ACTA ICHTHYOLOGICA ET PISCATORIA
Vol. XIII Fasc. 2 Szczecin 1983

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STUDIES ON GROWTH RATE OF YELLOW NOTOTHENIA, *NOTOTHENIA GIBBERIFRONS* LÖNNBERG, 1905 OFF SOUTH GEORGIA

BADANIA NAD SZYBKOŚCIĄ WZROSTU ŻÓŁTEJ NOTOTENII, *NOTOTHENIA GIBBERIFRONS* LÖNNBERG, 1905, Z REJONU POŁUDNIOWEJ GEORGII

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The paper demostrates that scales are not suitable for back readings, due to a poor legibility of their central parts, the peripheral regions being poorly legible in older fish scales as well. One can presume that the scales begin to grow as late as in the second year of life. Most otoliths (*sagitta*) can be used in back calculations. Based on measurements of radii of various growth zones on the otolith cross-section, mean lengths attained in subsequent years of life were calculated. The von Bertalanffy growth equation parameters were estimated as follows: $L_{\infty} = 57.48$ cm; $K = 1.04$; $t_0 = 0.439$ yr. The mean length at first maturity was estimated at 37.5 cm, i.e., 65% of L_{∞}.

INTRODUCTION

The yellow notothenia, *Notothenia gibberifrons*, is one of more important economically notothenids. The species played a major role in the reconnaissance catches of the RV "Profesor Siedlecki" in 1978/1979, its contribution to the total catch amounting to 25% (Skóra, 1979). The species was also important in catches of German Antarctic

expeditions (Kock, 1978, 1979, 1982). Biology of *N.gibberifrons* is still poorly known, though. Out of 4 papers dealing with the growth rate, that of Boronin and Frolkina (1978) is based on mean length in age groups, while Šust and Pinskaja (1978) worked with scale back reading on the assumption of a direct relationship between the total body length and scale radius length. Ciechanowski (1980) employed Wowk's procedure of age back reading from scales to study the yellow notothenia growth rate, while Boronin and Altman (1979) estimated the von Bertalanffy equation parameters and natural mortality coefficient from earlier data.

The objective of the present work was to examine the utility of scales and otoliths in growth rate back calculations.

MATERIALS AND METHODS

The materials for the work presented were collected in late March and in May 1977, during the 2nd Polish Antarctic Expedition, on fishing grounds NE off South Georgia, the trawl ground rope being provided with bobbins and chains as an auxiliary weights and its codend with a fine mesh (20 mm mesh size) insertion. The mean trawling depth ranged from 190 to 280 m. The yellow notothenia occurred in each haul, contributing to 5–60% of the catches. The species was most abundant at depths exceeding 250 m. Additionally, the catches contained some other species, e.g., *N. rossii marmorata* Fischer, 1885; *Pseudochaenichthys georgianus* Norman, 1937; *Chaenocephalus aceratus* (Lönnberg, 1906); *Champsocephalus gunnari* Lönnberg, 1905; *Trematomus hansoni* Boulenger, 1902.

Thirteen samples of fish were collected*. The total body length was measured to 0.5 cm on 907 individuals; additionally, the caudal length (l.c.) was measured. Scales were collected directly behind the end of the pectoral fin from 490 individuals. Otoliths were collected from 488 individuals. The scales, soaked in KOH and thoroughly cleaned, were placed between two cover glasses and examined under a microfilm reader. Scale contours were drawn on a sheet of paper placed on the reader screen (17.5 x magnification) and the oral radius was measured to 1 mm from the drawing with a ruler (Fig. 1). A total of 213 individuals yielded scales for the oral radius measurements. The otoliths were burned in an ovenproof glass vessel until orange-colored, broken transversely in two parts, and the broken surfaces were, when necessary, polished with a fine grain sandpaper. The otolith parts were mounted, the broken surface up, and viewed under a stereomicroscope in incident light. Growth zones visible on the broken surface were measured to 0.01 mm under a microscope with the micrometric screw, a section from the centre to the dorsal margin being measured (Fig. 2). In older fish, the increments on the otolith section

* As the project was aimed at studying growth rate and feeding (described in a separate paper; Kompowski, in prep.), the fish of extremal body lengths – very large and very small ones – were preferred when sampling.

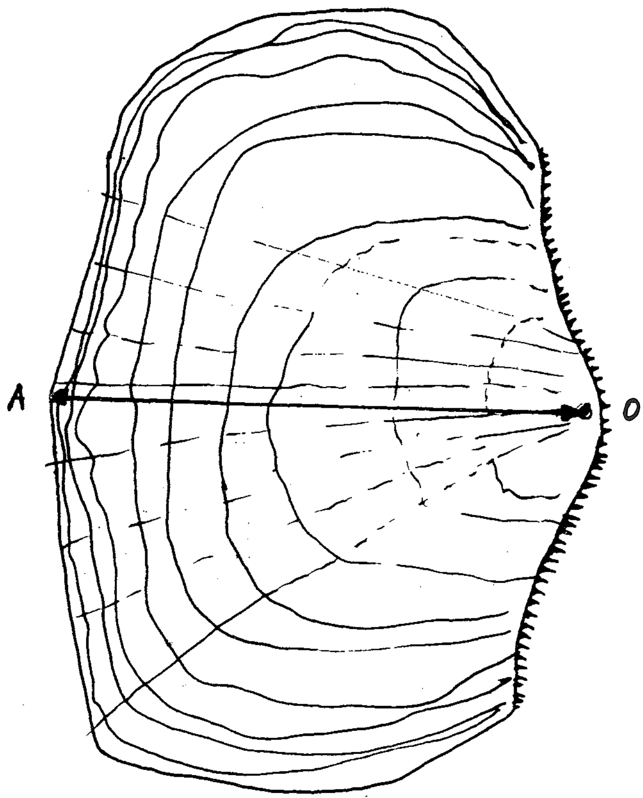

Fig. 1. Scale measurements in *Notothenia gibberifrons*

measured tended to deviate toward the internal margin (Fig. 5); this deviation, however, was usually small and therefore disregarded in calculations. A total of 266 fish individuals yielded otoliths for measurements. The procedures employed in back calculations are presented in a relevant section. The fish were sexed and the Maier scale gonad maturity stage determined in 487 individuals.

The measurements and determinations made are summarised in Table 1.

FISH LENGTH AND AGE

Total length – body length relationship

When recording the size of the Antarctic fish, the total body length (l.t.) is used most often. Some authors, however, use the body length (l.c.), i.e., the fish length is measured along the body to the outer margin of caudal scales. In order to compare growth data resulting from the two procedures, the total length – body length relationship was

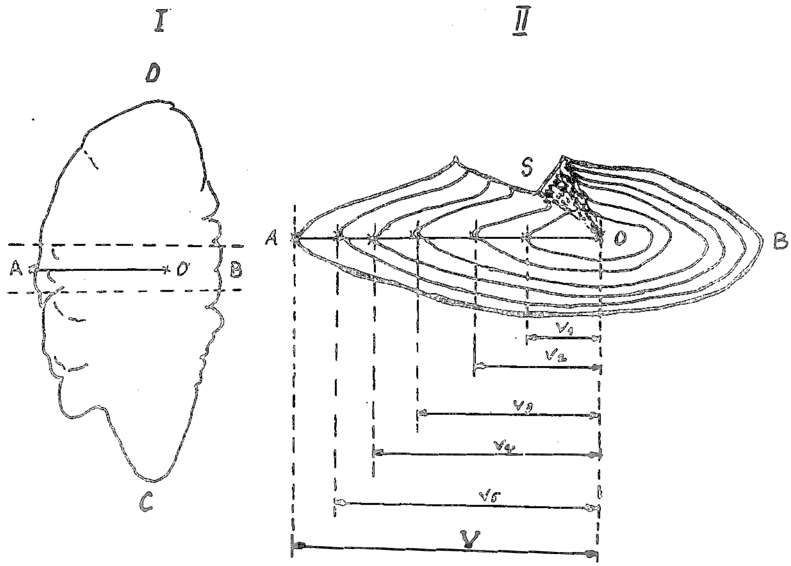

Fig. 2. Otolith measurements in *Notothenia gibberifrons*
I. External appearance of otolith; place of breakage marked with dashed line
A. dorsal margin, B. ventral margin, C. oral part, D. caudal part.
II. Otolith broken surface; OA = measured section; O = otolith *nucleus;* S = *sulcus acusticus*

looked into. In the yellow notothenia 13.5–50 cm long (l.t.) the relationship is almost linear and can be described by an equation of $y = a + bx$ type (Fig. 3). The equation parameters a and b were estimated by the least squares method, which yielded

$$\text{l.c.} = 0.8848\ \text{l.t.} - 0.3801 \qquad (1)$$

$$r = 0.9994$$

where l.c. = body length (cm)
l.t. = total length (cm)

LENGTH OF FISH CAUGHT

The fish caught ranged fairly widely in length, from 13.5 to 50.0 cm. The juveniles usually accompanied the adults. Those individuals measuring from 35 to 45 cm contributed the highest biomass to the catches (Fig. 4).

Table 1

Materials collected and analyses performed (no. of individuals examined)

Np.	Fishing site coordinates	Date	Mean trawling depth (m)	Measurements					
				Length	No. of otolith pairs collected	Otolith measured	Scales measured	Sex and gonad determined	No. of legible otoliths
1.	54°06′S ; 36°07′W	22.III/2	280	23	23	12	16	23	23
2.	53°58′S ; 36°03′W	23.III/2	280	23	22	12	17	23	22
3.	54°33′S ; 35°31′W	6.V/3	290	53	53	30	38	52	52
4.	54°25′S ; 35°34′W	9.V/2	280	54	54	38	47	54	51
5.	54°04′S ; 36°01′W	10.V/2	280	28	28	19	25	28	23
6.	54°04′S ; 36°09′W	11.V/1	280	50	50	21	20	49	49
7.	54°04′S ; 36°17′W	14.V/2	280	299	–	–	–	–	–
8.	54°07′S ; 35°47′W	17.V/3	240	57	57	28	9	57	55
9.	54°03′S ; 35°49′W	18.V/4	240	63	62	30	3	63	55
10.	53°55′S ; 36°17′W	19.V/4	220	26	25	23	–	26	25
11.	54°04′S ; 36°19′W	23.V/2	280	29	29	11	–	29	29
12.	54°29′S ; 35°31′W	24.V/3	270	42	42	24	25	42	39
13.	54°29′S ; 35°30′W	26.V/2	275	160	43	18	13	43	39
			Total	907	488	266	213	489	462

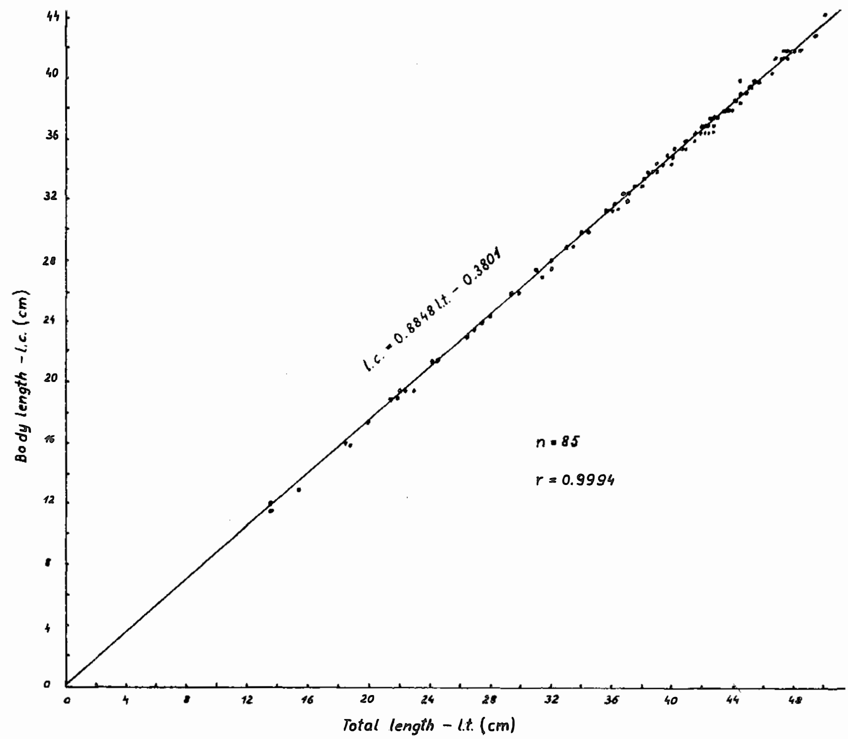

Fig. 3. Total length – body length relationship in *Notothenia gibberifrons* off South Georia

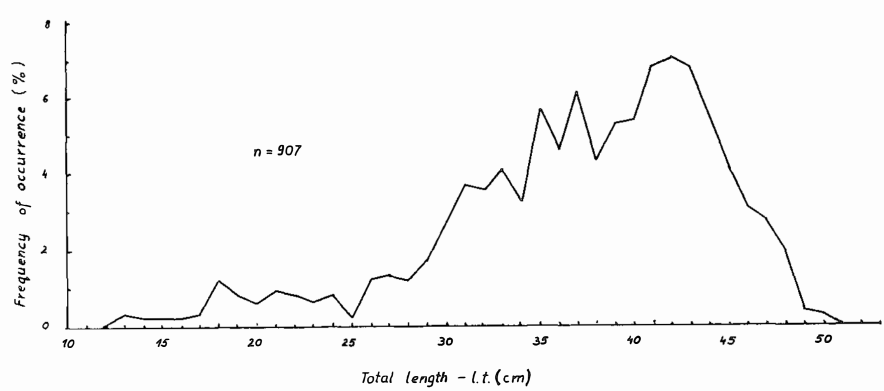

Fig. 4. *Notothenia gibberifrons* length distribution in bottom trawl catches off South Georgia in March and May 1977

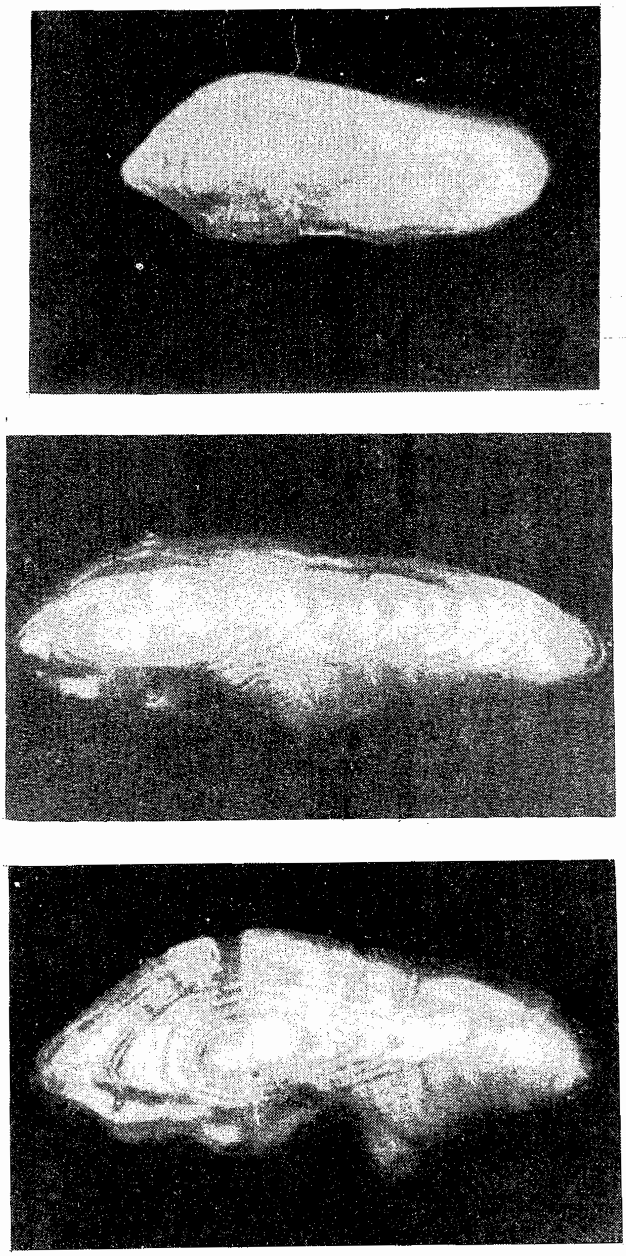

Fig. 5. *Notothenia gibberifrons* otoliths:
A. Date of capture May 17, 1977; l.t. 16.5 cm; age 3+; magnification 23.8 x
B. Date of capture May 6, 1977; l.t. 45.0 cm; ♂ V; age 16+; magnification 16.1 x
C. Date of capture May 6, 1977; l.t. 46.0 cm; ♂ V; age approx. 20; magnification 16.4 x

AGE OF FISH CAUGHT

Broken surfaces of the otoliths, often without any prior polishing, showed concentric layers (zones) made of alternating opaque and hyaline substances (Fig. 5). The otolith margin was opaque. The fish age was determined by counting annual increments, assuming that an annual increment consists of an opaque zone and an adjacent hyaline one, as is the case in other fish species. Otoliths of 488 individuals were examined, 462 yielding legible otoliths.

The material studied comprised fishes aged from 2+ to 23+ yr (Fig. 6). The determined age of fishes older than 15 yr is frequently an approximation only and in reality can be 1 or 2 yr higher or lower. Most illegible and therefore discarded otoliths were collected from older fishes, aged presumably more than 15 yr. For this reason, and also because of the bias towards younger individuals in detailed analyses, a real contribution of old fishes was likely to be slightly higher than that presented in Fig. 6.

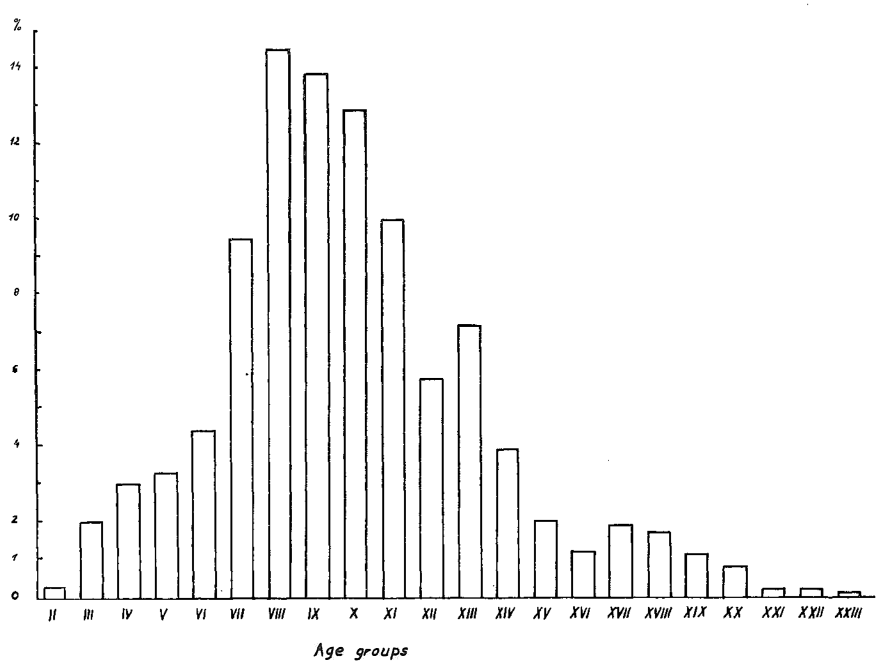

Fig. 6. *Notothenia gibberifrons* age distribution in bottom trawl catches off South Georgia in March and May 1977

GROWTH RATE

Scale oral radius – total length relationship

The yellow notothenia scales are relatively large; as their collection and storage present no greater difficulties, an attempt was made to utilise them in growth rate back

calculations. However, it was difficult to interpret annual rings (zones of closely packed sclerites). The first 3 or 4 rings are very poorly separated (Fig. 7B). Farther rings are fairly clearly set off, but often divided or accompanied by false ones difficult to distinguish from the proper rings. In older fish it was very difficult or even impossible to separate the rings located close to the scale margin.

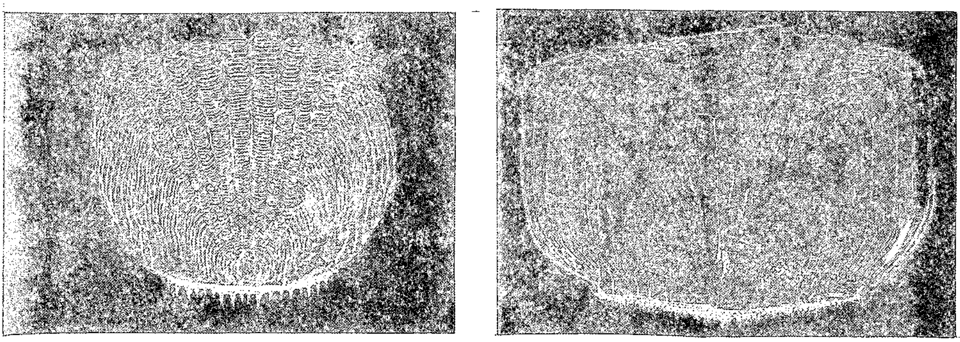

Fig. 7. *Notothenia gibberifrons* scales:
A. Date of capture May 26, 1977; l.t. 18.5 cm; age 3+; magnification 27 x
B. Date of capture May 6, 1977; l.t. 45.0 cm; ♂ V; age 16+; magnification 12.6 x

Fig. 8 presents the results of scale oral radius measurements, the scales being collected from individuals ranging in size within 13.5–50.0 cm. The scale oral radius – total length relationship is curvilinear, the curvilinearity resulting grom a gradual change in the shape of a scale with fish growth (Fig. 7). The following parabolic equation was fitted (the least squares method) to the empirical data:

$$V = -22.3487 + 3.9466 \text{ l.t.} - 0.02477 (\text{l.t.})^2 \quad (2)$$

where V = scale oral radius x 17.5 (mm),
l.t. = total length (cm).

The curve described by the above equation, when extrapolated beyond the empirical data, intersects the abscissa at l.t. of 5.8 cm. If, then, the relationship holds also for the fishes smaller than the smallest one found by the author (13.5 cm l.t.), *N.gibberifrons* is likely to start the scales at the total length of 5.8 cm, on the average. A possibility cannot be excluded that, at least in some fishes, the scales do not appear until the age of 1 and more. If so, such scales would lack the first annual ring. To investigate the matter further, studies on *N.gibberifrons* fry are required.

In view of the difficulties in the interpretation of annual rings, and owing to the presumably delayed growth of scales, they were not considered in back calculations in spite of numerous measurements of growth zones made.

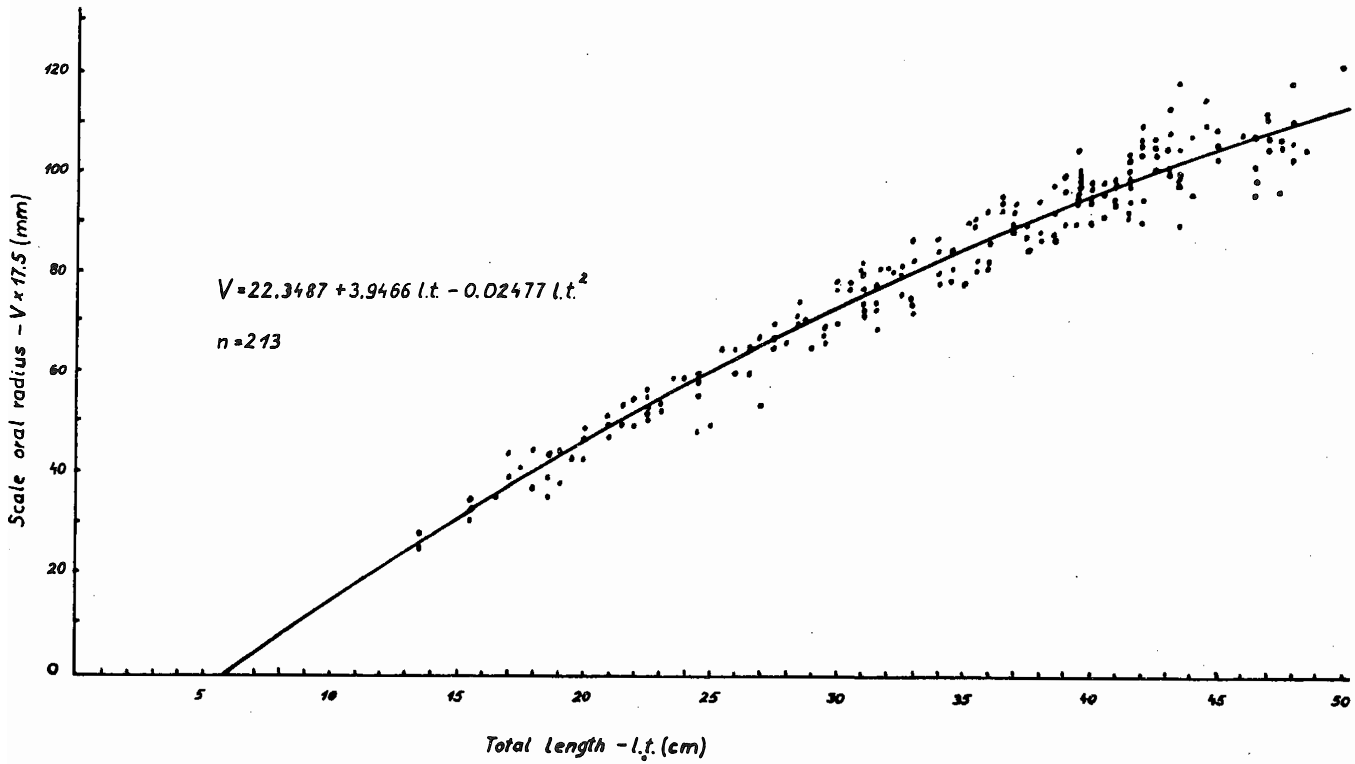

Fig. 8. Relationship between scale oral radius (V) and total length in *Notothenia gibberifrons* off South Georgia

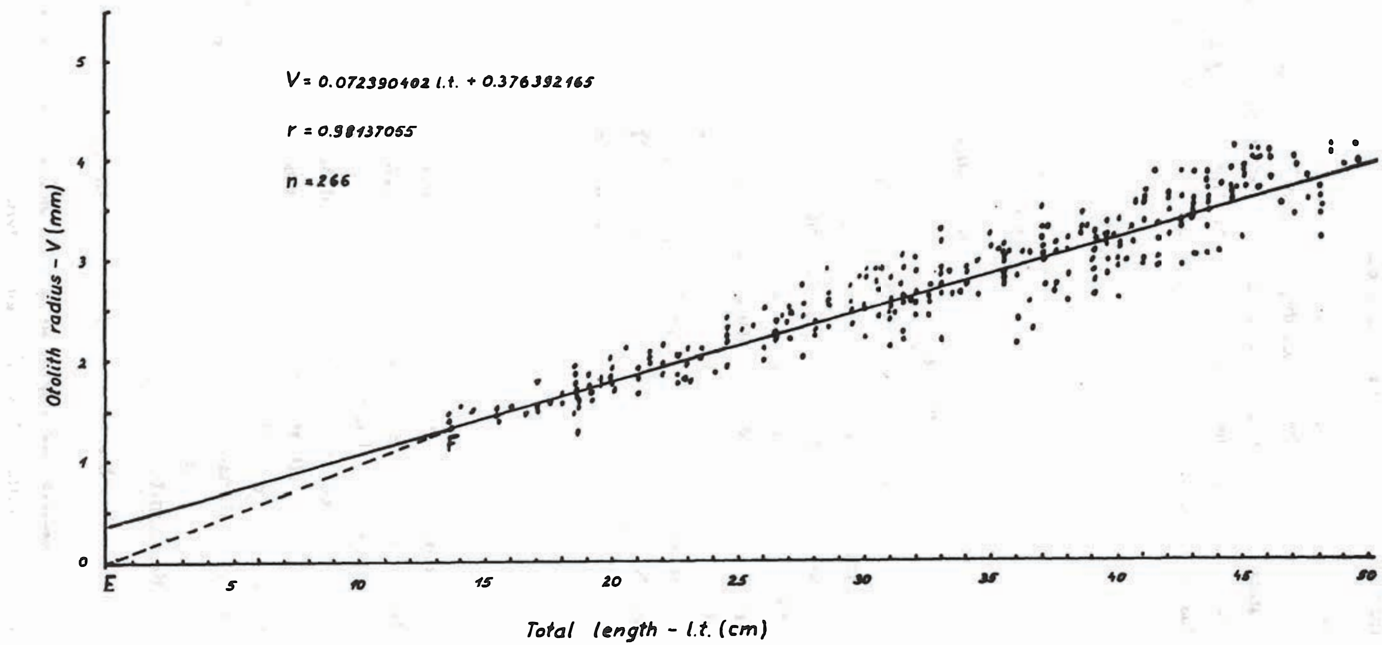

Fig. 9. Relationship between otolith cross-section radius (V) as measured between nucleus and dorsal margin and total length in *Notothenia gibberifrons* off South Georgia. Dashed line (EF) denotes arbitrarily adopted simplified course of relationship from coordinates origin to lower limit of empirical data

Otolith cross-section dorsal radius – total length relationship

Fig. 9 presents data on the cross-section dorsal radius of the otoliths collected from fishes 13.5–49.5 cm long (l.t.). The relationship between the radius and the total length is close to linear within the fish length range studied. A linear equation describing the relationship was fitted to the empirical data by the least squares method. The calculations are based on the mean radii for 0.5 cm fish length classes. The equation is as folows:

$$V = 0.07239 \text{ l.t.} + 0.3764 \qquad (3)$$

or

$$\text{l.t.} = 13.814\, V - 5.1995$$

where V = otolith cross-section dorsal radius (mm)
l.t. = total length (cm)

A high, close to unity, correlation coefficient ($r = 0.9814$) points to a good fit of the equation to the empirical data. However, the line described by the equation intersects the ordinate at some distance from the origin (Fig. 9). One can thus conclude that the fish smaller than the lower limit of the range studied, i.e., 13.5 cm, the otolith radius-total length relationship is of a different nature. At present, however, the lack of data prevents any explanation of the problem. Assuming some simplification, a straight line was drawn between the data point on the line corresponding to the lower size limit and the origin, although the relationship here may be curvilinear. This simplified relationship was adopted in the other of the two methods of back calculations.

BACK CALCULATIONS

The *N.gibberifrons* growth rate was calculated by means of two methods.

The first one involves calculating the mean radius of each growth zone, which results in otolith growth rate (Table 2). Then the lengths attained by the fish in consecutive years of life were reconstructed by inserting mean radii of otolith growth zones into the equation (3) describing the growth zone radius-fish total length relationship. The results obtained are presented in Table 3. The results for lengths in the first and second years of life are most likely underestimates as the equation (3) is fitted to the empirical data within the range of 13.5–49.5 cm total length. Based on data from Table 3, the following parameters of the von Bertalanffy equation were estimated:

$$L_\infty = 57.48 \text{ cm}; K = 0.1040; t_0 = 0.4391 \text{ yr.}$$

When estimating the parameters, the lengths in age groups I, II, and III were disregarded. The asymptotic length (L_∞) obtained is only slightly higher than the maximum length of *N.gibberifrons* recorded off South Georgia (52 cm, Šust and Pinskaja, 1978; 53 cm,

Table 2

Otolith growth rate in *Notothenia gibberifrons* (mean otolith cross-section radius, V_n, in subsequent years of life)

	V_1	V_2	V_3	V_4	V_5	V_6	V_7	V_8	V_9	V_{10}	V_{11}	V_{12}	V_{13}	V_{14}	V_{15}
V_n (mm)	0.62	1.02	1.36	1.67	1.94	2.20	2.43	2.64	2.81	3.01	3.17	3.28	3.45	3.49	3.62
$\pm\delta$	0.1178	0.1546	0.1948	0.2242	0.2439	0.2595	0.2620	0.2743	0.2625	0.2715	0.2851	0.2924	0.2308	0.1975	0.1570
$\pm m$	0.0078	0.0104	0.0131	0.0158	0.0182	0.0207	0.0221	0.0260	0.0290	0.0357	0.0416	0.0525	0.0481	0.0595	0.0555
n	224	223	220	202	179	157	140	111	82	58	47	31	23	11	8

Table 3

Length growth rate of *Notothenia gibberifrons* (total length, l.t., cm) calculated from equation: l.t. = 13.814 V – 5.1995 by inserting mean otolith radius (V_n) in each year; and theoretical growth rate according to von Bertalanffy equation

	Mean fish length in subsequent years of life														
	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}	L_{14}	L_{15}
Back calculations	3.38	8.93	13.55	17.83	21.65	25.18	28.35	31.22	33.65	36.42	38.53	40.07	42.44	43.01	44.81
Theoretical growth rate	3.26	8.62	13.44	17.78	21.70	25.24	28.42	31.29	33.88	36.21	38.31	40.20	41.91	43.45	44.83

Skóra, 1979). Theoretical lengths in subsequent age groups as calculated by means of the equation are presented in Table 3. As can be seen, the theoretical lengths are close to data from back calculations. Boronin and Altman's (1979) estimation of growth parameters for the years 1969–1974 differs somewhat from the present results: $L_\infty = 52.9$ cm; $K = 0.15$; $t_0 = 0.7$ yr. The differences are most likely brought about by a different growth rate estimation method used by those authors.

The other method of back calculations is applied after Wowk (1955) with a modification such that the otolith radius corresponding to the length of a given fish was first read from the graph (Fig. 9). This radius was then divided by the real otolith radius of the fish measured. The quotient obtained was treated as a correction factor to multiply it by the otolith radius at a given age, and a fish length corresponding to the corrected radius was read from the graph. For length readings smaller than 13.5 cm, an arbitrary, simplified otolith radius-fish length relationship was used, the relationship being expressed in Fig. 9 as a straight line connecting the coordinates origin with the lower limit of empirical data. The method described above allows to follow the individual variability in growth (Table 4), while the first procedure yields a mean growth rate only. As can be seen, individual variability in the *N.gibberifrons* growth rate is quite remarkable, particularly in the first few years of life.

The *N.gibberifrons* growth rates were followed separately in males and females to find out if there is any sexual dimorphism reflected in the species growth. Furthermore, growth rate of immature individuals (i.e., those in which sex could not be determined by eye) was examined as well. As seen from Table 4, growth rates of all three categories are similar. Boronin and Frolkina (1976) and Šust and Pinskaja (1978) did not observed any significant differences in growth rate between males and females either.

When the results obtained with the two methods are compared, a correspondence within the range of $L_3 - L_{12}$ is observed. The differences in the results for age groups XIII-XIV are most likely brought about by a small amount of data collected. On the other hand, considerable discrepancies between the results for L_1 and L_2 obtained with the two methods are caused by the arbitrarily adopted curve reflecting the fish length-otolith radius relationship.

LENGTH AND AGE AT FIRST MATURITY

The catches contained both mature and immature individuals. Gonads of the mature ones were at the Maier scale stages II-VI, no higher stage being ever observed. The wide length range of the fish examined allowed to determine the length and age at the first maturity. Those individuals whose sex could not be distinguished by eye were considered immature (Maier scale stage I); the remaining ones were regarded as mature. A similar criterion of maturity was applied by Kock (1981) to 3 species of the family *Chaenichthyidae*. The results are presented in Fig. 10; as can be seen, up to 27.5 cm total

Table 4

Growth rate of *Notohenia gibberifrons* Lönnberg off South Georgia. Back calculations from otoliths; Wowk's procedure. Total length (cm)

L_n	Immature individuals				Males				Females				Total			
	$\bar{x}$	±δ	n	Range	$\bar{x}$	±δ	n	Range	$\bar{x}$	±δ	n	Range	$\bar{x}$	±δ	n	Range
L_1	6.1	1.0712	135	3.3– 8.8	6.0	1.1344	37	3.4– 9.3	5.7	1.2386	32	3.4–8.8	6.0	1.1202	204	3.3– 9.3
L_2	10.0	1.4120	135	5.9–13.9	10.3	1.8100	37	7.6–15.7	10.0	1.5538	32	6.9–14.5	10.1	1.5167	204	5.9–15.7
L_3	13.9	2.3022	132	8.8–21.5	13.9	2.8469	37	9.7–21.5	13.4	2.5043	32	9.5–20.9	13.8	2.4514	201	8.8–21.5
L_4	18.2	2.8350	114	11.4–26.4	18.1	3.3936	37	11.9–26.8	17.3	2.6932	32	12.4–24.7	18.0	2.9514	183	11.4–26.8
L_5	22.4	2.8469	94	15.4–29.3	21.9	1.5007	37	15.3–31.5	20.9	2.8556	32	15.4–27.8	22.0	2.6663	163	15.3–31.5
L_6	26.0	2.6206	72	18.8–31.1	25.2	3.8398	37	17.5–34.9	24.3	2.9544	32	18.6–31.1	25.4	3.1342	141	17.5–34.9
L_7	29.0	2.2839	61	22.2–34.0	28.7	3.7195	37	22.0–36.9	28.0	3.3881	31	21.6–37.4	28.7	3.0593	129	21.6–37.4
L_8	31.5	2.4530	38	25.1–36.7	31.4	3.3633	35	25.5–36.3	31.4	3.4052	29	24.5–34.7	31.5	3.0696	102	24.5–36.7
L_9	33.4	2.6200	20	27.5–38.5	33.5	3.1776	30	28.0–38.0	33.5	4.0322	25	28.7–38.1	33.5	3.3600	75	27.5–38.5
L_{10}	34.4	–	4	33.1–35.9	35.6	4.3166	26	30.1–40.2	36.4	2.8935	23	29.5–40.0	35.9	3.6294	53	29.5–40.2
L_{11}	36.9	–	1	–	37.5	6.1338	23	32.1–41.3	38.8	3.0389	20	32.2–43.0	38.1	2.8010	44	32.1–43.0
L_{12}	--	–	–	–	39.5	2.2789	16	34.1–43.1	39.7	2.5524	13	36.0–44.5	39.5	2.4170	29	34.1–44.5
L_{13}	–	–	–	–	40.5	2.1670	12	35.5–43.7	40.8	–	9	38.1–44.0	40.6	2.0546	21	35.5–44.0
L_{14}	–	–	–	–	40.9	–	7	37.7–43.8	42.0	–	3	40.7–43.7	41.2	–	10	37.7–43.8

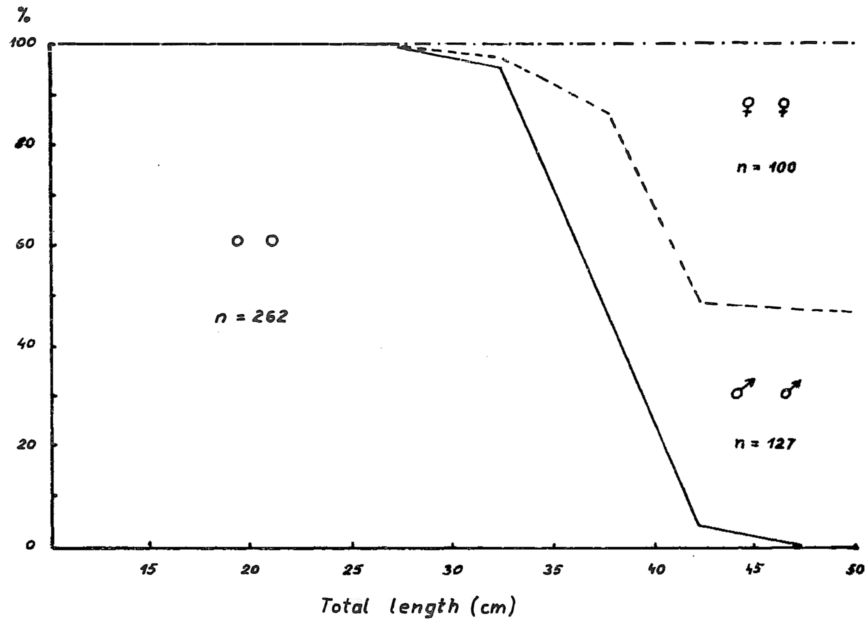

Fig. 10. Immature individuals (oo), females (♀♀), and males (♂♂) in various length classes of *Notothenia gibberifrons* caught off South Georgia in March and May 1977. n = 489.

length, i.e., up to approximately age 7, 100% of the fishes were immature. At 37.5 cm corresponding to the age of 10, sex could not be determined by eye in about half (48.93%) of the individuals examined. At 42.5 cm (i.e., approximately 12th year of life) almost all the individuals (95.54%) were mature, males being slightly more numerous than females (55.95% and 44.05%, respectively).

Kock (1981), following Thurow, considers L_m, the length at the first maturity, to be the size at which 50% of the individuals are mature. In our case L_m = 37.5 cm. Thus *N.gibberifrons* mature rather late. Beverton (1963) introduced L_m/L_∞ as an index describing the fish growth potential after the sexual maturity has been attained. The index for *N.gibberifrons* off South Georgia is 37.5 cm/57.5 cm = 0.65, i.e., 65% of L_∞. Indices for other Antarctic species (off South Georgia) can be invoked here as given by Kock (1981): *Champsocephalus gunnari* matures after 34% of L_∞; *Pseudochaenichthys georgianus* – after 67% of L_∞; females and males of *Chaenocephalus aceratus* mature at 61% and 80% of L_∞, respectively. Another index can be L_m/L_{max}, where L_{max} is the largest fish observed in the catch (Kock, 1981). Off South Georgia, Šust and Pinskaja (1978) observed L_{max} = 52 cm; in Skóra's (1979) data, L_{max} = 53 cm. Thus L_m/L_{max} = 37.5 cm/53 cm = 0.7, i.e., 70%.

DISCUSSION

A few authors only have studied age and growth rate of *N.gibberifrons*. Boronin and Frolkina (1976) determined age from scales and otoliths; furthermore, they found out that scale annual rings had been started during the austral winter (May-September in juveniles and July in mature individuals). According to North et al. (1980), hyaline zones on otoliths of the species are started during the austral winter as well. This is presumably a character common to the notothenids, as shown i.a., by Hureau (1970) and Hureau and Ozouf-Costaz (1980). Boronin and Frolkina (op. cit.) observed the first four annual rings on the *N.gibberifrons* scales to be very poorly set off, which they ascribed to the presumed presence of the species in upper or intermediate water layers during the initial years of life. To prevent errors in age calculations, those authors counted sclerites on those scales that displyed well-marked initial annual rings (zones of densely packed sclerites). Boronin and Frolkina assumed each annual zone to correspond to a certain number of sclerites. Their results confirmed their hypothesis. Thus the fish age can be estimated by counting sclerites on scales with poorly marked initial rings. Unfortunately, this procedure cannot be applied to back calculations. Šust and Pinskaja (1978) studied, i.a., the growth rate of *N.gibberifrons* by scale back reading on the assumption of a direct relationship between the scale radius and fish total length. Skóra (1979) dealed with the *N.gibberifrons* growth rate, too, without, however, giving any indication as to the procedure used. Ciechanowski (1980) used scales to back calculate the *N.gibberifrons* growth rate; he used Wowk's procedure and applied the curvilinear relationship between the scale radius and fish length. Having collected no individuals smaller than 19 cm, he assumed a simplified course of the relationship for the smaller fishes and plotted a tangent to the curve from the origin.

North et al. (1980), when examining procedures for *N.gibberifrons* age determinations, found the scales difficult to interpret: age readings taken from different scales of the same fish showed no agreement whatsoever. The scales showed numerous double and/or false rings difficult to distinguish from the proper ones; moreover, in older fishes' scales it was difficult to separate rings located close to the scale margin. The observations of North et al. (1980) are in a complete agreement with those made by the present author. On the other hand, they found the otoliths, burned and broken, to be readable.

Kelle (1982) studied in detail the utility of various organs of *N.gibberifrons* in age determination and concluded that scales were the best tools for the purpose. He measured between-sclerite distances, stained the scales with silver nitrate, made photographic prints, examined augmented images of the scales on TV screen, and viewed the scales in polarised light. He also considered otoliths to be applicable in age determinations, many otoliths, however, being poorly readable. Kelle used various treatments to increase the otolith legibility and found thin polished sections to be most suitable. However, he did not try the traditional, well-used technique of otolith burning.

As shown in section on back calculations, the *N.gibberifrons* otoliths can be used in the growth rate back calculations. However, there is a lingering question of how reliable

the values of L_1 and L_2 obtained in this way are. Furthermore, it would be interesting to solve the problem of scale growth start. The present author had no individuals smaller than 13.5 cm at his disposal. Presumably, the juveniles of the species are pelagic, thus avoiding the demersal trawl. One can, however, make an attempt to solve those problems in part at least, based on the existing studies on *N.gibberifrons* larvae. Such studies have been scarce so far. Efremenko (1979) described the *N.gibberifrons* larvae caught in the upper 100 m of the South Georgia shelf waters between November and February. The total length of the individuals caught ranged within 8.5–38.5 mm. Wörner and James (1981) described the *N.gibberifrons* larvae caught off South Georgia and in the Bransfield Strait. The mean length of the fish caught off South Georgia in November and December 1975 was 21 mm. Slósarczyk (in press) found that krill catches off South Georgia on April 11–17, 1981 contained a by-catch consisting of, i.a., *N.gibberifrons* larvae measuring (SL) 33–41 mm, which corresponds to the total length of approximately 40–47 mm. Two of the larvae collected he examined in detail (Slósarczyk, pers.comm.). The first, measuring (total length) 46.5 mm, had single scales scattered on the sides, dorsal part, above and behind the pectoral fins. The scales showed 4 sclerites, an empty space and a beginning of the fifth one being observed beyond the last one. The other larva, 44 mm long (total length) displayed no scales.

N.gibberifrons spawns during the austral winter (Boronin and Frolkina, 1976; Skóra, 1979; Wörner and James, 1981). From this time till November-December the juvenile fish attain about 21 mm of the total length and measure 40–47 mm in April next year, which is more than L_1 calculated from equation (3). As determined by Boronin and Frolkina (1976), the period of annual ring formation on scales of the immature fish is fairly long, from May until September. The rings in various individuals can form at different times. Maybe the period of the hyaline zone formation on scales of the immature fish is equally long and takes place at different times in different individuals, too. That could partly account for the wide range of sizes back calculated for the initial period of life.

It seems quite probable that between April (40–47 mm) and the termination of the hyaline zone formation the juvenile *N.gibberifrons* grow to attain the mean length of 60.3 mm, which is the L_1 value as estimated with the second back calculation procedure. Therefore the L_1 values obtained with this method should be considered more reliable.

As seen from the preliminary observations by Slósarczyk already referred to, the larvae start the scales in April. More comprehensive studies on larval biology are needed before the question whether the scales will appear in all the fish by the end of the austral summer and if 19–25 sclerites (the average number given by Boronin and Frolkina, 1976 as occurring in front of the first ring) will have time to form can be observed.

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BADANIA NAD SZYBKOŚCIĄ WZROSTU ŻÓŁTEJ NOTOTENII, *NOTOTHENIA GIBBERIFRONS* LÖNNBERG, 1905 Z REJONU PD. GEORGII

STRESZCZENIE

Materiał zebrano na łowiskach Pd. Georgii w marcu i maju 1981 r. (tab. 1). Między długością całkowitą (l.t) i długością ciała (l.c.) istnieje zależność: l.c. = 0.8848 l.t. – 0.3801. W połowach występowały ryby o długości od 13.5 do 50.0 cm (rys. 4) i wieku od 2+ do 23+ lat. Wykazano nieprzydatność łusek do odczytów wstecznych szybkości wzrostu ze względu na słabą czytelność środkowych partii, a u ryb starszych – również części peryferyjnych (rys. 7). Zależność między długością promienia oralnego łuski (V) i długością całkowitą ryby jest krzywoliniowa wg równania: $V = -22.3487 + 3.9466 \text{ l.t.} - 0.02477 \text{ l.t.}^2$. Krzywa wyrażona tym równaniem przecina oś odciętych w miejscu odpowiadającym 5.8 cm długości całkowitej ryby, co sugeruje zakładanie się łusek u *N.gibberifrons*, gdy osobniki tego gatunku mają przeciętnie 5.8 cm. Wykazano przydatność prażonych i przełamywanych otolitów do odczytów wstecznych szybkości wzrostu. Zależność między grzbietowym promieniem powierzchni przekroju otolitu i długością całkowitą ryby wyraża się dla ryb o zakresie długości 13.5 cm do 49.5 cm równaniem: $V = 0.07239 \text{ l.t.} + 0.3764$ (rys. 9). Obliczone dwiema metodami wartości L_n są podane w tab. 3 i 4. Wiarygodniejsze są L_1 i L_2 obliczone metodą Wowka. W oparciu o dane z tabeli 3 (pomijając L_1, L_2 i L_3) oszacowano następujące parametry równania von Bertalanffy'ego: $L_\infty = 57.48$ cm; $K = 0.104$; $t_0 = 0.4391$ roku. Żółta nototenia osiąga pierwszą dojrzałość płciową przy długości całkowitej 37.5 cm, co odpowiada 0.65% L_∞.

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ИССЛЕДОВАНИЕ СКОРОСТИ РОСТА У ЗЕЛЁНОЙ НОТОТЕНИИ (NOTOTHENIA GIBBERIFRONS , LÖNNBERG , 1905) ИЗ РАЙОНА ЮЖНОЙ ДЖОРДЖИИ

Р Е З Ю М Е

Материал был собран по местам ловли на территории южной Джорджии на протяжении месяцев марта и мая 1981 г. (таб.1). Между длиной в целом (l.t) и длиной тела (l.c.) существует зависимость: l.c. = 0.8848 l.t.-0.3801. Из ловли была получена рыба длиной с 13,5 до 50,0 см (рис.4) и в возрасте с 2+ до 23+ лет. Установлено непригодностъ чешуи для обратных расчислений темпа роста из-за небольшой чёткости центральных участков, а у более старых особей - также периферийных участков (рис.7). Зависимость между длиною орального радиуса чешуи (V) и полной длиною рыбы является криволинейной: $V = -22.3487 + 3.9466 \text{ l.t.} - -0,02477 \text{ l.t.}^2$ Кривая, изображенная этим уравнением пересекает ось абсцисс в точке соответстующей величине 5,8 см полной длины. На основании этого можно предполагать, что у

N.gibberifrons закладка чешуи происходит, когда особи этого вида представляют собой в среднем 5,8 см длины. Показана пригодность каленных и преодоленных отолитов для обратных расчислений темпа роста. Для рыбы длиной с 13,5 см до 49,5 см зависимость между хребтовым радиусом поверхности разреза отолита и полною длиною рыбы изображает уравнение:
V = 0.072391.t. + 0,3764 (рис.9).
Величины L_n, вычисленные с употреблением двух методов, составлены по таб. 3 и 4.

Более достоверными являются величины L_1 и L_2 вычисленные по методу Вовка. На основании данных, составленных в таб.3 (за исключением L_1, L_2 и L_3) оценивались следующие параметры уравнения von Bertalanffy: L_∞ = 57.48 см; K = 0.104; t_o = 0.4391 года. У зелёной нототении первая половая спелость

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Received: 8 July 1983