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Age and growth rate of *Pseudochaenichthys georgianus* Norman, 1937 (family *Chaenichthyidae)* of the South Georgia region

ABSTRACT: In the summer of 1977/78, materials for determining the age and growth rate of *Pseudochaenichthys georgianus* Norman, 1937 were obtained in the South Georgia region. The 11—51 cm long fishes were of the age 1+ to 13+. The curvilinear relationship between the body length and the otolith radius took an S shape. In the first four years annual increments are almost identical and start to decrease in the following years. Spawning may occur in the 5th or 6th year of life, and hatching of larvae from eggs laid in autumn (IV—VI) takes place at the end of winter (IX of X). Larvae and juvenile fish lead an exclusively pelagic life, while older fish feed in near-bottom layers; when resources are scare there they seek food in the pelagial.

Key words: *Pseudochaenichthys georgianus*, age, growth rate, South Georgia

1. Introduction

Intensive exploitation of the poorly known Antarctic fish makes it necessary to determine sensible limits of these catches in order to maintain the biological balance of stocks. Knowing the age and growth rate of fish, it is possible to estimate the abundance of commercially exploited fish. The aim of the present work has been to determine the nature and rate of growth of *Pseudochaenichthys georgianus* Norman, 1937 on the basis of materials obtained from commercial catches.

2. Material and method

The materials were collected during commercial fishing carried out from the motor trawler "MORS" in the summer of 1977/1978. The specimens of *Pseudochaenichthys georgianus* examined were obtained from four series of catches by means of a seine net at the depth 220—280 m off the South Georgia between January 10 and February 1, 1978.

The body length of 820 specimens was measured; in 321 ones sex, gonad maturity and age were determined. To analyse the age of fish examined their otoliths were collected and kept dry. The otoliths were prepared for reading by burning (Chojnacki and Palczewski, in press). Thermally — treated otoliths were fractured, their parts being placed in black rubber stoppers kept in water. A distinct picture of the fraction was obtained at the 25× eye piece magnification under incident light (Fig. 1). Distances of annual zones from the curve were measured along the determined otolith radius on the object stage. These results were used for back calculations by Wowk's method (Wowk 1955) (Table I, Fig. 2). As there were no specimens smaller than 10 cm a hypothetical section of the curve was plotted by joining the end of the determined curve with the coordinates origin. The curvilinear relationship between the body length and the otolith radius required a correction factor for the back-calculated annual increments of the letter. Empirical annual increments were corrected using Wowk's method (Wowk 1955):

$$\bar{r}_n = \frac{\bar{r}}{r} r_n$$

where: r — total otolith radius measured, $\bar{r}$ — total otolith radius as read from the curve, r_n — otolith radius measured for a given year of life, $\bar{r}_n$ — otolith radius corrected for a given year of life.

When calculating the empirical body length attained by a fish in its consecutive years of life (back calculations) the arithmetical mean was used. In order to determine the dispersion of elements of the set around this

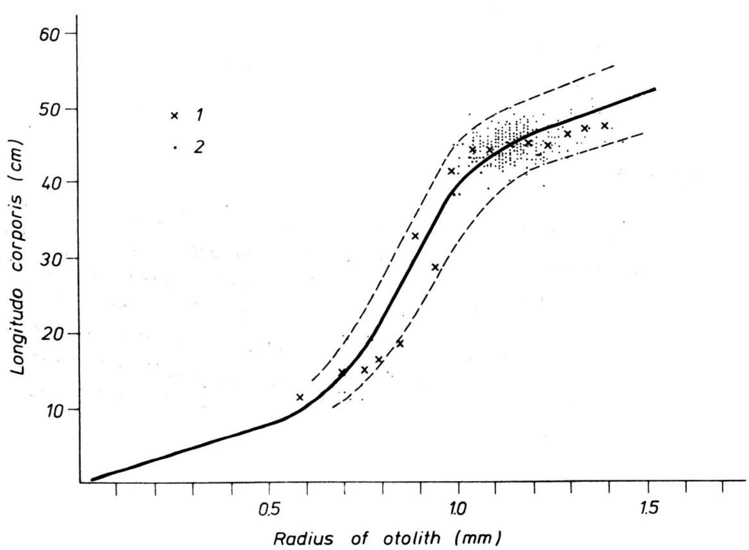

Fig. 2. Body length — otolith radius relationships for *Pseudochaenichthys georgianus* 1 — single observation, 2 — mean value in length classes

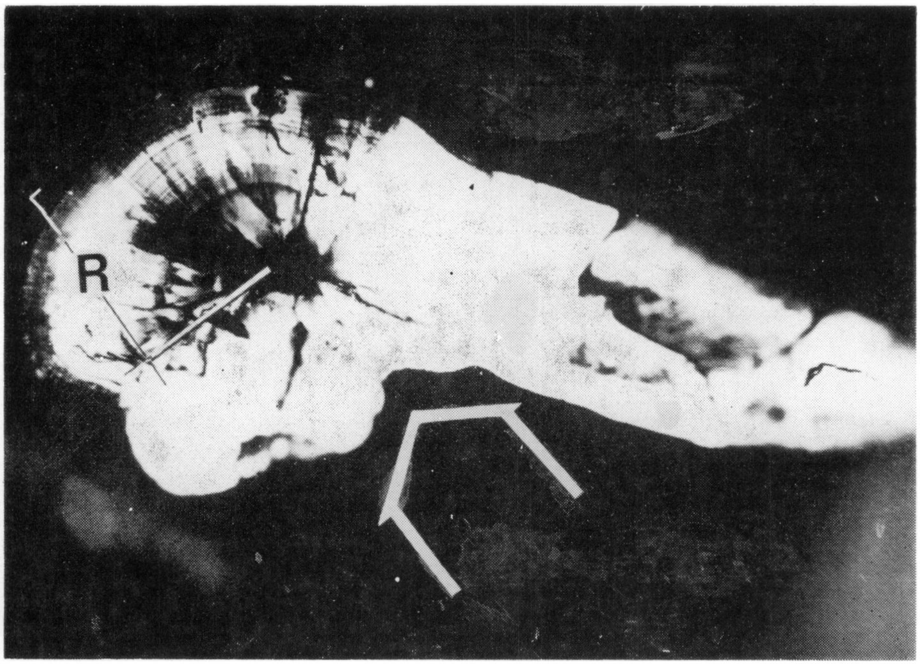

Fig. 1. Cross section of *Pseudochaenichthys georgianus* otolith

Fig. 1. Cross setion of *Pseudochaenichthys georgianus* otolith Arrow points place and direction of pressure when breaking an otoloith R — measuring radius of an otolith (Photo Chojnacki and Palczewski)

Table I.

Results of body length back calculations from otolith fractures of *Pseudochaenichthys georgianus* caught in the South Georgia region in 1978

		Fish age																									
Date	Sex	I	S. D.	II	S. D.	III	S. D.	IV	S. D.	V	S. D.	VI	S. D.	VII	S. D.	VIII	S. D.	IX	S. D.	X	S. D.	XI	S. D.	XII	S. D.	XIII	S. D.
10	females	8.4	0.75	16.46	1.86	25.13	2.56	35.5	0.96	40.57	1.65	43.85	0.51	45.33	0.23	46.6	0.46	47.6	0.14	48.15	0.07	49.0	—	—	—	—	—
Jan.	males	8.4	0.97	17.5	1.92	26.9	1.82	35.11	1.6	40.22	1.24	43.59	0.91	44.91	0.39	46.2	—	—	—	—	—	—	—	—	—	—	—
Total	mean	8.39	0.92	17.15	1.89	26.13	2.4	35.18	1.42	40.27	1.46	43.76	0.6	45.1	0.38	46.52	0.44	—	—	—	—	—	—	—	—	—	—
23	females	8.55	0.86	16.33	2.2	25.63	1.6	35.52	1.4	40.08	1.37	43.95	0.55	45.23	0.26	46.28	0.23	47.24	0.39	48.3	0.14	—	—	—	—	—	—
Jan.	males	8.33	0.9	17.0	2.58	26.07	1.58	35.66	1.41	40.73	0.95	43.55	0.67	45.0	0.28	46.04	0.16	47.1	0.0	48.2	0.28	—	—	—	—	—	—
Total	mean	8.44	0.88	16.6	2.27	25.84	1.46	35.58	1.35	40.69	1.24	43.79	0.57	45.21	0.29	46.2	0.2	47.21	0.35	48.3	0.11	—	—	—	—	—	—
26	females	8.01	0.92	17.28	2.48	26.06	1.91	35.18	1.66	40.11	0.96	43.17	0.45	44.29	0.25	45.38	0.14	46.37	0.43	47.8	—	48.7	—	—	—	—	—
Jan.	males	8.01	0.95	17.68	1.8	26.36	2.17	35.51	1.36	40.14	1.23	43.23	0.41	44.4	0.31	45.49	0.2	46.34	0.27	47.1	0.14	—	—	—	—	—	—
Total	mean	8.01	0.93	17.69	2.07	26.33	2.02	35.5	1.45	40.15	1.14	43.23	0.42	44.39	0.3	45.46	0.19	46.33	0.32	47.33	0.41	—	—	—	—	—	—
01	females	7.82	1.29	16.95	2.47	26.84	2.09	35.74	1.34	40.21	1.03	43.07	0.49	44.41	0.26	45.4	0.24	46.4	0.3	47.62	0.22	48.4	0.56	49.4	0.56	50.6	—
Feb.	males	7.68	0.7	17.06	2.44	26.15	1.83	36.14	1.75	40.5	0.87	43.26	0.53	44.72	0.27	45.31	0.17	46.3	0.25	47.05	0.35	48.0	—	48.4	—	—	—
Total	mean	7.41	1.2	17.05	2.46	26.43	1.96	35.74	1.44	40.46	0.99	43.18	0.52	44.42	0.26	45.35	0.22	46.42	0.28	47.45	0.34	48.26	0.46	49.0	0.7	—	—
Grand	females	8.19	0.33	16.75	0.44	25.91	0.72	35.48	0.23	40.42	0.31	43.51	0.45	44.81	0.54	45.91	0.62	46.9	0.61	47.96	0.31	48.7	0.3	49.4	—	50.6	—
Total	males	8.14	0.39	17.31	0.33	26.37	0.37	35.6	0.42	40.4	0.27	43.4	0.18	44.76	0.26	45.76	0.42	46.58	0.45	47.45	0.65	48.0	—	48.4	—	—	—
Total	mean	8.06	0.47	17.12	0.44	26.18	0.26	35.47	0.2	40.39	0.23	43.49	0.32	44.78	0.43	45.88	0.56	46.65	0.48	47.69	0.52	48.26	—	49.06	—	—	—
Annual	females	8.195		8.560		9.16		9.57		4.81		3.09		1.305		1.10		0.98		1.06		0.74		0.70		1.20	
increments	males	8.136		9.174		9.06		9.23		4.79		3.00		1.360		1.00		0.82		0.87		0.55		0.40		—	
Total	means	8.06		9.06		9.06		9.29		4.91		3.1		1.29		1.10		0.77		1.04		0.57		0.80		—	

Calculated values correspond to body length (*longitudo corporis*) value the standard deviation was calculated (Table I). Such calculations were done separately for each sample and then the results were compared. The growth rate curve for *Pseudochaenichthys georgianus* plotted from the empirical data (Fig. 3) has shown von Bertalanffy's (1934) mathematical

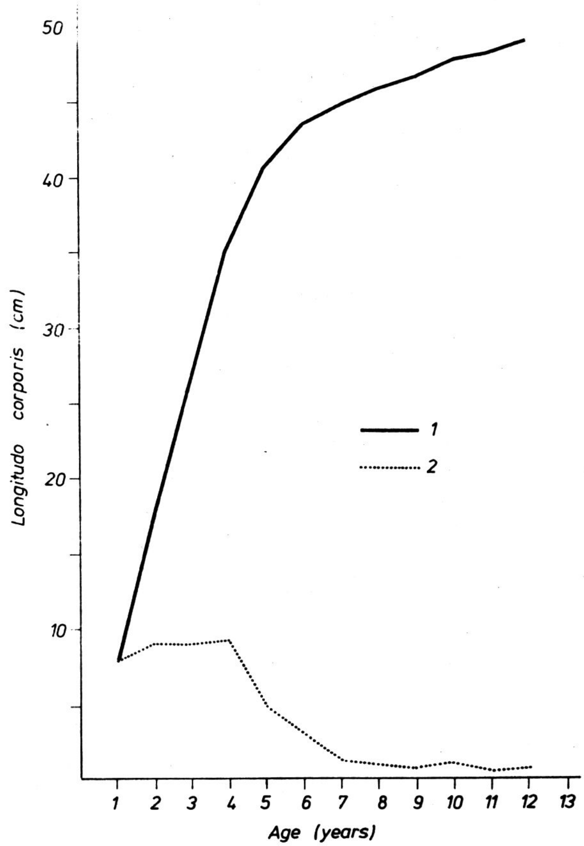

Fig. 3. Growth rate of *Pseudochaenichthys georgianus* (back calculations)
1 — length, 2 — annual increments

model of growth rate not to be applicable over the entire growth. Annual increments of this species in the first four years of life are almost identical, whereas von Bertalanffy's model assumes decreasing length increments in successive years. Thus the mathematical model of length growth rate was determined by estimating the linear regression of body length on the years of life. When calculating the linear regression the following equation (Markiewska-Krawiec and Krawiec 1976) was used:

$$a = \frac{\sum_{i=1}^{n} (x_i - \bar{x})(y_i - \bar{y})}{\sum_{i=1}^{n} (x_i - \bar{x})^2} \qquad b = \bar{y} - a\bar{x}$$

where: $\bar{x}$, $\bar{y}$ — mean values of sample characteristics, a — regression coefficient of (y) body length as releted to x (years of life), the former being an average measure of body length (y) when age (x) increases by unit.

Linear regression of y on x was estimated from the equation:

$$\check{y} = ax + b$$

Von Bertalanffy's method for growth rate calculations uses the equation:

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

were: L_t — fish length at age t, t — age for which the L_t length is calculated, e — natural logarithm base, L_∞, K, t_0 — empirical parameters.

3. Results

The body length of 820 *Pseudochaenichthys georgianus* individuals ranged between 11 and 51 cm. The majority of the population measured 39—51 cm (L_t 44—59 cm, respectively). The length distribution curve for the fishes examined shows one peak corresponding to the fish body length of 45 cm (L_t — 52 cm), whereas individuals below 39 cm and over 50 cm occurred sporadically (Table II, Fig. 4).

Table II.

Sex distribution in length classes of *Pseudochaenichthys georgianus* individuals whose otoliths were used for back calculations

Length classes (cm)	Number of individuals	Percentage	Sex			
			females		males	
			no. of indiv.	%	no. of indiv.	%
11—12	2	0.62	unidentified			
13—14	1	0.31	1	0.31	—	—
15—16	—	—	—	—	—	—
17—18	—	—	—	—	—	—
19—20	2	0.62	1	0.31	1	0.31
21—22	1	0.31	1	0.31	—	—
23—24	—	—		—	—	—
25—26	—	—	—	—	—	—
27—28	1	0.31	—	—	1	0.31
29—30	—	—	—	—	—	—
31—32	2	0.62	—	—	2	0.62
33—34	1	0.31	1	0.31	—	—
35—36	1	0.31	—	—	1	0.31
37—38	2	0.62	1	0.31	1	0.31
39—40	3	0.93	3	0.93	—	—
41—42	21	6.54	4	1.24	17	5.30
43—44	94	29.28	30	9.34	64	19.94
45—46	127	39.56	55	17.13	72	22.43
47—48	48	14.95	28	8.72	20	6.23
49—50	14	4.40	10	3.15	4	1.25
51—52	1	0.31	1	0.31	—	—
Total	321	100.0	136	42.37	183	57.01

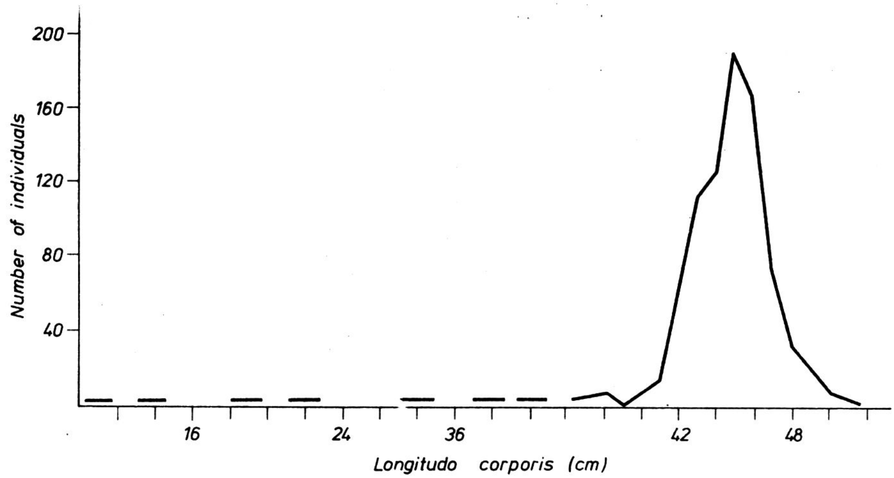

Fig. 4. Body length frequency distribution (L_c) in the *Pseudochaenichthys georgianus* population examined

About 80% of the individuals examined showed their gonads to be at stage 3 and 4 (according to the 8 — stage Maier scale). The gonad maturity stage combined with the body length of the individuals caught showed that the fishes commence to spawn at the age of 5 and 6 (Table III). The age, back-calculated from rings of thermally treated and fractured otoliths, was found to range from 1+ to 13+. Wowk's (1955) method of back calculations allowed to determine the otoliths radius-body length relationship, the curve taking an S shape (Fig. 2). On the basis of empirical data a growth rate curve (Fig. 3) was plotted, but because of an uneven growth rate of the fishes examined a simple mathematical model could not be constructed. For the first four years of life the linear regression of body length on age took the following form:

$$y = 9.1305x - 1.1175$$

In the next years *Pseudochaenichthys georgianus,* after attaining sexual maturity, showed an uneven growth and decreasing annual incremants, which allows to apply the model of von Bertalanffy, finally taking the form of:

$$L_t = 50.08(1 - e^{-0.2829(t+3.7453)})$$

The graphical presentation of the mathematical model of *Pseudochaenichthys georgianus* growth rate, very similar to the empirical one, is given in Fig. 5, wereas the annual increments are recorded in Table IV.

4. Discussion

The length distribution of the individuals examined (Table II, Fig. 4) indicates to several age groups existing in the stock, but exact age could only be read from otoliths. The white-blooded fish have their otoliths

Table III.

Gonad maturity stage (Maier scale) in body length classes of *Pseudochaenichthys georgianus* from the South Georgia region in January 1978

Length class (cm)	Number of unidentified	males	females	Gonad maturity stage															
				no. of indiv. males								no. of females							
				1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
below 38	2	6	5	4	1	—	—	1	—	—	—	3	1	1	—	—	—	—	—
39—40	—	—	3	—	—	—	—	—	—	—	—	—	2	1	—	—	—	—	—
41—42	—	17	4	—	4	9	4	—	—	—	—	—	1	3	—	—	—	—	—
43—44	—	64	30	—	10	40	10	4	—	—	—	—	6	19	5	—	—	—	—
45—46	—	72	55	—	11	43	17	1	—	—	—	—	4	38	10	1	—	2	—
47—48	—	20	28	—	1	13	5	1	—	—	—	—	4	16	7	—	—	1	—
49—50	—	4	10	—	1	2	—	—	1	—	—	—	—	5	3	2	—	—	—
above 50	—	—	1	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—
Total	2	183	136	4	28	107	36	7	1	—	—	3	18	83	26	3	—	3	—

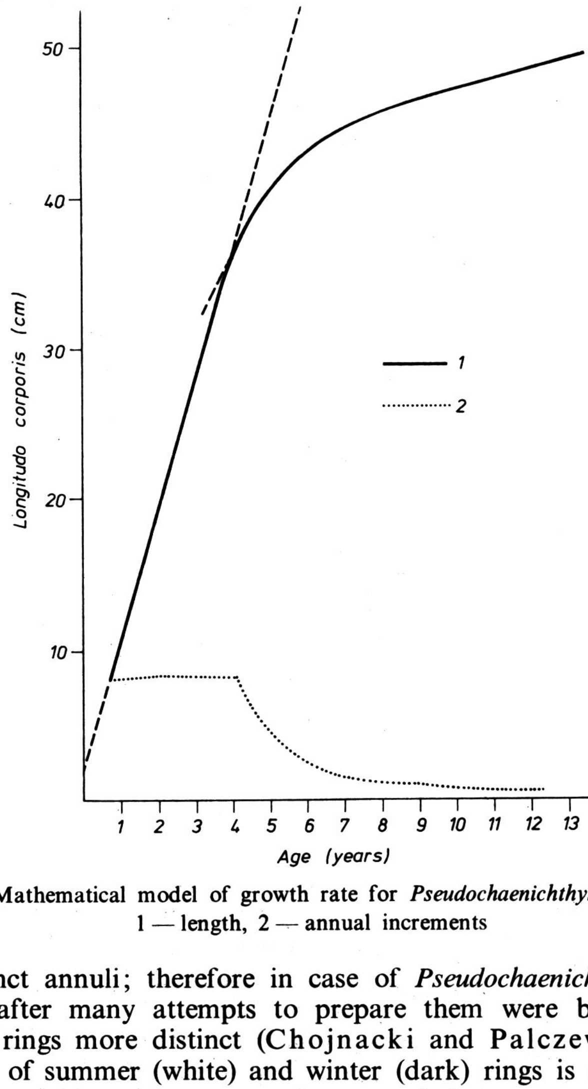

Fig. 5. Mathematical model of growth rate for *Pseudochaenichthys georgianus*
1 — length, 2 — annual increments

without distinct annuli; therefore in case of *Pseudochaenichthys georgianus* the otoliths after many attempts to prepare them were burned in order to make the rings more distinct (Chojnacki and Palczewski, in press). The presence of summer (white) and winter (dark) rings is due to different chemical composition of zones of seasonal increments. According to Christensen (1964) the broad zone of summer increments consist of inorganic matter (white before and after burning), whereas the narrow winter zones are formed by inorganic matter with an admixture of organic matteı carbonized as a result of burning and thus dark. The most difficult to read were those fragments of an otolith close to its centre (*nucleus*), and for fish over 5 years of age — those parts close to the fracture. In the first case the difficulty was in finding, within the growth zone, the first summer season and the additional rings immediately after the first winter zone. This phenomenon did not occur in all the individuals. The presence additional rings representing the period of the first summer zone was probably related to larval development stages. The rings occurring sometimes beyond the zone corresponding to the first year of life were probably

Table IV

Length growth rate of *Pseudochaenichthys georgianus* calculated from the mathematical model

Age	Body lenght (cm)	Annual increments (cm)
1	8.01	8.01
2	17.14	9.13
3	26.27	9.13
4	35.40	9.13
5	40.22	4.81
6	42.65	2.43
7	44.48	1.83
8	45.86	1.38
9	46.90	1.04
10	47.68	0.78
11	48.27	0.59
12	48.72	0.45
.	.	.
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due to the change of fish habitat (from pelagic way of life and plankton feeding to life in the near-bottom zone). According to the back calculations, *Pseudochaenichthys georgianus* change their way of life at the body length of 11 cm, but some divergences in both directions may occur. The fact that the otolith shows the change of environment and food composition is proven by a shade of otolith within this range, regardless of its zones, differing from those in other parts (more hyaline). The otoliths of older individuals usually show at their edges a great density of annuli, whereby even slight inaccuracies in burning may complicate back calculations. The fractures always showed the *nucleus* placed in the otolith centre. The *nucleus* is lumpy, slightly flattenned, about 0.1 mm thick, and measuring about 0.21 mm in a horizontal plane. It is made of a dark substance, which proves that the larvae hatch in autumn and winter. Back readings in some individuals show a distinct additional ring in the vicinity of the 5th and 6th annuli probably produced as a result of the first spawning.

The difficulties in analysing the otoliths of white-blooded fish are described by Olsen (1955), who tried to analyse otolith in several specimens of *Pseudochaenichthys georgianus,* but found that they were damaged when fixed in formalin. Thus he has finally determined approximately the age of a few specimens and then in connection with the species length distribution, drawn conclusions on the biology of this species. Back calculations from otoliths were confirmed by age readings from discs of the fishes. The determinations made by Olsen (1955) and the results presented here are similar.

An age analysis of *Pseudochaenichthys georgianus* has been also performed by Mucha and Cielniaszek (1979) who drew probably from length distributions analyses and Olsen's observations. The specimens examined were of 8—58 cm total length and 11 age groups were separated in the stock. Also, similarly to Olsen (1955), they revealed the body length to increase 10 cm per year in the first four years of life and to decrease distinctly after the six year. The authors mentioned pointed to the decreasing catches and a considerable renewal of the stock as compared to earlier fishing seasons.

The body length at which *Pseudochaenichthys georgianus* attains sexual maturity (L_t 40.5 to 45.5 cm) confirmed by gonad stage analysis in the individuals examined is consistent with determinations and observations of other authors. Sosiński and Skóra (1977) have found that fishes examined in the autumn 1977 off South Georgia, measuring less than 45 cm, were sexually immature. Permitin (1973) has stated that *Pseudochaenichthys georgianus* males and females attained sexual maturity at body length of 40—48 cm and 44—50 cm, respectively. Referring to Olsen's (1955) data he has assumed that this species commences spawning at the age of 4—6 years. According to Nodzyński (1978), sexually mature females have all above the total length of 45.1 cm. The analysis of the materials presented allows to state that the fish spawn in autumn, i.e. between April and June. Similar conclusions have been drawn by Olsen (1955), Permitin (1973), Kuranty and Formela (1978), Nowakowski (1978), Mucha and Cielniaszek (1979). Despite the lack of significant differences between males and females growth rates, the females are found to numerically dominate over males among the oldest individuals (body length over 47 cm). Similar observations have been made by Sosiński and Skóra (1977) — no males in length classes over 54 cm (L_c – 48 cm).

The analysis of otolith has shown that the central zone consists of a transparent substance corresponding to the winter growth zone. This contradicts the opinion of some other workers, e.g. Permitin (1973), Olsen (1955), Andrjašev (1965), that the incubation of eggs laid in autumn lasts all the winter. The larvae hatch probably in winter, and definitely at the end of this season (September-October). These observations confirme earlier studies by Efremenko (1979), who has described larval stages of some white-blooded fish species including *Pseudochaenichthys georgianus*. According to him, the larval stage of *Pseudochaenichthys georgianus* can be divided into two stages of development:

— undeveloped larvae 18.2—27.2 mm long
— developed larvae 33.0—54.5 mm long.

Larvae of the first stage were caught by Efremenko (1979) on the South Georgia shelf between August 8 and November 14, i.e., at the end of winter and at the beginning of spring, at the depth of 50 m. Fishes at the developed larvae stage were also inhibiting the same region but were caught on February 12 i.e., in summer, also at the depth of 50 m (depth of shelf 180—250 m). The development of larval forms may

produce additional rings in the otolith growth zone corresponding to the first year life. Descriptions of juvenile *Pseudochaenichthys georgianus* caught together with krill (Rembiszewski, Krzeptowski and Linkowski 1978) confirm the contention of Efremenko (1979) about the pelagic period of life in this species. The specimens caught together with krill were 7—32 cm long (Wolnomiejski et al. 1977, Rembiszewski, Krzeptowski and Linkowski 1978), but individuals 70—80 mm long differed from the other in their white-creamy colour (Rembiszewski, Krzeptowski and Linkowski 1978) which may prove adaptation of these larvae to the pelagic way of life. All the observations considered these specimens of *Pseudochaenichthys georgianus* caught together with krill should be divided into two groups:
— individuals at the pelagic life stage, i.e., these that have not changed their habitat when adult. The change of habitat takes place probably after the first year of life and at a certain length.
Light colouration of the body;
— individuals caught together with krill while feeding on this crustacean. Their habitat is the near-bottom zone, the fishes following krill swarms in to the pelagial. These fishes are definitely of a dark colour.

The fish caught in January 1978 with a seine were over 11 cm long (L_t) and occurred together with larger individuals the same species. These fishes were dark in colour their age being determined as 1+.
Šcerbič (1975) when describing the scales of *Notothenia rossi marmorata* Fischer, has observed that the spawning ring of Antarctic fishes is not visible because the growth inhibiting autumn spawning coincides with winter growth inhibition. The analysis of *Pseudochaenichthys georgianus* otoliths has shown that in some cases a spawning ring is very distinct, which may be due to spawning extended over longer period of time. The fishes begin to spawn under good food conditions of the australian autumn (April, May) but it also may be the beginning of winter. Permitin (1970) has pointed to a poor ossification of white — blooded fish skeletons therefore the best solution would be to analyse the age of species from the family in question on the basis of otoliths. Bone elements are much more difficult to obtain, store, and also to interpret.

5. Conclusions

1. Because of a poor ossification of skeletons and the lack of scales, otolith are the best source to examine the age and growth rate of *Pseudochaenichthys georgianus*. Otoliths have to be prepared by burning.

2. *Pseudochaenichthys georgianus* body length/otolith measuring radius relationship, when studied by Wowk's method, takes an S shape.

3. In the first four years of life of *Pseudochaenichthys georgianus* the annual increments are identical and the linear regression may be expressed by an equation:

$$\check{y} = 9.1305x - 1.1175$$

In the next years annual increments become gradually smaller and the growth rate calculated by von Bertalanffy method is:

$$L_t = 50.08(1-e^{-0.2829(t+3.7453)})$$

4. The first spawning of *Pseudochaenichthys georgianus* may occur in the fifth or sixth year of life and corresponds to body length 35.5—40.5 cm the growth rate decreasing after spawning.

5. *Pseudochaenichthys georgianus* larvae from autumn spawning hatch at the and of australian winter.

6. The *Pseudochaenichthys georgianus* individuals examined 11—51 cm long were found to be at the age of 1+ to 13+.

The authors wish to thank Mr. Marek Pietrucha, M. Sc., for making his unpublished data on the gonad maturity of the fishes examined available.

6. Summary

Problems concerning the biology of *Pseudochaenichthys georgianus* from commercial catches off South Georgia (January 1978) were investigated. The bodies of 820 individuals were measured and 321 detailed analyses made. The body length of the individual caught ranged from 11 to 51 cm, but single specimens only occurred in the interval 11—41 and over 50 cm (Fig. 4). Burned otoliths broken and the distances of annual zones vere measured on the fractures (Fig. 1). Length distribution of 321 individuals yeilding otoliths is given in Table II. Results of investigations were used to plot the *Pseudochaenichthys georgianus* body length otolith radius relationship; the curve taking an "S" shape (Fig. 2). On the basis of empirically obtained values of body length attained by the fishes in consecutive years of their life the growth rate curve was plotted (Fig. 3). Its characteristics were used to construct the mathematical model of growth rate of the species. In the first four years of life the annual increments were almost identical and in this section the mathematical model of growth rate was expressed by the equation:

$$y = 9.1305\,x - 1.1175.$$

In further years of life, after the first spawning (in the 5th or 6th year of life) annual increments decreased allowing thus to use von Bertalanffy model which took the following form:

$$L_t = 50.08(1-e^{-0.2829(t+3.7453)})$$

Empirical and mathematical models of growth rate (Figs. 3 and 5) are graphically consistent, whereas the accurate body lengths calculated for each year of life are given in Tables I and IV.

7. Резюме

Исследовано вопросы связанные с биологией *Pseudochaenichtys georgianus* Norman, 1937 происходящих из промышленной ловли в районе Южной Джоржии с января 1978 года. Измерено длину тела 820 особей и проведено 321 подробный анализ. Диапазон длины тела ловленных особей достигал 11—51 см с тем, что в пределе 11—41 и выше 50 см выступали единичные экземпляры. Отолиты подготовлены для исследований путём обжигания ломлено и не переломах были измерены расстояния годичных зон (рис. 1). Характеристику длины 321 особи которых отолиты исследовано представлено в таблице II. Итоги исследований послужили для намечения зависимости между длиной тела *Pseudochaenichthys georgianus* а лучом отолита; рисунок кривой походил на букву

„S" (рис. 2). На основании длины тела, которую достигают рыбы в очередных годах жизни намечено кривую темпа роста (рис. 3). Её характер послужил для вычисления математической модели тимпа роста двумя уравнениями из-за неравномерного роста рыб.

В первых четырёх годах жизни годичные прирощения почти одинаковы и на этом участке математическая модель темпа роста выражалась формулой:

$$\hat{y} = 9.1305x - 1.1175$$

В следующих глдах после первого нереста (в 5-том или 6-том году жизни) годичные прирощения уменьшаются что показывает применить модель вон Берталанффы которая выражается формулой

$$L_t = 50{,}08\ (1 - e^{-0{,}2829(t+3{,}7453)}).$$

Эмпирическая и математическая модель роста представлена графически (рис. 3 и 5) согласуются зато точное вычисление длины тела в отдельных годах жизни представлено в таблицах I и IV.

8. Streszczenie

Badano zagadnienia związane z biologią *Pseudochaenichthys georgianus* pochodzących z połowów przemysłowych w rejonie Południowej Georgii, dokonanych w styczniu 1978 roku. Zmierzono długości ciała 820 osobników i dokonano 321 analiz szczegółowych. Zakres długości ciała poławianych osobników wynosił 11—51 cm z tym, że w przedziale 11—41 i powyżej 50 cm występowały pojedyncze okazy. Otolity przygotowane za pomocą prażenia do badań przełamywano i na przełomach dokonywano pomiarów odległości stref rocznych (rys. 1). Charakterystykę długościową 321 osobników, których otolity przebadano, przedstawiono w tabeli II. Wyniki badań posłużyły do wykreślenia zależności między długością ciała *Pseudochaenichthys georgianus* a promieniem otolitu: kształt krzywej zbliżony był do litery "S" (rys. 2). Na podstawie empirycznych wartości długości ciała osiągniętych przez ryby w kolejnych latach życia, wykreślono krzywą tempa wzrostu (rys. 3). Jej charakter posłużył do wyliczenia matematycznego modelu tempa wzrostu dwoma równaniami ze względu na nierównomierne tempo wzrostu ryb. W pierwszych czterech latach życia roczne przyrosty są prawie jednakowe i na tym odcinku matematyczny model tempa wzrostu wyraża się wzorem:

$$\hat{y} = 9{,}1305x - 1{,}1175$$

W dalszych latach życia, po odbyciu pierwszego tarła (w 5 lub 6 roku życia) przyrosty roczne maleją co pozwala na zastosowanie modelu von Bertalanffy, który przybiera postać:

$$L_t = 50{,}08(1 - e^{-0{,}2829(t+3{,}7453)})$$

Empiryczny i matematyczny model tempa wzrostu przedstawiony graficznie (rys. 3 i 5) są ze sobą zgodne, natomiast dokładne wyliczone długości ciała w poszczególnych latach życia przedstawiono w tabeli I i IV.

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