ability of fyke net. The relative big mesh (1.25 cm x 1.25 cm) lead to capture only the biggest fishes within this age group.

# Five-bearded Rockling (*Ciliata mustela*) Fishes captured in 1988

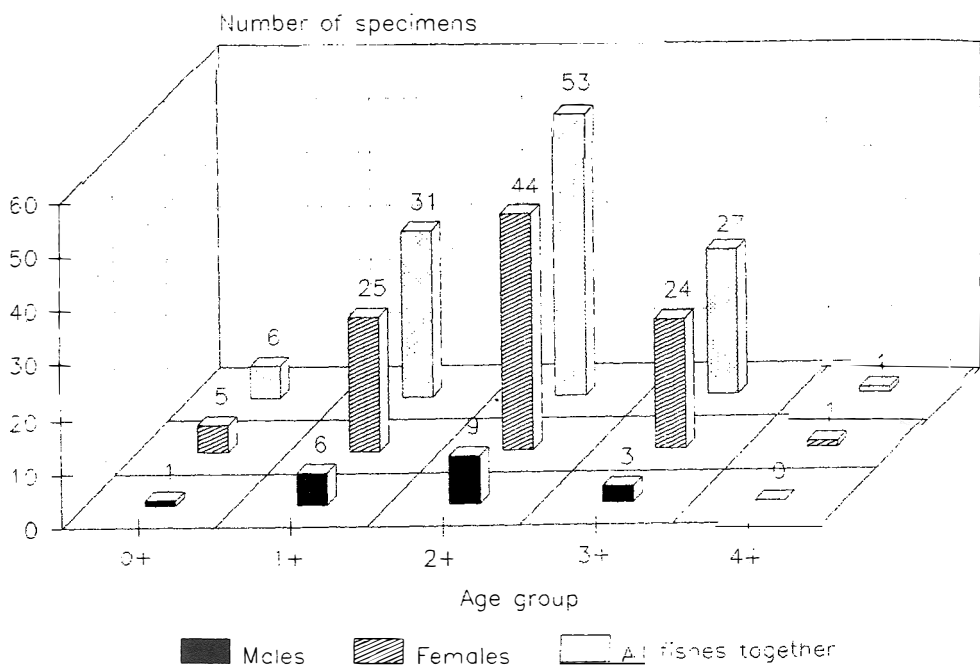


Fig. 4. Age distribution

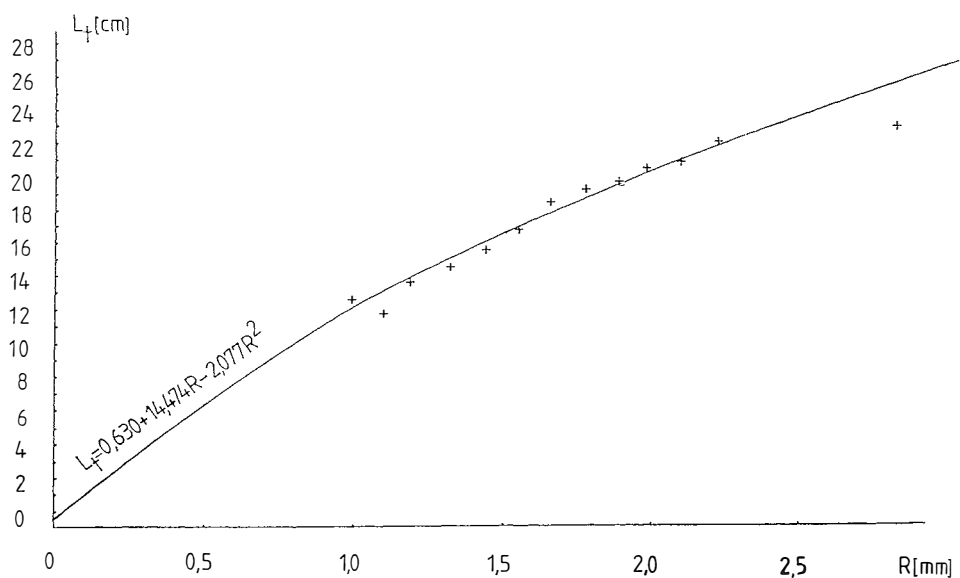


Fig. 5. Total length - otolith radius relationship of five-bearded Rockling  $L_t$  (cm) = total length,  $R$  (mm) = otolith radius length

Table 1

The length growth rate of Five-bearded Rockling obtained by the means of the measurements of mean lengths within age groups.

## All fishes together

Age group	n	$\bar{L}$ (cm)
0+	6	13.7
1+	31	16.8
2+	53	19.5
3+	27	21.8
4	1	24.1

## Females

Age group	n	$\bar{L}$ (cm)
0+	5	13.4
1+	25	16.0
2+	44	20.3
3+	24	22.1
4+	1	24.1

## Males

Age group	n	$\bar{L}$ (cm)
0+	1	14.9
1+	6	14.9
2+	9	16.0
3+	3	19.2

n = number of specimens

$\bar{L}$  = mean length of fishes within age group.

Table 2

The body growth length of *Ciliata mustela* L. obtained by means of the backwards reading method

## All fishes together

	$L_I$	$L_{II}$	$L_{III}$	$L_{IV}$	n
I	11.5				31
II	11.3	15.2			53
III	11.1	16.1	18.9		27
IV	12.3	18.3	21.6	23.2	1
$\bar{n}$	112	81	28	1	
$\bar{L}$	11.7	16.4	19.7	23.2	
S	1.393	1.741	1.632		
V	11.84	10.63	8.29		

## Females

	$L_I$	$L_{II}$	$L_{III}$	$L_{IV}$	n
I	11.7				25
II	12.1	16.8			44
III	12.0	16.5	19.9		24
IV	12.3	16.3	21.6	23.2	1
$\bar{n}$	94	69	25	1	
$\bar{L}$	12.0	16.8	19.9	23.2	
S	1.369	1.441	1.516		
V	11.44	8.58	7.52		

## Males

	$L_I$	$L_{II}$	$L_{III}$	$L_{IV}$	n
I	11.2				6
II	10.4	13.5			9
III	10.2	15.7	17.8		3
$\bar{n}$	18	12	3		
$\bar{L}$	10.7	14.0	17.8		
S	1.226	1.326	1.572		
V	8.71	10.30	8.83		

S = standard deviations, V = variation coefficient.

 $L_I$  ....  $L_{IV}$  = mean length of fishes within 1 .... 4 year of their life,

I .... IV = 1 ... 4 year of fishes' life



Table 3

Comparison of the length growth (cm) of Five-bearded Rockling obtained by means of mathematical models of growth rate of the results from the backwards readings method

	1	2	3	4	[1-2]	[1-3]	[1-4]
L <sub>1</sub>	11.7	11.1	9.8	11.8	0.6	1.9	0.1
L <sub>2</sub>	16.4	17.2	17.1	16.2	0.8	0.7	0.2
L <sub>3</sub>	19.7	20.6	20.9	19.9	0.9	1.2	0.2
L <sub>4</sub>	23.2	22.4	22.8	23.1	0.8	0.4	0.1
				[e-t]	0.77	1.05	0.15

1 = The backwards readings method

2 = Ford-Walford model

3 = Von Bertalanffy model

4 = Binomial

[e-t] = absolute mean difference.

The results of assessment of the growth rate obtained by means of the backwards readings method is shown in Table 2. Here is clear to see the highest increase of growth during the first year of fishes life (11.7 cm). The growth increasing during second year is distinctly lower (4.6 cm) and during subsequent years reaches values 3.3 cm and 3.5 cm. The latter value should be acceptable only as tentative (data of one specimen).

The statistic parameters of the results as above: standard deviation (S) and variation coefficient show relative high differentiation of fishes within the same generations (Tab. 3).

The comparison of the results obtained by means of the mean measurements within age groups and the backwards readings method shows higher rate of growth of the results of the first for mentioned above methods. This discordance raised from fact that the results obtained by using the backwards readings method reflected length of body of fishes just when the hyaline ring on their otoliths has been finished to build up exactly after time of fishes wintering. Moreover the results of measurements mean lengths within age groups represents length of fishes in November thus summer and autumn period older. The fact just have been described is the most conveniently to follow for data from 1+ to 3+ age group (the most quantitative in the sample).

The mean length of specimens within 0+ age group (13.7 cm) is higher than the mean length of fishes 1 year old (11.7 cm). It seems to concern the impact of selective ability of fyke net which increased the mean length of fishes within 0+ age group.

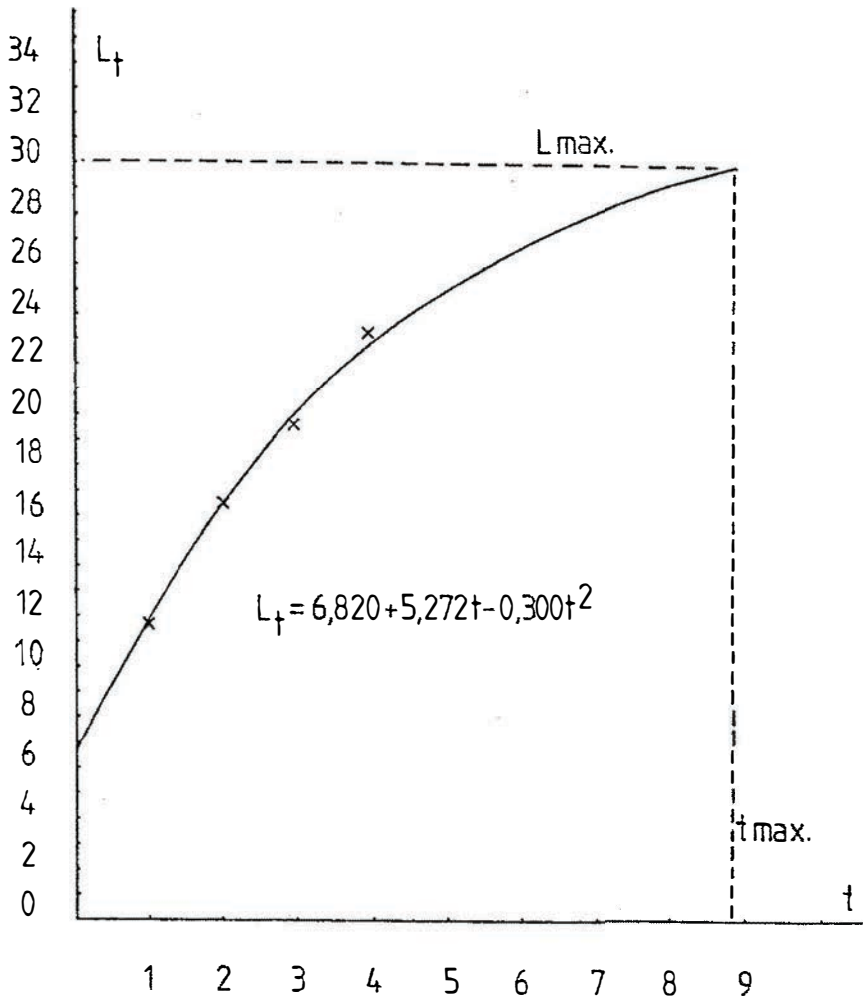


Fig. 6. Five-bearded Rockling length growth described with the binomial  $L_t$  (cm) = total length,  $t$  (year) = time, x = points denote lengths obtained by means of the backwards reading method

Equations of mathematical models describing the length growth rate to which input data were the results of the backwards readings methods are as below:

1. Ford-Walford model:

$$L_t = 11.1 \frac{1 - 0.55^t}{1 - 0.55}$$

$$L_{\infty} = 24.7 \text{ (cm)}$$

## 2. Von Bertalanffy model:

$$L_t = 25.0 (2 - e^{-0.6485(t-0.23)})$$

## 3. Binomial (Fig. 6):

$$L_t = 6.820 + 5.272 t - 0.300 t^2$$

$$L_{\max} = 30.0 \text{ (cm)}; \quad t_{\max} = 8.8 \text{ (years)}$$

The coefficient of length growth:

$$G_L = 196.0$$

Values of  $L_t$  obtained by means of binomial model distinguished themselves by the least absolute mean difference to the results of the backwards readings method (0.15 cm). Values of  $L_t$  obtained by equations Ford-Walford and Von Bertalanffy showed higher level of the absolute mean difference (Table 3).

Analysis collected materials by workers of The Netherlands Institute for Sea Research (NIOZ) during period 1974 – 87 and by author (Śmietana, 1988) showed statistically considerable difference of the length body between females and males of five-bearded rockling ( $t$ -test for 1 year old fishes  $n = 157$ ,  $t = 3,259$ ,  $p = 0.01$ ). Then an examine of the length growth rate for females and males separately in this study was justifiable. However there were rather small of males group (19 specimens) the results should to be consider only as showing a tendency.

The comparison of the results for both sexes obtained by means of the mean measurements within age groups is presented in Table 1 and with the use the backwards readings method in Table 2.

Binomial was chosen among mathematical models of the growth rate of five-bearded rockling as the best to both sexes together and as well as separately (Table 4).

Binomials were a shape (Fig. 7):

Males

$$L_t = 6.150 + 4.682t - 0.289 t^2.$$

Females

$$L_t = 6.790 + 5.460t - 0.390 t^2$$

Comparison of the coefficient of length growth ( $G_L$ ) indicates the advantage of growth rate of males ( $G_L = 152.31$ ) over females ( $G_L = 146.55$ ).

Thus on the contrary to the results of the backwards readings method. Responsibility for that bears lower value of  $c$  parameter ( $c = 0.289$ ) for males (about  $\frac{1}{3}$  times) with relation to females ( $c = 0.390$ ). Lower value of  $c$  parameter has an influence on shape of curve of the model (by approximation it to straight line). To follow this the

maximum value of theoretical time of growth is higher for males ( $t_{\max} = 8.1$  years) than females ( $t_{\max} = 7.2$  years). Because of the length growth coefficient which represents the area contained between the growth curve, x-axis (time-axis), and a line perpendicular to the latter and intersecting it at  $t_{\max}$ , is higher for males than females.

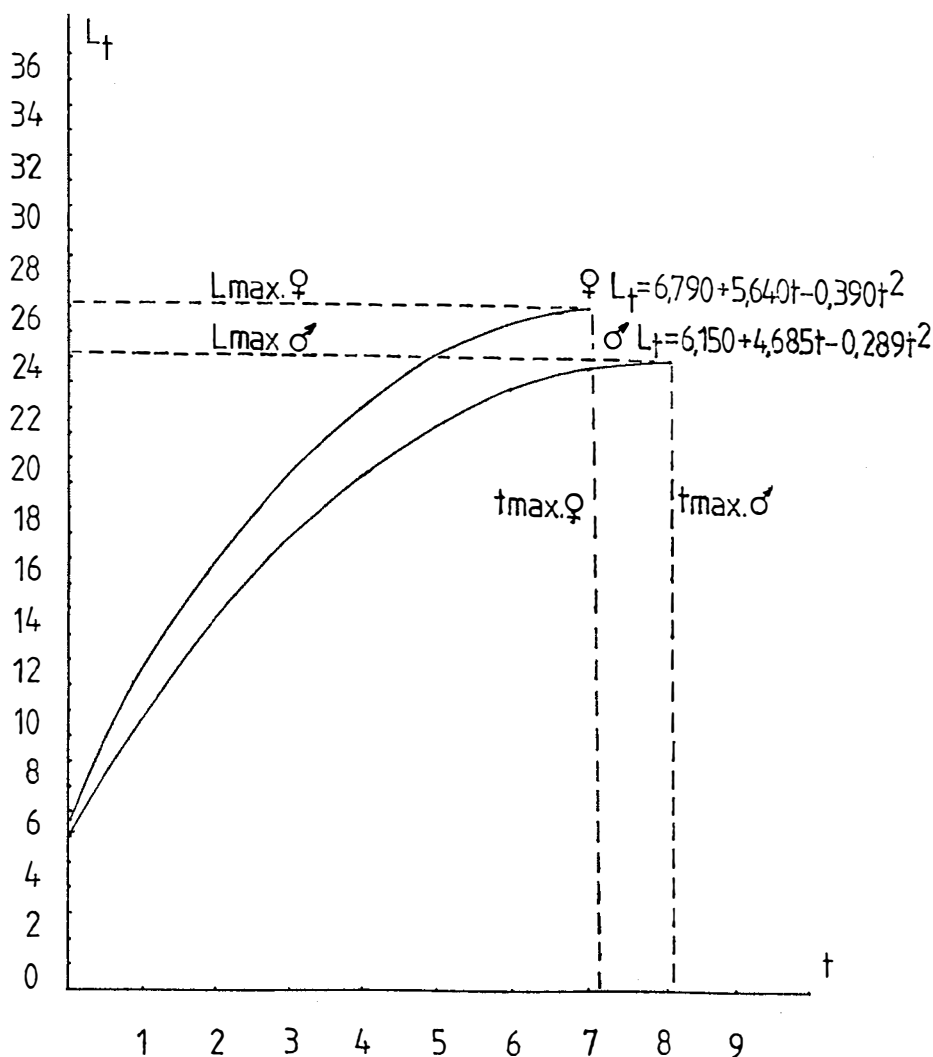


Fig. 7. Difference between males and females of Five-bearded Rockling length growth described with the binomials

$$L_t \text{ (cm)} = \text{total length, } t \text{ (year)} = \text{time}$$

Table 4

Comparison of the length growth (cm) of females and males of  
Five-Bearded Rockling obtained by means of various methods

Age	1		2		3		4	
	F	M	F	M	F	M	F	M
I	12.0	10.7	11.4	10.4	9.6	9.4	12.4	10.8
II	16.8	14.0	17.5	15.2	17.6	15.2	16.5	14.4
III	19.9	17.8	20.8	17.4	21.2	17.6	20.2	17.8
IV	23.2		22.6		22.9		23.1	

1 = The backwards readings method

2 = Ford-Walford model

3 = Von Bertalanffy model

4 = Binomial

F = Females

M = Males

## DISCUSSION

The subject of the growth rate of five-bearded rockling is little known as yet. Any paper on this subject has been found in literature, so far.

The results described the rate of growth obtained by means the mean measurements within age groups from data collected in 1988 were compared to the results of the same method from data of 1974 to 1978 (Šmietana, 1988) and for fish captured in Bristol Channel (Badsha, Sainsbury, 1978). (Tab. 5).

Table 5

Comparison of the length growth rate of Five-bearded Rockling obtained  
by means of the mean measurements within age groups

AUTHOR	YEAR	MONTH	AREA	0+	1+	2+	3+	4+
Data of NIOZ	1974-87	November	The Wadden Sea	12.7	15.8	21.7	22.6	
Badsha and Sainsbury (1978)	1976	November	Bristol Channel	14.2	18.3			
Data of this study	1988	November	The Wadden Sea	13.7	15.8	19.5	21.8	24.1

The growth rate of five bearded rockling of Bristol Channel origin is higher than fishes from the Wadden Sea. The length of body increased to  $L = 14.2$  cm during the first year of five-bearded rockling life and 4.0 cm during the second. These increments are higher for fishes from Bristol Channel than from the Wadden Sea (the latter correspondingly 13.7 and 2.1 cm). The warmer waters of Bristol Channel seems to be the reason. Moreover there were reported that fishes of Bristol Channel feed during the whole year, while in the Wadden Sea about 200 days per year. (Badsha, Sainsbury, 1978, Zijlstra, 1978).

The relationship between radius of the otolith ( $R$ ) and the body length of fish ( $L_t$ ) obtained during this study can be used for the length estimation of specimens of *Ciliata mustela* on the basis of the otolith that were found in the stomachs of sea birds.

Not only the asymptotic growth models as Ford-Walford model and von Bertalanffy model was applied, but non-asymptotic model of binomial as well.

Using of the latter was reasonable by as reports as:

- the results obtained by means of binomial are as accurate as by von Bertalanffy model (the most common) using (Szypuła, 1980),
- for some fish species the growth is better described with binomial then with other methods. (Szypuła, 1977).

The results of this study seems to confirm thesis above.

Value of the coefficient of length growth ( $G_L$ ) is mainly determined by value of  $c$  factor. There is influence of  $c$  factor on strength of bending curve of the model. Consequently factor  $c$  has also influence on value  $t_{max}$  parameter then value of  $G_L$  for all sexes together is the highest. Value of  $G_L$  for all sexes together can not be assumed as weighted arithmetical mean of  $G_L$  parameters males and females of five-bearded rockling.

## CONCLUSION

1. Five-bearded rockling is short time living fish rare approaching 4+ age.
2. Range of the total lengths of *Ciliata mustela* L. specimens bodies within age groups was vary. Values of the lengths of individual specimens within one age group were often similar as within neighboring age groups.
3. Relationship between the otolith radius ( $R$ ) and the total length of body was assumed as curvilinear and expressed with equation:  $L_t = 0.630 + 14.474 R - 2.077 R^2$ .
4. Five-bearded rockling is quick growing fish especially during first year of its life.
5. The mathematical model of the growth rate obtained by means of binomial for all fishes together and both sexes separately was the most correlate to results of the backwards readings method.
6. The growth rate of females has a tendency to be higher than one of males. Higher value of coefficient of length growth ( $G_L$ ) for males was connected with the higher

value of theoretical maximum age (growth age) ( $t_{\max}$ ) thus not slope of curve of the model.

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### REFERENCES

- Badsha K.S., M. Sainsbury, 1978: Aspects of the biology and heavy metal accumulation of *Ciliata mustella*. — J. Fish. Biol. 12: 213–230.
- Beverton R.J.H., S.J. Holt, 1957: On the dynamics of exploited fish populations. — Fishery Invest. Ser. II. Vol. XIX. London.
- Demir N., P. Dando, R. Southward, 1985: Comparative notes on post larvae and pelagic juveniles of the rocklings *Gaidropsaurus mediterraneus*, *Rhinonemus cimbrus*, *Ciliata mustella* and *Ciliata septentrionalis*. — J. Mar. Biol. UK 65: 801–839.
- Fonds M., 1978: The seasonal distribution of some fish in the Western Dutch Wadden Sea. Fishes and Fisheries of the Wadden Sea. — Report 5: 42–76 (NIOZ).
- Muus J., 1974: Collins guide to the Sea fishes of Britain and North-Western Europe. London.
- Nijssen H., S.I. de Groot, 1987: De vissen van Nederland. — Stichting Mitgeverij van de Koninklijke Nederlandse Natuurhistorische Vereniging. Utrecht.
- Rouseffel G.A., W.H. Everhart, 1953: Fishery Science, its Methods and Applications. New-York — London.
- Russell F.R.S., 1976: The eggs and planktonic stages of British marine fishes. — Academic Press.
- Rutkiewicz S., 1982: Encyklopedia of Sea Fishes — Wydawnictwo Morskie. Gdańsk.
- Szypuła J., 1977: Application of second and third order polynomials to fish growth description. Rozprawy nr 52. — AR Szczecin.
- Szypuła J., 1980: Assessment of the effect of environmental factors on fish growth using growth coefficients calculated from mathematical description of fish growth by means of polynomials. — Acta Ichth. et Pisc. Vol. 10. 1: 3–23.
- Szypuła J., 1983: Guide to exercises of fish biology. AR Szczecin.
- Śmietana P., 1988: Unpublished data of The Netherlands Institute for Sea Research (NIOZ).
- Tiews K., 1965: Lichtung des Nordseegarnelenbestand durch Wegfrass. — Archiv für Fischereiwissenschaft: 169–182. Berlin.
- Wheeler A., 1969: The Fishes of British Isles and North-West Europe. Macmillan. London.
- Wheeler A., 1978: Key to Fishes of Northern Europe. London.
- Wyszyński M., 1986: Attempt to determine the applicability of various bony elements for estimation of age and growth of hake *Merluccius australis* (Merlucciidae) from New Zealand waters.
- Zijlstra I.L., 1978: Quantitative aspects of the role fishes in the Wadden Sea food chains. Fishes and Fisheries... Report 5 (NIOZ).

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Z HOLENDERSKIEJ CZĘŚCI MORZA WADDEN

## STRESZCZENIE

W pracy przedstawiono wyniki analizy otolitów *Ciliata mustela* L. z Morza Wadden. Stwierdzono zależność krzywoliniową pomiędzy długością całkowitą  $L_t$  a promieniem otolitu  $R$ :

$$L_t = 0.630 + 14.474 R - 2.077 R^2.$$

Oznaczono tempo wzrostu długości ciała mostelki za pomocą metod średnich pomiarów w grupach wieku oraz odczytów wstecznych. Spośród zastosowanych modeli matematycznych opisujących tempo wzrostu długości ciała tej ryby (Forda-Walforda, von Bertalanffy'ego i wielomianu drugiego stopnia) najbardziej pokrywał się z wynikami odczytów wstecznych, model wielomianu drugiego stopnia. Model ten opisuje tempo wzrostu długości ciała mostelki równaniem:

$$L_t = 6.820 + 5.272 t - 0.300 t^2.$$

Stwierdzono tendencję do szybszego wzrostu samic w porównaniu do samców.

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