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AGE AND GROWTH RATE OF ROACH (*Rutilus rutilus* L.) FROM 3 LAKES USED FOR RECREATIONAL FISHING

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Summary. Roach were collected in the spring and autumn of 2004/05, from 3 lakes: Sierakowo, Błotno, and Wapnickie, differing in morphological characters, exploited only by anglers. Variations in total length, individual weight and condition were described. Age structure and growth rate were determined. Among the 3 analysed populations of roach, the fish from lake Wapnickie were characterised by the fastest growth rate, while the roach from lake Błotno exhibited the slowest growth rate. The fish from lake Sierakowo were characterised by the lowest coefficients of condition (Fulton's and Le Cren's factors). It seems that recreational catches conducted in the lakes influence not only the stocks of fish and their structures, but also affect some biological characters.

Key words: roach, growth rate, age, condition

INTRODUCTION

The roach represents one of the most commonly found and most widely distributed fishes in Europe [Brylińska 2000]. The fish inhabit nearly every type of water bodies, from large lakes, coastal brackish lagoons, and rivers, to small oxbow lakes and clay-pits [Brylińska 2000]. The abundance of roach is reflected in the composition of commercial catches, since it often exceeds 20% of the total lake fishery production [Wawrzyniak and Czerniejewski 2007]. The species also represents and important component of recreational catches carried out by amateur anglers. The issue is crucial due to dynamic development of recreational fisheries observed over the last 50 years, as well as in terms of the management type, referred to as angling management, applied to many smaller bodies of water in which recreational catches prevail. Since 1957, when Polish Angling Association

had some 150 thousand members, the number of amateur fishers increased many times [Bnińska and Leopold 1987]. Angling, termed by Leopold and Bnińska [1987] as „angling pressure", remains the chief form of exploitation in most small bodies of water under 30 ha of surface area. Studies by Mastyński [1985] have demonstrated that a single inquired angler catches on average 16.6 kg of fish per year, with an average angling catch being 52.6 kg ha^{-1}, ranging from 9.9 to 250 kg ha^{-1} depending on the lake. As a consequence of such pressure, densities of fish populations in the heavily exploited bodies of water may dramatically decrease, which may even lead to problems such as a general over-fishing of the stocks, selective fishing of certain species or size (age) groups, while leaving other species or groups under-exploited. With an incompetent management of recreational fishing in lakes or rivers, this effect may result in negative changes in fish stocks [Leopold and Bnińska 1987], as well as affect the biological characteristics of under-exploited fishes (mainly cyprinids, such as roach, bream, and silver bream).

The aim of this study was to determine some biological parameters of roach (including age composition, growth rate, and condition) from lakes Błotno, Sierakowo, and Wapnickie, which have been exploited entirely by recreational fishers for 10 years.

MATERIALS AND METHODS

The roach was collected from night catches carried out with gill nets of the mesh size 40, 50, and 60 mm; the catches took place in the spring and summer of 2004–2005 in three lakes differing in morphology (Tab. 1): Sierakowo (71 fish analysed), Błotno (74 fish), and Wapnickie (30 fish). Lake Wapnickie actually consists of two lakes, lake Wapnickie Północne (Northern) and Wapnickie Południowe (Southern), connected by a road culvert of large diameter, which allows the fish of various species to migrate from one lake to the other. As a result, the fish caught in either lake were analysed together.

The lakes from which the material was collected are located in the West Pomeranian Province of Poland, near the town of Recz. Following the catch, each fish was weighed (using the electronic scale type Axis with precision to 0.1 g) and measured for length (*L.t.*) using electronic calipers with precision to 0.1 mm. The condition was expressed in the form of Fulton's (K_F) and Le Cren's condition factors (K_C):

$$K_F = \frac{W \cdot 100}{L^3}$$

where:

W – total unit weight (g),
L – total length (mm).

$$K_C = \frac{W \cdot 100}{L^n}$$

where:

W – total unit weight (g),
L – total length (mm),
n – exponent from the relationship between total length and body weight.

In order to evaluate the condition of the fish, we applied both Fulton's condition factor and Le Cren's factor, since the value of the latter depends on the size of the fish and the exponent of the *L*-*W* relationship, while the value of K_F remains constant [Szypuła 2002]. For the species whose *n*-value deviates much from 3, we should apply – besides Fulton's condition factor – also the more reliable Le Cren's index.

Table 1. Basic morphometric features of particular lakes

Lake	Morphometric data [Jańczak 1996]				
	Water surface area (ha)	Volume (1000 m^3)	Max. depth (m)	Mean depth (m)	Shoreline development index
Błotno	21.2	1017.6	10.8	3.8	2.39
Sierakowo	64.8	3559.3	11.7	4.8	1.27
Wapnica Płn.	32.0	2464.0	18.6	7.7	1.89
Wapnica Płd.	28.1	2304.2	19.8	8.2	2.02

Moreover, the condition of the fish was estimated analysing the parameters *n* and *k* of the *L*-*W* relationship, between length and weight of the roach [Bolgier and Connolly 1989].

$$W = aL^b$$

where:

W – unit weight (g),
L – total length (mm),
a, b – parameters characteristic for the given species (population) based on empirical data.

The age and the growth rate of length and weight were read from scales. Some 10–20 scales were collected from each specimen from above the lateral line, in about the middle of the body length (beneath the dorsal fin) and, following removing residues of mucus in a solution of ammonia, the scales were fixed on slides. Age readings and radii measurements were carried out on the caudal parts of the scales using the following set: stereo microscope, video camera, and computer with the image analysis software „MultiScan" (measuring precision

0.001 mm). Growth rate was calculated directly from the measurements of mean lengths at age, as well as through back-reading of scales using the Rosa Lee formula, which – according to Heese [1992] – is considered as standard for cyprinids. The data collected this way were used to model the theoretical growth rate of length in the roach according to the following models: von Bertalanffy's, Ford-Walford's, Gompertz's, and 2nd degree polynomial by means of a modified power function. Such a number of applied models allowed us to decide which of them reflects the growth pattern of the studied fish best [Szypuła *et al.* 2001]. Significance of differences in total length, unit weight, and condition (K_F and K_C) of the roach between the lakes were analysed with ANOVA and Duncan's test applied as a post-hoc analysis. Verification of the hypothesis about equality of means was preceded by testing the distribution of the trait for normality (Shapiro-Wilk test) and homogeneity of variances (Levene's test) [Stanisz 1998].

RESULTS

Age composition of the fish is presented in Figure 1. Application of various mesh sizes (40–60 mm) of the gill nets allowed catching fish of various ages (4+ to 14+). Lake Sierakowo revealed 10 age groups of roach, with a distinct preva-

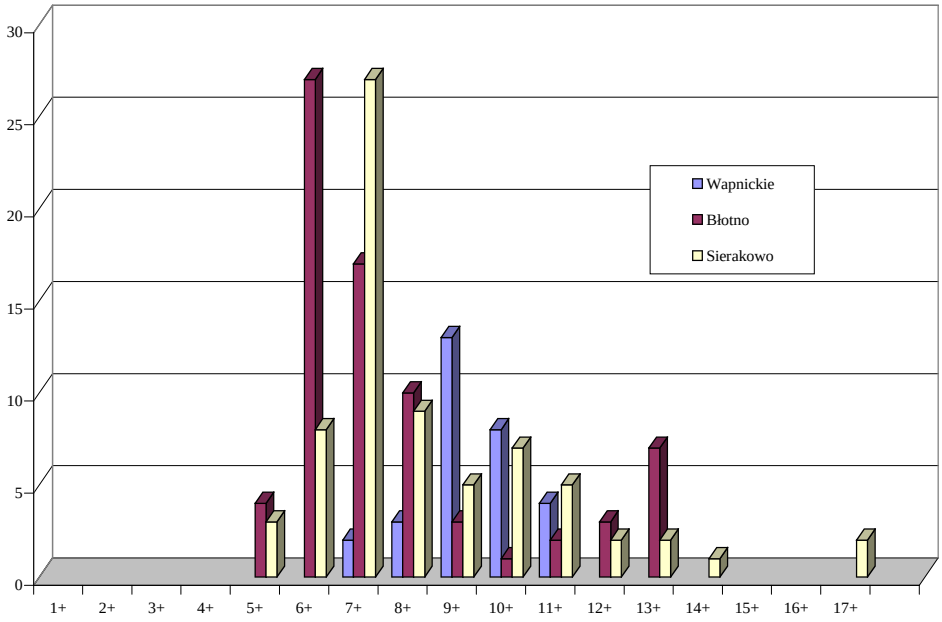

Fig 1. Age structure of roach in particular lakes
Table 2. Total lengths, individual weights, and condition of roach in particular lakes

Lake	Total length (mm)		Individual weight (g)		Coefficients of condition	
	Mean*	Range	Mean*	Range	Fulton	Le Cren
Błotno	184.60a	145.0–310.0	95.90a	33.8–418.3	1.20a	8.49a
Sierakowo	191.31a	120.0–315.0	93.91a	29.9–387.5	1.16b	0.75b
Wapnickie	254.93b	224.0–371.0	209.94b	133.3–401.2	1.25c	17.45c

*Values of particular biological data of roach population from 3 different lakes marked with the same letters show no significant differences ($p < 0,05$). Significant differences between the values of particular traits in the analysed roach populations marked with different letters (a, b, c).

lence of age group 7+. The lowest number of age classes were found in lake Wapnickie, with the highest frequency of ages (+ and 10+. The largest sample of fish collected from lake Błotno was dominated by fish at age 5+ (27 fish) and 6+ (17 fish).

The mean lengths and weights of the fish are presented in Table 2. Both parameters were characterised by a wide range of values and significant ($p < 0.05$) differences between populations from each lake. The fish from lake Wapnickie were characterised by significantly highest total lengths and unit weights.

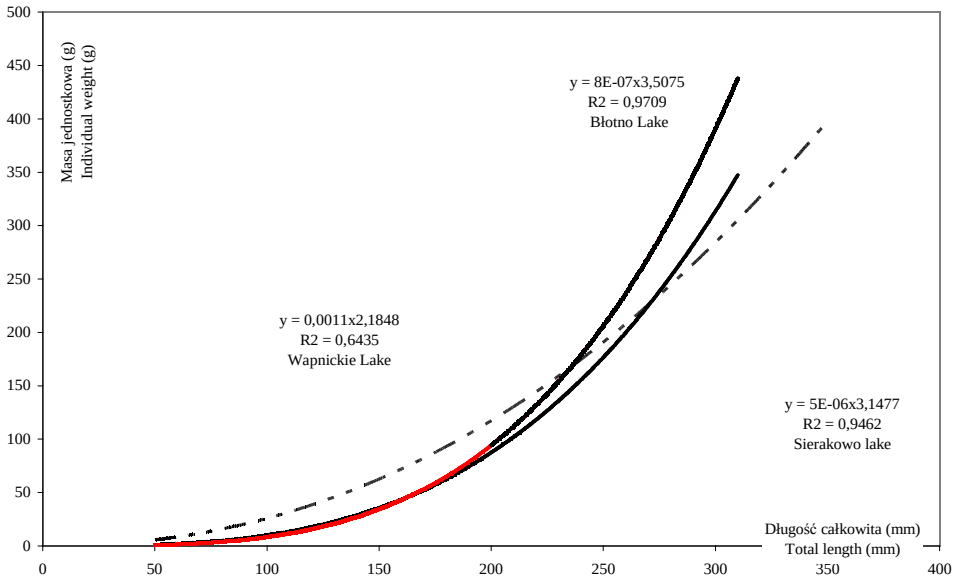

Fig. 2. Relationship between the total length (TI) and individual weight of roach in particular lakes

Table. 3. Mean total length of roach (mm) from Sierakowo Lake by age groups determined with mathematical models of growth

Age	Empirical data	Rosa Lee Back calculation	Ford-Walford	von Bertalan-ffy	Second degree polynomial	Modified power function
I		63	34	61	63	58
II		81	64	79	80	79
III		99	92	97	97	98
IV		115	117	114	114	116
V	157	131	139	131	130	132
VI	165	145	160	147	146	148
VII	172	160	179	163	162	164
VIII	181	174	196	178	177	179
IX	196	189	211	193	192	193
X	200	203	225	208	207	208
XI	235	224	237	222	222	222
XII	243	240	249	236	236	235
XIII	281	257	259	250	250	249
XIV	283	265	269	263	263	262

Table 4. Mean total length of roach (mm) from Blotno Lake by age groups determined with mathematical models of growth

Age	Empirical data	Rosa Lee Back calculation	Ford-Walford	von Bertalanffy	Second degree polynomial	Modified power function
I		54.1	32.6	53.6	54.5	53.2
II		70.1	61.3	69.3	69.7	69.4
III		85.5	86.4	84.8	84.8	85.1
IV	120	100.7	108.5	100.2	99.9	100.4
V	130	114.6	128.0	115.5	115.0	115.6
VI	143	128.7	145.0	130.6	130.0	130.6
VII	150	142.6	160.0	145.5	144.9	145.4
VIII	164	160.4	173.1	160.3	159.8	160.2
IX	180	176.3	184.7	175.0	174.7	174.8
X	210	191.0	194.8	189.5	189.5	189.3
XI	220	204.4	203.7	203.8	204.2	203.8

XII	233	217.6	211.5	218.1	218.9	218.2

Table 5. Mean total length of roach (mm) from Wickie Lake by age groups determined with mathematical models of growth

Age	Empirical data	Rosa Lee Back calculation	Ford-Walford	von Bertalanffy	Second degree polynomial	Modified power function
I		61.8				
II		85.6				
III		117.2				
IV		142.5				
V		164.8				
VI		187.7				
VII	234.0	203.0	214.7	207.1	209.8	207.1
VIII	243.0	217.3	235.1	226.5	229.2	226.0
IX	240.4	242.6	253.6	244.2	246.4	244.1
X	262.8	274.5	270.4	260.4	261.6	261.4

The condition of the fish was evaluated using Fulton's (K_F) and Le Cren's (K_C) condition factors as well as the parameters of the relationships between total length (*L.t.*) and unit weight (*W*). Condition parameters presented in Table 2 for the fish caught during 2004–2005 in lakes Wapnickie, Sierakowo, and Błotno differ significantly and considerably. Lower Fulton's parameters were found in the fish from lake Sierakowo. Poorer condition of lake Sierakowo roach, especially in the length classes of 170 to 270 mm, is also reflected by the pattern of the *L*-*W* relationship curve presented in Figure 2.

Growth rates of roach in each lake, determined basing on back readings and mathematical models, are gathered in Tab. 3–5. The roach attained the fastest growth rate at age 1 (the range of the mean calculated by the Rosa-Lee method in the analysed lakes was 54.1–63.0 mm). At ages 2 and 3, the length increments were about twice lower as compared with the previous year's gains. Among the analysed population, that from lake Wapnickie featured the fastest growth, for which the mean length at age for subsequent years (except for the first and second years) was more than 10% higher as compared with the fish from the remaining lakes.

The lengths calculated by means of back readings were used to determine the parameters of the mathematical growth models, which allowed estimation of the length at age for the roach (Tab. 3–5). Furthermore, an analysis of least-squares sums between the results of the equations and the empirical data shows that the 2nd degree polynomial is the best-fitting model for roach, whereas the Ford-Walford method reflects the growth least adequately.

DISCUSSION

Roach are caught in Poland by means of a number of fishing gear and equipment, mainly passive (gillnets, fyke-nets), but also active (such as seines). The previous group of gear are usually used in small inland bodies of water, due to low cost and ease of manipulation. It should be stressed, however, that such nets are quite selective [Psuty *et al*. 2007], thus various mesh sizes in gill-nets are used to catch fish for scientific purposes. The material used in the presented study was caught by means of gill-nets with mesh sizes from 40 to 60 mm, which enabled us to collect a considerable range of lengths, weights, and ages of fish. This diversity of material allowed, in consequence, minimising the error arising from selectivity of the fishing gear.

The condition of individual fish is an important information relating to a study on a fish population. According to a review by Bolgier and Connolly [1989], an analysis of the variability of this parameter is usually based on the function derived from the length-weight relationship as well as the formulae proposed by Fulton and Le Cren. The length-weight relationship is usually described with a power function. Its exponent is associated with, among other factors, body shape-slender fish are characterized by a value below 3, whereas more stocky-build fish will have a higher value of the power function exponent [Wootton 1996]. The roach exhibit a variety of values of this parameter, and those studied here were found to have (Fig. 2) from 2.1848 (in lake Wapnickie) to 3.5075 (in lake Błotno). The condition of the captured roach, as estimated using Fulton's and Le Cren's coefficients, attained slightly lower values compared to those reported by Borzęcka *et al*. [2002]. Comparing the condition of roach from the studied lakes with the data published by Stroński [1971] for the Lubiszowskie lakes, we observe also distinctly lower *K* values for lakes Wapnickie (1.25), Błotno (1.20) and Sierakowo (1.16), as compared with the roach from lake Białe (condition factor $K = 1.84$), lake Białeckie ($K = 1.65$), or lake Czarne ($K = 1.45$). Roach from the Międzyodrze waters and Pomeranian Bay also exhibited better condition if we compare it to our results [Więski and Załachowski 2000].

Another important issue in terms of adequate fisheries management is knowledge on the age structure and growth rate of the population. The roach is characterised by a varied growth rate depending on the lake [Brylińska 2000]. Most authors share the opinion that this results from a combination of three factors – duration of the growing season, water temperature, and food availability [Karpińska-Waluś 1961, Kampe 1962]. The first of these factors differentiates growth rate according to geographical location (the farther north, the slower the growth) and depth of the water body [Brylińska 2000]. Wilkońska [1975], who studied growth rate of roach on the background of a number of limnological and exploitational factors, observed that it also depends on the duration of the

growing season, population size and – to a lesser extent – on the depth and surface area. As a regularity characteristic for roach, Wilkońska [1975] observed the highest and also the least varied gains in length during the first year of age in fish from various bodies of water. The similarity in growth, according to the cited author, should be attributed to a high natural mortality rate observed during the first wintering.

Table 6 presents the results of back readings of the growth rate of the roach from the analysed lakes in relation to literature data. As compared with roach of lakes Charzykowo, Wigry, and Tajty, the fish from lakes Sierakowo, Wapnickie, and Błotno is characterised by a slightly slower growth, similar, however, to that presented by Karpińska-Waluś [1961] and Wilkońska [1975]. It probably results from differences in limnological parameters of the lakes and their feeding conditions.

Table 6. Length growth rate of roach from different lakes (SL and TL in cm) in Poland

Lake	Author	Age groups of roach											
		I_1	I_2	I_3	I_4	I_5	I_6	I_7	I_8	I_9	I_{10}	I_{11}	I_{12}
Average for 705 lakes of northern Poland	Wilkońska 1975	4.4	6.9	9.0	10.9	12.6	14.2	15.7	17.4	19.3	21.1		
Average for 22 Węgorzewskie lakes	Karpińska--Waluś 1961	4.4	6.8	9.0	10.8	12.7	14.1	15.8	17.8	–	–		
Pomeranian Bay	Załachowski *et al*. 1997	5.6	7.9	10.3	12.9	14.8	17.0	19.3	21.4	22.9	24.7		
Charzykowo	Stangenberg 1950	6.6	9.9	15.2	19.3	24.4	26.9	29.3					
Wigry	Stangenberg 1953	6.4	8.9	11.6	14.9	17.5	20.1						
Tajty	Zawisza 1953	5.1	8.2	11.2	14.5	16.9	19.2	22.0	24.3				
Błotno	This study	5.4	7.0	8.6	10.1	11.5	12.9	14.3	16.0	17.5	19.2	20.5	21.8
Wapnickie	This study	6.2	8.6	11.7	14.2	16.5	18.8	20.3	21.7	24.3	27.5	–	–
Sierakowo	This study	6.3	8.1	9.9	11.5	13.1	14.5	16.0	17.4	18.9	20.3	22.4	24.0

Another important factor affecting the growth rate of the roach from the discussed lakes, although difficult to verify, is the angling pressure. All the lakes have been used exclusively as angling fishing grounds for 10 years (no commercial catches are carried out, and those applied in this study to collect the material consisted in single, controlled catches). The highest numbers of anglers visit lake Wapnickie, due to the lake's attractive location and character (a pike-perch type of lake). Most probably, anglers catch the most roach in this particular lake; this results in lower population density and, in consequence, higher individual growth rate.

CONCLUSION

The results presented in this study indicate that angling pressure affects not only the biomass of the fish caught from the given body of water, but also some biological characters. In many bodies of water used as recreational fisheries, commercial fishing gear should be applied for controlled catches treated as a component of appropriate lake or river management, through the control of populations and species composition of fishes and, indirectly, to regulate their biological characters. Should such catches be neglected, a lake under low angling pressure will develop too dense populations of small cyprinid fishes, which may lead to inhibition of individual growth rate and negative changes in the fish condition; this is actually the case in lakes Błotno and Sierakowo.

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WIEK I TEMPO WZROSTU PŁOCI (*Rutilus rutilus* L.) W 3 JEZIORACH UŻYTKOWANYCH WĘDKARSKO

Streszczenie. Materiał do badań stanowiła płoć pozyskana w okresie wiosennym i letnim 2004/05 z trzech jezior: Sierakowo, Błotno i Wapnickiego, różniących się pod względem morfometrycznym, a użytkowanych wyłącznie wędkarsko. Określono zróżnicowanie długości całkowitej, masy jednostkowej oraz kondycji ryb. Przedstawiono strukturę wieku oraz tempo wzrostu ryb. Najlepszym wzrostem charakteryzowała się populacja płoci z jeziora Wapnickiego, natomiast najniższe przyrosty roczne stwierdzono u populacji z jeziora Błotno. Płoć z jeziora Sierakowo w porównaniu z pozostałymi charakteryzowała się najniższymi wartościami współczynników kondycji Fultona i Le Crena. Wydaje się, że eksploatacja wędkarska jezior ma wpływ nie tylko na zasoby ryb i ich strukturę, ale również na kształtowanie się niektórych cech biologicznych.

Słowa kluczowe: płoć, tempo wzrostu, wiek, kondycja