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MAGDALENA LAMPART- KAŁUŻNIACKA, TOMASZ HEESE

University of Technology, Division of Environmental Biology
75-453 Koszalin, ul. Śniadeckich 2; e-mail: mlampart@tu.koszalin.pl

Studies on the biology of non-commercial species, based on the example of the fourbeard rockling *Enchelyopus cimbrius* (L., 1766) (Gadiformes: Lotidae) in the southern Baltic

Badania biologiczne niekomercyjnego gatunku, na przykładzie moteli Fourbeard Rockling *Enchelyopus cimbrius* (L., 1766) (Gadiformes: Lotidae) w południowym Bałtyku.

ABSTRACT

The paper includes a detailed analysis of selected elements of the biology of the forebeard rockling. The study was conducted in the southern Baltic Sea. The sex structure, fertility, stomach contents, age, and growth of the species were analysed. As a result of the study, double predominance in numbers of males over females and high diversity in terms of development and size of oocytes were determined, suggesting partial spawning. A strong correlation was recorded between fertility and body mass and length. The analysis of the content of the fish stomachs revealed dominance of Polychaeta, Crustacea, and fish. Analyses of age and growth were also conducted, based on the otoliths. Individuals of 4 to 13 years of age were found. In the samples analysed, males were older than females. Additionally, differences in growth between the samples analysed were determined, along with similarities in growth between fish collected from the southern Baltic and the Atlantic forebeard rockling.

Key words: *Enchelyopus cimbrius,* sex structure, sustenance, fertility, age, growth, the Baltic Sea.

STRESZCZENIE

Badano motelę *Enchelyopus cimbrius* (L., 1766), rybę z rzędu dorszokształtne Gadiformes, rodziny miętusowatych Lotidae, pospolicie występującą m. in. w Morzu Bałtyckim. Przeprowadzono analizę struktury płci, płodności, zawartości układu pokarmowego, wieku i tempa wzrostu długości tego gatunku. W wyniku prowadzonych badań stwierdzono: dwukrotną przewagę w liczebności samców nad samicami, duże zróżnicowanie pod względem rozwoju i wielkości oocytów, co wskazuje na tarło porcyjne. Odnotowano silną korelację pomiędzy płodnością a masą i długością ciała ryby. Analizując treści pokarmowe żołądka stwierdzono, iż dominującą rolę miały wieloszczety Polychaeta, następnie skorupiaki denne Crustacea oraz ryby Actinopterygii. Przeprowadzono także analizę wieku i tempa wzrostu na podstawie otolitów. Stwierdzono osobniki w wieku od 4 do 13 lat. W analizowanych próbach samce były starsze od samic. Odnotowano również, iż istnieją różnice w tempie wzrostu pomiędzy analizowanymi próbami oraz podobieństwo w tempie wzrostu pomiędzy rybami pochodzącymi z łowiska kołobrzeskiego a motelą atlantycką. Prezentowana praca zawiera szczegółową analizę wybranych elementów biologii moteli, ryby niekomercyjnej, lecz posiadającej duże znacznie dla prawidłowego funkcjonowania ekosystemu wodnego.

Słowa kluczowe: *Enchelyopus cimbrius,* struktura płci, pokarm, płodność, wiek, wzrost, Morze Bałtyckie.

INTRODUCTION

Knowledge on biology is a determinant of any activities aimed at studies on selected species of ichtiofauna. Recording the occurrence of a given organism only contributes to the determination of its geographical distribution. Although organisms of one species prefer similar abiotic and biotic conditions, different geographical occurrence always entails certain variations. Those may concern the body size, age and growth rate, fertility, or alimentation. Such differences are the easiest to observe for commercial fish. Non-commercial fish species are equally important, however, because they constitute an inherent part of the aquatic ecosystem, allowing for the energy flow through all its trophic levels (Holmlund and Hammer 1999). One of such fish species is the fourbeard rockling *Enchelyopus cimbrius* (L.). In spite of its quite widespread occurrence in waters from North America to Europe, it is still a poorly known species. The main reason for the insufficiency of information on its biology is lack of commercial interest in the fish. The fourbeard rockling belongs to family Lotidae, living and reproducing in the Baltic Sea (Heese 1998; Krzykawski et al. 1999; Więcaszek et al. 2015).

An insight into selected elements of the biology of the fourbeard rockling is important from the point of view of the functioning of the Baltic Sea and conducting sustainable fishery management. Therefore, the objective of this paper is to determine the sex and age structure, growth rate, and total fertility of the fourbeard rockling from the Southern Baltic Sea, as well as the qualitative and quantitative composition of contents of its digestive system.

MATERIALS AND METHODS

The study material was collected in the years 1995 and 2000-2001 by means of a seabed trawl in the southern part of the Baltic Sea (Fig. 1). Six fourbeard rockling samples were analysed (Table 1).

Fertility of the fourbeard rockling was investigated by extracting oocytes from spawn samples collected on 11 and 27 April 2001. Sixty gonads were analysed. Each gonad was weighed. A small portion of oocytes was then sampled and weighed with accuracy to 1 mg. The oocytes were placed on a *Precoptic Co* glass tray with a 0.5 mm mesh net. They were distributed onto the entire surface of the glass by filling the chamber with 1 ml of water. Next, images were taken by means of a stereoscopic microscope and digital camera. The images were sent to a computer, where the oocytes were counted and their diameters measured with the application of the *Lucia* software. The results obtained were used to calculate total fecundity and to determine the size distribution of individual oocytes according to their length.

For the purpose of examining the stomach contents, the stomachs together with its content were removed, marked, and placed in 4% formaldehyde. A taxonomic analysis of foraged organisms was conducted by means of a stereoscopic microscope. Determined specimens were counted and weighed. A total of 488 stomachs extracted from fourbeard rockling samples (*K2,K3,K4,K5,Ł*) were examined. The data obtained were used to calculate the weight participation (i.e. the percentage share of the weight of individual components in the total weight of food and frequency of occurrence of a given food component, determining the number of fish in which the food component was found (10; 21).

In order to analyse the age and growth each fish was measured with accuracy to 1 mm. Then, the otolith was extracted by making an anatomic incision on the head. A total of 105 of the structures were used for the analysis. They were all submerged in resin solution and cut by means of an *Isomet™* low speed saw with a diamond blade disk. The fragments obtained were used to prepare microscope slides including the otolith nucleus. Photographic documentation was prepared using a *Nikon Eclipse E 400* microscope and *Nikon Coolpix 950* digital camera. The images revealed the otolith structure with marked opaque and haline zones. The zones were counted by means of the *Lucia* software (licence No. 11785). Distances from the centre to the edges of individual zones were also measured. Following the methodology presented in papers by Secor et al. (19), Gabriel et al. (5), and Panfili et al. (15), each pair of the rings was assumed to constitute annual growth. Data from back readings were used to calculate the growth rate in consecutive years of age of the fourbeard rockling. For this purpose, the power function was used, describing a curvilinear dependence between the body length (L) and otolith radius (O) (6)

$L=k*O^n$

where:

L – total length of a fish at the moment of catching,

O – total otolith radius at the moment of catching,

k – angular coefficient,

n – index of the power.

Next, the corrective adjustment was calculated for total otolith radius, according to the following formula:

$f=O_t/O_c$

where:

f – corrective adjustment

O_t – theoretical otolith radius calculated following the formula for total fish length,

O_c – total otolith radius at the moment of catching a given fish.

In order to calculate the growth of a given fish in consecutive years of age, the following formula was applied:

$L_1=k*(fO_1)^n$

$L_2=k*(fO_2)^n$

$L_n=k*(fO_n)^n$,

where:

$L_1, L_2,...L_n$ – total fish length in the 1st, 2nd,...nth year of age,

$O_1, O_2, ...O_n$ – distances between annual otolith growth zones in the 1st, 2nd,... nth year of age.

The study results were processed by means of the *STATISTICA PL* software, version 5.1, by *StatSoft* (licence No. SN:SP 7127999 105651), where the average values of certain variables and correlation coefficients were calculated, and the linear regression functions were graphed. In order to present the degree of significance of the calculated correlation coefficients verbally, a scale presented by Stanisz (20) was applied.

RESULTS

POPULATION STRUCTURE.

For research on fourbeard rockling population structure, 1011 fish from six fisheries of the southern Baltic Sea were used (Fig.1). In majority of samples, twice as many males (n = 638) as females (n=373) were found. Only in *K5*, the opposite situation was recorded (Table 1).

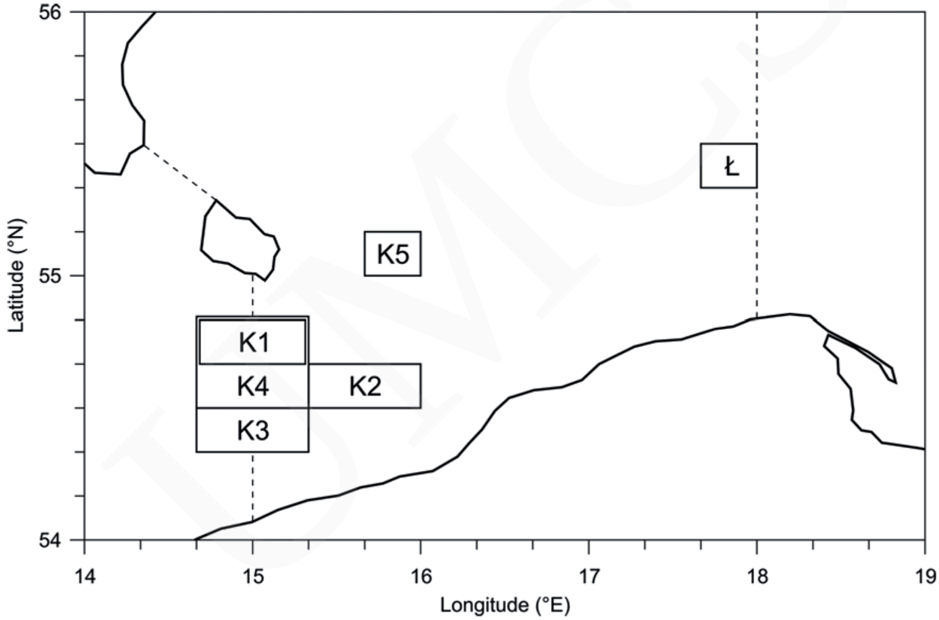


Fig. 1. Location of sampling areas of fourbeard rockling *Enchelyopus cimbrius* (L., 1766) in the southern Baltic.

Table 1. Samples of fourbeard rockling Enchelyopus cimbrius (L., 1766) collected from the southern Baltic

Fishery	Sample name	Date of catch	Depth (m)	Number of fish		
				Total	F	M
Kołobrzeskie	K1	28.02.1995	40-50	270	90	180
Kołobrzeskie	K2	15.11.2000	50-60	61	21	40
Kołobrzeskie	K3	08.12.2000	50-60	75	26	49
Kołobrzeskie	K4	11.04.2001	50-64	100	34	66
Kołobrzeskie	K5	27.04.2001	81-93	101	68	33
Łebskie	Ł	17-18.10.2000	72-76	374	134	240

TOTAL FERTILITY.

Total fertility was estimated based on female gonads from Kołobrzeg fisheries *K4* and *K5*. The samples were taken in April 2001, i.e. at the time considered as the fourbeard rockling spawning season. A total of 60 gonads were analysed, 30 of which belonged to sample *K4*, and 30 to sample *K5*.

High diversity in the degree of development of oocytes was determined in both samples analysed. The gonads included eggs with a diameter of 0.1–0.92 mm. The most numerous were oocytes in the fourth size class, with a diameter of 0.28–0.33 mm. Females from *K5* fishing ground had somewhat higher total fertility. Nonetheless, in the gonads analysed, oocytes of the 3rd and 4th size class with inconsiderable diameters were usually found (Fig. 2).

Linear functions were also determined, and correlation coefficient values were calculated for the relation of fertility to body mass (Fig. 3a), and fertility to body length. A stronger correlation was determined for the former relation analysed, where r>0.9 in both samples. Simultaneously, the correlation coefficient value (r>0.7) suggests a significant correlation, also for the relation of fertility to body length (Fig. 3b).

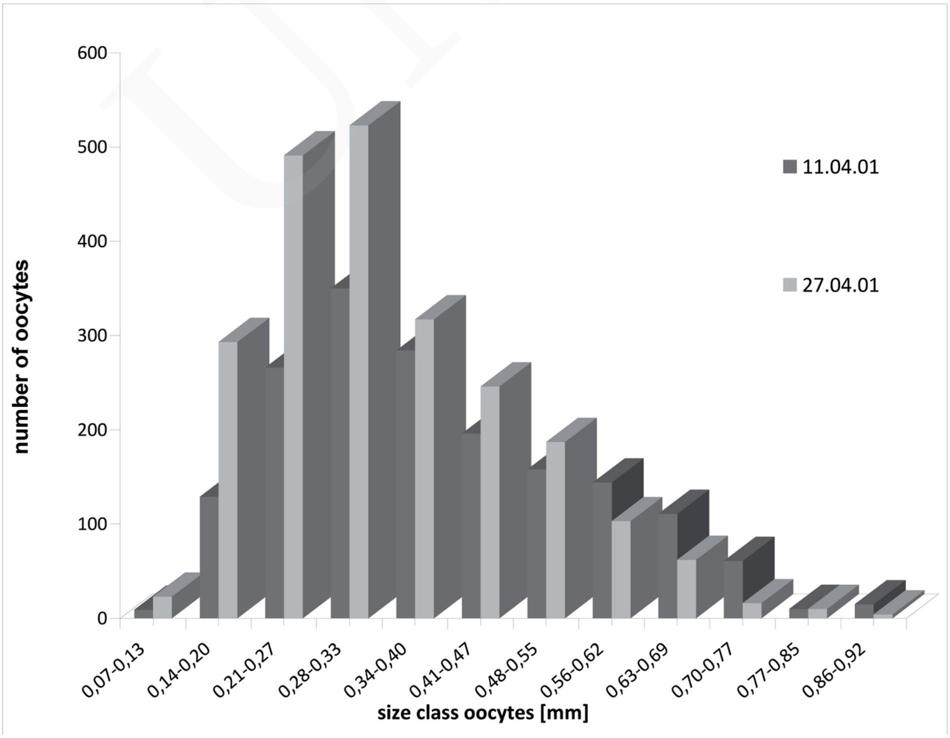
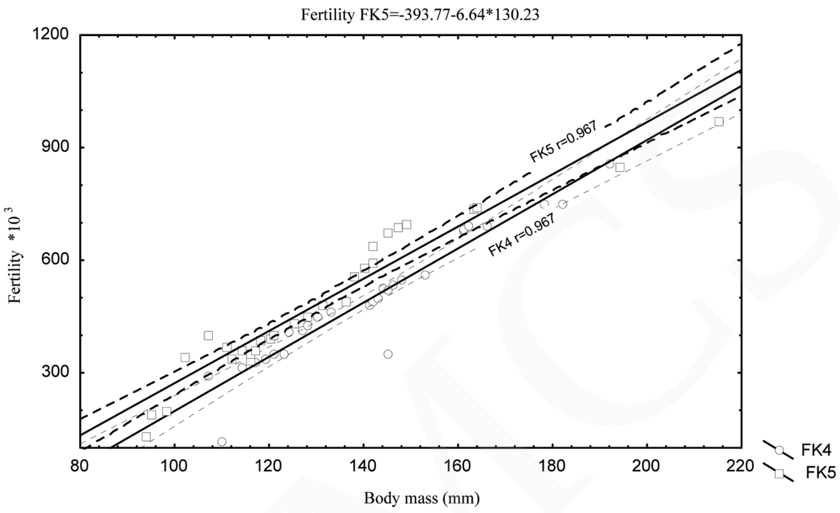


Fig. 2. Size classes of oocytes of the fourbeard rockling *Enchelyopus cimbrius* (L., 1766) from K4 (11 April 2001) and K5 (27 April 2001) Kołobrzeg fishing grounds

A)



B)

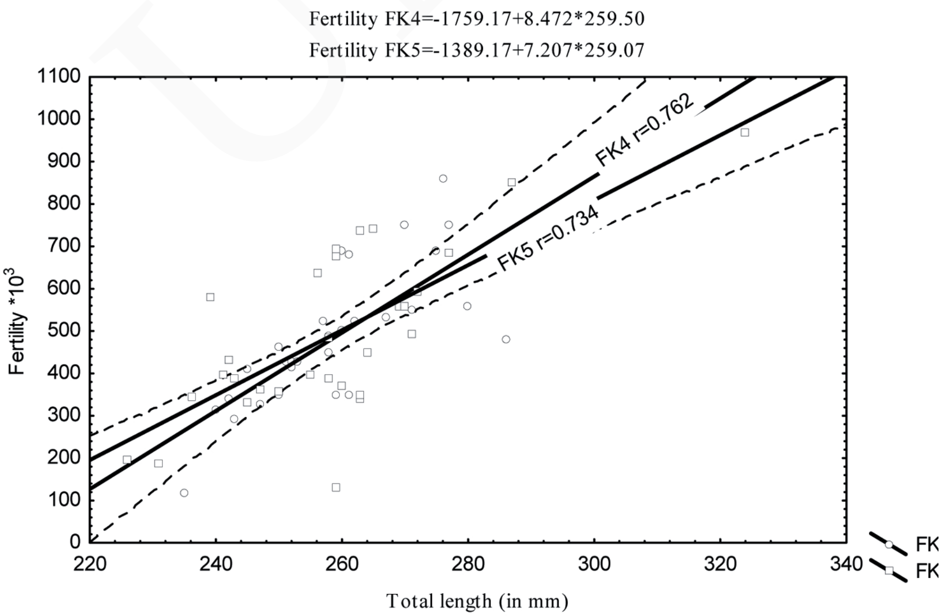


Fig. 3. Relation of total fertility to body mass (A) total length (B) of the fourbeard rockling *Enchelyopus cimbrius* (L., 1766) from K4 and K5 Kołobrzeg fishing grounds

ALIMENTATION

The analysis of the contents of the stomach contents was carried out on samples *K2, K3, K4, K5* and *Ł*. Occurrence frequency and weight proportions of individual food components were calculated The main source of alimentation for the fourbeard rockling is macrozoobenthos of the southern Baltic Sea. Apart from bottom invertebrates, the stomach contents sporadically included fish, significantly increasing the weight proportion. Among benthic organisms, numerous polychaetes and crustaceans were found. As a result of the analysis of the weight proportion and occurrence frequency index of individual macrozoobenthos taxa, predominance of mysid shrimp *Mysis mixta* was determined in sample *Ł*. In stomach contents of fish from Kołobrzeg fisheries, polychaete *Harmothoe sarsi* prevailed. In sample *K4*, quite numerous *Corophium volutator* was recorded, and in *K4* and *K5* – brown shrimp *Crangon crangon*, *Pontoporeia* sp., *Halicryptus spinulosus,* and *Nephthys ciliata* (Table 2). Notice that for fish from fisheries *K4* and *K5*, a significant weight proportion among the taxa mentioned was that of *Nephthys ciliata*, and among not mentioned taxa – that of fish. The samples also included a large weight proportion of unidentified contents (Table 2).

Table 2. Occurrence frequency and weight proportion of organisms identified in the stomach contents of the fourbeard rockling *Enchelyopus cimbrius* (L., 1766) collected in the Southern Baltic

Systematic group or species	Occurrence frequency					Weight proportion				
	Ł	K2	K3	K4	K5	Ł	K2	K3	K4	K5
Crangon crangon	0.94	0.00	0.00	2.94	4.17	0.25	0.00	0.00	1.82	3.66
Halicryptus spinulosus	0.00	0.00	2.41	8.82	5.56	0.00	0.00	0.61	3.23	3.05
Corophium volutator	0.94	0.00	26.51	5.88	2.78	0.32	0.00	11.22	0.56	0.27
Mysis mixta	73.58	5.56	20.48	8.82	5.56	87.79	0.21	15.76	1.64	1.87
Mesidotea entomon	2.83	0.00	0.00	0.00	0.00	0.94	0.00	0.00	0.00	0.00
Pontoporeia sp.	0.00	0.00	0.00	2.94	0.00	0.00	0.00	0.00	0.69	0.00
Oligochaeta	0.94	0.00	0.00	0.00	0.00	1.60	0.00	0.00	0.00	0.00
Harmothoe sarsi	22.64	64.81	65.06	51.47	31.94	9.11	90.62	63.12	61.78	49.53
Nephtys ciliata	0.00	1.85	0.00	17.65	22.22	0.00	0.73	0.00	14.54	28.35
Fish	0.00	0.00	1.20	5.88	4.17	0.00	0.00	0.63	17.55	13.27
Unrecognized contents	0.00	0.00	0.00	0.00	0.00	0.00	8.44	8.66	30.88	48.61

AGE

The age of the fourbeard rockling was estimated based on otolith microscope slides subject to digital image analysis. The age of fish analysed varied between 4 and 13 years The youngest (4-year-old) individual was recorded in the sample *Ł*. The oldest (13-year-old) fish were found in two samples, *K5* and *Ł*. The most numerous were seven-year-old specimens for fish from areas *K3* and *Ł*, and ten-year-old specimens from areas *K1* and *K5* (Tables 3, 4, 5). In the samples analysed, namely *K1, K3*, and *Ł*, the estimated age of males was higher than that of females. Only in sample *K5,* the situation was opposite (Tables 3, 4, 5).

GROWTH

Total length growth of fourbeard rockling from the southern fisheries of the Baltic Sea was estimated with the application of back readings. Empirical data (n = 103) were used to calculate the constants of the power function.

The obtained value of 0.7169 was substituted into the power BPH equation.

The length of the fourbeard rockling grew the fastest in its first year of age. From the second year, the total length growth decreased successively. Variability in the individual body length growth was also determined in the first year. For majority of samples analysed, the variability coefficient reached higher values in the initial period of life than in consecutive years (Tables 3, 4, 5).

As a result of the analysis of the growth in four fourbeard rockling samples, differences in total length growth were determined. Fish from area *K1* grew the fastest, the total length growth was somewhat slower for samples *K3* and *K5*, and fish from Łeba *(Ł)* had the slowest growth. The differences were revealed by comparison of entire samples and sex. For males from Kołobrzeg fishing grounds, very similar body length growth was determined, which was higher than that of males from Łeba fishing ground (Table 3, 4, 5).

DISCUSSION

The fourbeard rockling is a demersal fish (9) occurring at depth range of 20–250 m (16). It is caught at the western continental margins of the Atlantic Ocean at a depth of 170–227 m (4). In the Baltic Sea, the fourbeard rockling occurs at much smaller depths, with a maximum of 150 m (18). In the scope of this research, it was caught at a depth of 40–93 m. The fourbeard rockling grows up to a length of 50 cm (13). The total length of the fourbeard rockling from the Baltic Sea varied between 18.3 and 37.8 cm, and the length range determined for the Atlantic fish was 9.5–32.8 cm (4). The largest and the smallest specimens were recorded in the sample from Łeba (*Ł*). The most numerous, however, were individuals of 20–40 cm (2; 14). This was also confirmed by this research, in which fish with a length from 20 to 30 cm prevailed.

Table 3. Total body length growth rate (cm) of the fourbeard rockling *Enchelyopus cimbrius* (L., 1766). (l_1...l_n – growth in a given year of age

Age class	Total length (cm) of the fourbeard from Kołobrzeg fishing ground K1													N
	l_1	l_2	l_3	l_4	l_5	l_6	l_7	l_8	l_9	l_{10}	l_{11}	l_{12}	l_{13}	
V	11.49	14.97	18.60	22.10	23.70									1
VI	10.74	14.25	17.05	20.22	22.76	25.19								4
VII	9.73	13.12	16.16	18.99	21.68	24.29	26.34							5
VIII	9.64	12.60	15.68	18.47	20.97	23.37	25.67	27.90						4
IX	10.61	13.58	16.93	19.93	22.64	25.20	27.10	28.89	30.14					2
X	10.29	13.14	15.78	18.53	21.09	23.31	25.57	27.29	29.22	30.79				10
XI	11.04	13.92	16.59	19.84	22.71	24.78	27.10	29.19	31.38	32.45	33.51			1
Age class	Total length (cm) of the fourbeard rockling from Kołobrzeg fishing ground K3													N
	l_1	l_2	l_3	l_4	l_5	l_6	l_7	l_8	l_9	l_{10}	l_{11}	l_{12}	l_{13}	
VI	10.42	13.05	15.60	18.24	20.73	22.47								4
VII	8.94	12.17	15.13	18.24	21.04	22.65	23.89							3
VIII	10.15	13.03	15.46	18.31	20.43	22.64	24.33	25.65						7
IX	9.79	13.23	16.46	18.94	21.06	22.80	24.63	26.17	27.18					3
X	10.41	13.61	16.50	19.01	21.58	23.68	26.13	27.43	29.06	30.35				3
XI	11.15	13.97	16.26	18.53	20.69	22.96	24.86	26.54	28.43	30.19	31.27			2
XII	10.79	14.26	16.96	19.24	21.33	23.55	26.12	28.22	30.17	31.24	32.29	33.15		4
Age class	Total length (cm) of the fourbeard rockling from Kołobrzeg fishing ground K5													N
	l_1	l_2	l_3	l_4	l_5	l_6	l_7	l_8	l_9	l_{10}	l_{11}	l_{12}	l_{13}	
VII	10.75	13.22	16.86	19.33	21.40	23.54	25.04							3
VIII	10.95	13.43	16.31	18.83	21.22	23.95	25.65	26.82						4
IX	7.93	9.97	12.68	14.85	17.92	19.50	21.33	22.83	24.43					2

Contd. Table 3.

X	8.81	11.60	14.20	16.47	19.01	21.18	23.08	24.82	26.39	27.76				8
XI	11.47	14.35	17.20	20.03	22.34	24.56	26.28	27.96	29.67	31.37	33.11			6
XII	10.99	14.02	16.29	18.45	21.96	23.64	26.37	28.11	29.48	30.90	32.07	32.92		2
XIII	10.74	14.10	16.17	18.62	20.03	21.85	24.48	26.99	28.82	30.41	32.35	33.49	34.43	1
Age class	Total length (cm) of the fourbeard rockling from Łeba fishing ground Ł													N
	l_1	l_2	l_3	l_4	l_5	l_6	l_7	l_8	l_9	l_{10}	l_{11}	l_{12}	l_{13}	
IV	8.76	12.43	14.84	17.79										1
V	10.14	13.40	15.30	17.49	19.78									4
VI	8.68	11.29	13.89	16.87	18.42	20.70								3
VII	9.39	11.65	13.88	16.52	19.64	21.92	23.45							6
VIII	9.76	11.91	14.36	17.65	19.96	21.81	23.95	26.36						1
IX	9.26	12.57	15.20	17.46	20.22	22.55	24.12	25.78	27.69					3
X	10.58	12.94	15.44	17.83	20.19	22.48	24.42	26.13	27.73	29.00				6
XIII	9.53	13.28	15.87	18.08	19.95	22.00	23.49	25.30	26.95	28.41	29.38	30.68	31.79	2

Table 4. Total body length growth rate (cm) of the females fourbeard rockling *Enchelyopus cimbrius* (L., 1766). (l_1...l_n – growth in a given year of age

Age class	Total length (cm) of the females fourbeard rockling from Kołobrzeg fishing ground K1													N
	l_1	l_2	l_3	l_4	l_5	l_6	l_7	l_8	l_9	l_{10}	l_{11}	l_{12}	l_{13}	
V	11.49	14.97	18.60	22.10	23.70									1
VI	10.74	14.25	17.05	20.22	22.76	25.19								4
VII	10.27	13.49	16.26	18.93	21.62	24.19	26.36							2
VIII	9.38	12.46	15.48	18.44	21.13	23.70	25.81	28.04						3
IX	10.61	13.58	16.93	19.93	22.64	25.20	27.10	28.89	30.14					2
X	11.10	14.66	17.97	20.66	23.20	25.63	27.91	29.33	31.08	32.20				2
Age class	Total length (cm) of the females fourbeard rockling from Kołobrzeg fishing ground K3													N
	l_1	l_2	l_3	l_4	l_5	l_6	l_7	l_8	l_9	l_{10}	l_{11}	l_{12}	l_{13}	
VI	10.42	13.05	15.60	18.24	20.73	22.47								4
VII	8.90	12.95	15.59	19.41	22.54	23.90	25.10							1
VIII	9.23	12.33	15.17	17.85	19.96	21.99	23.42	24.81						3
IX	9.79	13.23	16.46	18.94	21.06	22.80	24.63	26.17	27.18					3
X	11.20	13.99	16.36	18.41	21.13	22.99	24.62	25.51	27.07	28.09				1
XI	11.15	13.97	16.26	18.53	20.69	22.96	24.86	26.54	28.43	30.19	31.27			2
Age class	Total length (cm) of the females fourbeard rockling from Kołobrzeg fishing ground fishing ground K5													N
	l_1	l_2	l_3	l_4	l_5	l_6	l_7	l_8	l_9	l_{10}	l_{11}	l_{12}	l_{13}	
VIII	7.06	9.73	12.67	15.03	18.02	21.53	22.79	24.16						1
IX	7.93	9.97	12.68	14.85	17.92	19.50	21.33	22.83	24.43					2

Cont. Table 4.

X	8.52	11.47	14.25	16.11	18.21	20.19	22.06	23.73	25.16	26.45				5
XI	9.99	13.12	16.59	19.43	21.60	24.16	25.56	26.78	28.08	29.66	30.88			2
XII	10.87	13.71	16.33	18.43	22.02	23.73	26.04	27.33	28.59	29.68	30.44	31.20		1
XIII	10.74	14.10	16.17	18.62	20.03	21.85	24.48	26.99	28.82	30.41	32.35	33.49	34.43	1
Age class	Total length (cm) of the females fourbeard rockling from Łeba fishing ground Ł													N
	l_1	l_2	l_3	l_4	l_5	l_6	l_7	l_8	l_9	l_{10}	l_{11}	l_{12}	l_{13}	
IV	8.24	11.69	13.95	16.73										1
V	10.14	13.40	15.30	17.49	19.78									4
VI	10.16	11.92	14.12	18.17	19.75	21.58								1
VII	10.21	12.71	14.88	17.75	21.43	23.48	25.00							3
IX	9.26	12.57	15.20	17.46	20.22	22.55	24.12	25.78	27.69					3

The determination of the sex structure and percentage share for the analysed samples of the fourbeard rockling from the Baltic Sea revealed a significant prevalence of males over females. Twice as many males were recorded in five samples analysed. Only in population *K5*, the situation was opposite. Similar results were obtained by Deree (4) for the Atlantic population, also dominated by males in quantitative terms. Such a sex distribution, however, is typical of older fish, with a total length of more than 25 cm. In lower length classes of the Atlantic forebeard rockling, Deree (4) observed equal participations of both sexes in the population structure, or even an insignificant predomination of females. The opposite sex structure in sample *K5* may result from forming spawning stocks by females. The sample was collected in April at the maximum depth recorded in the research (81–93 m), and according to Wheeler (24), spawning of the species occurs at larger depths between February and August (14).

The fourbeard rockling is a fish living in shoals and preferring sandy or muddy bottom (26). It feeds on benthos and small fish (19). The analysis of the stomach contents of populations from the Baltic Sea confirmed the literature data determining macrozoobenthos as the main component of food of the forebeard rockling. Certain differences were observed, however, in dominance in terms of numbers and weight of identified taxa, depending on the place of collecting a given sample. In populations from Kołobrzeg, the most numerous were polychaetes, namely *Harmothoe sarsi* and *Nephthys ciliata*, and in the sample from Łeba – crustacean mysid shrimp *Mysis mixta*. Studies by Deree (4) concerning stomach contents of the Atlantic population of the fourbeard rockling also confirm a considerable participation of invertebrate organisms (*Polychaeta*, *Decapoda*) in the food of particularly older specimens. The author of the cited paper also states that younger fish prefer molluscs and pelagic and pelagic-benthic invertebrate forms. Studies on stomach contents of larvae and juvenile forms of the fourbeard rockling were also conducted by Tully and O'Ceidigh, (22) and Albert (1). The studies revealed the occurrence of pelagic invertebrates in stomachs of the forebeard rockling. The presence of pelagic and pelagic-benthic organisms in the stomach contents confirms the earlier supposition on periodical abiding of the fish in pelagic waters (1: 22). Older fish prefer bottom waters. Their stomach contents are dominated by typical bottom fauna, as evidenced by both this study and the paper by Deree (4).

The present paper attempts to estimate total fertility of the forebeard rockling. Two samples were used, collected in April 2001 at a depth of 50–64 m and 81–93 m, respectively. The fourbeard rockling is characterised by relatively high fertility (450,000 and 470,000 eggs, respectively). The fertility calculated is approximate to the literature data, where it is estimated at the level of 500,000 eggs (2; 27).

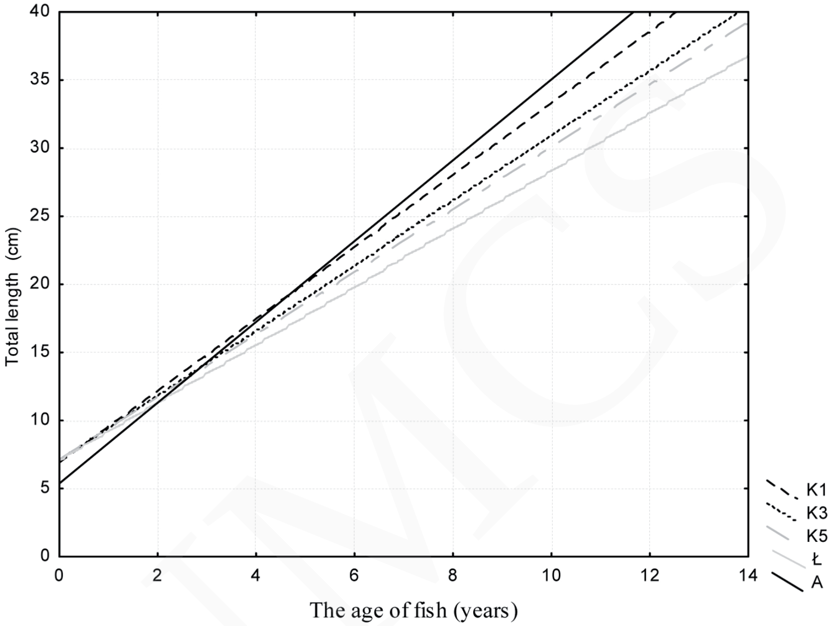
The degree of development of oocytes, determined in the scope of the research, and their size variation for females analysed (0.1–0.9 mm) suggests partial spawning. A higher participation of eggs with a smaller diameter was also observed in a sample collected at the end of April. A female probably spawns several times. In the available literature two spawning terms are recognised: the first one in the early months of spring, and the second in summer (16; 17; 18) states that the largest oocytes of *Gadus morhua* are laid during the first spawn, while the smallest – with the last portion. This may be related to a certain reproductive strategy, where part of larvae from the later hatch falls prey to the faster growing and stronger fry of the earlier hatch

The age of the fourbeard rockling from the Baltic Sea, estimated based on otoliths, varied between 4 and 13 years. The oldest fish were recorded in samples *K5* and *Ł*. Their estimated age was higher than that determined by Deree (4) for the West Atlantic population of the forebeard rockling, and by Cohen et al. (3) for the East Atlantic population, where the authors recorded specimens with a maximum of 9 years of age. It is worth of notice that fish analysed in studies by Deree (4) and Cohen et al. (3) had somewhat smaller total length (max *l.t.*=32.8 cm in the case of the West Atlantic population, and max *l.t.*=30.5 cm for the East Atlantic population) in relation to samples from the Baltic Sea (max *l.t.*=37.8 cm). The published results of the study by Deree (4) allowed for comparing the growth rate of the Atlantic fourbeard rockling with that of fish used for purposes of this paper. The analysis of graphs reveals that the Atlantic fourbeard rockling is similar in terms of growth rate to fish from Kołobrzeg, particularly *K1* (Fig.4a). It is visible in the case of comparison of the entire samples and in comparison of females (Fig. 4b) that males of the Atlantic population also have the same growth rate as males from Kołobrzeg fisheries (Fig. 4c). Fish from Łeba fisheries (*Ł*) have a significantly lower growth rate.

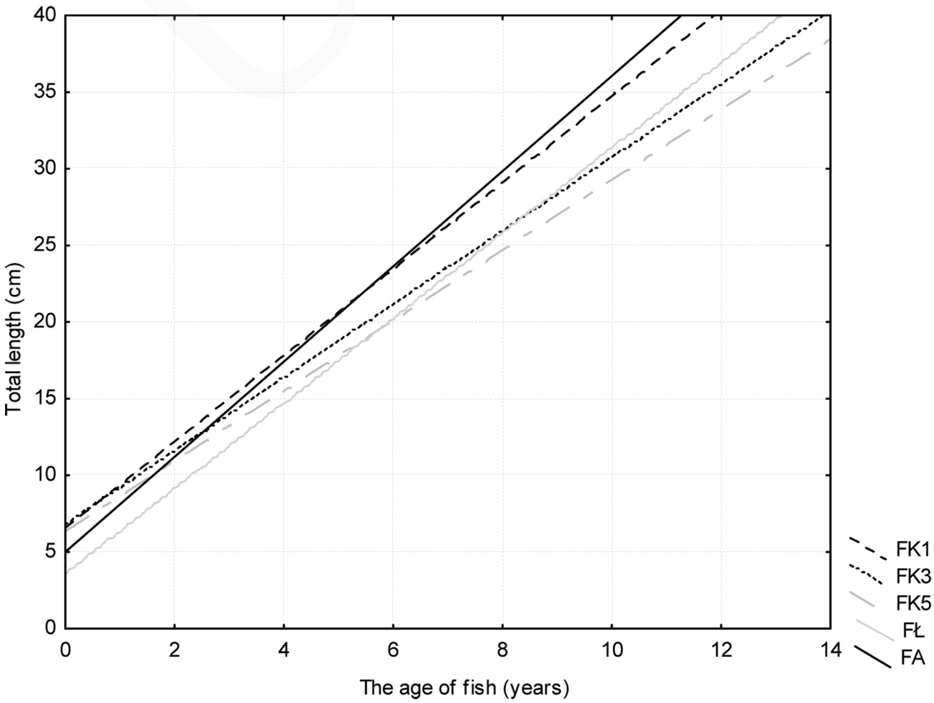
A similar, almost identical growth rate of the Atlantic fourbeard rockling and fish from Kołobrzeg fishing ground suggests high similarity of both populations. Perhaps the populations of fish from the Baltic Sea have sporadic contact with the populations of the North Sea. Also differences in the growth rate revealed among groups analysed (fish from Kołobrzeg in relation to fish from Łeba fishing grounds) suggest the existence of separate stocks of the fourbeard rockling inhabiting the southern waters of the Baltic Sea. Both hypotheses could be confirmed by genetic analyses, which would contribute to a deeper insight into this interesting, widespread, but still little known fish species.

According to Holmlund and Hammer (8) and Kjell (11), recognition of the significance of studies on the biology of non-commercial species is necessary for obtaining greater knowledge on the structure and functioning of aquatic ecosystems. The fish constitute their integral part. Lack of basic information on the age, sex structure, and fertility of specific populations considerably constrains

A)


Total length (cm)
The age of fish (years)
K1
K3
K5
Ł
A

B)


Total length (cm)
The age of fish (years)
FK1
FK3
FK5
FŁ
FA

C)

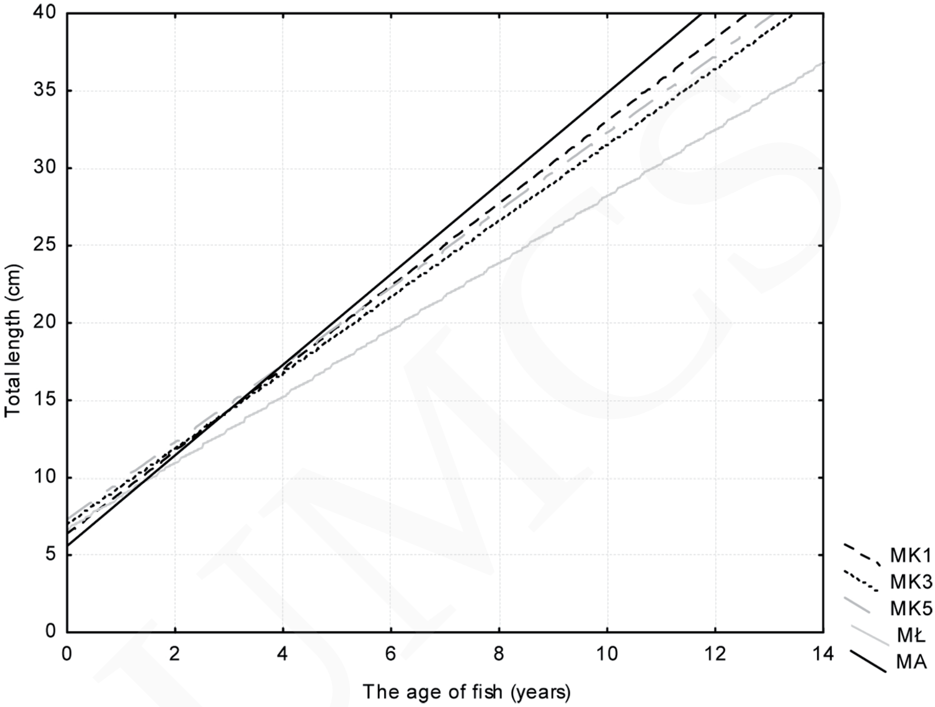


Fig. 4. Graphic presentation of comparison between the growth rate (A) and of females (B)/ males (C) of the fourbeard rockling *Enchelyopus cimbrius* (L.,1766) from the Baltic Sea (own research marked from K1 to Ł) and the Atlantic population of *Enchelyopus cimbrius*, marked as A (4).

activities in the scope of environmental management. Therefore, the studies presented herein provide information not only on the species, but also on the ecosystem in which it occurs.

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