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Fish biology

GROWTH RATE OF ZANDER (*STIZOSTEDION LUCIOPERCA* L., 1758) IN THE WATERS OF MIĘDZYODRZE IN 1996–1998

WZROST SANDACZA (*STIZOSTEDION LUCIOPERCA* L., 1758) W WODACH MIĘDZYODRZA W LATACH 1996–1998

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Growth rate of zander (European pikeperch) was studied in the waters of Międzyodrze—the wetland area situated in the lower course of the River Odra, Poland. The fish, 546 individuals, were caught with fyke-net. Of the total number, 544 zander were aged and 379 were studied for growth rate using back calculations. Edge coefficient, K_r, was used to verify age determination. The linear growth rate of zander was similar to this characteristic of the fish living in adjacent waters in the corresponding period of time, however, clear differences were observed when compared to previous studies in the region, carried out 10 and 20 years before.

INTRODUCTION

The studied zander population is targeted by local fishers in Międzyodrze, a delta area of the river Odra, located between Widuchowa and Szczecin, where the river splits into two arms. Międzyodrze is a wetland area with a network of sluggish channels open to the lotic waters of the river. The boundaries of the studied population have not been clearly determined. Growth of zander was last studied in the mid-1970s by Krzykawski and Szypuła (1982) in the Regalica, the right-bank arm of the Odra. Analogous studies were conducted in the Szczecin Lagoon and its adjacent waters (Wiktor 1954; Krzykawski and Szypuła 1982; Szypuła 1996, 1998; Neja and Turowska 1998). The aim of the present study was to describe growth rate of length and weight of the Międzyodrze zander population and to compare obtained results with the data by other authors.

MATERIAL AND METHODS

The fish for the studies were collected from commercial catches carried out in a Międzyodrze channel called "Stara Regalica", a few kilometres upstream from the town of

Gryfino. Deepwater eel fyke-nets were used for the catches, with 4 m high entrance chamber and with the side wings length 50–70 m, depending on the gear actual location. The stretched mesh size of the last chamber (bag) was 15 mm. Total length (*TL*) and standard length (*SL*) were measured to 5 mm. Total body weight, W_1, and eviscerated body weight, W_2, were determined to 1 g.

Table 1

Analyses breakdown

Analysis	n			
	1996	1997	1998	Total
Length and weight measurements	225	144	177	546
Ageing	223	144	177	544
Back-calculations	147	103	129	379

Age and growth rate estimation was based on scales collected from the left side of a fish, below lateral line, at the tip of pectoral fin, according to the method described by Nagięć (1961). The scales were cleaned with detergent solution and viewed at 17.5× magnification. Around the scale focus, a zone of crowded sclerites could be seen, and its ridge was interpreted as juvenile ring. The first annulus was expected to be found between the average scale radius of the young-of-the-year fish, with or without an annual ring near the edge. On the whole, the scales of 544 fish were qualified for age reading, and only two individuals (0.37%) had unreadable scales.

The age of a fish was basically determined as the number of annuli, however, during the months of annulus formation, also the increment around the most recent annulus was taken into account. The rationale presented by Kompowski and Horbowy (1997) was applied for ageing decisions and for birth date determination. In order to delimit the period of annulus formation, the edge coefficient, K_r, was calculated for each scale (Szypuła 1998):

$$K_r = \frac{R - r_n}{r_n - r_{n-1}}; \qquad (1)$$

where: R—oral scale radius; r_n—radius measured from the focus to the most recent annulus; r_{n-1}—radius measured from the focus to the previous annulus. The value $K_r > 0.5$ was considered as the "critical" value that allowed qualifying an individual to the age group one year older than if resulted from the number of annuli (Szypuła 1998).

The zander growth rate was estimated from back-calculations of length at age, however, for comparability with data by other authors (Krzykawski and Szypuła 1982; Szypuła 1996, 1998; Neja and Turowska 1998), the length at age was also estimated as average length of given age group.

The radii measurements for back-calculations were done on the oral part of a scale. The measurements were then converted to length at age using previously derived relationship between fish length and scale radius (L–R relationship). The linear function describing the relationship was as follows:

$$L = a + bR\,; \qquad (2)$$

where: L—fish length; R—oral radius length; a and b—constants.

The lengths in consecutive years of life were calculated according to the Ricker-Lagler formula (Tesch 1968):

$$l_n = a + b\frac{R}{\hat{R}}r_n\,; \qquad (3)$$

where: l_n—length at age; a, b and R—as in equation (2); r_n—radius of annulus; $\hat{R}$—total scale theoretical radius calculated from equation (2).

Additionally, in order to compare the results with other authors (Neja and Turowska 1998), the Whitney-Carlander back-calculation formula was applied (Francis 1990):

$$l_n = L\left(\frac{a + br_n}{a + bR}\right); \qquad (4)$$

where a and b—as in (2).

Apart from the above equations, in which the linear L–R relationship was used, length at age was also calculated by non-linear L R function with so called *standard*, i.e. the length at which scale formation moment is observed. For zander, the *standard* has been reported to be 2.5 cm (Szypuła 1996, 1998). The following power equation was estimated:

$$L = 2.5 + cR^d; \qquad (5)$$

where c and d—parameters derived basing on empirical values.

In this case, the theoretical length at age was calculated with equation (3), whereas the equation (5) was used for theoretical scale radius computation, after conversion to the following form:

$$\hat{R} = \exp\left[\frac{1}{d}\ln\left(\frac{L - 2{,}5}{c}\right)\right]; \qquad (6)$$

The theoretical growth of zander was described with use of back-calculations results, and the parameters of von Bertalanffy equation were estimated:

$$L_t = L_\infty\{1 - \exp[-K(t - t_0)]\}; \qquad (7)$$

where: L_t—length at age t; L_∞, K and t_0—parameters derived basing on empirical values.

RESULTS

Fig. 1 presents the variability of mean edge coefficient, K_r, expressed by the coefficient of variability, V, throughout the year. The mean edge coefficient was the highest in January (0.62), when nearly 62% of the fish showed this value being over 0.5. All the fish caught in January had the K_r higher then 0.3. As the dispersion of the values was relatively low ($V = 0.34$) as compared with the other months, the annual ring to be formed in the given season had not probably appeared on the scale yet. Direct scale examinations confirmed this assumption. In the following months, the mean value of K_r gradually decreased, whereas its variability increased, reaching its peak in June. In July the edge coefficient reached the minimum (0.18), with its variability decreasing as well, by nearly 1/3 as compared to June.

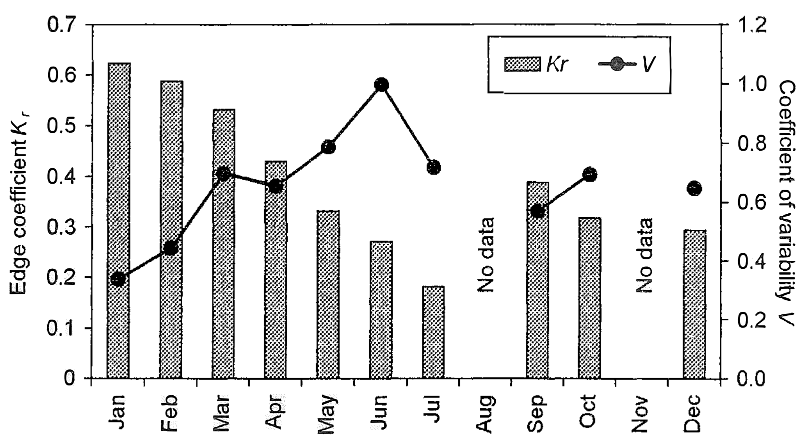

Fig. 1. Mean value and variability of edge coefficient, K_r, by month during 1996–1998

It was then assumed that in July, as well as in the remaining months of the second half of the year, the majority of individuals formed their annual rings. The period of intensified annuli formation were the months May–June, and 1 June was assumed as the birth date.

The relationship between body length and scale radius, in its linear form, was estimated as follows:

$$L = 5.11 + 7.25R \tag{8}$$

The parameters ($a = 5.11$) and ($b = 7.25$) were used in the equations (3) and (4), in order to calculate the consecutive lengths at age, l_n.

The length were also calculated according to the estimated non-linear function:

$$L = 2.5 + 9.02R^{0.91} \tag{9}$$

These parameters (c = 9.02) and (d = 0.91) were applied to the equation (6) for the theoretical scale radius computation:

$$\hat{R} = \exp\left[1.099 \cdot \ln\left(\frac{L - 2.5}{9.02}\right)\right] \tag{10}$$

The values derived from the above equation were used to calculate theoretical length at age with the equation (3).

To estimate the parameters of von Bertalanffy equation, the back-calculated lengths at age of 379 individuals from age groups 1–6 were used. Older individuals were ignored, due to their minor representation. The results of the estimation of von Bertalanffy equation parameters, along with the breakdown of empirical (l_i) and theoretical ($\hat{l}$) length at age values, are presented in Tab. 2.

Table 2

Mean lengths, *SL* (cm), at age, *t*, calculated with various methods. l_i—back-calculations data, $\hat{l}$ —theoretical lengths derived from von Bertalanffy equation

Back-calculation formula		l_1	l_2	l_3	l_4	l_5	l_6	L_∞	k	t_0
Ricker-Lagler (3)	l_i	21.2	30.9	39.1	44.8	49.8	55.6	61.5	0.342	–0.056
	$\hat{l}$	18.7	31.1	39.9	46.2	50.6	53.8			
Ricker-Lagler (3)*	l_i	21.2	30.9	39.1	44.8	50.0	56.0	62.5	0.333	–0.060
	$\hat{l}$	18.6	31.0	39.9	46.3	50.9	54.1			
Whitney-Carlander (4)	l_i	19.2	29.8	38.4	44.3	49.6	55.5	64.3	0.303	–0.045
	$\hat{l}$	17.5	29.7	38.8	45.5	50.4	54.0			

* for non-linear *L–R* relationship

Table 3

Mean lengths at age calculated with Ricker-Lagler equation

Age	n	l_1	l_2	l_3	l_4	l_5	l_6
1	115	21.5	—	—	—	—	—
2	89	19.4	28.3	—	—	—	—
3	71	21.6	31.5	37.7	—	—	—
4	59	22.0	32.7	39.8	43.8	—	—
5	37	22.6	32.5	39.9	45.4	49.2	—
6	8	22.9	34.4	42.7	48.8	52.6	55.6
Total	379	21.2	30.9	39.1	44.8	49.8	55.6
	n	379	264	175	104	45	8
	SD	4.4	6.1	6.4	5.7	5.4	6.0
	V	20.9	19.6	16.4	12.8	10.9	10.7

Detailed data on the mean lengths at age, calculated with Ricker-Lagler formula, is presented by particular age groups in Tab. 3. The von Bertalanffy growth curve plot is displayed in Fig. 2.

The lengths at age achieved by particular age groups are presented in Fig. 3. This demonstrates that older fish reached larger size at a given age, compared to younger individuals.

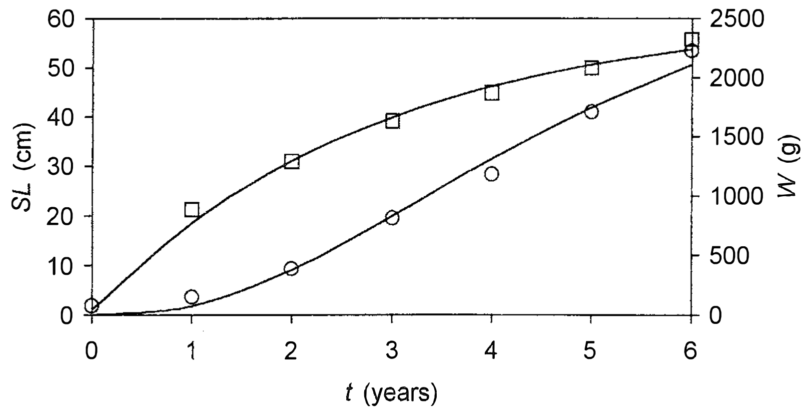

Fig. 2. Von Bertalanffy curves of length and weight growth of zander, estimated using Ricker-Lagler back-calculation formula

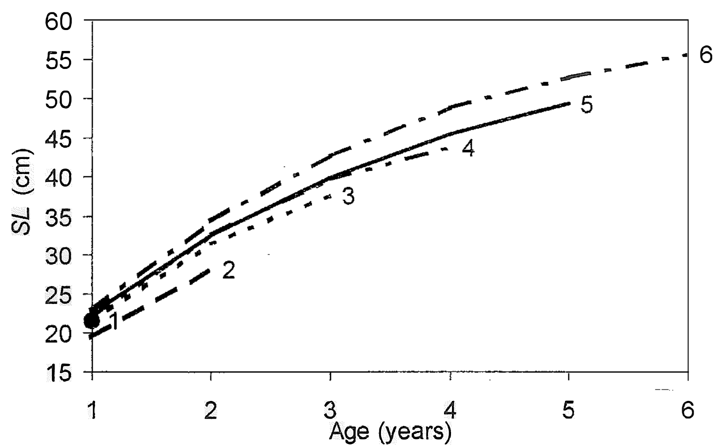

Fig. 3. Length at age for particular age groups

The length–weight relationship (L–W) was estimated based on total length (TL), and total body weight, W_1. These data (n = 546) were used to estimate the following power expression ($R^2 = 0.995$):

$$W = 0.0092L^{3.11} \tag{11}$$

The mean total body weights by immature, male and female individuals were calculated from direct weight measurements and are presented in Tab. 4.

The weight growth pattern was approximated for the entire sample, basing on the linear growth parameters evaluated with the three mentioned back-calculation formulas. Using the parameter $n = 3.11$ of the L–W relationship, the growth rate of weight was estimated according to the modified von Bertalanffy equation for weight growth. The results are presented in Tab. 5, and the respective curve is shown in Fig. 2.

Table 4

Mean body weight at age

Age	Immature		Males		Females		Total	
	W_1 (g)	n	W_1 (g)	n	W_1 (g)	n	W_1 (g)	n
0	82	93					82	93
1	153	170	283	3			155	173
2	338	57	448	16	600	10	391	83
3	346	21	1025	17	1163	18	815	56
4	572	9	1348	20	1273	23	1180	52
5	915	1*	1652	21	1792	24	1709	46
6	1060	1*	2158	17	2378	15	2225	33
7			3062	3			3062	3
8			3230	1	3922	2	3691	3
10					5015	2	5015	2

*sex not determined

Table 5

Zander body weight growth estimated with direct measurements and from back-calculated lengths using L–W relationship (g)

Data/Method	Age						W_∞
	1	2	3	4	5	6	
Direct weight measurements	155	391	815	1180	1709	2225	—
Weight data from back-calculated lengths							
Ricker-Lagler	78.5	383	834	1312	1746	2108	3203
Ricker-Lagler*	76.0	374	821	1303	1747	2122	3308
Whitney-Carlander	64.8	338	773	1267	1746	2170	3733

* for non-linear L–R relationship.

DISCUSSION

According to Krzykawski and Szypuła (1982), who studied the growth rate of zander in the Regalica River, annuli formation took place mainly in May, when the most variable edge increments were observed. Szypuła (1996) stated that in Pomeranian Bay, this period was observed to be prolonged, expanding from February to May. In the present study, the period of the most intensive annuli formation was observed in May and June, and the date of birth was assumed to be 1 June, however, new annuli were also observed as early as in February. This corresponds to the data by many authors who stated that the "precision" of determination of annuli formation time can reach several months (Nagięć 1961).

The growth of zander inhabiting Central European inland and coastal waters remains relatively stable, as far as its rate and pattern is concerned, despite the biotic and abiotic differences among the bodies of water (Nagięć 1961). Comparing this characteristic in various regions of zander distribution, Nagięć (1961) found differences in zander growth depending of the climate zone of the population territory; the most rapid growth was recorded in the Caspian basin, and the slowest growth rate in Scandinavian waters. Clear differences in growth rate can be even observed for the zander populations living within Scandinavian inland waters and the Baltic itself; the farther north, the slower is the local zander growth (Lehtonen et al. 1996). However, the growth rate can vary within the same body of water in a longer period of time, mainly due to long-term environmental changes (Neja and Turowska 1998).

The comparison of body length in the first year of life of the fish caught in 1996–1998 (own data) and the zander caught in 1975–1976 (Krzykawski and Szypuła 1982) in the Regalica—the river branch adjacent and connected to the studied area—displays a difference in this characteristic. The size of one-year-old fish in the present study was larger by 1.6 cm. Greater differences, also in favour of the recent period, can be observed for age groups II (4.2 cm) and III (3.9 cm). In age group IV the difference decreases to 1.8 cm, and the pattern becomes reversed, as the six-year-old fish were observed to attain smaller sizes at the recent period of study, than in the mid-1970s (by 5 cm on the average).

Also, if compared to previous studies in the neighbouring waters of Lake Dąbie (Krzykawski and Szypuła 1982; Neja and Turowska 1998), the pattern of differences appears to be similar. The fish of age groups I–III displayed more rapid growth in Międzyodrze in the late 1990s than the same age fish 10 or 20 years before, whereas older, five- and six-year-old zander attained larger sizes in the past. The same effect was observed when compared to the Szczecin Lagoon population studied in the mid-1980s (Neja and Turowska 1998). Different ageing precision can be possible explanation of these differences, however on the other hand, they may have resulted from the time lag. Within such long span of time the growth pattern may have changed, which can be confirmed by the comparison of the present data to the recent results by Szypuła (1996, 1998) who studied Pomeranian Bay zander in the parallel period of time (Tab. 6).

Comparing the growth data in the corresponding period of time, it can be observed that the present results display similar pattern to those obtained by Szypuła (1996, 1998) in Pomeranian Bay. In the first year of life, the Pomeranian Bay zander—belonging to the population of Szczecin Lagoon (Kraczkiewicz 1969)—grew faster, however, larger sizes can be observed for two-year-olds in the studied area, and after that, the growth of older age groups is parallel in both areas.

A considerable variability in length at age was observed in the studied area, especially for the youngest fish, as in the first age group the coefficient of variability was 21%. Krzykawski and Szypuła (1982) recorded lower length variability within age group I in Regalica: about 11% in 1975 and over 17% in 1976. In Lake Dąbie, the variability within this age group was 10–16% (Krzykawski and Szypuła 1982; Neja and Turowska 1998), and in the Szczecin Lagoon it was approx. 11% (Neja and Turowska 1998). The variability of length at age decreases with age, and in the present study was the lowest for the six-year-old fish, about 11%.

Table 6

Comparison of pike-perch linear growth rate in various bodies of water

Area of study	Length at age (*SL* in cm)										Reference
	l_1	l_2	l_3	l_4	l_5	l_6	l_7	l_8	l_9	l_{10}	
12 Masurian lakes[2]	14.6	25.5	35.8	43.8	49.7	54.2	59.1	59.3			Nagięć 1961
24 north Germany lakes	13.0	24.0	34.0	43.0	49.0	55.0	56.0	57.0		70.0	Bauch, after Nagięć 1961
Vistula[2]	15.1	25.0	37.8	47.5	54.8	62.2	62.6	70.2	73.5		Nagięć 1964
Vistula Lagoon[1, 6]	19.7	31.2	40.1	49.5	—	50.9	52.9	58.5	64.9	67.7	Filuk 1955
Pomeranian Bay[4]	22.2	30.0	37.5	43.9	49.5	53.7					Szypuła 1996
Pomeranian Bay[4]	19.4	27.5	34.3	40.2	46.5	51.4	53.9	55.1			Szypuła 1998
Szczecin Lagoon[1, 5]	14.5	26.0	37.9	46.8	52.9	59.3	63.8	67.6			Neja and Turowska 1998
Szczecin Lagoon[1, 6]	19.0	27.3	37.0	44.7	53.1	58.9	64.3	69.2	71.8		Wengrzyn[7]
Lake Dąbie[3]	16.9	26.2	34.4	43.3	52.0	58.0	65.2	69.3	72.4	79.1	Krzykawski and Szypuła 1982
Lake Dąbie[1, 5]	14.8	26.2	36.3	45.7	54.5	57.6					Neja and Turowska 1998
Regalica[3]	17.1	26.9	36.0	44.4	51.0	58.8	65.3	67.4			Krzykawski and Szypuła 1982
Międzyodrze[6]	24.2	32.0	39.3	45.9	52.1	57.7					Present study
Międzyodrze[3]	18.7	31.1	39.9	46.2	50.6	53.8					
Międzyodrze[4]	18.6	31.0	39.9	46.3	50.9	54.1					
Międzyodrze[5]	17.5	29.7	38.8	45.5	50.4	54.0					

[1] results in *TL* converted to *SL*

[2] Dahl-Lea method

[3] Ricker-Lagler method

[4] Ricker-Lagler method for non-linear *L–R* relationship

[5] Whitney-Carlander method

[6] direct measurements

[7] after Neja and Turowska 1998

As it was illustrated in Fig. 3, the back-calculated length values are higher for older age groups. Neja and Turowska (1998) recorded a similar effect in both Lake Dąbie and the

Szczecin Lagoon. Also the data by Krzykawski and Szypuła (1982) display similar pattern. This probably demonstrates higher mortality of slow-growing individuals. It should be stressed that the gear used for samplings in this study was of low selectivity, as a proportion of juvenile fish caught was considerably high (about 65%). Many authors have observed a reversed pattern (Lee effect), based on the samples collected with selective gears. This has been explained with higher vulnerability of rapidly growing individuals.

As far as individual weight is concerned, the studied zander were heavier than those examined by Krzykawski and Szypuła (1982) and by other authors (Tab. 7). However, different sampling periods might have caused a bias restraining any further conclusions, as the fish for the present study were collected mainly in the first halves of the studied years, during the period of gonad development.

Table 7

Comparison of individual weight growth in different bodies of water (g).

Area of study	Method* or data type	Age 1	2	3	4	5	6	Reference
Pomeranian Bay	Ricker-Lagler**	95	258	506	978	1500	2161	Szypuła 1996
Pomeranian Bay	Ricker-Lagler**	72	255	551	929	1351	1787	Szypuła 1998
Szczecin Lagoon	Whitney-Carlander	48	259	782	1456	1084	2935	Neja and Turowska 1998
Vistula Lagoon	empirical data	—	—	754	1124	1509	2010	Filuk 1955
Lake Dąbie	Ricker-Lagler	31	212	591	1168	1904	2754	Krzykawski and Szypuła 1982
Lake Dąbie	Whitney-Carlander	43	237	644	1316	2264	2687	Neja and Turowska 1998
Regalica	Ricker-Lagler	30	238	672	1287	2007	2767	Krzykawski and Szypuła 1982
Międzyodrze	empirical data	155	391	815	1180	1709	2225	This paper
	Ricker-Lagler	79	383	834	1312	1746	2108	
	Ricker-Lagler**	76	374	821	1303	1747	2122	
	Whitney-Carlander	65	338	773	1267	1746	2170	

* back-calculation formula for the modified von Bertalanffy equation
**for non-linear *L–R* relationship

Neja and Turowska (1998) reported that in the Szczecin Lagoon the females in age groups I–IV attained larger individual weight than the males, whereas at older age the males were heavier. In Lake Dąbie, on the other hand, the growth of weight for males and females was correspondent during the first two years of life, and in the older age groups the females where heavier. The results of the present study do not allow to conclude on any differences in body weight between males and females (Tab. 4).

CONCLUSIONS

1. Annuli on the scales of Międzyodrze zander form most frequently in June, however, the process is prolonged in time, and some individuals may form annuli as soon as in February, which confirms other authors' observations.
2. The pattern and rate of growth for the studied zander population was similar to the zander in the Pomeranian Bay, which was caught during analogous period, whereas the differences could be observed if compared to the zander studied 10 or 20 years before in the Regalica, Lake Dąbie, and the Szczecin Lagoon.
3. Younger individuals showed slower growth rate than those of older age groups, which probably demonstrates that the faster growing individuals feature higher survival rate.

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WZROST SANDACZA (*STIZOSTEDION LUCIOPERCA* L., 1758) W WODACH MIĘDZYODRZA W LATACH 1996–1998

STRESZCZENIE

Badaniom wieku i wzrostu poddano 546 sandaczy złowionych żakiem głębokowodnym w kanale Stara Regalica na obszarze Międzyodrza w latach 1996–1998. Wiek określono u 544 ryb, zaś 379 osobników posłużyło do określenia tempa wzrostu przy użyciu metody odczytów wstecznych. W celu dokładniejszego określenia wieku ryb obliczono współczynnik krawędziowy łusek, K_r. Zastosowano kilka metod rekonstrukcji długości w poszczególnych latach życia, aby uzyskać dane w dużym stopniu porównywalne do wyników innych autorów. Według metody Rickera-Laglera dla liniowej zależności między długością ciała ryby a promieniem oralnym łuski, uzyskano następujące parametry równania von Bertalanffy'ego: L_∞ = 61,5 cm, k = 0,342 i t_0 = –0,056 roku. Wyznaczono zależność między długością a masą ciała sandacza: $W = 0{,}0092L^{3{,}11}$, a masa asymptotyczna w zmodyfikowanym równaniu von Bertalanffy'ego dla wzrostu masy wyniosła 3203 g.

W wyniku badań stwierdzono, że pierścień roczny zakłada się najczęściej w czerwcu, choć proces ten jest rozciągnięty w czasie i u niektórych osobników pierścień może pojawić się już w lutym, co potwierdza obserwacje innych badaczy. Sandacze w badanym rejonie nie różniły się znacznie charakterystyką i tempem wzrostu od sandaczay z Zatoki Pomorskiej, złowionych w zbliżonym okresie, natomiast wykazywały odmienny kształt krzywej wzrostu w porównaniu do sandaczy łowionych 10–20 lat wcześniej w Regalicy, jeziorze Dąbie i Zalewie Szczecińskim. Młodsze osobniki charakteryzują się wolniejszym tempem wzrostu niż starsze, co może wskazywać na większy procent przeżywalności osobników szybciej rosnących.

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