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Fish biology

GROWTH RATE OF ROACH - *Rutilus rutilus (L.)* IN LAKE DĄBIE

TEMPO WZROSTU PŁOCI - *Rutilus rutilus (L.)* W JEZIORZE DĄBIE

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Length and weight growth rates of roach as well as the lenght-weight relationship were determined from 196 individuals caught in 1992. Separate determinations were made for males and females and for different age groups. The von Bertalanffy equation and the binomial model were used to determine growth. Significance of differences between results obtained for 6 samples of different size, collected within July - October, was compared. Differences between growth rate indicators for the period 1974 -- 1976 and 1992 were evaluated.

INTRODUCTION

A research program on "Growth rate of fish in the unstable environment of the River Odra estuary system" (supported by the State Committee for Scientific Research from funds diverted to statutory activities) was launched in 1992. The work, reported here, on growth rate of roach in the Lake Dąbie is thus a part of a comprehensive project.

In terms of its surface area (56 km^2), Lake Dąbie is the fourth largest freshwater reservoir in Poland. Due to its location within the City of Szczecin, it is exposed to the runoff of municipal and harbour effluents. Additionally, agricultural effluents reach the lake from the east. The hydrochemical regime is unstable and dependent upon the river discharge and the range of the Baltic water inflows [Tadajewski and Rutkowski 1993; Bastidas 1994].

The estuarine nature of the lake and its advanced eutrophication affect living conditions of the fish. The effect can be to some extent reflected in the growth rate. The very rich set of data on roach growth in several hundred Polish lakes, published by Wilkońska [1975], can serve as a reference. It has also been possible to compare temporal changes, as the growth rate of the Lake Dąbie roach was determined in the seventies within the framework of a research project, supported by the Institute of Meteorology and Water Management, on effects of the Dolna Odra power plant cooling water. The data [Filipiak et al. 1975, 1976], so far unpublished, are fully comparable with those used in this work as the fish age was determined by the same persons. The seventies' data served to additionally calculate the von Bertalanffy model parameters in this work.

Apart from evaluating the Lake Dąbie roach growth rate in relation to data collected from other Polish lakes and in relation to temporal changes in the lake itself, the present paper touches upon still another matter. To assess the representativeness of samples of different size, results yielded by several samples collected during one year were compared and significance of differences relative to the overall mean was determined.

MATERIALS AND METHODS

A total of 196 roach individuals, caught in traps within July - October 1992, were examined. The fish were measured to 0.1 or 0.5 cm and weighted whole to 1 g. Both the total (l.t) and body (l.c. = longitudo corporis) lengths were recorded. The latter value was used in all the tables and can be converted to the former with the equation.

$$l.t. = 0.57 + 1.1733\, l.c.\ (r = 0.9987)$$

All the fish except 4 individuals, which were disregarded in growth rate determinations, were sexed. The fish age was determined from scales collected from above the lateral line on the left-hand side of the body. Growth rings on scales of individuals aged up to 10 years were distinct. Growth rate was determined using the Rosa Lee formula applied to back-calculations. Fig. 1 shows the linear relationship between the caudal radius (R) and the body length (l.c.). The correction factor (l.c. at R = 0) was 0.8 cm, i.e. underestimated relative to the mean value of 1.55 cm calculated by Heese [1992] from measurements made also on small fish.

Table 1 provides a detailed description of the 6 samples, while Figs 2-3 show length and age distributions, respectively, of all the individuals examined. Females, twice as abundant as males, prove more long lived and, consequently, larger.

Significance of differences in fish growth between groups of individuals assembled according to various criteria (date of capture, sex, etc.) was tested with the Student's t test. Lengths obtained from back-calculations were used when calculating the von Bertalanffy models. The length-weight relationship was determined with the power function, whereas a modified von Bertalanffy equation served to determine the weight growth rate.

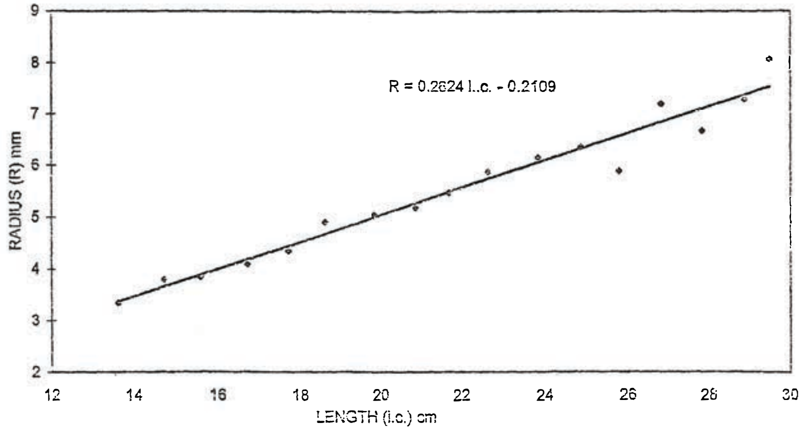

Fig. 1. Scale radius (R) - body length (l.c.) relationship

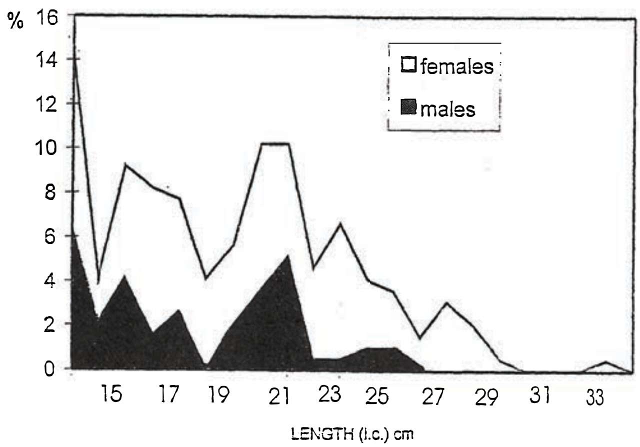

Fig. 2. Sex-dependent length distribution of the roach examined

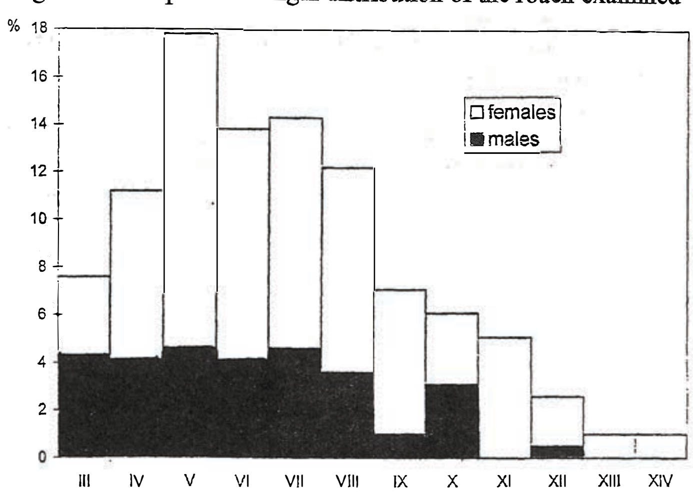

Fig. 3. Age distribution of individuals of both sexes

The binomial and the growth coefficient (GL) as determined by Szypuła [1977] were applied to analysis of length growth rate in different age groups. The growth coefficient is an integer determined within the interval of 0 to t_{max} of the binomial growth equation. The coefficient was slightly modified here as year 10 instead of t_{max} was included as the upper limit of the integer.

Table 1

Description of samples collected in 1992

Date of fishing	Males		Females		Sex indetermined		Total	
	n	length range l.c. cm	n	length range l.c. cm	n	length range l.c. cm	n	length range l.c. cm
10 July	14	13.5 - 23.5	12	13.5 - 29.5	2	14.0 - 21.5	28	13.5 - 29.5
17 July	7	21.0 - 22.0	19	18.5 - 28.5	2	21.0 - 21.5	28	18.5 - 28.5
28 August	8	15.0 - 22.5	26	13.0 - 29.0			34	13.0 - 29.0
28 September	15	13.0 - 22.0	33	13.5 - 33.5			48	13.0 - 33.5
12 October			16	15.2 - 28.0			16	15.2 - 28.0
21 October	14	13.5 - 24.5	28	13.0 - 29.0			42	13.0 - 29.0
Total	58	13.0 - 24.5	134	13.0 - 33.5	4	14.0 - 21.5	196	13.0 - 33.5

RESULTS

Table 2 shows the back-calculation data separately for each of the 6 samples examined as well as means for all the individuals collected in 1992. Differences between lengths in individual samples and the overall mean were regarded as a measure of growth rate variation. The differences proved statistically significant for 2 samples, within a limited period of the roach life in both: the fish caught on 10 July grew to a significantly larger size between years 2 and 6, while those caught on 28 September grew to a significantly smaller size between years 2 and 5. Sample means between those extremes and in the fish older than 6 years did not produce significant differences, when compared to the overall mean (except for 2 instances, year 1 and 7, in the 28 August sample). Noteworthy was the fact that the growth rate in year 1 was uniform: only the difference between the smallest mean length (28 August) and the overall mean bordered on the significance, the difference amounting to as little as 0.21 cm.

As the between-sample differences could have been produced by taking males and females together into account, Table 3 contains data arranged separately for males and females, but only for those samples which showed extreme values in Table 2. Among the females, the 10 July sample is still significantly different from the overall female mean, but for 4 years of life (years 3 to 6) only, while only one length in the 28 September sample showed a difference bordering on the significance. Similar was the case among males: 3 significant differences (years 3 to 5) were retained in the 28 September sample, a single significant difference (year 3) being found in the 10 July sample.

Table 2

Variability in length (l.c. cm) growth rate in the samples
(n - number of individuals; S, standard deviation; t°, empirical value of test function.
Boldface indicates significant differences at $p = 0.05$)

Date of sampling		Age													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
10 July	l.c.	5.05	8.42	11.60	14.08	16.42	18.68	20.09	22.22	21.40	23.23	24.65	26.80	27.80	28.90
	n	26	26	26	18	16	14	10	6	3	3	2	1	1	1
	± S	0.78	1.52	1.59	1.29	1.87	2.23	2.57	3.37	1.04	0.71	1.34			
	t°	0.77	**2.86**	**3.97**	**3.54**	**3.24**	**2.70**	1.51	1.96	0.41	0.02	0.13			
17 July	l.c.	4.93	7.78	10.19	12.53	14.78	16.96	18.99	20.54	22.00	22.97	26.10	26.90		
	n	26	26	26	26	26	26	23	16	9	3	1	1		
	± S	0.62	1.14	1.27	1.18	1.25	1.35	1.21	1.41	1.29	1.43				
	t°	0.16	0.33	0.38	0.42	0	0.02	0.18	0.10	0.27	0.33				
28 August	l.c.	4.74	7.43	10.11	12.60	14.36	16.15	17.34	19.42	21.20	22.50	24.27	24.35	28.00	
	n	34	34	34	33	27	21	12	9	9	7	6	2	1	
	± S	0.40	0.96	1.31	1.35	1.47	1.78	1.70	2.21	2.47	3.01	3.13	3.46		
	t°	**1.99**	1.28	0.71	0.23	1.08	1.59	**2.23**	1.53	0.89	0.79	0.51	1.06		
28 September	l.c.	4.93	7.26	9.61	12.00	13.89	16.26	18.71	19.91	21.51	23.09	24.22	25.25	26.00	25.80
	n	48	48	48	47	38	25	20	13	9	7	5	2	2	1
	± S	0.60	1.08	1.73	2.02	2.45	3.23	3.45	1.25	1.48	1.43	1.70	0.64	1.13	
	t°	0.21	**2.39**	**2.73**	**2.78**	**2.41**	1.32	0.30	1.05	0.50	0.21	0.60	0.58	0.73	
12 October	l.c.	4.79	7.51	10.17	12.56	14.69	16.56	18.97	21.07	22.72	24.00	25.43	27.00		
	n	16	16	16	16	15	9	8	7	5	3	3	2		
	± S	0.55	0.79	1.12	1.29	1.01	1.34	1.52	1.49	1.44	1.31	1.59	1.41		
	t°	1.04	0.65	0.35	0.26	0.18	0.54	0.08	0.78	1.07	0.61	0.41	0.55		
21 October	l.c.	5.14	7.98	10.62	13.01	15.40	17.53	19.26	20.61	22.24	23.94	27.05	28.30		
	n	42	42	42	38	34	26	22	17	9	8	2	1		
	± S	0.54	0.97	1.25	1.45	1.75	1.93	2.15	1.73	2.01	2.26	0.49			
	t°	1.91	1.46	1.21	1.18	1.72	1.18	0.66	0.24	0.61	0.81	1.35			
10 July - - 21 October	l.c.	4.95	7.70	10.31	12.61	14.78	16.97	18.90	20.49	21.83	23.26	24.87	26.13	26.95	27.35
	n	192	192	192	178	156	121	95	68	44	31	19	9	4	2
	± S	0.59	1.15	1.54	1.63	1.92	2.23	2.32	1.88	1.76	2.01	2.16	1.92	1.28	2.19

The data in Table 3 evidence sex-dependent differences in growth rate. The fact that the differences between mean lengths were significant in the initial two and the final three years of life compared, those in the mid-life (years 3 - 7) being non-significant, can be explained by a change occurring as the fish grew: males grew faster as juveniles, while females grew faster in later years. As a result, the growth curves cross over, as illustrated in Fig.4 in which the growth rate is based on the von Bertalanffy equation. The curve representing all the individuals is much closer to that of the females, which is a consequence of prevalence of females among the fish examined.

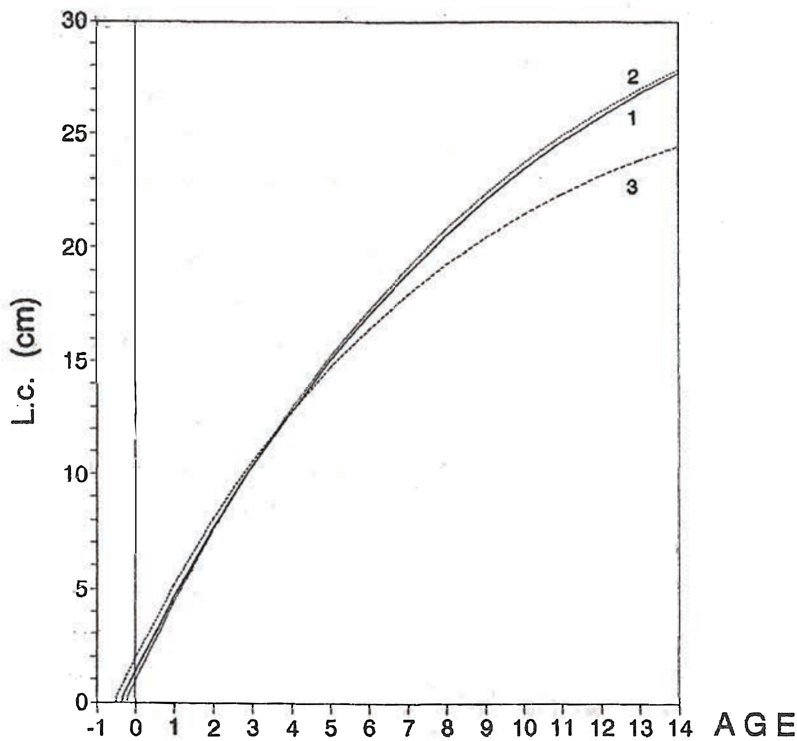

Fig. 4. Length growth curves plotted from the von Bertalanffy model; 1, entire 1992 sample; 2, females; 3, males (equation parametres as in Table 7).

Table 4 groups the fish caught in 1992 by age. Each age group represents a generation born in a different calendar year, between 1978-1989. The data give no evidence that in certain years growth of the roach from at least several age groups would be faster or slower than in other years. The table gives also the binomial terms which describe the growth rate of each generation. In this case the binomial seems to be more appropriate than the von Bertalanffy equation as the beginning of growth is located at point 0 of the time axis. This renders the growth coefficient, i.e. the area between the growth curve and the time axis, comparable. The coefficient used was that determined by the integer covering the year 0 - year 10 interval. The highest coefficient (161) was recorded for the roach aged 3, the values decreasing from 150 to 134 as the fish grew older.

Table 3

Variability in length (l.c. cm) growth rate of males and females (for explanation see Table 2)

	Date of sampling		Age											
			1	2	3	4	5	6	7	8	9	10	11	12
Fema	10 July	l.c.	4.69	8.09	11.39	14.39	17.13	19.55	21.10	22.90	21.75	23.30	24.65	26.80
		n	12	12	12	10	10	8	6	4	2	2	2	1
		± S	0.63	1.45	1.32	1.27	1.89	2.24	2.76	3.66	1.20	0.99	1.34	
		t°	1.07	1.57	**2.61**	**3.13**	**3.49**	**2.80**	1.95	1.88	0.44	0.36	0.35	
		l.c.	4.88	7.17	9.57	12.07	14.12	16.75	19.13	19.97	21.55	23.09	24.22	25.25
		n	33	33	33	32	26	18	16	11	8	7	5	2

Table 4

Length (l.c. cm) growth rate of roach in various age groups in 1992
[GL = $\int_0^{10} (a + bt + ct^2)\,dt$, t = time in years]

Age group	n	Age														l.c. = $a+bt+ct^2$			
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	a	b	c	GL
III	14	5.6	9.2	12.1												2.01	3.830	-0.150	161
IV	22	5.1	8.0	10.9	13.4											1.90	3.280	-0.100	150
V	35	4.7	7.1	9.7	12.6	14.8										2.02	2.613	-0.007	148
VI	26	4.6	7.6	19.6	13.3	15.4	18.0									1.41	3.306	-0.092	149
VII	27	5.1	8.0	10.7	13.1	15.4	17.7	19.9								2.17	3.030	-0.072	149
VIII	24	4.9	7.7	10.3	12.6	14.7	17.0	19.1	21.3							2.32	2.749	-0.049	144
IX	13	5.0	7.5	10.1	12.3	14.5	16.5	17.2	20.6	22.3						2.74	2.490	-0.038	139
X	12	4.8	7.7	10.1	12.3	14.2	16.1	17.8	19.5	21.2	22.8					2.44	2.688	-0.067	137
XI	10	4.6	7.0	9.6	12.0	13.8	15.6	17.6	19.8	21.8	23.6	24.8				2.13	2.559	-0.044	135
XII	5	4.9	7.2	9.1	11.3	13.7	15.8	18.0	20.1	21.8	23.6	25.1	26.2			2.15	2.546	-0.042	135
XIII	2	4.5	7.1	8.9	11.7	13.2	15.5	18.2	20.6	22.2	23.5	24.9	26.2	27.4		1.44	2.792	-0.060	134
XIV	2	4.5	6.8	9.6	11.9	13.9	16.6	18.9	20.6	21.7	23.0	24.4	25.8	26.5	27.3	1.18	3.067	-0.086	137

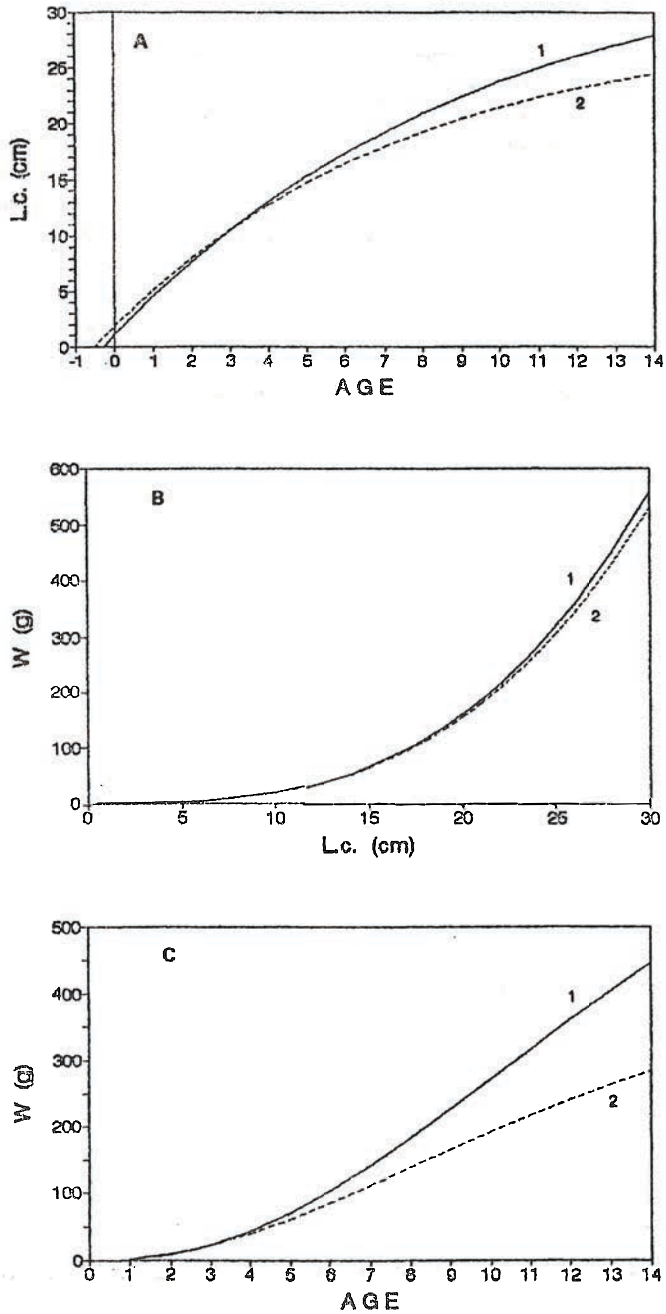

Fig. 5. Growth rate of roach females (1) and males (2); A, length growth; B, length-weight relationship; C, weight growth (equation parameters as in Table 7).

The weight growth rate was calculated once the length-weight relationship was determined. The relationship proved similar for both sexes (Fig. 5). As, however, body weight is proportional to the length cube, the difference between weight growth rate of females and males is more pronounced than that in the length growth. This is illustrated in Fig.5 in which the von Bertalanffy equation was used to plot the growth curves of both sexes. The point of inflection of the weight growth curves, indicating the age at which annual increments start to diminish, falls at year 11 in females and at year 9 in males.

Table 5 compares the 1992 data with those obtained in the seventies. It was only in 4 out of 40 cases examined that the differences between mean length for the two periods were significant. However, even the significant differences produced a range as small as 0.5-1.2 cm in the 15-23 cm length classes. Three out of the four significant differences mentioned were found in the materials obtained in 1975; indeed, the growth curve plotted from those data deviates most from a compact bunch of curves presented in Fig.6. The bunch starts to split as late as past year 10, the differences in the younger fish being almost imperceptible.

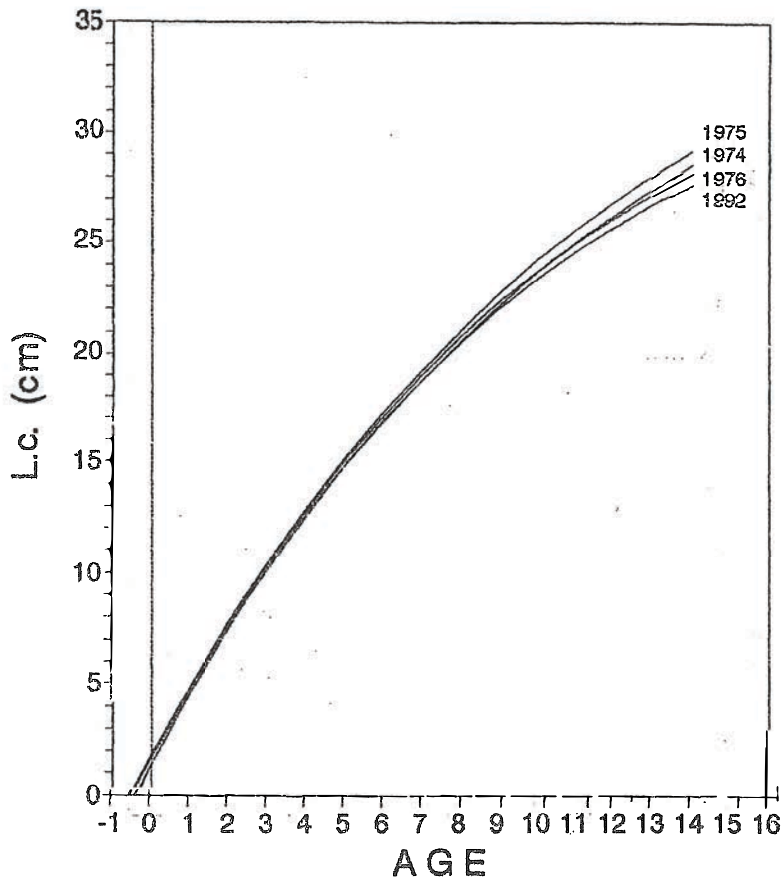

Fig. 6. Length growth rate in different calendar years (von Bertalanffy equation parameters as in Table 7)

Table 5

Length (l.c. cm) growth rate of roach caught in various years
(for explanation see Table 2)

Year		Age														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1992	l.c.	5.0	7.7	10.3	12.7	14.8	17.0	18.9	20.5	21.8	23.3	24.9	26.1	27.0	27.4	
	n	192	192	192	178	156	121	95	68	44	31	19	9	4	2	
	± S	0.59	1.15	1.54	1.63	1.92	2.23	2.32	1.88	1.76	2.01	2.16	1.92	1.28	2.19	
1974	l.c.	4.9	7.6	10.4	12.6	14.8	16.8	18.8	20.5	22.6	24.0	25.1	26.2	27.4	29.7	31.5
	n	200	200	199	150	105	73	42	29	24	20	18	10	8	4	1
	± S	0.60	0.93	1.28	1.52	1.75	1.97	2.06	2.20	1.91	2.04	1.83	1.51	1.56	0.48	
	t^0	1.66	0.95	0.70	0.57	0.00	0.63	0.24	0.00	1.71	1.18	0.29	0.12	0.40	1.64	
1975	l.c.	4.9	7.7	10.4	13.0	15.3	17.5	19.7	21.2	23.0	24.4	25.1	27.0	26.6	28.5	29.8
	n	221	221	220	182	129	94	55	35	28	18	10	4	1	1	1
	± S	0.63	0.37	1.34	1.77	1.78	2.10	1.58	2.35	2.64	2.84	2.91	3.51			
	t^0	1.65	0.00	0.70	1.67	**2.25**	1.66	**2.26**	0.00	**2.28**	1.55	0.20	0.55			
1976	l.c.	4.9	7.5	10.2	12.7	14.9	17.3	19.3	21.1	22.6	23.9	25.1	25.9	27.5	27.9	27.9
	n	213	213	213	212	189	166	116	86	51	36	24	14	4	2	1
	± S	0.44	0.92	1.06	1.23	1.39	1.57	1.59	1.83	1.63	1.61	1.70	1.83	0.88	1.06	
	t^0	1.94	1.94	0.77	0.00	0.56	1.33	1.47	1.98	**2.27**	1.33	0.33	0.24	0.56	0.29	

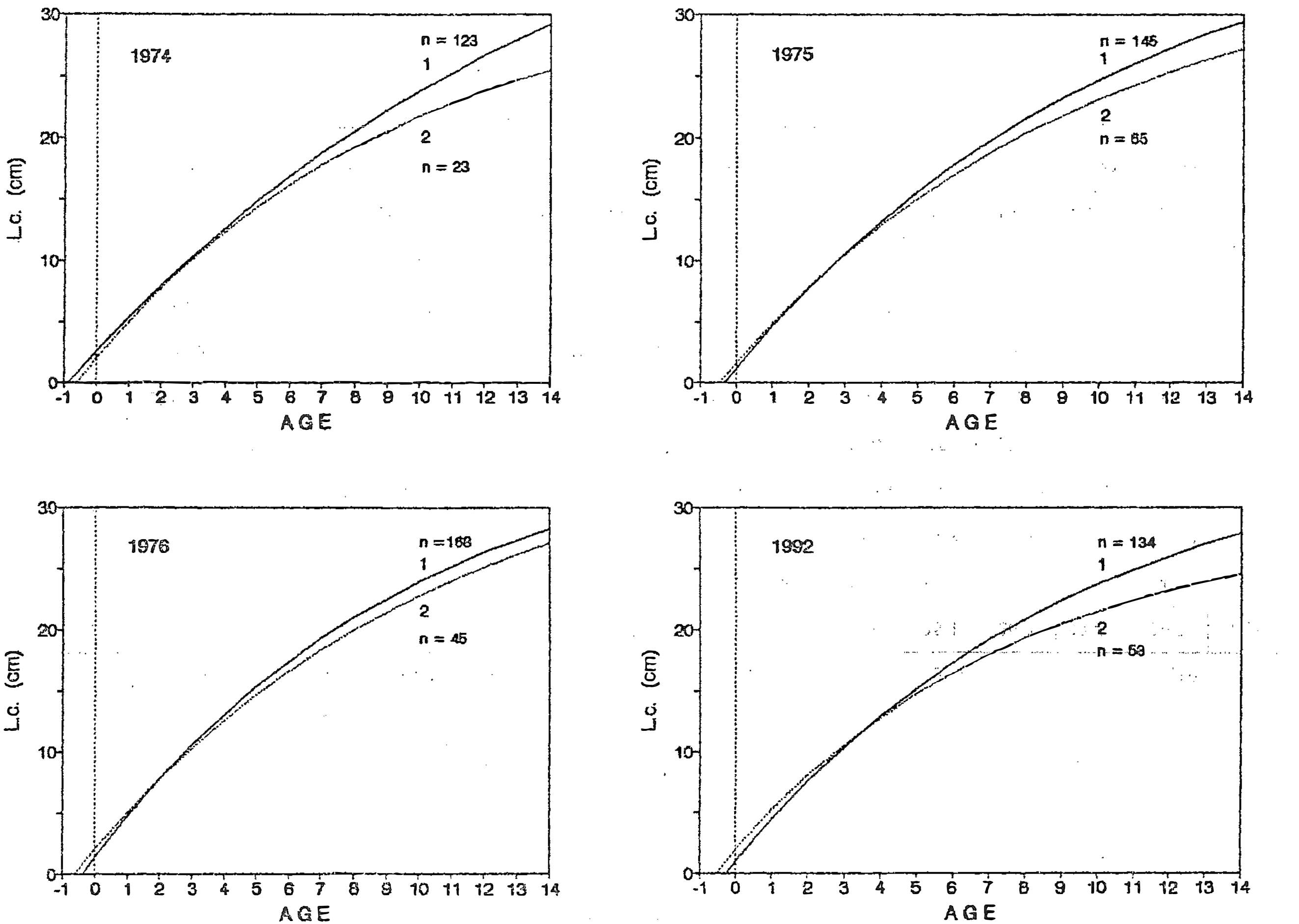

Fig. 7. Growth rate of females (1) and males (2) in different calendar years (n = sample size) (von Bertalanffy equation parameters in Table 7)

Two additional criteria confirm the similarity between growth rates of the roach caught in 1992 and in the seventies. The first is the difference between growth rates of males and females. As shown in Fig.7, the difference was the same in all the samples compared. In all the samples, females grew larger than males with time, while in three samples (except for the 1974 one) a slightly faster growth of males was initially observed.

The other criterion involves the growth rates of fish belonging to different age groups. In Table 6, values of growth length coefficient, calculated from the binomial (as in Tab.4) are compiled. A similar decreasing trend of the coefficient with fish age is seen in all the data sets compared; additionally, if age group 3 is disregarded, the coefficient values are similar, regardless of the year of sampling.

Table 6

Variability in length growth rate of roach in various age groups, as measured with growth coefficient $GL = \int_0^{10} (a+bt+ct^2)\,dt$ (t=time in years)

Age group	Years							
	1974		1975		1976		1992	
	n	GL	n	GL	n	GL	n	GL
III	49	218	38	136			14	161
IV	45	150	53	167	23	148	22	150
V	32	159	35	154	23	147	35	148
VI	31	145	39	146	50	152	26	149
VII	13	147	20	151	30	146	27	149
VIII	5	132	7	144	35	145	24	144
IX	4	136	10	145	15	143	13	139
X	2	136	8	150	12	141	12	137
XI	8	136	6	139	10	143	10	135
XII	2	136	3	142	10	140	5	135
XIII	4	130			2	136	2	134
XIV	3	141					2	137

Table 7

Parameters of von Bertalanffy equation and power function

Sex	Year	$L\infty$	K	t_0	$W\infty$	k	n
Males and females	1992	36.53	0.0988	-0.365	1,006.4	0.01634	3.065
	1974	41.14	0.0816	-0.521			
	1975	41.82	0.0824	-0.534			
	1976	37.68	0.0959	-0.385			
Males	1992	28.82	0.1297	-0.522	468.4	0.01799	3.025
	1974	32.55	0.1044	-0.589			
	1975	35.24	0.1021	-0.468			
	1976	37.10	0.0895	-0.616			
Females	1992	35.91	0.1051	-0.245	966.7	0.01619	3.071
	1974	48.01	0.0632	-0.854			
	1975	39.67	0.0945	-0.315			
	1976	37.19	0.0993	-0.356			

DISCUSSION

The study shows the Lake Dąbie roach to grow fast. Following the criterion proposed by Wilkońska [1975] (i.e., the length attained in year 6), the population's growth rate is intermediate between "good" and "very good". If one considers the weight attained in year 6, the growth rate is "very good" and corresponds to score 5 in a 6-score scale. Szczerbowski [1981] suggested a 4-score scale to be used for roach. According to that classification, the Lake Dąbie roach can be assigned to the highest-scoring class (the "very fast" growth) until year 8, following which the growth rate resembles populations of a "fast" growth. The change can be attributed to the decreasing growth rate type, typical of which is a reduction in annual increments with age. Alongside the uniform growth, this is one of the two growth types observed in roach inhabiting Polish lakes. As observed by Wilkońska [1975], the growth type is poorly correlated with growth rate, although the decreasing type is more frequent in slower-growing populations. This relationship does not hold for the population studied in this work. The Lake Dąbie roach population's fast growth rate can be related - based on the data presented by Wilkońska [1975] - to the geographical location of the lake (the western part of the country) and its being relatively shallow. The two factors enhance the length of the feeding period during the year, provided food resources are adequate.

Growth rate can be changed, however, even given the adequate food resources. The relationship between food and growth is controlled by a very complex set of external and biological factors [Brett 1972]. Different populations of the same species may utilise the energy derived from their food very differently, depending on conditions prevailing in their respective habitats. Some may grow fast, while others may maintain a better condition or store more reserve materials [Šulman 1972]. Variability in roach growth, observed by a numerous authors in different water bodies, can thus result both from differing food resources and from environmental effects on physiological and biochemical processes controlling food utilisation. On the other hand, growth rate of the roach in a water body may stabilise for a long time, provided the habitat does not experience drastic changes [Wilkońska 1975]. This line of reasoning may lead to the conclusion that Lake Dąbie has not experienced drastic changes within the last 20 years or so, because the roach growth indicators obtained in 1992 are almost identical to those of 1974-1976. The growth indicators mentioned include the type and rate of growth, sex-dependent differences in growth, and even the trend towards decreasing growth rates with age. The latter is most probably an artifact related to the selective effects of fisheries. Comparative data on fish condition and chemical composition of tissues would be needed to confirm the conclusion of the relative habitat stability vs. physiological condition of the population. A comparative analysis in the population size during the period in question would be also very helpful.

Another problem touched upon in this paper is how representative of the large lake are samples collected, one at a time, from different locations at different times. The samples of 30 - 50 individuals turned out to yield data close to mean values calculated from about 200 individuals. However, a risk of an error does exist at such sample size, as evidence by the presence of significant differences between the mean and the extreme (maximum and minimum) values found here. Inhomogeneity of the samples in terms of sex ratio may be one of the reasons, as sex-dependent differences in growth rate were obvious. One should, however, bear in mind that the differences between the samples of the size dealt with in this work were manifested within a limited age interval only. No within-age group differences in length were found in the roach aged 1 and older than 7 years.

CONCLUSIONS

1. The roach population in Lake Dąbie shows fast length and weight growth rates, the rates being faster than the respective averages in Polish lakes.
2. The length increments were found to decrease with fish age.
3. Having attained sexual maturity, the females grew faster than males, while male grew slightly faster when juvenile.
4. In the seventies (1974 - 1976), the Lake Dąbie roach growth rate was the same as that in 1992.
5. A sample size of 20 - 50 individuals may not be entirely representative in order to characterise the growth rate of roach in a lake as large as the Dąbie, particularly when the samples differ in their sex ratio.

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TEMPO WZROSTU PŁOCI-*Rutilus rutilus (L.)* W JEZIORZE DĄBIE

STRESZCZENIE

W okresie od lipca do października 1992 roku pobrano 6 prób zawierających łącznie 196 osobników płoci, w tym 58 samców, 134 samice i 4 osobniki o nieoznaczonej płci. Wiek ich określono na podstawie łusek. Tempo wzrostu długości zostało wyznaczone za pomocą metody odczytów wstecznych, przy zastosowaniu wzoru Rosy Lee z wartością korekcyjną 0,8 cm. Wyliczono parametry równań von Bertalanffy'ego dla wzrostu długości i ciężaru, a przy analizie wzrostu ryb należących do różnych grup wieku zastosowany został wielomian drugiego stopnia i współczynnik wzrostu (GL), zaproponowany przez Szypułę (1977). Wykorzystując, pochodzące z lat 70., nie publikowane dane autorów tej pracy wskazano zakres zmian wskaźników wzrostu w ciągu prawie 20 lat.

Badania wykazały, że płoć w jeziorze Dąbie należy do najszybciej w kraju rosnących populacji tego gatunku. Reprezentuje typ wzrostu malejącego, charakteryzujący się spadkiem przyrostów rocznych wraz z wiekiem osobników. Samce w okresie młodocianym rosną nieco szybciej od samic, jednakże po osiągnięciu dojrzałości płciowej znacznie szybciej rosną samice. Odnotowano pozorną zmianę tempa wzrostu wraz z wiekiem - młodsze ryby wykazywały szybszy wzrost niż starsze. Wskazuje to na intensywną eksploatację zasobów i selektywne działanie rybołówstwa. Materiał porównawczy z lat 70. wykazał, że w ostatnim dwudziestoleciu tempo wzrostu płoci w badanym jeziorze nie uległo zmianie. Świadczą o tym zarówno nakładające się na siebie krzywe wzrostu, jak i analogiczne różnice pomiędzy szybkością wzrostu samic i samców, a ponadto podobne wskaźniki wzrostu ryb z różnych grup wieku.

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