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FECUNDITY OF ROACH (*RUTILUS RUTILUS* L.) IN HEATED LAKE GOSŁAWSKIE

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A B S T R A C T. Studies were carried out on the effect of long-term lake heating upon the fecundity of roach. Fecundity increased noticeably due to more rapid growth of the fish, but also to higher number of eggs produced by the females (on the average from 154 to 199 eggs per 1 g of body weight). Age of attaining the first maturity changed and life span of the fish shortened, leading to changes in age structure of the population.

Key words: HEATED LAKES, *RUTILUS RUTILUS*, FECUNDITY

INTRODUCTION

The discharge of heated effluents from power plants into 5 lakes of Konin resulted in persisting heating of these water bodies. Hence, it became possible to observe fish fertility in the same lake before and after the heating. The aim of the study was to find out to what an extent changes of the thermal regime affected fecundity of roach.

MATERIAL AND METHODS

Materials were collected in 1967 - 1986 from Lake Gosławskie, and - for comparison - Lake Ślesińskie. Lake Gosławskie received first irregular discharge of heated effluents in 1968. Since 1969 cold water is collected from this lake (22 m^3/s) and the same amount of effluents is discharged. The effluents are heated by 4 - 7°C compared to natural lake temperature. Lake Ślesińskie received heated effluents only since 1970, and only during the growing season (May - September), while in other seasons its thermal conditions were almost natural. Detailed description of the water flow and thermal conditions in the lakes is given in the paper by Zdanowski et al. (1988).

Samples from Lake Gosławskie comparised one year before the heating and 15 years afterwards. The first numerous samples from Lake Ślesińskie were collected in

1971. Dates of sampling and numbers of the fish examined are presented in Table 1. Fish samples were collected from commercial catches. Females were weighed, measured, scales were collected for age determination, and gonads were removed. Whole gonads were weighed, and 3 weighted subsamples collected from different parts (anterior, middle and posterior), in which all eggs were counted. The obtained data were used to calculate average number of eggs per 1 g and in the whole gonad. Dependence between fecundity (P) and fish body length (L) was calculated from the equation $P = aL^b$, using the coefficent V instead of the factor b (Ricker 1973).

TABLE 1

Sample numbers, range of roach age and size in lakes Gosławskie (A) and Ślesińskie(B) in 1967-1986

Date	n	Length (Lc) in cm	Age,
	A		
1967.III.09	48	13.5-27.5	2-7
1971.III.29	85	11.2-24.5	2-7
1972.III.24	99	14.5-22.5	1-5
1974.III.14	62	14.5-26.5	1-5
1975.I.28	32	15.5-27.5	1-6
1976.I.26	43	14.5-27.5	1-5
1977.II.15	88	14.5-31.5	1-7
1978.X.17	53	14.5- 20.5	1-2
1980.I.08	35	16.5-32.5	2-8
1983.XI.	55	14.5-20.5	1-3
razem	**607**		
	B		
1967.III.08	12	17.5-22.5	
1971.V.05	81	10.5-24.5	1-9
1972.IV.12	18	10.5-20.5	2-6
1973.III.03	25	12.5-19.5	
1978.IV.15	22	15.5-24.5	2-5
1982.II.16	51	14.5-28.5	2-6
1986.III.03	117	11.5-35.5	
razem	**326**		

RESULTS

Dependence between fecundity and body length (L. corp.) is described by the equations presented in Table 2. In the control Lake Ślesińskie, deviation from the average fecundity (13.6 and 40.9 thousand, Tab. 2) did not exceed 5 thousand during

TABLE 2

GM regression equations (logarithms) for absolute fecundity (F in thousand) on body length (Lc cm) for roach in Lake Gosławskie (A) and Lake Ślesińskie (B).

Year	Numbers	Average		logF=a+VlogL		Correlation coefficient		Expected fecundity in thousand for*	
		lc cm	F thousand	log a	V	r	r^2	15 cm	20 cm
A									
1967	48	19.67	31.48	-3.5210	3.9675	0.9596	0.9208	11.32	33.54
1971	85	18.71	30.40	-2.9897	3.5809	0.9679	0.9368	13.19	39.08
1972	99	17.1	21.09	-2.5422	3.9217	0.7956	0.6330	12.86	38.09
1974	62	20.71	38.54	-2.6834	3.9753	0.8086	0.6538	11.39	33.75
1975	39	20.65	45.63	-3.6851	4.9776	0.8080	0.6529	13.64	40.40
1976	43	21.34	49.45	-2.6700	3.7747	0.8620	0.7430	13.06	38.70
1977	88	18.70	33.15	-2.6182	3.7362	0.8608	0.7410	14.42	42.72
1978	53	16.66	20.47	-2.8354	3.8693	0.8727	0.7616	13.77	40.78
1980	35	22.87	73.28	-3.6258	4.1999	0.9487	0.9000	14.90	44.14
1983	55	17.97	27.57	-2.6751	4.1842	0.7812	0.6103	13.93	41.27
Mean 1967-83	607	19.03	33.48	-2.9279	3.7740	0.9098	0.8277	13.78	40.83
B									
1967	12	19.64	27.20	-3.4036	4.9834	0.7485	0.5602	9.73	29.13
1971	81	15.84	17.56	-3.2764	3.8761	0.9437	0.8906	14.27	42.73
1972	18	16.06	15.60	-3.7575	4.2129	0.9667	0.9345	12.04	36.05
1973	25	16.34	19.02	-3.4347	4.0206	0.9489	0.9004	13.72	41.09
1978	22	20.25	36.36	-2.5595	3.7471	0.8322	0.6926	15.80	34.68
1982	51	18.64	27.49	-3.0612	3.6677	0.9503	0.9031	12.01	35.96
1986	117	19.40	36.68	-2.8494	3.6502	0.9216	0.8493	13.74	41.15
Mean 1967-86	326	18.04	27.60	-3.1838	3.8141	0.9440	0.8911	13.65	40.87

**expected fecundity calculated using GM regression coefficient 3.7740 in Lake Gosławskie and 3.8141 in Lake Ślesińskie.*

15 years (1971 - 1986); usually amounting to less than 2 thousand, and the fecundity remained at a similar level notwithstanding annual variations. Only in 1967 fecundity was noticeably lower due to low representativeness of the sample which contained only 12 females of similar length (Tab. 1). In Lake Gosławskie deviations from the average (13.8 and 40.8 thousand) usually did not exceed 3 thousand eggs, but despite

annual variations, the differences between particular years pointed to a noticeably growing trend. The lowest fecundity was observed in 1967, when the lake was characterized by natural temperatures. The highest fecundity was recorded in 1980, when the lake was already heated. Fecundity of 14.5 cm fish increased in 1983 by a factor of 1.8 compared to 1967, of 18.5 cm fish increased 1.5-fold, and of 20.5 cm - 1.4-fold. The differences analysed with the test for the fish 14.5 - 20.5 cm long and the years 1967 and 1977 (more numerous data than in 1983) proved to be very significant ($t = 6.65$, $p = 0.001$), and between 1971 and

TABLE 3

Relative fecundity of roach in lakes Gosławskie (A) and Ślesińskie (B) in 1967-1983.

Length class in cm	A							B	
	1967	1972	1974	1976	1977	1980	1983	1978	1982
14,5	131	169	170	196	187	156	185	166	153
15,5	135	175	171	197	188	160	188	166	155
16,5	138	181	173	198	189	166	191	167	157
17,5	142	188	174	199	190	171	193	167	160
18,5	145	194	176	199	192	177	196	168	162
19,5	148	200	177	200	193	182	198	168	164
20,5	152	207	179	201	194	188	201	168	166
21,5	155	213	180	201	195	193	204	169	168
22,5	159	219	182	202	197	198	206	169	170
23,5	162	226	184	203	198	204	209	170	172
24,5	165	232	185	203	199	210	211	170	174
25,5	169	238	187	204	200	215	214	170	176
average	154	207	178	200	194	191	199	168	166

1977, and 1967 and 1971 the differences were also significant: $t = 3.15$ and 2.66 respectively ($p = 0.05$). Similar analyses were made for Lake Ślesińskie and the years 1971, 1978 and 1982 (fish length 15.5 - 24.5 cm) but no significant differences were found: respectively $t = 0.75$, 0.78 and 0.01 (Ostle 1964). This confirms an earlier conclusion that roach fecundity did not change in Lake Ślesińskie.

Coefficients of correlation between fecundity and length ranged from $r = 0.7485$ to $r = 0.9667$, and the coefficients of determination were 56.0 - 93.7% (Tab. 2). Hence, their range was a little broader than the ranges given by other authors, eg. Turanova (1972) calculated $r = 0.85$, Mann (1973) $r = 0.817$, Mackay and Mann (1969) $r = 0.886$, and Vjatcanina (1970) gave 96%.

The differences between fecundity in 1967 and the subsequent years were revealted in Lake Gosławskie also during the analyses of relative fecundity (Tab. 3). Females of body length 14 - 25 cm produced in 1967 from 131 to 169 eggs per 1 g of body weight, and in the subsequent years from 156 to 238 eggs. In Lake Ślesińskie, both the absolute and the relative fecundity remained at a stable level.

Dependence between fecundity and age, calculated from the real data, revealted that the bigger the fish in the given age group, the higher the fecundity (Tab. 4). This is quite obvious in view of avery strong correlation between fecundity and length. Hence, the dependence fecundity-age was determined by the fish length, and not by a significant role of age. Mackay and Mann (1969) calculated multiple correlation (R) for fecundity, length and age of roach, which showed that the fish age had no effect ($r = 0.0079$).

TABLE 4

Dependence between fecundity, age and body length of roach in Lake Gosławskie

Length class in cm lc	Absolute fecundity (thousand) at the age of				
	1+	2+	3+	4+	5+
14.0 - 15.9	14.9	14.2			
16.0 - 17.9	20.3	22.9			
18.0 - 19.9		30.5	31.9		
20.0 - 21.9		42.5	39.0	43.8	
22.0 - 23.9			65.6	53.7	65.0
24.0 - 25.9				86.0	88.2
26.0 - 27.9				95.4	100.3

DISCUSSION

In the case of Lake Gosławskie attention should be given to the difference in fecundity before and after 1967, and always higher - though variable in particular years - level of fecundity after lake heating. Changes in the thermal regime were probably the main reason for these differences, as roach responce to heating consisted of accelerated growth rate (Wilkońska 1977, Chmielewski 1985). On the other hand, annual variations were probably caused by differences in the growth rate of the females (Fig. 1) in particular years, resulting from variable weather and temperature.

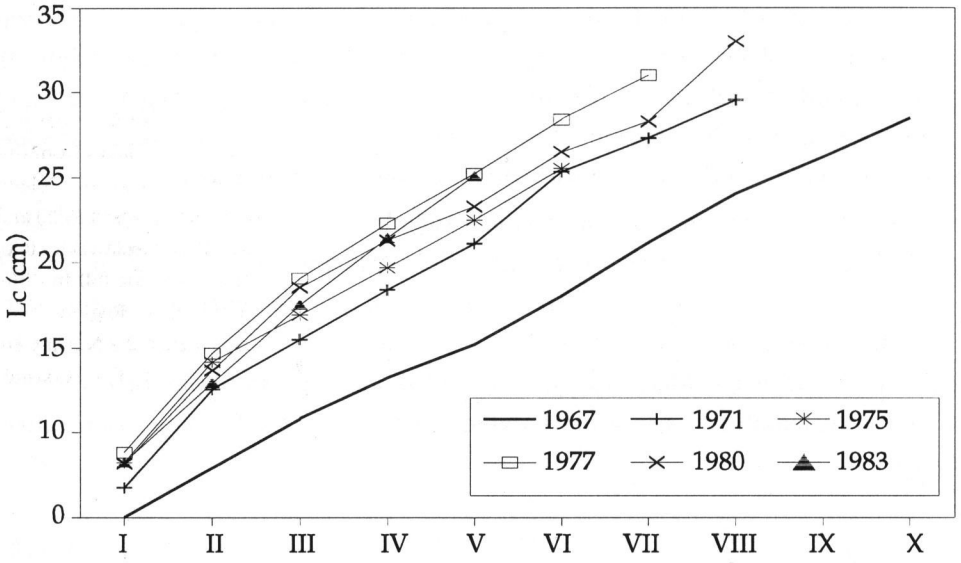

Fig. 1. Differentiation of growth rate (lc cm) of roach females in particular years

Variations of fecundity in particular years were observed in „natural" conditions by Backiel and Zawisza (1988). In the heated lakes temperature was a yet another factor stimulating fecundity. Variations of temperature, both in plus (too high) and in minus (shortening of the vegetation season) may inhibit fish growth and decrease fecundity. Similar differences were observed among others by Spanovskaja et al. (1963), Vjatcanina and Domcenko (1982), and Cugunova (1951).

Roach fecundity in Lake Gosławskie was a little lower before the heating than in the control Lake Ślesińskie. It became much higher after the heating, and with much more pronounced annual fluctuations.

Compared to the fecundity in other Polish lakes (Backiel, Zawisza 1988), roach fecundity in Lake Gosławskie was one of the highest. Despite considerable variations, even in the „worse" years this fecundity oscillated around levels observed by other authors both in pond-type lakes and in eutrophic waters located in the same region as Konin lakes (Fig. 2). On the other hand, fecundity of roach from Lake Ślesińskie was similar as in other lakes of this region, but higher than in lakes located in North-East Poland (fig. 2).

When comparisons are made with other heated waters, roach fecundity in Lake Gosławskie is lower than in Kachowski Resrvoir (Spivak et al. 1979), similar to

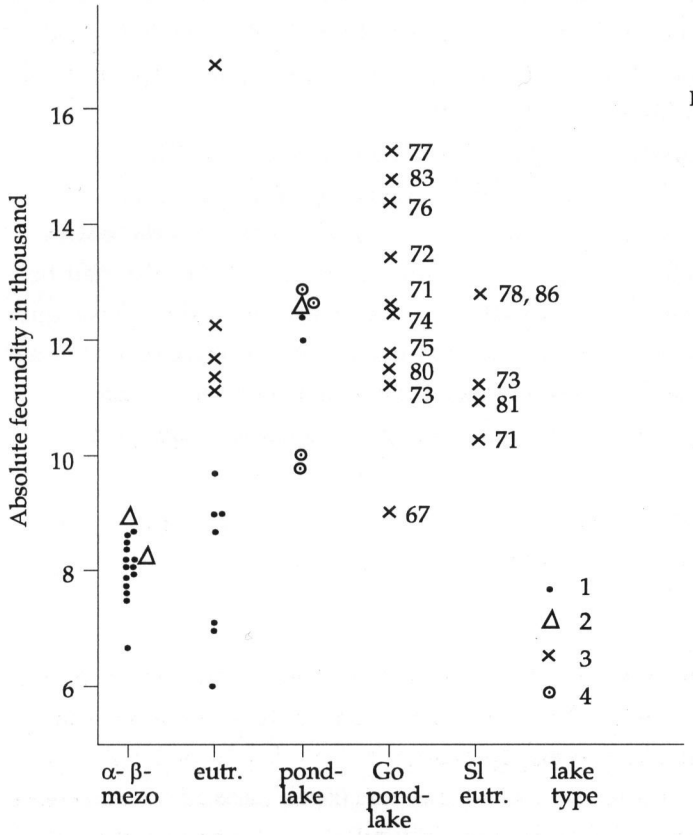

Fig. 2. Fecundity of 15 cm (Lc) roach in the lakes from different regions of Poland (Backiel, Zawisza 1988) and in lakes Gosławskie (Go) and Ślesińskie (Sl) in different years. Regions: 1 - North-East, 2 - North-Central, 3 - Central, 4 - Coastal

Kachurgan Liman (Statova 1973), and higher than in a Greek Lake Volvo (Papageorgiou 1979).

The observed increase of roach fecundity in Lake Gosławskie was caused not only by accelerated fish growth. As mentioned earlier, fecundity after heating was on the average 1.5 times higher in fish of the same length. Also relative fecundity increased (Tab. 3). Number of eggs produced by a female per 1 g of body weight was 154 on the average in 1967 and 199 in the subsequent years (1971 - 1983).

Changes of thermal conditions and of water retention accelerated also sexual maturation of the fish (Długosz 1983). Spanovskaja et al. (1963) revealed correlation between fecundity and fish size. Number of eggs in the fish of the same age depended mostly on the growth rate till the first maturation. It is possible that this is also true of Lake Gosławskie because growth rate of fry (0+) was much more rapid than before

lake heating, and roach reached sexual maturity at the age of 1+, and not at the age of four or five years as in lakes with „normal" temperature. Smaller fish may produce more eggs than bigger fish, and the decrease of egg numbers was accompanied by an increase of their weight (Wilkońska, unpubl. data).

According to the suggestion by Spanowska and Grigoras (1977), higher energy use for life processes results in quicker physiological ageing of the fish and their earlier death, viz. in a decreased survival. In heated Lake Gosławskie there were no fish older that 8 years, whereas before the heating even 12-year old fish had been numerous. Shorter life span was compensated for by increased fecundity. This is quite significant considering that fecundity of a population depends to a large extent on age composition and affects fish numbers in a lake. Knowledge on the age composition is an important criterium for establishing legal fish sizes and fishing regulations.

Trans. by Maria Bnińska

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STRESZCZENIE

PŁODNOŚĆ PŁOCI, (*RUTILUS RUTILUS* L.), W PODGRZANYM JEZIORZE GOSŁAWSKIM

Celem pracy było sprawdzenie, czy zmiana warunków termicznych wpłynęła na płodność płoci. Materiał obejmował dane z Jez. Gosławskiego rok przed i 15 lat po rozpoczęciu ogrzewania, a z kontrolnego Jez. Ślesińskiego - z pierwszych lat po jego podgrzewaniu tylko w sezonach letnich V - IX (tab. 1).

Stwierdzono, że ogrzewanie Jeziora Gosławskiego spowodowało wyraźny wzrost płodności (tab. 2). Wzrost ten był konsekwencją przyśpieszenia tempa wzrostu (rys. 1) i zwiększenia liczby jaj produkowanych przez samice (tab. 3).

O zależności pomiędzy płodnością a wiekiem w znacznie większym stopniu decydowała długość ryb w danej grupie wieku niż sam wiek (tab. 4). W Jeziorze Ślesińskim, bez względu na rok pobrania próby, płodność była podobna i zawsze nieco wyższa od płodności płoci gosławskiej w 1967 (przed ogrzaniem). W porównaniu do innych jezior Polski, płodność płoci gosławskiej należała do najwyższych (rys. 2).

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